SYNCHRONY IN RECRUITMENT OF FISHES IN OHIO RIVER TRIBUTARIES

by

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A Thesis
Submitted in Partial Fulfillment of the Requirements for the
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Department of Zoology
in the Graduate School
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Approved by:

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KATHRYN A. EMME, for the Master of Science degree in ZOOLOGY, presented on 25 March 2008, at Southern Illinois University Carbondale.

TITLE: SYNCHRONY IN RECRUITMENT OF FISHES IN OHIO RIVER TRIBUTARIES

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Recruitment is the point in life when cohort strength in fishes is determined. Tributaries of large rivers contain a variety of fish species; yet not much is known about factors influencing variation in year-class strength. I hypothesized that abiotic conditions within main channels of large rivers would have a strong impact on growth and survival of tributary fish, and that this impact would be similar among species with similar life history characteristics. Tributary populations of bluegill, longear sunfish, redear sunfish, and largemouth bass were sampled to determine how discharge and temperature in tributaries and adjacent rivers affected their cohort strength in the lower Ohio River. Fishes were sampled using AC electrofishing during fall 2002 through spring 2003 and fall 2003 through spring 2004. Otoliths were used to determine fish age, while age frequencies were used to back-calculate length-at-age to analyze year class patterns. Using residual analysis of catch curves, I found that significantly stronger than expected year classes of bluegill and largemouth bass were produced during years of low river discharge (bluegill winter discharge P=0.04, bluegill spring discharge P=0.04, largemouth bass spring discharge P=0.01). Redear sunfish exhibited significantly better year classes when temperatures were warm (winter temperature P=0.04). Synchrony in recruitment among fish species was explained by discharge and temperature, largely as a function of the effects of the large river adjacent to the tributaries.

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INTRODUCTION

RECRUITMENT IN FISH

Recruitment to the adult population is the point when cohort strength is determined in fish populations. Factors such as hatch date (Kohler et al. 1993; Cargnelli and Gross 1996), weather (Summerfelt 1975; Oliver et al. 1979), body size (Oliver et al. 1979; Gutreuter and Anderson 1985; Garvey et al. 1998), ontogenetic diet shifts (Olson 1996), energy stores (Oliver et al. 1979; Thompson et al. 1991), predation (Post et al. 1998), consumption (Giannico and Healey 1998; Jonas and Wahl 1998), and density (Matthews et al. 2001) have all been identified as potential sources of variation in survival among year classes. Typically, these mechanisms have the greatest impact on fishes during the first year of life (Sheehan et al. 1990; Wright et al. 1999). Most studies, however, have focused on fish in lentic habitats (Kohler et al. 1993; Jonas and Wahl 1998), and less is known about relevant mechanisms influencing fish year-class strength in rivers.

OFF-CHANNEL HABITATS IN LARGE RIVERS

Large rivers pose many challenges to fish recruitment. Habitat and hydrologic fluctuations likely result in variable survival between years for fishes. The 1,579 kilometer Ohio River has been impounded by the construction of 20 lock and dams to create a 3-meter navigation channel for commercial vessels (Pearson and Krumholz 1984), potentially reducing essential habitat for riverine fish. Off-channel habitats such as backwaters, islands, and tributaries have been recognized as crucial sites for spawning and nursery habitats, and are also considered essential for winter survival of age-0 fish

(Sheehan et al. 1990; Brown and Coon 1994; Peterson and Rabeni 2001). One important feature seems to be slow-moving water provided most of the year by these slackwater habitats. Braaten and Guy (1999) observed that fish would routinely use tributaries of the Missouri River to escape high flow. However, degradation reported in high-traffic rivers such as the Mississippi (Sheehan et al. 1990) and Missouri (Braaten and Guy 1999) would likely apply to the lower Ohio River as well. Accessibility to tributaries might even be considered more essential in the Ohio River than other rivers because the lower Ohio River travels through unglaciated land (Pearson and Krumholz 1984), resulting in fewer backwater habitats when compared to the Mississippi River (Nielsen et al. 1986).

Previous studies have demonstrated the importance of tributary habitats for a variety of riverine fishes for juvenile and spawning habitat. Brown and Coon (1994) and Nunn et al. (2002) determined that native species such as gizzard shad (*Dorsosoma cepedianum*) and dace (*Leuciscus leuciscus* [*L.*]) were found frequently in tributaries. Commercial species such as paddlefish (*Polyodon spathula*) and shovelnose sturgeon (*Scaphirhynchus platorynchus*) have been found in tributaries (Keenlyne 1997; Runstrom et al. 2001), as well as sportfish such as walleye (*Sander vitreus*) (Mion et al. 1998) and pike (*Esox lucius* [L.]) (Kostrzewa et al. 2003). Many species with varying life history strategies coexist in limiting habitats such as tributaries.

ABIOTIC FACTORS ON FISH RECRUITMENT

Fish living in lentic and lotic systems must also deal with extreme abiotic conditions. Random fluctuations in water level and flow can sweep larval and juvenile fish from safe habitats, potentially affecting survival and year class strength. Several papers have investigated abiotic factors of reservoirs on crappie (*Pomoxis spp.*) recruitment (Mitzner 1991; Sammons et al. 2002; Maceina 2003). Other papers have shown a contrasting view of high water conditions on riverine fish (Sammons and Bettoli 2000; DiCenzo and Duval 2002)

Mitzner (1991) found that various environmental factors such as floodwater storage, wind, turbidity, and temperature affected juvenile crappies during an investigation of Rathbun Lake, Iowa from 1972 to 1983. Sammons et al. (2002) found that variable year class strength in Tennessee reservoirs showed a stronger relationship to lake-level fluctuations for crappie residing in tributaries. Maceina (2003), studying crappie in Alabama reservoirs, found that year class strength was directly related to hydrology. Other more riverine fish species like white bass (*Morone chrysops*) (DiCenzo and Duval 2002) and saugeye (*Sander vitreus* x *S. canadensis*) (Sammons and Bettoli 2000) populations depend on high water conditions during the spawning period to set the base for a strong year class. Waters and Noble (2004) suggested that largemouth bass in tropical waters should have high stable water levels in order to maximize survival. Even though several studies have been done looking at abiotic factors on fish year class survival, few studies have been conducted on rivers.

CENTARCHID FEEDING STRATEGIES AND YEAR CLASS STRENGTH

Although many studies have explored early life survival of sunfish (*Lepomis* spp.), mechanisms affecting survival for the following year is not well established in tributaries and other lotic systems. More suited for lentic habitats (Jenkins and Burkhead 1993), larval bluegills (*L. machrochirus*) feed on zooplankton (Partridge and DeVries

1999), eventually switching to invertebrates later in life (Hillman 1982). A study on the upper Mississippi River concluded that the larval stage of fish development was the critical period for survival and emphasized the importance of backwaters to sunfish (Zigler and Jennings 1993). Cargnelli and Gross (1996) focused on the effects of hatching date and body size on age-0 survival in bluegill (*L. macrochirus*), and found that fish hatched earliest were more likely to survive to the following year. Conversely, Garvey et al. (2002) and Santucci and Wahl (2003) both emphasized the importance of seasonal spawning of sunfish by suggesting that early hatched *Lepomis* spp. often have a greater chance of mortality than do those spawned later in the year. Winter might also affect sunfish demographics. Santucci and Wahl (2003) reported considerable overall winter mortality that was not size-selective. However, larger bluegills typically emerged from winter in better condition (Cargnelli and Gross 1997), suggesting that higher energy depletion and mortality may have occurred in small individuals under some circumstances. These conflicting reports underscore the need to understand mechanisms driving yearly success of sunfish in both tributaries and other systems.

Although extensive research has been conducted on largemouth bass (*Micropterus salmoides)* (Garvey et al. 2003), reasons for variation in year-class strength are still not well understood, particularly in tributaries. Commercially (Adams et al. 1982a) and ecologically (Heidinger 1975) important, these warmwater visual predators (Jenkins and Burkhead 1993) consume zooplankton and invertebrates as juveniles and typically switch to piscivory at some point within the first year of life (Garvey and Stein 1998). Predation has been suggested to increase size-selective mortality in lower latitudes (Miranda and Hubbard 1994a). Conversely, Ludsin and DeVries (1997) proposed that date of hatching, ontogenetic diet change, lipid stores, and first winter conditions were crucial factors in determining successful recruitment of largemouth bass. Many studies have dealt with these stages individually (Miranda and Pugh 1997; Greene and Maceina 2000), but have failed to focus on largemouth bass dynamics on a seasonal scale. Further insight into black bass recruitment may be gained through a seasonal focus on these fishes in tributaries.

FACTORS THAT INFLUENCE COHORT STRENGTH

Many studies have demonstrated that reaching maximum body size increased odds of survival to the following spring season (Oliver et al. 1979; Miranda and Hubbard 1994b; Cargnelli and Gross 1997; Post et al. 1998), yet others have found that winter mortality was not size-selective (Garvey and Stein 1998; Jackson and Noble 2000; Santucci and Wahl 2003). One factor influencing size and survival might be the role of energy stores throughout the season. Sutton and Ney (2001) proposed that stocking reservoirs with larger striped bass (*Morone saxatilis*) would translate to increased age-0 survival because the larger striped bass retained more fat stores and experienced less mortality during winter. Despite cold temperatures forcing largemouth bass to cease feeding around 5°C (Johnson and Charlton 1960), lipids seemed to provide the necessary energy stores for bass and a variety of other species to survive winter (Thompson et al. 1991; Miranda and Hubbard 1994b; Schultz and Conover 1997), with larger fish possessing the ability to store a greater quantity of lipids. The role of lipids would appear to be well established, yet few studies detail year-round energy patterns (Adams et al.

1982b) or take into account the role of protein as an energy source (Brown and Murphy 1994) for winter.

Numerous studies analyzing physiological condition of fish in other families have examined this by determining proximate composition. Brett et al. (1969), Jonosson et al. (1997), and Payne et al. (1999) all used proximate analysis to determine energetic reserves of sockeye salmon (*Oncorhynchus nerka*), Atlantic salmon (*Salmo salar*), and several Pacific Ocean species. Although proximate composition is a useful method of assessing fish condition, it requires sacrificing fish and is time consuming (Brown and Murphy 1991). Previous studies (Brown and Murphy 1991; Blackwell et al. 2000) have attempted to link condition indices such as relative weight (W_r) and relative condition factor (K_n) (Le Cren 1951) to fish condition as a quick, non-lethal method of measuring overall health. Relative weight had been successfully correlated with proximate analysis results of striped bass and hybrid striped bass (*M. saxatilis* ♀× *M. chrysops* ♂) placed in indoor aquaria (Brown and Murphy 1991), but few studies have attempted to focus on energetics of fish feeding in the field.

RESEARCH GOALS

To further explore mechanisms influencing cohort strength of fishes, I compared discharge and temperature of a tributary and the Ohio River to growth and survival of centrarchids (bluegill, longear sunfish, redear sunfish, and largemouth bass) in four tributaries in the Smithland Pool of the lower Ohio River. Age frequencies of the focal species were used to back-calculate length-at-age for analyzing historical year class patterns (Maceina 1997), and to potentially use adult age structure as a tool to determine future population structure and trends. Condition of the target fish species was also determined. The primary goal was to understand how abiotic mechanisms in a riverine environment interact and influence survival of fishes in Ohio River tributaries.

EXPECTATIONS

Since each are independent systems with theoretically different fish communities, Ohio River main channel discharge and tributary discharge were predicted to act independently of each other. Therefore, Ohio River main channel discharge was not predicted to have an effect on centrarchid spawning success, juvenile growth, or adult winter survival of historical or sampled fish populations.

Ohio River main channel and tributary temperature were predicted to be related. Warmer Ohio River and tributary temperatures were predicted to encourage growth of juvenile centrarchids, and contribute to increased winter survival of adults from historical and sampled fish populations.

Due to harsh winter conditions, centrarchids in this study were expected to exhibit size-selective mortality. Fish condition was expected to decline from fall to winter seasons. Spring was expected to show the poorest condition for centrarchids.

METHODS

SITE DESCRIPTIONS

Construction of the Smithland Lock and Dam (R. Km. 1478, R.M. 918.5) on the lower Ohio River was completed in 1980 (Heidinger and Waddell 1989), creating 9,308 hectares of water and 117 kilometers of shoreline between it and the John T. Myers Lock & Dam (R.Km. 1362, R.M. 846). Pearson and Pearson (1989) reported that there were 159 fish species in the Ohio River, with the lower reach (R.Km. 1054-1579, R.M. 655-981, from New Amsterdam, IN to Cairo, IL) containing 119. However, the lower species diversity was attributed to the fewer number of samples collected in the lower reach compared to the middle and upper reaches.

Four tributaries of the lower Ohio River, Bay Creek (R.Km. 1465, R.M. 910-IL) (Figure 1), Lusk Creek (R.Km. 1452, R.M. 902.5-IL) (Figure 2), Deer Creek (R.Km. 1437, R.M. 893-KY) (Figure 3), and Hurricane Creek (R.Km. 1426, R.M. 886-KY) (Figure 4). Selected to represent the entire stretch of the Smithland Pool, most were somewhat narrow (average channel width of 5 meters at the mouth), with Hurricane Creek being the smallest (around 3 meters at the mouth) followed by Deer Creek, Lusk Creek, and Bay Creek (about 8 meters at the mouth). There were a fair amount of shading by riparian trees, and all tributary mouths have sporadically distributed stumps and other woody debris. Except during high water events, low flow conditions existed for most of the year in the tributaries.

FIELD SAMPLING

Water parameters

Daily mean discharges from Smithland Lock & Dam were obtained through the United States Geological Society (USGS) and the United States Army Corps of Engineers (USACOE). These daily mean discharges were averaged to monthly and yearly mean discharges to analyze the effects of discharge on year class strength of centrarchids. Daily mean air temperatures (°C) recorded in Paducah, KY were obtained from the National Weather Service station in Paducah, and were used as a surrogate for Ohio River water temperatures. For ease of calculation, daily mean air temperatures were converted to monthly and yearly air temperatures to analyze effects of temperature on year class strength of centrarchids. These same metrics, along with dissolved oxygen, were obtained to compare abiotic variables between sampling years. Monthly discharge and temperature were acquired from the sources listed above, while dissolved oxygen was obtained from the USACOE.

Daily historical and sampling year temperatures (°C) and discharges (m^3/s) of the tributaries (specifically Lusk Creek) were obtained to test the strength of relationship between both abiotic factors and historical year class strength of target fishes. All historical variables were obtained from the USGS, and were converted to monthly and yearly variables. The gauging station where Lusk Creek variables were obtained was not located in the same reach that this study took place. Sampling year surface water temperatures and dissolved oxygen readings were obtained in the field during each sampling event using a Hydrolab, and discharges were obtained through the USGS.

