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Sr. Fisheries Research Biologist

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Project 5—Lake and Reservoir Research

Subproject 1: Warmwater Fisheries Investigations: Larval Crappie

Subproject 2: Warmwater Fisheries Investigations: Crappie Age and Growth

By

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TABLE OF CONTENTS

Page

SUBPROJECT 1: WARMWATER FISHERIES INVESTIGATIONS....1
ABSTRACT....1
INTRODUCTION....2
MANAGEMENT GOAL....3
OBJECTIVES....3
METHODS....3
RESULTS....6
DISCUSSION....7
RECOMMENDATIONS....9
ACKNOWLEDGEMENTS....10
LITERATURE CITED....11
APPENDICES....32
SUBPROJECT 2: WARMWATER FISHERIES INVESTIGATIONS....45
ABSTRACT....45
INTRODUCTION....46
MANAGEMENT GOAL....46
OBJECTIVES....46
METHODS....47
RESULTS....48
DISCUSSION....50
RECOMMENDATIONS....51
ACKNOWLEDGEMENTS....53
LITERATURE CITED....54
APPENDICES....68

LIST OF TABLES

Page

Table 1. The CPUE (fish/h) of fish species captured during spring/fall electrofishing in Brownlee Reservoir, C.J. Strike Reservoir, Hayden Lake, and Mann Lake, Idaho for the years 2005-2009.....14

Table 2. The CPUE (fish/net night) of fish species captured during spring/fall trap netting in Brownlee Reservoir, C.J. Strike Reservoir, Hayden Lake, and Mann Lake, Idaho for the years 2005-2009.....15

Table 3. Estimated back calculated length-at-ages of crappie pooled over all year classes from Brownlee Reservoir, C.J. Strike Reservoir, Hayden Lake, and Mann Lake from 2005-2009 including number aged (N), age (years), mean length (mm), standard error, 95% confidence interval, standard deviation (StDev), minimum length (Min), maximum length (Max), range of lengths (Range), and the incremental growth between ages (Inc; mm). 57

Table 4. Estimated growth coefficients (Intercept, slope, r^2) from log length/log age regression and Von Bertalanffy coefficients (Linf, K, and t_0) for crappie from Brownlee Reservoir, C.J. Strike Reservoir, Hayden Lake, and Mann Lake, Idaho for the years 2005-2009.....58

Table 5. The frequency and percent occurrence of crappie with stomachs at the different states of fullness (empty, few, 1/4 full, 1/2 full, 3/4 full, and full) from Brownlee Reservoir, C.J. Strike Reservoir, Hayden Lake, and Mann Lake, Idaho in 2009. 59

Table 6. The frequency and percent occurrence of crappie stomachs that contained food, contained the four prey types (zooplankton, fish, insects, other), and those where one food type were the only contents in the stomachs of crappie from Brownlee Reservoir, C.J. Strike Reservoir, Hayden Lake, and Mann Lake, Idaho in 2009. 60

Table 7. The frequency and percent occurrence of crappie stomachs that were ¾ full or full that contained only one of the four prey types (zooplankton, fish, insects, other) from Brownlee Reservoir, C.J. Strike Reservoir, Hayden Lake, and Mann Lake, Idaho in 2009. 61

LIST OF FIGURES

Page

Figure 1. Estimated density of larval crappie (fish/1000 m^3) captured using neuston net trawls for three strata (Upper, Middle, and Lower) in Brownlee Reservoir from 2005-2009. 16

Figure 2. Estimated density of larval crappie (fish/1000 m^3) captured using neuston net trawls for three strata (Bruneau, Main, and Snake arms) in C.J. Strike Reservoir from 2005-2009. 17

Figure 3. Estimated density of larval crappie (fish/1000 m^3) captured using neuston net trawls for three strata (Upper, Middle, and Lower) from Hayden Lake 2005-2009....18

Figure 4. Estimated density of larval crappie (fish/1000 m^3) captured using neuston net trawls for Mann Lake from 2005-2009. 19

Figure 5. The mean date (Julian) the 30 day moving average air temperature ($AirT_{MA30}$) reached 16°C and the mean date (Julian) of the peak larval crappie density at Brownlee Reservoir, C.J. Strike Reservoir, Mann Lake, and Hayden Lake from 2005-2009. Horizontal error bars represent the range of dates the peak larval crappie density was measured. Vertical error bars represent the range of dates when the $AirT_{MA30}$ reached 16°C....20

Figure 6. Length frequency histograms of crappie sampled from Brownlee Reservoir with electrofishing and trap nets in the fall of 2005-2008 and spring/fall 2009. 21

Figure 7. Length frequency histograms of crappie sampled from C.J. Strike Reservoir with electrofishing and trap nets in the fall of 2005-2008 and spring/fall 2009. 22

Figure 8. Length frequency histograms of crappie sampled from Hayden Lake with electrofishing and trap nets in the fall of 2005-2008 and spring/fall 2009. Note: Hayden Lake was not electrofished in 2006 because of a boat malfunction. 23

Figure 9. Length frequency histograms of crappie sampled from Mann Lake with electrofishing and trap nets in the fall of 2008 and spring/fall 2009. 24

Figure 10. Regression comparison between peak larval crappie density (data pooled from Idaho Power Company for the years 1994-1998 and from the Idaho Department of Fish and Game for the years 2005-2008) and mean peak inflow rates (m^3/s) at Brownlee Reservoir....25

Figure 11. Regression comparison between peak larval crappie CPUE and mean peak inflow rates (m^3/s) at Brownlee Reservoir collected by the Idaho Department of Fish and Game for the years 2005-2009....26

Figure 12. Regression comparison between peak larval crappie density and mean peak inflow rates (m^3/s) from the Bruneau River Arm of C.J. Strike Reservoir collected by the Idaho Department of Fish and Game for the years 2006-2009. 27

Figure 13. Regression comparison between peak larval crappie density and mean peak inflow rates (m^3/s) from the Snake River Arm of C.J. Strike Reservoir collected by the Idaho Department of Fish and Game for the years 2006-2009. 28

List of Figures, continued.

Page

Figure 14. Regression comparison of peak larval crappie density and the CPUE of the crappie cohort at age-1 sampled during the fall from Brownlee Reservoir 2005-2009. 29

Figure 15. Regression comparison of peak larval crappie density and the CPUE of the crappie cohort at age-1 sampled during the fall from C.J. Strike Reservoir 2005-2009. 30

Figure 16. Regression comparison of peak larval crappie density and the CPUE of the crappie cohort at age-1 sampled during the fall from Hayden Lake 2005-2009.....31

Figure 17. Estimated back-calculated length-at-ages of crappie pooled over all year classes from Brownlee Reservoir, C.J. Strike Reservoir, Hayden Lake, and Mann Lake from 2005-2009. Error bars are 95% confidence intervals. 62

Figure 18. Regression comparisons of $\log_{10}$ length x $\log_{10}$ age of back-calculated length-at-ages of crappie pooled over all year classes from Brownlee Reservoir, C.J. Strike Reservoir, Hayden Lake, and Mann Lake from 2005-2009. Equations are for the regression line at each respective water body.....63

Figure 19. Estimated back-calculated length-at-ages of crappie for individual year classes sampled from C.J. Strike Reservoir. Error bars are 95% confidence intervals. 64

Figure 20. Estimated back-calculated length-at-ages of crappie for individual year classes sampled from Brownlee Reservoir. Error bars are 95% confidence intervals. 65

Figure 21. Estimated back-calculated length-at-ages of crappie for individual year classes sampled from Hayden Lake. Error bars are 95% confidence intervals. 66

Figure 22. Estimated back-calculated length-at-ages of crappie for individual year classes sampled from Mann Lake. Error bars are 95% confidence intervals. 67

LIST OF APPENDICES

Page

Appendix A. Locations (UTM, NAD83, Zone 11), strata, and nomenclature of sites sampled by larval trawling and for water quality measurements in Brownlee Reservoir, C.J. Strike Reservoir, Hayden Lake, and Mann Lake, Idaho for the years 2005-2009. 33

Appendix B. Surface means of water quality parameters measured at Brownlee Reservoir during the summers of 2005-2009, including temperature (Temp; °C), dissolved oxygen (DO; mg/L), conductivity, pH, and secchi depth (m). N/A-data not available. 34

Appendix C. Surface means of water quality parameters measured at C.J. Strike Reservoir during the summers of 2005-2009, including temperature (Temp; °C), dissolved oxygen (DO; mg/L), conductivity, pH, and secchi depth (m). N/A-data not available. 35

Appendix D. Surface means of water quality parameters measured at Hayden Lake during the summers of 2005-2009, temperature (Temp; °C), dissolved oxygen (DO; mg/L), conductivity, pH, and secchi depth (m). N/A-data not available. 36

Appendix E. Surface means of water quality parameters measured at Mann Lake during the summers of 2005-2009, including temperature (Temp; °C), dissolved oxygen (DO; mg/L), conductivity, pH, and secchi depth (m). N/A-data not available. 37

Appendix F. Mean biomass (g/m) of zooplankton collected with three different mesh size nets (153, 500, and 750 µm) and the Zooplankton Ratio (ZPR; 750 µm /500 µm) and Zooplankton Quality Index (ZQI; (500 µm + 700 µm)*ZPR) at different sample sites from Brownlee Reservoir, C.J. Strike Reservoir, Hayden Lake, and Mann Lake sampled during the summer of 2005. 38

Appendix G. Mean biomass (g/m) of zooplankton collected with three different mesh size nets (153, 500, and 750 µm) and the Zooplankton Ratio (ZPR; 750 µm /500 µm) and Zooplankton Quality Index (ZQI; (500 µm + 700 µm)*ZPR) at different sample sites from Brownlee Reservoir, C.J. Strike Reservoir, Hayden Lake, and Mann Lake sampled during the summer of 2006. 39

Appendix H. Mean biomass (g/m) of zooplankton collected with three different mesh size nets (153, 500, and 750 µm) and the Zooplankton Ratio (ZPR; 750 µm /500 µm) and Zooplankton Quality Index (ZQI; (500 µm + 700 µm)*ZPR) at different sample sites from Brownlee Reservoir, C.J. Strike Reservoir, Hayden Lake, and Mann Lake sampled during the summer of 2007. 41

Appendix I. Mean biomass (g/m) of zooplankton collected with three different mesh size nets (153, 500, and 750 µm) and the Zooplankton Ratio (ZPR; 750 µm /500 µm) and Zooplankton Quality Index (ZQI; (500 µm + 700 µm)*ZPR) at different sample sites from Brownlee Reservoir, C.J. Strike Reservoir, Hayden Lake, and Mann Lake sampled during the summer of 2008. 42

List of Appendices, continued.

Page

Appendix J. Mean biomass (g/m) of zooplankton collected with three different mesh size nets (153, 500, and 750 µm) and the Zooplankton Ratio (ZPR; 750 µm /500 µm) and Zooplankton Quality Index (ZQI; (500 µm + 700 µm)*ZPR) at different sample sites from Brownlee Reservoir, C.J. Strike Reservoir, Hayden Lake, and Mann Lake sampled during the summer of 2007.....44

Appendix K. Estimated back-calculated length-at-ages of crappie for individual year classes from Brownlee Reservoir, C.J. Strike Reservoir, Hayden Lake, and Mann Lake from 2005-2009 including year class, number aged, age (years), standard error, 95% confidence interval, standard deviation (StDev), minimum length (mm), maximum length (mm), and range of lengths (mm).....69

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ABSTRACT

Angling for warmwater species is becoming more popular throughout Idaho and increased management of those fisheries is necessary. We sampled crappie *Pomoxis sp*. from Brownlee and C.J. Strike reservoirs in southwest Idaho and Hayden Lake and Mann Lake in northern Idaho to calculate CPUE as an index of crappie abundance. We sought to determine the timing of peak larval density of crappie and factors that affected both the timing and level of density and compared peak larval crappie density to the CPUE of age-1 crappie from fall sampling to determine whether we could predict age-1 abundance from peak larval crappie densities in the previous year. Peak larval density occurred between 10 and 40 days after the 30 d moving-average air temperature reached 16°C, typically between the third week of June and the end of July. Electrofishing was considerably more effective at capturing crappie than was trap netting, the preferred method to capture crappie in most studies. Mean weekly inflow into Brownlee and C.J. Strike reservoirs was related to the density of larval crappie. We also noted a weak relationship between peak larval density and the CPUE of age-1 crappie in Brownlee Reservoir; however, peak density was not useful to predict age-1 crappie CPUE at the other water bodies sampled.

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INTRODUCTION

Idaho's warmwater fisheries are becoming more popular with anglers, and the management of those fisheries by the Idaho Department of Fish and Game (IDFG) is gaining importance. According to 1999 angler opinion surveys, preference for warmwater species has increased from 7% in 1977 to 20% in 1999 (IDFG 2001). Species targeted by anglers include smallmouth bass *Micropterus dolomieu*, largemouth bass *M. salmoides*, black crappie *Pomoxis nigromaculatus*, white crappie *P. annularis*, bluegill *Lepomis macrochirus*, yellow perch *Perca flavescens*, walleye *Sander vitreous*, and channel catfish *Ictalurus punctatus*. These species provide sport fisheries in approximately one-third of the surface waters in Idaho (IDFG 2001).

Most warmwater fisheries in Idaho were created to provide angling opportunity in water bodies with suitable habitat. Such fisheries are easy to create, oftentimes self sustaining, and require lower levels of management activities. For these reasons, however, managers generally know less about the status, characteristics, and factors that influence warmwater fish populations than many coldwater species in Idaho. With the increasing popularity, especially among crappie anglers, a better understanding of the factors that affect recruitment, growth, mortality, and year class strength (YCS) of Idaho crappie populations is becoming necessary. First, a statewide perspective of population characteristics, such as size structure and growth, will help IDFG managers and anglers understand the variation between populations and set reasonable expectations for a fishery. Second, increased knowledge of the biological and environmental factors that influence these population characteristics would allow managers to determine which combinations of recruitment, growth, and mortality result in desirable fisheries and whether they can be influenced by management practices such as harvest regulations or the hydrologic management of the water body. Furthermore, increasing the knowledge and understanding of crappie fisheries will allow managers to effectively communicate the status of these fisheries with anglers and forecast the quality of a fishery.

Warmwater fisheries are often difficult to manage successfully through biological mechanisms because the factors that affect fluctuations in spawn timing, year class strength, or body size are not well understood (Allen 1997; Boxrucker and Irwin 2002; Martin and Maceina 2004). Fluctuations in population structure and growth are likely a result of different environmental characteristics such as temperature, water volume, lake or reservoir bathymetry, and biological variables such as food supply or fish density (Mitzner 1991; Pope et al. 2004). Although the mechanisms remain elusive, many studies exist on the effects of these variables on crappie populations in midwestern and southeastern waters in the United States. Investigations studying the influences of biotic and abiotic factors on crappie populations in Idaho and other western states are lacking because of the relatively recent increase in the popularity of warmwater fisheries.

Standardized methods to assess population characteristics of crappie populations have been developed by other states (Gablehouse 1984; Hill 1984; Hammers and Miranda 1991; Guy and Willis 1995; Allen et al. 1998; St. John and Black 2004; McInerny and Cross 2005). Notably, Colvin and Vasey (1986) describe a method where information collected during annual fall sampling with trap nets in Missouri allowed biologists to evaluate and qualitatively describe five important parameters, including population density, growth rate, age structure, size structure, and recruitment. These parameters can be used not only to describe the status of a fishery but also to adequately describe the causes of potential problems such as stunting or poor catch rates. Measuring these parameters on an annual basis can lead to other potential benefits as well. For example, catch rates of age-2 and older crappie during fall surveys at four reservoirs were significantly and positively correlated with angler harvest estimates during the following

year (Colvin 1991). Such correlation allowed managers to predict when anglers could expect a quality harvest along with the age and size of fish.

Accurately estimating YCS is the basis for proper management of warmwater species, and understanding the factors that influence YCS allows the implementation of management strategies (Sammons and Bettoli 1998). However, crappie are difficult to successfully sample in steep-sided basins that are often characteristic of Idaho reservoirs, and assessing YCS of crappie using standard methods such as trap nets and electrofishing can be challenging. Some researchers have suggested utilizing larval trawl sampling to index YCS and relate YCS back to abiotic and biotic factors. Sammons and Bettoli (1998) found that although larval crappie were only briefly available to capture with neuston nets, peak larval density accurately predicted the geometric mean density of age-1 crappie. The production of larval crappie is dependent on spawning success while survival is influenced by many factors (Mitzner 1991; Sammons et al. 2002a), but the onset of spawning is controlled principally by water temperatures (Carlander 1977). Understanding when crappie spawn is integral to the ability to sample larval fish during their peak susceptibility to the sampling gear. Although black and white crappie have slightly different temperature preferences, 16°C is commonly accepted as the threshold temperature for crappie to begin spawning (Carlander 1977).

The use of larval sampling as an index of YCS for crappie is beneficial only when YCS is set during the first growing season (Sammons and Bettoli 1998). If substantial mortality occurs during the first winter, then YCS estimates based on larval sampling may be misleading. However, if YCS is fixed before the end of the first growing season, larval sampling may offer a reliable method in which problems are detected early, offering managers the time and ability to take desired actions. Sampling larval crappie would also allow for a better understanding of factors that influence successful reproduction and recruitment in Idaho waters. Water level, discharge, temperature, wind, and zooplankton abundance have all been linked to successful spawning and growth of crappie (Beam 1983; Pope and Willis 1998; Sammons et al. 2002a, 2002b; St. John and Black 2004).

MANAGEMENT GOAL

1. Improve warmwater sportfishing and fisheries management in Idaho lakes and reservoirs.

OBJECTIVES

1. Determine timing of peak larval abundance, identify any mechanisms that influence timing, and what factors affect peak larval abundance.

2. Determine if larval abundance predicts year class strength to provide managers the ability to forecast angling success.

METHODS

Larval fish were collected at Hayden Lake in the IDFG Panhandle Region, Mann Lake in the Clearwater Region, and C.J. Strike and Brownlee reservoirs in the Southwest Region from 2005 to 2009. We collected samples on a biweekly basis from late May through August to

identify peak larval density (fish/1,000 m^3). Because of an equipment malfunction, larval densities from C.J. Strike Reservoir in 2005 were excluded from analysis. Fixed sites were randomly selected (see Butts et al. 2007 for locations) and sampled at night by towing a 1 m x 2 m floating neuston net of 1 mm bar mesh equipped with a flow meter to estimate the volume of water sampled (Sammons and Bettoli 1998; St. John and Black 2004). Sites were located using a boat mounted Garmin GPS unit. At Brownlee and C.J. Strike reservoirs and Hayden Lake, where temperature and habitat variation occurred along the longitudinal axes of each water body, sampling was stratified into three strata within each lake (Appendix A). The net was towed for 5 minutes at each station with a 6.4 m boat powered by a 175 hp outboard motor. Mean boat speed was 2.6 m/s and mean tow volume was 362 m^3. Tows were made by driving the boat in a circle to keep the net out of the wake and in undisturbed water. Samples were immediately preserved in a 10% formalin solution and later transferred to ethanol (St. John and Black 2004). Larval fish were identified in the laboratory using meristic features described by Auer (1982). All larval fish were identified, counted, and measured to the nearest millimeter. Larval crappie were not identified to species because the differences in meristic characteristics at that size are unreliable (Sammons and Bettoli 1998). Larval crappie density was calculated by dividing the number of larval crappie captured in a net tow by the volume of water sampled and averaged over the strata and water body. The peak larval density is reported as the sample date with the highest density of larval crappie for each water body.

Also examined in this report are Idaho Power Company (IPC) larval data collected yearly (1994-1998) between April and August (Richter and Chandler 2007) from Brownlee Reservoir. Larval fish were collected by IPC personnel using oblique tows with paired, 0.5 m diameter, 750 µ-mesh ichthyoplankton nets. Tows were made at five depths (0-4 m) for one minute at each depth for a total of five minutes at a constant speed (for full description, see Richter 2001). Density of larval crappie was calculated as stated previously and larval density data from both sources were used in the analysis for Brownlee Reservoir.

We investigated the effect of temperature on the timing of peak larval crappie density. Because continuous water temperature data is lacking, we compared the 30 d moving average of the daily average air temperature ($AirT_{MA30}$) and the average surface water temperature from C.J. Strike Reservoir from April through September over a four-year period. Using linear regression to determine if air temperatures were related to water temperatures, we found that $AirT_{MA30}$ was directly associated with daily mean water temperatures ($P < 0.05$, $r^2 = 0.72$), and therefore a good surrogate for mean water temperatures. We acquired the daily maximum, minimum, and average air temperatures from the National Weather Service for locations closest to the study water bodies. Air temperatures were collected from Ontario, Oregon (Brownlee Reservoir), Grandview, Idaho (C.J. Strike Reservoir), Lewiston, Idaho (Mann Lake), and Coeur d'Alene, Idaho (Hayden Lake). We calculated the $AirT_{MA30}$ for each location and determined the dates the $AirT_{MA30}$ reached 10, 13, 16, 18, and 21°C, temperatures encompassing those associated with crappie spawning (Carlander 1977). We compared the dates when peak larval density occurred and the dates $AirT_{MA30}$ reached the different temperatures to determine which $AirT_{MA30}$ temperature was most closely related to the date of peak larval density. Understanding the relationship between temperature and peak larval timing will provide a method to estimate peak larval timing using easily accessible information and allow managers to focus sampling efforts around those dates to increase the chance of sampling the peak larval density.

Crappie and other warmwater species were sampled in the fall (2005-2009) and spring (2005 and 2009 only) in Brownlee Reservoir, C.J. Strike Reservoir, Mann Lake, and Hayden Lake to calculate catch-per-unit-effort (CPUE) as an index of year class abundance. From 2005 to 2008, all water bodies were sampled in late September and October; however, in 2009 we

sampled the water bodies in August and September while water temperatures were warmer than 16°C. We also sampled all the water bodies in spring 2009 to compare to fall sampling catch rates and population structure. Index sampling followed the Lowland Lakes Standard Survey protocol (IDFG, unpublished data) to sample populations using electrofishing, trap netting, and gill nets. Gill nets were only used in Brownlee and C.J. Strike reservoirs in the spring 2009 sampling. Only trap netting was completed on Hayden Lake in 2006 because of an electrofishing boat malfunction. We did not complete fall sampling at Mann Lake in either 2006 or 2007 because of extremely low water levels. We electrofished using a 5.5 m long Smith Root boat equipped with a Smith Root GPP 5.0 electrofisher using pulsed DC at night along the shoreline using a combination of short parallel and perpendicular boat movements for any given distance of shoreline. Two persons netted stunned fish from the front of the boat and attempted to capture all fish. One hour of current-on electrofishing equaled one unit of effort. Trap nets were constructed from 13 mm treated black mesh with a 0.9 x 1.8 m frame and a 22.9 m lead. Shoreline trap net locations were randomly selected and depths ranged from 2 to 10 m. Trap nets were placed in the same locations in all years, with exceptions due to water level changes in the reservoirs. One net night equaled one unit of effort. Gill nets consisted of one floating and one sinking experimental net 45.7 m long x 1.8 m deep, constructed with six panels of 19, 25, 32, 38, and 51 mm monofilament mesh. Like trap nets, we randomly selected locations for gill net placement. We set the pair of gill nets within 50 m of each other and perpendicular to the shore in suitable locations with the smaller mesh sections toward the shore. Gill nets were set in different locations in the two years in which they were used. The pair of gill nets fished for one night equaled one unit of effort. We calculated CPUE by dividing the number of target fish captured by the effort for each gear type and summed for a total CPUE. We identified and measured all fish captured and weighed a subsample from both trap nets and electrofishing.

A subsample of crappie were kept to estimate age and develop age-length keys. Up to ten crappie per 10 mm length group were retained from fall surveys during each year except 2007. Both white crappie *P. annularis* and black crappie *P. nigromaculatus* were present in Brownlee and C.J. Strike reservoirs. However, because we were unable to distinguish the two species as larval fish, no distinction was made between the two species as adults for cohort comparisons. Sagittal otoliths were removed from sampled crappie and stored dry (Hammers and Miranda 1991). Otoliths were placed in saline solution, viewed whole with reflected light, photographed using a Leica EZ4D dissecting scope/camera and saved as digital files. Using the digital images, we estimated ages from whole otoliths following the procedure outlined by Maceina and Betsill (1987). Two readers estimated ages independently, and when disagreements occurred, ages were determined by committee. If agreement could not be reached, the sample was disregarded. We used estimated ages to calculate age-length keys for each year using the computer application Fish BC (Ver. 3.0.1, 2007, Ball State University). We used age-length keys to allocate crappie CPUE to the proper year class for comparison to larval density.

