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Kurt T. Smith

Neil P. Rude

Matthew R. Noatch

Dawn R. Sechler

Quinton E. Phelps

See next page for additional authors

Authors
Kurt T. Smith, Neil P. Rude, Matthew R. Noatch, Dawn R. Sechler, Quinton E. Phelps, and Gregory Whitledge

Contrasting population characteristics of yellow bass (*Morone mississippiensis*) in two southern Illinois reservoirs

By K. T. Smith, N. P. Rude, M. R. Noatch, D. R. Sechler, Q. E. Phelps, and G. W. Whitledge

Fisheries and Illinois Aquaculture Center, Department of Zoology, Southern Illinois University, Carbondale, IL, USA

Author's Address: Gregory W. Whitledge

Fisheries and Illinois Aquaculture Center

1125 Lincoln Drive

Southern Illinois University

Carbondale, IL 62901-6511, USA

E-mail: gwhit@siu.edu

Summary

We investigated two southern Illinois reservoirs with contrasting size structures of yellow bass (*Morone mississippiensis*) to compare growth, mortality and recruitment patterns. Yellow bass were collected from Crab Orchard and Little Grassy Lakes during April-May 2009 using AC electrofishing. Total length and weight were recorded and sagittal otoliths sectioned and aged by two readers. Increments between otolith annuli were measured and the Weisberg linear growth model was used to assess age and environmental (growth year) effects on individual growth for fish from the two lakes. Von Bertalanffy growth models indicated faster growth and a greater maximum total length for yellow bass in Little Grassy Lake. However, growth of fish in Little Grassy Lake nearly ceased after age 4. The Weisberg model indicated differences in individual growth rate between the two lakes that were consistent across years (age effects were significant but growth year effects and the age-growth year interaction were not). Inter-lake differences in fish growth were present up to age 3. Recruitment was relatively stable in Crab Orchard, with year classes up to age 7 observed. Recruitment was more erratic in Little Grassy, with age 5 being the dominant year class and fish up to age 11 present. Differences in growth and recruitment patterns for yellow bass in these two lakes may be attributed to substantial inter-lake differences in turbidity, morphoedaphic index, or yellow bass density. Maximum age of yellow bass (age 11) was higher than previously reported for this species, likely due to the use of otoliths to age fish rather than scales. This study provides baseline information on age and growth, mortality, recruitment, and size structure of yellow bass that can be compared to data from future studies to elucidate factors influencing population dynamics of this species.

Introduction

Yellow bass *Morone mississippiensis* is a temperate bass species (family Moronidae) that is native to thirteen states in the Mississippi River basin from Minnesota and Wisconsin south to Louisiana and smaller river systems flowing into the Gulf of Mexico from the Mobile River, Alabama westward to the Galveston Bay drainage in Texas; this species has also been introduced to other parts of the U.S.A. (Page and Burr, 1991). The yellow bass typically inhabits pools and backwaters of larger streams and rivers, as well as reservoirs and natural lakes (Pflieger, 1997). They are sometimes considered a nuisance species and are generally less popular among anglers than the closely related white bass *Morone chrysops* because of their tendency to overpopulate and stunt, particularly in the southern portion of their range (Tomelleri and Eberle, 1990; Pflieger, 1997). Yellow bass seldom exceed a total length of 305 mm or a weight of 0.45 kg (Tomelleri and Eberle, 1990; Pflieger, 1997). However, yellow bass are listed as a game fish in at least 10 states and in some localities have routinely attained a size desirable to anglers (Carlander et al., 1953; Schoffman, 1963; Priegel, 1975; Iowa Sportsman, 2007; IDNR, 2008).

Despite their wide distribution and status as a game fish in several states, few studies on yellow bass ecology or population dynamics have been conducted. Published research has investigated diet of yellow bass and potential diet overlap with other sport fishes (Collier, 1959; Welker, 1962; Bulkley, 1970, 1976; Van Den Avyle et al., 1983; Driscoll and Miranda, 1999). The few published studies that have described age and growth of yellow bass used scales to age fish (Ricker and Lagler, 1942; Stroud, 1947; Carlander et al., 1953; Schoffman, 1963; Priegel, 1975). Scales are known to underestimate age of fish, particularly for older individuals, which can bias length-at-age estimates (DeVries and Frie, 1996). Failure of yellow bass scales to form annuli, leading to underestimation of fish age, has also been documented (Buchholz and

Carlander, 1963). The objectives of this study were to assess differences in population characteristics, including age and growth, mortality, and recruitment and condition indices, of yellow bass in two reservoirs in southern Illinois that differ in physical and chemical characteristics and fish communities and were identified in preliminary sampling as having distinct size structures of yellow bass.

Study area

Crab Orchard Lake (37° 44.0’ N, 89° 8.8’ W) and Little Grassy Lake (37° 38.7’ N, 89° 8.7’ W) are located within the Crab Orchard National Wildlife Refuge in Williamson County, Illinois. Both impoundments are in the Big Muddy River watershed and are within the native range of yellow bass. Crab Orchard Lake has a surface area of 2,819 ha, with 201 km of shoreline, a mean depth of 2.74 m, and a morphoedaphic index (MEI) of 63 (Heidinger and Brooks, 2002). Crab Orchard is a relatively turbid lake, with a mean secchi depth of 0.31 m (Heidinger and Brooks, 2002). Little Grassy Lake has a surface area of 405 ha, 45.5 km of shoreline, a mean depth of 10.7 m, and a MEI of 5. Little Grassy exhibits summer stratification and is a relatively clear lake in comparison to Crab Orchard, with a mean secchi depth of 2.26 m (Illinois EPA, 2009). The primary sport fishes in both lakes include bluegill *Lepomis macrochirus*, redear sunfish *Lepomis microlophus*, black crappie *Pomoxis nigromaculatus*, white crappie *Pomoxis annularis*, largemouth bass *Micropterus salmoides*, channel catfish *Ictalurus punctatus*, and yellow bass (Heidinger and Brooks, 2002). White bass *Morone chrysops* are present in Crab Orchard Lake, but are absent from Little Grassy Lake.

