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Age, Growth, and Fecundity of Alabama Shad (*Alosa alabamae*) in the Apalachicola River, Florida

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AGE, GROWTH AND FECUNDITY OF ALABAMA SHAD (*Alosa alabamae*) IN THE APALACHICOLA RIVER, FLORIDA

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ABSTRACT

Age and growth of Alabama shad *Alosa alabamae* were estimated by examining scales and otoliths from 203 adult fish collected on their spawning run in the upper Apalachicola River from 2005 and 2006. Ages of Alabama shad ranged from 1 – 4 years. All sampled spawning males were between 1 and 3 years old, whereas females were 2 - 4 years of age. Scales and otoliths both gave similar age estimates. Although otoliths are the preferred aging structure, scales can be removed in the field without sacrificing the specimen. Age distributions from this study differed from those of previous studies for both males and females. Female Alabama shad, on average, were found to be larger than males at age 2 and age 3. Growth of male and female Alabama shad is best described by the equations: $L_t = 359.6\ [1 - e^{-2.1712(t-0.3757)}]$ and $L_t = 389.5\ [1 - e^{-2.3193(t-0.6424)}]$. Mean back-calculated lengths were similar to those of observed values for males and females. Alabama shad demonstrated a positive correlation of length to fecundity, with fecundity estimates ranging from 26,095 to 208,494 eggs per female. Fecundity estimates appeared similar to other studies from the Apalachicola River. Variations in fecundity estimates may be contributed to partial spawning. Gonosomatic indices of female shad ranged from 3.6 – 24.0. In contrast to earlier studies, no spawning marks were found on scales.

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INTRODUCTION

The Alabama shad *Alosa alabamae* is one of two alosine species that are distributed throughout Gulf of Mexico drainages (Mettee and O'Neil 2003). This species was once common over the entirety of its range, but is now considered a species of special concern. The major cause of decline in numbers appears to be due to the construction of locks and dams that block migration routes and alter flows (Hildebrand 1963; Mettee et al.1996; Buchanan et al. 1999). One of the larger remaining breeding populations appears to be in Apalachicola River, Florida (Mettee and O'Neil 2003).

Little is known about the natural history and overall biology of this species. Males enter into the river in late February when water temperatures rise above 12°C (Laurence 1967). Males captured during spawning runs tend to be younger on average than females, and weigh less than same-age females (Laurence 1967; Mettee and O'Neil 2003). Spawning occurs between 19-23°C (Laurence 1967; Mills 1972; Mettee and O'Neil 2003). Young of year individuals migrate into seawater prior to their first winter (Mettee and O'Neil 2003). Mortality may occur after spawning, although a portion of the population is believed to spawn more than once (Laurence 1967; Mills 1972). Differences in age at maturity between studies may be due to aging method (Laurence 1967; Mills 1972; Mettee and O'Neil 2003). Fecundity estimates range from 16,477 to 357,189 per female (Laurence 1967; Mills 1972; Mettee and O'Neil 2003). Little information exists on the age, growth, and fecundity of this species, especially in the Apalachicola River. The objectives of this study were to describe the age, growth, fecundity and spawning population size structure of Alabama shad in the Apalachicola River, Florida, and to compare the use of scales and otoliths in determining age.

METHODS

All study fish were collected in the Apalachicola River, Florida, within 2 km of Jim Woodruff Lock and Dam (JWLD). Jim Woodruff Lock and Dam is located at river km 172 and represents the first barrier to migration for anadromous fish. Positioned at the confluence of the Flint and Chattahoochee rivers, JWLD forms Lake Seminole (Figure 1). JWLD is currently used for hydroelectric power and locking from the Apalachicola River to Lake Seminole. The location was chosen because migrating adult Alabama shad impeded by the dam congregate in this area. Unfortunately, no spawning range documentation exists prior to dam construction. It is believed that spawning occurred in the Flint and Chattahoochee Rivers. Limestone and clay banks, and a substrate composition of sand, silt and gravel characterize the area. An area of limestone shoals bounded the sampling area at the lower end.