To assess factors affecting potential differences in peak larval density and year class strength, several environmental parameters were collected. Water quality profiles and zooplankton samples were collected at fixed sites concurrently during larval trawling (Appendices B-J). Collections were made at three locations at Brownlee and C.J. Strike reservoirs and Hayden Lake, and one site at Mann Lake. Vertical water quality profiles were collected using a MiniSonde 4a (Hach Environmental) attached by a cable to a Surveyor 4a. We measured temperature (°C), dissolved oxygen (mg/l), specific conductivity (µs/cm), and pH from the surface to the bottom at 1 m intervals (mean surface measurements are reported in Appendices B-J), and measured water clarity with a Secchi disk.

We also gathered data from other sources for comparisons, including reservoir inflow rates (m^3/s), dam outflow rates (m^3/s), and reservoir elevation (m), for Brownlee and C.J. Strike reservoirs and Mann Lake; no similar data exists for Hayden Lake. Inflow and outflow rates were practically identical for both Brownlee and C.J. Strike reservoirs; therefore, inflow rates were used for comparisons because they were measured on a more consistent basis and are more reliable. Inflow rates for Brownlee Reservoir were measured at the USGS gauge on the Snake River immediately upstream of the slack water to the reservoir. Similar measurements for C.J. Strike Reservoir were collected from both the USGS gauge from the Bliss section of the Snake River approximately 28 k upstream of the slack water of the Snake River Arm and from the Bruneau River, approximately 3 km upstream of the Bruneau Arm. Inflow rates for Mann Lake were collected from the canal feeding the reservoir (U.S. Bureau of Reclamation). Reservoir elevations for Brownlee and C.J. Strike reservoirs were provided by IPC (T. Richter, unpublished data). The weekly mean inflow rates and reservoir elevations were calculated to decrease the variability of daily measurements. We used linear regression (SAS 2008) to determine if peak larval density of crappie at Brownlee and C.J. Strike reservoirs, and Mann Lake was related to inflow rates or reservoir elevation ($\alpha = 0.05$). Because C.J. Strike Reservoir has inflow from both the Snake River and Bruneau River, larval densities from the Snake River Arm were compared to the inflow from the Snake River and densities from the Bruneau Arm were compared to inflow from the Bruneau River.

We analyzed the relationship between the peak larval density of crappie with the CPUE of the same cohort at age-1, -2, and -3 years. We used linear regression (SAS 2008) to identify whether the peak larval density of crappie was related to the CPUE of crappie in subsequent years ($\alpha = 0.05$) for each water body. As mentioned previously, CPUE was allocated to the proper year class by calculating the proportion of crappie in different age classes using length-age keys developed for the different water bodies. The total CPUE for a given year was multiplied by the proportion in each year class to obtain the CPUE for the different age classes.

RESULTS

Larval densities were variable over all years and water bodies; however, dates of peak density were similar between years within water bodies. The peak density for larval crappie in Brownlee Reservoir was observed between July 1 and July 17 from 2005 through 2008 and was June 16 in 2009 (Figure 1). Comparably, we observed the peak larval density in C.J. Strike Reservoir between July 2 and July 13 from 2005 through 2008 and on June 17, 2009 (Figure 2). At Hayden Lake, peak densities were more inconsistent occurring from June 28, 2005, June 27, 2006, to July 30, 2007, July 27, 2008, and July 6, 2009 (Figure 3). Peak larval densities at Mann Lake occurred approximately a month earlier than the other water bodies with peaks on June 29, 2005, June 1, 2006, June 5, 2007, June 25, 2008, and June 11, 2009 (Figure 4).

Comparing the dates of peak larval crappie density and average air temperatures suggests the date $AirT_{MA30}$ reached 16°C most consistently predicted peak density occurrence (Figure 5). The peak larval density of crappie occurred, on average, 20 d (range 10-40 days) after the $AirT_{MA30}$ reached the threshold of 16°C during all years at all water bodies. At Brownlee Reservoir the peak larval density occurred 10-25 d (mean = 13 d) after the threshold. The highest range occurred at C.J. Strike Reservoir where the peak occurred within 20-40 d (mean = 30 d) of the threshold. The peak occurred most consistently at Mann Lake at 10-14 days (mean = 11 d) after the threshold. The peak occurred between 20-35 days (mean = 26 d) after the threshold at Hayden Lake.

Crappie CPUE from electrofishing was variable among water bodies and years (Table 1). In Brownlee Reservoir, fall electrofishing CPUE for crappie ranged from a low of 20 fish/h in 2005 to a high of 342 fish/h in 2007. In C.J. Strike Reservoir, crappie CPUE ranged between 2 fish/h in 2007 to 185 fish/h in 2006. In Hayden Lake, fall electrofishing CPUE was lowest in 2007 (5 fish/h) and highest in 2008 (113 fish/h). Electrofishing CPUE for crappie in Mann Lake ranged from 77 fish/h in 2005 to 40 fish/h in 2008 (Table 1). Catch rates between spring and fall sampling were generally similar.

Likewise, trap netting CPUE was variable among years for all water bodies sampled. However, compared to trap net CPUE, the electrofishing CPUE was 4-1,000 times higher in all water bodies in all years (Table 2). Fall trap net CPUE ranged from a low of 1 crappie/net night in Hayden Lake in 2005 to a high of 22 crappie/net night in Brownlee in 2007 (Table 3). The gill net CPUE in the spring of 2009 in Brownlee Reservoir was 285 crappie/net night; comparable to that for electrofishing (292 crappie/net night). However, at C.J. Strike Reservoir in 2009, the CPUE using gill nets (19 crappie/net night) was considerably lower than the CPUE from electrofishing (387 crappie/h). Although gill net CPUE for crappie was higher than trap nets overall and similar to electrofishing in Brownlee Reservoir, the amount of time expended processing fish captured in gill nets was approximately eight times that spent electrofishing.

The length frequencies for crappie from the study waters were variable from year to year (Figures 6-9). In both Brownlee (Figure 6) and C.J. Strike (Figure 7) reservoirs, the 2006 year class was the primary cohort observed. Indeed, the 2006 year class was the dominant cohort present in both reservoirs with no other year classes represented substantially until the 2009 year class. In contrast, at Hayden Lake, several year classes were observed in 2009, indicating that several cohorts have survived since 2005 (Figure 8). The population in Mann Lake also appeared to recruit consistently (Figure 9) with several year classes represented. The CPUE for other species captured during fall electrofishing and trap netting are shown in Tables 1 and 2, respectively.

Reservoir inflow was positively related to peak larval crappie density at Brownlee and C.J. Strike reservoirs. Regression analysis of the combined IPC and IDFG larval crappie data from Brownlee Reservoir suggests that reservoir inflow is positively associated with peak larval crappie density (F = 11.8, P = 0.007, r^2 = 0.57; Figure 10). The effect of inflow on peak larval CPUE for IDFG data alone is also significant (F = 21.2, P = 0.02, r^2 = 0.88; Figure 11). At C.J. Strike Reservoir, inflow from the Bruneau River was related to the larval density of crappie sampled from the Bruneau Arm (F = 19.8, P = 0.047, r^2 = 0.90; (Figure 12). However, inflow from the Snake River into C.J. Strike Reservoir was negatively related to the density of larval crappie measured in the Snake Arm (F = 99.7, P = 0.01, r^2 = 0.99; Figure 13). No relationship was found between inflow and larval crappie density at Mann Lake (F = 0.08, P = 0.81, r^2 = 04).

The relationship between the peak larval density of crappie and the CPUE of the cohorts at age-1 was variable. The relationship was significant at Brownlee Reservoir (F = 20.3, P = 0.046, r^2 = 0.91; Figure 14), but was not significant at C.J. Strike Reservoir (F = 0.47, P = 0.57, r^2 = 0.19; Figure 15) or Hayden Lake (F = 3.3, P = 0.21, r^2 = 0.62; Figure 16).

DISCUSSION

The timing of peak larval density was relatively similar for all years within each lake. Water temperatures are important in controlling spawn timing, thereby influencing when larval fish are present (Travnichek et al. 1996; Mitzner 1991). In our study, peak larval densities were

consistently measured within 10-40 days of when the $AirT_{MA30}$ reached 16°C. Focused sampling in the several weeks after the $AirT_{MA30}$ reaches 16°C should provide a good probability of measuring the peak larval density. In addition, peak larval crappie timing in our study oftentimes occurred 30-60 days later than other studies where peak timing occurred from mid-April through late May (Sammons et al. 2001; Travnichek et al. 1996; Mitzner 1991). Such variable timing is probably due to climate and watershed differences affecting temperatures of the water bodies in our study that delay crappie spawning until later in the year.

Our index of crappie abundance (CPUE) was variable at all water bodies as mentioned in other studies (Sammons et al. 2001; Travnichek et al. 1996; Mitzner 1991; Colvin and Vasey 1986), but is likely a result of sample timing or poor trap net catch rates. Sampling in the spring and earlier in the fall of 2009 while water temperatures were between 15-20°C improved catch rates over other years (Tables 1 and 2). In other studies, age-1 crappie were successfully sampled late in the year (Sammons et al. 2002b; Colvin and Vasey 1986) often in October and November, primarily using trap nets. However, trap nets appear less effective at capturing crappie in our sample waters, likely due to the steep banks and overall deeper water bodies than those in other studies. Although certain areas in our study waters are suitable for setting trap nets, the behavior of crappie and their subsequent use of those areas may be affected by the overall morphology of our study water bodies. Sampling should be conducted in the spring after average water temperatures reach 15°C or in the fall before average water temperatures drop below 15°C to increase the success of capturing age-1 crappie. Overall, catch rates with electrofishing were many times those with trap nets and appeared to be the most effective technique to sample crappie in the water bodies we studied.

Inflow rates at the large reservoirs we studied were significantly, positively related to larval density. Studies on Tennessee reservoirs determined that crappie recruitment increased in years where high winter flow patterns occurred before the spawning season (Sammons et al. 2002a; Sammons et al. 2001. Likewise, abundance of age-0 black crappie was correlated to high lake levels in Lake Okeechobee, Florida during winter months (Miller et al. 1990). Strong year classes of crappie in Alabama reservoirs were also related to high winter water levels but not reservoir hydrology during or after spawning. Although the reason for such a relationship is unclear, peak spring inflow rate was the only parameter we measured that appeared to be related to larval crappie density. Flow and water levels may be a spawning cue for adult crappie (Maceina and Stimpert 1998), although high discharge during the spawning period appeared to be harmful to crappie recruitment in some Tennessee reservoirs (Sammons et al. 2002a). Possibly, the number of spawning crappie was responsible for larval numbers; however, crappie fecundity was not related to crappie recruitment in a Pennsylvania reservoir (Mathur et al. 1979). Larval crappie may be susceptible to entrainment through dams because of their pelagic behavior during times of year when dam discharge is highest (Sorenson et al. 1998); however, larval densities were highest in years with high flow in our study. Predation on larval crappie may also affect year class strength, although other studies suggest crappie comprise a small proportion of the diet of predator species (Pelham et al. 2001; Bennett and Dunsmoor 1986; Ellison 1984; O'Brien et al. 1984). Although inflow appeared to influence peak larval density, the direct mechanism responsible for larval crappie recruitment or failure remains unclear. Recruitment success or failure has been attributed to fluctuations in water level (Beam 1983), reservoir discharge (Sammons et al. 2002a), entrainment (Sorenson et al. 1998), winter water temperatures (McCollum et al. 2003), and turbidity (Ellison 1984; Mitzner 1991).

Peak larval density does not appear to be related to year class strength on an annual basis in the water bodies we studied. We were unable to find evidence that larval density is related to year class strength, although logic dictates that higher larval densities should result in

strong year classes. However, the inability to demonstrate a relationship is likely due to the wide variability in larval densities and CPUE of crappie from the different water bodies, either from recruitment variability (Allen and Pine 2000) or the variability in our sampling. Variability in sampling crappie populations has been noted in other studies (Colvin and Vasey 1986; Beam 1983) and emphasizes the point that attention to individual waters is necessary to determine specific characteristics important to local crappie populations (Sammons et. al 2002b).

RECOMMENDATIONS

1. To measure the peak crappie density, sampling should occur within 30 days after the $AirT_{MA30}$ reaches 16°C.

2. Continue to sample peak larval densities and compare to the peak, mean weekly inflow from the Snake and Bruneau rivers into Brownlee and C.J. Strike reservoirs to increase the power of predictive models and possibly identify the mechanism underlying the positive relationship between inflow and larval crappie density.

3. When focusing surveys on crappie, perform sampling in the spring when average water temperatures range between 15 and 18°C or in the fall before average water temperatures drop below 15°C.

4. Primarily use electrofishing to sample crappie populations to more consistently estimate the index of crappie abundance (CPUE).

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Table 1. The CPUE (fish/h) of fish species captured during spring/fall electrofishing in Brownlee Reservoir, C.J. Strike Reservoir, Hayden Lake, and Mann Lake, Idaho for the years 2005-2009.

			Species					
Water body	**Year**	**Sampling Period**	**Crappie (var sp.)**	**Smallmouth bass**	**Largemouth bass**	**Bluegill**	**Pumpkin-seed**	**Yellow perch**
Brownlee Reservoir	2005	Spring	14.4	117.1	0.4	17.5	0.0	1.5
		Fall	20.2	187.0	2.1	69.5	1.1	9.8
	2006	Fall	114.7	90.0	35.1	0.0	0.0	0.0
	2007	Fall	342.7	189.0	1.7	0.0	0.3	0.0
	2008	Fall	156.1	157.4	1.6	14.9	0.0	0.3
	2009	Spring	291.9	455.0		36.0	2.0	
		Fall	172.8	662.0	38.0	371.0	3.0	5.0
C.J. Strike Reservoir	2005	Spring	8.8	140.3	7.0	45.4	1.5	4.0
		Fall	167.9	129.0	64.2	249.7	10.8	25.6
	2006	Fall	185.3	119.9	52.9	17.0	2.7	0.0
	2007	Fall	1.7	201.0	24.3	63.3	9.3	14.3
	2008	Fall	17.7	75.4	65.5	127.6	21.7	10.9
	2009	Spring	387.0	367.0	15.0	49.0	2.0	2.0
		Fall	344.9	372.0	230.0	528.0	73.0	380.0
Hayden Lake	2005	Spring	78.5	119.5	50.5	0.0	112.0	44.5
		Fall	79.4	75.3	24.0	0.0	0.0	0.0
	2006	Fall	*	*	*	*	*	*
	2007	Fall	5.3	75.3	36.3	0.0	23.0	133.0
	2008	Fall	112.8	19.9	55.8	0.6	48.7	112.2
	2009	Spring	9.0		59.0	60.0	34.0	
		Fall	21.9		233.0	275.0	196.0	
Mann Lake	2005	Fall	77.0	0.0	231.5	201.0	114.5	0.0
	2006	*						
	2007	*						
	2008	Fall	39.7	0.0	186.2	39.7	32.8	0.0
	2009	Spring	69.0	573.0	20.0	1.0	246.0	67.0
		Fall	49.5	203.0	153.0	130.0	315.0	210.0

[a] Hayden Lake not sampled in 2006 due to boat malfunction.
[b] Mann Lake not sampled in 2006 or 2007 due to low water levels.

Table 2. The CPUE (fish/net night) of fish species captured during spring/fall trap netting in Brownlee Reservoir, C.J. Strike Reservoir, Hayden Lake, and Mann Lake, Idaho for the years 2005-2009.

			Species					
Water	**Year**	**Sampling Period**	**Crappie (var sp.)**	**Smallmouth bass**	**Largemouth bass**	**Bluegill**	**Pumpkin-seed**	**Yellow perch**
Brownlee Reservoir	2005	Spring	7.7	0.0	0.0	0.5	0.3	0.3
		Fall	2.9	0.1	0.0	1.5	0.0	0.1
	2006	Fall	16.5	0.0	0.0	7.7	0.3	0.0
	2007	Fall	22.3	1.7	0.1	0.0	0.1	0.1
	2008	Fall	20.7	0.2	0.0	0.3	0.0	0.1
	2009	Spring	10.3	0.0	0.0	20.0	1.0	4.0
		Fall	20.6	32.0	0.0	256.0	27.0	223.0
C.J. Strike Reservoir	2005	Spring	6.5	1.0	0.0	0.2	0.2	1.7
		Fall	10.5	0.6	0.1	11.8	0.2	4.6
	2006	Fall	9.6	0.6	0.1	2.8	0.2	0.0
	2007	Fall	2.0	1.3	0.3	0.0	0.5	0.0
	2008	Fall	1.5	0.7	0.0	0.7	0.1	0.7
	2009	Spring	26.6	285.0	0.0	5.0	1.0	13.0
		Fall	14.3	21.0	0.0	24.0	19.0	150.0
Hayden Lake	2005	Spring	0.0	0.0	0.0	0.0	1.3	0.1
		Fall	1.0	0.0	0.4	0.1	4.4	1.8
	2006	Fall	15.8	0.7	0.2	0.1	2.4	0.0
	2007	Fall	7.4	0.0	0.3	0.2	0.2	4.5
	2008	Fall	2.2	0.0	0.1	0.4	1.9	2.5
	2009	Spring	1.5	0.0	0.0	20.0	60.0	0.0
		Fall	1.8	0.0	4.0	5.0	92.0	0.0
Mann Lake	2005	Fall	3.5	0.0	2.5	6.9	12.8	0.0
	2006	*						
	2007	*						
	2008	Fall	1.8	0.0	0.2	0.8	10.2	0
	2009	Spring	2.2	0.0	0.0	0.0	28.0	10.0
		Fall	2.0	2.0	8.0	30.0	164.0	19.0

* Mann Lake not sampled in 2006 or 2007 due to low water levels.

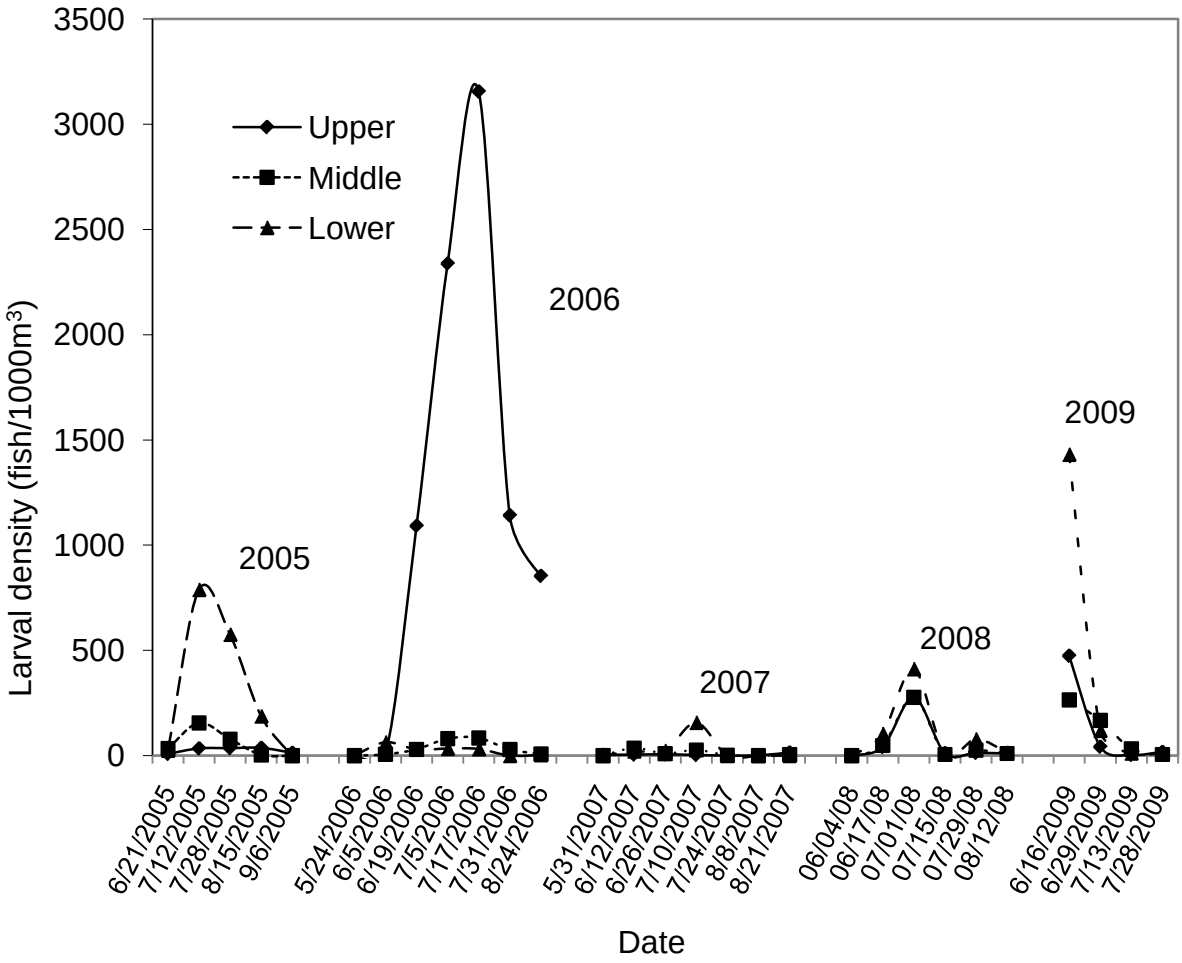

Figure 1. Estimated density of larval crappie (fish/1000 m^3) captured using neuston net trawls for three strata (Upper, Middle, and Lower) in Brownlee Reservoir from 2005-2009.

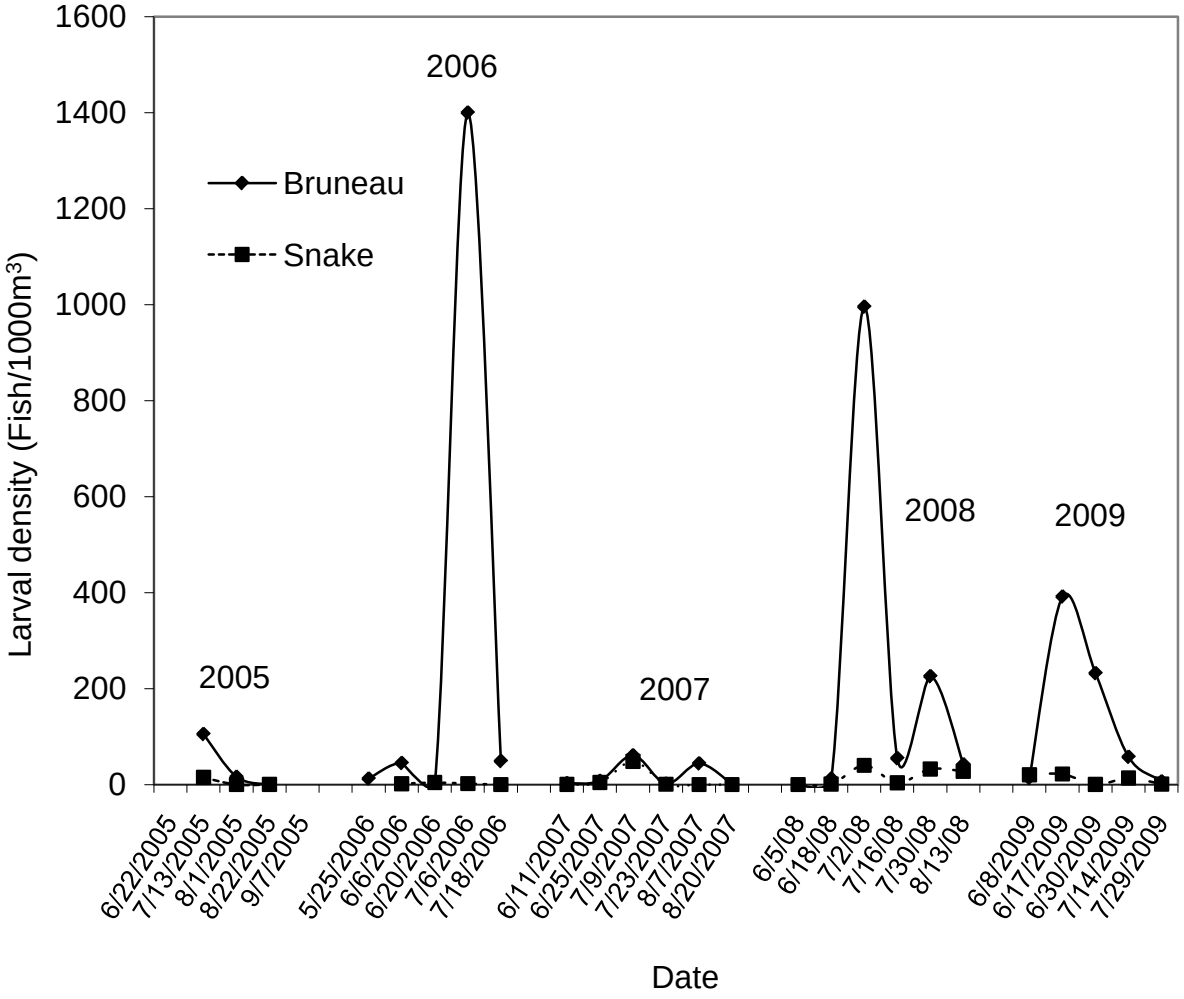

Figure 2. Estimated density of larval crappie (fish/1000 m^3) captured using neuston net trawls for three strata (Bruneau, Main, and Snake arms) in C.J. Strike Reservoir from 2005-2009.