Fish

During September 2002 through April 2003 (designated as year 1 sampling), and during August 2003 through May 2004 (designated as year 2 sampling), I collected adult bluegill, longear sunfish, redear sunfish, and largemouth bass. Due to low numbers, all data from tributaries were combined. Seasons were classified into the following based on months having similar water temperatures in the tributaries: fall (Aug.-Nov.), winter (Dec.-Mar.), and spring (Apr.-May). Tributary sites were sampled by three-phase, boat-mounted, AC electrofishing. Six shoreline sites from around one mile upstream to the mouth of each tributary (four in Hurricane Creek) were sampled parallel to shore, with total pedal time twenty minutes per site. Depending on conductivity levels (ranging from a low value of 67 μS to a high value of 432 μS for all four tributaries), one electrode from each pair (3 pairs on each boom) was taped in order to decrease the amount of current entering the water. Adult target species (bluegill, longear sunfish, redear sunfish, and largemouth bass) collected during year one were placed on ice and returned to the lab for removal of otoliths. Fish lengths (total length, mm) and weights (g) were quantified. Target adult fishes collected during year two were processed in the field for total length (mm) and wet weight (g).

Aging

Fish ages can provide insight into growth and mortality of the fish population residing in a particular habitat. Centrarchid scales have been shown to give inaccurate estimates of age 1+ and old fish (Heidinger and Clodfelter 1987), so all target fish species were aged using otoliths. When possible, ten adult bluegill, longear sunfish, redear sunfish, and largemouth bass were placed in ten centimeter length groups. A key using the subsampled fish ages and fish lengths was developed to assign ages to fish that were not aged. Sagittal otoliths were removed by dissection on the ventral side of the fish. Otoliths were sectioned if necessary, and aged under a dissecting microscope at 25x magnification. Digital pictures of all the otoliths were taken.

Back-Calculation

Using Scion Image software, radius measurements were taken from the nucleus to each otolith ring and edge. The direct proportion method, which makes the assumption that otolith and body growth are proportional (DeVries and Frie 1996), was used to determine centrarchid length at each age by using the following equation: $L_i=(S_i/S_c)*L_c$ where L_i=back-calculated length of the fish when the ith increment was formed, S_i=radius of the otolith at the ith increment, S_c=radius of the otolith at capture, and L_c=length of fish at capture (DeVries and Frie 1996).

Catch per Unit Effort

Catch per unit effort was calculated for all target fish species by calculating the total number of fish caught over one season and divide that by the total effort expended sampling the fish.

Condition Analysis

Condition indices can be used to track a fish's plumpness (Murphy et al. 1990), giving insight on overall fat content (Anderson and Neumann 1996). Relative weight

(W_r) provides a direct method for comparing condition across species and systems. They were calculated for adult bluegill (Hillman 1982), largemouth bass (Wedge and Anderson 1978), and redear sunfish (*L. microlophus*) (Pope et al. 1995) using the equation W_r= 100 x (W/W_s), where W=fish's weight and W_s= species-specific standard weight equation determined by a length-weight regression (Anderson and Neumann 1996). Because there is no standard weight equation for longear sunfish, condition was not calculated.

STATISTICAL ANALYSIS

All statistical tests were performed using Statistical Analysis Software (SAS) (SAS Institute, Inc. 1999) at the 0.05 significance level. Linear least-squares regression was used to determine the relationship between Lusk Creek and main channel Ohio River discharge. The 2DKS test was utilized to examine the level of relationship between discharges of the two bodies of water (Garvey et al. 1998). This test explores differences in bivariate data that has multiple confounding factors associated with it. ANOVAs were used to compare mean annual values of tributary and main channel Ohio River temperature (°C) and dissolved oxygen (mg/L) between sampling years.

Two-way ANOVAs were used to test effects of temperature and discharge of both Lusk Creek and the main channel of the Ohio River on historical year class strength of the target fishes. Catch-curve residuals (Maceina 1997) were used to determine past year class strength of the four target species compared to seasonal Ohio River discharge and air temperatures recorded at Paducah, KY (substitute for Ohio River water temperatures). This test is done by plotting the natural log of catch per unit effort of the target fish species by their ages. From the regression line, an equation predicting the average survival through time is developed. The actual age of the target fish is subtracted from the predicted age for that year to find the residual value.

River discharge and air temperature (used as a surrogate for river temperature) were regressed against the residual values (designated as historical fish year class strength in the results). If the plotted number was above the predictive regression line, that fish species exhibited a strong year class for that year. If the plotted number was below the predictive regression line, that fish species had a poor year class for that year (Maceina 1997).

Multiple regression was used to determine variance levels of Lusk temperature and discharge, as well as Ohio River temperature and discharge, to year class strength of the sampled fish species. Age and growth of the target species were compared between years by looking at the intercept of linear regression analysis. If the intercept was positive, this represented increased growth between years. If the intercept was negative, this showed growth declined between years.

In order to test significance of growth between years one and two, mean length of each fish species from year two was subtracted by the same value from year one. This difference was regressed against age class in order to indicate consistent or variable growth of the target fish species between years. Two-way ANOVAs were performed to analyze mean length at age for the target species over the two effects season and year. Target species length distributions among seasons and years were compared using the Kolmogorov-Smirnov test. Catch per unit effort (CPUE) and fish condition significance were determined using two-way ANOVAs with season and year as the two effects. A two-way ANOVA was also used to compare years and season (the two effects) to adult fish condition.

RESULTS

DISCHARGE AND TEMPERATURE EFFECTS ON FISH

Lusk Creek (the only tributary from which discharge could be obtained from a USGS gauging station) and Ohio River discharges were analyzed using least squares linear regression, and main channel discharge was found to have a weak effect on stream discharge (Figure 5). The USGS gauging station for Lusk Creek was farther upstream than where sampling took place, which might account for the weak effect. A 2DKS test showed a non-random relationship between the Ohio River and Lusk Creek discharge (P=0.01, D=0.18), meaning that discharge of these two water bodies were associated with one another. This result was likely because discharge in Lusk became more variable as discharge in Smithland increased (Figures 5-6). Pearson's correlation showed that winter and spring main channel discharge were not correlated (P=0.36), meaning that they could be analyzed separately. Since sampling began in fall 2002, winter discharges always preceded spring discharge, and would be followed by fish spawning for that year.

ABIOTIC FACTORS ANALYSIS

Tributary monthly temperature readings sampled for this project between year one (13.7 °C) and year two (14.0 °C) were similar (P=0.68, F=0.17,df=1,229) (Table 1). However, monthly sampled dissolved oxygen concentrations were significantly higher in year one (8.15 mg/L) than year two (7.40 mg/L) (P=0.01, F=6.51, df=1,229) (Table 1). Higher dissolved oxygen levels during warmer temperatures indicated that oxygen producers such as zooplankton were being efficient during the daytime, which was when temperature and dissolved oxygen measurements were recorded. Daily discharge measurements taken by USGS on Lusk Creek were significantly higher in year one (3 m^3/s) compared to year two (1 m^3/s) (P=0.01, F=21.99, df=1,880) (Table 1).

Daily discharge at Smithland Lock and Dam recorded by USGS gauging stations was significantly higher in year two (6960 m^3/s) than year one (6245 m^3/s) (P=0.02, F=5.31, df=1,880) (Table 2). NOAA air temperature data showed that year two was significantly warmer (17.0° C) than year one (14.4° C) (P=0.02, F=9.40, df=1,514) (Table 2). Dissolved oxygen concentrations for year one (7.47 mg/L) were higher than year two (6.63 mg/L) (P=0.01, F=7.48, df=1,151) (Table 2).

LUSK CREEK ABIOTIC FACTORS AND YEAR CLASS STRENGTH

Lusk Creek discharge was found to have a greater yet non-significant effect on bluegill year class strength (P=0.07, t=-2.00, R^2=0.02) than temperature (P=0.67, t=-0.44, R^2=0.02). Neither Lusk Creek discharge (P=0.36, t=1.00, R^2=0.14) or temperature (P=0.73, t=-0.36, R^2=0.02) had a measurable effect on longear sunfish year class strength. Redear sunfish year class strength was also not influenced by Lusk Creek discharge (P=0.50, t=-0.70, R^2=0.06) or temperature (P=0.63, t=0.51, R^2=0.03). Similar to longears and redears, largemouth bass cohort strength was not influenced by Lusk Creek discharge (P=0.21, t=-1.30, R^2=0.10) or temperature (P=0.99, t=0.0, R^2=0.0).

HISTORICAL OHIO RIVER DISCHARGE AND YEAR CLASS STRENGTH

Bluegill year class strength was negatively correlated to Ohio River discharge during the 1996-2001 winters as well as 1996-2001 spring seasons, showing that bluegill had stronger year classes in years when the Ohio River discharge was under 10,000 m^3/s (Figure 7, Table 4).

Longear sunfish showed a decline in year class strength during winter 1998-2001 as main channel river discharge increases, with the same pattern repeated during spring of those years. This pattern demonstrates that longear sunfish year class strength was variable (Figure 8, Table 4). However, longear sunfish and bluegill exhibited the strongest year class strength in 2001 (Figures 7-8, Table 4).

Redear sunfish year class declined in 1993, 1995, 1997-1999 when winter main channel discharge increases (Figure 9, Table 4). No strong relationship was apparent for spring year class strength (Figure 9, Table 4).

Largemouth bass year class strength was unrelated to winter 1994-2001 main channel discharge (Figure 10, Table 4). However, spring 1994-2001 main channel discharge did have a significant effect on year class strength of largemouth bass, with bass exhibiting stronger year classes when the discharge was below 6000 m^3/s (Figure 10, Table 4).

Bluegill year class strength for 1996-2001 winter and spring closely resembled one another (Figure 11). 1996 was a poor for bluegill, while 2001 was the best (Figure 11). Bluegill year class strength was unrelated to mean winter and spring 1996-2001 air temperatures (Figure 11, Table 4).

Longear sunfish followed a similar pattern as bluegill, with no relationship between year class strength and winter 1998-2001 and spring mean air temperatures (Figure 12, Table 4). Longear sunfish also exhibited a strong year class in 2001 (Figure 12).

Year class strength of redear sunfish was positively related to winter (during 1993, 1995, 1997-1999) mean air temperatures (Figure 13, Table 4). Mean spring 1995, 1997-1999 air temperatures were unrelated to redear year class strength (Figure 13, Table 4).

Largemouth bass year class strength was unrelated to winter and spring 1994-2001 mean air temperatures (Figure 14, Table 4). Similar to bluegill and longear sunfish, largemouth bass had the best year class in 2001 (Figure 14).

One consistent pattern between fish species was the discharge and temperature effect on year class strength. 1999 and 2001 were warm years compared to the others, and that, coupled with low main channel discharges, resulted in strong year classes for the target fish. Also, Ohio River hydrograph was flashy, resulting in poor year class strength of centrarchids during years of high discharge (Figures 7-10).

AGE, LENGTH, AND CPUE

Bluegill lengths followed a typical growth curve, with L_∞ reaching 167 mm for year one and 171 mm in year two (Figure 15). Bluegill reached longer lengths in year two compared to year one, yet had a similar K in the year one (Table 5). Ages 1,2, and 5 experienced consistent differences in growth, while ages 3 and 4 had varying differences (Figure 16). Regression analysis indicated that growth differences between years one and two were not significant (P=0.76, F=0.12, df=1,3) (Figure 16).

Longear sunfish experienced an asymptotic growth curve like bluegill (Figure 15). Longears, contrary to bluegills, had a greater L_∞ and K for year one compared to year two (Table 5). Growth among ages was not consistent (Figure 16), yet regression analysis showed that growth in year one was significantly greater than year two in longears ($P=0.02$, $F=42.86$, df=1,2) (Figure 16).

Redear sunfish showed a pattern of older fish sampled during year one compared to year two (Figure 15). Similar to bluegill, redears showed a larger L_∞ in year one, but a larger K in year two (Table 5). Similar to longear sunfish, redears experienced no consistencies in growth between ages (Figure 16). Regression analysis indicated growth between years one and two did not differ ($P=0.22$, $F=1.96$, df=1,5) (Figure 16).

Largemouth bass also followed a similar growth curve shape as redear sunfish (Figure 15). Contrary to longear sunfish, largemouth bass exhibited a larger L_∞ and K in year two compared to year one (Table 5). Largemouth bass growth varied across ages (Figure 16). Regression analysis demonstrated that year two experienced greater growth than year one ($P=0.01$, $F=14.39$, df=1,5) (Figure 16).

Bluegill length frequency distributions showed a minimum fall mean total length ranage of 1.09 cm for both years one and two (Figure 17), to 1.29 cm during winter of year one (Figure 17). Results of the Kolmogorov-Smirnov test showed no significant difference in bluegill length distributions among years or seasons (fall: $P=0.12$, KSa=1.18, winter: $P=0.98$, KSa=0.47, spring: $P=0.34$, KSa=.94).

Longear sunfish were larger on average throughout year one (mean average total lengths: 0.97 cm, 1.00 cm, and 1.01cm respectively) compared to year two (mean average total lengths: 0.94 cm, 0.98 cm, and 0.99 cm respectively) (Figure 18). Even with the differences in mean length, the Kolmogorov-Smirnoff tests showed no difference for longears among seasons and years (fall: $P=0.34$, KSa=0.94, winter: $P=0.34$, KSa=0.94, spring: $P=0.98$, KSa=0.47).

Redear sunfish length distributions ranged from a minimum of 1.50 cm in fall year two to a maximum of 1.90 in spring year two (Figure 19). However, mean total length changes did not differ for redear in both years among seasons (fall: P=0.99, KSa=0.45, winter: P=0.99, KSa=0.22, spring: P=0.99, KSa=0.45).

Largemouth bass length frequency distributions ranged from a minimum of 2.09 cm for the fall year one (Figure 20) to a maximum of 2.85 cm for spring year two (Figure 17). Similar to bluegill, lengths did not differ for both years among seasons (fall: P=0.44, KSa=0.87, winter: P=.99, KSa=0.29, spring: P=0.99, KSa=0.29). Overall, length distributions of bluegill, longear sunfish, redear sunfish, and largemouth bass do not differ much over both years or seasons.

Bluegill CPUE (number caught/hour) did not differ between year (P=0.24, F=1.52, df=5,16) or season (P=0.10, F=2.73, df=5,16). No interaction between year and season was observed (P=0.17, F=2.02, df=5,16) (Figure 21).

For longear sunfish, no significant differences were found among yearly (P=0.29, F=1.18, df=5,16) or seasonal (P=0.09, F=2.82, df=5,16) catch. However, there was an interaction between year and season (P=0.05, F=3.54, df=5,16) (Figure 21).

Catch of redear sunfish averaged fairly low throughout the sampling season with the highest catch occurring in fall 2002 with an average of 13 ± 5 (mean ± standard error). Catch among years (P=0.29, F=1.18, df=5,16), season (P=0.09, F=2.82, df=5,16), and the interaction between year and season (P=0.99, F=0, df=5,16) did not differ (Figure 21).