Alabama shad (n=203) were collected from March to May in 2005 and 2006. Collection of similar numbers of each sex was attempted during sampling but often was not possible. Specimens were primarily collected using a boat-mounted electrofisher (Type 7.5; Smith-Root, Seattle, Washington, USA), and some were attained through angling. After capture, total length (TL; mm) and weight (W; g) were recorded and specimens were frozen for later analysis. Sagital otoliths were removed, cleaned and stored dry in plastic vials. Scales

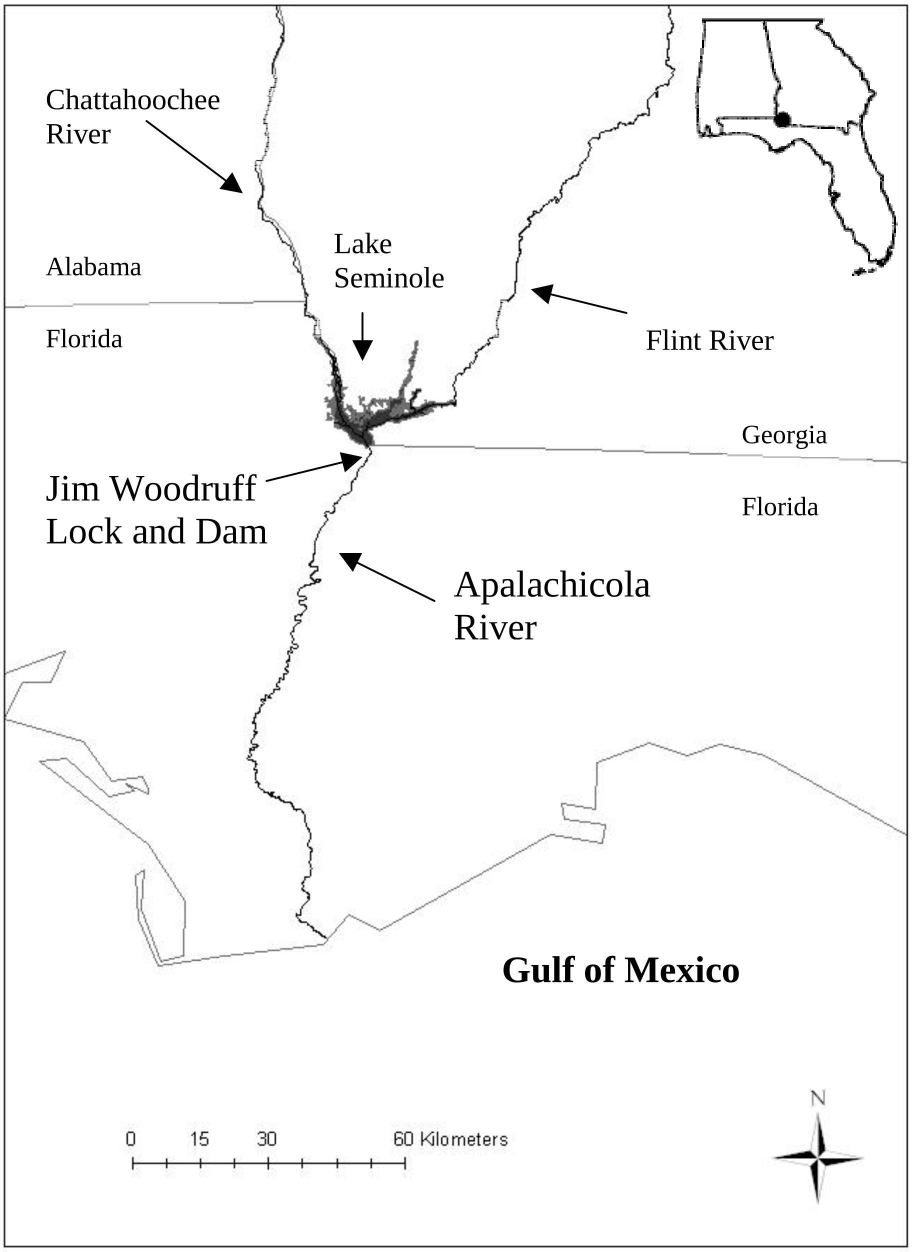


Figure 1. Map of study area, study was conducted directly below Jim Woodruff Lock and Dam.

were removed from the left side of each shad above the lateral line and below the dorsal fin, and placed in paper envelopes to dry. The sex of each shad was obtained through dissection and verification of either ovaries or testes. Ovaries were preserved in 10% formalin for fecundity estimates. Ages were determined from both scales and otoliths. Scales were pressed into acetate using standard methods (Devries and Frie 1996) and evaluated using a microfiche reader. Ages were assigned using the methods of Cating (1953) with modifications as described by Judy (1961) and Laurence (1967). Briefly, annuli were identified based on the appearance and frequency of transverse grooves, and configuration of circuli (Cating 1953; Judy 1961; Laurence 1967). Scales were examined for spawning marks using Cating's (1953) method as modified by Laurence (1967). Otoliths were examined in whole view under reflected light at 24X magnification. Annuli were identified as the distal edge of the transition from opaque to translucent zones. Scales and otoliths were reexamined when discrepancies between age estimates occurred. Differences (P=0.05) between scale and otolith ages were evaluated using analysis of variance.