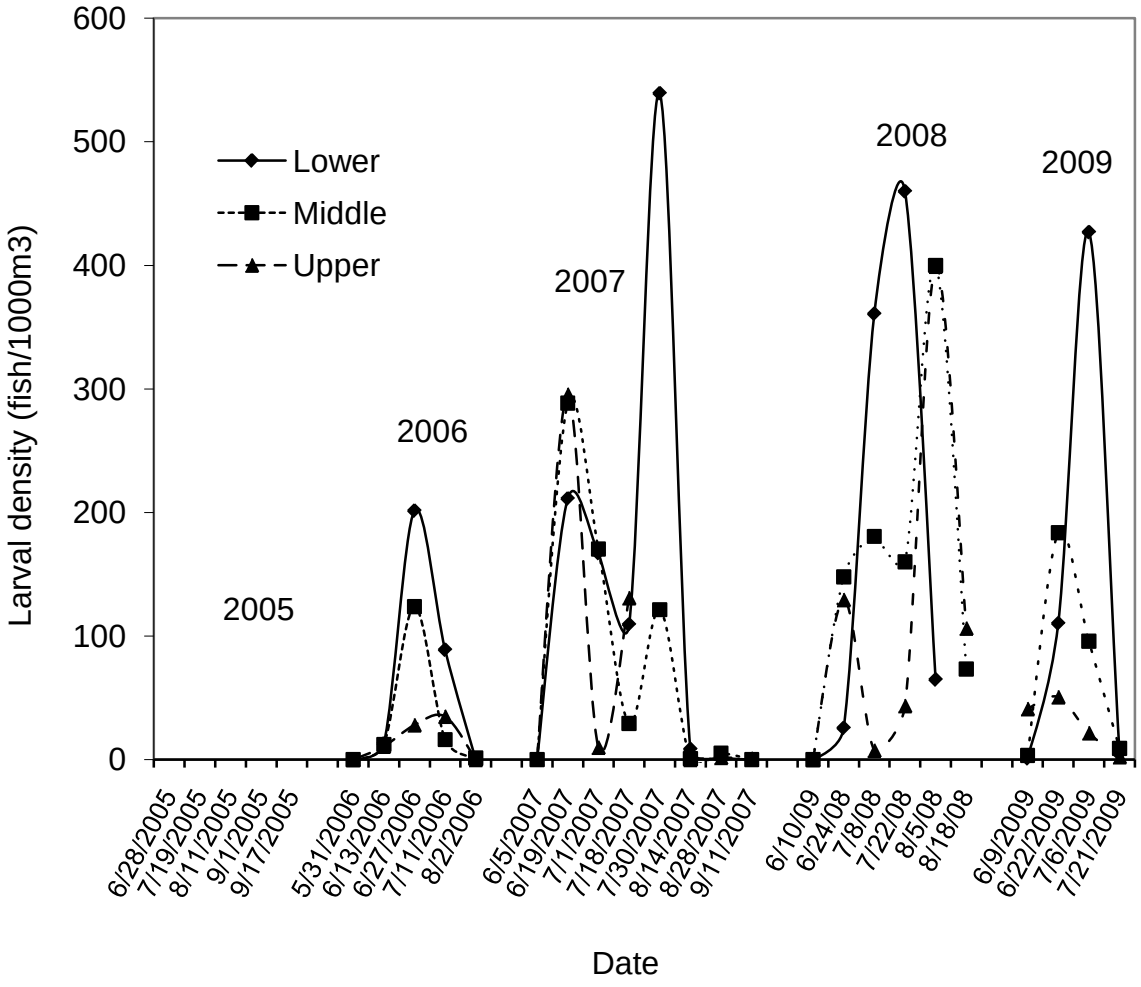

Figure 3. Estimated density of larval crappie (fish/1000 m^3) captured using neuston net trawls for three strata (Upper, Middle, and Lower) from Hayden Lake 2005-2009.

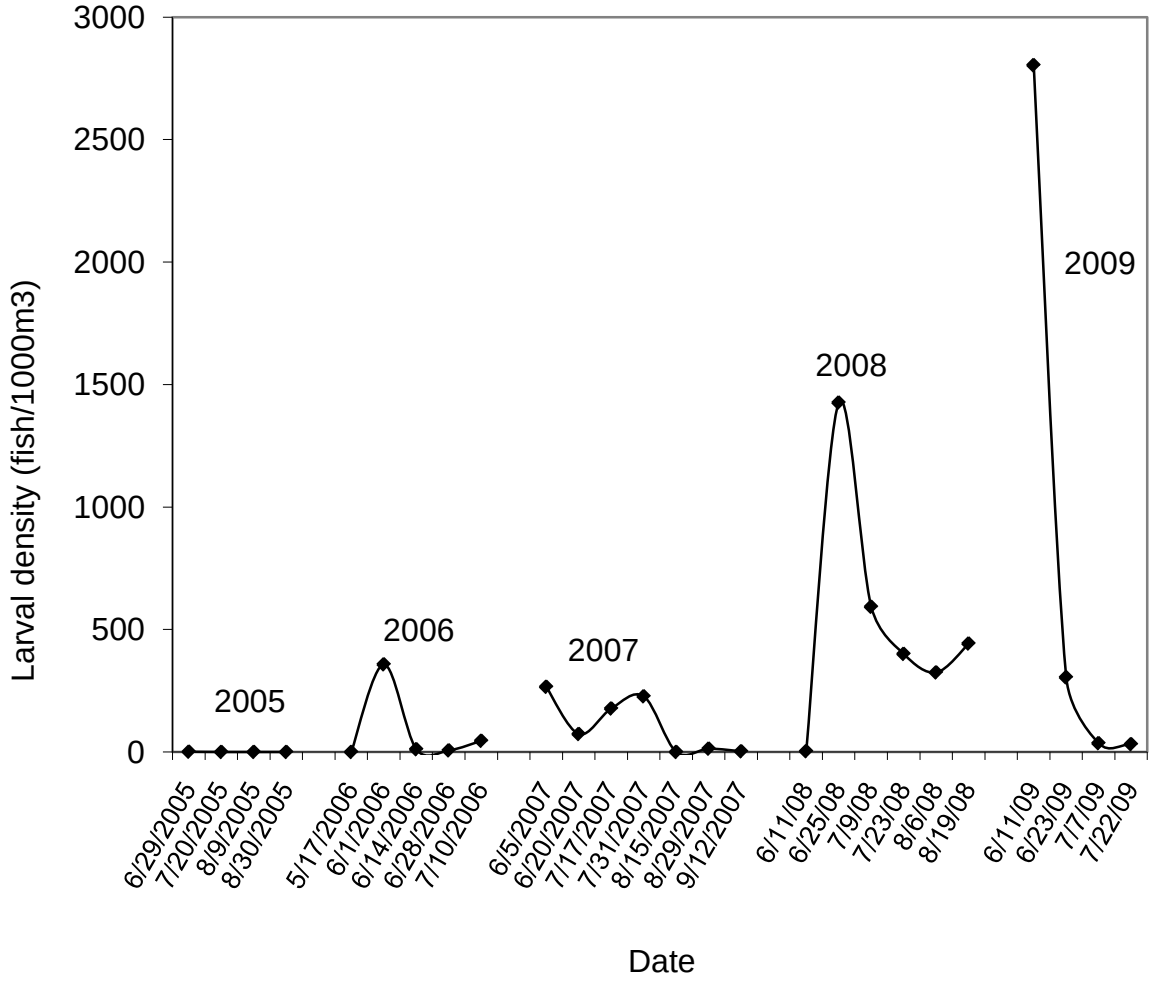

Figure 4. Estimated density of larval crappie (fish/1000 m^3) captured using neuston net trawls for Mann Lake from 2005-2009.

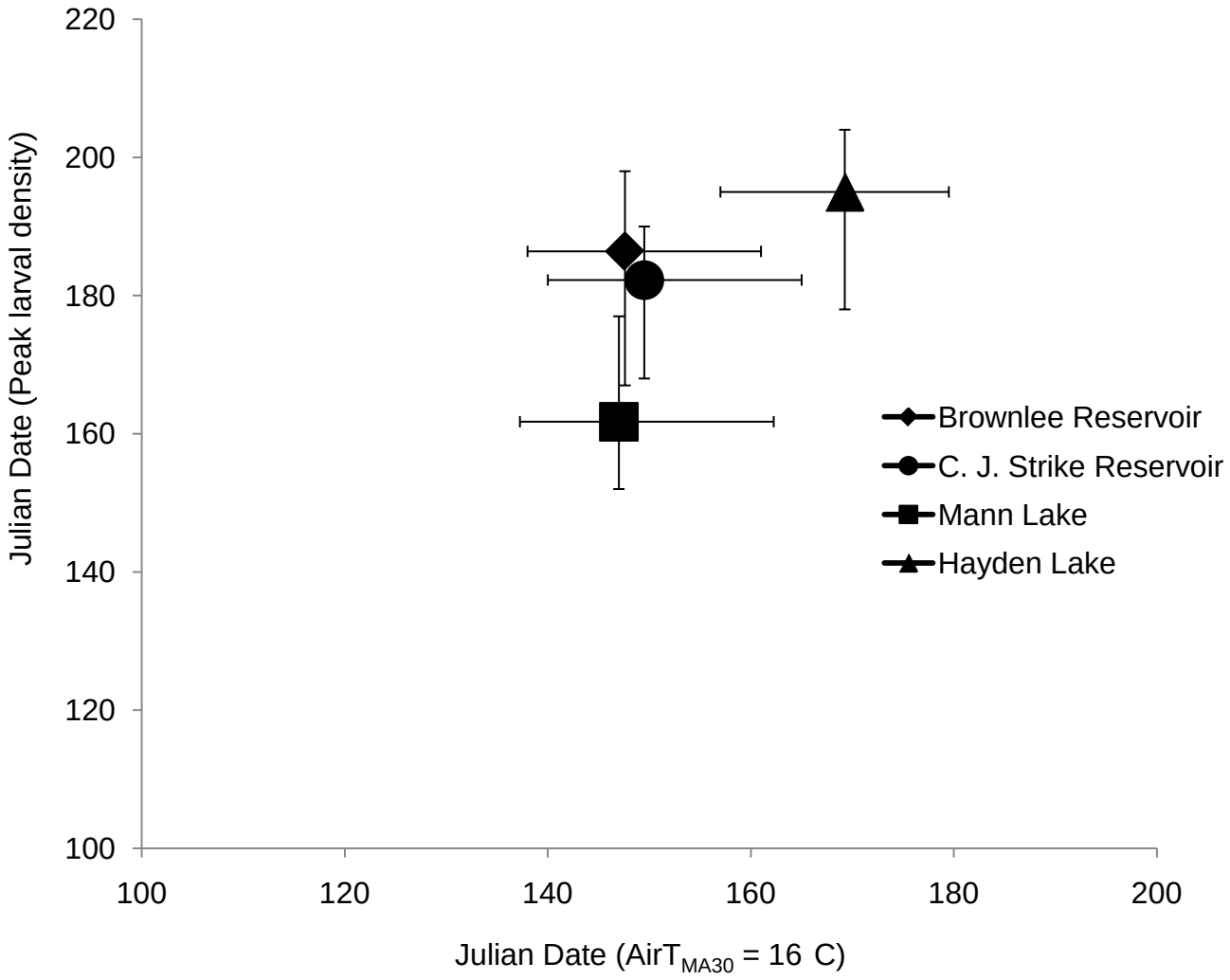

Figure 5. The mean date (Julian) the 30 day moving average air temperature ($AirT_{MA30}$) reached 16°C and the mean date (Julian) of the peak larval crappie density at Brownlee Reservoir, C.J. Strike Reservoir, Mann Lake, and Hayden Lake from 2005-2009. Horizontal error bars represent the range of dates the peak larval crappie density was measured. Vertical error bars represent the range of dates when the $AirT_{MA30}$ reached 16°C.

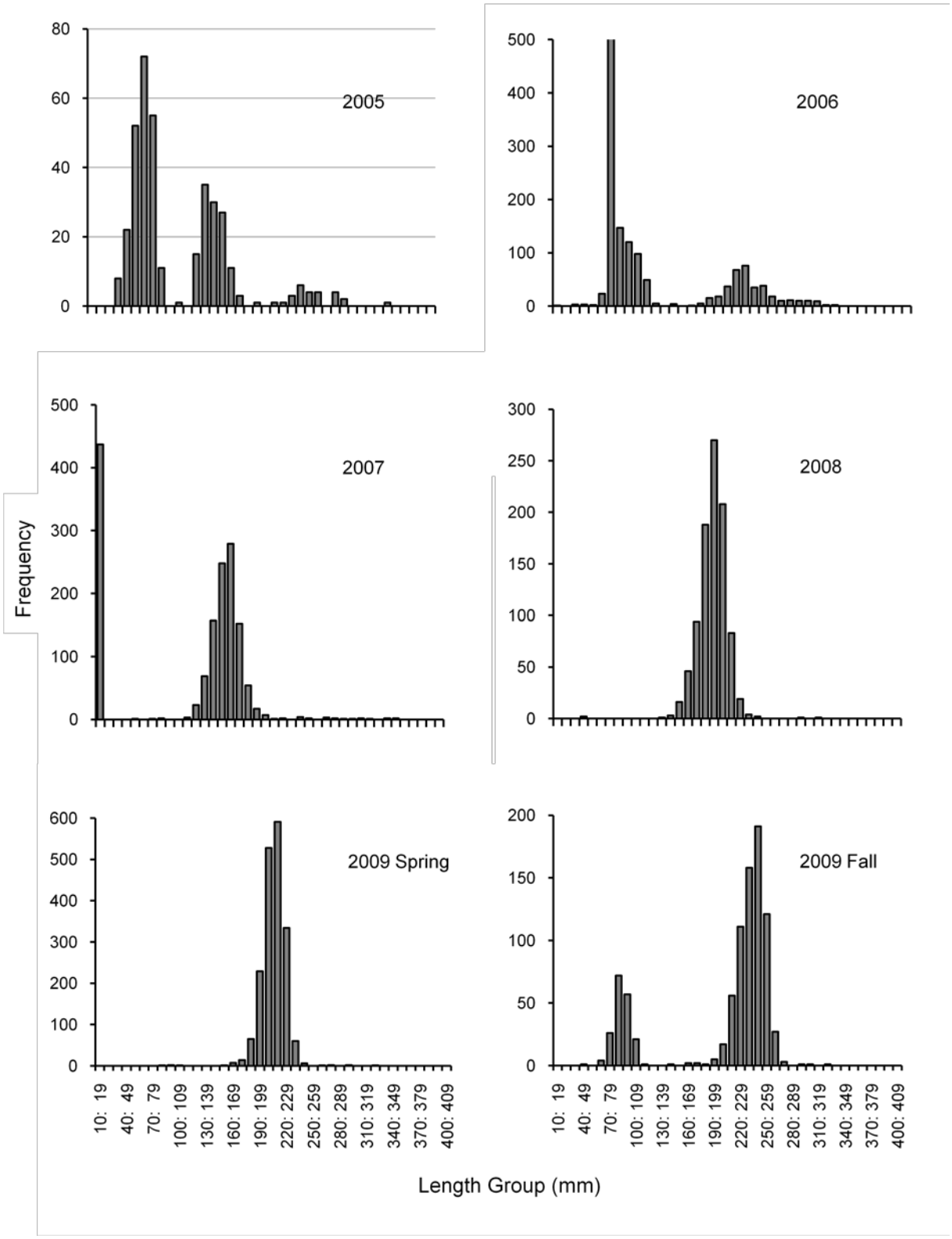

Figure 6. Length frequency histograms of crappie sampled from Brownlee Reservoir with electrofishing and trap nets in the fall of 2005-2008 and spring/fall 2009.

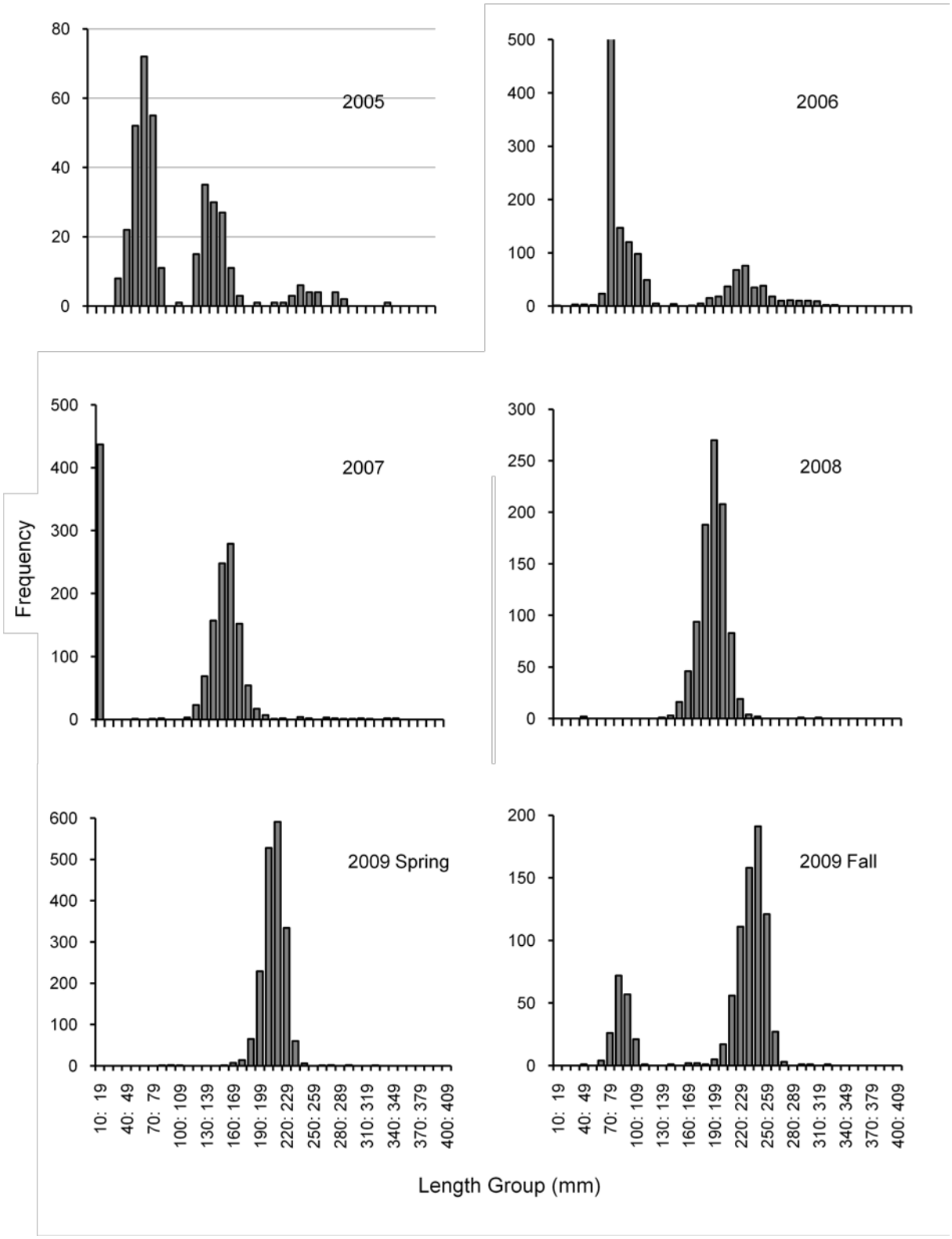

Figure 7. Length frequency histograms of crappie sampled from C.J. Strike Reservoir with electrofishing and trap nets in the fall of 2005-2008 and spring/fall 2009.

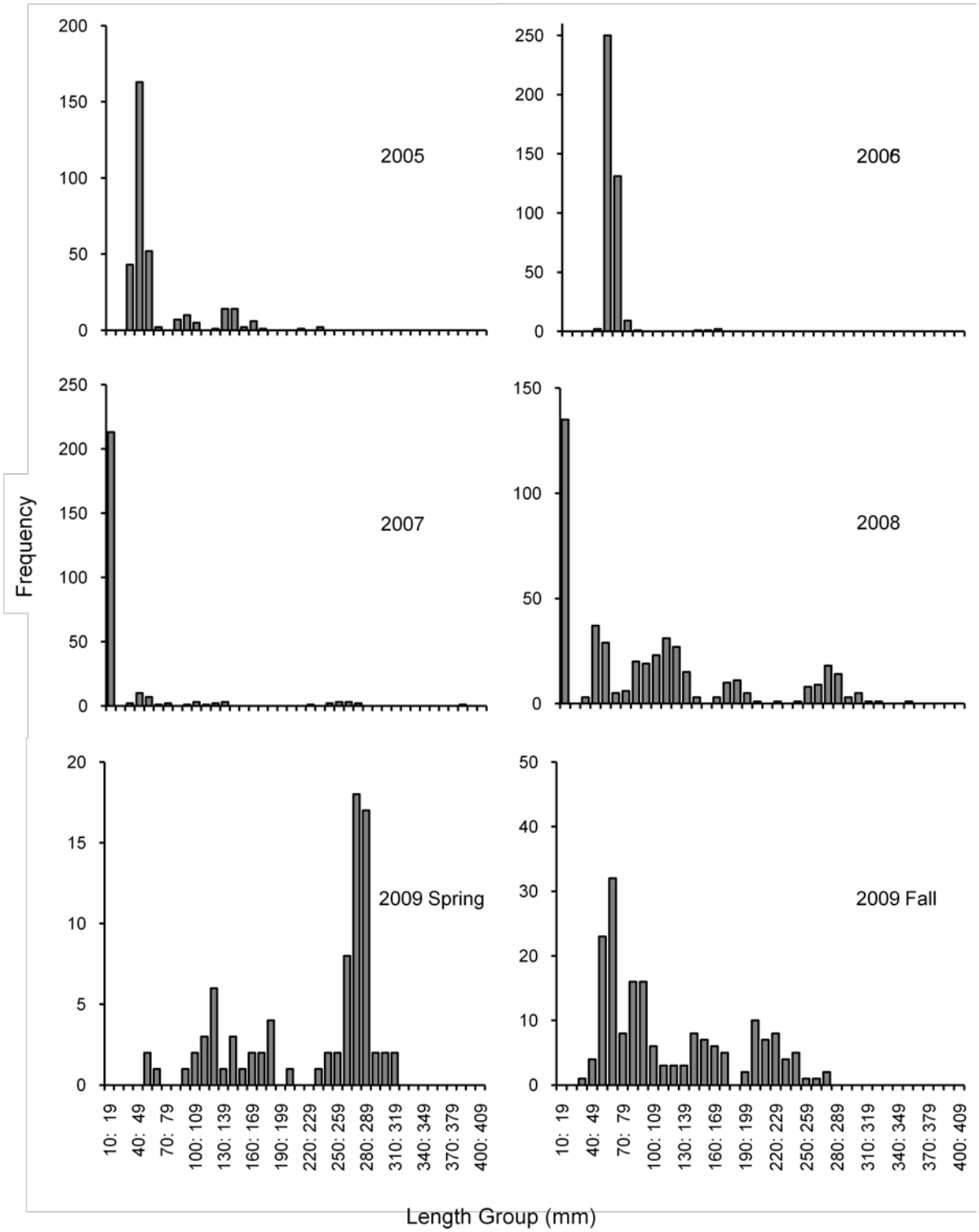

Figure 8. Length frequency histograms of crappie sampled from Hayden Lake with electrofishing and trap nets in the fall of 2005-2008 and spring/fall 2009. Note: Hayden Lake was not electrofished in 2006 because of a boat malfunction.

