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# Assessment Of Aging Structures And Recruitment Of Walleye Sander Vitreus In Cedar Bluff Reservoir

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ASSESSMENT OF AGING STRUCTURES AND RECRUITMENT OF WALLEYE

*SANDER VITREUS* IN CEDAR BLUFF RESERVOIR

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ABSTRACT

Most walleye *Sander vitreus* populations in Kansas are supplemented or sustained with stocking. In 2006, gamete collection for hatchery production was initiated at Cedar Bluff Reservoir because the walleye population has a high abundance of potential brood fish and has been sustained by natural reproduction since 2001. However, no quantitative index has been developed to assess walleye recruitment in this fishery. Accordingly, from July through November 2010, I evaluated catch-per-unit-effort (overnight sets) of age-0 walleye in 19 and 25-mm mesh gill nets biweekly and at random and standard sites. There was not a significant difference in catch-per-unit-effort between site types ($t = -0.04$, $df = 142$, $P = 0.97$) or mesh sizes ($n = 144$, $U = 2{,}154$, $P = 0.07$).

Recruitment also can be evaluated with a one-time age structure sample. Therefore, the precision among age estimates was evaluated through taking a sample of 95 walleye: (1) by comparing age estimates between two readers, and (2) the consistency of estimates from one reader among hard structures, by evaluating age bias plots, age frequency tables, and coefficients of variation derived from scales, sagittal otoliths, and sectioned sagittal otoliths. Best fit regression slopes from age bias plots derived with otoliths and sectioned otoliths were not significantly different from a slope of one ($t = 1.39$, $df = 2$, $P < 0.01$; $t = 0.44$, $df = 2$, $P < 0.01$) suggesting strong agreement among estimates. However, the best fit regression slope derived by using scales was significantly different from one ($t = -3.42$, $df = 2$, $P < 0.01$), suggesting scales did not provide adequate precision for additional recruitment analyses.

Age structure data were utilized, ages estimated from 210 fish (5 to 6 individuals in each 10 mm length group) and then extrapolated to a sample of un-aged fish (n = 928) based on size classes, to evaluate recruitment variability with the Recruitment Variability Index. The Recruitment Variability Index estimate was 0.69 and similar to estimates from over a decade earlier suggesting consistent recruitment in this population. An age structure was also used and historical catch-per-unit-effort of age-0 walleye to evaluate their utility in predicting year-class strength. Historical catch-per-unit-effort of age-0 walleye explained 72% (adjusted $r^2$ value) of the variation in the current estimated size of the corresponding year-classes ($F = 29.29$, $df = 11$, $P < 0.01$). Natural reproduction appears to be sustaining both walleye population and gamete harvest at Cedar Bluff Reservoir.

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# PREFACE

This thesis is written in the style of North American Journal of Fisheries Management.

## INTRODUCTION

Recruitment is a major factor that influences the size and structure of fish populations (Gulland 1982; Allen and Pine 2000; Quist 2007). Annual variability in recruitment is common, (Sissenwine et al. 1988) especially in walleye *Sander vitreus* (Smith and Krefting 1954; Smith and Pycha 1960; Forney 1976; Kallemeyn 1987; Hansen et al. 1991; Quist et al. 2003a; Quist et al. 2010). Accordingly, walleye recruitment has been the impetus for numerous research projects (e.g., Busch et al. 1975; Willis and Stephen 1987; Madenjian et al. 1996; Hansen et al. 1998; Quist et al. 2003a). Factors that have been determined to affect walleye recruitment and early life history include: the rate of warming in spring (Busch et al. 1975; Madenjian et al. 1996), reservoir discharge (Willis and Stephen 1987), spawner density and gizzard shad *Dorosoma cepedianum* density (Madenjian et al. 1996), intraspecific competition (Hansen et al. 1998; Quist et al. 2003a), temperature variation in May of the year of hatching, predation by and competition with yellow perch *Perca flavescens*, (Hansen et al. 1998), air temperature, water elevation in the spring, precipitation, wind speed, abundance of white crappie *Pomoxis annularis*, white bass *Morone chrysops*, and gizzard shad (Quist et al. 2003a). Many of these factors cannot be altered by fisheries managers (Fielder 1992). However, stocking is a tool commonly used to mitigate for low recruitment (Forney 1976; Laarman 1978; Mosher 1987; Ellison and Franzin 1992; Fielder 1992; Fayram et al. 2005) and influence angler perceptions (Fayram et al. 2006); therefore, many state agencies devote resources to this management practice.

In Kansas, walleye hatchery production and stocking rely on gamete harvest from naturalized populations. Because the walleye is a valuable portion of the angling experience in Kansas (Burlingame 1998; KDWPT 2008), reservoirs used for gamete harvest must maintain adult populations to insure hatchery production (Quist et al. 2010) and the recreational fishery. The walleye population of Cedar Bluff Reservoir has been used for gamete harvest since 2006. Over the last decade, natural recruitment at Cedar Bluff Reservoir has been highly variable (Kansas Department of Wildlife Parks and Tourism, Cedar Bluff Reservoir Progress and Management Reports, 1998-2010) and a concern to Kansas Department of Wildlife Parks and Tourism (KDWPT) fisheries managers (D. Spalsbury, KDWPT District Fisheries Biologist, personal communication). Accordingly, reliable recruitment data are necessary for efficient management of this valuable walleye population.

An evaluation of recruitment is best obtained by using an index for estimating year-class abundance (Isermann et al. 2002; Quist 2007). An index for estimating year-class abundance can be developed from long-term data and derived by following an initial year-class or recruitment-class over time (Willis 1987; Isermann et al. 2002; Quist 2007). Age-0 walleye abundance in late September is a common index of future abundance of the year-class or year-class strength in the fishery (Kempinger and Churchill 1972; Serns 1982; Willis 1987; Quist 2007). In Kansas, standard state protocol (SSP) sampling for walleye consists of one to several complements of overnight sets of gill nets; the number of sets is influenced by lake size (D. Spalsbury, KDWPT District Fisheries Biologist, personal communication). A complement contained four separate gill nets, each 30.5-m X 1.8-m, with mesh (bar measure) of 25, 38, 64, and 102-mm, respectively. Catch-per-unit-effort (CPUE) of age-0 walleye in the 25-mm mesh gill net is used as an index of age-0 abundance (Willis 1987; Quist 2007), but there is uncertainty in the consistency of recruitment to gear and whether enough units were deployed to detect significant changes overtime. In 2010, KDWPT changed SSPs to standards after Miranda and Boxrucker (2009), which consist of eight core mesh sizes, including panels with 19, 25, 32, 38, 44, 51, 57, and 64-mm bar mesh. Each panel is 3.1-m X 1.8-m.

In addition, fall night-time electrofishing is widely used gear to sample age-0 walleye. In Wisconsin, Serns (1982 and 1983) reported a high correlation between fall night-time electrofishing catch-per-effort and fingerling and yearling density, and Fayram et al. (2005) used fall electrofishing to evaluate stocking rates. Lucchesi (2002) used night electrofishing in September to evaluate the contribution of stocked walleye fry and fingerlings to year-class strength in South Dakota waters. In Kansas, Mosher (1987) reported electrofishing for age-0 walleye at Lyon State Fishing Lake provided a useful recruitment index of age-0 walleye too small to be sampled with traditional gill nets. Accordingly, spatial and temporal evaluation of gears used to index age-0 abundance would be valuable for making management decisions at Cedar Bluff Reservoir. Furthermore, it might provide information pertinent to the management of walleye at other reservoirs.

Due to the paucity of long-term, standardized data sets capable of detecting significant changes in recruitment, a number of techniques using age structure information have been developed to estimate recruitment variability (e. g. Guy and Willis

1995; Maceina 1997; Isermann et al. 2002). Age structure data are used in a variety of population analyses including: establishing growth rate, recruitment, and year-class strength, ranking it among the most influential of biological variables (Campana 2001). To avoid excessive mortality, scales typically have been used by KDWPT to estimate age of individual walleye and most other fish species valued by anglers. However, sagittal otoliths are reported to be a more accurate (Erickson 1983) and precise (Campbell and Babaluk 1979; Marwitz and Hubert 1995; Kocovsky and Carline 2000; Isermann et al. 2003) structure to age walleye. In Kansas, precision and correlation of age estimations made with sagittal otoliths and scales have not been formerly evaluated. High quality age estimations are essential to age structure analyses (Maceina et al. 2007). Walleye longevity varies with latitude (Colby et al. 1979; Quist et al. 2003b); therefore, an evaluation of the precision in age estimations among hard structures in Kansas is warranted.

The Recruitment Variability Index (RVI) was developed by Guy and Willis (1995), to estimate recruitment variability using age structure information.

The RVI is estimated as:

$$RVI = [\ S_N / (\ N_M + N_P\ )] - (\ N_M / N_P\ ),$$

where $S_N$ is the sum of the cumulative, relative frequencies across age-classes in the sample, $N_M$ is the number of year-classes missing within the sample, and $N_P$ is the number of year-classes in the sample. Recruitment variability index varies from 1 to -1, and values close to 1 represent stable recruitment. Recruitment variability index estimates are reduced with increasing number of missing year-classes. Assumptions for valid estimates of RVI include: only fish fully recruited to the sampling gear can be used, samples need to represent more than three year-classes, $N_P > N_M$, catch-at-age is a valid representation of year class strength, and year-classes older than those represented in the sample do not occur. Recruitment Variation Index is a useful tool to evaluate recruitment variability when a long-term data set is not available (Quist 2007).

The purpose of this study was to improve the understanding of walleye recruitment at Cedar Bluff Reservoir by addressing the following objectives: (1) establish the framework to develop an index of age-0 abundance by evaluating CPUE of age-0 walleye, spatially and temporally, in a variety of gears; (2) determine the structure and preparation method that produces the most precise age estimations by comparing precision in age estimations among structures and readers; (3) estimate recruitment variability by using the RVI; and (4) determine relevance of historical data by evaluating the relationship between fall CPUE of age-0 walleye in the 25-mm mesh gill nets on standard sites and the relative frequency of the corresponding year-classes from the estimated age structure.