Methods

Fish collection and aging

Yellow bass were collected at Crab Orchard and Little Grassy Lakes between 15 April and 1 May 2009 using three-phase alternating current (AC) electrofishing (250 volts and 7-10 amperes) at randomly selected sites throughout each reservoir. Catch per unit effort (CPUE) was determined for each lake as the number of yellow bass captured per hour of electrofishing. Total length (mm) and weight (g) were recorded for each fish. Fish were euthanized, placed on ice and transported to the laboratory for subsequent otolith extraction for age and growth analysis.

Sagittal otoliths were removed from each fish following methods of Secor et al. (1991), placed in scintillation vials, and allowed to dry for two weeks prior to annuli determination. One otolith from each fish was sectioned in the transverse plane using a Buehler Isomet low-speed saw (Buehler Inc., Lake Bluff, Illinois), placed in plumber's putty with immersion oil, viewed under a microscope, and photographed using Scion Image 4.0.2 (Scion Corp., Frederick, Maryland) for aging and otolith increment-length measurements. Two independent readers evaluated age of each fish from otolith annuli counts to account for potential reader bias. If any disagreement occurred, concert aging using both readers was completed. If agreement in age assignments by the two readers could not be reached for a particular otolith, that otolith was not included in age and growth analysis. Otolith increment-lengths were measured along a transect from the nucleus to the edge along the long axis of the otolith section. Otolith radius (mm) and distances between the otolith nucleus and the first annulus and between pairs of adjacent annuli were measured along this transect for each fish (Weisberg, 1993).

Assessment of population characteristics

Length-frequency distributions were constructed for yellow bass collected from both lakes and were used to calculate proportional size structure (PSSq; 100 (number of fish $\geq$ stock length / number of fish $\geq$ quality length); Guy et al., 2006) for fish from each lake. Ninety-five percent confidence intervals for PSSq of yellow bass from each lake were calculated using procedures described in Gustafson (1988). Relative weight (Wr) was calculated for each fish using the equation developed for yellow bass by Bister et al. (2000);

$$\text{Log}_{10}(\text{Ws}) = -5.142 + 3.133 \ \text{Log}_{10}(\text{total length})$$

where Ws is length-specific standard weight (g). To describe somatic growth rates of yellow bass from Crab Orchard and Little Grassy Lakes, von Bertalanffy functions were developed from length-at-age data for fish from each lake using Fisheries Analysis and Simulation Tools (FAST; Slipke and Maceina, 2002):

$$Lt = L\infty \,(1 - e^{-K(t-t_0)});$$

where Lt is the length at time t, L∞ is the theoretical maximum length, K is the growth coefficient (the rate at which fish approach L∞), and t_0 is the time when length would theoretically equal 0 mm.

Total annual mortality (A) was estimated for yellow bass from each lake using weighted catch curves that were limited to those age classes considered fully recruited to our sampling gear (Van Den Avyle and Hayward, 1999; Miranda and Bettoli, 2007). Weighted regression was used in catch-curve analyses to deflate the influence of older and rarer year classes (Maceina and Pereira, 2007). Catch curves were developed using FAST version 2.0 (Slipke and Maceina, 2002). Residuals from catch curve regression analyses were used as an index of year class strength for fish from each of the two lakes (Maceina, 1997). Stronger year classes were identified with positive residuals and weaker year classes were identified with negative residuals.

The Weisberg linear growth model (Weisberg, 1993) was used to evaluate age-specific and environmental influences on individual growth of yellow bass from the two populations. The model assesses the effects of age, year and their interaction on annual growth increments measured in otoliths or other aging structures (Weisberg, 1993; Coffin et al., 2003) as:

$$\text{Annual growth increment} = \text{age effect} + \text{year effect} + \text{age} * \text{year interaction.}$$

More specifically, the age effect is the portion of the annual growth increment inherent to a particular fish at a specific age (the genetic component of growth). The year or environmental effect represents the variability in annual growth increment due to extrinsic factors that may vary among years (e.g., temperature, food availability). The age by year interaction term accounts for the possibility of differential effects of year of growth on annual growth increment for fish of different ages (e.g., if environmental conditions favor growth of young fish but not older fish in a population). The model enables comparison of growth patterns for specific, pre-defined groups of fish (e.g., fish from different sites) within a larger set of data (Weisberg, 1993; Coffin et al., 2003).

Statistical analyses

Differences in length-frequency distributions for yellow bass collected from Crab Orchard and Little Grassy Lakes were assessed using a Kolmogorov-Smirnov test. A twosample t-test was used to test for a difference in mean relative weight (Wr) of individual fish collected from the two populations. Linear regressions were used to evaluate relationships between Wr and age for fish from each lake. Instantaneous mortality rates (Z) derived from catch curves developed for yellow bass from each lake were compared using a homogeneity of slopes test (test for interaction with ANCOVA). Differences in von Bertalanffy growth curves for fish from the two lakes were evaluated using residual sum of squares (RSS) analysis (Chen et al., 1992). Residual sum of squares analysis is a technique similar to analysis of covariance (ANCOVA) that can be used for nonlinear models.

Least squares linear regression of otolith radius on total length of individual fish was used to assess whether otolith growth was proportional to fish growth in length. Weisberg's linear growth model (Weisberg, 1993) was fit to otolith increment data for fish from both sites combined and to otolith increment data for fish from individual lakes using the MIXED procedure in SAS version 9.1. All models were fit with autoregressive covariance structures to account for autocorrelation between otolith growth increments for an individual fish (Coffin et al., 2003). The initial model included data from both sites combined and included age and year as main effects, as well as an age-year interaction term. Next, a model incorporating a 'site effect' term was fit to the combined data set to assess whether subdividing the data by site was appropriate to examine potential differences in growth chronologies for yellow bass from the two lakes (Coffin et al., 2003):

Annual growth increment = age effect + year effect + site effect + site $*$ year interaction.

AICc scores were used to evaluate the relative support of the two models fit to otolith increment data from both lakes combined (Burnham and Anderson, 2002). The LSMEANS procedure in

SAS was used to assess differences in mean otolith increment between fish from the two lakes for each age of fish common to the two populations (otolith increment data were available for fish up to age 7 in each lake). Separate Weisberg growth models were then fit to otolith increment data for fish from each of the two lakes.

