Pilarczyk et al 2006

2006 SOUTHEASTERN NATURALIST 5(2):205–226

Current and Recent Historical Freshwater Mussel Assemblages in the Gulf Coastal Plains

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Abstract - This study qualitatively surveyed freshwater mussel assemblages at 24 sites in the Choctawhatchee, Yellow, and Conecuh-Escambia river drainages of southeastern Alabama and northwest Florida in 2004. A specific focus of the study was to determine the current status of seven narrowly endemic candidate species: *Margaritifera marrianae*, *Fusconaia escambia*, *Hamiota australis*, *Pleurobema strodeanum*, *Ptychobranchus jonesi*, *Quincuncina burkei*, and *Villosa choctawensis*. Presence-absence analysis was used to compare 2004 data to recent historical records from the 1990s. There was no significant difference between the number of taxa found in the 1990s and in 2004. There was, however, a significant decrease from the 1990s to 2004 in the number of candidate species found at a site and the number of sites at which candidate species were found.

Introduction

The greatest diversity of freshwater mussels (Bivalvia: Margaritiferidae and Unionidae) in the world is found in North America (Williams et al. 1993). Over 90% of the 297 species endemic to the United States inhabit the southeastern portion of the country, and a vast majority of these species belongs to the Unionidae (Neves et al. 1997, Williams et al. 1993). The Southeast's riverine ecosystems may partially explain the high diversity levels of freshwater mussels found in the region. These riverine ecosystems are historically more permanent entities than other aquatic environments, such as lakes, and contain greater physical and chemical variability that results in a wide range of biological niches, from small headwater streams to large coastal plain rivers (Neves et al. 1997). While riverine systems like those in the Southeast are found in other parts of the United States, southeastern systems are often coupled with a variety of different ecoregions. For instance, Alabama, which contains more freshwater mussel species (175) than any other US state (Neves et al. 1997), is comprised of six different level III ecoregions (Griffith et al. 2001).

Despite their high levels of diversity, freshwater mussels are among the most threatened faunal groups in the United States, with over 70% of unionids listed as extinct or imperiled due to habitat degradation and

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introductions of non-native species (Master 1993, Neves et al. 1997, Williams et al. 1993). The plight of freshwater mussels is seen by many as representative of the imminent biodiversity crisis in the streams of North America. Unionids are threatened by a variety of stressors such as sedimentation, channelization, impoundments, human and animal refuse, and toxic chemical waste (Neves et al. 1997, Schloesser and Nalepa 1995, Stewart and Swinford 1995, Stewart et al. 2000). Anthropogenically induced habitat alterations have been implicated as factors responsible for reducing the abundance and diversity of freshwater mussels (Havlik and Marking 1987, Neves 1999, Schloesser et al. 1996).

Numerous studies have documented decreases in diversity and abundance among mussel assemblages in southeastern United States riverine systems (Ahlstedt 1983, Blalock-Herod et al. 2005, Garner and McGregor 2001, Houp 1993, Hughes and Parmalee 1999, McGregor and Garner 2004, McGregor et al. 2000, Parmalee et al. 1982, Schmidt et al. 1989, Stansbery 1973). The present study surveyed freshwater mussel assemblages at 24 sites in southeastern Alabama and northwest Florida in 2004 and compared current population data to recent historical population data collected in the 1990s. The current status of seven narrowly endemic mussel species—*Margaritifera marrianae* Johnson, *Fusconaia escambia* Clench and Turner, *Hamiota australis* (Simpson), *Pleurobema strodeanum* (Wright), *Ptychobranchus jonesi* (van der Schalie), *Quincuncina burkei* (Walker), and *Villosa choctawensis* Athearn—was of particular interest in this study. All are members of the Unionidae except for *Margaritifera marrianae,* which belongs to the Margaritiferidae. *Margaritifera marrianae* was classified by the US Fish and Wildlife Service as a candidate for Endangered Species Act protection in 1999 (US Fish and Wildlife Service 1999), and the other six species of interest were recently elevated as candidates in 2004 (US Fish and Wildlife Service 2004). The purpose of this study was to report the current status, with a historical perspective, of freshwater mussel assemblages, particularly candidate species, in the Choctawhatchee, Yellow, and Conecuh-Escambia river drainages.