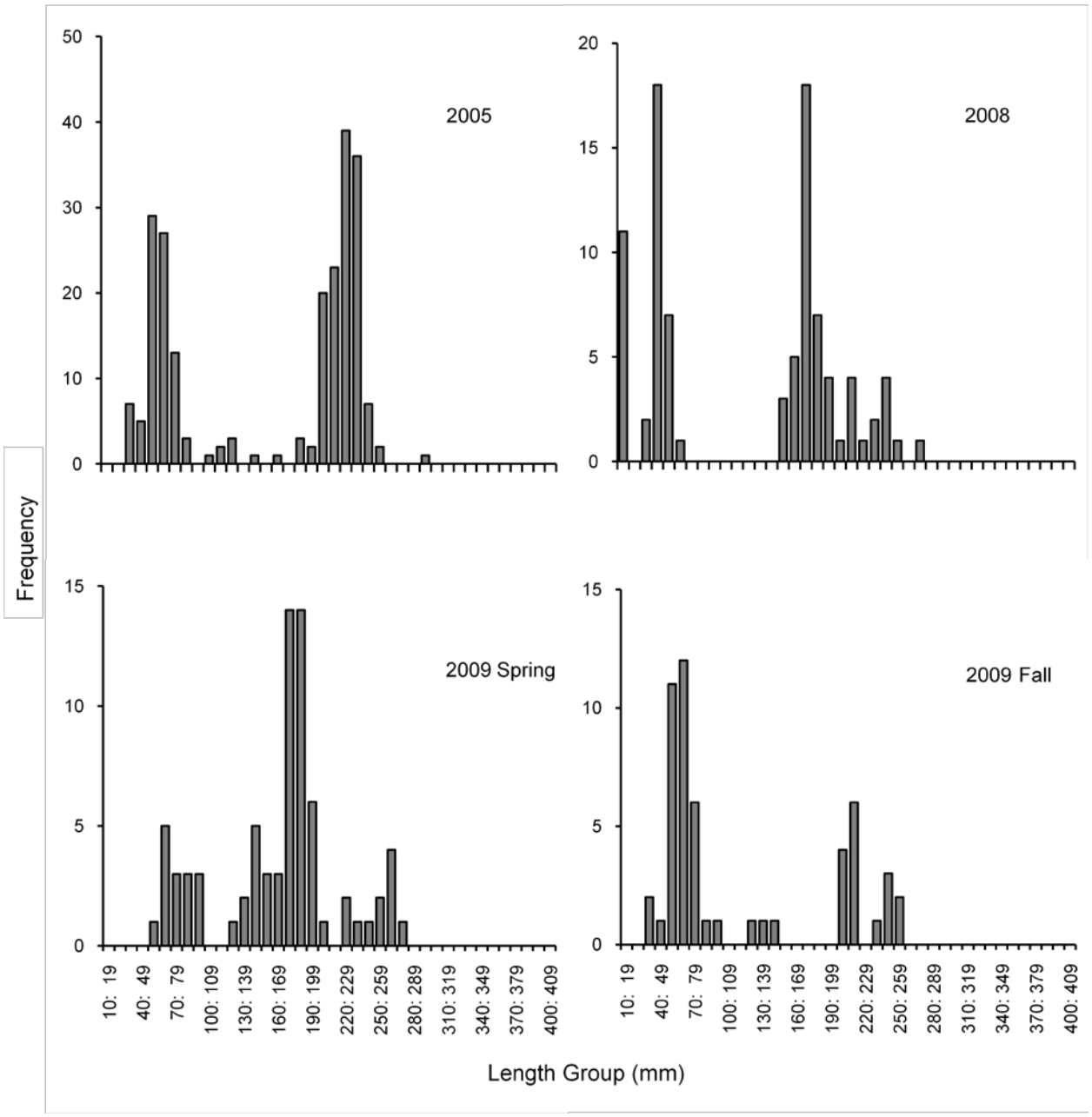

Figure 9. Length frequency histograms of crappie sampled from Mann Lake with electrofishing and trap nets in the fall of 2008 and spring/fall 2009.

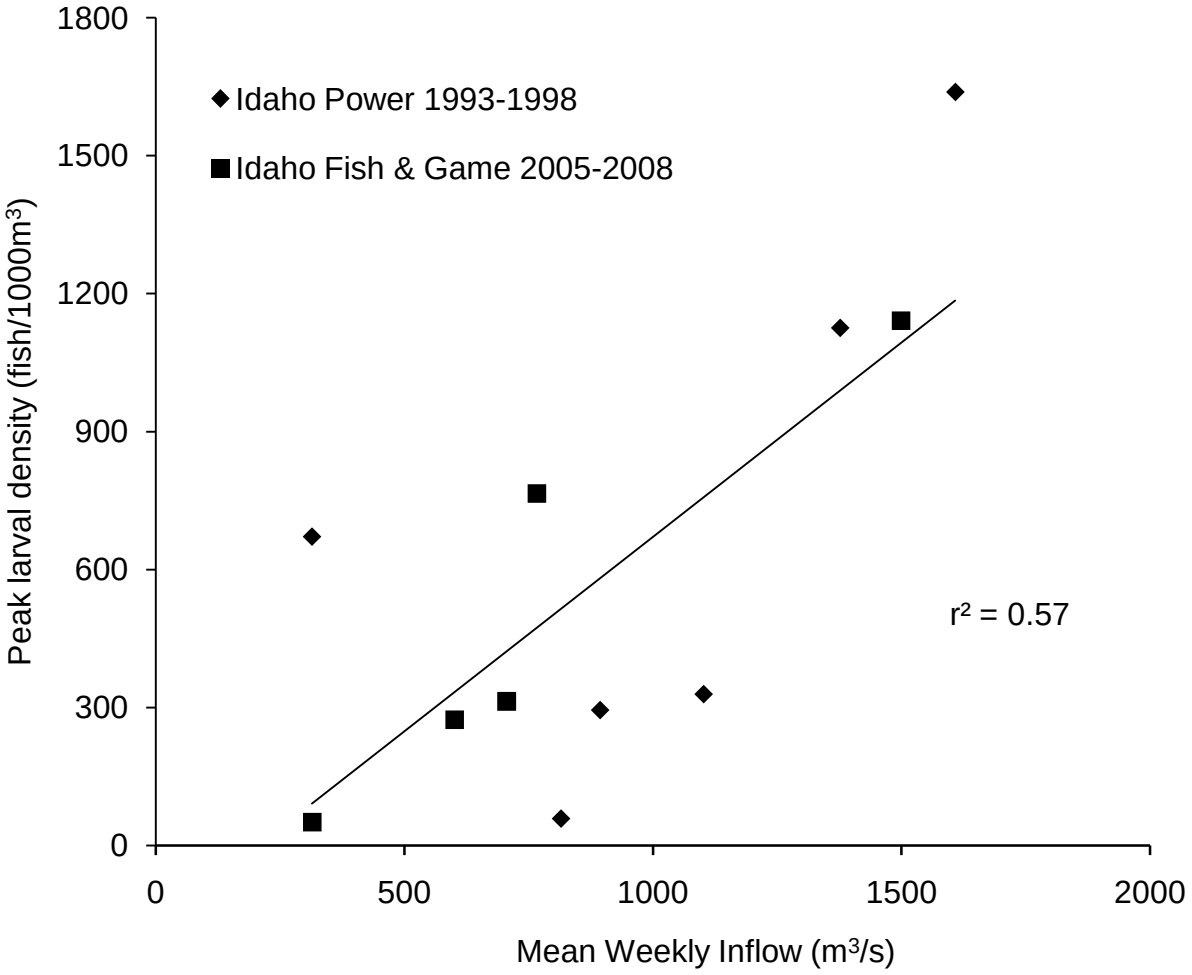

Figure 10. Regression comparison between peak larval crappie density (data pooled from Idaho Power Company for the years 1994-1998 and from the Idaho Department of Fish and Game for the years 2005-2008) and mean peak inflow rates (m^3/s) at Brownlee Reservoir.

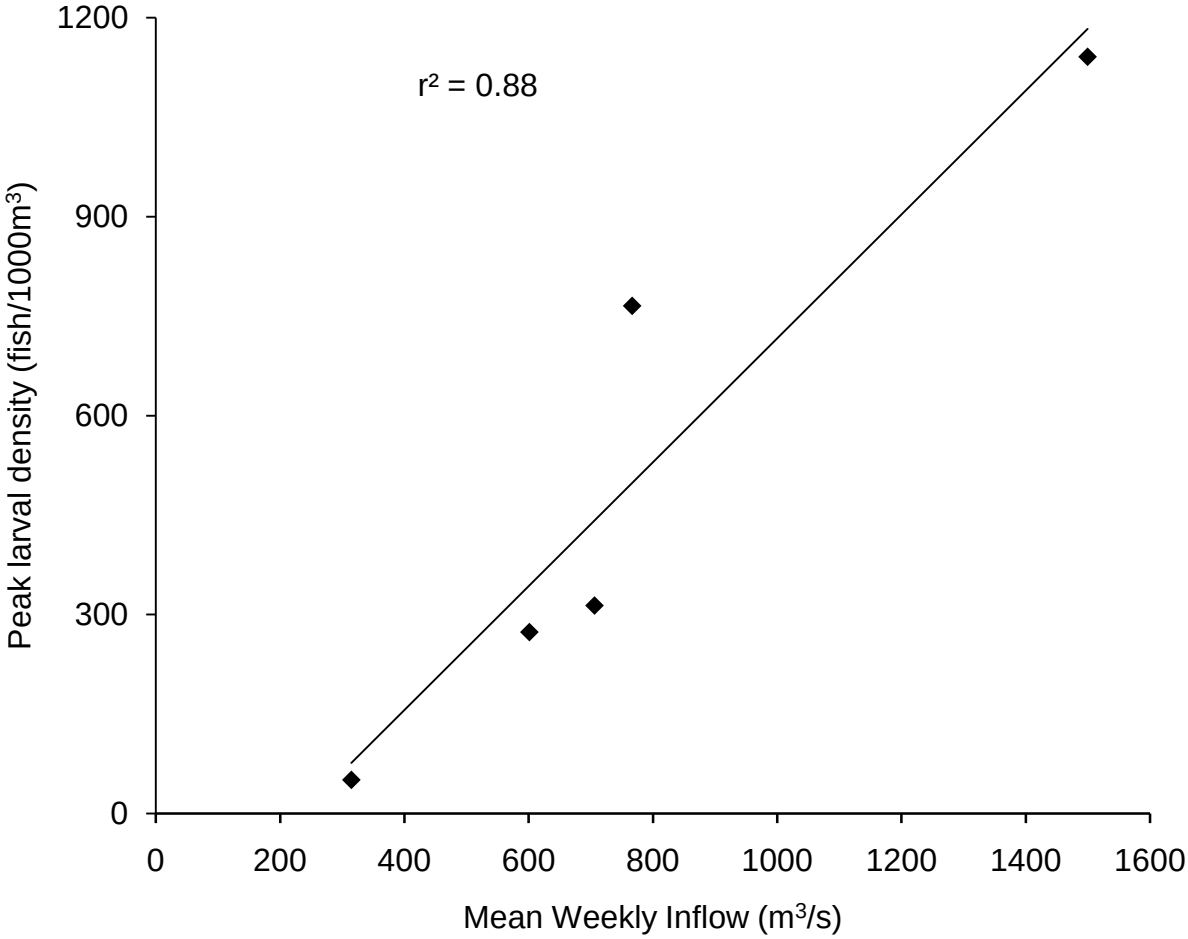

Figure 11. Regression comparison between peak larval crappie CPUE and mean peak inflow rates (m^3/s) at Brownlee Reservoir collected by the Idaho Department of Fish and Game for the years 2005-2009.

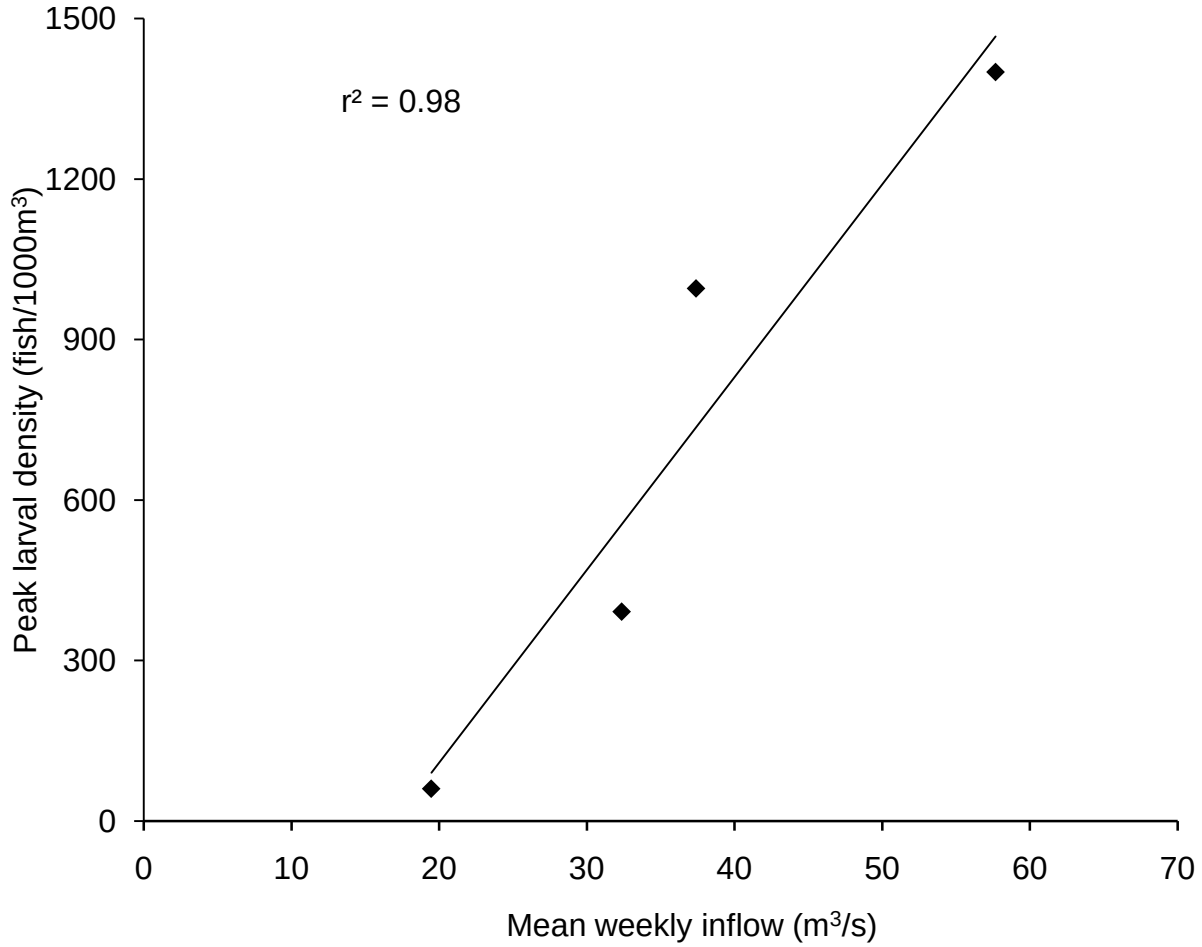

Figure 12. Regression comparison between peak larval crappie density and mean peak inflow rates (m^3/s) from the Bruneau River Arm of C.J. Strike Reservoir collected by the Idaho Department of Fish and Game for the years 2006-2009.

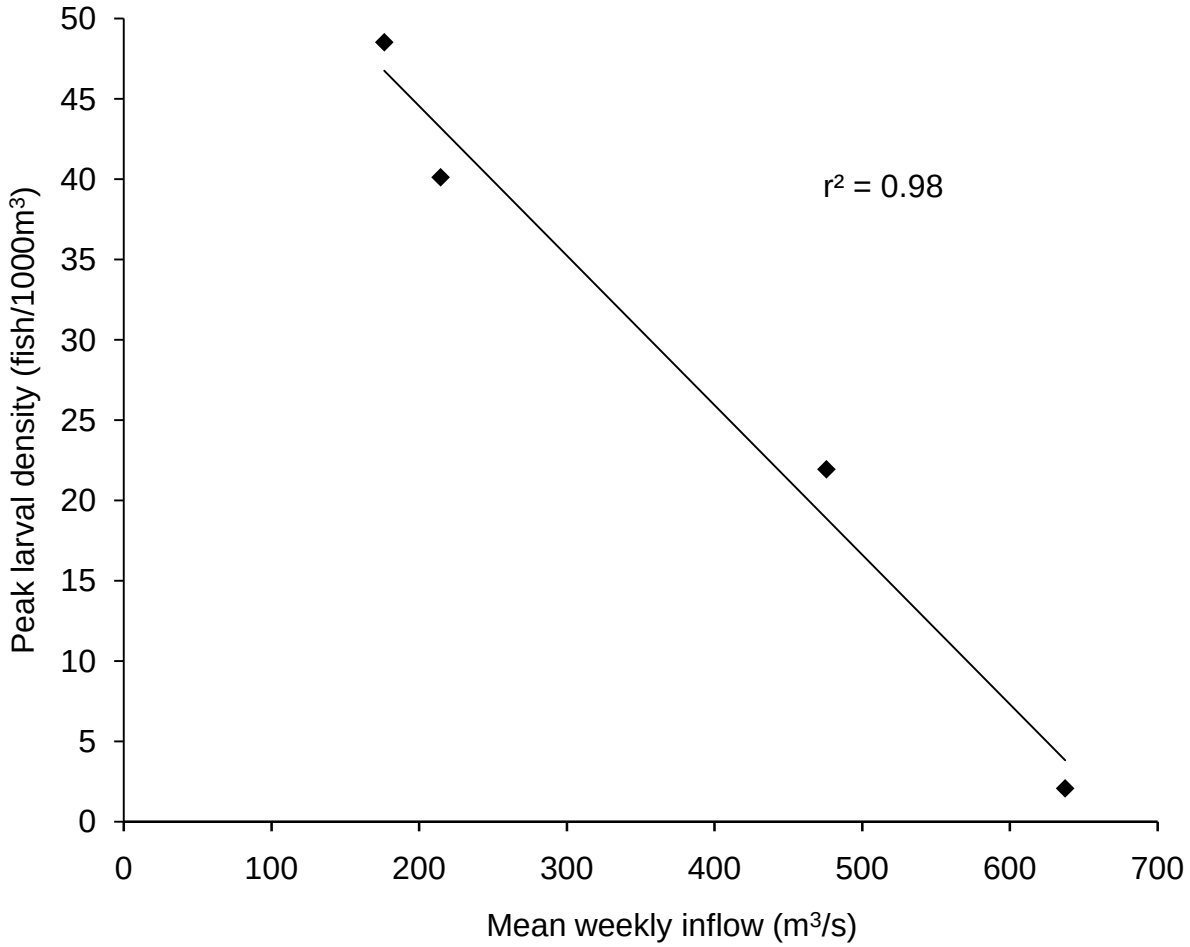

Figure 13. Regression comparison between peak larval crappie density and mean peak inflow rates (m^3/s) from the Snake River Arm of C.J. Strike Reservoir collected by the Idaho Department of Fish and Game for the years 2006-2009.

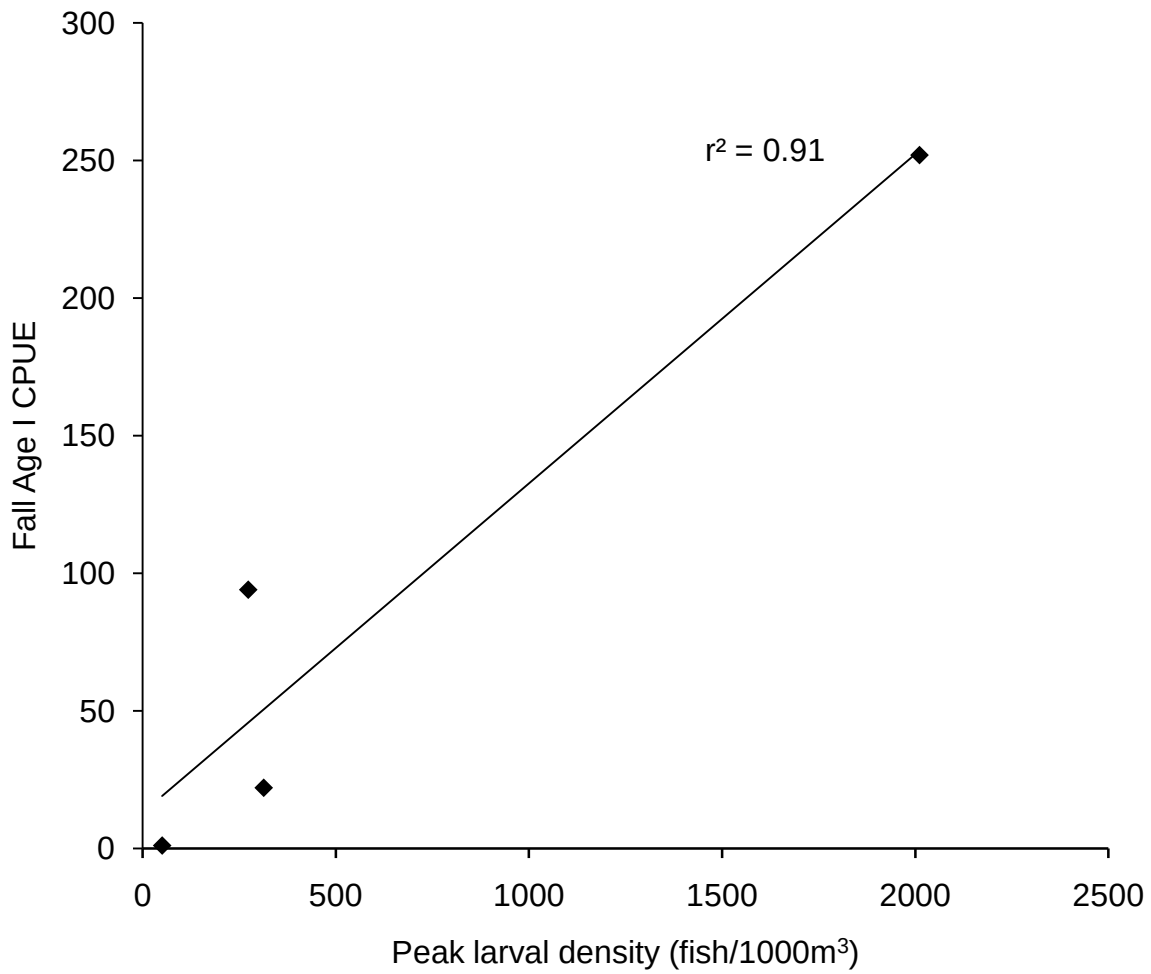

Figure 14. Regression comparison of peak larval crappie density and the CPUE of the crappie cohort at age-1 sampled during the fall from Brownlee Reservoir 2005-2009.

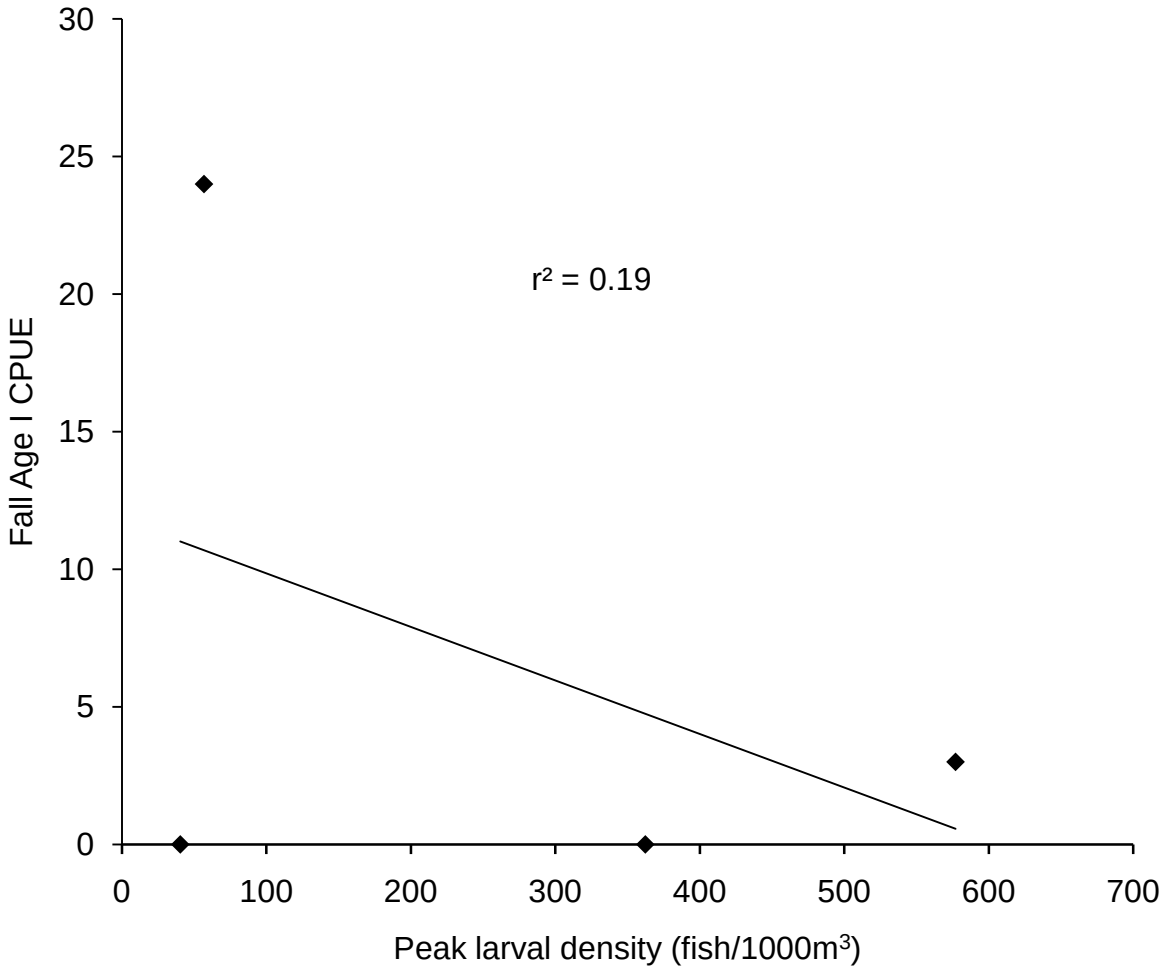

Figure 15. Regression comparison of peak larval crappie density and the CPUE of the crappie cohort at age-1 sampled during the fall from C.J. Strike Reservoir 2005-2009.

