Journal of the Arkansas Academy of Science

Volume 53 Article 5

1999

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Thomas M. Buchanan
University of Arkansas at Fort Smith

Josh Nichols
University of Arkansas at Fort Smith

Don Turman
Arkansas Game & Fish Commission

Colton Dennis
Arkansas Game & Fish Commission

Stuart Woolridge
Arkansas Game & Fish Commission

See next page for additional authors

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Thomas M. Buchanan* and Josh Nichols
Department of Biology
Westark College
Fort Smith, AR 72913

Don Turman, Colton Dennis, Stuart Wooldridge, and Brett Hobbs
Arkansas Game & Fish Commission
2 Natural Resources Drive
Little Rock, AR 72205

*Corresponding Author

Abstract

The anadromous Alabama shad, *Alosa alabamae*, has drastically declined in abundance in recent decades throughout its historic range and has previously been reported in Arkansas from only five localities. Three of those locality records are pre-1900. Sampling by seine in the Ouachita River drainage system of southern Arkansas in July and August of 1997 and 1998 produced more than 300 juvenile *A. alabamae* from two localities on the Little Missouri River and four localities on the Ouachita River. One record of an adult Alabama shad, taken on 4 April 1997 by an angler below Remmel Dam on the Ouachita River, was also documented. Adults apparently ascended the Ouachita River and spawned successfully in 1997 and 1998 despite the construction of four locks and dams on that river in Louisiana and Arkansas in the 1980s. The Ouachita River drainage and a few streams in east-central Missouri are currently the only known spawning areas for *A. alabamae* in noncoastal regions of the entire Mississippi River basin. Continued survival of the Alabama shad in Arkansas depends on protecting critical spawning and nursery habitats in the Ouachita River system from deleterious alteration and on preserving that migratory species' access to those habitats.

Introduction

The Alabama shad, *Alosa alabamae* Jordan and Evermann, has a unique life history pattern among Arkansas fish species. It is the only anadromous species known from Arkansas, with the adults inhabiting coastal marine environments of the Gulf of Mexico from Louisiana to Florida. The sexually mature adults ascend the Mississippi River system and a few other coastal drainages in late winter and early spring to spawn in fresh water in April and May from Florida to Missouri (Mills, 1972; Pflieger, 1997), and from May through July in more northern states (Coker, 1930). The juveniles remain in tributary streams until late summer or fall and then migrate downstream toward the ocean after reaching a length of 75-125 mm.

The Alabama shad formerly ascended the Mississippi River and many of its major tributaries, including the Red, Ouachita, Arkansas, Missouri, Ohio, and Tennessee rivers, for considerable distances (Burgess, 1980). In the late 1800s, it was common enough during its spring spawning runs to support a limited commercial fishery in the Mississippi River system (Mills, 1972) and was reportedly a highly regarded food fish (Pflieger, 1997). However, *A. alabamae* drastically declined throughout its range during the 20th century, especially in recent decades. The construction of numerous dams severely limited the number of streams available for spawning migrations, and Burr and Warren (1986) suggested that increased siltation and dredging also contributed to its decline. There are no recent records of Alabama shad from Tennessee and only one recent record (a migrating adult taken in 1986) from Kentucky (Etnier and Starnes, 1993). Burr et al. (1996) reported the first Illinois records in over 30 years, two juveniles taken from the Mississippi River (one in November 1994, and one in September 1995), and Pflieger (1997) reported several recent records of juveniles and adults from Missouri. Declines in abundance have also been recently documented in coastal drainages, such as the Pearl River system of Louisiana and Mississippi (Gunning and Suttkus, 1990), and in Alabama and Florida (Mettee et al., 1996). Mettee et al. (1996) also reported that *A. alabamae* still spawns successfully in the Choctawhatchee and Conecuh river systems in southeastern Alabama, and that the largest known remaining spawning population occurs in the Apalachicola River system of the Florida panhandle below Jim Woodruff Dam. The United States Fish and Wildlife Service (USFWS) is currently reviewing the status of the Alabama shad to determine its conservation needs (Stuart Poss, USFWS, pers. comm.).

There are only five previously reported collection localities for Alabama shad in Arkansas, and three of those records are more than 100 years old. The pre-1900 records (Fig. 1) are based on specimens in the United States National Museum (USNM) of the Smithsonian Institution and are as follows:

(1) One female specimen (USNM 22709) collected by T.M. Thorpe on 15 April 1879 from the Washita (sic) River, 8 miles from Hot Springs, AR.