# METHODS

*Study site*—Cedar Bluff Reservoir is situated on the Smoky-Hill River, in northwest Kansas. The watershed was approximately 6,928.23 $km^2$ (Kansas Department of Health and Environment, http://www. kdheks. gov/tmdl/ss/CedarBluffE. pdf , accessed 16 January 2012) and the landcover types within the watershed were almost exclusively rangeland and row crops (Data Access and Support Center, Kansas land cover). Cedar Bluff Reservoir had a surface area of 2,678.21 ha, a mean depth of 7.8 m and was marginally eutrophic at conservation pool. The reservoir ranged from 3.7 to 5.04 m below conservation pool during the study period (U.S. Bureau of Reclamation, (http://www.usbr.gov/gp-bin/arcweb_cbks.pl, accessed 16 January 2012). Temperature and dissolved oxygen concentrations rarely stratify at Cedar Bluff Reservoir.

*Age-0 abundance*—Site type, gear, and time of sampling for young cohorts were evaluated from July through November, 2010. Gill nets with 19 and 25-mm (bar measure) mesh, each 30.5-m X 1.8-m, were deployed biweekly in overnight sets on four standard sites and four sites randomly chosen. Standard sites were sampled with 25-mm mesh gill nets from 1998 to present. Random sample locations were selected from a map of the reservoir surface layered by a grid of 333-m X 333-m quadrats . The map was produced by the Kansas Biological Survey in ArcGIS 10 (M. Houts , Kansas Biological Survey, personal communication) and provided by KDWPT (D. Spalsbury, KDWPT District Fisheries Biologist, personal communication). A random number generator was used to select four quadrats in each sample period and a gill net was deployed within each quadrat in a location that met the specifications listed in Miranda and Boxrucker (2009).

These specifications include: nets must be deployed along the bottom, perpendicular to the bank, normally in depths of 3-8 m, and they must not be set on steep slopes (e.g., >45°) or over drop-offs that can compress and close the meshes (Miranda and Boxrucker 2009). Grid sections devoid of habitats listed in Miranda and Boxrucker (2009) were eliminated.

Nighttime electrofishing also was evaluated as a potential sampling method. There was no KDWPT standard electrofishing protocol for walleye; however, based on previous experience and a literature review (Forney 1976; Colby et al. 1979). There were three sample periods (Reynolds 1983); one in August, one in early September, and one in late September. Electrofishing samples were collected at four standard sites and four random sites each sample period. Random electrofishing sites were selected with the same procedure as the random gill net sites. Samples were collected after sunset. Each site was fished for 600 seconds of electrified-field-time with a single netter, which is similar to the KDWPT standard protocol for sampling largemouth bass *Micropterus salmoides*. The electrofishing boat was a 1996 Smith-Root SR16S (16' long) [Smith Root GPP 5. 0 control box] configured for two anode booms. The high output DC setting and an output pulse frequency of 60 pps allowed an amperage range from 12 to 14 amps.

Ten walleye per 10 mm length-group from fall 2010 gill net samples were aged by one reader using the whole-view otolith method. Only fish estimated as age-0, or determined to be age-0 by length at the time of capture, were included in CPUE estimates. A student's t-test was used to compare CPUE between site types and a Mann-

Whitney U test was used to compare CPUE between gill net mesh sizes. Due to small sample size, no statistical analysis was performed on the electrofishing samples.

*Aging structures*—Age estimations among hard structures (otoliths and scales) and preparations were assessed to determine the most precise aging method. In spring 2010, during the annual harvest of walleye gametes by KDWPT from Cedar Bluff Reservoir, walleye were collected with 25-mm mesh trap-nets, and 76-mm mesh gill nets. Each gill net measured 91. 44-m X 1. 83-m. Paired samples of scales and sagittal otoliths were removed systematically in consecutive 20 mm length-groups in an attempt to collect three individuals of each sex per group. Scales were removed between the lateral line and anterior portion of the dorsal fin and placed in coin envelopes labeled with fish length, sex, and date of capture (Devries and Frie 1996). In the lab, scales were cleaned with water to remove fish mucus and dirt. Several scales from each fish were pressed with an Ann Arbor roller press onto acetate impression slides (25-mm X 75-mm) to provide a permanent impression of scale annuli. Scale impressions were randomized, assigned a code number, and separated from length measurements to minimize reader bias (Campana 2001). Impressions were photographed by using an Olympus szx16 microscope and Altra 20 camera. Two readers independently estimated age from the same photograph of one scale per fish.

Sagittal otoliths were removed from fish and placed in a vial with the same code as the corresponding fish scale impression (Devries and Frie 1996). A mixture of 50% glycerin and water was added to the vial to promote annulus visibility (Devries and Frie 1996). Once the otoliths had sufficiently cleared and annuli were visible, within 4 to12 days, photographs were taken with the same equipment used for the scales. Two readers independently estimated age from the same photograph of one whole-view otolith per fish.

Once photographed, sagittal otoliths were mounted in Enviro Tex Lite epoxy© and cut in a transverse section with a Buehler Isomet low-speed saw on the posterior end near the core (Secor et al. 1991). The anterior side of the otolith was then mounted to a clear glass slide with Super Glue Liquid© and cut to a thin section of approximately 300 µm. The mounted thin sections were photographed with an Olympus BX51 microscope and an Olympus DP71 camera. Two readers independently estimated the age from the same photograph of one sectioned otolith per fish.

Age bias plots, age frequency tables, and coefficients of variation were produced to analyze precision in age determinations made with scales, whole-view otoliths, and otolith thin-sections (Campana1995). Additionally, exact agreements in age estimates among hard structures and readers were calculated. Statistically significant results were determined by comparing slopes of best fit regression lines generated from age bias plots to a slope of one (complete agreement) with an analysis of covariance (ANCOVA).

*RVI: relevance of historical data*—The collection protocol, during the spring 2011 harvest of walleye gametes, was modified to improve precision, and include smaller size classes to better estimate year-class strength. Accordingly, five walleye, independent of sex, were collected in consecutive 10 mm length-groups (Devries and Frie 1996). Additionally, 19 and 25-mm mesh gill nets, each 30.5-m X 1.8-m, were deployed concurrently with the annual gamete harvest. Sagittal otoliths were extracted from individuals until the length-group sub-sample size was met. Total lengths and sex were recorded for all subsequent captures and, prior to their release, walleye were marked with a whole punch through one of the rays on the anterior edge of the anal fin to avoid counting the same individual more than once. Age was estimated from sectioned, sagittal otoliths by two readers as above. A third reader was used when there was disagreement in an age estimate and only estimates agreed upon by two readers were used in analyses. Age structure of the population was estimated with an age-length-key (Bettoli and Miranda 2001), produced by Fish BC 3.0 software (Fish BC. 2007. Fisheries Age and Growth Software, J. C. Doll. Ball State University 2007). Age structure was used to estimate RVI.

Linear regression was used to evaluate the relationship between fall CPUE of age-0 walleye in the 25-mm mesh gill nets on standard sites and the relative frequency of the corresponding year-classes from the estimated age structure. For example, fall CPUE of age-0 walleye in 2003 was plotted against the relative frequency of age-8 walleye. Catch-per-unit-effort of age-0 walleye in 2008 was plotted against the relative frequency of age-3 walleye and so forth.

# RESULTS

*Age-0 abundance* —In nine independent sampling periods 32 sites were fished with gill nets (Table 1).The total number of walleye captured was 581, of which 258 were aged by one reader using the whole-view otolith method. Only fish estimated as age-0, or determined to be age-0 by length at the time of capture, were included in CPUE estimates. The longest age-0 walleye captured was 297 mm in November and the shortest was 154 mm in August.

Length frequency distributions for each sampling period are presented in Figure 1. Age-0 walleye were first collected in 19-mm mesh gill nets in August. A single age-0 walleye was captured in August in the 25-mm mesh gill net. By October, more age-0 individuals were captured in the larger mesh size than the smaller mesh size. However, the smaller mesh size continued to capture fish through the study. When the mean total length of age-0 walleye was less than 240 mm the 19-mm mesh gill net captured more individuals than the 25-mm mesh gill net. Age-0 walleye CPUE ranged from 0 to 12. 5 per-net-night. Catch-per-unit-effort in both site types, increased through the duration of the study (Figure 2A). Between random and standard sites CPUE was not significantly different ($t = -0.04$, $df = 142$, $P = 0.97$). In October and November, CPUE was higher in the 25-mm mesh gill net than in the 19-mm mesh gill net(Figure 2B); however, there was not a significant difference in CPUE between the two mesh sizes ($n = 144$, $U = 2{,}154$, $P = 0.07$).

Four age-0 walleye were captured in 14,400 seconds of electrofishing effort over three sampling dates comprised of 24 sample sites (Table 2). No statistical analysis was performed on the electrofishing data due to small sample size.

*Aging structures* —In spring 2010, during the annual harvest of walleye gametes by KDWPT at Cedar Bluff Reservoir, 95 walleye were collected in 25-mm mesh trap-nets and 76-mm mesh gill nets. Total length ranged from 339 mm to 735 mm. Paired samples of scales and sagittal otoliths were removed from walleye in eighteen 20 mm length-groups. The oldest fish captured, estimated by the otolith section method, was 13 years old and the youngest was 2 years old.