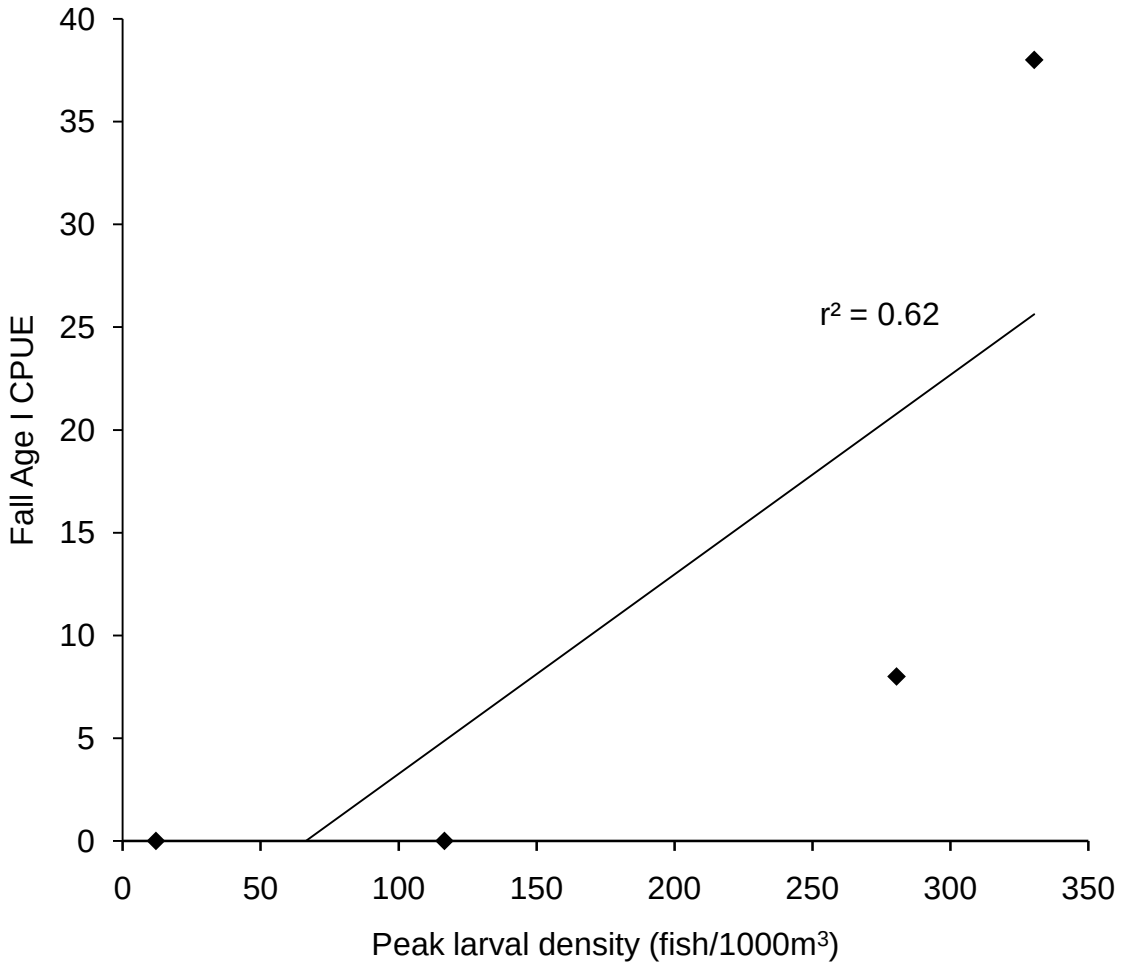

Figure 16. Regression comparison of peak larval crappie density and the CPUE of the crappie cohort at age-1 sampled during the fall from Hayden Lake 2005-2009.

APPENDICES

Appendix A. Locations (UTM, NAD83, Zone 11), strata, and nomenclature of sites sampled by larval trawling and for water quality measurements in Brownlee Reservoir, C.J. Strike Reservoir, Hayden Lake, and Mann Lake, Idaho for the years 2005-2009.

Water Body	Strata	Larval Trawl Site	Water Quality Site	UTM Easting	UTM Northing
Brownlee Reservoir	Upper	BL01	BR LIM 1	482909	4922286
		BL02		484003	4926717
		BL03		484575	4928341
		BL04		490802	4940607
	Middle	BL05	BR LIM 2	491672	4942248
		BL06		492384	4944880
		BL07		492969	4946345
		BL08		493909	4948181
	Lower	BL09		498598	4955528
		BL10		503455	4957931
		BL11		507404	4964524
			BR LIM 3	506283	4962798
C.J. Strike Reservoir	Bruneau Arm	CJ01		592019	4752101
		CL02	CJ LIM 1	590515	4752311
		CJ03		590226	4752872
		CJ04		590281	4752714
	Snake Arm	CJ05		584855	4754605
			CJ LIM 2	583871	4755376
		CJ06		585653	4755710
		CJ07		584046	4755832
	Main Pool	CJ08		584140	4758235
		CJ09		584357	4759244
		CJ10	CJ LIM 3	587220	4761523
Hayden Lake	Upper	HY03	HYLIM 1	522783	5293705
		HY04		522853	5293522
	Middle	HY05		523347	5291489
		HY06		524107	5290804
		HY07		523824	5291403
		HY08		522059	5290848
	Lower	HY09	HYLIM 2	522987	5288607
		HY10		523338	5289319
		HY11		521200	5289112
		HY12	HYLIM 3	518954	5289228
Mann Lake	Only	MN01		511448	5135810
		MN02		511285	5135593
		MN03		511486	5135482
		MN04		511452	5135284
		MN05		511340	5135353
		MN06		511383	5135495
		MN07		511182	5135489
		MN08	MNLIM 1	511275	5135235
		MN09		511248	5135110
		MN10		511346	5135197

Appendix B. Surface means of water quality parameters measured at Brownlee Reservoir during the summers of 2005-2009, including temperature (Temp; °C), dissolved oxygen (DO; mg/L), conductivity, pH, and secchi depth (m). N/A-data not available.

Water Body	Date	Temp (°C)	DO (mg/L)	Conductivity	pH	Secchi Depth (m)
Brownlee Reservoir	6/21/2005	21.1	7.7	325	9.36	1.15
	7/12/2005	24.2	14.8	334	10.29	0.80
	7/28/2005	25.2	10.5	373	10.07	1.20
	8/15/2005	26.2	-	399	10.33	1.29
	9/6/2005	23.5	9.3	431	8.46	2.55
	5/24/2006	16.1	10.2	201	8.78	0.35
	6/5/2006	21.1	10.7	207	9.12	2.00
	6/19/2006	19.3	9.9	-	-	0.73
	7/5/2006	26.3	8.4	254	8.79	4.00
	7/17/2006	25.5	6.7	356	9.00	1.30
	7/31/2006	25.1	6.5	348	9.00	1.08
	8/24/2006	23.4	10.2	368	8.93	1.35
	5/31/2007	19.4	8.6	309	8.97	3.17
	6/12/2007	20.8	7.5	300	8.79	3.50
	6/26/2007	24.8	6.6	312	8.72	3.50
	7/10/2007	26.1	9.6	335	8.99	3.50
	7/24/2007	26.2	8.7	368	8.82	1.75
	8/8/2007	25.5	4.6	399	8.24	2.42
	8/21/2007	23.6	7.1	406	8.33	2.71
	6/17/2008	19.1	11.0	187	8.71	1.83
	7/1/2008	23.8	6.5	219	8.90	1.53
	7/15/2008	25.2	9.5	294	9.19	1.82
	7/29/2008	24.4	9.6	376	8.87	1.63
	8/12/2008	25.7	11.1	413	8.88	1.32
	4/21/2009	20.3	8.3	298	9.02	3.85
	6/3/2009	22.6	6.5	273	8.80	5.20
	6/16/2009	22.2	10.5	264	9.37	1.88
	6/29/2009	23.7	12.3	264	8.91	1.89
	7/13/2009	22.6		331	8.84	1.47
	7/28/2009	13.9	6.4	229	6.25	2.58

Appendix C. Surface means of water quality parameters measured at C.J. Strike Reservoir during the summers of 2005-2009, including temperature (Temp; °C), dissolved oxygen (DO; mg/L), conductivity, pH, and secchi depth (m). N/A-data not available.

Water Body	Date	Temp (°C)	DO (mg/L)	Conductivity	pH	Secchi Depth (m)
C.J. Strike Reservoir	6/22/2005	19.5	8.9	369	9.92	1.75
	7/13/2005	22.8	10.4	395	10.09	1.85
	8/22/2005	25.0	12.5	421	8.77	-
	9/7/2005	21.5	11.4	439	8.85	2.05
	10/12/2005	15.8	11.3	489	8.77	2.05
	5/25/2006	20.7	13.8	373	9.09	1.00
	6/6/2006	23.8	13.2	190	-	0.85
	6/20/2006	21.1	9.7	-	-	0.93
	7/6/2006	23.8	8.5	329	8.53	0.81
	7/18/2006	24.8	12.4	344	8.85	0.76
	10/12/2006	14.8	8.1	321	8.89	1.45
	6/25/2007	22.5	7.4	340	8.67	1.59
	7/9/2007	25.2	8.0	344	8.88	1.30
	7/23/2007	26.0	12.2	353	8.97	1.25
	8/7/2007	24.1	6.9	405	8.50	1.68
	8/20/2007	24.2	7.2	412	8.55	1.40
	6/18/2008	21.0	10.7	241	8.88	1.28
	7/2/2008					1.65
	7/16/2008	23.4	10.5	389	9.00	1.08
	7/30/2008	23.7	8.7	419	8.77	1.24
	8/13/2008	23.8	10.1	442	8.81	1.32
	6/17/2009	20.7	9.2	398	9.06	1.69
	6/30/2009	21.8	8.9	216	9.23	1.24
	7/29/2009	24.6	10.9	289	8.29	1.22

Appendix D. Surface means of water quality parameters measured at Hayden Lake during the summers of 2005-2009, temperature (Temp; °C), dissolved oxygen (DO; mg/L), conductivity, pH, and secchi depth (m). N/A-data not available.

Water Body	Date	Temp (°C)	DO (mg/L)	Conductivity	pH	Secchi Depth (m)
Hayden Lake	7/19/2005	22.5	8.1	52	9.12	8.50
	8/11/2005	24.3	-	52	9.20	6.05
	9/1/2005	21.5	8.0	52	7.97	6.50
	9/17/2005	17.7	8.3	52	7.92	-
	5/16/2006	17.1	9.7	51	7.81	5.85
	5/31/2006	17.9	8.9	52	8.04	5.18
	6/13/2006	18.4	8.0	-	-	5.53
	6/27/2006	23.4	7.3	50	7.68	6.47
	7/11/2006	23.3	6.9	49	7.86	6.67
	8/2/2006	22.7	6.7	49	8.01	5.53
	10/17/2006	14.1	8.6	49	8.56	7.83
	6/5/2007	23.1	6.2	49	7.77	6.50
	7/1/2007	20.5	7.3	48	7.76	-
	7/18/2007	24.1	7.5	38	7.69	7.59
	7/30/2007	24.3	6.7	48	7.65	5.80
	8/14/2007	23.1	6.2	49	7.77	6.46
	8/28/2007	20.8	6.6	49	8.08	9.29
	9/11/2007	20.5	6.9	49	7.97	7.74
	6/24/2008	16.9	7.0	42	7.85	6.35
	7/8/2008	21.9	7.7	59	8.04	7.38
	7/22/2008	21.8	7.4	60	8.19	6.68
	8/5/2008	23.0	7.5	61	8.11	6.08
	8/18/2008	23.6	7.1	62	8.16	6.00
	10/9/2008	14.9	8.3	61	8.39	6.33
	6/8/2009	22.6	6.5	273	8.80	5.20
	6/22/2009	18.2	7.9	61	8.44	6.29
	7/6/2009	21.7	7.9	59	8.53	6.93
	7/21/2009	24.1	8.5	54	8.79	6.39

Appendix E. Surface means of water quality parameters measured at Mann Lake during the summers of 2005-2009, including temperature (Temp; °C), dissolved oxygen (DO; mg/L), conductivity, pH, and secchi depth (m). N/A-data not available.

Water Body	Date	Temp (°C)	DO (mg/L)	Conductivity	pH	Secchi Depth (m)
Mann Lake	6/29/2005	25.4	12.3	96	10.78	1.25
	7/20/2005	25.9	-	84	10.13	1.90
	8/9/2005	20.4	9.0	79	8.83	0.85
	8/30/2005	19.5	7.9	77	8.80	5.50
	5/17/2006	28.1	7.7	89	8.29	2.50
	6/1/2006	21.9	9.1	92	8.80	1.15
	6/14/2006	19.1	7.6			1.45
	6/28/2006	27.4	7.7	85	8.67	1.25
	7/10/2006	25.0	7.4	9	81.80	1.25
	7/17/2007	25.9	7.8	78	8.94	1.66
	7/31/2007	25.2	7.6	74	9.05	1.30
	8/15/2007	24.5	8.1	72	8.95	0.80
	8/29/2007	23.8	6.9	68	8.70	1.40
	9/12/2007	20.6	6.2	67	8.52	1.00
	7/9/2008	25.7	7.7	90	9.05	1.34
	7/23/2008	22.9	7.8	89	8.90	1.10
	8/6/2008	26.1	10.8	93	9.37	0.09
	8/19/2008	23.6	7.3	90	9.47	0.61
	8/6/2008	26.1	10.8	93	9.37	-
	8/19/2008	23.6	7.3	90	9.47	-
	7/7/2009	23.6	6.2	92	9.35	1.95
	7/22/2009	27.7	7.1	90	9.43	1.20

Appendix F. Mean biomass (g/m) of zooplankton collected with three different mesh size nets (153, 500, and 750 µm) and the Zooplankton Ratio (ZPR; 750 µm /500 µm) and Zooplankton Quality Index (ZQI; (500 µm + 700 µm)*ZPR) at different sample sites from Brownlee Reservoir, C.J. Strike Reservoir, Hayden Lake, and Mann Lake sampled during the summer of 2005.

			Mean biomass (g/m)				
Water	**Date**	**Sample Site**	**153 µm**	**500 µm**	**750 µm**	**ZPR**	**ZQI**
Brownlee	6/21/2005	BR LIM 3	3.42	3.30	1.75	0.53	2.68
Reservoir	7/12/2005	BR LIM 1	-	9.13	9.03	0.99	17.96
	7/28/2005	BR LIM 3	-	4.96	2.98	0.60	4.77
		BR LIM 1	2.15	1.40	0.93	0.66	1.55
	8/15/2005	BR LIM 1	-	10.90	5.71	0.52	8.70
		BR LIM 3	-	5.35	4.47	0.84	8.20
	9/6/2005	BR LIM 1	-	12.37	11.42	0.92	21.96
		BR LIM 3	15.35	9.86	11.43	1.16	24.68
	10/5/2005	BR LIM 3	-	0.30	0.18	0.60	0.29
C.J. Strike	6/16/2005	CJ LIM 3	7.83	2.67	2.40	0.90	4.56
Reservoir	6/22/2005	CJ LIM 3	15.50	8.91	6.80	0.76	11.99
	7/13/2005	CJ LIM 3	5.46	2.38	1.31	0.55	2.03
	8/2/2005	CJ LIM 3	-	-	7.85	-	-
	8/22/2005	CJ LIM 3	-	3.80	3.47	0.91	6.64
	9/7/2005	CJ LIM 3	-	0.65	0.46	0.71	0.79
	10/12/2005	CJ LIM 3	-	0.94	0.42	0.45	0.61
Hayden Lake	7/19/2005	HYLIM 1	2.36	1.20	1.09	0.91	2.08
		HYLIM 2	1.50	1.11	0.77	0.69	1.30
	8/11/2005	HYLIM 1	0.59	0.40	0.12	0.30	0.16
		HYLIM 2	0.60	0.34	0.16	0.47	0.24
	9/1/2005	HYLIM 1	0.40	0.17	0.02	0.12	0.02
		HYLIM 2	0.77	0.52	0.31	0.60	0.49
	9/21/2005	HYLIM 1	0.63	0.55	0.20	0.36	0.27
		HYLIM 2	1.30	0.79	0.41	0.52	0.62
Mann Lake	7/21/2005	MNLIM 1	4.82	1.98	0.02	0.01	0.02
	8/9/2005	MNLIM 1	16.40	4.25	0.30	0.07	0.32
	8/30/2005	MNLIM 1	6.20	1.12	0.41	0.37	0.56
	9/13/2005	MNLIM 1	7.00	0.90	0.10	0.11	0.11

Appendix G. Mean biomass (g/m) of zooplankton collected with three different mesh size nets (153, 500, and 750 µm) and the Zooplankton Ratio (ZPR; 750 µm /500 µm) and Zooplankton Quality Index (ZQI; (500 µm + 700 µm)*ZPR) at different sample sites from Brownlee Reservoir, C.J. Strike Reservoir, Hayden Lake, and Mann Lake sampled during the summer of 2006.

			Mean biomass (g/m)				
Water	**Date**	**Sample Site**	**153 µm**	**500 µm**	**750 µm**	**ZPR**	**ZQI**
Brownlee Reservoir	5/24/2006	BR LIM 3	4.76	0.51	0.33	0.65	0.54
	6/5/2006	BR LIM 3	15.19	14.6	17.81	1.22	39.54
	6/19/2006	BR LIM 1	6.56	6.82	12.40	1.82	34.95
	7/5/2006	BR LIM 3	21.23	15.12	9.29	0.61	15.00
		BR LIM 1	2.82	0.48	0.13	0.27	0.17
	7/17/2006	BR LIM 3	28.88	30.05	26.21	0.87	49.07
		BR LIM 1	43.74	31.65	11.37	0.36	15.45
	7/31/2006	BR LIM 3	18.13	16.11	35.32	2.19	112.76
		BR LIM 1	0.83	0.13	0.06	0.46	0.09
	8/24/2006	BR LIM 3	10.96	4.81	5.40	1.12	11.46
		BR LIM 1	3.78	0.10	0.06	0.60	0.10
	10/4/2006	BR LIM 1	17.15	0.03	0.02	0.67	0.03
C.J. Strike Reservoir	5/25/2006	CJ LIM 3	8.68	1.02	1.20	1.18	2.61
	6/6/2006	CJ LIM 3	21.13	10.71	8.26	0.77	14.63
		CJ LIM 1	6.50	2.57	2.40	0.93	4.64
		CJ LIM 2	2.27	0.33	0.31	0.94	0.60
	6/20/2006	CJ LIM 3	7.80	3.43	2.69	0.78	4.80
		CJ LIM 1	16.19	19.81	8.49	0.43	12.13
		CJ LIM 2	5.90	0.15	0.20	1.33	0.47
	7/6/2006	CJ LIM 3	18.5	1.84	1.22	0.66	2.03
		CJ LIM 1	15.07	5.27	5.09	0.97	10.01
		CJ LIM 2	2.70	3.31	2.60	0.79	4.64
	7/18/2006	CJ LIM 3	8.89	0.35	0.21	0.60	0.34
		CJ LIM 1	16.67	12.8	5.57	0.44	7.99
		CJ LIM 2	1.35	0.26	0.32	1.23	0.71
	10/12/2006	CJ LIM 3	16.30	5.17	5.20	1.01	10.43
		CJ LIM 1	9.75	3.15	2.15	0.68	3.62
		CJ LIM 2	6.01	0.04	0.02	0.50	0.03
Hayden Lake	5/16/2006	HYLIM 1	0.59	0.07	0.09	1.29	0.21
		HYLIM 2	0.80	0.04	0.01	0.25	0.01
		HYLIM 3	0.85	0.12	0.34	2.83	1.30
	5/31/2006	HYLIM 1	0.97	0.32	0.01	0.03	0.01
		HYLIM 2	0.42	0.02	0.01	0.50	0.02
	6/13/2006	HYLIM 1	2.37	0.08	0.01	0.13	0.01
		HYLIM 2	1.61	0.22	0.07	0.32	0.09
		HYLIM 3	0.94	0.05	0.01	0.20	0.01
	6/27/2006	HYLIM 1	2.67	1.70	1.06	0.62	1.72
		HYLIM 2	1.48	0.28	0.10	0.36	0.14
		HYLIM 3	0.65	1.50	3.52	2.35	11.78
	7/11/2006	HYLIM 1	0.78	0.46	0.32	0.70	0.54
		HYLIM 2	1.52	1.33	0.61	0.46	0.89
		HYLIM 3	2.09	2.16	1.47	0.68	2.47
	8/2/2006	HYLIM 1	0.41	0.35	0.18	0.51	0.27
		HYLIM 2	1.74	1.20	0.91	0.76	1.60
		HYLIM 3	4.44	4.58	2.40	0.52	3.66

Appendix G. Continued.

Water	Date	Sample Site	Mean biomass (g/m) 153 µm	500 µm	750 µm	ZPR	ZQI
Mann Lake	5/17/2006	MNLIM 1	10.58	7.52	5.92	0.79	10.58
	6/1/2006	MNLIM 1	2.97	0.84	0.09	0.11	0.10
	6/14/2006	MNLIM 1	4.97	2.46	0.46	0.19	0.55
	6/28/2006	MNLIM 1	7.25	6.05	0.89	0.15	1.02
	7/10/2006	MNLIM 1	4.04	1.42	0.27	0.19	0.32

Appendix H. Mean biomass (g/m) of zooplankton collected with three different mesh size nets (153, 500, and 750 µm) and the Zooplankton Ratio (ZPR; 750 µm /500 µm) and Zooplankton Quality Index (ZQI; (500 µm + 700 µm)*ZPR) at different sample sites from Brownlee Reservoir, C.J. Strike Reservoir, Hayden Lake, and Mann Lake sampled during the summer of 2007.

			Mean biomass (g/m)				
Water	**Date**	**Sample Site**	**153 µm**	**500 µm**	**750 µm**	**ZPR**	**ZQI**
Brownlee Reservoir	5/31/2007	BRLIM3	6.09	6.19	4.78	0.77	8.46
	6/12/2007	BRLIM3	1.98	1.05	1.39	1.33	3.24
	6/26/2007	BRLIM3	0.50	0.27	0.21	0.78	0.38
	7/10/2007	BRLIM3	0.64	0.47	0.72	1.53	1.82
	7/24/2007	BRLIM3	0.98	0.51	0.37	0.73	0.64
	8/8/2007	BRLIM1	0.44	0.18	0.00	0.01	0.00
		BRLIM2	0.23	0.06	0.01	0.12	0.01
		BRLIM3	0.57	0.49	0.27	0.55	0.42
	8/21/2007	BRLIM1	0.09	0.02	0.01	0.31	0.01
		BRLIM3	1.53	1.23	0.78	0.64	1.28
C.J. Strike Reservoir	6/25/2007	CJLIM1	0.43	0.28	0.23	0.83	0.42
		CJLIM2	0.16	0.07	0.04	0.52	0.06
	7/9/2007	CJLIM1	0.18	0.22	0.04	0.20	0.05
		CJLIM2	0.58	0.18	0.16	0.90	0.31
	7/23/2007	CJLIM1	0.60	0.28	0.14	0.51	0.22
		CJLIM2	0.16	0.10	0.00	0.00	0.00
	8/7/2007	CJLIM1	1.44	0.72	0.22	0.31	0.29
		CJLIM2	0.53	0.10	0.05	0.52	0.08
		CJLIM3	1.28	0.89	0.00	0.00	0.00
	8/20/2007	CJLIM1	4.55	0.95	0.01	0.01	0.01
		CJLIM2	0.64	0.17	0.00	0.00	0.00
		CJLIM3	1.33	0.41	0.12	0.30	0.16
Hayden Lake	7/1/2007	HYLIM2	0.24	0.11	0.03	0.23	0.03
	7/18/2007	HYLIM1	0.09	0.06	0.01	0.16	0.01
		HYLIM2	0.03	0.05	0.03	0.65	0.05
		HYLIM3	0.10	0.07	0.05	0.71	0.08
	7/30/2007	HYLIM3	0.13	0.06	0.10	1.69	0.28
	8/14/2007	HYLIM1	0.18	0.15	0.06	0.38	0.08
		HYLIM2	0.07	0.05	0.04	0.86	0.08
		HYLIM3	0.13	0.01	0.01	1.30	0.03
	8/28/2007	HYLIM1	0.05	0.01	0.01	0.69	0.02
		HYLIM2	0.07	0.04	0.01	0.18	0.01
		HYLIM3	0.09	0.04	0.00	0.05	0.00
	9/11/2007	HYLIM1	0.03	0.01	0.00	0.80	0.01
		HYLIM2	0.02	0.01	0.01	1.71	0.03
		HYLIM3	0.11	0.06	0.03	0.58	0.05
Mann Lake	7/17/2007	MNLIM	0.19	0.05	0.01	0.12	0.01
	7/31/2007	MNLIM	0.26	0.05	0.00	0.08	0.00
	8/15/2007	MNLIM	0.18	0.09	0.04	0.40	0.05
	8/29/2007	MNLIM	0.71	0.15	0.02	0.15	0.03
	9/12/2007	MNLIM	0.18	0.09	0.05	0.52	0.07

Appendix I. Mean biomass (g/m) of zooplankton collected with three different mesh size nets (153, 500, and 750 µm) and the Zooplankton Ratio (ZPR; 750 µm /500 µm) and Zooplankton Quality Index (ZQI; (500 µm + 700 µm)*ZPR) at different sample sites from Brownlee Reservoir, C.J. Strike Reservoir, Hayden Lake, and Mann Lake sampled during the summer of 2008.