Results

A total of 253 yellow bass were collected from Little Grassy ($n = 73$) and Crab Orchard Lakes ($n = 180$). Estimated three-phase AC electrofishing CPUE was 72 fish/h and 24 fish/h for Crab Orchard Lake and Little Grassy Lake, respectively. Individuals collected from Crab Orchard Lake had total lengths ranging from 116-201 mm, which corresponded to ages 1-7 (Fig. 1a), whereas individuals from Little Grassy Lake had total lengths ranging from 180-261 mm, which corresponded to ages 2-11 (Fig. 1b). The proportional size structure (PSSq) index was substantially higher for yellow bass collected from Little Grassy Lake in comparison to fish sampled from Crab Orchard Lake (Table 1). Confidence intervals of PSSq estimates for fish from the two lakes did not overlap, suggesting a significant difference in yellow bass size structure between lakes. The Kolmogorov-Smirnov test comparing length frequency distributions also indicated significant differences in yellow bass size structure for the two lakes ($P < 0.0001$; Fig. 1). Mean Wr of yellow bass from Crab Orchard Lake was significantly higher than that of fish collected from Little Grassy Lake (t-test, $P < 0.0001$; Table 1). Relative weight did not change with age for fish from Crab Orchard Lake ($P = 0.57$), but Wr declined significantly with age for yellow bass collected from Little Grassy Lake ($r^2 = 0.22$; $P = 0.05$).

The youngest age class that appeared to be fully recruited to our gear differed between yellow bass collected from the two lakes. Age 1 was the first fully recruited year class in Crab Orchard Lake, whereas age 5 was the first fully recruited year class in Little Grassy Lake. Weighted regression analysis of the catch curve from Crab Orchard Lake ($r^2 = 0.86$; $P = 0.0029$) estimated a total annual mortality rate of 44.4 % and a theoretical maximum age of 8.5 years (Fig. 2a). The residual method indicated relatively consistent recruitment among years for yellow bass in Crab Orchard Lake, as evidenced by the lack of missing year classes and the relatively small residuals obtained from the catch curve regression. Age 4 fish represented the strongest year class. Catch curve analysis for fish from Little Grassy Lake ($r^2 = 0.77$; $P = 0.0085$) estimated a total annual mortality rate of 30.7% and a theoretical maximum age of 13.1 years (Fig. 2b). Fish ≤ age 4 were underrepresented in the catch from Little Grassy Lake. Relatively strong year classes were detected at ages 5, 10, and 11, while fish ages 6 and 9 represented relatively weak year classes. The homogeneity of slopes test indicated that mortality rates were significantly different ($P = 0.0442$) between yellow bass populations from the two lakes.

von Bertalanffy growth models developed for yellow bass from the two lakes indicated that the growth coefficient (k) and theoretical maximum length ($L\infty$) were higher for fish from Little Grassy lake than for fish from the Crab Orchard Lake population (Table 1). The residual sum of squares method (Chen et al., 1992) indicated that growth curves for yellow bass were significantly different between the two lakes ($P < 0.001$; Figure 3).

Otolith radius was significantly and positively correlated with yellow bass total length ($r^2 = 0.8718$; $P < 0.0001$; Fig. 4), indicating that otolith growth was proportional to fish growth in length for these populations. The Weisberg linear growth model including otolith increment data from both lakes combined (AICc = -3013) yielded a significant effect of fish age on mean otolith increment ($P < 0.0001$), indicating that growth due to age is a significant factor influencing overall fish growth. However, the growth year ($P = 0.4659$) and the age by growth year interaction ($P = 0.0753$) terms were not significant for the combined set of otolith increment data from both lakes. The model incorporating a 'site effect' term (AICc = -3069) detected significant differences in otolith increment growth between fish from the two lakes ($P = 0.0162$). For this model, the growth year by site interaction term was not significant ($P = 0.2364$), indicating that differences in otolith growth between fish from the two lakes were consistent across years. Significant differences in mean annual otolith growth increment for fish from the two lakes were present during ages 0-3 ($P < 0.05$; Fig. 5), with fish from Little Grassy Lake consistently exhibiting a higher growth rate compared to fish of the same age from Crab Orchard Lake during each of these first 4 years of life.

Due to the presence of a significant site effect in the model incorporating otolith increment data from both sites combined, separate Weisberg linear growth models were also fit to otolith increment data for fish from each of the two lakes. The model fit to otolith increment data for yellow bass from Crab Orchard Lake indicated that there was no growth year effect ($P = 0.2849$) or age by growth year interaction ($P = 0.9342$) effect on otolith growth rate, but the age effect term was highly significant ($P < 0.0001$). Similarly, the model fit to data obtained from fish from Little Grassy Lake showed that growth year ($P = 0.1974$) and the age by growth year interaction ($P = 0.0953$) terms were not significant, but there was a significant effect of age on otolith growth ($P < 0.0001$). Absence of significant growth year effects in models fit to data from each lake was consistent with the lack of a significant growth year effect for the models fit to the data set from both lakes combined.

Disscussion

Substantial differences in size and age structure and age-specific individual growth rates were exhibited by yellow bass from Little Grassy and Crab Orchard Lakes despite the close proximity of these two impoundments to one another. Yellow bass from Little Grassy Lake had a larger mean and maximum size and age and faster growth rate prior to age 4 in comparison to their counterparts from Crab Orchard Lake. The Weisberg linear growth model that included otolith increment data from both lakes combined indicated that mean annual growth rate for individual yellow bass $\leq$ age 3 differed between the two lakes, and the absence of a significant site by year interaction effect on mean annual otolith growth increment indicated that differences in age-specific annual growth rates between these two yellow bass populations were consistent across years. Additionally, the growth year effect was not significant within Weisberg linear growth models fit to the combined data set or to otolith increment data for fish from the two lakes individually, also indicating that patterns of mean annual age-specific growth rates for yellow bass within each of these two populations have been consistent across years (Weisberg, 1993). Modeling results revealed that observed differences in size structure of yellow bass in Crab Orchard and Little Grassy Lakes were not simply the result of 1-2 unusually strong or rapidly growing year classes of yellow bass in Little Grassy Lake. Rather, differences in age-specific individual growth and size and age structure between the two lakes appear to persist across years. Thus, the factors that have resulted in different size structures and age-specific growth rates for yellow bass in these two lakes were not inter-annually variable, and must be attributed to genetic differences between these two yellow bass populations or environmental factors that are consistently different between these two lakes among years (Weisberg, 1993).