(2) Three specimens (USNM 36424) collected by D.S. Jordan and C.H. Gilbert in 1884 (no month or day) from the Washita (sic) River at Arkadelphia, AR.

(3) One specimen (USNM 62225) collected by S.E. Meek (no date given) from the Mulberry River at Mulberry, AR. (the specimen was reported missing in 1946).

The approximate date of Meek's collection from the Mulberry River can be inferred. Seth Meek was a professor at the Arkansas Industrial University (University of Arkansas) and collected fishes in Arkansas from 1889 to 1893 (Robison and Buchanan, 1988). The only reported collection by Meek from the Mulberry River occurred in the spring of 1892 (Meek, 1894), and his Mulberry River specimen of *A. alabamae*, initially reported as *Clupea chrysochloris*, was almost certainly taken during that 1892 collecting trip.

The only recent records of *A. alabamae* from Arkansas were reported by Stackhouse (1982) and Loe (1983). Stackhouse reported 16 juvenile Alabama shad from the Saline River in Ashley County collected on 5 August 1972 and deposited in the Northeast Louisiana University Museum of Zoology (NLU 24173). Loe's survey of the fishes of the Little Missouri River produced three juvenile specimens of Alabama shad from the mouth of that river in Ouachita County. Two of the specimens were collected on 18 September 1982 (NLU 51697), and one specimen was taken on 24 September 1982 (NLU 51720).

Our specimens of *A. alabamae* reported herein are the first records for that species from the mainstem Ouachita River in more than 100 years. We also document its occurrence at additional sites on the Little Missouri River and provide the only recent record for an adult Alabama shad from Arkansas.

Materials and Methods

Eighteen localities in the Ouachita River drainage system of southern Arkansas were sampled by seine in 1997 and 1998. The 1997 sampling included two localities on tributary creeks of the Ouachita River in Clark County on 7 July, three localities on the Saline River in Bradley and Drew counties on 14 July, three localities on the Little Missouri River in Clark, Nevada, and Ouachita counties on 21 and 22 July, and one locality on the Ouachita River in Dallas County on 22 July. In 1998, fishes were sampled at one locality on the Saline River in Drew County on 6 July, four localities on the Little Missouri River in Clark, Nevada, and Ouachita counties on 13, 22, and 24 July, and four localities on the Ouachita River in Clark, Dallas, Hot Spring, and Ouachita counties on 13, 20, and 24 July, and 10 August.

All fish collections were made between the hours of 1000 and 1700 with 3 x 1.2 m and 9 x 1.8 m nylon seines of 3.2 mm mesh. At each collecting site all available habitats were sampled, and specimens were preserved in 10% formalin and later washed and transferred to 45% isopropanol. Preserved specimens were identified in the laboratory, and

Table 1. Comparison of morphometric characters of *Alosa alabamae* and *A. chrysochloris*.

Character	*A. alabamae*	*A. chrysochloris*
Relative lengths of upper and lower jaws	Jaws approximately equal in length	Lower jaw projecting distinctly beyond upper jaw
Number of gill rakers on lower limb of first gill arch	30 or more	24 or fewer
Scales in a lateral series	Usually more than 50	Usually fewer than 50
Dark humeral spot behind operculum	Present	Absent
Dark pigment on lower jaw	Extending along most of jaw length	Restricted to tip of jaw
Principal dorsal rays	14-16 ($\bar{x}$ = 15.5)	15-17 ($\bar{x}$ = 16.9)
Principal anal rays	18-20 ($\bar{x}$ = 18.8)	15-18 ($\bar{x}$ = 16.9)
Number of prepelvic scutes	20-22 ($\bar{x}$ = 21.4)	18-20 ($\bar{x}$ = 19.5)
Number of postpelvic scutes	13-16 ($\bar{x}$ = 15.2)	15-18 ($\bar{x}$ = 16.6)

several meristic and morphological characters were examined to determine the best features for distinguishing *A. alabamae* from the very similar skipjack herring, *A. chrysochloris* (Table 1). Fifty-six specimens of skipjack herring from the Arkansas, Mississippi, Ouachita and White river drainages of Arkansas were also examined for comparison with *A. alabamae*. At localities where *A. alabamae* was found, we measured the following habitat features: water temperature, pH, depth, current velocity, substrate composition, vegetation present, and Secchi disk visibility.