Methods

Study area

The study area is within the Choctawhatchee, Yellow, and Conecuh-Escambia river drainages (Fig. 1), which are located within the Southeastern Plains Level III ecoregion of southeastern Alabama and northwestern Florida (Griffith et al. 2001). This area lies between the Apalachicola River basin in the east and the Mobile River basin in the west. The substrate of the ecoregion is primarily comprised of sand, clay, marl, and limestone (Sawyer et al. 2004). Biological diversity of this area was shaped about 60 million

years ago, when the area was drowned by the ocean, forcing freshwater organisms into isolated refuges (Hilton 2000).

The Choctawhatchee River drains an area of 8608 km^2, 59% of which is located in southeast Alabama (Northwest Florida Water Management District 2002). The Yellow River drainage basin covers about 2208 km^2, mostly in Florida (US Environmental Protection Agency 1998). The Conecuh-Escambia River drainage basin spans nearly 9000 km^2 and is located primarily in the central portion of southern Alabama, where it is the Conecuh River, and in northwest Florida, where it is the Escambia River (US Environmental Protection Agency 1998).

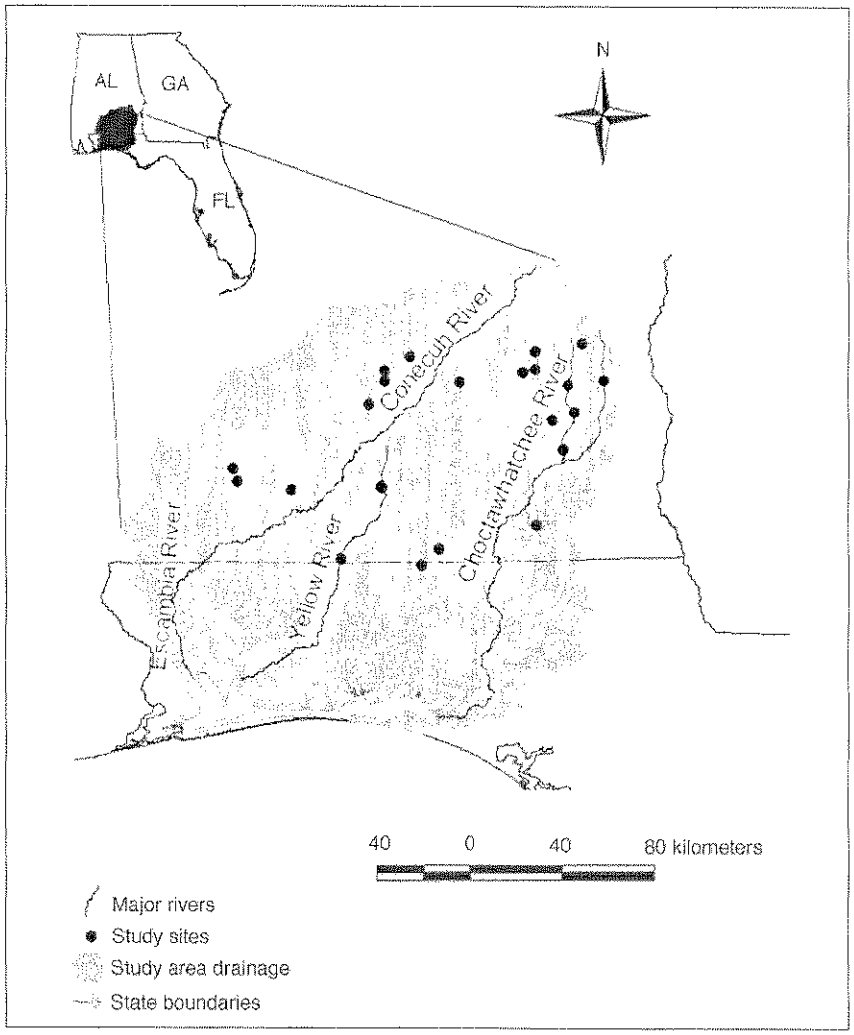

Figure 1. Sites surveyed for mussels in 2004 in the Choctawhatchee, Yellow, and Conecuh-Escambia river drainages.

Sites for this study were selected based on locations previously surveyed in the Choctawhatchee, Yellow, and Conecuh-Escambia river drainages from 1991–1999 (Blalock-Herod et al. 2005; J.D. Williams, unpubl. data). Survey sites were given a site identification number for the 2004 survey (Table 1). Sites included in this survey were typically ones at which one or more candidate species were historically found. Fourteen sites are in the Choctawhatchee River drainage, two sites are in the Yellow River drainage, and eight sites are in the Conecuh-Escambia River drainage. All study sites are in Alabama except for Eightmile Creek (04028), which is located in Walton County, FL.

Recent historical records

Records of collections from 1991–1999 were taken from Blalock-Herod et al. (2005) and J.D. Williams (unpubl. data). Both of these studies used qualitative tactile searches covering 100–500 m of stream reach, and each site was surveyed for at least 1.5 man hours until all suitable habitats had been examined. Within the Choctawhatchee basin, surveys were conducted across 100–500 m, for a minimum of 1.5 man hours, searching all suitable habitats, and were then terminated after 15 minutes had elapsed following collection of the last new species (Blalock-Herod et al. 2005).