Age bias plots (Figures 3A, B, and C) and age frequency tables (Tables 1A, B, and C), were produced to visually assess precision in age estimations between readers. Age bias plots and age frequency tables revealed greatest precision between readers was derived with age estimates from otolith sections (Figure 3A and Table 1A). Age bias plot (Figure 3B) and age frequency table (Table 1B) of whole-view otoliths indicate decreasing precision with age among the age estimates by two readers. Using whole-view otoliths, reader age estimates were not congruent at age eight and older (Table 1B). Using otolith sections, reader age estimates were congruent among 30 fish age eight and older; half of which were estimated to be age-11 (Table 1A). Slopes of best fit regression lines from age bias plots between readers using the whole-view otolith ($t = 1.39$, $df = 2$, $P < 0.01$) and sectioned otolith ($t = 0.44$, $df = 2$, $P < 0.01$) methods were not significantly different from a slope of one, but the $r^2$ value was higher and the slope was closer to one for otolith sections (Figure 3A, B). Consistency in age estimates between readers was lowest when estimates were based on scales (Figure 3C and Table 1C) and slope of the best fit regression line was significantly different from one ($t = -3.42$, $df = 2$, $P < 0.01$). The number of congruent age estimates between readers using scales was low in all estimated age classes compared to age estimates from other structures (Table 1C). Age frequency distributions for each structure as estimated by reader one are presented in Figure 4. The age frequency distributions derived from age estimates using scales and whole-view otoliths suggest a more productive population compared to the age frequency distribution derived from age estimates using otolith sections. Also, age frequency distributions by using scales and whole-view otoliths suggest little variation in year-class strength. In the age frequency distribution from otolith sections a pattern of strong year-class production was identified.

Age bias plots (Figures 5 and 6) and age frequency tables (Tables 2 and 3) were produced to visually analyze precision in age estimations among aging methods for each reader. Best fit regression slopes from each age bias plot were significantly different from a slope of one (Table 4A). Using the scale and whole-view otolith methods, both readers tended to under-estimate the age of older fish compared to age estimated with the otolith section method (Figure 5A and B and Figure 6A and B). Paired observations in Tables 2A and B and 3A and B indicate younger age assignments for older fish by each reader using whole-view otoliths and scales relative to assignment based on otolith sections.

For each reader, age estimates comparing whole-view otoliths and scale methods appear more precise than other structure comparisons (Figure 5C, 6C and Table 2C, 3C).

However, age estimates from scales and whole-view methods had bias in the same direction relative to age estimates using otolith sections.

Coefficients of variation, and reader agreement among age estimates and aging methods are presented in Table 5. Between-reader comparisons yielded the least amount of variation using the otolith section method. Variation increased with age for the whole-view ototlith and scale method between-reader comparisons. However, there was more variation between readers in age estimates by using scales. Otolith sections produced the highest percent agreement (92%) in between-reader comparisons, followed by whole-view otoliths (53%) and scales (37%).

Comparisons between aging methods for each reader had more variation than did between-reader comparisons. Comparisons between aging methods for each reader had lower agreement than comparisons between readers using otolith section and whole-view otolith methods.

In two of the nine comparisons, male and female best fit regression slopes were determined to be significantly different (Table 4B). However, the direction of the differences was the same and not biologically meaningful in this context. Sexes were combined and the best fit regression slope derived from the resulting age bias plot was used in subsequent analyses.

*RVI: relevance of historical data* —In spring 2011, during the annual harvest of gametes at Cedar Bluff Reservoir, otoliths were extracted from (n = 210) walleye for age estimation by the otolith section method. An additional 928 individuals were marked and released. Fifty individuals were recaptured. Mean lengths-at-age of the individuals used for age estimation are presented in Figure 7.

Age structure was estimated from 210 individuals (5-6 individuals in each 10 mm length group) and then extrapolated to un-aged fish by size class with an age-length-key (Figure 8). Fourteen consecutive year-classes were identified. However, reproductively immature fish were undersampled because capture effort was concentrated in spawning areas. Age-1 and age-2 fish were removed from RVI analysis. The RVI estimate was

$$0.69 = [8.27/(0+12)]-(0/12).$$

Catch-per-unit-effort of age-0 walleye in fall from the 25-mm mesh gill net explained 72% adjusted $r^2$ value of the variation in the estimated current size of the corresponding year-classes ($F = 29.29$, $df = 11$, $P < 0.01$) (Figure 9). Age-1 and age-2 fish were removed from linear regression analysis. Positive residuals indicate stronger than expected year-classes (e. g. 1999 year-class) and negative residuals indicate weaker than expected year-classes (e. g. 2005 year-class).

# DISCUSSION

*Age-0 abundance*—Age-0 walleye were first collected in the 19-mm mesh gill net at a randomly chosen site in August. The 19-mm mesh gill net had higher CPUE than the 25-mm mesh gill net until October when mean total length of age-0 walleye was greater than 240 mm. No significant difference in CPUE between the mesh sizes was detected with the non-parametric Mann-Whitney U test. Monitoring CPUE in the 19-mm mesh gill net over time might provide a useful index of age-0 walleye recruitment. Catch-per-unit-effort in the 19-mm mesh gill net was highest in August, outside the traditional sampling season (September-October). Development of a walleye recruitment index based on samples from August will reduce time spent sampling during the traditional season by moving sampling of age-0 walleye to August. However, Kempinger and Churchill (1972), and Forney (1976), suggested smaller age-0 walleye might have reduced survival relative to larger age-0 walleye. Consequently, survival to age-1 might be reduced for age-0 walleye too small to be captured in the 25-mm mesh gill net but large enough to be captured in the 19-mm mesh gill net. Therefore, an index developed from the 19-mm mesh gill net might erroneously forecast a strong year-class when the year-class is dominated by smaller individuals with low survival to age-1. Collection of paired CPUE by mesh size over time will be required to answer this question.

Variation in CPUE was more equal between site types than between mesh sizes, and allowed the use of a parametric technique. A student's t-test indicated no significant difference in CPUE between the two site types. Gill net deployment within a random quadrat was constrained to the conditions listed by Miranda and Boxrucker (2009).

These conditions also were met on standard sites. Habitat within a depth of 3-8 m, bottom slope < 45°, and free of woody debris varies little in Cedar Bluff Reservoir. Additionally, the 2010 year-class was the strongest year-class ever measured at Cedar Bluff Reservoir as judged by CPUE in traditional gill nets. Because sampled habitat varied little and age-0 walleye were ubiquitous, similar catch rates at the two site types was not surprising. These data suggest the development of a recruitment index based on samples of age-0 walleye CPUE from either site type might be effective forecasts of future year-class strength.

The higher catch rates using gill nets compared to electrofishing suggest that age-0 walleye might remain in open water, in depths where electrofishing is least effective. Additionally, Cedar Bluff Reservoir is characterized by high conductivity which has been shown to limit electrofishing success (Reynolds 1983). Electrofishing might be more effective later in the fall when water temperatures are lower and individuals are less likely to be restricted to deeper waters.

*Aging structures*—In a review of fish aging procedures, Maceina et al. (2007) suggested precision of age estimates should be assessed in all aging studies. Inaccurate age estimates can lead to erroneous population assessment and mismanagement (Beamish and McFarlane 1995). The accuracy of age estimates was not evaluated in this study. However, otolith sections were determined, both graphically and statistically, to produce the most precise age estimations. Age estimations derived from whole-view otoliths also were precise between readers. Scale based age estimations had low precision between readers. Additionally, all between structure comparisons for each reader had low precision.

Precision between readers in age estimates derived from whole-view otoliths decreased with fish age. Age estimates from more experienced readers might be different, but reader experience did not appear to effect precision in age estimates from otolith sections. Results from this study agree with Isermann et al. (2003), that whole-view otoliths produce age estimates with high precision between readers for fish age-5 and younger. Reader experience potentially influenced age estimates using scales; however, results from this study agree with results from other studies (Campbell and Babaluk 1979; Marwitz and Hubert 1995; Kocovsky and Carline 2000; Isermann et al. 2003) that indicate scales produce less precise age estimations relative to sagittal otoliths. Both readers tended to underestimate the age of older fish using scales compared to age estimated with otolith sections. This produces an age frequency distribution derived from scales that suggests a younger more productive population compared to age frequency distribution derived from age estimates using sectioned otoliths. Additionally, reader agreement was low (35%) using scales, indicating strong year-classes might be incorrectly identified, or might be assigned to multiple age-classes and not identified (Figure 4).

To obtain precise age estimates of walleye at Cedar Bluff Reservoir, I recommend sectioned otoliths be used to estimate age. If the sample is restricted to fish age-5 and younger, whole-view otoliths can be used to obtain precise age estimates. Annual sampling using overnight sets of gill nets and otolith removal from captured fish, at

Kansas Reservoirs will increase the amount of information collected with no additional mortality. The walleye population size at Cedar Bluff Reservoir as estimated with a multiple mark recapture technique was 8,449 (95% confidence limits = 6,401-11,265). Age-structured subsamples were used in this study, and 210 walleye were sacrificed for otolith removal, or approximately 3% of the population estimate. Age structure of this quality is necessary to evaluate population parameters (e. g. recruitment, growth, and mortality). However, estimates of age structure based on this level of precision might be necessary only once every four to five years (approximate cycle of strong year-classes Figure 8) to provide adequate information to evaluate recruitment variability, population growth, and mortality rates.

*RVI: relevance of historical data*—The strength of the RVI is that recruitment can be evaluated with one sampling event (Guy and Willis 1995; Isermann et al. 2002; and Quist 2007). Quist (2007) reported mean RVI values adequately indexed recruitment variability when other techniques using age-structure data did not. Guy and Willis (1995), Isermann et al. (2002), and Quist (2007) agree that recruitment variability is best assessed with a long-term data set.

The estimated age structure might be bias toward reproductively active fish and therefore, fish younger than age-3 were removed from the analysis. The calculated RVI in 2011 was 0. 69, which is similar to the estimate provided by Quist (2007) for Cedar Bluff Reservoir using age structure data from the mid-1990s. These values suggest recruitment was similar from the mid-1990s to the present. However, Isermann et al. (2002) reported that RVI is sensitive to missing year-classes and relatively insensitive to weak year-classes. The current age-structure estimate (Figure 8) identified no missing year-classes. Although present, Age-10, 11, and 14, were relatively weak year-classes.