Stomach contents were examined from ten *A. alabamae* juveniles from the 24 July 1998 Ouachita River sample and from ten specimens from the 10 August 1998 Ouachita River sample. Stomach contents of each fish were identified using a dissecting microscope, and percent volume of each food item category was estimated visually. The intestinal contents, which were generally too digested to be identified and enumerated accurately, were also examined.

Alabama shad specimens were sent to L. Knapp of the Smithsonian Institution's United States National Museum (USNM) for confirmation of our identification. Twelve of those specimens from the Ouachita River were deposited in the USNM fish collection (USNM 351074). Most of the remaining preserved specimens of *A. alabamae* were catalogued into the Westark College Zoology Collection (WZC 1549, 1551, 1596, 1597, and 1598) and four specimens each were donated to the collections of Arkansas Tech University and Southern Arkansas University.

Results

Alosa alabamae was found at two of the localities sampled in the Little Missouri River and at four localities in the Ouachita River (Fig. 1) and was abundant at most of those sites. Seventy-one juvenile Alabama shad were preserved during the two summers of field work, ten in 1997 and 61 in 1998. Over 100 juvenile specimens were captured and released at each of three of the sample sites.

The ten juvenile specimens taken on 21 and 22 July 1997 ranged in total length (TL) from 47 to 65 mm ($\bar{x}$ = 56.5 mm). Thirty-four juveniles collected one year later on 22 and 24 July 1998 were 47 to 85 mm TL ($\bar{x}$ = 68.7 mm), and juveniles collected from the Ouachita River on 10 August 1998 were 103 to 131 mm TL ($\bar{x}$ = 115.5 mm).

Alosa alabamae juveniles occurred in moderate to swift current ranging in velocity from 0.47 m/s (Little Missouri River, 22 July 1998) to 1.14 m/s (Ouachita River, 10 August 1998) and at water depths of 0.55 to 0.76 m. The substrate at most sites was entirely gravel, but two sites also had small patches of sand. All collection sites had sparse to heavy growths of the filamentous green alga, *Spirogyra*, on the gravel substrate. The most upstream locality where juvenile *A. alabamae* were found on the Ouachita River (near Malvern) was the most heavily vegetated site, having dense growths of the macrophytes *Anacharis* and *Potamogeton*, in addition to *Spirogyra*. Water temperatures at the capture sites ranged from 27.8°C (Ouachita River site closest to Remmel Dam) to 32.5°C (Little Missouri River). The pH varied from 6.9 to 7.2, and water was clear, with Secchi disk visibility extending to the substrate at each site. Thirty-eight other fish species were captured at localities with *A. alabamae*.

Juvenile *A. alabamae* with a mean total length of 73.4 mm fed exclusively on benthic invertebrates in the Ouachita River. Of the ten stomachs examined from the 24 July 1998 collection, two were empty (but the intestines were full), two had only a small amount of food, and six were full. The most commonly eaten items by percent frequency of occurrence were larval Trichoptera (80%), Diptera (60%), Plecoptera (30%), Pelecypoda (10%), and terrestrial Hymenoptera (10%). By estimated percent volume, those same food items made up 70, 20, 8, 1, and 1% of the diet, respectively. The ten larger specimens ($\bar{x}$ = 113.1 mm TL) from the 10 August 1998 Ouachita River sample all had full stomachs. By percent frequency of occurrence, those stomachs contained adult Amphipoda (100%), and larval Diptera (80%), Trichoptera (80%), Odonata (20%), and Plecoptera (10%). By estimated percent volume, those food items made up 63, 21, 9, 6, and 1% of the diet, respectively. No fish remains or plant material were found in any stomachs or intestines.

Table 1 compares nine morphological and meristic features of *A. alabamae* and *A. chrysochloris*. The most reliable characters for distinguishing the two species are differences in relative lengths of upper and lower jaws, number of scales in lateral series, and number of gill rakers on the lower limb of the first gill arch. These species also differ in two pigmentary patterns, with *A. alabamae* having melanophores distributed along the lower jaw (vs pigment confined to tip of jaw in *A. chrysochloris*) and having a small, dark humeral spot (vs humeral spot absent in *A. chrysochloris*). Additional meristic features are also useful, but show some overlap in values.