Catch of largemouth bass was considerably lower than bluegill, with the highest catch being 16 ± 2 (mean ± standard error) in spring 2003. As with the other species, largemouth bass catch was the same in sampling years one and two (P=0.11, F=2.82, df=5,16) as was the interaction between year and season (P=0.17, F=2.00, df=5,16). However, there was a difference in the number of largemouth bass caught compared by seasons with more largemouth bass captured during spring (P=0.01, F=5.76, df=5,16) (Figure 21)

FISH CONDITION

Two-way ANOVA results showed that condition of fishes in tributaries differed between years and among seasons. Relative weight of bluegills differed throughout the three seasons (P=0.01, F=5.54, df=5,1435) (Figure 22). Condition significantly declined from an average Wr of 74 in year one (fall 2002-spring 2003) to an average Wr of 71 in year two (fall 2003-spring 2004) (P=0.01, F=20.68, df=5,1435) (Figure 22), with bluegill exhibiting higher plumpness in year one. There was an interaction between season and year (P=0.02, F=3.98, df=5,1435) for bluegill condition with year one bluegill exhibiting better condition each season than year two (Figure 22).

Relative weight of redear sunfish differed between seasons with redear sunfish caught in the winter exhibiting the best condition (P=0.01, F=8.35 df=5,534) (Figure 22). Condition was higher in year one (Wr=96) than in year 2 (Wr=88) (P=0.01, F=71.06, df=5,534) (Figure 22). There was an interaction between year and season on redear relative weight (P=0.01, F=6.45, df=5,534) with year one redear sunfish exhibiting more plumpness each season than year two (Figure 22).

Largemouth bass condition differed among seasons (P=0.01, F=6.04, df=5,404), with winter exhibiting the best condition (105) and fall the poorest (97) (Figure 22).

Year one largemouth bass had significantly higher condition (110) than year two (91) (P=0.01, F=74.8, df=5,404) (Figure 22). Unlike the other two target species, there was no interaction between season and year that affected largemouth bass relative weight (P=0.09, F=2.38, df=5,404) (Figure 22).

DISCUSSION

HISTORICAL DISCHARGE AND TEMPERATURE EFFECTS ON FISH

Main river discharge influenced the discharge of connecting tributaries above some threshold. When the Ohio River did not have high discharge, Lusk Creek also did not have high flow. However, when river discharge exceeded 4800 m^3/s, Lusk Creek discharge became highly variable and did not pattern after Ohio River discharge. High water events such as heavy rain and snow melt off likely influenced Lusk Creek (and other connecting tributaries) discharge levels more than the main channel of the river. The timing of these high water events could potentially affect spawning habits, juvenile centrarchid habitat use (Harvey 1987), spawning success (Garvey et al. 2000), and population dynamics of fishes living in these streams.

Ohio River winter discharge produced stressful conditions on centrarchids that continued into spring. This likely affected adult spawning centrarchids, and had an apparent causal effect on fish year class survival and production, with congruence among species. The key to good recruitment among species would have been stable main channel discharge throughout the year, likely for all of the centrarchid family. Year class strength in tributaries appeared to model the flood-pulse concept developed by Junk et al. (1989). Hydrology is a dominant force that affects river biota survival. When floods occur, especially at sensitive times for fish such as spring spawning, centrarchids are more likely to produce a poor year class. Productivity that is generated when rivers flood provide nutrients that provide fishes with prey to consume. High discharges at certain times of the year affected recruitment, thereby influencing cohort strength of fishes in large rivers. A study conducted by Deegan et al. (1999) illustrated how different environmental variables affected artic grayling. River discharge and water temperature in particular influenced juvenile and adult artic graylings differently. Adult artic grayling was positively correlated with discharge, whereas the converse was true for juvenile artic grayling. A study conducted by Theiling et al. (1996) illustrated how centrarchid abundance within a large river was related to river discharge levels. They found that centrarchid abundance peaked on the Upper Mississippi River in years of low discharge due to development of aquatic vegetation. In years of high river velocities, centrarchid abundances declined (Theiling et al. 1996). Variable flood events on the Ohio River during spring flood and in the connecting tributaries have the potential to flush eggs and age-0 fishes downstream away from the protective habitat that are necessary for growth and survival of centrarchid fishes in tributaries. Even though discharge in recent years appeared to be more conducive to positive centrarchid year class strength, the Ohio River hydrograph is flashy, similar to the Illinois River (Sparks et al. 1998), which can result in poor year class strength of centrarchids during years of high discharge. Low discharge does not translate into strong year class strength for all fish species. DiCenzo and Duval (2002) found that white bass year class strength was poor in years with low discharge. They hypothesized that streamflow during the spawning season might influence spawning success. This would increase the likelihood of a good year class for white bass, which exhibits a different life history than centrarchids.

Conflicting studies done by Maceina and Bettoli (1998) and Raibley et al. (1997) on centrarchid recruitment would suggest there was not a clear pattern of main channel discharge effect on centrarchid cohort strength. Average spring Ohio River discharges did not follow such a defined pattern as the average winter river discharges when analyzing year class strength. Perhaps spring discharge affected these fishes more severely during the spawning season for these lentic, and likely year-round residents, of tributaries by displacing vulnerable eggs and age-0 centrarchids from protective flow refuge that tributaries provide. The general findings from this study indicated that all four centrarchid species, regardless of their different feeding habits and life histories, showed patterns of stronger year classes in years with lower average spring river discharges. Bluegill was the only species to show significant differences in year class strength in both winter and spring. However, there were apparent discharge thresholds where all target centrarchid species would exhibit poor year class strength. Around discharges of 11,000 m^3/s, year classes were poorer than predicted. These findings disagree with ones reported by Sammons and Bettoli (2000). They found that largemouth bass in Normandy Reservoir, Tennessee, required high water during the spring spawning season. Previous studies on crappies by Mitzner (1991) and Sammons and Bettoli (2000) also suggested that high water levels and flows are necessary for strong year classes. These studies were done in riverine systems somewhat similar to Ohio River that provides minimal backwater habitat. Depending on the season, tributaries directly connected to the mainstem of the Ohio River exhibited both lentic and lotic properties. Sammons et al. (2002) concluded that year class strength is more variable in tributaries compared to reservoirs because of variable water levels. This statement was applicable for this study since tributary levels were higher in times of high main channel discharge (typically late winter into early spring). Overall, each of the target fish species in this study exhibited strong year class strength in 1999 and 2001 when main channel discharge was low (usually around 5,000 m^3/s).

Temperature appeared to have a smaller yet noticeable effect on fish year class strength. Bluegill recruitment was generally higher in years with warmer average winter air temperatures around 13°C (1996, 1999, 2001). A previous study by Knights (1995) found that black crappies and bluegills, typically more lentic species, would move to areas of lower water temperatures with higher dissolved oxygen concentrations if oxygen levels become too low. Longear sunfish and largemouth bass did not have a defined relationship with year class strength and average winter air temperatures. Redear sunfish produced a positive year class with years of significantly higher average winter air temperatures (1996, 1999). This suggests that temperature might be a factor fish use to determine the best suitable habitat for them during the winter. When temperatures were warmer in 1999 and 2001, cohort strength of the target fishes was above the predicted regression line of year class strength.

Earlier studies done by Tomcko and Pierce (2001, 2005) had indicated that biotic factors such as predator and prey availability had a larger affect on bluegill growth and population structure than environmental factors such as temperature and Secchi depth. In this study, environmental factors did appear to dictate centrarchid growth and population strength to a point. General trends for bluegill, longear sunfish, redear sunfish, and largemouth bass showed stronger year class strength in years of higher average spring air temperature. Maceina and Bettoli (1998), as well as Garvey et al. (2000), found that year class strength for largemouth bass was best during years of low rainfall and higher temperature. Those conclusions would be supported by this research with stronger year classes in years of low spring precipitation and subsequent lower spring discharges. When comparing the two variables, main channel discharge appeared to have more of an influence on year class strength than air temperatures on centrarchid year class strength. Managers should focus on more than main channel discharge as an indicator of strong of poor year classes of these fishes. Further studies should examine effects of other abiotic variable such as dissolved oxygen and turbidity on cohort strength of fishes.

AGE, LENGTH, AND CPUE

Expectations before this study were that fishes would exhibit size-selective mortality that is common for centrarchids, due to harsh winter conditions for age-0 fishes (Garvey and Stein 1998; Wright et al. 1999). Year two air temperatures on the Ohio River were warmer than year one, which suggested that abiotic factors might have explained growth and size-dependent mortality. Growth of bluegill and redear sunfish did not significantly differ between years one and two. However, longear sunfish experienced better growth in year one while the converse was true for largemouth bass (better growth in year two). Catch per effort of target fishes also varied by species. The trend for bluegill, longear sunfish, and redear sunfish were higher catch rates during the fall and winter season compared to spring. Largemouth bass, however, exhibited the lowest catch of all ages during the winter season. General results indicated few changes in growth of size-dependent survival for the target fish species. This gave further evidence that high spring discharges on the main channel of the Ohio River disrupted spawning of adult fishes and displacement of eggs and juvenile fishes rather than affecting later age classes.

No significant differences were found between length distributions of all target fish species when compared to season and year of sampling, meaning that no size-selective mortality was observed in any of the fishes. In fact, mean lengths of bluegill and redear sunfish decreased from winter to spring during the first year of sampling. Winter conditions in tributaries of the lower Ohio River did not appear to be severe enough to hinder survival of these lentic fish species to the spring season. Karchesky and Bennett (2004) also found that largemouth bass in the Pend Oreille River moved to locations that were close to the main channel and had no flow, which can be characteristic of the tributaries that were sampled in this study. Curiously, the fewest number of targeted fish were captured during the spring season for the second year of sampling. Perhaps spring water temperatures were not warm enough to encourage fish to migrate closer to the surface to reproduce or feed (Reynolds 1996). Also, small fish might not have been susceptible to the sampling gear, thereby decreasing the number of smaller individuals sampled (Anderson 1995; Bayley and Austen 2002),

Except for longear sunfish and largemouth bass, typically seasonal catch of centrarchids did not vary by season. Other studies have found seasonal differences in catch. Schultz and Haines (2005) found that more bluegill were sampled during fall, and that year significantly affected catch. Schoenebeck and Hansen (2005) sampled greater numbers of largemouth bass during the spring compared to fall in lakes, likely picking up spawning adults. Numbers of centrarchids caught were constant throughout the season, possibly indicating that these fish stayed within the tributaries for most of the year.

FISH CONDITION

Expectations before this study were that centrarchid condition would decline from fall to winter, and would experience the largest drop in condition during spring. All of the centarchid species examined for condition exhibited changes in condition on a seasonal and yearly basis. Bluegill relative weight was highest in spring, followed declining condition in fall and winter. However, relative weight values were far below the expected value of 100 during both years. Redear sunfish and largemouth bass both showed better condition during winter compared to other seasons. Interestingly, condition of the three species were better in year one than year two. For largemouth bass, this meant that the longer fish captured in year two contained fewer lipids than their smaller on average counterparts sampled in year one. Seasonal condition differences found in this study agree with previous studies. Liao et al. (1995) found low relative weight values for pumpkinseed (*L. gibbosus*) and golden shiner (*Notemigonus crysoleucas*) during spring. Findings from this study might further give evidence to less harsh conditions existing in a middle latitude river such as the Ohio, which translates into relatively decent condition between seasons, given the small changes in relative weight between seasons for each target species. The differences in condition between years might be linked to higher discharge levels in year two (Table 3), possibly washing away prey items, and forcing adults to expend more energy (lipid reserves) to maintain position in tributaries.

Another interesting fish condition result to note is that, for all species except largemouth bass, there is an interaction effect between season and sampling year. In year one, all three sunfish species were in better condition than the year two. Because no significant differences in length distributions were found, this signifies that fish of approximately similar length were not as plump in year two versus year one. Perhaps unmeasured factors such as limited prey availability due to high discharge flushing invertebrates, and other prey items out of tributaries accounted for the differences in condition.

Fish living in tributary systems must survive in a dynamic system. Main river conditions such as discharge, and to a lesser extent air/water temperatures, play a role in influencing which year class of fish survive and which do not. Other factors not included in this study such as predation and primary productivity likely influence survival of riverine fishes. Variations in recruitment will likely continue, yet other lentic species such as the ones targeted in this study still have a strong presence in these systems. This is likely due to generally favorable conditions in tributaries, and their direct connection to the main channel of the Ohio River. As Brown and Coon (1994) and many other studies have shown, slackwater habitats such as tributaries house a wide variety of fishes at some point in their life histories. Abiotic factors do explain a lot of the variance why certain year classes of fish live, and why the majority of certain year classes fail to make it to the following spring.

MANAGEMENT IMPLICATIONS

Most research to date examining recruitment factors in fishes has been focused on biotic interactions in fishes living in lentic systems. However, this research demonstrates two key points. More research must be conducted about fish recruitment in lotic systems. These dynamic habitats support a large base of fishes that are important for recreational, commercial, and diversity purposes. Another point is that fisheries professionals need to analyze abiotic interactions when analyzing historical, present, and future recruitment of fishes in lentic and lotic systems. Aquatic systems involve complex, multiple processes that influence fish behavior, and fisheries professionals need to examine all aspects of a fish in order to grasp a complete picture of a fish’s life history and actions.

Table 1. Average monthly temperature (°C), dissolved oxygen (mg/L), and discharge (m^3/s) readings for all four tributaries on the Ohio River for the two sampling sessions (year 1-fall 2002 to spring 2003 and year 2-fall 2003 to spring 2004). Only Lusk Creek was used to obtain discharge readings (m^3/s) since data were obtained from USGS.

Year	Temperature	Dissolved oxygen	Discharge
1	13.7	8.15	3.10
2	14.0	7.40	1.22

Table 2. Average monthly air temperature (°C), dissolved oxygen (mg/L), and discharge (m^3/s) readings for the Ohio River (Smithland Lock and Dam) for the sampling season (year 1-fall 2002 to spring 2003 and year 2-fall 2003 to spring 2004). Data were obtained from USGS. Air temperatures were used as a surrogate for Ohio River water temperatures, and data were obtained from NOAA.

Year	Air temperature	Dissolved oxygen	Discharge
1	4.4	7.47	6245
2	17.0	6.63	6960

Table 3. Regression values comparing main channel Ohio River (Smithland Lock and Dam-L&D) discharge (m^3/s) and temperature (°C) (air temperature for the Ohio River) and their significance to the target fishes' year class strength.

Species	Variable	Season	R^2	P
bluegill	discharge	winter	0.69	0.04
		spring	0.69	0.04
longear sunfish	discharge	winter	0.02	0.87
		spring	0.77	0.12
redear sunfish	discharge	winter	0.75	0.06
		spring	0.02	0.88
largemouth bass	discharge	winter	0.26	0.20
		spring	0.74	0.01
bluegill	temperature	winter	0.07	0.61
		spring	0.30	0.26
longear sunfish	temperature	winter	0.01	0.93
		spring	0.24	0.51
redear sunfish	temperature	winter	0.81	0.04
		spring	0.01	0.92
largemouth bass	temperature	winter	0.01	0.87
		spring	0.24	0.57

Table 4. Von Bertalanffy growth curves for adult fish species in tributaries of the lower Ohio River. Year one designates sampling done fall 2002-spring 2003, and year two defines sampling done fall 2003-spring 2004.