There are several plausible mechanisms that may explain the consistently higher mean annual growth rates of yellow bass ≤ age 3 in Little Grassy Lake in comparison to conspecifics from Crab Orchard Lake. Inter-lake differences in growth rates for fish ≤ age 3 may be density dependent. Electrofishing CPUE for yellow bass was threefold higher in Crab Orchard Lake than in Little Grassy Lake. While our electrofishing efficiency may have differed in the two lakes, the relatively large difference in CPUE between lakes suggests that relative abundance of yellow bass was higher in Crab Orchard Lake. Consistently higher density of young yellow bass in Crab Orchard Lake across years, as suggested by catch curves that showed more consistent recruitment in this population in comparison to Little Grassy Lake, may explain the consistently lower mean annual growth rates of yellow bass ≤ age 3 in Crab Orchard Lake. Density has routinely been suggested as an important factor limiting individual growth of yellow bass (Carlander et al., 1953; Bulkley, 1970; Ross, 2001); stunting has also been reported as common in yellow bass populations (Pflieger, 1997). Young yellow bass are primarily zooplanktivorous (Bulkley, 1970; Van Den Avyle et al., 1983), while adults consume both zooplankton and fish, including young yellow bass (Bulkley, 1970). Diet overlap among life stages has been suggested as a mechanism for potential competition within yellow bass populations (Bulkley, 1970). Whether persistent differences in zooplankton community structure or density occur between Crab Orchard and Little Grassy lakes is unknown, but, if present, could also potentially underlie observed differences in yellow bass growth in the two lakes. White bass are present in Crab Orchard Lake but are absent from Little Grassy Lake; competition between young yellow bass and white bass or other planktivores may also potentially explain the slower growth rates of yellow bass in Crab Orchard Lake. Diet overlap between yellow bass and other planktivorous fishes, including young white bass, has been documented in other lakes (Stroud, 1947; Bulkley et al., 1976). Persistently higher turbidity in Crab Orchard Lake compared to Little Grassy Lake may also underlie the consistently lower mean annual growth rates of yellow bass ≤ age 3 in Crab Orchard Lake. Higher turbidity can reduce foraging efficiency and growth (Gardner, 1981; Wolfe et al., 2009) and decrease predation risk (Shoup and Wahl, 2009). Thus, higher turbidity may have been at least partially responsible for both the slower growth rates and more consistent recruitment (due to decreased predation risk) of yellow bass in Crab Orchard Lake relative to Little Grassy Lake. Additional research is suggested to elucidate mechanisms underlying differences in yellow bass growth between the two lakes in this study, as well as differences in yellow bass growth and size structure that have been observed among other lakes and rivers (Ricker and Lagler, 1942; Stroud, 1947; Carlander et al., 1953; Schoffman, 1963; Priegal, 1975) in which this species occurs.

Yellow bass ≥ age 4 in Little Grassy Lake exhibited poor growth and declining Wr with age, and the presence of fish of multiple ages within the 240-250 mm total length range suggests that a growth "bottleneck" is present for adult yellow bass in this lake. Poor growth of adult yellow bass in Little Grassy Lake is not likely due to excessively warm summer temperatures, as water temperatures in this lake rarely exceed 34° C (Whitledge, unpublished data), the reported upper thermal limit for growth of this species (Welch and Lindell, 1992). Adult yellow bass are known to consume both zooplankton and small fish (Bulkley, 1970). Examination of stomach contents from a subset of adult yellow bass collected from Little Grassy Lake revealed that zooplankton were the primary component of their diet (Q. Phelps, unpublished data), suggesting that growth of age 4 and older yellow bass may be limited by reliance on zooplankton rather than fish as their primary prey. Size "bottlenecks" and food limitation for adult fish due to absence of normal ontogenetic diet shifts to larger prey items have been documented in other fish species

(Hayward and Margraf, 1987). Further study is suggested to identify factors limiting growth of adult yellow bass in Little Grassy Lake.

Annual mortality rates differed between yellow bass collected from Crab Orchard and Little Grassy Lakes, although differences in the minimum age of fish that were apparently fully recruited to our sampling gear in the two lakes limits the comparability of annual mortality rate estimates for these two populations. We are unaware of any published mortality rates for yellow bass from other populations for comparison to our mortality estimates. Apparently missing year classes and less consistent recruitment for yellow bass in Little Grassy Lake compared to Crab Orchard Lake suggests that predation on age-0 yellow bass may be relatively high in Little Grassy Lake; predation was cited as an important factor regulating year class strength of yellow bass in Clear Lake, Iowa (Carlander et al., 1953). Increased predation risk (including cannibalism; Bulkley, 1970) for age-0 yellow bass in Little Grassy Lake may be associated with low turbidity and greater predator efficiency (Shoup and Wahl, 2009). Further studies should assess the importance of turbidity in regulating recruitment and year class strength in yellow bass populations. Significantly higher Wr for yellow bass collected from Crab Orchard Lake was somewhat surprising given that higher relative weight values are typically associated with faster growth rates (Guy and Willis, 1995). However, the significantly different size structure exhibited by yellow bass populations from Crab Orchard and Little Grassy Lakes likely biased comparison of mean Wr values for fish from the two lakes (Brenden et al., 2003).