Length at age was estimated from both scales and otoliths using the relationship between structure size and fish size. Scale radius and radius to each growth increment was measured in a straight line at a 45° angle from the focus. Otolith radius and radius to each growth increment was measured on a straight line from the nucleus to the posterior margin. Scales or otoliths that were damaged or unreadable were not used in these measurements. The direct proportion method was used to estimate length at previous age (Lea 1910; Shramm et al. 1992) using the equation:

$$L_i = (S_i/S_c)(L_c)$$

where L_i is the back-calculated length at age; L_c is the length at capture; S_i is the distance to annulus; and S_c is the otolith or scale radius at capture. Length-weight relationships for males and females were modeled using the equation:

$$Wt = a + bTL,$$

where Wt = weight (g) and TL = total length (mm).

Growth rates were constructed by fitting calculated lengths into the von Bertalanffy growth model:

$$L_t = L_\infty \, [1 - e^{-k(t-t_0)}]$$

where L_t is the total length at time t; L_∞ is the maximum theoretical total attainable length; k is the growth coefficient; and t_0 is the time when length would be zero (von Bertalanffy 1957). Model parameters were estimated using Statistical Analysis Software (SAS 9.0; Statistical Analysis Software, Cary, North Carolina, USA). Sex-specific differences (P=0.05) in size at age were evaluated using analysis of variance.

Fecundity estimates were based on methods used by Mills (1972). Both ovaries were weighed, and a 1-g sample of eggs was taken from the left ovary and counted under a binocular dissecting microscope. Fecundity was calculated by the following formula:

$$E_g = (E_s/W_s)(W_g)$$

where E_g is the estimated number of eggs in the ovaries, E_s is the number of eggs in the sample, W_s is the weight of the sample (1g), and W_g is the total weight of the ovaries (Mills 1972). Gonosomatic index was calculated for females by dividing the weight of ovaries by fish weight and multiplying by 100.

RESULTS

Ages of Alabama shad ranged from 1 to 4 years (Figure 2). Age distributions in this study appeared different from previous studies for both males ($X^2 = 134.74$; df = 6;

$P < 0.05$) and females ($X^2 = 113.77$; df = 6; $P < 0.05$; Figure 3). Length-weight relationships for males and females are described by the equations:

Male;

$$Wt = -4.9926 + 2.9992TL,$$

Female;

$$Wt = -5.8707 + 3.3699TL.$$

Length-weight relationships are demonstrated in Figure 4. Males (N=123) ranged from age 1 to 3 years. The majority (49%) of males were age 1 (N=60). Total length and weight of males averaged 308 mm (± 55.30; SE) and 273 g (± 132.54; SE) respectively. Females (N=61) ranged from 1 to 4 years. Females were larger and are longer lived than their male counterparts. Only one age-1 female was collected. Age-3 (N=33) females comprised 50% of the sample. Total length and weight of females averaged 380 mm (± 38.59; SE) and 655 g (± 243.51; SE), respectively. All age-4 shad were females. Age-4 females averaged 414 mm TL (± 19.80; SE) and 753 g W (± 51.62; SE). Females were larger than males in TL and W on average at age 2 (TL: $F = 8.06$; df = 72; $P < 0.05$; W: $F = 8.06$; df = 72; $P < 0.05$) and age 3 (TL: $F = 8.51$; df = 45; $P < 0.05$; W: $F = 9.14$; df = 32; $P < 0.05$; Figure 5).