We also documented a recent record for an adult Alabama shad from Arkansas. In 1997 the Arkansas Game & Fish Commission certified a new state angling record for skipjack herring, *Alosa chrysochloris*. In August 1998 we obtained the frozen specimen from the fisherman (Monte Pascoe of Hot Springs) who had caught and saved it for over one year. We reidentified that specimen and verified it to be an adult *A. alabamae*, 46 cm TL, with a mass of 1.3 kg when caught. The adult Alabama shad was caught on an artificial lure (yellow marabou leadhead jig) on 4 April 1997 in the Ouachita River immediately below Remmel Dam in swift current and was deposited in the Westark College Zoology Collection (WZC 1595).

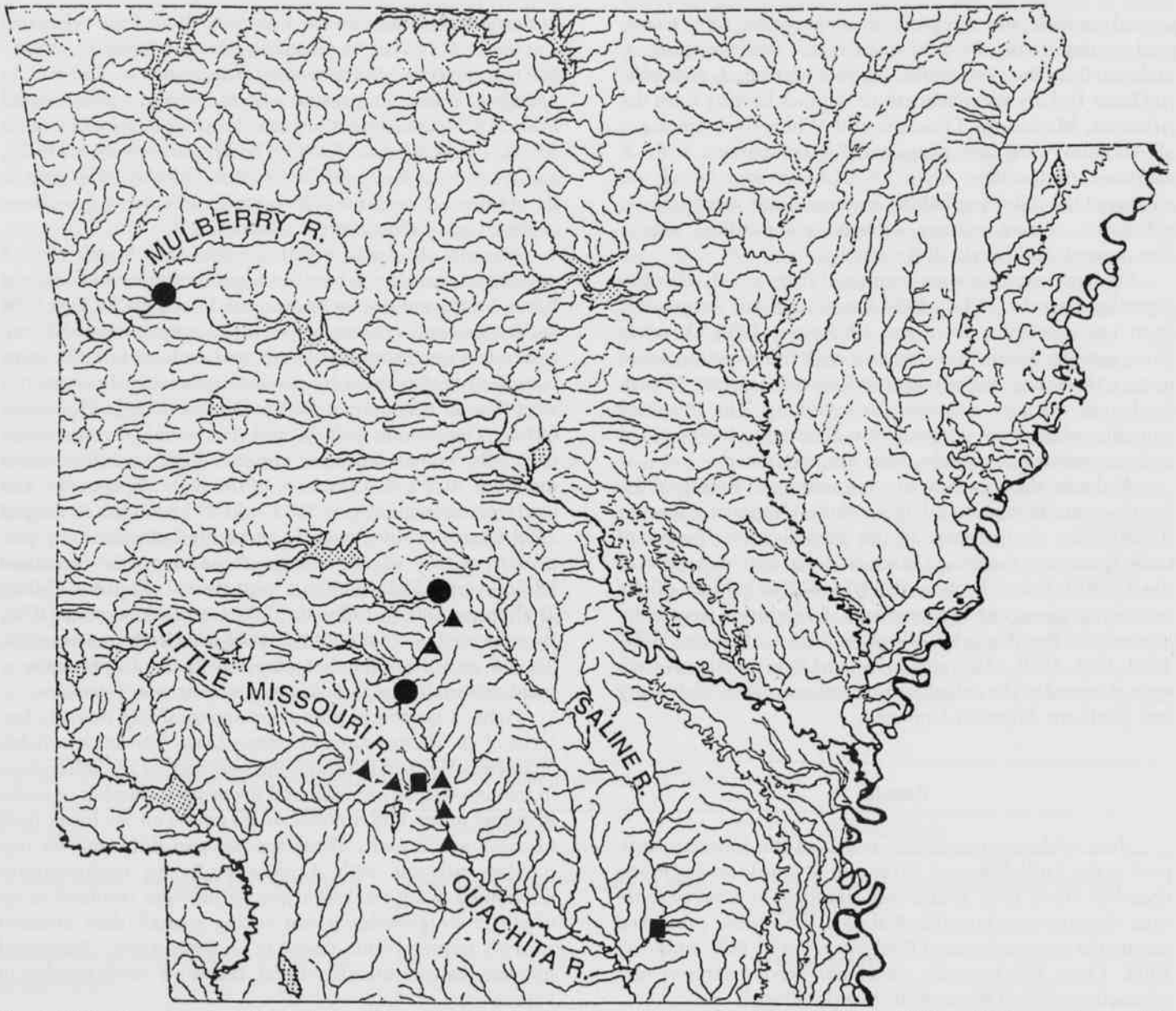

Fig. 1. Collection sites for *Alosa alabamae* in Arkansas. Circles are pre-1900 records, squares are 1972 or 1982 records, and triangles are this survey's 1997 and 1998 records.