Yellow bass as old as age 11 were collected from Little Grassy Lake, which is two years older than the previously oldest yellow bass documented (Buchholz and Carlander, 1963) and older than the typical maximum age of 6-7 years reported for this species (Pflieger, 1997). The higher maximum age for yellow bass in this study compared to maximum ages reported in the literature for this species is likely due to differences in structures used to age yellow bass. Published studies of yellow bass age and growth used scales to age fish (Ricker and Lagler, 1942; Stroud, 1947; Carlander et al., 1953; Buchholz and Carlander, 1963; Schoffman, 1963; Priegel, 1975), whereas we aged fish using otoliths. Scales are known to underestimate age of fish, particularly for older individuals (DeVries and Frie, 1996). Failure of yellow bass scales to form annuli, leading to underestimation of fish age, has also been documented (Buchholz and Carlander, 1963). Our results indicated that otolith growth was strongly related to fish growth in length, and we recommend the use of otoliths for future studies of yellow bass age and growth. Growth rates of yellow bass sampled from Little Grassy Lake were relatively high compared to published length-at-age data for this species, whereas growth rates of fish collected from Crab Orchard Lake were lower than growth rates reported for other yellow bass populations (Ricker and Lagler, 1942; Stroud, 1947; Carlander et al., 1953; Buchholz and Carlander, 1963; Schoffman, 1963; Priegel, 1975). This study provides baseline information on age and growth, mortality, recruitment, and size structure of yellow bass that can be compared to data from future studies to elucidate factors influencing population dynamics of this species. In particular, we recommend additional studies to assess the roles of density, ontogenetic diet shifts, and turbidity in regulating growth and recruitment patterns in yellow bass.

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Table 1. Estimates of proportional size structure (PSSq and 95% confidence limits), annual mortality rate, theoretical maximum age, mean relative weight (Wr ± SE), and von Bertalanffy growth model perameters (theoretical maximum length ($L\infty$) and the growth coefficient (k)) for yellow bass collected from Crab Orchard and Little Grassy Lakes. Parameter estimates were obtained using FAST version 2.0 (Slipke and Maciena 2002).

Parameter	Crab Orchard Lake	Little Grassy Lake
PSSq	13 ± 1	100 ± 1
Annual mortality (%)	44.4	30.7
Theoretical maximum age (yrs.)	8.5	13.1
Wr	90.0 ± 0.43	85.7 ± 0.50
$L\infty$ (mm)	209.0	253.3
k	0.367	0.817

Figure Captions

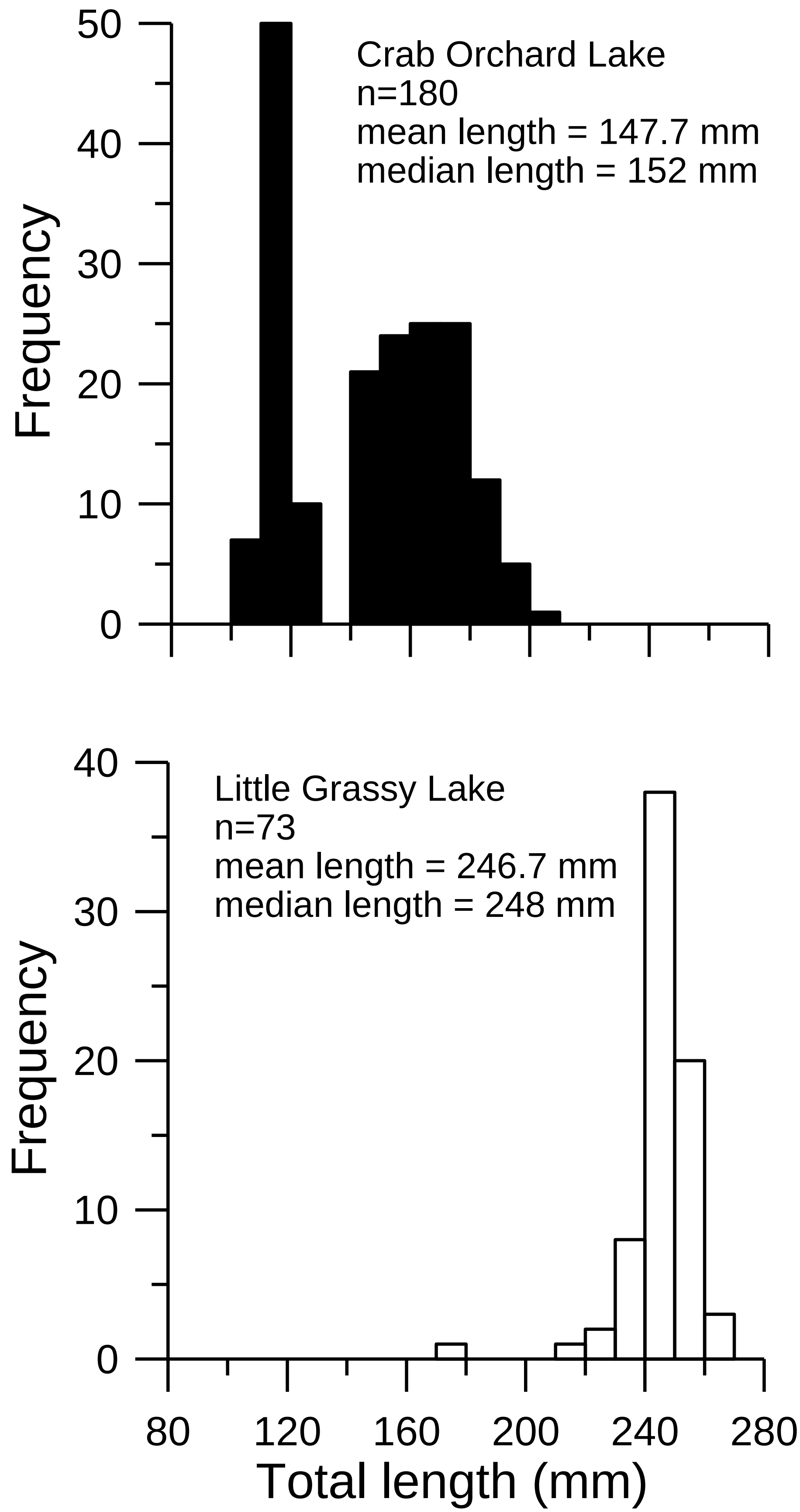
Fig. 1. Length-frequency distributions for yellow bass (*Morone mississippiensis*) collected during April-May 2009 from Crab Orchard Lake and Little Grassy Lake, Illinois, USA.