Contemporary records

Recent distributions were determined by revisiting 24 sites surveyed in the 1990s during summer 2004. Methods followed recently drafted mussel survey protocols (Carlson et al. 2003). Mussel assemblages at each site were assessed using qualitative visual and tactile searches that covered a minimum of 150 m upstream and 250 m downstream from the bridge crossing. Search times at each site averaged 7.4 man hours (s.e. ± 0.34).

Mussels were collected in a mesh bag, identified to species, and classified as live, fresh dead (FD), or weathered dead (WD). Common and scientific names follow Turgeon et al. (1998), except for *Hamiota australis*, which follows Roe and Hartfield (2005), and *Quadrula succissa*, which follows Lydeard et al (2000). The number of individuals for each species was recorded. Mussels were returned to the stream by placing them in the substrate at the site of collection. A minimal number of voucher specimens were collected, preserved in 70% ethanol, and deposited in the Troy University collection.

Comparison of recent historical and current data

Records from the 1990s used in this study do not always quantitatively account for the total number of individuals found at a site. Often, all that was recorded was the number and identity of voucher specimens that were retained. Presence-absence analysis was therefore used to compare current and recent historical records. Presence-absence data were determined at each site for live taxa and total taxa, which includes both live individuals and

those represented only by shell material. Presence-absence data for 19 of the 24 sites surveyed in 2004 were compared to data from only one recent historical visit. Current survey data from the West Fork Choctawhatchee River (04005) and Little Patsaliga Creek (04060, 04061) were compared to data from two recent historical visits, and 2004 data from Bottle Creek (04055) and Jordan Creek (04057) were compared to data from four recent historical visits. In cases where current data were compared to data from more than one recent historical visit, the total number of taxa found historically was determined by counting all species reported by the multiple recent historical visits. The nonparametric Wilcoxon Signed Ranks test ($\alpha = 0.05$) was used to evaluate the change from the 1990s to 2004 in the total number of taxa found at a site, based on both live taxa and total taxa.