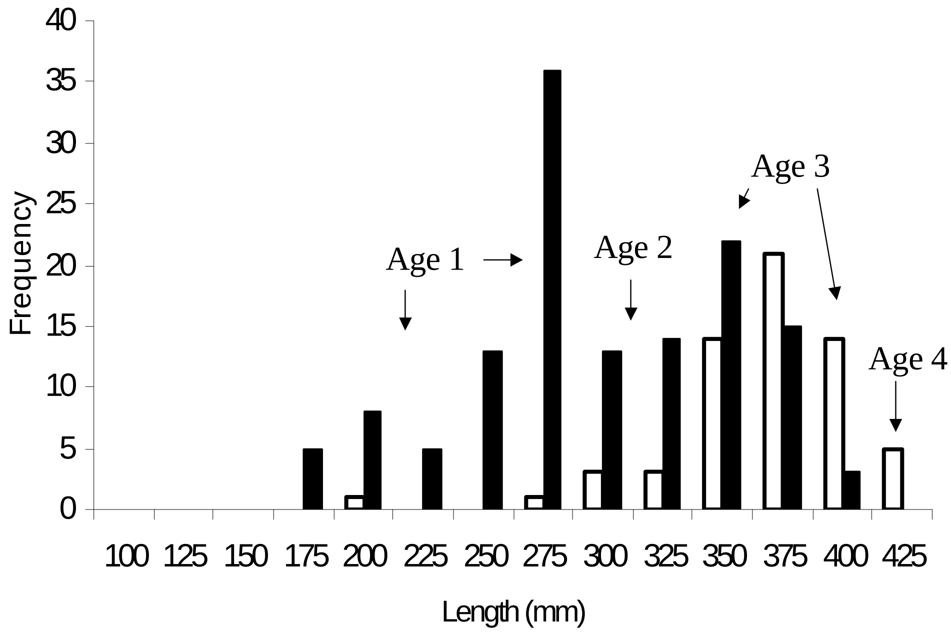


Figure 2. Length-frequency histogram of Alabama shad from the Apalachicola River. Solid and open bars represent males and females, respectively.

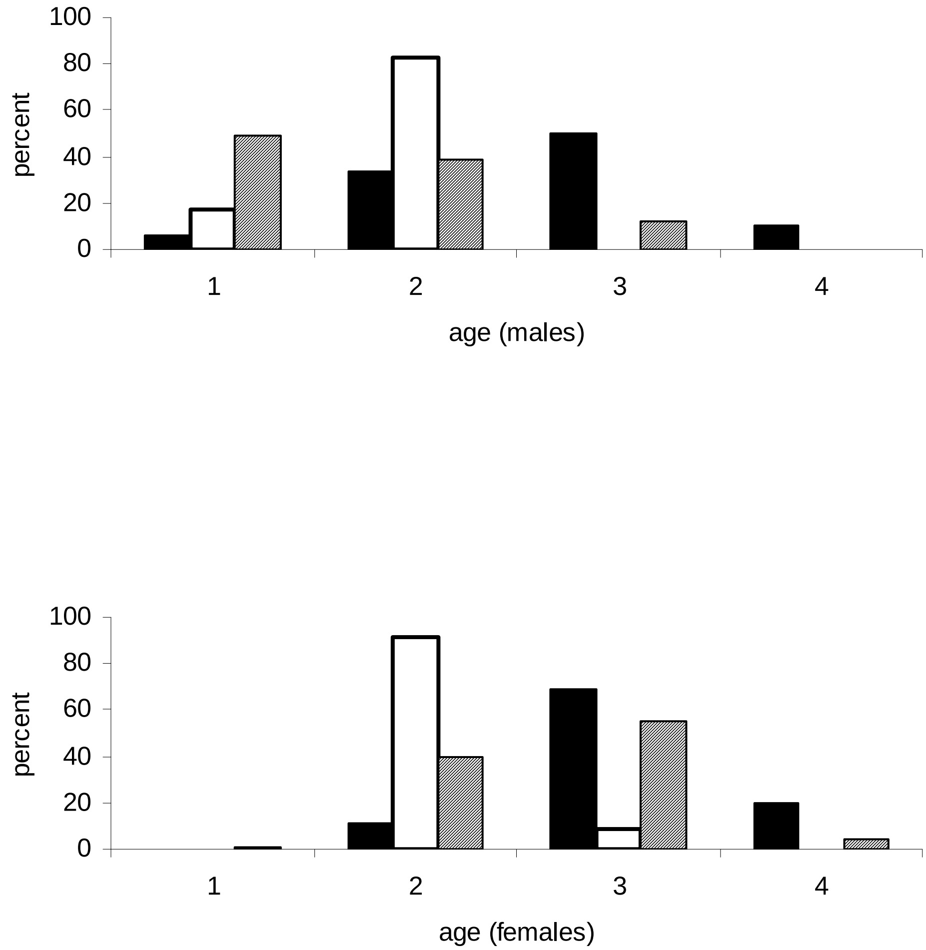


Figure 3. Percent - age distribution of males and females of Alabama shad between studies conducted in the Apalachicola River. Solid bars represent Laurence (1967), open bars represent Mills (1972), and crosshatch bars represent this study (2006).