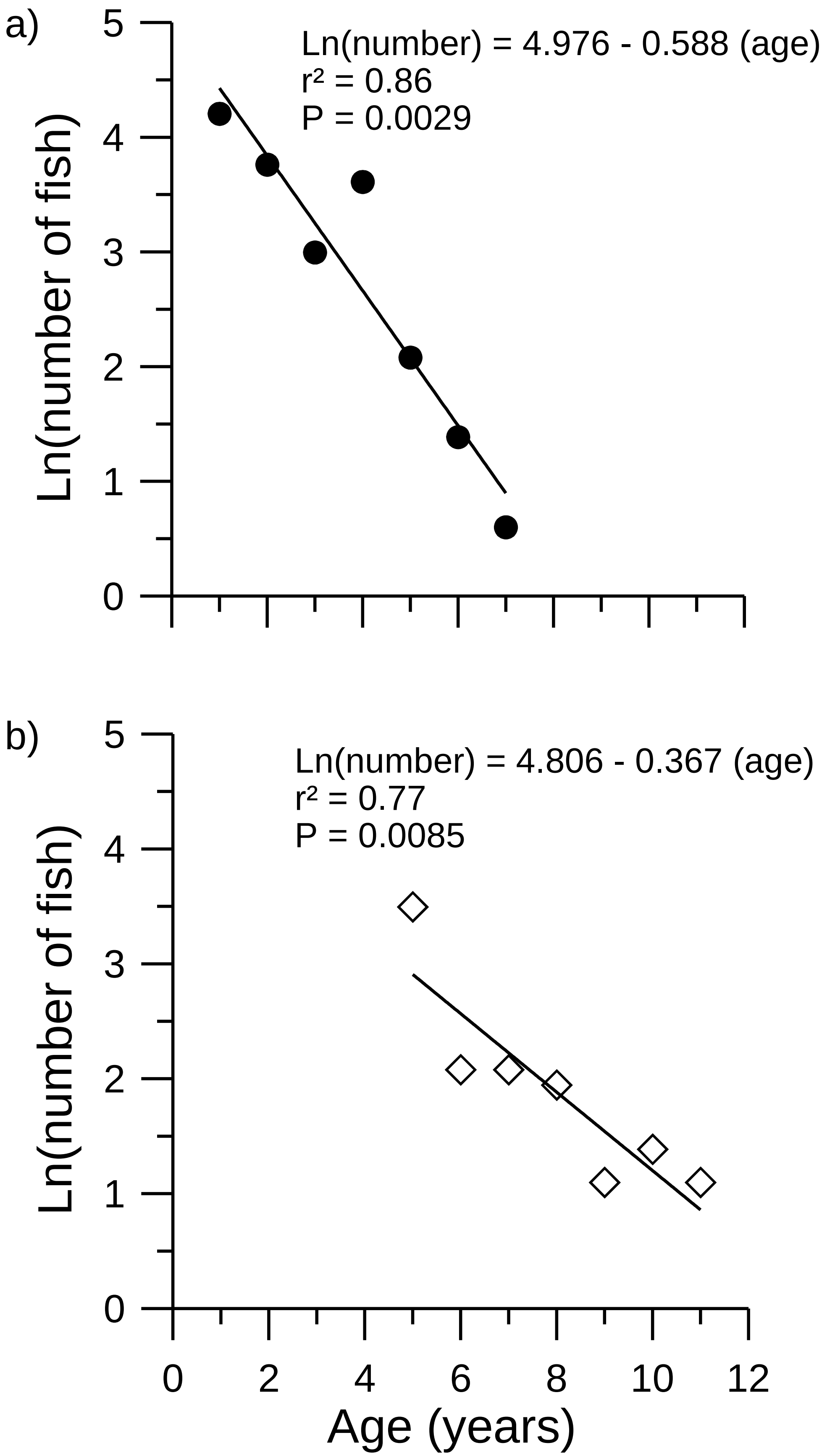
Fig. 2. Ln (number of fish collected) plotted as a function of age (catch curve analysis) for yellow bass (*Morone mississippiensis*) collected during April-May 2009 from (a) Crab Orchard Lake and (b) Little Grassy Lake, Illinois, USA. n=5-67 fish per data point.