			Mean biomass (g/m)				
Water	**Date**	**Sample Site**	**153 µm**	**500 µm**	**750 µm**	**ZPR**	**ZQI**
Brownlee Reservoir	7/1/2008	BRLIM1	5.05	1.78	0.75	0.42	1.07
		BRLIM2	0.87	0.22	0.08	0.37	0.11
		BRLIM3	1.59	0.26	0.25	0.96	0.49
	7/15/2008	BRLIM1	3.14	2.65	0.44	0.17	0.51
		BRLIM2	0.34	0.08	0.03	0.41	0.04
		BRLIM3	0.91	0.37	0.20	0.55	0.31
	7/29/2008	BRLIM1	2.14	0.72	0.05	0.07	0.06
		BRLIM2	1.17	0.29	0.06	0.23	0.08
		BRLIM3	1.11	0.18	0.08	0.42	0.11
	8/12/2008	BRLIM1	0.13	0.09	0.02	0.18	0.02
		BRLIM2	0.86	0.34	0.09	0.26	0.11
		BRLIM3	2.23	0.82	0.29	0.36	0.39
C.J. Strike Reservoir	6/5/2008	CJLIM3	1.14	0.20	0.08	0.39	0.11
	6/18/2008	CJLIM1	0.63	0.29	0.22	0.76	0.38
		CJLIM3	2.07	1.48	0.76	0.51	1.15
	7/2/2008	CJLIM1	0.41	0.23	0.15	0.65	0.25
		CJLIM2	0.78	0.41	0.51	1.24	1.15
		CJLIM3	2.49	2.66	1.60	0.60	2.57
	7/16/2008	CJLIM1	1.65	0.12	0.17	1.39	0.41
		CJLIM2	0.76	0.28	0.34	1.21	0.76
		CJLIM3	1.67	1.29	0.94	0.73	1.62
	7/30/2008	CJLIM1	2.48	0.14	0.18	1.29	0.41
		CJLIM2	0.95	0.04	0.04	0.93	0.08
		CJLIM3	0.86	0.15	0.25	1.64	0.65
	8/13/2008	CJLIM1	0.96	0.28	0.13	0.46	0.19
		CJLIM2	0.53	0.04	0.02	0.59	0.04
		CJLIM3	1.31	0.69	0.33	0.48	0.49
Hayden Lake	6/10/2008	HYLIM1	0.04	0.04	0.00	0.03	0.00
	6/24/2008	HYLIM1	0.21	0.06	0.01	0.15	0.01
		HYLIM2	0.09	0.01	0.00	0.31	0.01
		HYLIM3	0.09	0.01	0.00	0.20	0.00
	7/8/2008	HYLIM1	0.37	0.22	0.06	0.25	0.07
		HYLIM2	0.06	0.02	0.01	0.45	0.01
		HYLIM3	0.08	0.05	0.03	0.67	0.06
	7/22/2008	HYLIM1	0.03	0.01	0.00	0.33	0.01
		HYLIM2	0.08	0.01	0.01	0.62	0.01
		HYLIM3	0.04	0.01	0.01	0.62	0.01
	8/5/2008	HYLIM1	0.12	0.05	0.04	0.70	0.06
		HYLIM2	0.04	0.00	0.00	0.00	0.00
		HYLIM3	0.05	0.00	0.00	0.00	0.00
	8/18/2008	HYLIM1	0.00	0.02	0.00	0.00	0.00
		HYLIM2	0.07	0.00	0.00	0.00	0.00
		HYLIM3	0.00	0.00	0.00	0.00	0.00
	10/9/2008	HYLIM1	0.03	0.00	0.00	0.00	0.00
		HYLIM2	0.03	0.00	0.00	0.00	0.00
		HYLIM3	0.03	0.00	0.00	0.00	0.00

Appendix I. Continued.

Water	Date	Sample Site	Mean biomass (g/m) 153 µm	500 µm	750 µm	ZPR	ZQI
Mann Lake	7/9/2008	MNLIM	0.57	0.38	0.36	0.95	0.70
	7/23/2008	MNLIM	0.03	0.01	0.01	1.10	0.02
	8/6/2008	MNLIM	0.09	0.04	0.00	0.00	0.00
	8/19/2008	MNLIM	0.10	0.06	0.00	0.02	0.00

Appendix J. Mean biomass (g/m) of zooplankton collected with three different mesh size nets (153, 500, and 750 µm) and the Zooplankton Ratio (ZPR; 750 µm /500 µm) and Zooplankton Quality Index (ZQI; (500 µm + 700 µm)*ZPR) at different sample sites from Brownlee Reservoir, C.J. Strike Reservoir, Hayden Lake, and Mann Lake sampled during the summer of 2007.

			Mean biomass (g/m)				
Water	**Date**	**Sample Site**	**153 µm**	**500 µm**	**750 µm**	**ZPR**	**ZQI**
Brownlee Reservoir	4/21/2009	BRLIM3	0.37	0.01	0.01	1.00	0.02
	6/3/2009	BRLIM2	2.01	1.79	0.57	0.32	0.75
	6/16/2009	BRLIM1	0.40	0.25	0.29	1.16	0.63
		BRLIM2	0.60	0.51	0.45	0.88	0.85
		BRLIM3	0.41	0.19	0.11	0.58	0.17
	6/29/2009	BRLIM1	0.11	0.00	0.00	0.00	0.00
		BRLIM2	0.83	0.24	0.19	0.79	0.34
		BRLIM3	0.62	0.34	0.21	0.62	0.34
	7/13/2009	BRLIM1	1.93	1.04	0.47	0.45	0.68
		BRLIM2	0.94	0.70	0.36	0.51	0.55
	7/28/2009	BRLIM1	0.86	0.49	0.48	0.98	0.95
		BRLIM2	0.51	0.27	0.19	0.70	0.32
		BRLIM3	1.73	0.93	0.73	0.78	1.30
C.J. Strike Reservoir	6/17/2009	CJLIM1	0.46	0.21	0.33	1.57	0.85
		CJLIM2	0.97	0.46	0.53	1.15	1.14
		CJLIM3	0.57	0.08	0.07	0.87	0.13
	6/30/2009	CJLIM1	0.61	0.41	0.55	1.34	1.29
		CJLIM2	0.37	0.02	0.02	1.00	0.04
		CJLIM3	0.39	0.01	0.01	1.00	0.02
	7/14/2009	CJLIM1	0.94	0.22	0.70	3.18	2.93
		CJLIM2	0.60	0.05	0.02	0.40	0.03
		CJLIM3	0.50	0.03	0.03	1.00	0.06
	7/29/2009	CJLIM1	2.79	1.21	1.09	0.90	2.07
		CJLIM2	0.73	0.15	0.13	0.87	0.24
		CJLIM3	0.36	0.03	0.04	1.33	0.09
Hayden Lake	6/22/2009	HYLIM1	0.00	0.01	0.01	1.00	0.02
		HYLIM2	0.14	0.01	0.01	1.00	0.02
		HYLIM3	0.08	0.01	0.01	1.00	0.02
	7/6/2009	HYLIM1	0.01	0.01	0.01	1.00	0.02
		HYLIM2	0.13	0.01	0.01	1.00	0.02
	7/21/2009	HYLIM1	0.10	0.00	0.00	0.00	0.00
		HYLIM2	0.07	0.00	0.00	0.00	0.00
		HYLIM3	0.19	0.00	0.00	0.00	0.00
Mann Lake	6/11/2009	MNLIM	0.17	0.04	0.01	0.25	0.01
	6/23/2009	MNLIM	0.63	0.15	0.01	0.07	0.01
	7/7/2009	MNLIM	0.40	0.28	0.01	0.04	0.01
	7/22/2009	MNLIM	0.00	0.00	0.00	0.00	0.00

ANNUAL PERFORMANCE REPORT
SUBPROJECT 2: WARMWATER FISHERIES INVESTIGATIONS

State of: Idaho | Grant No.: F-73-R-31 Fishery Research

Project No.: 5 | Title: Lake and Reservoir Research

Subproject #2: Warmwater Fisheries Investigations: Crappie Age and Growth

Contract Period: July 1, 2009 to June 30, 2010

ABSTRACT

Crappie *Pomoxis* ssp. are becoming more popular to anglers in Idaho and information on growth and diet of crappie populations will help managers understand the population dynamics and make decisions on management of crappie populations. Aging structures were sampled from crappie collected from Brownlee Reservoir, C.J. Strike Reservoir, Hayden Lake, and Mann Lake from 2005-2009 to estimate mean back calculated length-at-age through age-4 for each water body and individual year classes within each water body. Crappie stomachs were collected during spring and fall of 2009 to identify seasonal use of primary food types (zooplankton, insects, or fish). Growth was variable between water bodies ranging from 70-130 mm at age-1 to 200-250 mm by age-4. Crappie from C.J. Strike Reservoir were largest overall while those from Mann Lake were smallest. Growth rates were similar from Brownlee Reservoir, C.J. Strike Reservoir, and Mann Lake, but length at age-1 was different which influenced ultimate length. However, the growth rate of crappie from Hayden Lake was faster. In general, insects were the primary food item in crappie stomachs in the spring, whereas zooplankton was most common in the fall. Crappie from Mann Lake contained mostly insects in both spring and fall. Few fish were found in stomachs from any water body, but were more common in the fall than spring. The ages, growth, and diet of crappie are variable in different water bodies in Idaho.

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INTRODUCTION

Crappie *Pomoxis* ssp. are, along with bass *Micropterus* ssp., one of the most popular freshwater fish in the U.S. (Miranda 1999). In Idaho, a 1999 survey showed that angling for crappie was becoming more popular because they are easy to catch, there are usually no limits, and harvest can be high. With more people desiring quality crappie fisheries, more effort and attention is being given to management and understanding of factors influencing crappie populations in Idaho.

Crappie populations are often unpredictable, usually with inconsistent recruitment of year classes that can lead to slower growth and smaller crappie overall (Mitzner 1984; Guy and Willis 1995b). Oftentimes, population factors conspire and cyclic populations result (Mitzner 1984; Mitzner 1991; Allen and Miranda 2001). For example, large year classes may overwhelm food supplies causing slower growth due to density dependant factors (Allen and Miranda 2001), prolonging the time those fish take to reach acceptable size to anglers (Miranda and Dorr 2000). The availability and quantity of food are factors that drive growth along with density. Zooplankton and insects are often the primary food items for crappie until they reach the length when they become piscivorous (190-220 mm; Carlander 1977). Crappie usually reach lengths desirable to anglers (~200 mm; Carlander 1977; Miranda and Dorr 2000) and spawn for the first time by age-2 or -3 (Carlander 1977). Many studies have evaluated factors that influence crappie recruitment and growth including lake or reservoir hydrology (Mitzner 1981; Beam 1983; Maceina and Stimpert 1998; Sammons et al. 2002), population density (Allen and Miranda 2001), diet (Ellison 1984; Pelham et al. 2001), or harvest (Colvin 1991). Yet, given the body of work to determine factors that affect crappie populations, identification of the mechanisms that influence crappie dynamics remains elusive (Mitzner 1984; Guy and Willis 1995a) and makes management challenging (Boxrucker and Irwin 2002).

Understanding the age and growth of crappie populations in Idaho will aid in management decisions to provide more consistent fisheries, to make decisions regarding harvest regulations, and to inform anglers whether they can expect to be successful. We conducted a study to estimate the age and growth characteristics of crappie populations in four Idaho water bodies over several years, compare length-at-age between water bodies and year classes within water bodies, and identify the basic diet composition of crappie from different seasons during the year.

MANAGEMENT GOAL

1. Improve warmwater sportfishing and fisheries management in Idaho lakes and reservoirs.

OBJECTIVES

1. Describe and compare the estimated ages and growth of crappie populations among, and year classes within, four Idaho water bodies.

2. Identify and compare the basic diet composition of crappie from Idaho water bodies during the spring and fall.

METHODS

Crappie and other warmwater species were sampled in the fall (2005-2009) by electrofishing and trap netting in Brownlee Reservoir, C.J. Strike Reservoir, Mann Lake, and Hayden Lake. Sampling followed the Lowland Lakes Standard Survey protocol (IDFG, unpublished data) to sample populations. Brownlee and C.J. Strike reservoirs and Mann lake have no length or bag limits regarding crappie, while Hayden Lake has a harvest regulation of six crappie per day, none under 254 mm. From 2005 to 2009, all water bodies were sampled during the same time periods in the fall (September and October) for abundance index sampling (see Job 1 for complete description). We captured fish with a combination of trap netting and electrofishing. We used trap nets constructed from 13 mm treated black mesh with a 0.9 x 1.8 m frame and a 22.9 m lead. Shoreline trap net locations were randomly selected and depths ranged from 2 to 10 m. We electrofished using a 5.5 m long Smith Root boat equipped with a Smith Root GPP 5.0 electrofisher using pulsed DC at night using a combination of short parallel and perpendicular boat movements for any given distance of shoreline. Two persons netted stunned fish from the front of the boat. Up to ten crappie per 10 mm length group were retained from each year except 2007 during fall sampling to estimate age. In 2009, crappie were also sampled during spring (May-June) as well as fall to evaluate diet. Both white crappie *P. annularis* and black crappie *P. nigromaculatus* were present in Brownlee and C.J. Strike reservoirs. However, because white crappie comprised less than 10% of the catch, white crappie were removed for analysis.

Both scales and sagittal otoliths were removed from sampled crappie and stored dry; however, only otoliths were used to estimate age and growth (Hammers and Miranda 1991). Scales were taken as a backup in case otoliths were damaged or unreadable. We placed otoliths in saline solution and viewed them whole with reflected light under a microscope. Otoliths were photographed using a Leica EZ4D dissecting scope/camera and saved as digital files. We estimated ages from whole otoliths following the procedure outlined by Maceina and Betsill (1987). Two readers estimated ages independently, and when disagreements occurred, ages were determined by committee. If agreement could not be reached, the sample was disregarded. We measured annuli and estimated back calculated lengths-at-age (BCLA) using the computer application Fish BC (Ver. 3.0.1, 2007, Ball State University), which uses the Frazier Lee method to back calculate length at annulus formation (Devries and Frie 1996). We calculated the mean BCLA and 95% confidence intervals for each age group over all years to compare the general lengths-at-age between the different water bodies and, because we sampled crappie over several years, we followed the growth of individual year classes through time. We averaged the BCLA for individual year classes across all samples and calculated 95% confidence intervals ($\alpha = 0.05$) for each water body. (Table 12; Appendix B).

The age and growth of crappie were analyzed among water bodies and for year classes within water bodies from BCLA through age-4. Age classes older than age-4 were excluded from analysis because of low sample sizes for those groups. Length and age were $\log_{10}$ transformed to meet the assumptions of equal variance and normality. Differences in growth were evaluated by comparing slope and elevation calculated using analysis of covariance of log transformed length and age with water body as the covariate (α=0.05; SAS 2008). Growth data was also fitted to a Von Bertalanffy growth curve and coefficients reported.

We removed stomachs and evaluated diet of crappie during the spring and fall of 2009. All fish retained for diet analysis were killed immediately and placed on ice to reduce further digestion of stomach contents. Fish either had stomachs removed the next day or were frozen

and stomachs were removed later in the lab. After removal, stomachs were placed in whirl-packs and preserved with 90% ethanol until counting could take place.

We devised a rating system to evaluate diet items and the fullness of stomachs for crappie. Stomach contents were grouped by general prey item (zooplankton, insect, fish, and other). Prey items classified as “other” included all items that were not zooplankton, insects, or fish and those that were not identifiable. A scale for the proportion of prey occurrence was used to determine the relative contribution of each prey group to the total stomach content (0—none, 1—few—2-25%, 3—50%, 4—75%, and 5—100%). A scale for fullness was also used to quantify the volume of food in the stomach and ranked between and 0-5 (0—empty, 1—few, 2—25%, 3—50%, 4—75%, and 5—full). These rankings allowed us to identify what crappie consumed, what proportion each item type contributed to the total, and the relative amount present. The frequency of occurrence of each prey item was evaluated for each water body between the spring and fall using Chi square ($\alpha = 0.05$; SAS 2008) to determine if a shift in prey utilization took place. Likewise, we evaluated the frequency of occurrence where the food item was the only item present in the stomach to identify whether crappie were targeting a specific prey. We tested the frequency of occurrence of prey items in stomachs between crappie <200 mm and >200 mm to determine if larger crappie preferred different food items and no differences were detected ($p > 0.05$; SAS 2008), so data were pooled for comparisons.

RESULTS

We estimated ages for 2,752 otolith samples among the water bodies we studied. The oldest crappie was 11 years old from Hayden Lake and was 375 mm long, but the majority of crappie sampled were age-3 or younger (Table 3). In general, BCLA indicated that age-1 crappie ranged between 70 mm and 140 mm, depending on water body, and grew approximately 30-50 mm/yr until they reached age-3, when yearly growth slowed considerably (Table 3; Figure 17). Crappie from C.J. Strike Reservoir were longest at each age through age-4 while those from Mann Lake were shorter on average than the other water bodies, but growth was variable between year classes within each water body. From all water bodies, age-4 and older crappie were poorly represented in our samples with few fish reaching 300 mm.

The growth among water bodies was significantly different ($F = 14.96$, $P < 0.001$, $r^2 = 0.96$) when comparing the $\log_{10}$-length x $\log_{10}$-age of mean BCLA for crappie through age-4 (Figure 18). Crappie from Brownlee and C.J. Strike reservoirs and Mann Lake exhibited similar growth rates through age-4 (slope of regression was similar); however, BCLA varied (elevation was different; Table 4). In contrast, crappie from Hayden Lake grew at a faster rate (steeper slope) through age-4 and, although they were smaller at age-1, reached a similar size as those from other waters by age-4 (Table 3; Figure 18).

Estimated growth also varied between year classes for crappie at each water body ($p < 0.001$). Crappie from C.J. Strike Reservoir were the longest overall with a mean BCLA at age-1 ranging between 110-140 mm, and grew to 270 mm by age-4 (Table 3; Figure 19). Crappie from Brownlee Reservoir were slightly shorter with a mean BCLA at age-1 ranging between 100-130 mm, and reached 240-260 mm by age-4 (Table 3; Figure 20). From Hayden Lake, crappie were smaller at age-1 (70-100 mm) and 180-205 mm at age-3, but were more similar by age-4 (230-240 mm; Table 3; Figure 21). Crappie from Mann Lake were similar in length-at-age-1 (70-100 mm) to Hayden Lake, but were considerably smaller through age-3 (160-200 mm) and age-4 (180-225 mm; Table 3; Figure 21) than the other water bodies. In most cases, growth

rates were similar between year classes (similar slopes) with only elevation differing, indicating that the length crappie attained by age-1 influenced the sizes reached at subsequent ages.

In general, insects were the most common food item identified in crappie stomachs in the spring, whereas zooplankton was the main food item found in stomachs in the fall. We examined 320 crappie stomachs sampled during the spring of 2009 and sampled 503 stomachs during the fall of 2009. Of the spring samples, 14% of the stomachs were empty. Of those that contained prey items, 85% of the stomachs contained insects, 53% contained zooplankton, and 5% contained fish. In the fall, 19% of the crappie stomachs were empty and of stomachs containing prey, 67% contained zooplankton, 43% contained insects, and 13% contained fish (Table 5). Of the stomachs from spring that contained only one food type, 45% contained only insects, 14% only zooplankton, and 1% contained only fish. From the fall, 55% contained only zooplankton, 19% only insects, and 5% only fish (Table 5).

The frequency of occurrence of prey items in crappie stomachs was different between the spring and fall at all the water bodies (Table 5). A similar proportion of crappie from Brownlee Reservoir (*n* = 59 with food) contained zooplankton (63%) and insects (54%) in their stomachs in spring, but almost twice as many had zooplankton (73%) than insects (42%) in the fall (*n* = 137 with food). The difference between spring and fall is more pronounced when zooplankton or insects were the only item present. In spring, 44% of the crappie contained only zooplankton and 36% only insects, while in fall, 53% contained only zooplankton compared to 12% with only insects. More crappie also contained fish in fall (18%) than spring (2%). Age-0 bluegill were the species of fish found in crappie stomachs in all but two stomachs from Brownlee Reservoir. Two crappie sampled in the fall contained age-0 crappie.

Most of the crappie from C.J. Strike Reservoir (*n* = 79 with food) contained zooplankton (87%) an*d* insects (96%) in spring, but few contained only zooplankton (7%) or insects (7%). In the fall (*n* = 138 with food), approximately four times more contained zooplankton (95%) than insects (28%) and 86% contained only zooplankton compared to 1% with only insects. Age-0 bluegill were the only fish found in stomachs from C.J. Strike Reservoir.

From Hayden Lake in the spring (*n* = 53 with food), 91% contained insects, 50% other, 45% zooplankton, and 9% contained fish; however, 50% contained only insects, 9% only zooplankton, 4% with only fish, and none contained only other. The two crappie with only fish in their stomachs contained fingerling westslope cutthroat trout *Oncorhynchus mykiss lewisi* that had recently been stocked into the lake. More crappie in fall (*n* = 76 with food) contained zooplankton (80%), while 33% contained other, 11% had fish, and 6% had insects. Of those, 66% contained only zooplankton, 13% had only other, 4% had only fish, and none had insects only. The majority of food items that comprised the “other” category at Hayden Lake were Mysis shrimp *Mysis relicta* or other amphipods.

Most of the crappie from Mann Lake in spring (*n* = 98 with food) contained insects (95%), while 27% had zooplankton, 8% had fish, and 2% had other. In spring, one fish each contained only zooplankton or fish while 77% contained only insects. Similarly, most of the crappie in the fall (*n* = 84 with food) contained insects (91%), 20% contained fish, and 4% contained zooplankton. Like spring, 73% crappie contained only insects in the fall, 7% contained only fish, and 1% contained only zooplankton.

Overall, most of the crappie stomachs sampled (>80%) contained food. In the spring, only 14% of the stomachs were empty and in the fall, 19% were empty. In contrast, 49% of the stomachs sampled in the spring were ¾ full or full while 53% in the fall were ¾ full or full (Table

15). The remaining stomachs with food present ranged from a few items to ½ full in relatively even numbers. The difference in food items in crappie stomachs between spring and fall is more pronounced when comparing the number of stomachs that were ¾ full or full and the number with only one food type present (Table 5). Considerably more stomachs contained zooplankton in the fall than the spring at Brownlee and C.J. Strike reservoirs and Hayden Lake. Insects were the main prey item in crappie from Mann Lake. No crappie that were full in the spring contained fish at any water body, but several did in the fall.

DISCUSSION

The differences in the estimated age and growth of crappie among the four water bodies we sampled were not surprising. Given the morphological and landscape variability between the water bodies, differences were expected. Variability in growth and recruitment in crappie populations is well noted (Guy and Willis 1995a, Sammons et al. 2002, Colvin 1991). For example, Allen and Pine (2000) found that the variability in crappie growth among year classes made it impossible to detect differences in a study evaluating length restrictions. They found it difficult even when year class recruitment was relatively stable. Although variable, the age and growth of crappie in Idaho were comparable to those found in other studies (Carlander 1977; Guy and Willis 1995b). The mean BCLA of crappie from Idaho water bodies is within the range summarized by Carlander (1977) for different locations in the United States. In a South Dakota study (Guy and Willis 1995b), crappie growth was slowest in small impoundments, fastest in large, natural lakes, and intermediate in large impoundments. However, they also noted that mean BCLA at all ages was highly variable across water bodies. The variability in Idaho crappie populations, along with those found in other studies, illustrates the necessity that specific attention be given to individual waters before taking management action concerning crappie. Many studies have evaluated factors that influence crappie recruitment and growth including lake or reservoir hydrology (Sammons et al. 2002; Maceina and Stimpert 1998; Mitzner 1981; Beam 1983), population density (Allen and Miranda 2001), diet (Ellison 1984; Pelham et al. 2001), or harvest (Colvin 1991). Yet, given the body of work to determine factors that affect crappie populations, identifying the mechanisms that influence crappie growth remains unclear (Mitzner 1984; Guy and Willis 1995a).