Fish	Year	L_∞	K	t_o
bluegill	1	167	0.5	0.067
	2	171	0.5	0.008
longear sunfish	1	135	0.9	0.312
	2	128	0.9	0.417
redear sunfish	1	385	0.1	0.999
	2	319	0.2	0.530
largemouth bass	1	519	0.1	1.480
	2	579	0.2	0.720

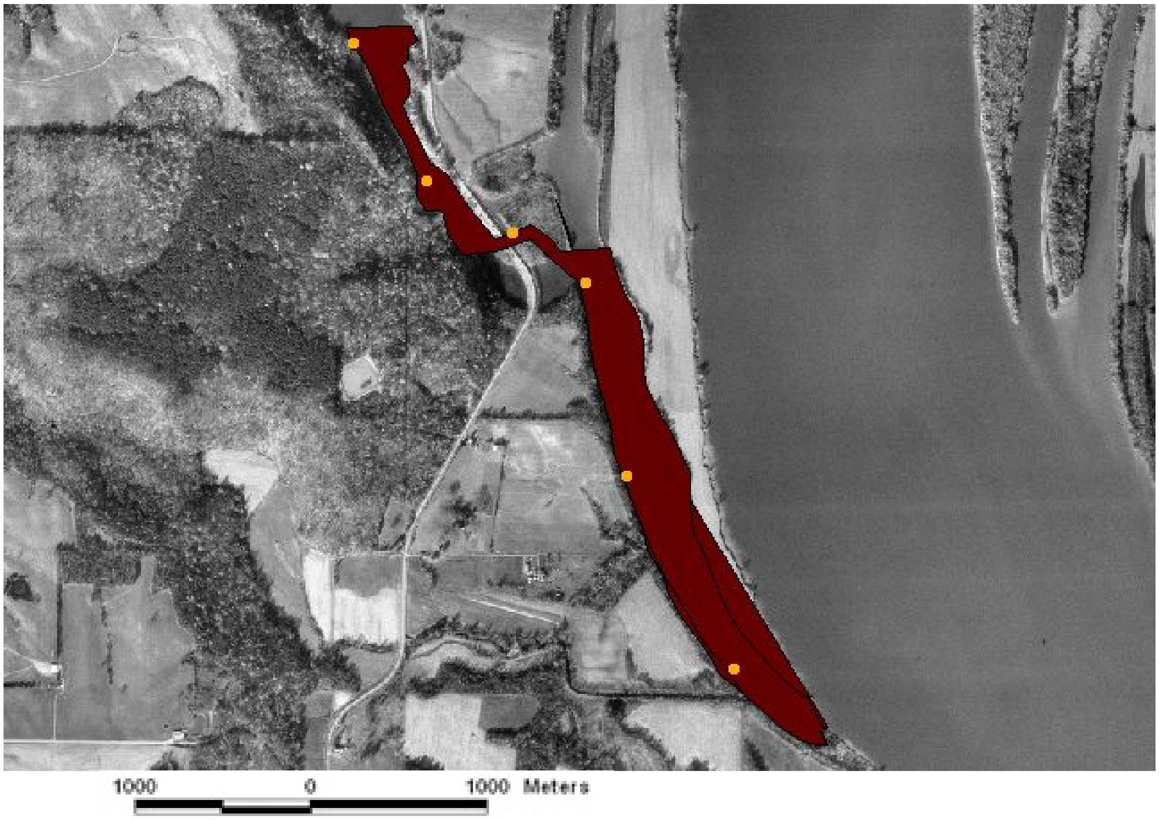

Figure 1. An aerial view of Bay Creek, a tributary of the Ohio River on the Illinois side (R.Km. 1465, R.M. 910). The shaded area represents the tributary, and the circles represent the six sampling points for the target fish and abiotic parameters. North is at the top of the panel.

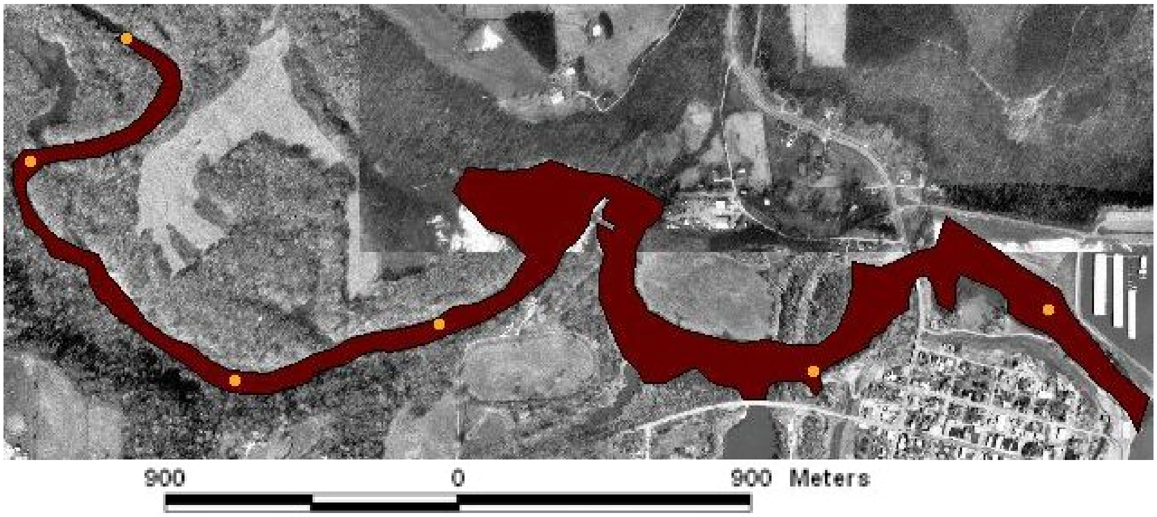

Figure 2. An aerial view of Lusk Creek, a tributary of the Ohio River on the Illinois side (R.Km. 1452, R.M. 902.5-IL). The shaded area represents the tributary, and the circles represent the six sampling points for the target fish and abiotic parameters. The Ohio River is located to the right of the panel, and north is at the top of the panel.

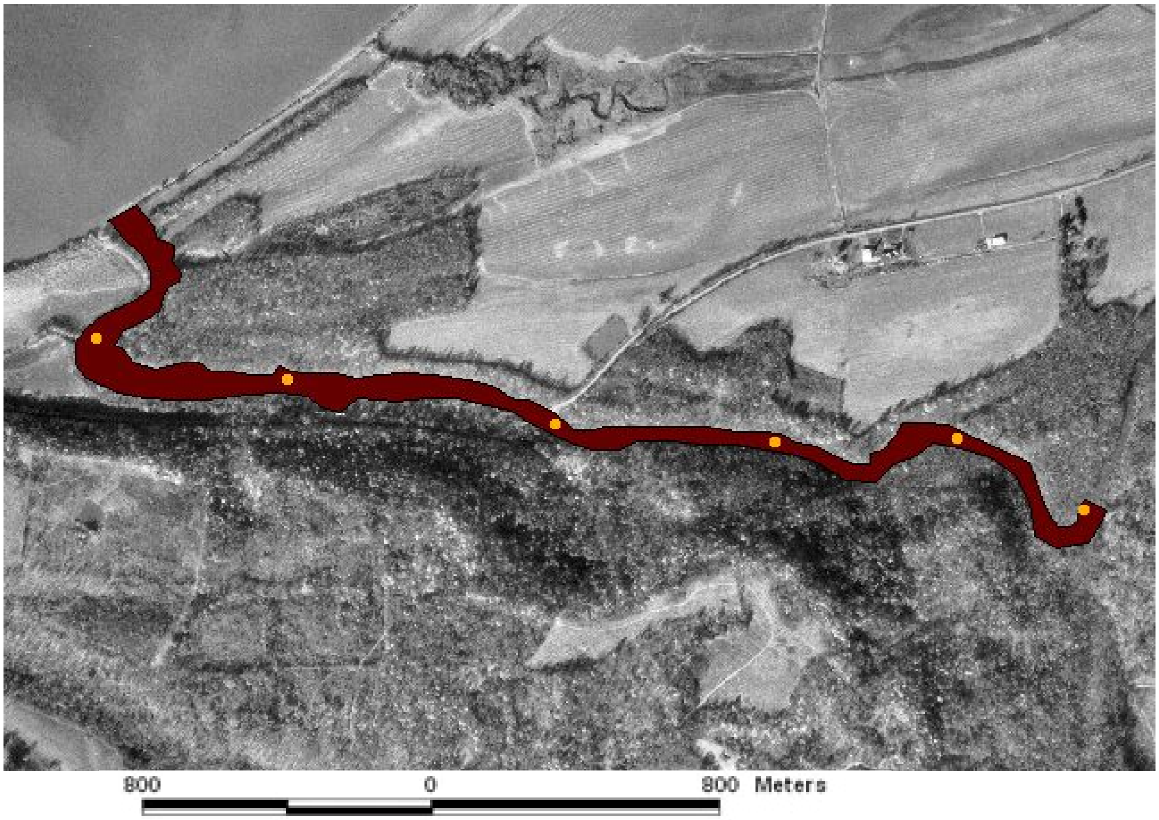

Figure 3. An aerial view of Deer Creek, a tributary of the Ohio River on the Kentucky side (R.Km. 1437, R.M. 893-KY). The shaded area represents the tributary, and the circles represent the six sampling points for the target fish and abiotic parameters. North is at the top of the panel.

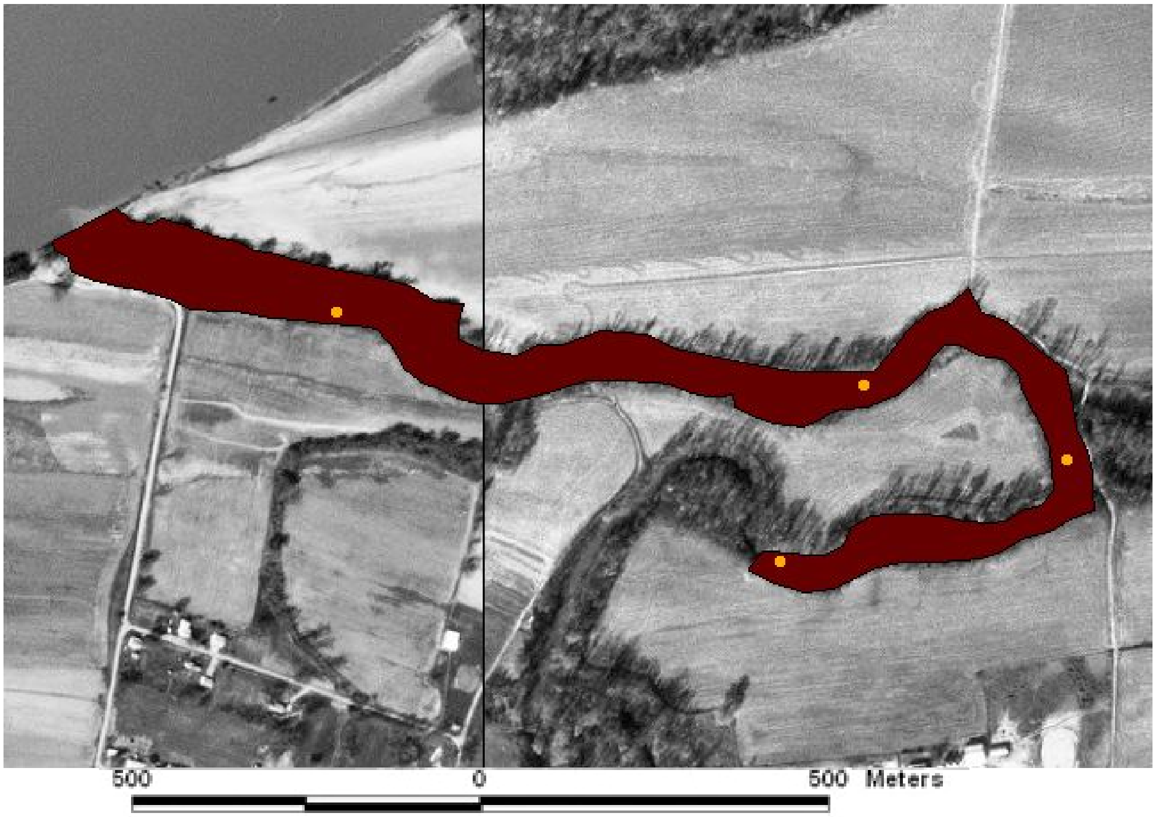

Figure 4. An aerial view of Hurricane Creek, a tributary of the Ohio River on the Kentucky side (R.Km. 1426, R.M. 886-KY). The shaded area represents the tributary, and the circles represent the four sampling points for the target fish and abiotic parameters. North is at the top of the panel.

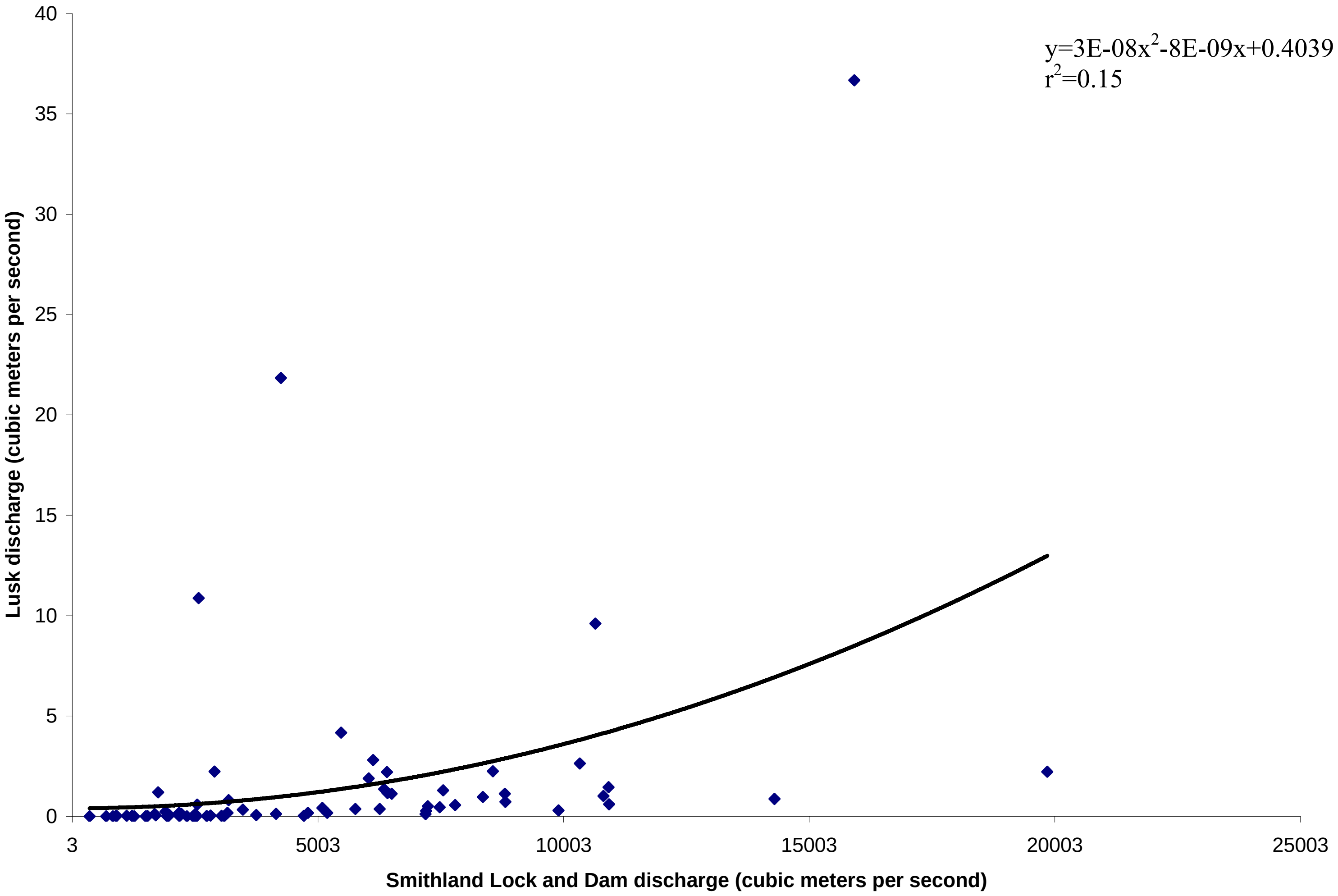

Figure 5. Historical relationship between mean monthly discharges in the Ohio River Smithland Lock and Dam and Lusk Creek, a tributary of the Ohio River, during fall 1993 through winter 2003.