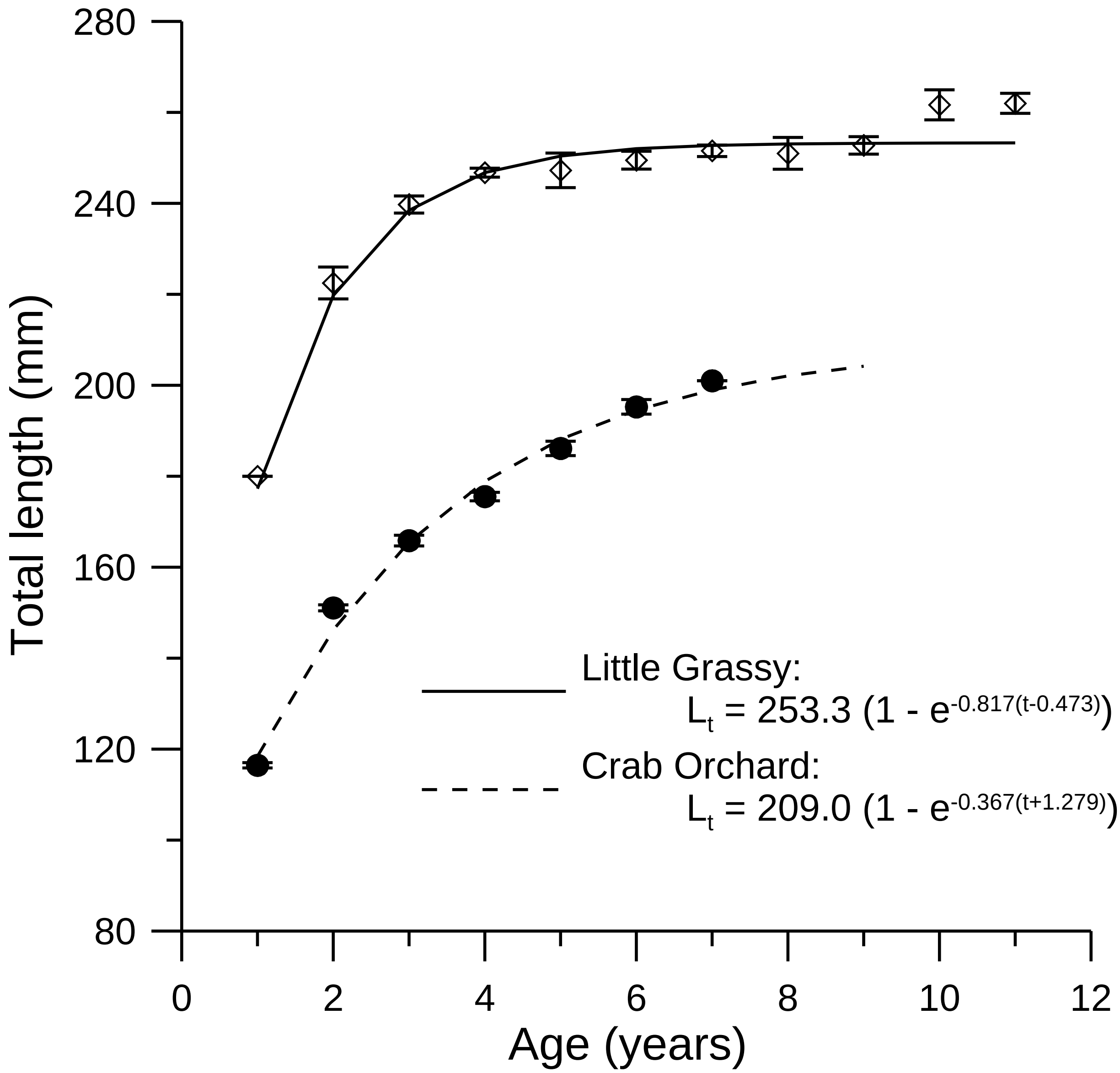
Fig. 3. von Bertalanffy growth curves and mean lengths at age ± SE for yellow bass (*Morone mississippiensis*) collected during April-May 2009 from Crab Orchard Lake (filled circles; n=180 fish) and Little Grassy Lake (open diamonds; n=73 fish), Illinois, USA. Equations represent von Bertalanffy growth models for fish from each lake.

Fig. 4. Relationship between otolith radius (mm) and total length of yellow bass (*Morone mississippiensis*) (n=253 fish) collected during April-May 2009 from Little Grassy and Crab Orchard Lakes, Illinois, USA.

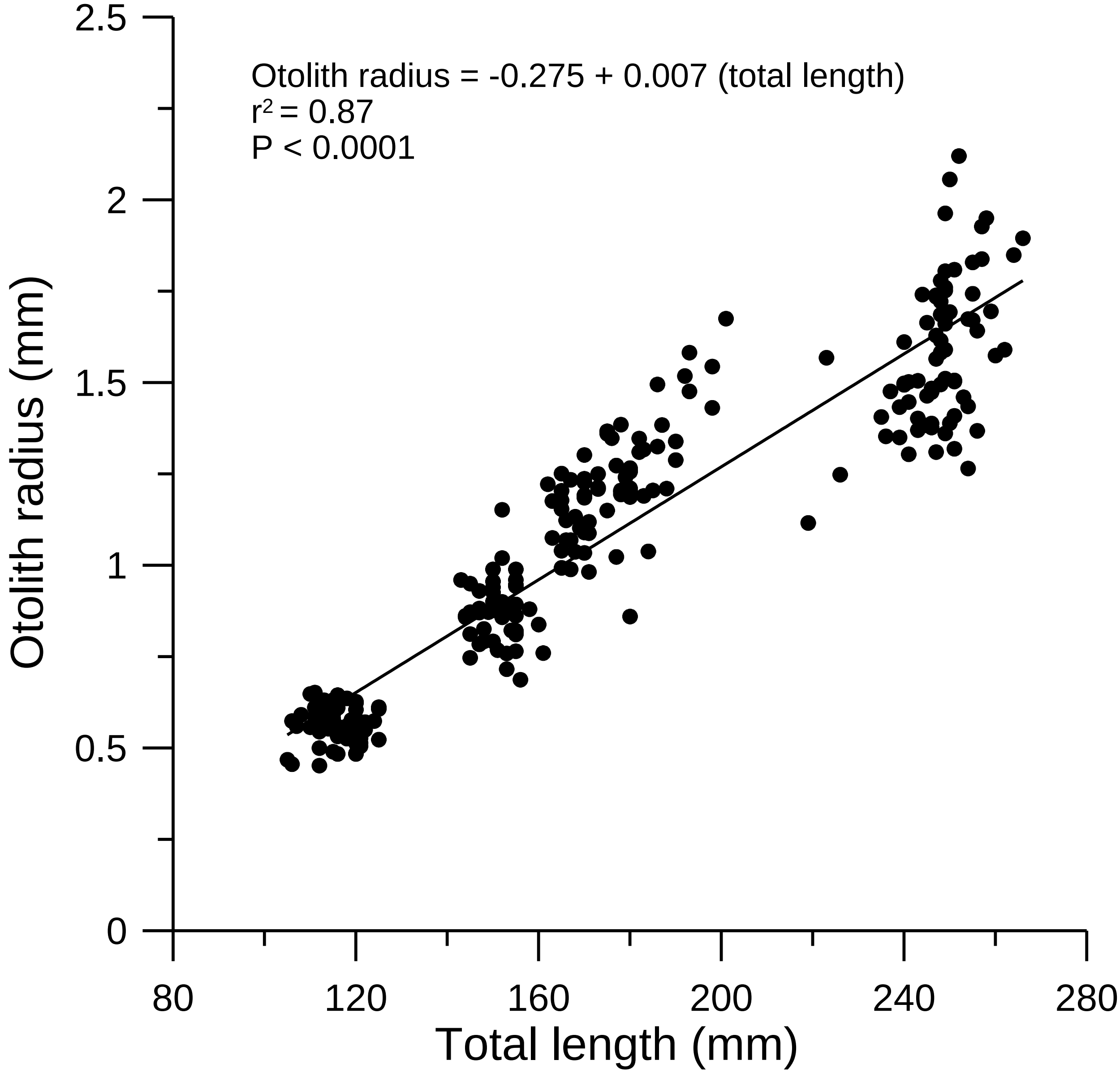
Fig. 5. Mean ± SE annual otolith growth increment as a function of fish age for yellow bass (*Morone mississippiensis*) collected from Crab Orchard Lake (n=180 fish) and Little Grassy Lake (n=73 fish), Illinois, USA. Mean otolith increment values for each age were calculated from individuals representing multiple year classes. Asterisks indicate ages in which mean annual otolith growth increment differed significantly between fish from the two lakes ($p<0.05$).