Historical data for Cedar Bluff Reservoir contains a long-term (1998 to present) data set with CPUE of age-0 walleye at standard sites. Linear regression was used to determine variation in year-class strength as explained by age-0 CPUE of the year-class. Age-0 CPUE explained 72% ($r^2$) of the variation in the estimated current size of the corresponding year-class. Age structure was used to estimate the current size of the year-class. Fall CPUE of age-0 walleye in the 25-mm mesh gill net on standard sites appeared to be an adequate index of walleye recruitment.

# MANAGEMENT IMPLICATIONS

Temporal variation in the estimated year-class size of age-0 walleye is common in Cedar Bluff Reservoir (KDWPT Cedar Bluff Reservoir Progress and Management Reports 1998-2010). Catch-per-unit-effort of age-0 walleye from gill nets ranged from 0. 5 to 10. 25 over the last 13 years. However, Willis (1987) and Quist (2007) reported catch rates of age-0 walleye in Kansas reservoirs were highly correlated to and provide an excellent measure of recruitment to age-1. Cedar Bluff Reservoir is frequently sampled and long-term trend data might provide the best means of assessing recruitment. In addition, changes in SSP warranted an evaluation of the gear used to sample age-0 walleye.

No significant difference could be detected between CPUE of age-0 walleye in two mesh sizes or on two site types; however, I suggest use of the 25-mm mesh gill net during the last week of October or the first week of November to sample age-0 walleye. This gear type provides temporal consistency in data bases and recruitment variability is best assessed with a long-term dataset. Catch-per-unit-effort was higher in the 25-mm mesh gill net in late October and early November than any other time or net combination. Additionally, CPUE of age-0 walleye in the 25-mm mesh gill net explains 72% ($r^2$) of the variation in future year-class strength. Considering variability in angling pressure (12,762 h/year in 1997 to 149,691 h/year in 2003; unpublished creel survey data) and resulting variability in harvest among age classes, explaining 72% ($r^2$) of the variation in year-class strength is substantial.

The water level in Cedar Bluff Reservoir fluctuates resulting in standard sites that might be dry or deviate from the gill net deployment specifications suggested by Miranda and Boxrucker (2009). In fall of 2010, there was not a significant difference in age-0 walleye CPUE at standard and randomly chosen sites. If gill net deployment specifications are not met at standard sites, random sites that meet the specifications provide an adequate alternative to sample age-0 walleye.

Natural reproduction appears to be sustaining the walleye population at Cedar Bluff Reservoir. Walleye recruitment has been observed every year since at least 1997. Some years (2003, 2008, and 2010) realized exceptional walleye recruitment. If recruitment is detected every year and the cyclic pattern of large walleye year-class production continues, natural reproduction will support a gamete harvest and a vibrant sport fishery. Ellison and Franzin (1992) reported the possibility of introducing negative genetic effects of artificial selection when stocking into natural, self-sustaining walleye populations. Also, there might be underlying genetic benefits to a naturally reproducing brood fish population. Accordingly, stocking walleye in Cedar Bluff Reservoir is not recommended.

Similar to results of many previous studies at other latitudes, ages estimated from otoliths were determined to be more precise than ages estimated from scales. Using scales, reader agreement was 35%. Using whole-view otoliths, variation in age estimation was considerably lower but increased with age. Sectioned otoliths produced age estimations with the highest agreement and lowest variation and therefore, produced the highest quality age estimates. These data produced markedly different estimates of year-class strength relative to data generated for other hard structures (Figure 4). Accordingly, the periodic sacrifice, of a sample of walleye for otolith removal, might be justified to obtain high quality age structure information, if recruitment is evaluated or if growth parameters are needed for population growth or harvest models.

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| Sample date | Grid number | Latitude | Longitude |
|---|---|---|---|
| Standard sites | | | |
| | 302 | 38.80524 | -99.74343 |
| | 352 | 38.78084 | -99.72259 |
| | 134 | 38.79099 | -99.79991 |
| | 241 | 38.78954 | -99.75806 |
| Random sites | | | |
| 7-19/7-21 | 353 | 38.79026 | -99.77139 |
| | 309 | 38.78044 | -99.73853 |
| | 268 | 38.79072 | -99.80735 |
| 8-2/8-3 | 172 | 38.78335 | -99.78055 |
| | 294 | 38.78644 | -99.72268 |
| | 165 | 38.78332 | -99.78425 |
| | 331 | 38.77955 | -99.74968 |
| 8-17/8-20 | 190 | 38.78416 | -99.77334 |
| | 238 | 38.78248 | -99.75484 |
| | 256 | 38.78248 | -99.75484 |
| | 355 | 38.79896 | -99.73572 |
| 8-28/8-29 | 309 | 38.78044 | -99.73853 |
| | 331 | 38.77955 | -99.74968 |
| | 101 | 38.79087 | -99.72306 |
| | 210 | 38.79106 | -99.73382 |
| 9-14/9-18 | 268 | 38.79072 | -99.80735 |
| | 256 | 38.78248 | -99.75484 |
| | 172 | 38.78335 | -99.78055 |
| | 101 | 38.79087 | -99.72306 |
| 9-25/9-26 | 197 | 38.78229 | -99.73555 |
| | 315 | 38.79944 | -99.73958 |
| | 321 | 38.78133 | -99.73540 |
| | 130 | 38.77963 | -99.80447 |
| 10-9/10-10 | 210 | 38.79106 | -99.73382 |
| | 165 | 38.78332 | -99.78425 |
| | 255 | 38.78241 | -99.75224 |
| | 341 | 38.78176 | -99.72609 |
| 10-20/10-22 | 331 | 38.78182 | -99.72988 |
| | 350 | 38.77887 | -99.72461 |
| | 335 | 38.79356 | -99.73011 |
| | 238 | 38.78248 | -99.75484 |
| 11-6/11-7 | 266 | 38.77437 | -99.75203 |
| | 321 | 38.79896 | -99.73572 |
| | 192 | 38.79039 | -99.77629 |
| | 167 | 38.79078 | -99.78571 |

Table 1.—Date and location of sites sampled for walleye with gill nets at approximately two week intervals July to November 2010, at Cedar Bluff Reservoir. Standard sites were sampled with both sizes of gill net each sample. Random sample locations were selected from a map of the reservoir surface layered by a grid of 333-m X 333-m quadrats. The map was produced by the Kansas Biological Survey in ArcGIS 10 and provided by KDWPT. A random number generator was used to select four quadrats in each sample period and each random site was sampled with both sizes of gill net.

| Sample date | Grid number |
|---|---|
| Standard sites | |
| | 331 |
| | 134 |
| | 172 |
| | 302 |
| Random sites | |
| 8-4 | 351 |
| | 293 |
| | 241 |
| | 165 |
| 9-1 | 105 |
| | 114 |
| | 264 |
| | 350 |
| 9-27 | 233 |
| | 196 |
| | 354 |
| | 337 |

Table 2.—Date and grid number location of sites sampled for walleye with electrofishing in Fall of 2010, at Cedar Bluff Reservoir. Standard sites were sampled each sample. Random sample locations were selected from a map of the reservoir surface layered by a grid of 333-m X 333-m quadrats. The map was produced by the Kansas Biological Survey in ArcGIS 10 and provided by KDWPT. A random number generator was used to select four quadrats in each sample period.

| Otolith section | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **A** N=95 | | | | | **Reader 2** | | Matched age observations = 87 | | | | | | |
| **Reader 1** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
| 1 | | | | | | | | | | | | | |
| 2 | | 10 | | | | | | | | | | | |
| 3 | | 1 | 11 | 1 | | | | | | | | | |
| 4 | | | | 13 | | | | | | | | | |
| 5 | | | | | 2 | | | | | | | | |
| 6 | | | | | 1 | 6 | | | | | | | |
| 7 | | | | | | 1 | 12 | | | | | | |
| 8 | | | | | | | | 3 | | | 1 | | |
| 9 | | | | | | | | | 3 | | 1 | | |
| 10 | | | | | | | | | 1 | 1 | | | |
| 11 | | | | | | | | | | | 15 | | |
| 12 | | | | | | | | | | | 1 | 10 | |
| 13 | | | | | | | | | | | | | 1 |

| Whole-view otolith | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **B** N=95 | | | | | **Reader 2** | | Matched age observations = 50 | | | | | |
| **Reader 1** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| 1 | | | | | | | | | | | | |
| 2 | | 12 | | 1 | | | | | | | | |
| 3 | | | 15 | 2 | | | | | | | | |
| 4 | | 1 | 2 | 10 | 1 | | | | | | | |
| 5 | | | | 3 | 4 | 4 | | | | | | |
| 6 | | | | 1 | 2 | 5 | 6 | 2 | | | | |
| 7 | | | | | 2 | 2 | 3 | | 1 | 1 | 1 | |
| 8 | | | | | | | 3 | 1 | 3 | | 1 | |
| 9 | | | | | | | 1 | | | 1 | 2 | |
| 10 | | | | | | | | | | | | 1 |
| 11 | | | | | | | | | | 1 | | |
| 12 | | | | | | | | | | | | |

| Scale | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **C** N=95 | | | | | **Reader 2** | | Matched age observations = 35 | | | | | |
| **Reader 1** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| 1 | | | | | | | | | | | | |
| 2 | | 7 | 7 | 1 | 1 | | | | | | | |
| 3 | | 1 | 4 | 2 | 1 | 2 | | | | | | |
| 4 | | 1 | 1 | 14 | 1 | | | | | | | |
| 5 | | | 2 | 4 | 3 | 3 | 3 | | | | | |
| 6 | | | 3 | 1 | 5 | 3 | 1 | 1 | 1 | | | |
| 7 | | | | 1 | 4 | 4 | 3 | 1 | | | | |
| 8 | | | | | 1 | 1 | 2 | 1 | | | | |
| 9 | | | | | | | | 1 | | | | |
| 10 | | | | | | | | | 1 | | | |
| 11 | | | | | | | 2 | | | | | |
| 12 | | | | | | | | | | | | |

Table 3.—Age frequency tables summarizing paired age estimates by two independent readers based on otolith sections (A) whole-view otoliths, (B) and scales (C). Tabled values indicate the number of individuals estimated at a specific age by each reader. Shaded cells indicate matched age observations. Structures were removed from 95 walleye collected during the 2010 gamete harvest at Cedar Bluff Reservoir.