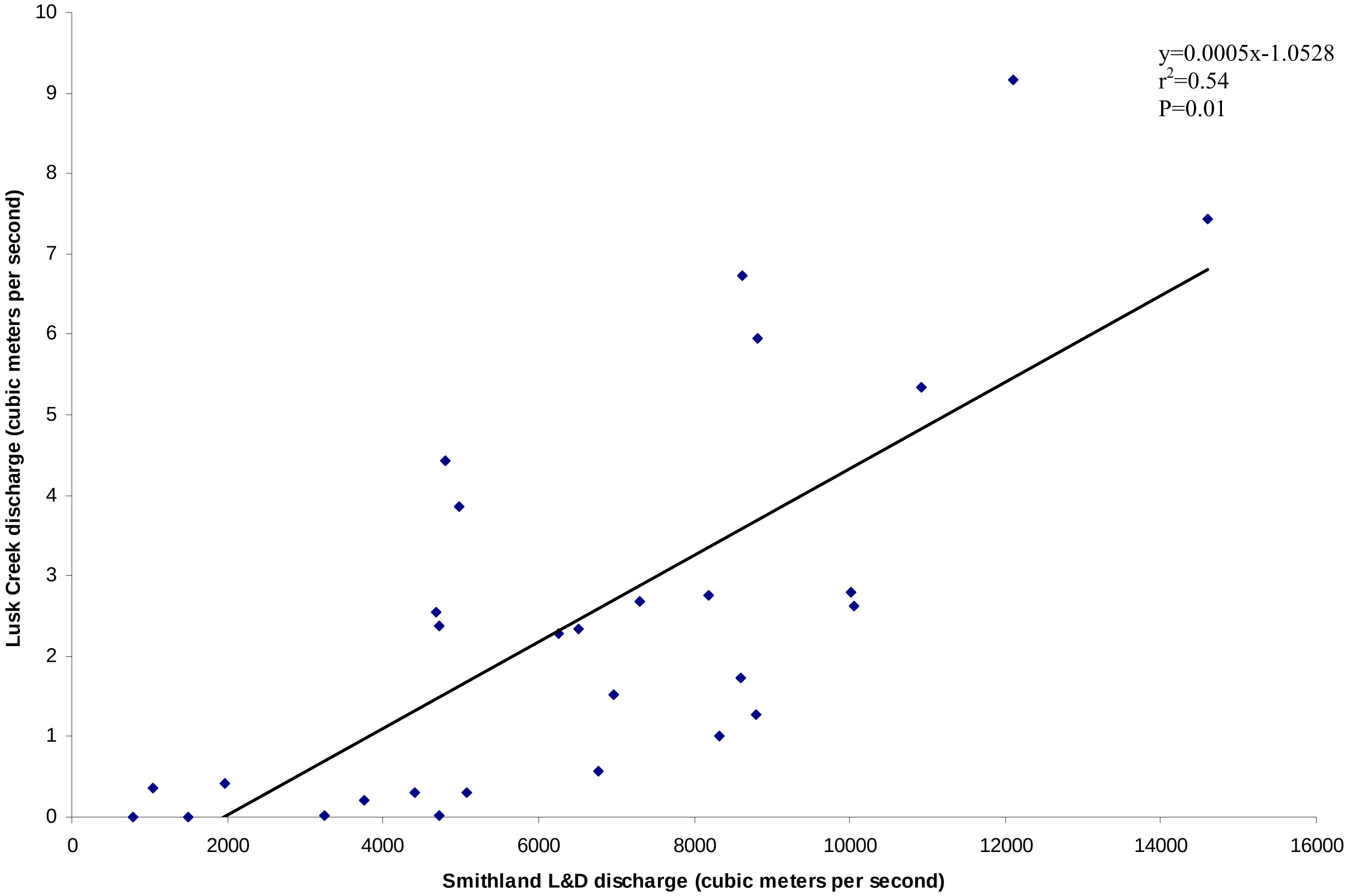

Figure 6. Discharge values for the Ohio River at Smithland Lock and Dam and Lusk Creek during the sampling season (year 1-fall 2002 to spring 2003 and year 2-fall 2003 to spring 2004) using a linear model.

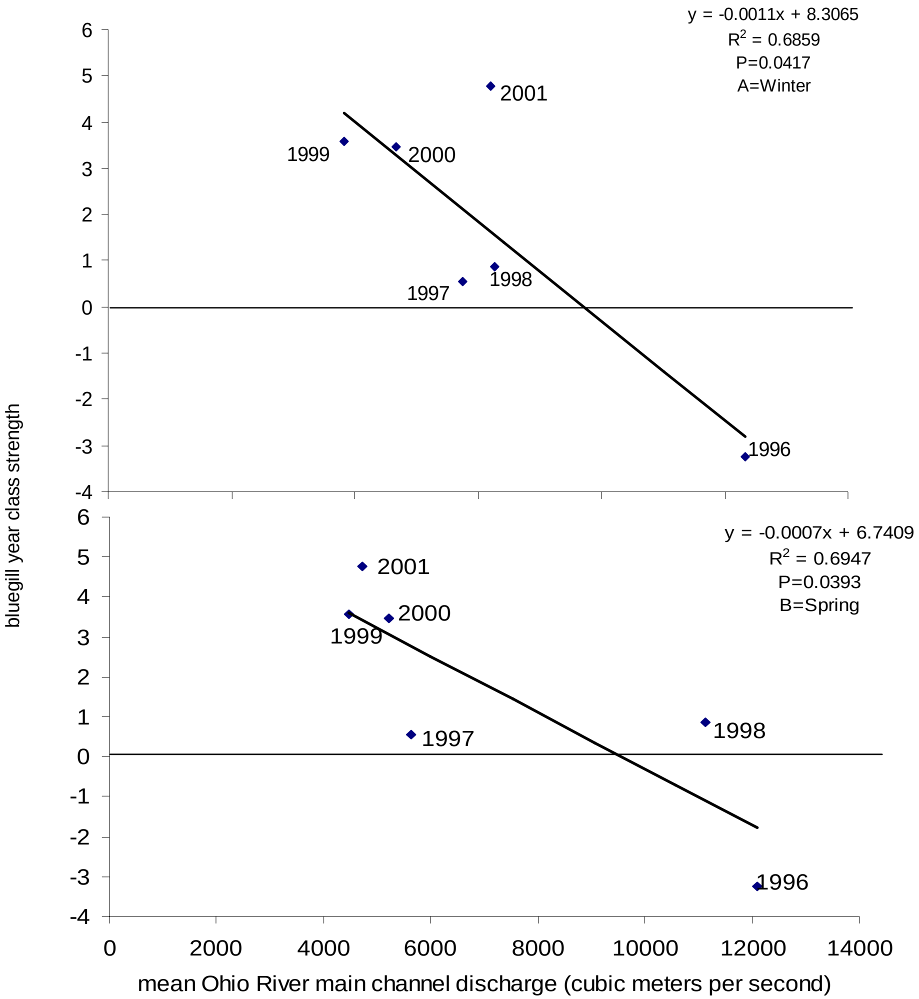

Figure 7. Effects of average main channel discharges during winter (Panel A) and spring (Panel B) 1996-2001 on bluegill year class strength in four tributaries on the Smithland Pool, Ohio River. The horizontal line extending from zero represents the a priori predictive regression line of year class strength.

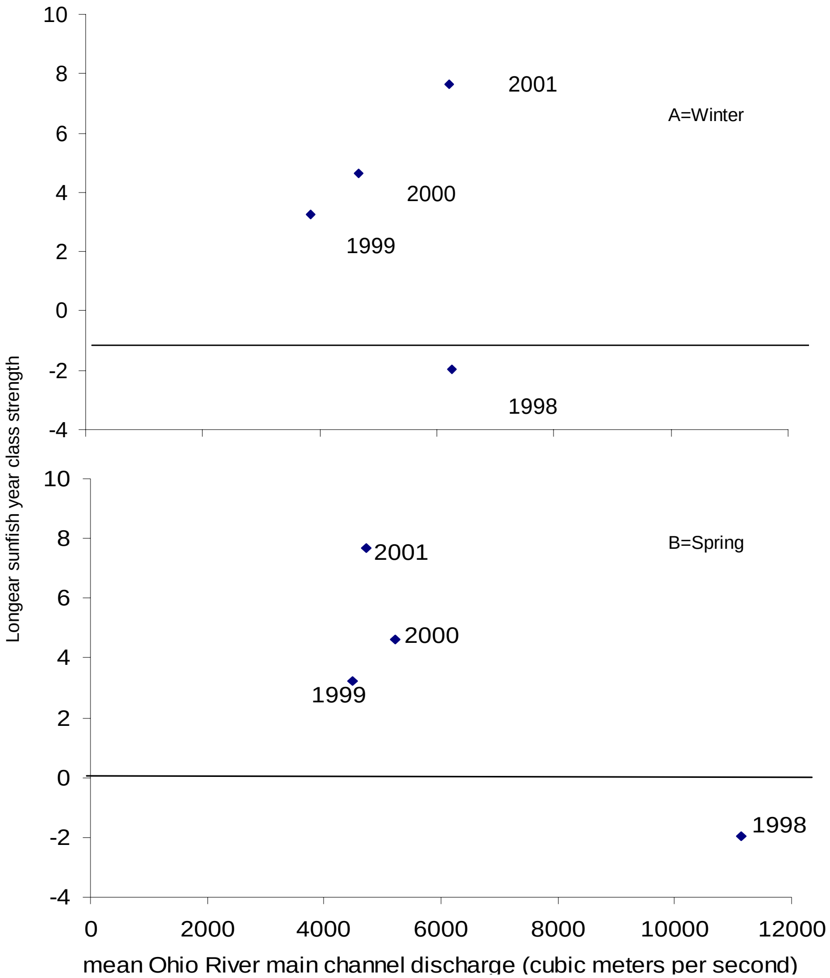

Figure 8. Relationship of average main channel winter (Panel A) and spring (Panel B) 1998-2001 discharges on year class strength of longear sunfish sampled in four tributaries on the Smithland Pool, Ohio River. The horizontal line extending from zero represents the a priori predictive regression line of year class strength.

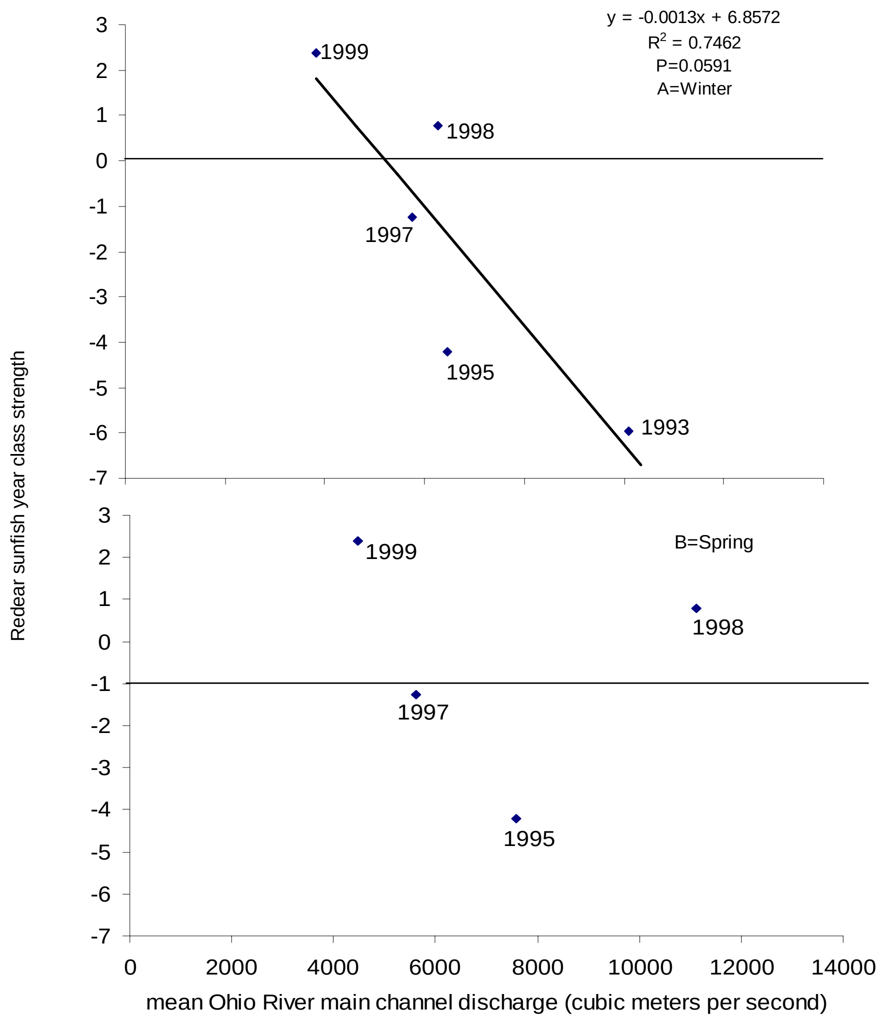

Figure 9. Redear sunfish year class strength in relation to average 1993, 1995, 1997-1999 winter (Panel A) and spring (Panel B) discharges in the main channel of the Ohio River. The horizontal line extending from zero represents the a priori predictive regression line of year class strength.