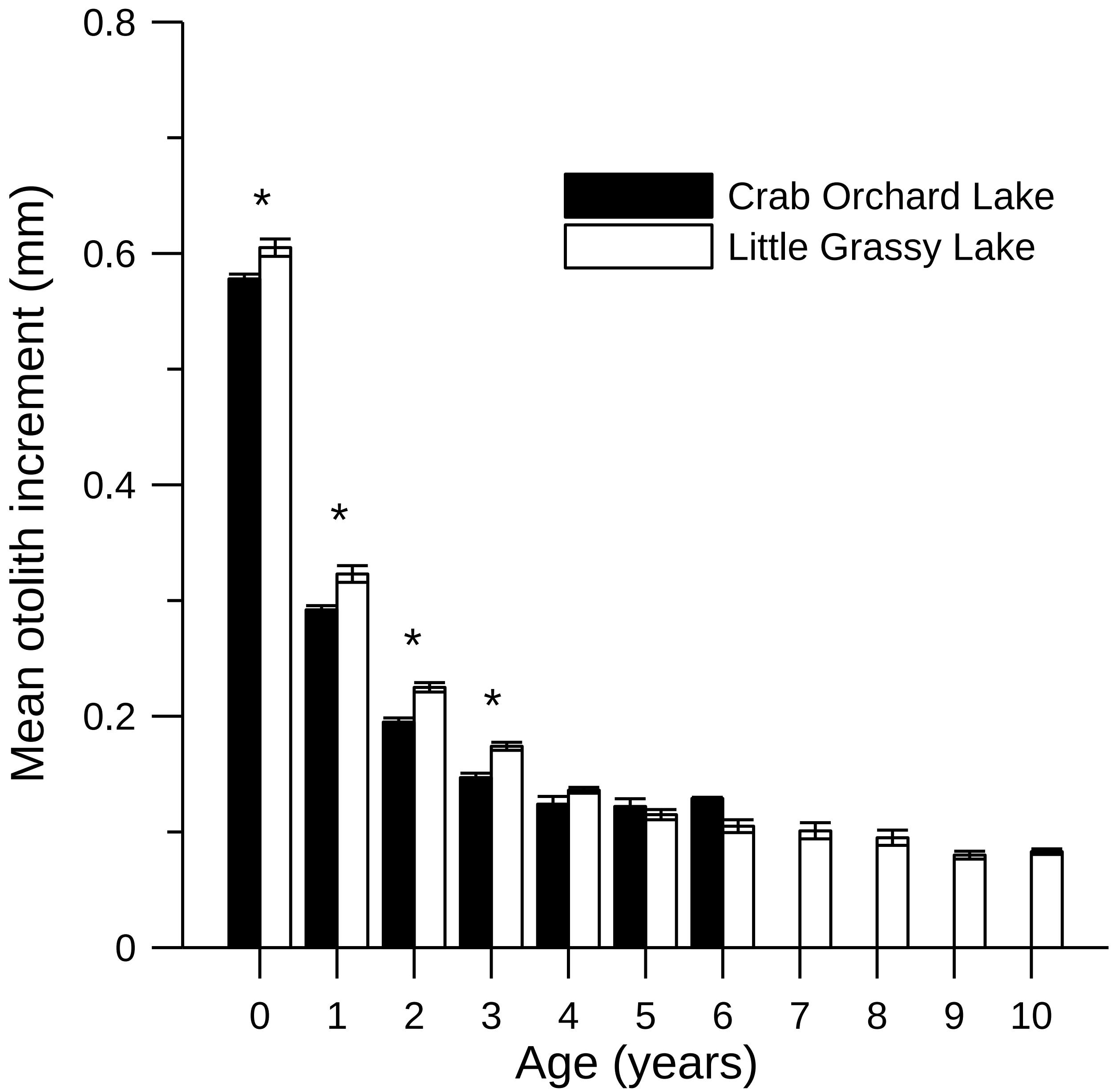

Crab Orchard Lake
n=180
mean length = 147.7 mm
median length = 152 mm
Frequency
50
40
30
20
10
0
Little Grassy Lake
n=73
mean length = 246.7 mm
median length = 248 mm
Frequency
40
30
20
10
0
80
120
160
200
240
280
Total length (mm)


a)
Ln(number of fish)
Ln(number) = 4.976 - 0.588 (age)
r² = 0.86
P = 0.0029
0
1
2
3
4
5
b)
Ln(number of fish)
Ln(number) = 4.806 - 0.367 (age)
r² = 0.77
P = 0.0085
0
1
2
3
4
5
0
2
4
6
8
10
12
Age (years)



Total length (mm)
280
240
200
160
120
80
0
2
4
6
8
10
12
Age (years)
Little Grassy:
$L_t = 253.3\,(1 - e^{-0.817(t-0.473)})$
Crab Orchard:
$L_t = 209.0\,(1 - e^{-0.367(t+1.279)})$


Otolith radius = -0.275 + 0.007 (total length)
$r^2 = 0.87$
$P < 0.0001$
Otolith radius (mm)
2.5
2
1.5
1
0.5
0
80
120
160
200
240
280
Total length (mm)



Crab Orchard Lake
Little Grassy Lake
Mean otolith increment (mm)
0.8
0.6
0.4
0.2
0
*
*
*
*
0
1
2
3
4
5
6
7
8
9
10
Age (years)