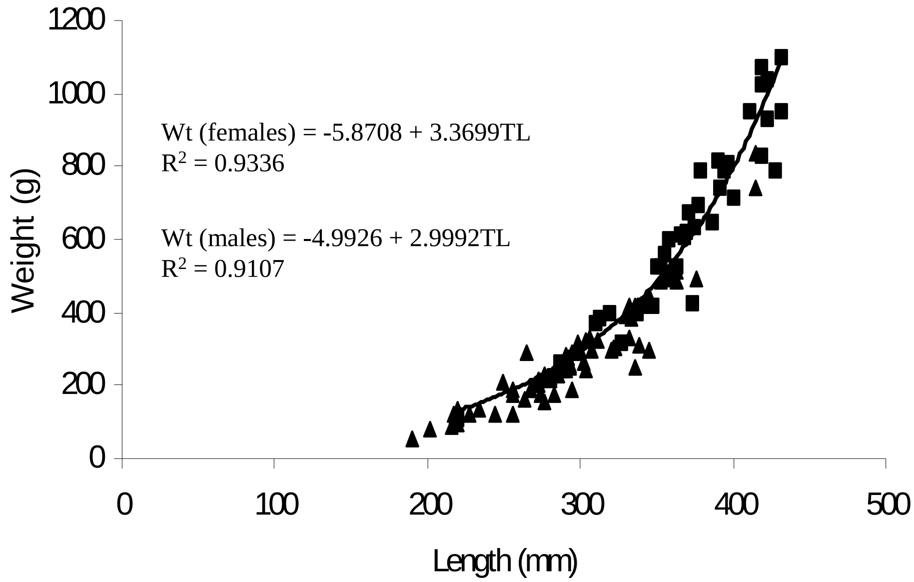
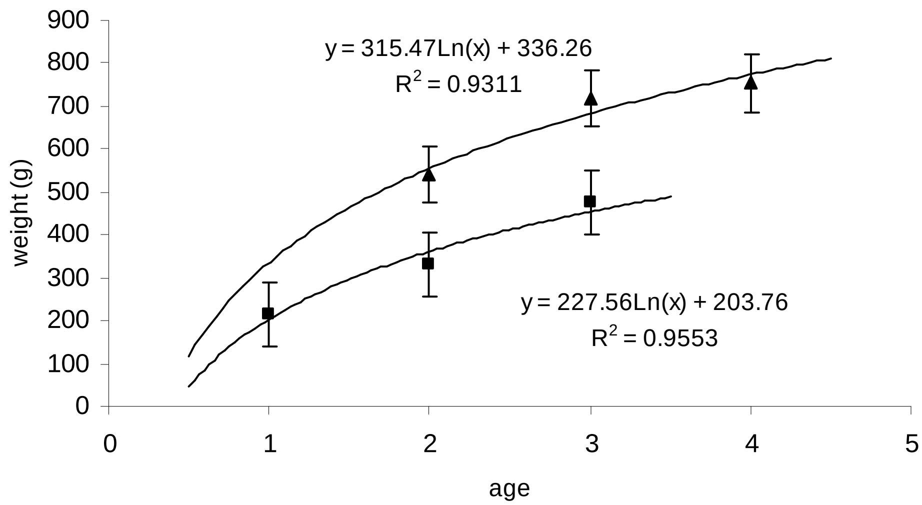


Figure 4. Length-weight relationships for male (triangles) and female (squares) Alabama shad in the Apalachicola River.