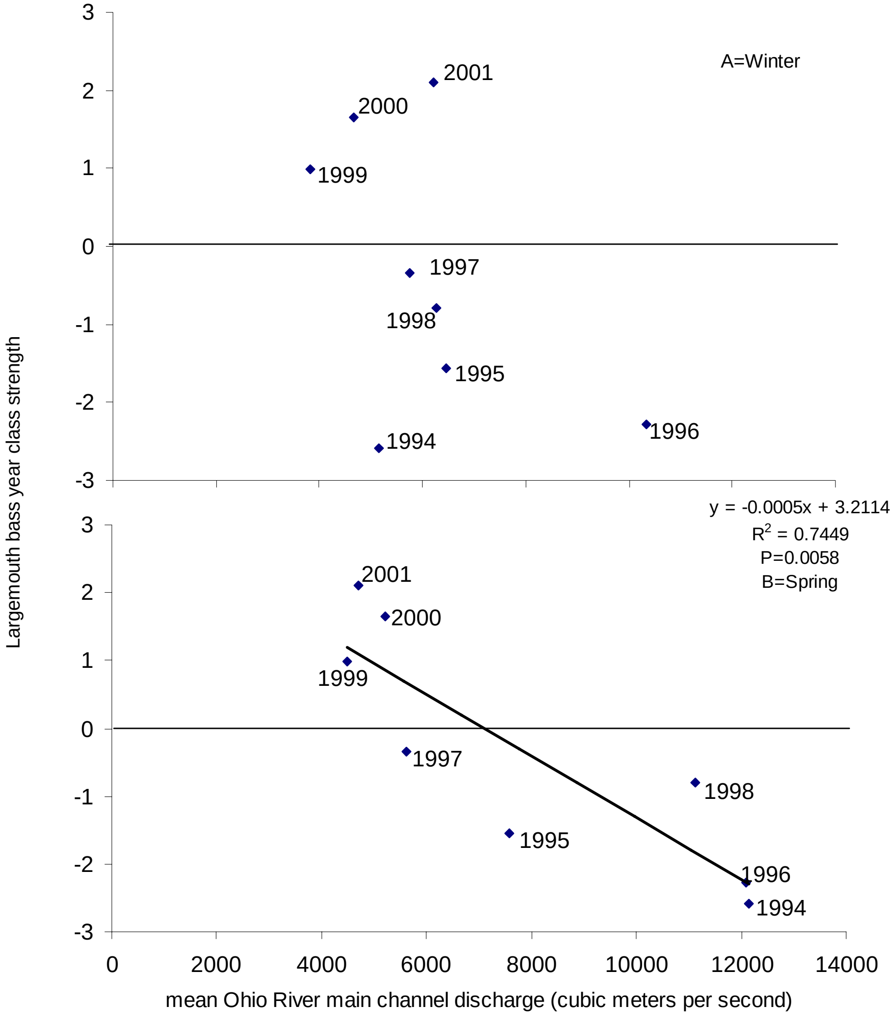

Figure 10. Relationship of largemouth bass year class strength to average winter (Panel A) and spring (Panel B) 1994-2001 main channel discharges on the Ohio River. The horizontal line extending from zero represents the a priori predictive regression line of year class strength.

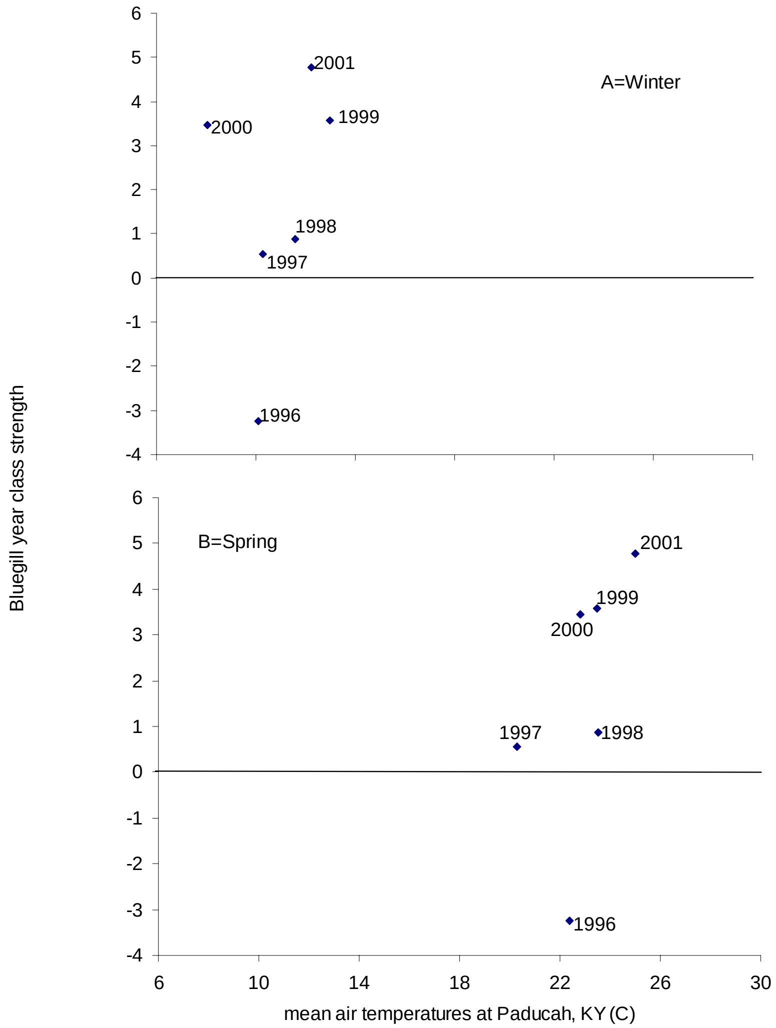

Figure 11. Relationship between mean air temperatures recorded in Paducah, KY and year class strength of Ohio River bluegill during the 1996-2001 winter (Panel A) and spring (Panel B) seasons. The horizontal line extending from zero represents the a priori predictive regression line of year class strength.

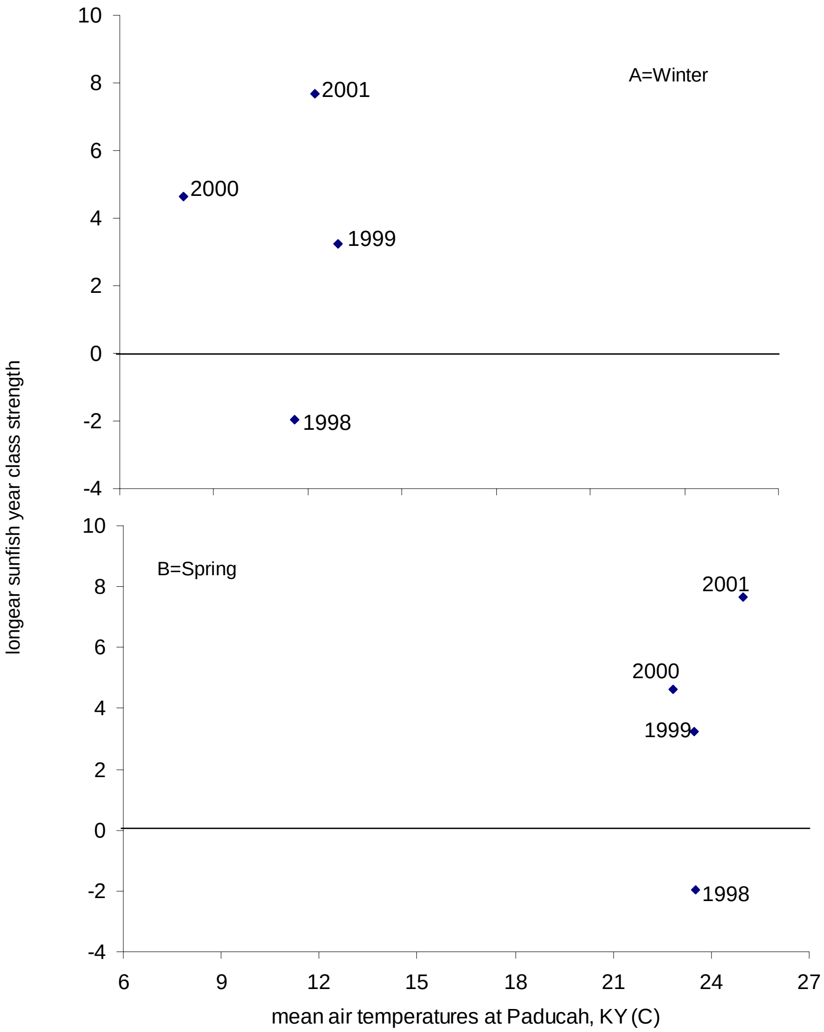

Figure 12. Relationship between mean air temperatures recorded at Paducah, KY and year class strength of Ohio River longear sunfish during the 1998-2001 winter (Panel A) and spring (Panel B) seasons. The horizontal line extending from zero represents the a priori predictive regression line of year class strength.

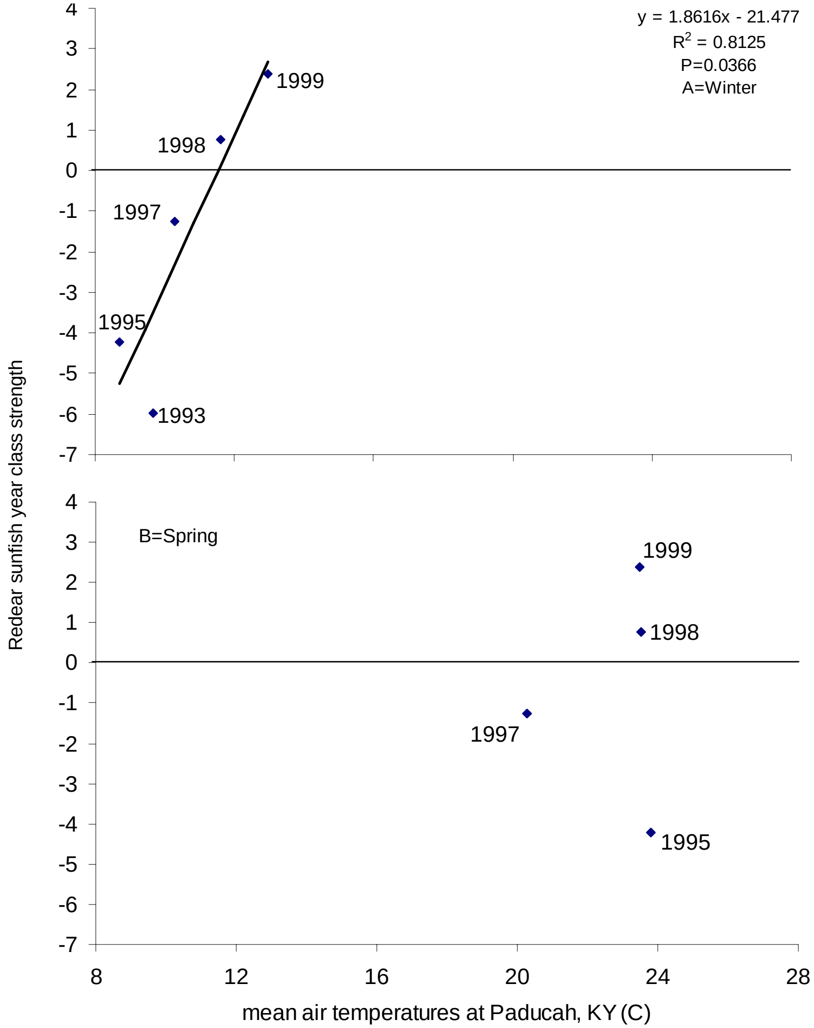

Figure 13. Relationship between mean air temperatures recorded in Paducah, KY and year class strength of Ohio River redear sunfish during the 1993, 1995, 1997-1999 winter (Panel A) and spring (Panel B) seasons. The horizontal line extending from zero represents the a priori predictive regression line of year class strength.

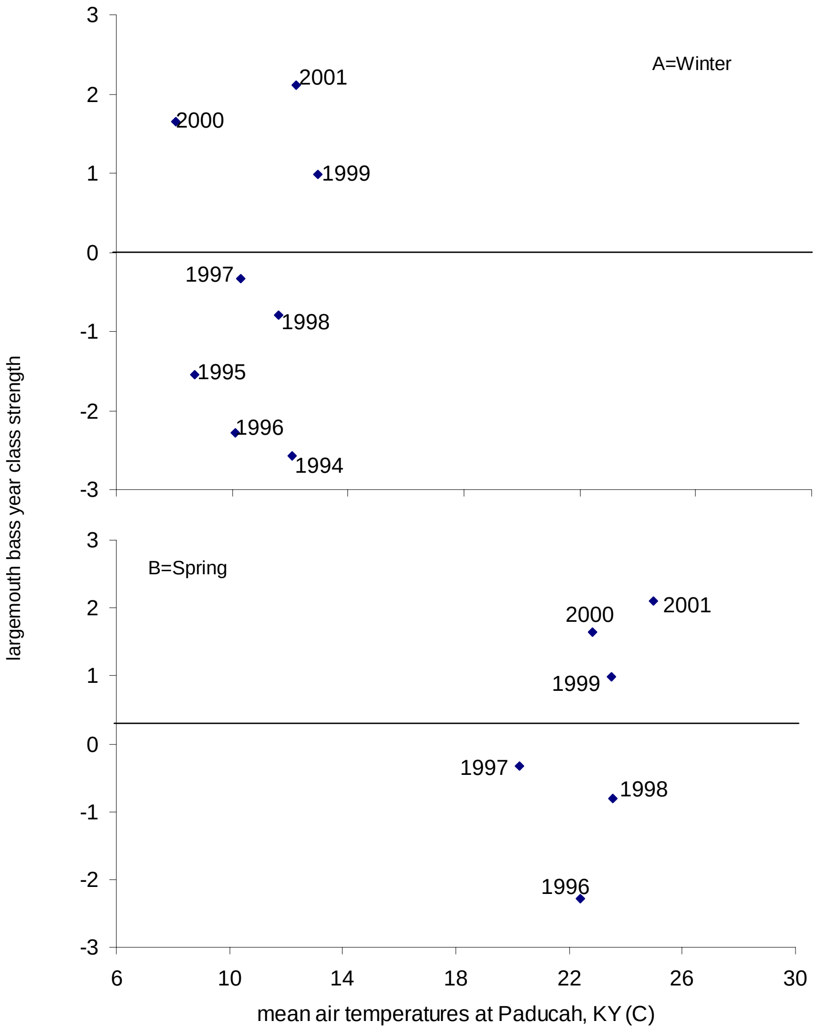

Figure 14. Relationship between mean air temperatures recorded in Paducah, KY and year class strength of Ohio River largemouth bass during the 1994-2001 winter (Panel A) and spring (Panel B) seasons. The horizontal line extending from zero represents the a priori predictive regression line of year class strength.