Reader 1

**A** N=95 **Whole-view otolith** Matched age observations = 31

| Otolith section | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | | | | | | |
| 2 | | 9 | 1 | | | | | | | | | | |
| 3 | | 3 | 9 | | | | | | | | | | |
| 4 | | | 5 | 9 | | | | | | | | | |
| 5 | | | 1 | | 1 | | | | | | | | |
| 6 | | 1 | 2 | 2 | 1 | 1 | | | | | | | |
| 7 | | | | 2 | 6 | 3 | 2 | | | | | | |
| 8 | | | | | 1 | 3 | | | | | | | |
| 9 | | | | | 1 | 3 | | | | | | | |
| 10 | | | | | 1 | | | | 1 | | | | |
| 11 | | | | | | 3 | 4 | 5 | 3 | | | | |
| 12 | | | | | | 3 | 3 | 3 | | 1 | 1 | | |
| 13 | | | | | | | 1 | | | | | | |

**B** N=95 **Scale** Matched age observations = 22

| Otolith section | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | | | | | | |
| 2 | | 7 | 1 | 1 | | | 1 | | | | | | |
| 3 | | 4 | 5 | 1 | 1 | 1 | | | | | | | |
| 4 | | 3 | 1 | 8 | 2 | | | | | | | | |
| 5 | | | 1 | | | 1 | | | | | | | |
| 6 | | 1 | 2 | 3 | | | 1 | | | | | | |
| 7 | | | | 4 | 4 | 3 | 1 | 1 | | | | | |
| 8 | | | | | 3 | | 1 | | | | | | |
| 9 | | | | | 2 | 1 | 1 | | | | | | |
| 10 | | | | | 1 | | | 1 | | | | | |
| 11 | | | | | 1 | 7 | 6 | | | | 1 | | |
| 12 | | | | 1 | 1 | 1 | 2 | 4 | 1 | | 1 | | |
| 13 | | | | | | | | | | 1 | | | |

**C** N=95 **Scale** Matched age observations = 35

| Whole-view otolith | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | | | | | |
| 2 | | 10 | 3 | 1 | | | | | | | | |
| 3 | | 5 | 5 | 4 | 1 | 2 | | | | | | |
| 4 | | 1 | 1 | 8 | 3 | | 2 | | | | | |
| 5 | | | 1 | 4 | 4 | 1 | | 1 | | | | |
| 6 | | | | 1 | 4 | 5 | 4 | 2 | | | | |
| 7 | | | | 1 | 1 | 2 | 3 | 1 | | 1 | 1 | |
| 8 | | | | | | 2 | 2 | | 1 | | 1 | |
| 9 | | | | | 1 | 1 | 2 | | | | | |
| 10 | | | | | | | | 1 | | | | |
| 11 | | | | | | | | 1 | | | | |
| 12 | | | | | | | | | | | | |

Table 4.—Age frequency tables summarizing paired age estimates among structures from the first independent reader (A) otolith sections and whole-view otoliths (B) otolith sections and scales (C) whole-view otoliths and scales. Tabled values indicate the number of individuals estimated at a specific age using each structure. Shaded cells indicate matched age observations. Structures were removed from 95 walleye collected during the 2010 gamete harvest at Cedar Bluff Reservoir.

Reader 2

| **A** | N=95 | | | | **Whole-view otolith** | | Matched age observations = 36 | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Otolith Section** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
| 1 | | | | | | | | | | | | | |
| 2 | | 11 | | | | | | | | | | | |
| 3 | | 2 | 8 | | | | | | | | | | |
| 4 | | | 5 | 10 | | | | | | | | | |
| 5 | | | 2 | 1 | | | | | | | | | |
| 6 | | | 1 | 3 | 2 | | | | | | | | |
| 7 | | | 1 | 2 | 2 | 4 | 3 | | | | | | |
| 8 | | | | | 1 | 1 | 2 | | | | | | |
| 9 | | | | | 1 | 2 | 1 | | | | | | |
| 10 | | | | | | | 1 | | | | | | |
| 11 | | | | 1 | 1 | 2 | 3 | 3 | 3 | 2 | 3 | | |
| 12 | | | | | 2 | 2 | 3 | | 1 | 1 | 1 | 1 | |
| 13 | | | | | | | | | | | | | |

| **B** | N=95 | | | | | **Scale** | Matched age observations = 20 | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Otolith Section** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 |
| 1 | | | | | | | | | | | | | |
| 2 | | 6 | 4 | | 1 | | | | | | | | |
| 3 | | 1 | 6 | 1 | 2 | | | | | | | | |
| 4 | | 1 | 3 | 8 | 1 | 1 | 1 | | | | | | |
| 5 | | | 2 | | | 1 | | | | | | | |
| 6 | | | 1 | 3 | 2 | | | | | | | | |
| 7 | | | | 5 | 3 | 4 | | | | | | | |
| 8 | | | | 1 | 1 | 2 | | | | | | | |
| 9 | | | | 2 | 2 | | | | | | | | |
| 10 | | | | | | | 1 | | | | | | |
| 11 | | | 1 | | 4 | 5 | 6 | 1 | 1 | | | | |
| 12 | | | | 2 | 2 | 1 | 3 | 2 | | | | | |
| 13 | | | | | | | | | 1 | | | | |

| **C** | N=95 | | | | | **Scale** | Matched age observations = 36 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Whole-view otolith** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| 1 | | | | | | | | | | | | |
| 2 | | 7 | 4 | 1 | 1 | | | | | | | |
| 3 | | 1 | 9 | 3 | 3 | 1 | | | | | | |
| 4 | | | 3 | 9 | 2 | 2 | 1 | | | | | |
| 5 | | | | 3 | 5 | | 1 | | | | | |
| 6 | | | | 3 | 3 | 4 | 1 | | | | | |
| 7 | | | 1 | 2 | 3 | 4 | 2 | 1 | | | | |
| 8 | | | | | | | 3 | | | | | |
| 9 | | | | 1 | 1 | | 2 | | | | | |
| 10 | | | | | | 1 | | 1 | 1 | | | |
| 11 | | | | | | 1 | 1 | 1 | 1 | | | |
| 12 | | | | | | 1 | | | | | | |

Table 5.—Age frequency tables summarizing paired age estimates among structures from the second independent reader (A) otolith sections and whole-view otoliths (B) otolith sections and scales (C) whole-view otoliths and scales. Tabled values indicate the number of individuals estimated at a specific age using each structure. Shaded cells indicate matched age observations. Structures were removed from 95 walleye collected during the 2010 gamete harvest at Cedar Bluff Reservoir.

| **A** Comparison | t | Degrees of freedom | *P* |
|---|---|---|---|
| **Reader 1** | | | |
| Otolith section<br>Whole-view otolith | -11.98 | 2 | <0.01* |
| Otolith section<br>Scale | -9.58 | 2 | <0.01* |
| Scale<br>Whole-view otolith | -3.42 | 2 | <0.01* |
| **Reader 2** | | | |
| Otolith section<br>Whole-view otolith | -9.58 | 2 | <0.01* |
| Otolith section<br>Scale | -5.87 | 2 | <0.01* |
| Scale<br>Whole-view otolith | -4.98 | 2 | <0.01* |

| **B** Comparison | t | Degrees of freedom | *P* |
|---|---|---|---|
| **Between Readers** | | | |
| Otolith section | 0.86 | 2 | <0.01 |
| Whole-view otolith | 2.37 | 2 | <0.01* |
| Scale | -0.18 | 2 | <0.01 |
| **Reader 1** | | | |
| Otolith section<br>Whole-view otolith | 2.62 | 2 | <0.01* |
| Otolith section<br>Scale | 0.38 | 2 | <0.01 |
| Scale<br>Whole-view otolith | 0.36 | 2 | <0.01 |
| **Reader 2** | | | |
| Otolith section<br>Whole-view otolith | 1.59 | 2 | <0.01 |
| Otolith section<br>Scale | 1.10 | 2 | <0.01 |
| Scale<br>Whole-view otolith | 0.36 | 2 | <0.01 |

Table 6.—(A) Statistical results comparing a line with a slope of one to the slope of the best fit regression line derived in age bias plots of pairwise age estimates from two independent readers using otolith sections, whole-view otoliths, and scales. (B) Statistical results comparing slopes of male and female best fit regression lines derived in age bias plots. Structures were removed from 95 walleye collected during the 2010 gamete harvest at Cedar Bluff Reservoir. (*)Indicates significant difference.

| Comparison | Percent agreement | Mean CV | Mean coefficient of variation within age class | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
| **Between readers** | | | | | | | | | | | | | | |
| Otolith section | 92% | 0.89 | 0 | 2.64 | 0 | 0 | 1.30 | 0.51 | 3.95 | 2.5 | 2.63 | 0 | 0.40 | 0 |
| Whole-view otolith | 53% | 5.33 | 2.38 | 1.68 | 4.76 | 5.21 | 6.34 | 6.68 | 7.06 | 9.09 | 9.44 | 10.1 | - | - |
| Scale | 37% | 11.36 | 5.01 | 5.26 | 5.88 | 10.1 | 10.8 | 11.5 | 11.7 | 12.7 | 14.2 | 22.2 | - | - |
| **Reader 1** | | | | | | | | | | | | | | |
| Otolith section<br>Whole-view otolith | 3% | 13.77 | 3.33 | 5 | 5.49 | 12.5 | 23.68 | 13.66 | 16.48 | 22.14 | 19.29 | 19.07 | 22.94 | 30 |
| Otolith section<br>Scale | 23% | 17.89 | 11.72 | 11.74 | 10.50 | 17.05 | 26.34 | 15.80 | 19 | 22.41 | 2.22 | 25.11 | 25.07 | 13.04 |
| Whole-view otolith<br>Scale | 37% | 10.80 | 7.18 | 14.63 | 10.42 | 9.23 | 7.23 | 11.85 | 12.62 | 18.39 | 11.11 | 15.79 | - | - |
| **Reader 2** | | | | | | | | | | | | | | |
| Otolith section<br>Whole-view otolith | 38% | 12.09 | 0 | 4 | 4.76 | 20.37 | 18.58 | 13.22 | 12.67 | 20.26 | 17.65 | 16.48 | 25.13 | 8.33 |
| Otolith section<br>Scale | 21% | 19.28 | 11.17 | 8.42 | 8.97 | 19.70 | 18.59 | 18.09 | 21.25 | 33.52 | 17.65 | 28.52 | 33.46 | 18.18 |
| Whole-view otolith<br>Scale | 38% | 10.89 | 11.16 | 10.07 | 7.78 | 5.56 | 8.63 | 14.0 | 6.67 | 19.58 | 13.79 | 19.36 | 33.33 | - |

Table 7.—Coefficients of variation (CV) by age and percent agreement among age estimations generated from two readers. Structures were removed from 95 walleye collected during the 2010 gamete harvest at Cedar Bluff Reservoir.