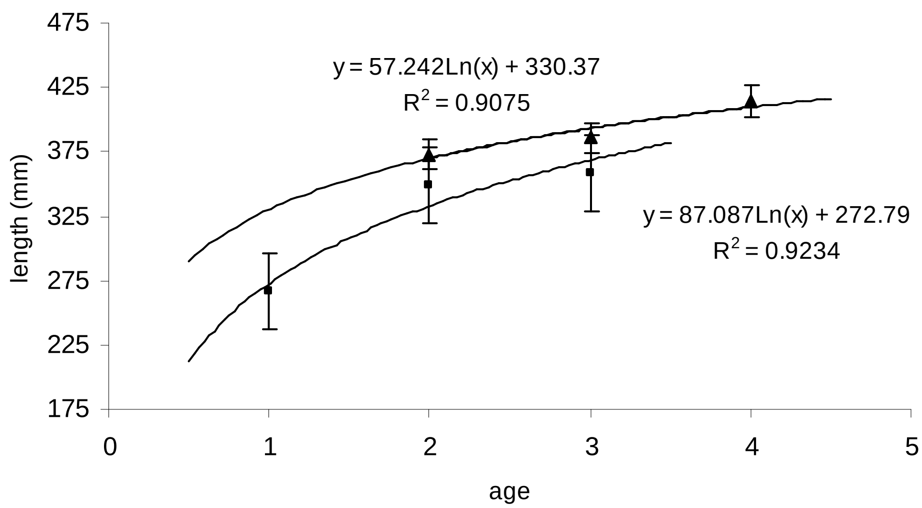


Figure 5. Relationship of weight and length at age, between female (triangles) and male (squares) Alabama shad from the Apalachicola River. Error bars represent standard error.

Growth of Alabama shad is described by the equations:

male;

$$L_t = 359.6\ [1 - e^{-2.1712(t-0.3757)}],$$

female;

$$L_t = 389.5\ [1 - e^{-2.3193(t-0.6424)}].$$

Growth models reveal larger attainable lengths for female shad (Figure 6). The following represent ninety-five percent confidence intervals for growth parameters of

female ($L_\infty \pm 13$, k ± 1.20, $t_o \pm 0.27$), and male ($L_\infty \pm 23$, k ± 2.25, $t_o \pm 0.57$) shad. Mean back-calculated lengths for each sex were similar to observed values for males (F = 7.71; df = 5; P > 0.05) and females (F = 5.99; df = 7; P > 0.05; Table 1).

Alabama shad produce between 26,095 and 208,494 eggs per female. Age-2 female fecundity estimates ranged from 30,895 to 126,419, age 3 estimates ranged from 26,095 to 185,750, and age 4 from 30,129 to 208,494 (Table 2). Average fecundity estimates in this study are similar to those in other studies on Alabama shad (Figure 7). Alabama shad show a positive correlation between fish length and egg production (Figure 8). Gonosomatic indices for Alabama shad ranged from 3.6 to 24.0.

Both scales and otoliths provided similar age estimates for Alabama shad. No difference (F = 0.27; df = 377; P > 0.05) was found between scale ages and otolith ages. No spawning marks were identified on scales.

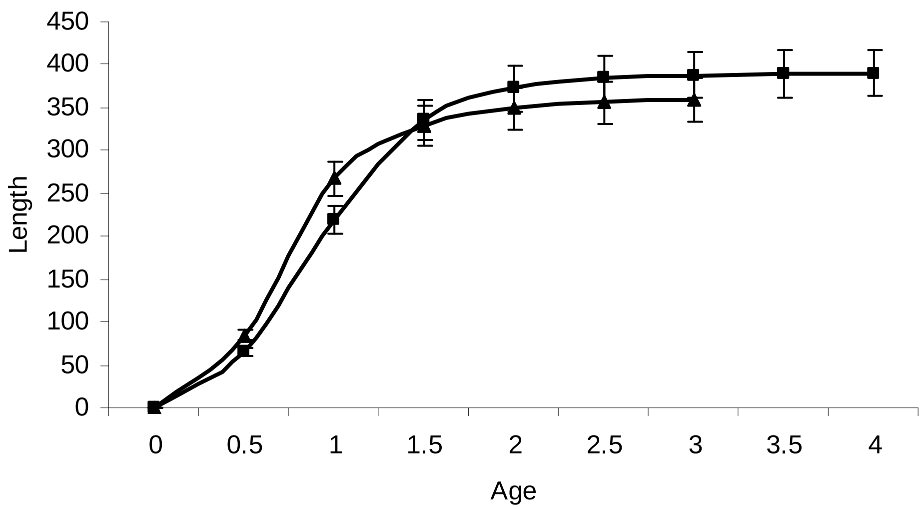


Figure 6. Comparison of von Bertalanffy modeled growth curves of male (triangle) and female (square) Alabama shad in the Apalachicola River. Error bars represent standard error.