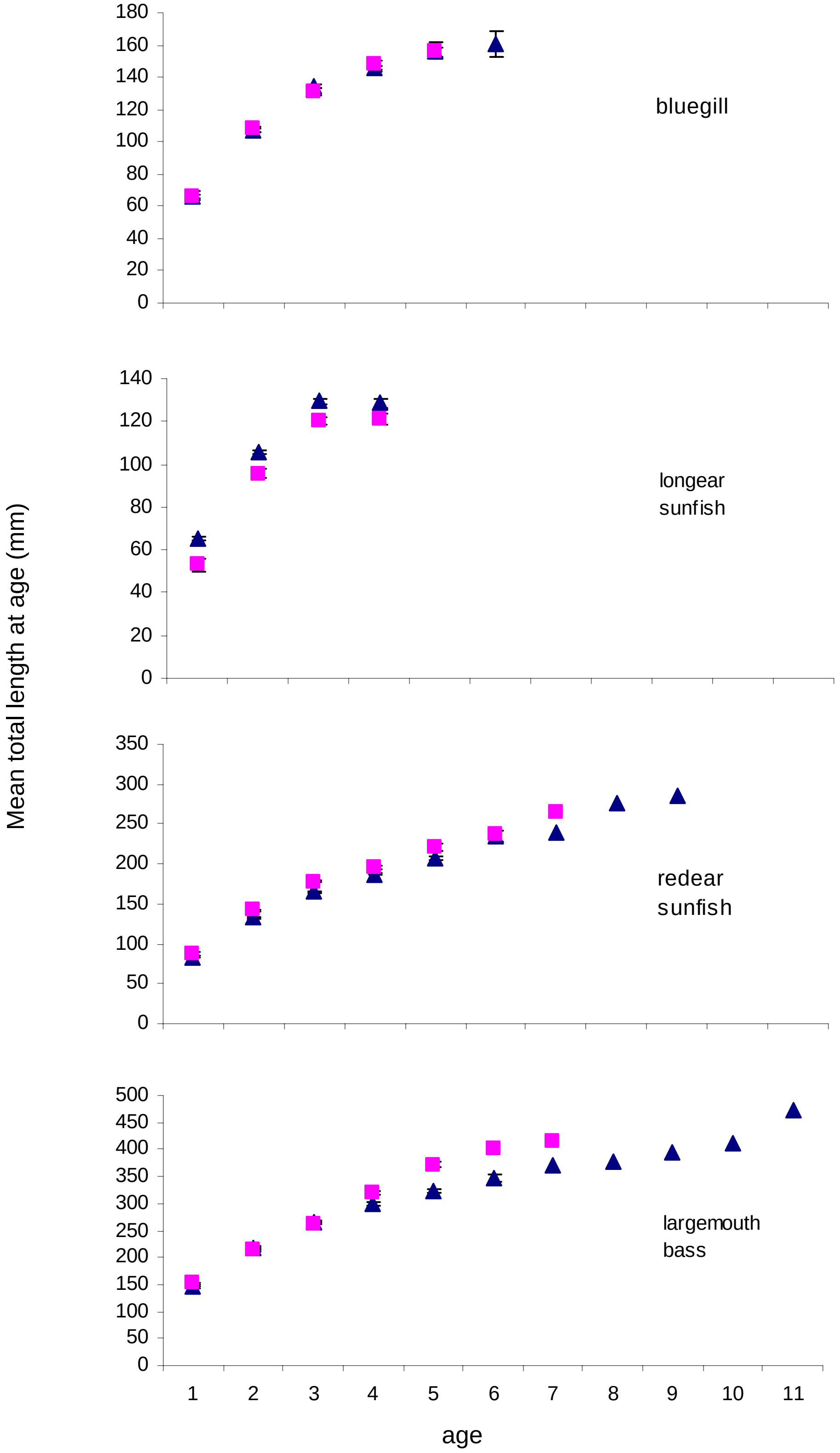

Figure 15. Mean length-at-age (mm) and standard error bars for bluegill, longear sunfish, redear sunfish, and largemouth bass found in tributaries of the Ohio River. The triangles represent fish sampled in 2002, and the squares represent fish sampled in 2003.

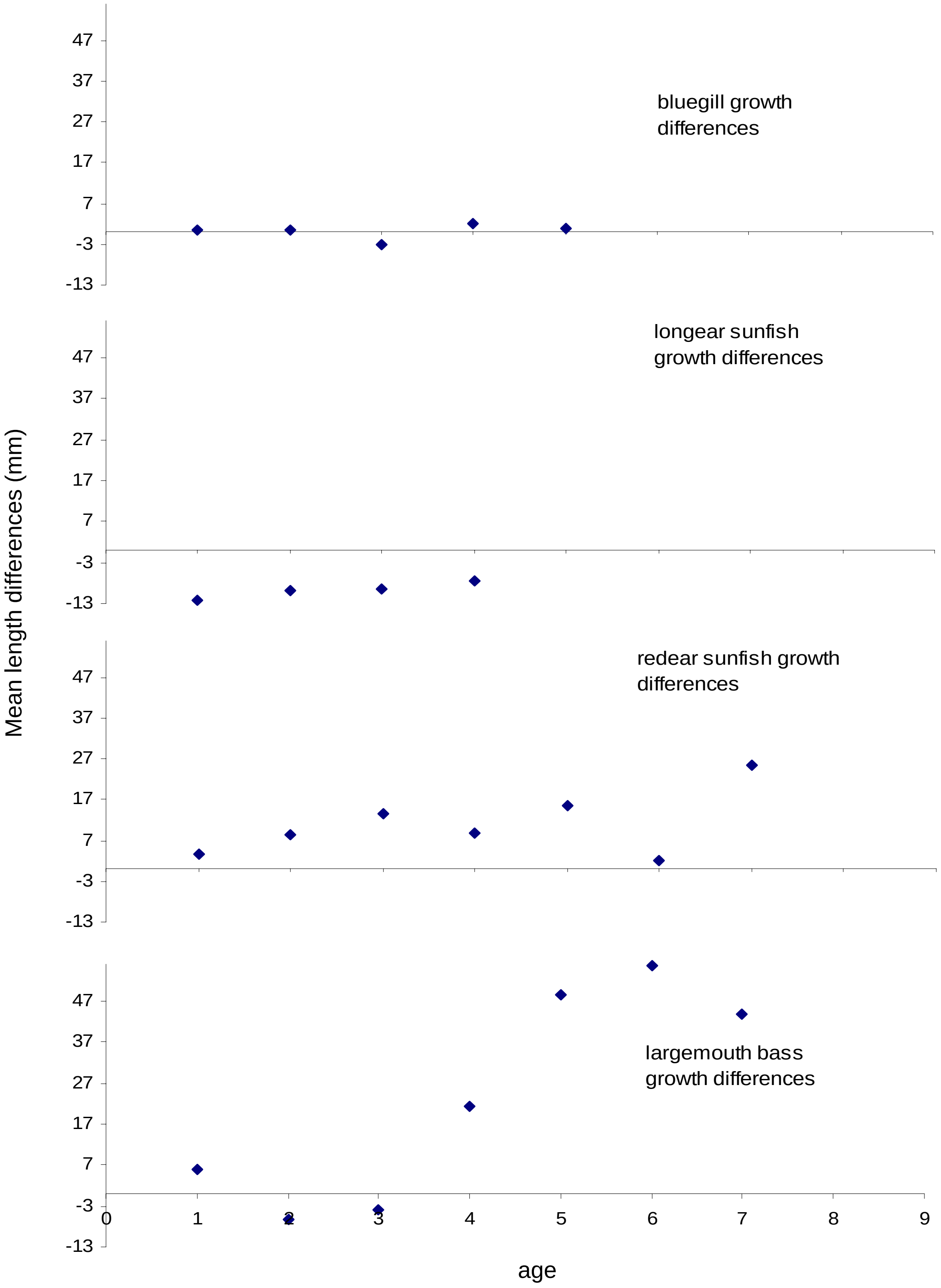

Figure 16. Comparison of growth differences versus age for bluegill, longear sunfish, redear sunfish, and largemouth bass in the Ohio River.

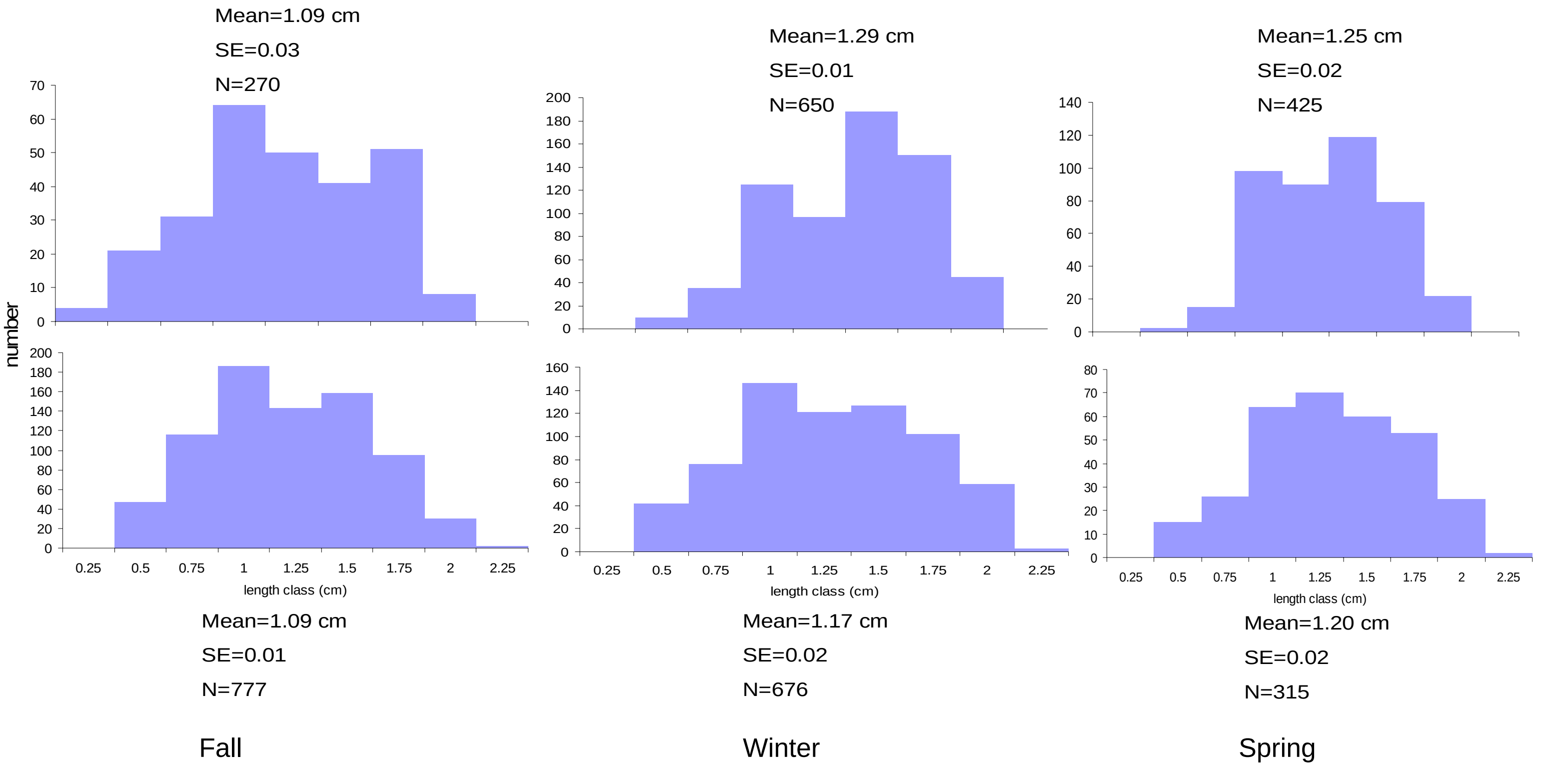

Figure 17. Length-frequency distributions of bluegill sampled during year one (top panel) and year two (bottom panel) in four tributaries of the lower Ohio River. The left side panels represent fall distributions, the middle panel winter, and the right panel spring.

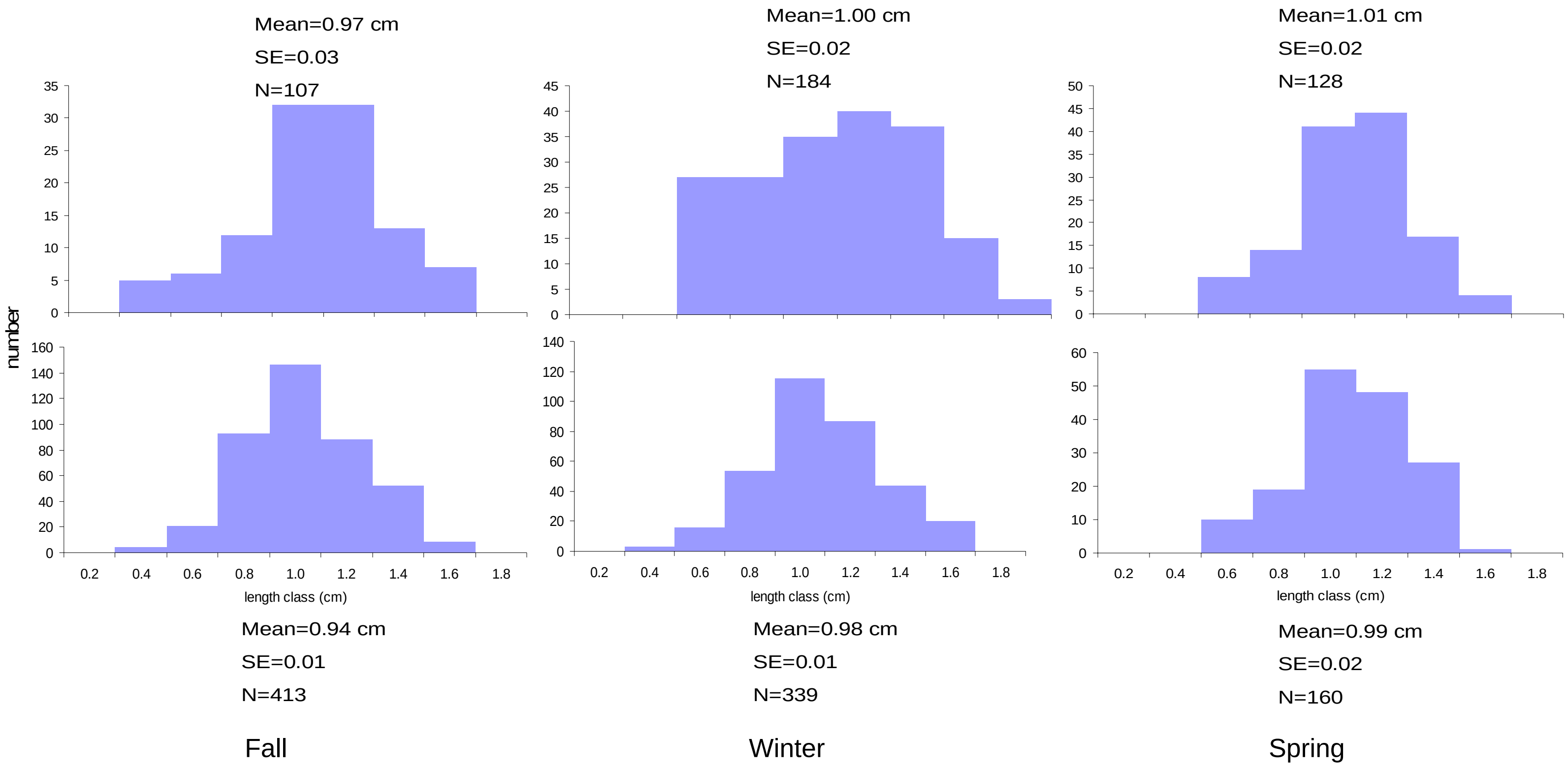

Figure 18. Length-frequency distributions of longear sunfish sampled during year one (top panel) and year two (bottom panel) in four tributaries of the lower Ohio River. The left side panels represent fall distributions, the middle panel winter, and the right panel spring.