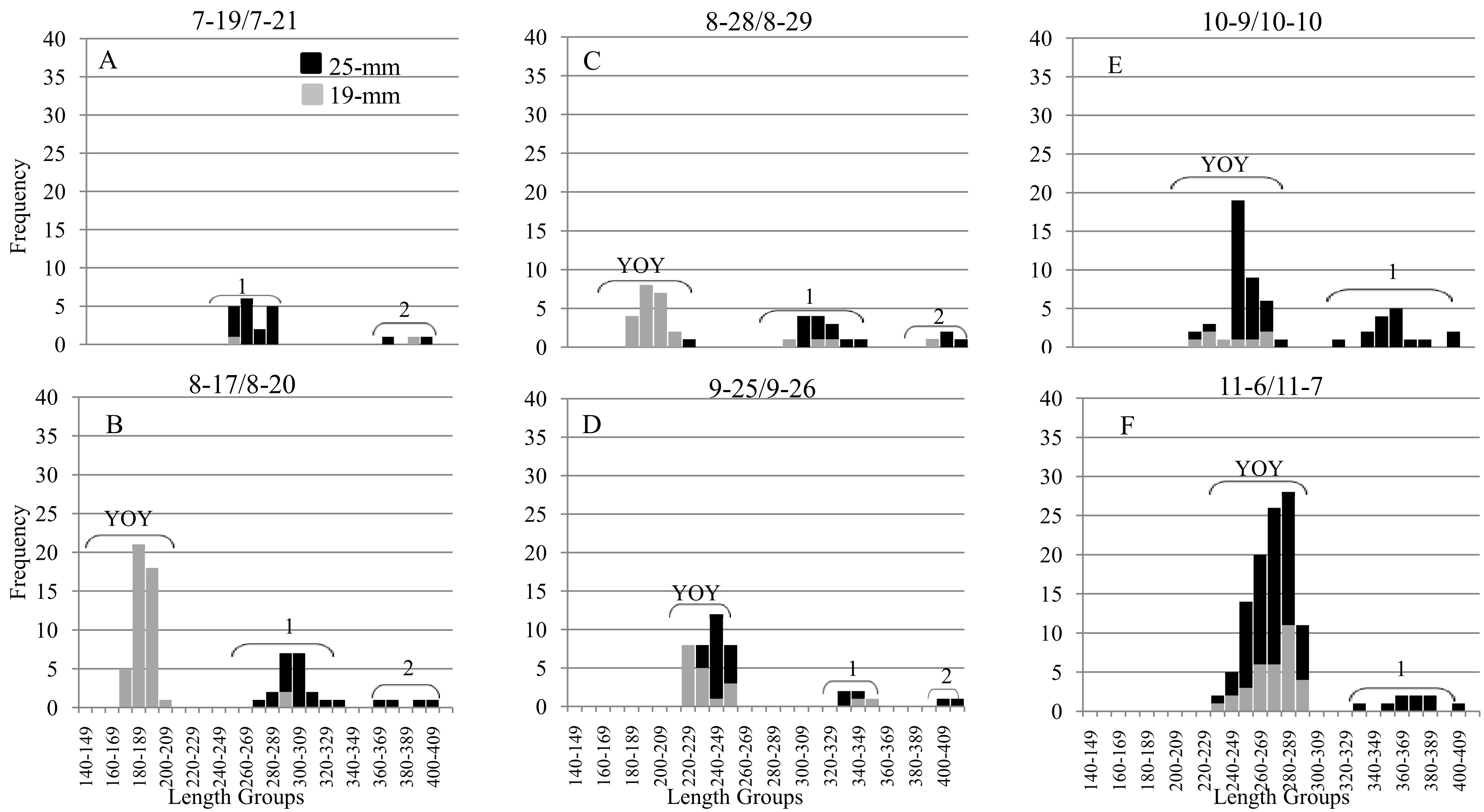


Figure 1.—Length frequency distributions of walleye sampled with gill nets at approximately two week intervals July to November 2010, at Cedar Bluff Reservoir. Black bars represent captures from 25-mm mesh gill nets and grey bars represent captures from 19-mm mesh gill nets. Ages were estimated from a subsample with whole-view otoliths and extrapolated from an age-length-key.

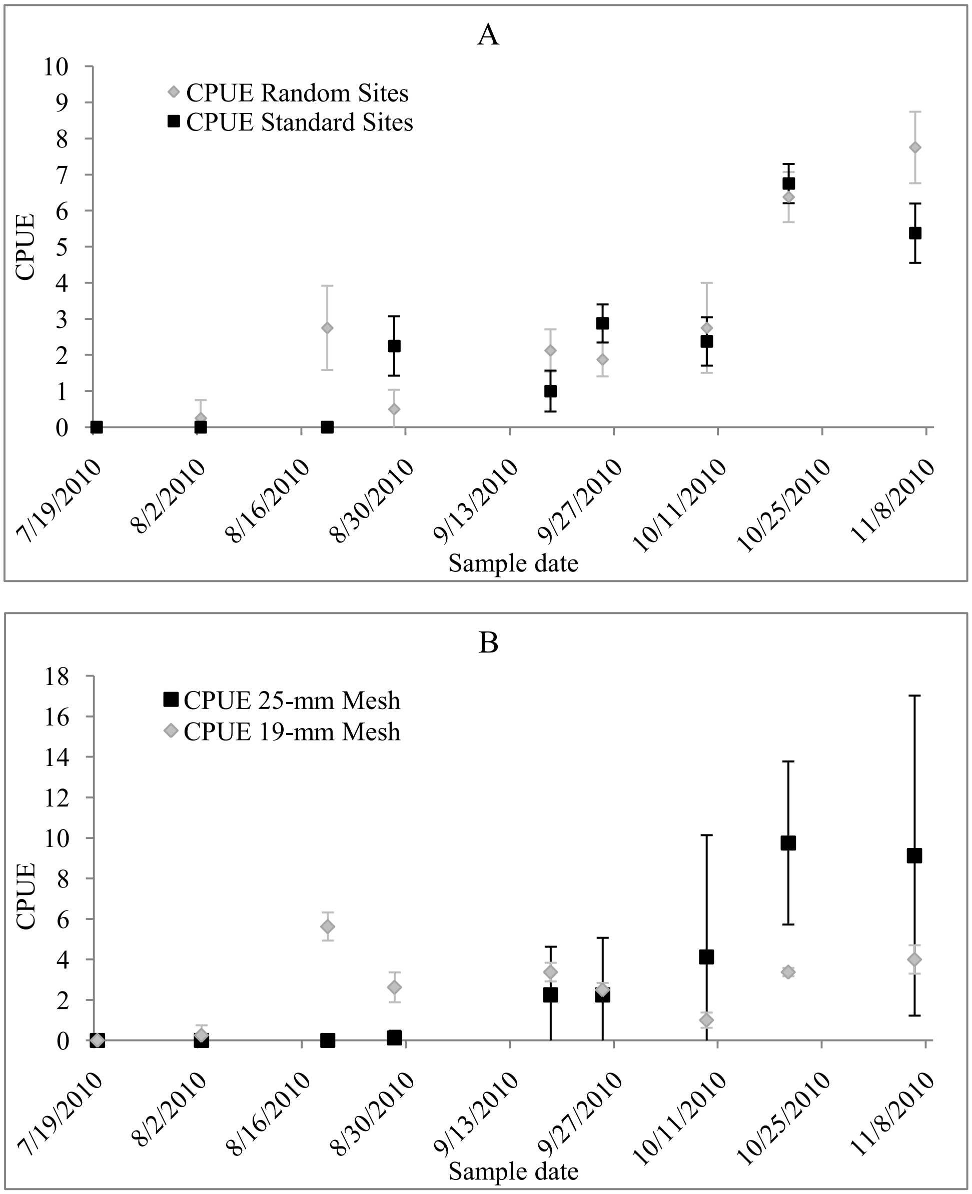


Figure 2.—(A) Mean catch-per-unit-effort (CPUE) and standard errors (vertical bars) of age-0 walleye sampled at approximately two week intervals from Cedar Bluff Reservoir in 2010. Black line and squares represent CPUE at standardized sample sites and light grey dashed line and diamonds represent CPUE at sample sites chosen at random. Bars represent standard errors. (B) Mean CPUE and standard errors of age-0 walleye sampled at approximately two week intervals from Cedar Bluff Reservoir in 2010. Black line and squares represent CPUE in 25-mm mesh gill nets and light grey dashed line and diamonds represent CPUE in 19-mm mesh gill nets.