Table 1. Mean back-calculated length (mm) of Alabama shad in the Apalachicola River.

		Length at Age (Females)			
Age Group	Number of Fish	1	2	3	4
1	1	219			
2	22	288	374		
3	31	275	344	386	
4	2	276	331	371	414
Mean TL		265	350	379	414
Actual TL		219	373	385	414

		Length at Age (Males)		
Age Group	Number of Fish	1	2	3
1	58	266		
2	49	275	348	
3	11	276	321	357
Mean TL		265	335	357
Actual TL		266	349	357

Table 2. Average fecundity estimates and gonosomatic index (ovary weight / fish weight x 100) at age for Alabama shad in the Apalachicola River.

		Total egg numbers		Gonosomatic index	
Age-class	Sample size	Range	Mean	Range	Mean
2	12	30,895-126,419	66,175	6.7-15.4	11.5
3	20	26,095-185,750	100,659	3.6-24.0	12.7
4	3	30,129-208,494	129,897	6.3-12.4	9.4

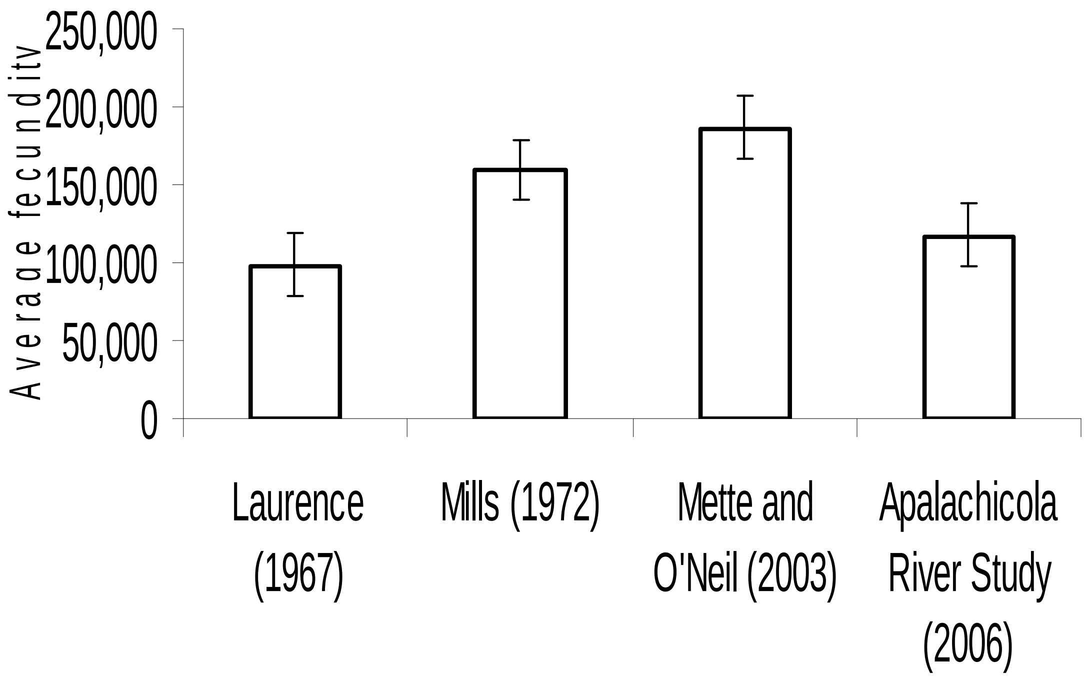


Figure 7. Average fecundity (eggs per female) for Alabama shad between studies. Error bars represent standard error.