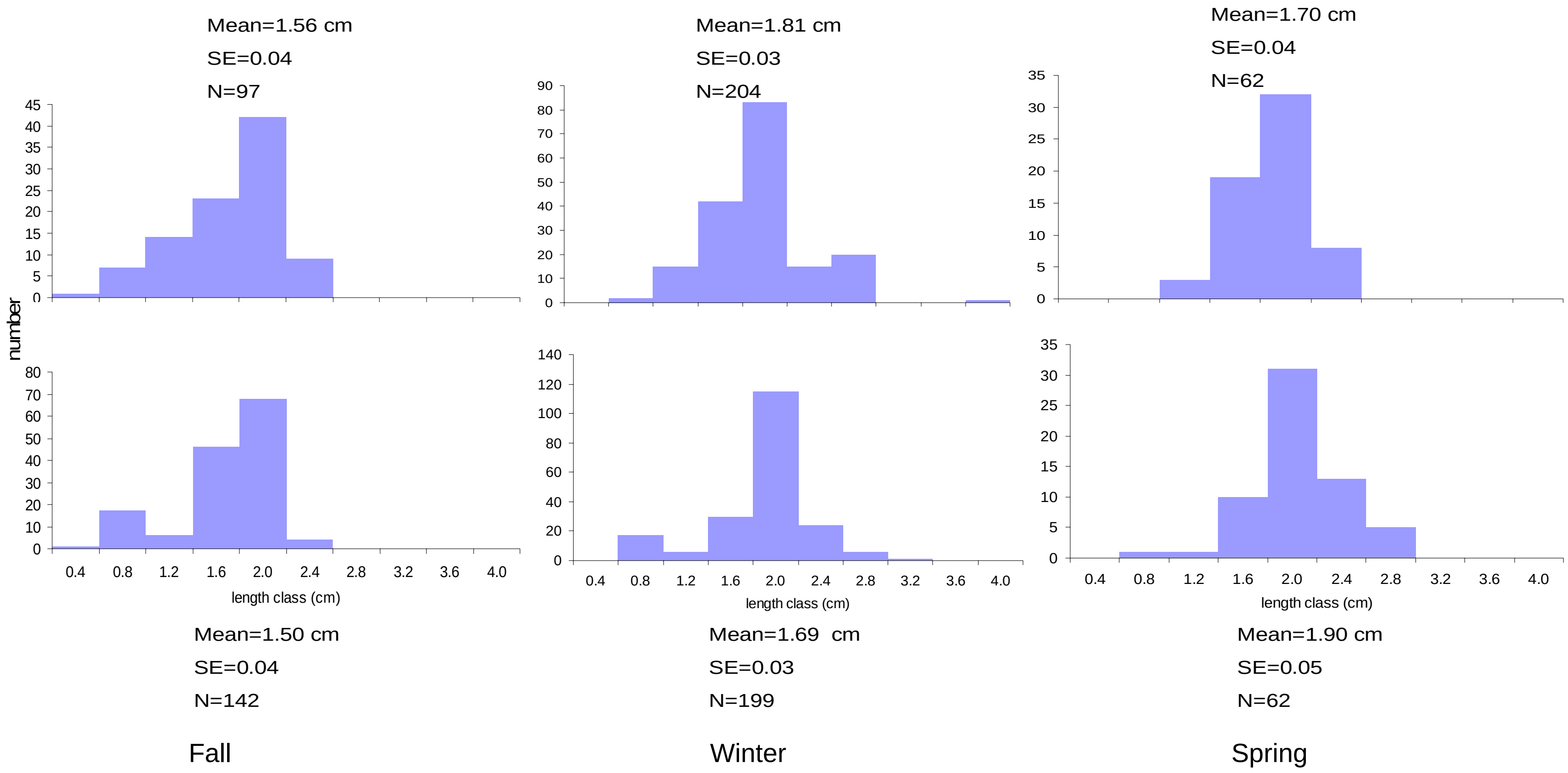

Figure 19. Length-frequency distributions of redear sunfish sampled during year one (top panel) and year two (bottom panel) in four tributaries of the lower Ohio River. The left side panels represent fall distributions, the middle panel winter, and the right panel spring.

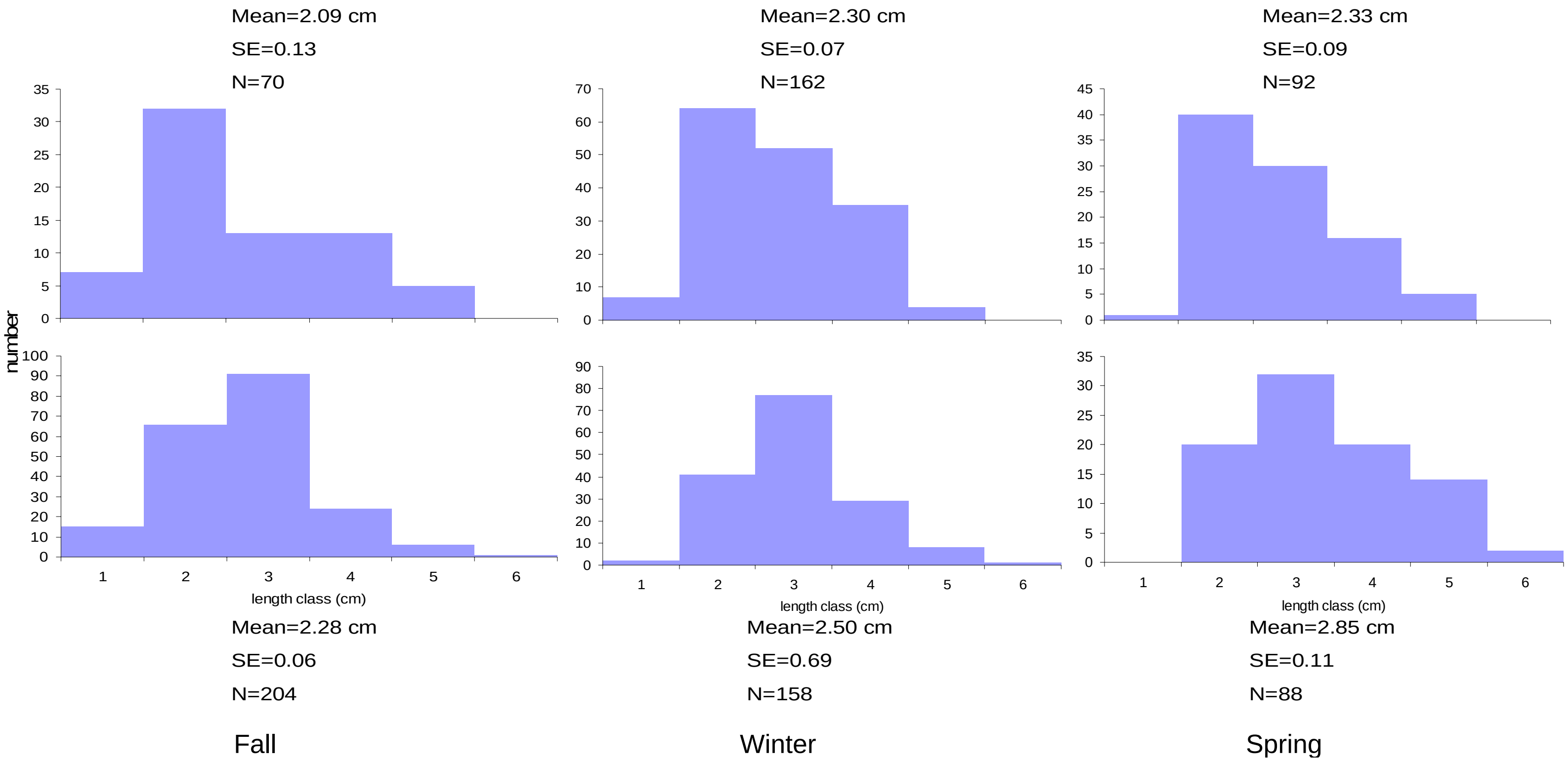

Figure 20. Length-frequency distributions of largemouth bass sampled during year one (top panel) and year two (bottom panel) in four tributaries of the lower Ohio River. The left side panels represent fall distributions, the middle panel winter, and the right panel spring.

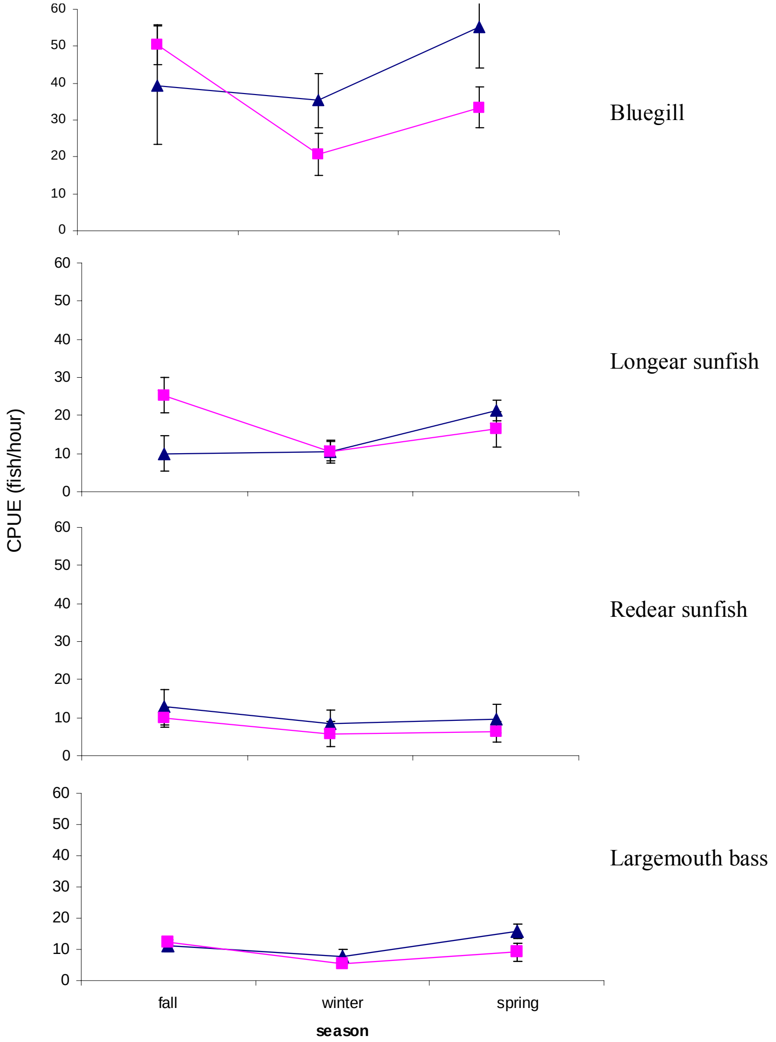

Figure 21. Catch per unit hour (CPUE) of bluegill, longear sunfish, redear sunfish, and largemouth bass sampled in year one (fall 2002-spring 2003, triangles) and year two (fall 2003-spring 2004, squares) in tributaries of the lower Ohio River. Error bars denote standard error.

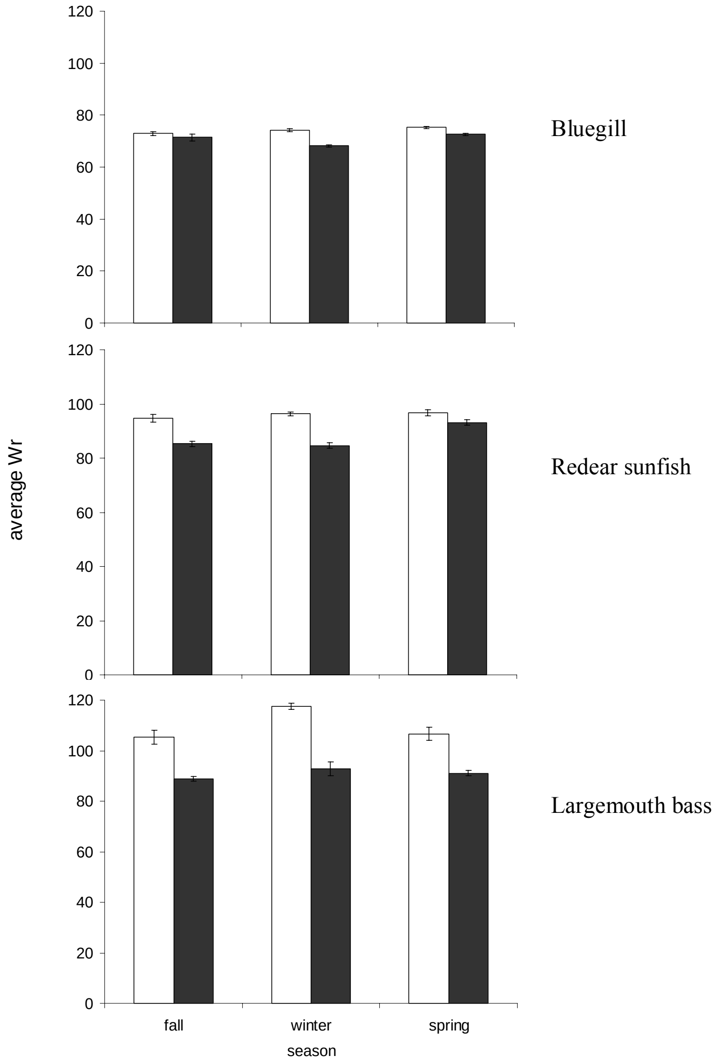

Figure 22. Relative weights (Wr) of bluegill, redear sunfish, and largemouth bass sampled year one (fall 2002-spring 2003, open bars) and year two (fall 2003-spring 2004, shaded bars) in tributaries of the lower Ohio River. Error bars denote standard error.

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