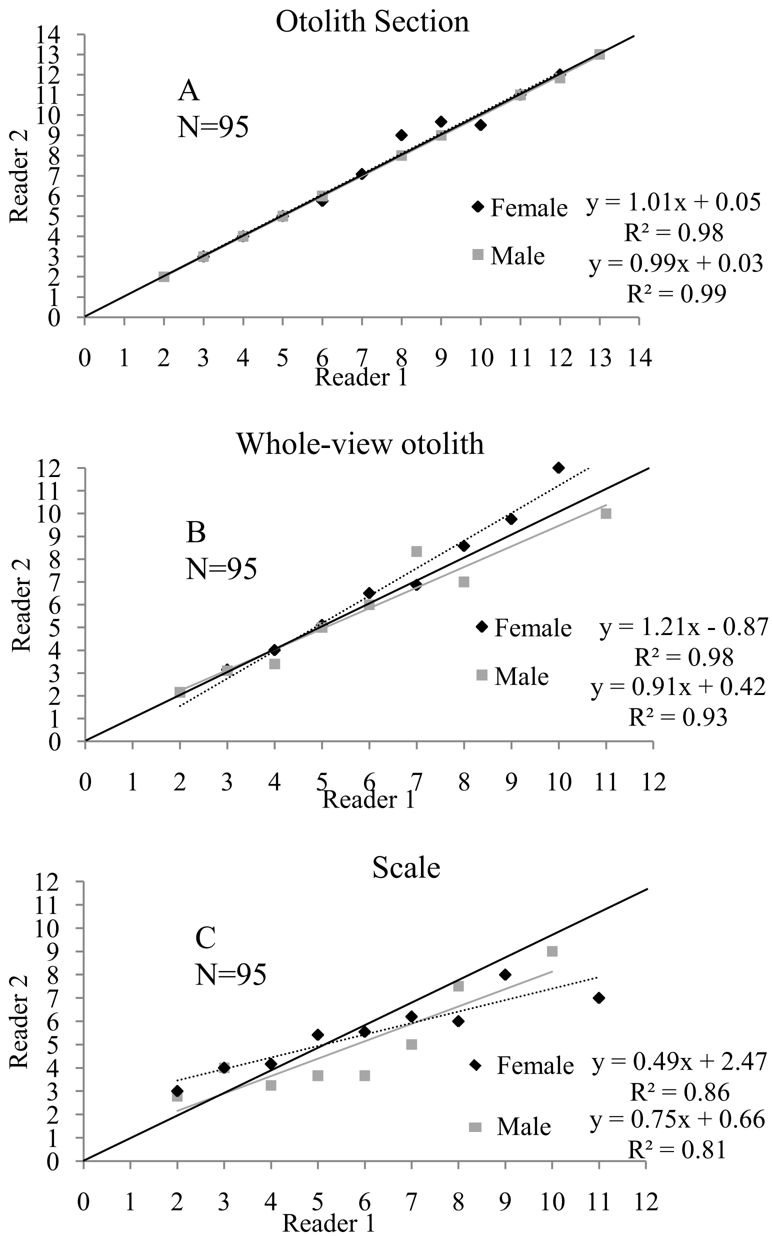


Figure 3.—Age bias plots comparing age estimations by two independent readers from otolith sections (A), whole-view otoliths (B), and scales (C) removed from 95 walleye collected during the 2010 gamete harvest at Cedar Bluff Reservoir. Grey squares represent mean age estimated by reader two for all males estimated a given age by reader one. Black diamonds represent mean age estimated by reader two for all females estimated a given age by reader one. Total numbers of individuals estimated at a specific age by each reader are presented in Table 1. Solid Black lines represent complete agreement between readers in age estimates for all structures. Dashed black lines represent best fit regression lines for females and solid grey lines for males. Coefficients of determination ($R^2$) and regression equations reported.

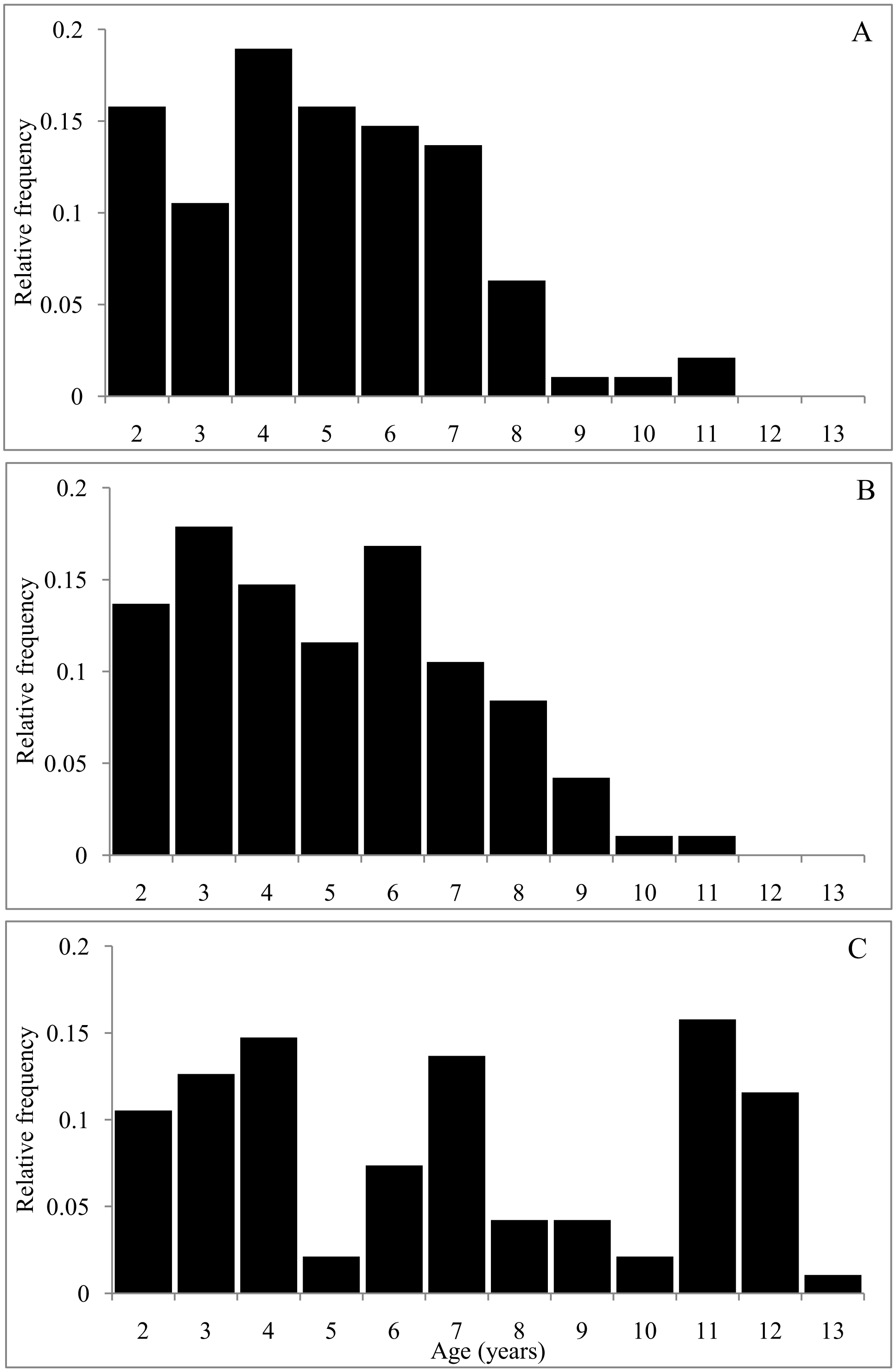


Figure 4.—Age (years) frequency distribution of (n=95) walleye sampled during gamete harvest at Cedar Bluff Reservoir in the spring of 2010. Age was estimated by reader one using (A) scales, (B) whole-view otoliths, (C) sectioned otoliths.

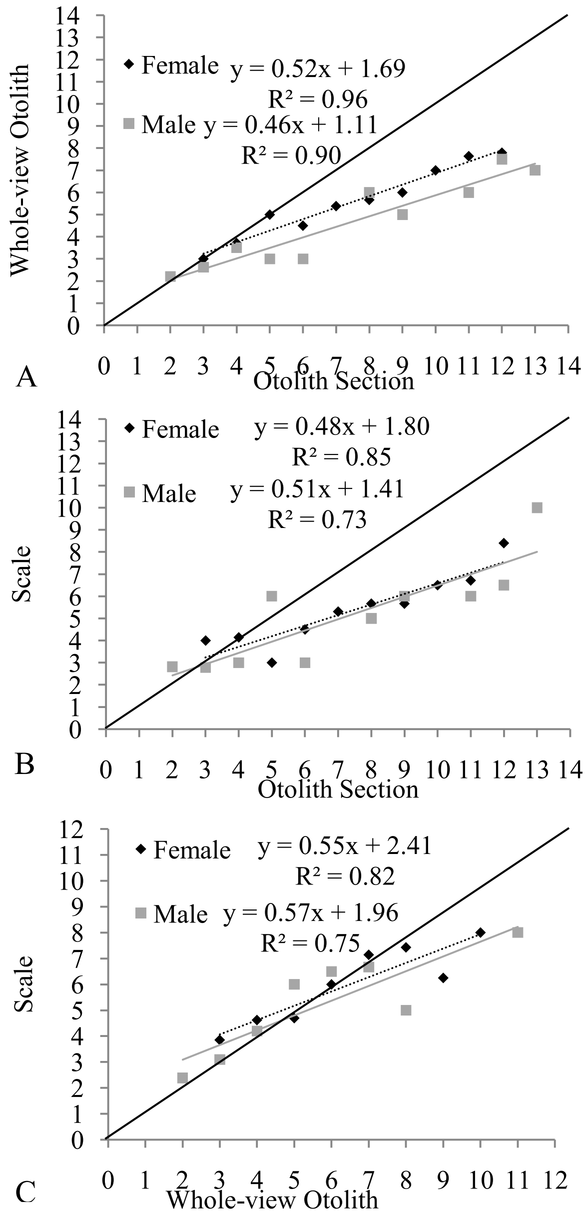


Figure 5.—Age bias plots generated from the first independent reader comparing age estimations among structures (A) otolith sections and whole-view otoliths (B) otolith sections and scales (C) whole-view otoliths and scales. Structures were removed from 95 walleye collected during gamete harvest at Cedar Bluff Reservoir, 2010. Grey squares represent mean estimated age using one structure for all males estimated a given age using the other structure. Black diamonds represent mean estimated age using one structure for all females estimated a given age using the other structure. Total numbers of individuals estimated at a specific age using each structure are presented in Table 2. Solid Black lines represent complete agreement in age estimates from both structures. Dashed black lines represent best fit regression lines for females and solid grey lines for males. Coefficients of determination ($R^2$) and regression equations are reported.