The differences in BCLA between year classes within water bodies are due to density dependent factors affecting the populations. Factors, such as water levels (Maceina and Stimpert 1998; Sammons et al. 2002), population density (Allen and Miranda 2001), diet (Pelham et al. 2001; Ellison 1984), or harvest (Colvin 1991) have been linked to the success of year classes. However, large year classes are often influenced by density dependent factors such as interspecific competition that limit growth (Allen and Miranda 2001). In both Brownlee and C.J. Strike reservoirs, a large year class was produced in 2006 compared to the surrounding years. The BCLA from the 2006-2008 year classes are all smaller than average (Table 3). Allen and Miranda (2001) found that crappie populations under the influence of both environmental and population factors are “quasi”-cyclic with strong year classes produced every two to four years. The reduced growth of the 2006-2008 year classes suggests that interspecific competition is a factor and the populations in Brownlee and C.J. Strike reservoirs are probably cyclic.

A majority of the crappie we sampled consumed insects or zooplankton, while relatively few consumed fish, mostly in the fall when small fish are more available. Most studies have found that crappie eat zooplankton and insects, but that crappie prefer fish as they grow larger (Ager 1976; Reid 1949; Guy and Willis 1993; Pelham et al. 2001). However, where crappie were

found to consume fish, the systems also have populations of prey fish present such as gizzard shad *Dorosoma cepedianum* (Reid 1949) or threadfin shad *Dorosoma petenense* (Range 1973), that provide a source of fish for crappie. None of the waters we studied in Idaho contain species of fish that would provide consistent prey for crappie. Dunsmoor (1990) stated that the lack of prey species in Brownlee Reservoir probably limited the growth of smallmouth bass and suggested planting a prey species. Ellison (1984) found that when crappie were unable to incorporate fish in their diet, crappie did not survive past age-4. The few fish found in crappie stomachs and the low number of crappie that apparently survived past age-3 suggests that a lack of prey fish may be limiting the growth and survival of crappie in Idaho waters.

Crappie populations in Brownlee and C.J. Strike reservoirs appear cyclic (Allen and Miranda 2001) with a pulse of crappie appearing every 2-5 years (Mitzner 1981). The growth of these populations is likely hampered by interspecific competition that overpopulation creates. Therefore, maximum harvest should be encouraged to take advantage of crappie while present and to decrease the density of crappie in large year classes in Brownlee and C.J. Strike reservoirs. Although crappie in Brownlee and C.J. Strike reservoirs are the fastest growing, they do not live long enough (Boxrucker 2002) to provide more than one or two years of decent angling. Despite a few crappie reaching age-6, none grew larger than 300 mm. Harvest restrictions are usually unsuccessful when crappie populations are cyclic (Miranda and Allen 2000; Bister et al. 2002), and we recommend no harvest or length restrictions be placed on crappie at either Brownlee or C.J. Strike reservoirs.

The population dynamics of crappie from Hayden Lake were more consistent, and it was the only water body where we sampled crappie over age-4 that were longer than 300 mm, unlike the crappie populations from Brownlee and C.J. Strike Reservoirs. Along with the presence of more diverse prey items, protecting crappie until they reach age-4, such as the current restriction of ten crappie, none over 254 mm, should increase the number of larger crappie available (Colvin 1991; Boxrucker 1999; Miranda and Allen 2000). The harvest and population dynamics of crappie in Hayden Lake should continue to be monitored to ensure the harvest regulations are successful.

Conversely, crappie from Mann Lake are shorter and show little potential to reach lengths that would make restrictions worthwhile. Considering the small size of the water body and that insects were the main food items present in stomachs throughout the year, a size restriction would probably be unsuccessful (Bister et al. 2002). Recruitment appears relatively consistent and self-sustaining, and unless anglers complain, regulations concerning harvest should remain unchanged. Crappie growth may be improved, but would require reducing overall fish biomass to increase food availability, which may conflict with other management objectives.

RECOMMENDATIONS

1. Continue with no restrictions on harvest for crappie in Brownlee and C.J. Strike reservoirs to exploit large year classes and possibly increase growth.

2. Continue current length and bag restrictions on crappie harvest at Hayden Lake to protect crappie and provide an increased number of larger fish.

3. Continue with no harvest restrictions for crappie at Mann Lake because they are unlikely to reach necessary sizes.

4. Continue to study crappie populations before making management changes because of the site-specific variability in growth and survival of year classes.

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We would like to thank Lori Burchard, Adrianna Veloza, and Carlos Camacho for assisting with data collection, estimating crappie ages, and stomach analysis. Appreciation also goes to Anna Owsiak and everyone at Cecil Andrus WMA for allowing us to stay in the facilities near Brownlee Reservoir. We also thank Art Butts and Jim Fredericks for constructive comments and suggestions on the manuscript. Cheryl Zink formatted the report.

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Table 3. Estimated back calculated length-at-ages of crappie pooled over all year classes from Brownlee Reservoir, C.J. Strike Reservoir, Hayden Lake, and Mann Lake from 2005-2009 including number aged (N), age (years), mean length (mm), standard error, 95% confidence interval, standard deviation (StDev), minimum length (Min), maximum length (Max), range of lengths (Range), and the incremental growth between ages (Inc; mm).

Water	N	Age	Mean	SE Mean	95% CI	StDev	Min	Max	Range	Inc
Brownlee Reservoir	305	1	111.8	1.0	1.9	16.9	47.3	157.0	109.7	111.8
	259	2	174.7	1.1	2.2	18.4	129.3	219.5	90.2	62.9
	111	3	208.6	2.1	4.1	22.2	164.9	263.5	98.6	33.9
	21	4	255.1	2.8	5.5	12.8	231.7	276.5	44.8	46.5
	12	5	270.0	3.3	6.5	11.5	251.8	283.6	31.9	14.8
	7	6	288.5	3.6	7.0	9.4	269.1	297.9	28.8	18.5
	4	7	294.2	5.3	10.4	10.7	278.3	301.3	22.9	5.7
C.J. Strike Reservoir	151	1	132.7	1.6	3.2	20.2	87.7	191.9	104.2	132.7
	111	2	194.2	2.0	3.9	21.2	124.8	258.2	133.4	61.4
	74	3	218.0	2.6	5.1	22.3	169.1	302.2	133.1	23.9
	2	4	270.4	32.6	63.9	46.2	237.7	303.0	65.3	52.4
Hayden Lake	251	1	82.8	1.0	2.0	16.4	50.8	136.5	85.7	82.8
	147	2	139.4	1.6	3.1	19.2	100.4	192.6	92.2	56.6
	77	3	197.9	2.1	4.1	18.3	135.2	246.8	111.6	58.5
	52	4	233.5	2.1	4.1	15.1	203.4	264.4	61.0	35.6
	46	5	260.2	2.3	4.4	15.3	218.9	297.2	78.3	26.7
	13	6	288.3	5.0	9.9	18.1	263.1	326.5	63.4	28.1
	3	7	306.6	5.0	9.7	8.6	300.8	316.5	15.6	18.3
Mann Lake	148	1	91.8	1.1	2.2	13.7	52.1	129.1	77.0	91.8
	131	2	142.5	1.2	2.4	14.2	105.0	176.7	71.8	50.7
	105	3	177.6	1.5	3.0	15.5	149.7	213.9	64.2	35.1
	50	4	192.4	2.9	5.7	20.7	165.3	231.1	65.8	14.8
	40	5	197.7	3.2	6.2	20.1	173.7	246.2	72.6	5.3
	33	6	200.2	1.7	3.3	9.6	185.5	221.9	36.3	2.5
	32	7	208.7	1.8	3.5	10.1	193.0	232.1	39.1	8.4

Table 4. Estimated growth coefficients (Intercept, slope, r^2) from log length/log age regression and Von Bertalanffy coefficients (Linf, K, and t_0) for crappie from Brownlee Reservoir, C.J. Strike Reservoir, Hayden Lake, and Mann Lake, Idaho for the years 2005-2009.

Water body	**Intercept**	**Slope**	**r^2**	**Linf**	**K**	**t_0**
Brownlee Reservoir	117	0.51	0.98	325	0.34	-0.233
C.J. Strike Reservoir	135	0.49	0.98	563	0.12	-1.257
Hayden Lake	87	0.68[a]	0.99	378	0.24	-0.02
Mann Lake	102	0.41	0.93	209	0.62	0.073

[a] Slope from Hayden Lake is significantly different from other waters.

Table 5. The frequency and percent occurrence of crappie with stomachs at the different states of fullness (empty, few, 1/4 full, 1/2 full, 3/4 full, and full) from Brownlee Reservoir, C.J. Strike Reservoir, Hayden Lake, and Mann Lake, Idaho in 2009.

				Fullness					
Season	**Water body**		**N**	**Empty**	**Few**	**1/4**	**1/2**	**3/4**	**Full**
Spring	Brownlee Reservoir	#	79	20	1	9	9	5	35
		%		25.3	1.3	11.4	11.4	6.3	44.3
	C.J. Strike Reservoir	#	79	10	13	16	15	11	14
		%		12.7	16.5	20.3	19.0	13.9	17.7
	Hayden Lake	#	64	11	3	6	10	7	27
		%		17.2	4.7	9.4	15.6	10.9	42.2
	Mann Lake	#	98	5	5	8	21	4	55
		%		5.1	5.1	8.2	21.4	4.1	56.1
	Total	#	320	46	22	39	55	27	131
		%		14.4	6.9	12.2	17.2	8.4	40.9
Fall	Brownlee Reservoir	#	199	62	12	28	22	14	61
		%		31.2	6.0	14.1	11.1	7.0	30.7
	C.J. Strike Reservoir	#	138	7	6	5	18	22	80
		%		5.1	4.3	3.6	13.0	15.9	58.0
	Hayden Lake	#	76	21	3	8	13	7	24
		%		27.6	3.9	10.5	17.1	9.2	31.6
	Mann Lake	#	90	6	6	4	18	5	51
		%		6.7	6.7	4.4	20.0	5.6	56.7
	Total	#	503	96	27	45	71	48	216
		%		19.1	5.4	8.9	14.1	9.5	42.9

Table 6. The frequency and percent occurrence of crappie stomachs that contained food, contained the four prey types (zooplankton, fish, insects, other), and those where one food type were the only contents in the stomachs of crappie from Brownlee Reservoir, C.J. Strike Reservoir, Hayden Lake, and Mann Lake, Idaho in 2009.

					Food Type Present				Only			
Season	**Water body**		**N**	**# w/Food**	**Zoop**	**Fish**	**Insect**	**Other**	**Zoop**	**Fish**	**Insect**	**Other**
Spring	Brownlee Reservoir	#	79	59	37	1	32	3	26	0	21	0
		%		74.7	62.7	1.7	54.2	5.1	44.1	0.0	35.6	0.0
	C.J. Strike Reservoir	#	79	69	59	1	66	2	5	0	5	0
		%		87.3	85.5	1.4	95.7	2.9	7.2	0.0	7.2	0.0
	Hayden Lake	#	64	53	24	5	48	26	5	2	26	0
		%		82.8	45.3	9.4	90.6	49.1	9.4	3.8	49.1	0.0
	Mann Lake	#	98	93	25	7	88	2	1	1	72	0
		%		94.9	26.9	7.5	94.6	2.2	1.1	1.1	77.4	0.0
	Total	#	320	274	145	14	234	33	37	3	124	0
		%		85.6	52.9	5.1	85.4	12.0	13.5	1.1	45.3	0.0
Fall	Brownlee Reservoir	#	199	137	100	24	57	3	73	12	17	1
		%		68.8	73.0	17.5	41.6	2.2	53.3	8.8	12.4	0.7
	C.J. Strike Reservoir	#	138	131	126	5	37	6	113	1	1	1
		%		94.9	96.2	3.8	28.2	4.6	86.3	0.8	0.8	0.8
	Hayden Lake	#	76	55	44	6	3	18	36	2	0	7
		%		72.4	80.0	10.9	5.5	32.7	65.5	3.6	0.0	12.7
	Mann Lake	#	90	84	3	17	76	0	1	6	61	0
		%		93.3	3.6	20.2	90.5	0.0	1.2	7.1	72.6	0.0
	Total	#	503	407	273	52	173	27	223	21	79	9
		%		80.9	67.1	12.8	42.5	6.6	54.8	5.2	19.4	2.2

Table 7. The frequency and percent occurrence of crappie stomachs that were ¾ full or full that contained only one of the four prey types (zooplankton, fish, insects, other) from Brownlee Reservoir, C.J. Strike Reservoir, Hayden Lake, and Mann Lake, Idaho in 2009.

				Only Food Type Present			
Season			**N**	**Zoop**	**Fish**	**Insect**	**Other**
Spring	Brownlee Reservoir	#	40	22	0	13	0
		%		55.0	0.0	32.5	0.0
	C.J. Strike Reservoir	#	25	5	0	2	0
		%		20.0	0.0	8.0	0.0
	Hayden Lake	#	34	4	0	17	0
		%		11.8	0.0	50.0	0.0
	Mann Lake	#	59	0	0	46	0
		%		0.0	0.0	78.0	0.0
Fall	Brownlee Reservoir	#	75	50	11	1	0
		%		66.7	14.7	1.3	0.0
	C.J. Strike Reservoir	#	102	92	1	1	1
		%		90.2	1.0	1.0	1.0
	Hayden Lake	#	31	21	2	0	4
		%		67.7	6.5	0.0	12.9
	Mann Lake	#	56	1	6	38	0
		%		1.8	10.7	67.9	0.0

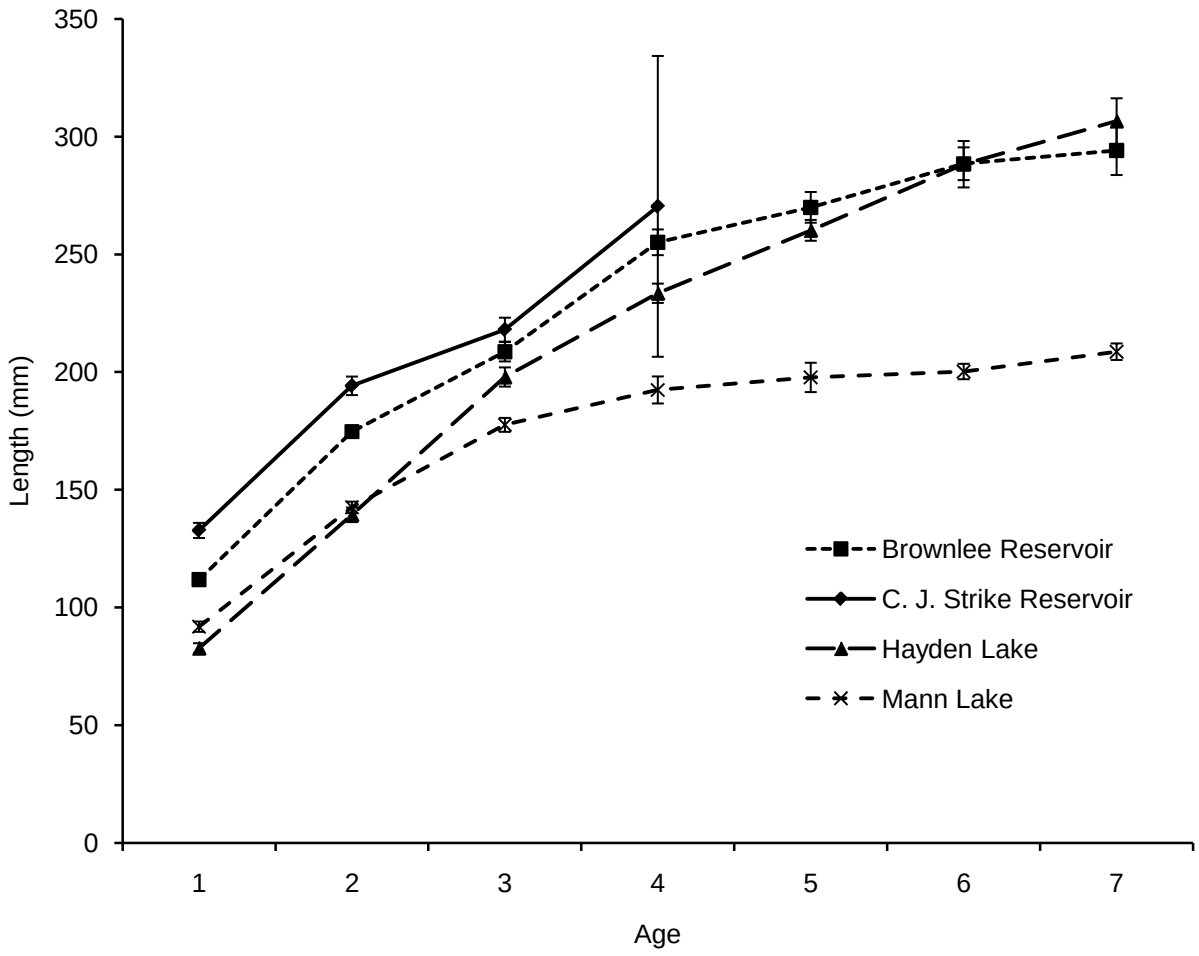

Figure 17. Estimated back-calculated length-at-ages of crappie pooled over all year classes from Brownlee Reservoir, C.J. Strike Reservoir, Hayden Lake, and Mann Lake from 2005-2009. Error bars are 95% confidence intervals.

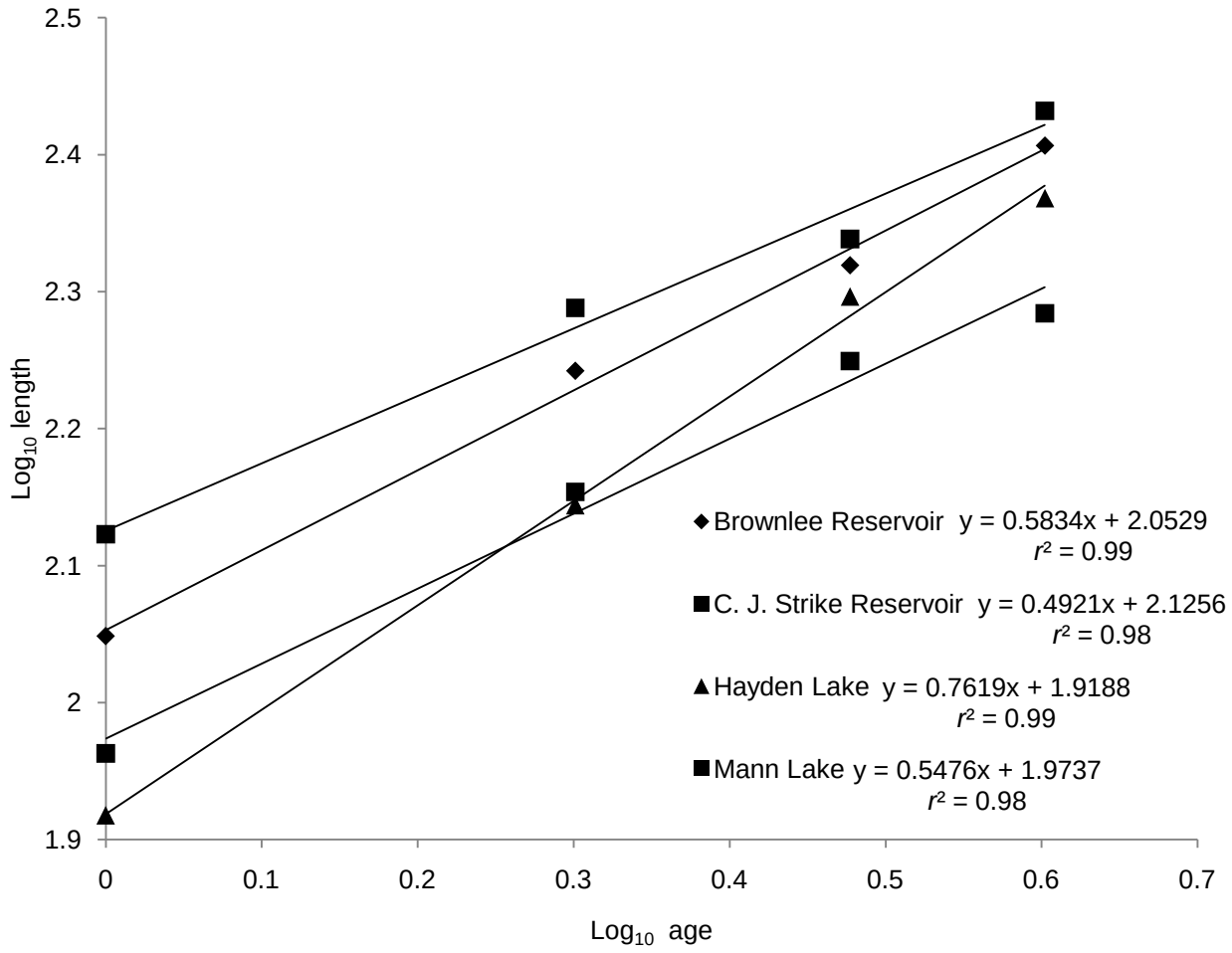

Figure 18. Regression comparisons of $\log_{10}$ length x $\log_{10}$ age of back-calculated length-at-ages of crappie pooled over all year classes from Brownlee Reservoir, C.J. Strike Reservoir, Hayden Lake, and Mann Lake from 2005-2009. Equations are for the regression line at each respective water body.

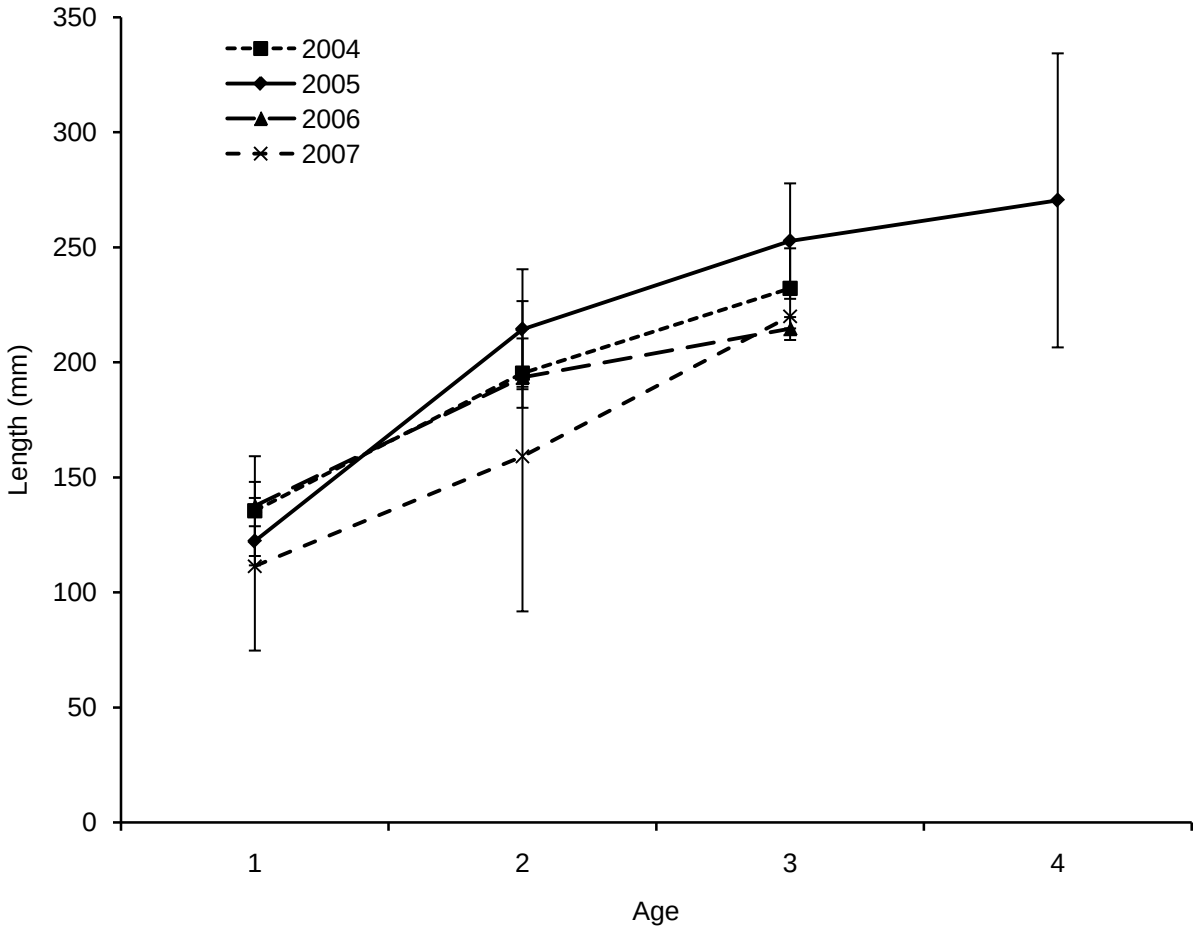

Figure 19. Estimated back-calculated length-at-ages of crappie for individual year classes sampled from C.J. Strike Reservoir. Error bars are 95% confidence intervals.