Discussion

Alosa alabamae adults still ascend the Ouachita River system from the Mississippi River and spawn successfully in the Little Missouri and mainstem Ouachita rivers of Arkansas, despite the drastic decline of that species throughout its range. The only recent report of successful reproduction of the Alabama shad from farther inland than the Ouachita River drainage of Arkansas is from tributaries of the Mississippi River in Missouri (Pflieger, 1997). The number of juveniles preserved during our study was similar to the total number reported from 14 sites over nine years of sampling in Missouri. We probably could have taken many more juvenile specimens in our 1997 and 1998 sampling based on the large amount of suitable habitat that was not sampled at some of our collecting sites.

The main cause of the decline of the Alabama shad throughout its range appears to be the construction of barriers that prevent upstream migration to spawning grounds. In Arkansas the upstream spring spawning runs of *A. alaba-*

mae are blocked at Remmel Dam, near Jones Mills, Hot Spring Co., on the Ouachita River and at Narrows Dam, Pike Co., on the Little Missouri River, yet successful spawning apparently occurs in the tailwaters below those dams. Variability in water releases from the dams produces drastic fluctuations in discharge, current velocity, and water temperature in the spawning areas. Water levels in the rivers below the dams fluctuate as much as 1-2 m daily, and water temperatures can vary as much as 27 C° daily. The present ability of *A. alabamae* to ascend the Ouachita River system is even more remarkable considering the completion of a series of four locks and dams, two in Louisiana and two in Arkansas, on the Ouachita River in 1985. However, during March and April of most years, the peak months of the spring spawning run, high water frequently flows over and around those locks and dams, providing access to upstream habitats up to Remmel Dam.

The Saline River of Arkansas is the only remaining free-flowing major tributary of the Ouachita River, but specimens of *A. alabamae* were taken in that stream only in 1972 (Stackhouse, 1982). Previous fish sampling from the Saline River, including an extensive survey by Reynolds (1971), produced no specimens of Alabama shad. Stackhouse collected no specimens in his study in the early 1980s, and we collected no specimens from the Saline River in 1997 and 1998.

The scarcity of records of Alabama shad from Arkansas during the past century is probably related to that species' unusual life history pattern, to its overall decline in recent decades throughout its range, to the lack of sampling effort, and to the difficulty in distinguishing *A. alabamae* from the closely related skipjack herring, *A. chrysochloris*. The skipjack herring, which is widespread and common today in the largest rivers of Arkansas, is morphologically similar to the Alabama shad, and misidentifications have occurred. Records of *A. alabamae* from the Illinois, Poteau, and Little rivers of Oklahoma in the 1940s and 1950s confirm that species occurrence in the Mississippi, Arkansas, and Red rivers of Arkansas at those times (Moore, 1973). Dams on the Illinois and Little rivers now block upstream access to those rivers. Isolated records from the Mississippi River of Missouri (Pflieger, 1997), Kentucky (Etnier and Starnes, 1993), and Illinois (Burr et al., 1996) in the 1970s, 1980s, and 1990s demonstrate that adults migrated through Arkansas in those decades as well.

Our documentation of successful spawning of *A. alabamae* in the Ouachita River drainage of Arkansas in two consecutive years suggests that spawning may occur frequently in that system. Successful spawning occurred in 1972 and 1982, based on the juvenile specimens reported by Stackhouse (1982) and Loe (1983) and examined during this study. It is possible that in some years, spawning does not succeed because of the variability in discharge patterns at the dams on the Ouachita and Little Missouri rivers. It is surprising that fish surveys of the Ouachita (Raymond, 1975) and Little Missouri (Meyers, 1977) rivers produced no Alabama shad specimens, although Loe's 1983 survey did produce three juveniles from the mouth of the Little Missouri River. A recent change in the tailwater release from Narrows Dam on the Little Missouri River occurred in 1996. Prior to 1996, a cold-water release occurred, but the dam has now been modified to achieve a multi-level water release. As a result, the tailwaters are now much warmer than before for most of the year. The new release pattern, also produces a more consistent discharge in the Little Missouri River. It is not known whether the modified release pattern influenced the successful spawning of *A. alabamae* in that river in 1997 and 1998.