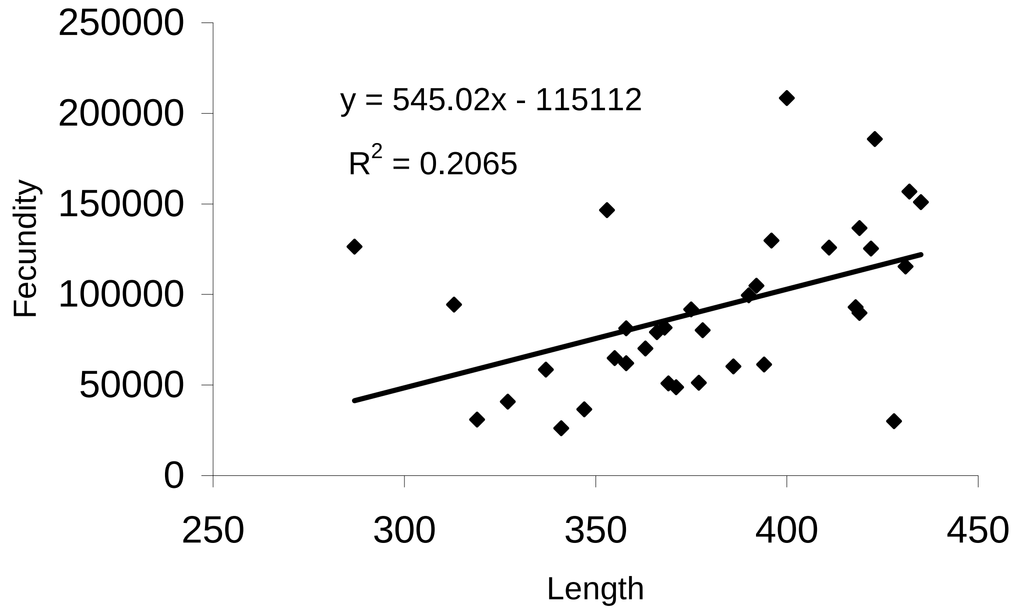


Figure 8. Fecundity of Alabama shad at total length (mm).

DISCUSSION

Alabama shad lengths and weights at age were similar to those collected by Laurence (1967) and Mills (1972). Laurence (1967) reported that age-1 and -4 males represented only a small proportion of the sample size, contrary to the higher percentage of age-1 males and no age-4 males in this study. Fewer age classes and an earlier age at maturity are consistent with over-harvested or declining populations (Olsen and Rulifson 1992). Observed differences in mean size at age between sexes observed in this study are consistent with previous studies on the species (Laurence 1967; Mills 1972) and on alosids in general (Marcy 1969; Leggett 1972).

Average fecundity estimated by Laurence (1967) was lower than observed in other studies. Walburg (1960) estimated a larger fecundity for American shad *Alosa sapidissima* in the St. Johns River; 277,000 - 659,000 eggs. Large ranges in fecundity estimates may be attributed to time of capture. Shad that have partially spawned before capture may have lower estimated fecundities than those that have not (Nigro and Ney 1982; Mettee and O'Neil 2003).

Alabama shad appear to become sexually mature earlier than American shad, which reach sexual maturity at 3-6 years of age (Nichols and Massmann 1962). LaPointe (1957) found that American shad in the St. Johns River first matured at age 3, but 4- and 5-year-old fish dominated the spawning population. American shad show a latitudinal trend in the frequency of repeat spawners (Carscadden and Leggett 1975; Glebe and Leggett 1981). LaPointe (1957) found no repeat spawners in the St. Johns River, Florida; fewer than 3% repeat spawners in the Neuse River, North Carolina, and 37% in the Susquehanna River, Maryland. Leggett (1972) hypothesized that increased water temperatures in southern regions may lead to large post spawning mortalities of American shad. This phenomenon could explain the absence of spawning marks on Alabama shad scales taken from the Apalachicola River in this study. However, Laurence (1967) found spawning marks on 32% of the Alabama shad sampled in the Apalachicola River. The discrepancies in spawning marks between these studies may be due to possible long-term effects from impediments to migration and altered flow regime. Flow regime changes could significantly affect temperatures below the dam, thus causing increased mortality during low flow years.

Although otoliths are the preferred structure to be used for age determination, scales may prove more valuable to fisheries biologists when dealing with a species of special concern where it would be unrealistic to sacrifice large numbers of specimens for aging purposes (Devries and Frie 1996). However, scales were more difficult to interpret than otoliths. Scales tend to underestimate older age fish; however, this was not a problem in the present study given the young ages of Alabama shad.

It is clear that more work is needed on the biology of Alabama shad. The construction of dams and their effects on riverine systems has had an impact on anadromous species, significantly reducing the spawning areas of many anadromous species (Rulifson 1994). More research is needed on the long-term effects of dams on Alabama shad biology. Although populations comprised of few year classes tend to rebound quickly when environmental conditions change (Rutherford et al. 1992), they also tend to be less stable than populations comprised of more year classes and may be extirpated under prolonged periods of degraded environment (Everhart and Youngs 1981). The concern over the long-term sustainability of Alabama shad populations appears to be justified.

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