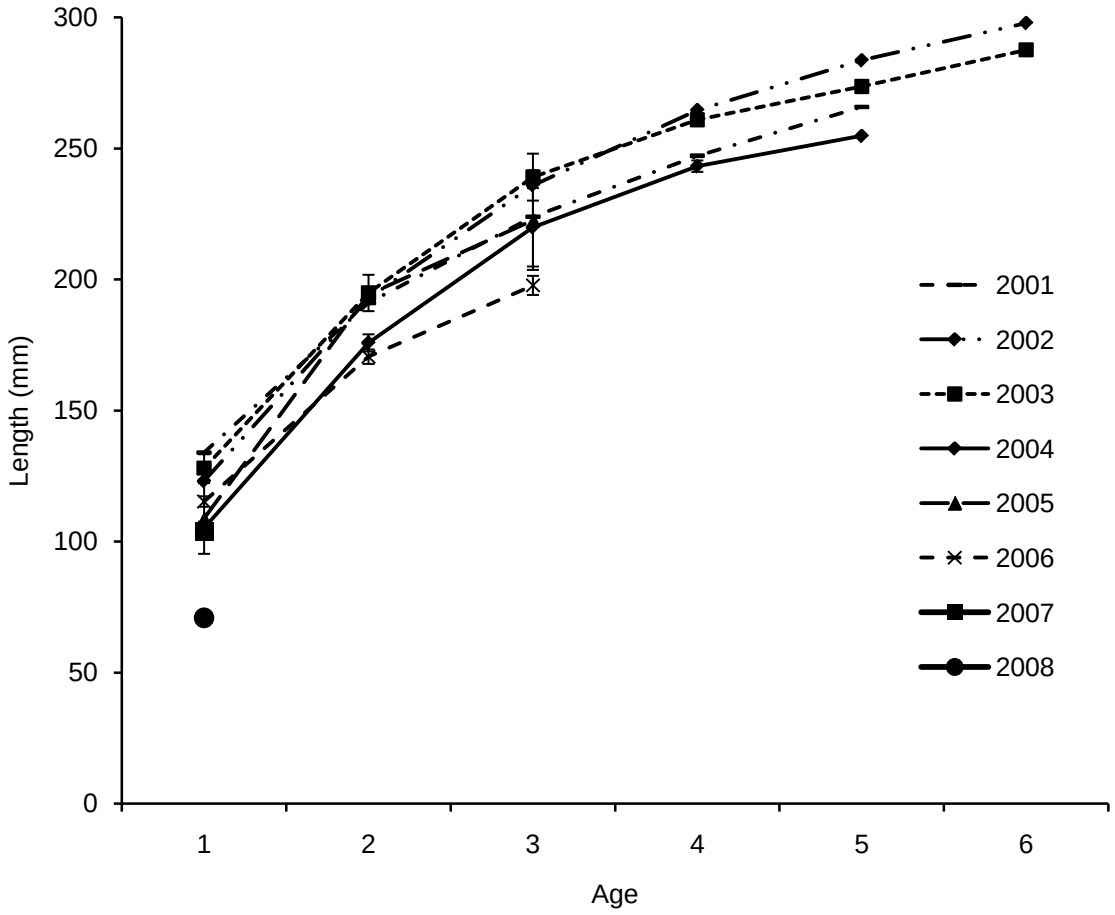

Figure 20. Estimated back-calculated length-at-ages of crappie for individual year classes sampled from Brownlee Reservoir. Error bars are 95% confidence intervals.

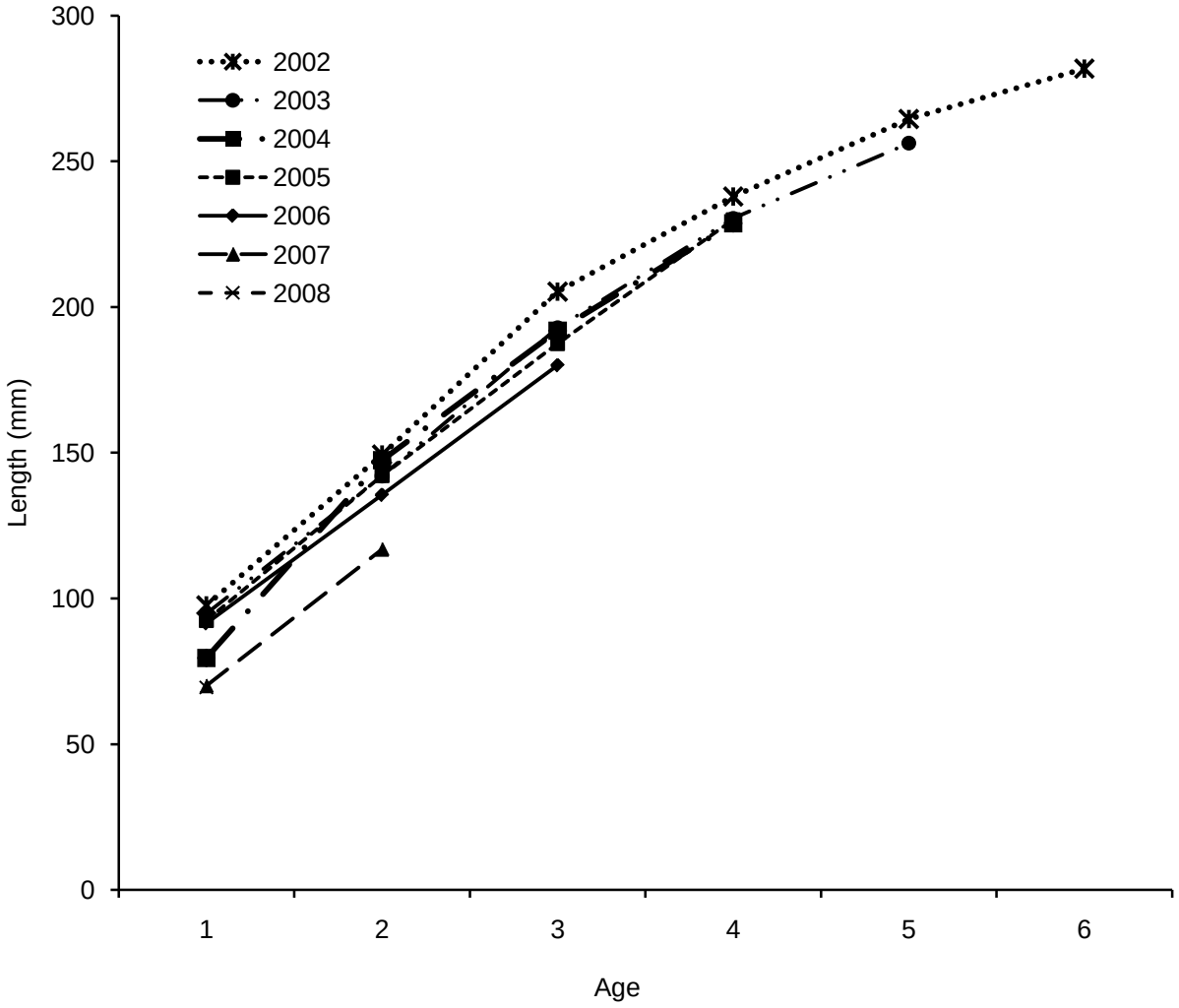

Figure 21. Estimated back-calculated length-at-ages of crappie for individual year classes sampled from Hayden Lake. Error bars are 95% confidence intervals.

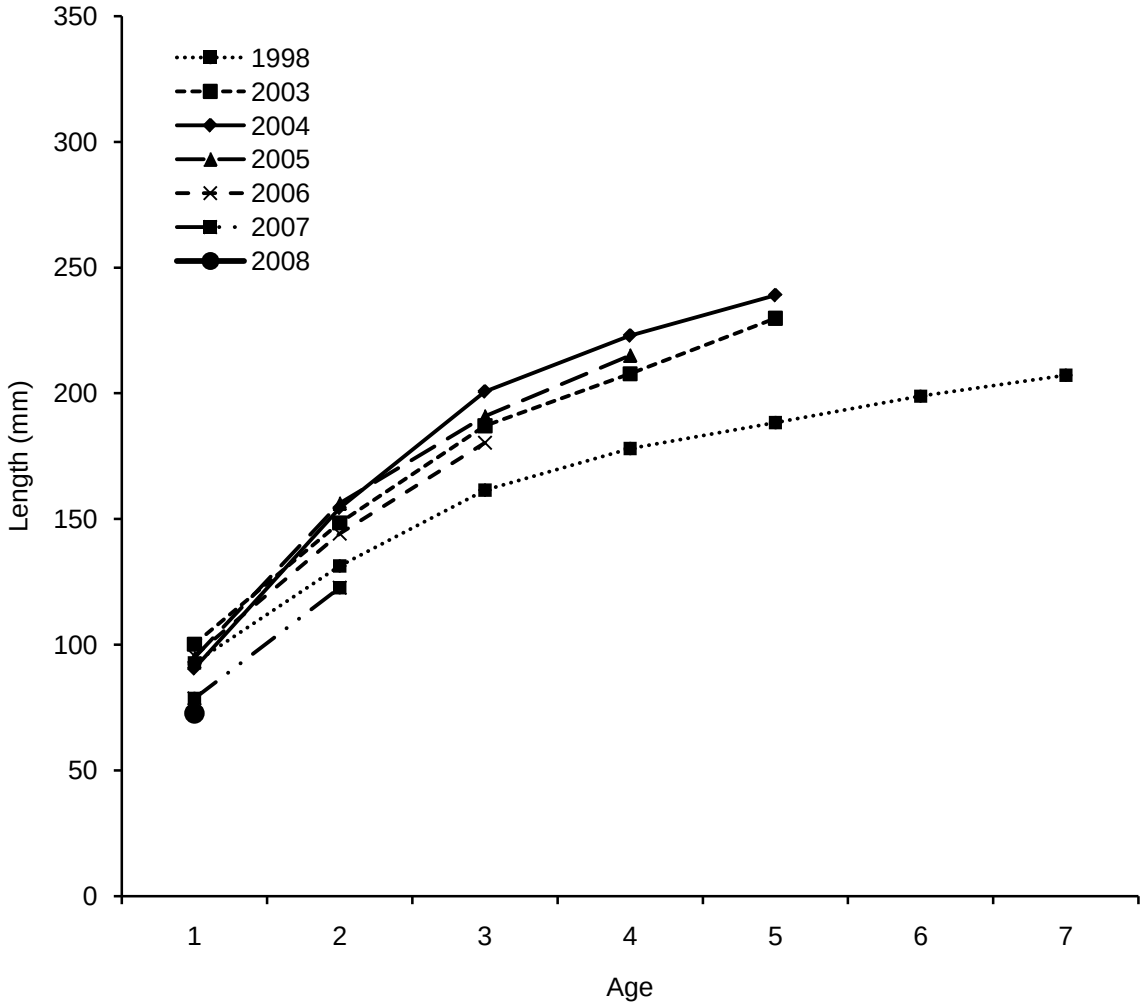

Figure 22. Estimated back-calculated length-at-ages of crappie for individual year classes sampled from Mann Lake. Error bars are 95% confidence intervals.

APPENDICES

Appendix K. Estimated back-calculated length-at-ages of crappie for individual year classes from Brownlee Reservoir, C.J. Strike Reservoir, Hayden Lake, and Mann Lake from 2005-2009 including year class, number aged, age (years), standard error, 95% confidence interval, standard deviation (StDev), minimum length (mm), maximum length (mm), and range of lengths (mm).

Water body	Year Class	N	Age	Mean	SE Mean	95% CI	StDev	Minimum	Maximum	Range
Brownlee Reservoir	1999	4	1	121.7	5.8	11.4	11.7	107.5	135.7	28.2
	1999	4	2	196.3	5.7	11.2	11.4	183.3	210.0	26.8
	1999	4	3	230.7	7.2	14.1	14.4	210.7	244.9	34.2
	1999	4	4	254.4	7.7	15.0	15.3	231.7	265.4	33.7
	1999	4	5	272.0	5.7	11.1	11.3	255.8	282.2	26.5
	1999	4	6	285.1	5.5	10.8	11.1	269.1	294.4	25.4
	1999	4	7	294.2	5.3	10.4	10.7	278.3	301.3	22.9
	2000	1	1	109.7	*		*	109.7	109.7	0.0
	2000	1	2	190.9	*		*	190.9	190.9	0.0
	2000	1	3	225.1	*		*	225.1	225.1	0.0
	2000	1	4	256.9	*		*	256.9	256.9	0.0
	2000	1	5	276.1	*		*	276.1	276.1	0.0
	2000	1	6	293.8	*		*	293.8	293.8	0.0
	2001	6	1	134.0	4.2	8.3	10.3	117.7	145.3	27.6
	2001	6	2	191.1	5.9	11.6	14.6	170.6	211.8	41.2
	2001	6	3	224.0	4.4	8.6	10.7	213.4	239.0	25.6
	2001	6	4	247.2	4.9	9.7	12.1	233.0	264.6	31.6
	2001	4	5	265.9	6.6	13.0	13.3	251.8	281.1	29.3
	2002	10	1	123.1	4.9	9.7	15.6	105.7	157.0	51.4
	2002	10	2	192.8	5.0	9.8	15.8	167.1	219.5	52.4
	2002	10	3	236.0	3.2	6.3	10.1	224.7	251.7	27.0
	2002	7	4	264.7	3.4	6.7	9.1	256.2	276.5	20.3
	2002	1	5	283.6	*		*	283.6	283.6	0.0
	2002	1	6	297.9	*		*	297.9	297.9	0.0
	2003	12	1	128.0	2.7	5.3	9.3	114.2	141.2	27.0
	2003	12	2	194.9	3.5	6.9	12.3	173.5	216.9	43.4
	2003	10	3	239.1	4.6	9.0	14.5	217.0	263.5	46.4
	2003	1	4	261.0	*		*	261.0	261.0	0.0
	2003	1	5	273.6	*		*	273.6	273.6	0.0
	2003	1	6	287.6	*		*	287.6	287.6	0.0
	2004	79	1	105.2	1.2	2.4	11.0	83.6	130.9	47.3
	2004	50	2	175.8	1.7	3.3	11.8	147.3	195.7	48.4
	2004	2	3	219.9	7.6	15.0	10.8	212.3	227.6	15.3
	2004	2	4	243.3	1.1	2.2	1.6	242.1	244.4	2.2
	2004	1	5	254.8	*		*	254.8	254.8	0.0

Appendix K. Continued.

Water body	Year Class	N	Age	Mean	SE Mean	95% CI	StDev	Minimum	Maximum	Range
	2005	5	1	108.8	6.9	13.5	15.4	93.0	125.5	32.6
	2005	2	2	194.3	1.1	2.2	1.6	193.1	195.4	2.2
	2005	2	3	222.7	9.7	19.0	13.7	213.0	232.3	19.4
	2006	174	1	115.3	1.0	2.0	13.5	72.5	146.8	74.3
	2006	174	2	170.6	1.4	2.8	18.6	129.3	215.6	86.3
	2006	76	3	197.8	1.9	3.6	16.2	164.9	242.7	77.8
	2007	1	1	103.9	*		*	103.9	103.9	0.0
	2008	13	1	70.9	6.1	12.0	22.1	47.3	121.9	74.6
C.J. Strike Reservoir	2002	2	1	130.3	19.3	37.8	27.4	110.9	149.6	38.7
	2002	2	2	204.9	14.4	28.2	20.4	190.5	219.3	28.9
	2002	2	3	232.6	24.8	48.6	35.1	207.7	257.4	49.7
	2003	6	1	137.7	8.4	16.5	20.6	117.4	171.0	53.6
	2003	6	2	198.1	5.8	11.4	14.3	184.1	218.3	34.3
	2004	4	1	135.5	12.1	23.7	24.2	115.8	170.6	54.8
	2004	3	2	195.3	7.7	15.1	13.3	183.9	210.0	26.1
	2004	3	3	232.2	8.9	17.4	15.4	221.5	249.8	28.3
	2005	43	1	122.3	3.3	6.5	21.7	87.7	180.6	92.9
	2005	4	2	214.4	13.3	26.1	26.6	176.6	237.5	60.9
	2005	4	3	252.7	12.8	25.1	25.6	218.2	279.9	61.7
	2005	2	4	270.4	32.6	63.9	46.2	237.7	303.0	65.3
	2006	94	1	137.6	1.8	3.5	17.4	100.7	191.9	91.1
	2006	94	2	193.5	2.1	4.1	20.3	148.1	258.2	110.1
	2006	64	3	214.7	2.5	5.0	20.3	169.1	302.2	133.1
	2007	2	1	111.4	18.7	36.7	26.4	92.8	130.1	37.4
	2007	2	2	159.2	34.4	67.4	48.7	124.8	193.7	68.9
	2007	1	3	220.0	*		*	220.0	220.0	0.0
	2008	1	1	90.7	*		*	*	*	*
Hayden Lake	1997	1	1	115.5	*		*	115.5	115.5	0.0
	1997	1	2	168.8	*		*	168.8	168.8	0.0
	1997	1	3	218.7	*		*	218.7	218.7	0.0
	1997	1	4	254.2	*		*	254.2	254.2	0.0
	1997	1	5	275.5	*		*	275.5	275.5	0.0
	1997	1	6	289.6	*		*	289.6	289.6	0.0
	1997	1	7	300.8	*		*	300.8	300.8	0.0

Appendix K. Continued.

Water body	Year Class	N	Age	Mean	SE Mean	95% CI	StDev	Minimum	Maximum	Range
	1999	1	1	123.1	*		*	123.1	123.1	0.0
	1999	1	2	172.9	*		*	172.9	172.9	0.0
	1999	1	3	222.3	*		*	222.3	222.3	0.0
	1999	1	4	264.4	*		*	264.4	264.4	0.0
	1999	1	5	297.2	*		*	297.2	297.2	0.0
	1999	1	6	326.5	*		*	326.5	326.5	0.0
	2001	2	1	101.3	5.6	10.9	7.9	95.7	106.9	11.2
	2001	2	2	151.8	10.7	21.0	15.1	141.1	162.4	21.3
	2001	2	3	214.9	4.8	9.4	6.8	210.0	219.7	9.6
	2001	2	4	251.3	0.6	1.3	0.9	250.6	251.9	1.3
	2001	2	5	280.1	0.1	0.2	0.1	280.0	280.2	0.2
	2001	2	6	297.8	3.8	7.5	5.4	294.0	301.6	7.6
	2001	2	7	309.5	7.0	13.6	9.8	302.6	316.5	13.9
	2002	29	1	97.7	2.4	4.7	13.0	79.8	136.5	56.7
	2002	29	2	149.4	3.2	6.3	17.4	119.5	192.6	73.1
	2002	29	3	205.3	3.4	6.7	18.5	164.9	246.8	82.0
	2002	9	4	237.9	5.5	10.8	16.5	217.3	262.6	45.3
	2002	9	5	264.5	5.1	10.0	15.3	245.0	282.2	37.2
	2002	9	6	281.8	5.1	10.1	15.4	263.1	299.0	35.9
	2003	59	1	94.8	1.5	2.9	11.4	69.9	121.9	52.0
	2003	59	2	142.0	2.4	4.6	18.0	107.1	171.4	64.2
	2003	33	3	192.9	2.1	4.0	11.8	172.2	221.4	49.1
	2003	33	4	230.4	2.3	4.5	13.4	203.4	255.4	52.0
	2003	33	5	256.2	2.3	4.5	13.3	218.9	283.0	64.0
	2004	14	1	79.6	3.7	7.3	13.8	64.2	115.9	51.8
	2004	4	2	147.4	7.8	15.3	15.6	126.0	159.7	33.8
	2004	4	3	191.9	11.0	21.6	22.0	159.2	207.3	48.0
	2004	4	4	228.7	6.2	12.2	12.5	210.4	236.8	26.3
	2005	3	1	92.4	1.0	2.0	1.8	90.7	94.3	3.6
	2005	3	2	142.1	6.7	13.2	11.7	131.2	154.4	23.2
	2005	3	3	187.4	14.5	28.4	25.1	161.8	212.0	50.2
	2005	2	4	229.9	18.0	35.3	25.5	211.9	247.9	36.0
	2006	27	1	91.5	2.0	4.0	10.6	69.9	118.8	48.9
	2006	27	2	135.5	2.8	5.4	14.3	101.0	182.9	81.9
	2006	4	3	180.0	15.1	29.6	30.3	135.2	201.6	66.3
	2007	89	1	70.1	1.1	2.1	10.0	52.1	93.8	41.8
	2007	21	2	116.9	2.7	5.2	12.2	100.4	159.3	58.9
	2008	26	1	69.5	1.4	2.6	6.9	50.8	80.5	29.7

Appendix K. Continued.

Water body	Year Class	N	Age	Mean	SE Mean	95% CI	StDev	Minimum	Maximum	Range
Mann Lake	1998	30	1	92.7	1.8	3.4	9.6	65.2	108.3	43.1
	1998	30	2	131.3	1.7	3.3	9.1	114.3	152.1	37.8
	1998	30	3	161.5	1.4	2.7	7.6	149.7	176.4	26.8
	1998	30	4	178.0	1.4	2.7	7.7	165.3	193.4	28.1
	1998	30	5	188.3	1.5	3.0	8.3	173.7	202.8	29.1
	1998	30	6	198.9	1.5	3.0	8.4	185.5	216.0	30.5
	1998	30	7	207.2	1.6	3.1	8.7	193.0	225.8	32.8
	1999	3	1	117.9	6.3	12.3	10.8	107.4	129.1	21.6
	1999	3	2	151.8	7.1	13.8	12.2	138.0	161.1	23.2
	1999	3	3	176.4	1.5	3.0	2.6	174.8	179.4	4.7
	1999	3	4	191.8	4.5	8.8	7.8	183.1	198.0	14.9
	1999	3	5	201.5	4.5	8.9	7.8	192.6	207.5	14.9
	1999	3	6	214.1	6.6	12.9	11.4	201.0	221.9	20.9
	1999	2	7	230.4	1.7	3.4	2.4	228.7	232.1	3.4
	2002	7	1	80.7	2.4	4.7	6.4	72.2	88.7	16.5
	2002	7	2	141.4	1.9	3.6	4.9	133.4	148.1	14.7
	2002	7	3	173.8	2.3	4.6	6.2	166.1	182.7	16.6
	2003	3	1	100.2	8.1	15.8	14.0	88.9	115.8	26.9
	2003	3	2	148.4	3.5	6.9	6.1	141.4	152.0	10.6
	2003	2	3	187.1	2.4	4.7	3.4	184.7	189.5	4.8
	2003	2	4	207.8	0.2	0.3	0.2	207.6	207.9	0.3
	2003	2	5	229.8	1.2	2.3	1.7	228.6	231.0	2.4
	2004	12	1	90.5	3.4	6.6	11.6	69.3	105.7	36.3
	2004	8	2	154.4	2.7	5.3	7.6	143.5	166.8	23.3
	2004	8	3	200.7	2.4	4.6	6.7	191.3	210.9	19.6
	2004	8	4	223.0	2.3	4.4	6.4	209.4	231.1	21.7
	2004	5	5	239.1	4.0	7.7	8.8	224.1	246.2	22.1
	2005	15	1	94.8	2.8	5.4	10.6	67.2	107.7	40.5
	2005	15	2	156.2	2.9	5.6	11.1	134.0	176.7	42.7
	2005	15	3	190.9	2.8	5.4	10.7	167.6	211.6	44.0
	2005	7	4	215.1	5.1	9.9	13.4	188.9	230.9	42.0
	2006	60	1	95.5	1.6	3.1	12.4	71.9	121.0	49.1
	2006	60	2	144.1	1.7	3.3	12.9	113.8	169.0	55.2
	2006	40	3	180.3	1.9	3.8	12.2	159.1	213.9	54.7
	2007	7	1	78.7	4.0	7.9	10.7	64.1	96.1	32.0
	2007	5	2	122.7	8.0	15.6	17.8	105.0	151.9	47.0
	2008	11	1	72.7	4.0	7.7	13.1	52.1	91.4	39.4

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