One possible selective advantage of the unusual anadromous life history pattern of *A. alabamae* is the rapid growth of the young in freshwater environments. Growth rates in fishes typically vary from year-to-year with varying environmental conditions. The difference in growth rates for July 1997 ($\bar{x}$ = 56.5 mm. TL) and July 1998 ($\bar{x}$ = 68.7 mm TL) may reflect such variables as food availability, water temperature, or even spawning date. Information on the growth rate in 1998 was obtained by comparing the lengths of *A. alabamae* taken on 24 July and 10 August from the Ouachita River. In approximately three weeks, the mean total length increased by 46.8 mm, assuming that the shad at those two sites hatched on approximately the same date. Based on the total lengths of the juvenile specimens collected in August 1972 (NLU 24173), September 1982 (NLU 51697, 51720), and July 1997 and 1998, spawning of Alabama shad probably occurs in Arkansas from April to early June. Juveniles have been collected in Arkansas between 22 July and 24 September.

The juveniles collected on 24 July 1998 fed primarily on Trichoptera and Diptera larvae, while larger juveniles collected three weeks later at a site further upstream fed mainly on Amphipoda and Diptera larvae. Those dietary differences were probably related more to food availability than to fish size. The latter site was heavily vegetated with macrophytes, providing more amphipod habitat, while the 24 July site lacked macrophytes, having only the filamentous green alga, *Spirogyra*. The lack of fish remains in the stomachs and intestines of the largest juveniles was surprising. Adult Alabama shad fed mainly on fish in their marine environment, and juveniles fed on small fishes and aquatic insects in the Apalachicola River, Florida (Laurence and Yerger, 1966).

Two of the three pre-1900 Arkansas records for *A. alabamae* came from the Ouachita River, and the third came from near the mouth of the Mulberry River (Arkansas River). This species may no longer be able to ascend the Arkansas River due to the construction of 17 locks and dams on the river in Arkansas and Oklahoma. During the last 25 years, the Arkansas River has been extensively sampled by seine (more than 200 samples by T. Buchanan), rotenone (at least

six annual samples by the Arkansas Game & Fish Commission), and various sampling methods by the U.S. Army Corps of Engineers (Sanders et al., 1985). *Alosa chrysochloris* was commonly reported in those sampling efforts, but no *A. alabamae* specimens were found. The Ouachita River drainage of Arkansas and a few streams in east-central Missouri are currently the only known spawning areas for *A. alabamae* in noncoastal regions of the entire Mississippi River basin. The continued survival of the Alabama shad as part of the Arkansas fish fauna depends on protecting its critical spawning and nursery habitats in the Ouachita River system from deleterious alteration and on preserving access to those habitats for that migratory species. It is important to identify the conditions required by *A. alabamae* for successful spawning in the Ouachita and Little Missouri rivers and to learn as much as possible about its biology in those fresh waters. That information is essential for making recommendations about water release patterns from Narrows and Remmel dams, especially during spawning runs, to provide optimum conditions for the conservation of this rare species.

ACKNOWLEDGMENTS.—We are grateful to Westark College for providing partial funding for this study through a faculty development grant and the Scholar-Preceptor Program. Additional funding was provided through a National Science Foundation grant to South Central Partnership for Environmental Technology Education for an internship by TMB with the Arkansas Game & Fish Commission. We also thank Leslie Knapp of the United States National Museum for verifying our identification of *Alosa alabamae*, Neil Douglas of Northeast Louisiana University for the loan of specimens from the NLU Museum of Zoology, and Charles J. Gagen of Arkansas Tech University for a helpful review of the manuscript. Jerry Smith, Diana Saul, Randy Johnson, Daniel Ellis, Deanna Buie, and Ross Wooldridge assisted in the field work, and Cheryl Pacheco and Vicki Bond helped prepare the manuscript.

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