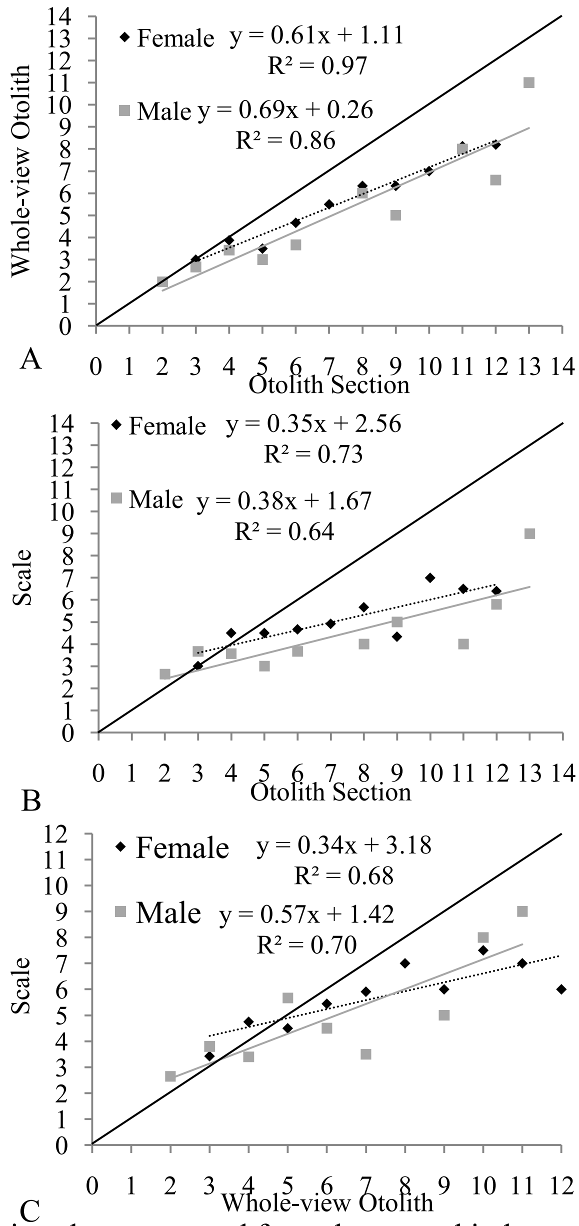


Figure 6.—Age bias plots generated from the second independent reader comparing age estimations among structures (A) otolith sections and whole-view otoliths (B) otolith sections and scales (C) whole-view otoliths and scales. Structures were removed from 95 walleye collected during gamete harvest at Cedar Bluff Reservoir, 2010. Grey squares represent mean estimated age using one structure for all males estimated a given age using the other structure. Black diamonds represent mean estimated age using one structure for all females estimated a given age using the other structure. Total numbers of individuals estimated at a specific age using each structure are presented in Table 3. Solid Black lines represent complete agreement in age estimates from both structures. Dashed black lines represent best fit regression lines for females and solid grey lines for males. Coefficients of determination ($R^2$) and regression equations are reported.

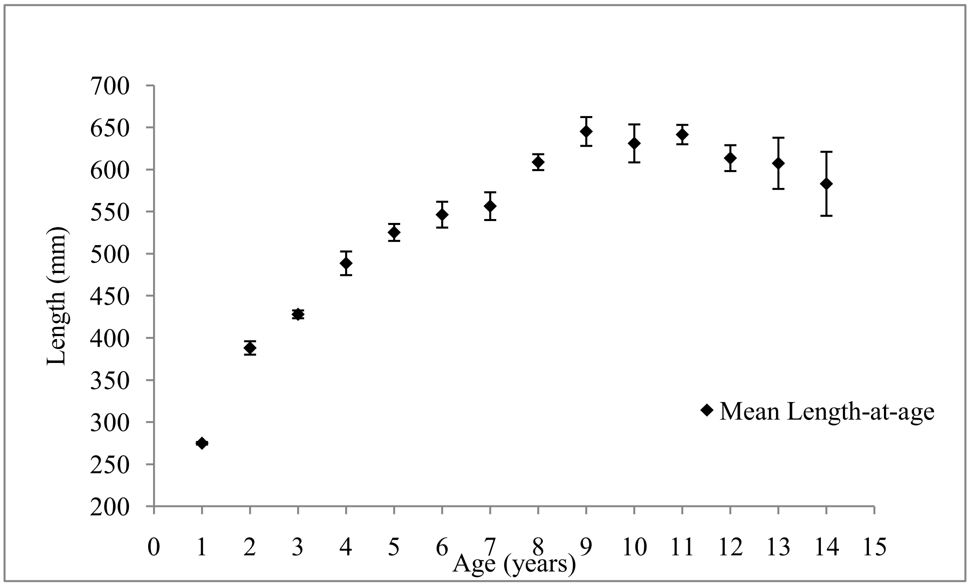


Figure 7.—Mean length-at-age and standard errors (vertical bars) using sectioned otoliths and total lengths from (n = 210) walleye collected during gamete harvest at Cedar Bluff Reservoir in the spring of 2011.

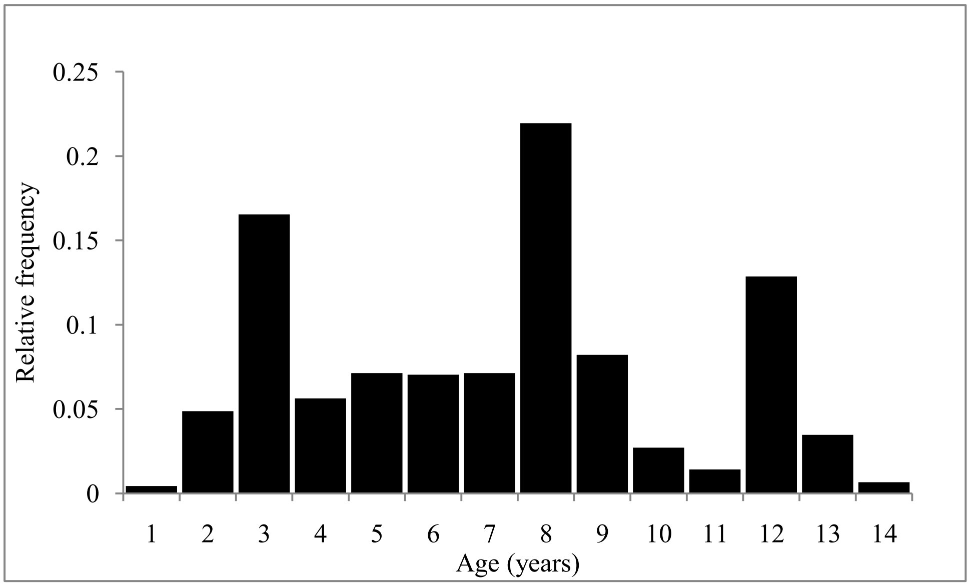


Figure 8.—Age (years) frequency distribution of (n=1138) walleye sampled during gamete harvest at Cedar Bluff Reservoir in the spring of 2011. Age was estimated using sectioned otoliths from 210 walleye and extrapolated to the entire sample using an age-length-key.

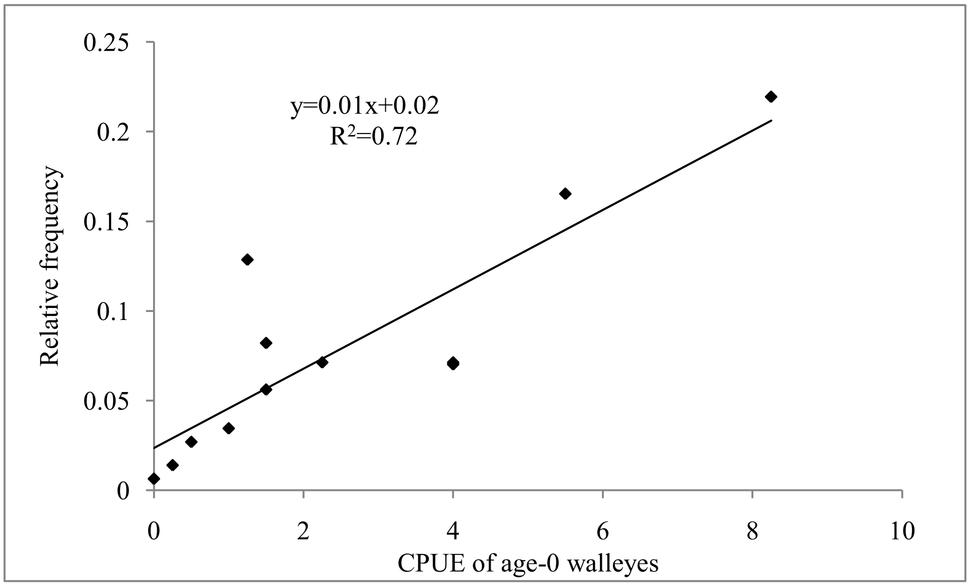


Figure 9.—Linear regression plot of fall age-0 walleye catch-per-unit-effort against the estimated relative size of the corresponding year-classes in spring 2011. Age-0 walleye were collected in 25-mm mesh gill nets at standardized sample sites. Relative size of the corresponding year-class was estimated from age structure distribution of walleye sampled during gamete harvest at Cedar Bluff Reservoir in the spring of 2011.