Since the number of species found at a site will likely increase, up to a certain point, with the number of visits to that site, it is possible that comparing data from only one recent visit to data from multiple recent historical visits may skew the results. Thus, the presence-absence data was also analyzed using a second approach. For sites with data from more than one recent historical visit, the "best effort" visit was evaluated. This means that current data was compared to data from the one recent historical visit where the most species were recorded. The best effort recent historical visit chosen for a site was sometimes different for live taxa and total taxa and was analyzed accordingly.

Recent historical records refer to the *Uniomerus* species found in the Choctawhatchee, Yellow, and Conecuh-Escambia river drainages as *Uniomerus tetralasmus* (Blalock-Herod et al. 2005; J.D. Williams, unpubl. data). However, the *Uniomerus* species found in the Choctawhatchee, Yellow, and Conecuh-Escambia river drainages is classified by the recent 2004 survey data as *Uniomerus carolinianus*. Rather than debating taxonomy and challenging established names, this paper will refer to this species as *Uniomerus* sp. The taxonomy for *Toxolasma* species also has not been resolved. All species determinations are based on shell characters that vary little between species, and there is considerable disagreement as to the distribution of *Toxolasma* species (D.N. Shelton, pers. observ.). Therefore, this paper will refer to this group as *Toxolasma* sp.

A particular focus in this study is the current status of the seven candidate species. Thus, to show trends for these candidate species, the Wilcoxon Signed Ranks test ($\alpha = 0.05$) was used to evaluate the number of candidate species found at a site when comparing the recent historical records of the 1990s to recent data from the 2004 survey. This presence-absence data, like the total number of taxa data, was evaluated using the two statistical approaches described above for only the candidate species. The change in the number of sites from the 1990s to 2004 at which candidate species were found was also analyzed using the Wilcoxon Signed Ranks test. In this case,

multiple recent historical visits were viewed as one unit, and if a particular species was found during any of the recent historical visits, it was considered present in the 1990s.

Results

Survey summary

Twenty-four sites were surveyed from late May 2004 to late July 2004 (Table 1). Twenty-four taxa were found historically, and 23 taxa were found during the current survey (Appendix 1). Twenty-one of these species were represented by live taxa, and two (*Anodontoides radiatus* and *Megalonaias nervosa*) were represented only by FD shells. *Corbicula fluminea* (Asian clams) were encountered at most sites. However, since this alien species is so ubiquitous throughout the survey area, *C. fluminea* data were not counted or recorded. No *Dreissena polymorpha* (zebra mussels) were detected within the survey area.

Since this survey focused its efforts on finding live taxa, the data will be addressed from the perspective of number of species based on live organisms found. The number of live species found per site ranged from 0 to 12. The site with the greatest number of live species was the West Fork Choctawhatchee River (04005). Ten species were found at Flat Creek (04027), which was the

Table 1. Sites in the Choctawhatchee (C), Yellow (Y), and Conecuh-Escambia (C-E) river drainages surveyed for mussels during summer 2004.

Site name	ID #	Drainage	Coordinates
West Fork Choctawhatchee River	04005	C	N31°39.765' W085°30.332'
Trib. to Lindsey Creek	04008	C	N31°49.351' W085°26.560'
Flat Creek	04027	C	N31°02.590' W086°06.076'
Eightmile Creek	04028	C	N30°58.835' W086°10.762'
Yellow River	04029	Y	N30°58.835' W086°10.762'
Patsaliga Creek	04030	C-E	N31°35.768' W086°24.286'
Pea River	04031	C	N31°42.868' W085°42.448'
Pea Creek	04032	C	N31°47.744'W085°39.167'
Big Creek	04033	C	N31°40.688' W085°59.696'
Big Creek	04034	C	N31°43.507' W085°39.273'
East Fork Choctawhatchee River	04035	C	N31°40.667' W085°20.726'
Judy Creek	04036	C	N31°31.592' W085°35.009'
West Fork Choctawhatchee River	04037	C	N31°33.288' W085°28.916'
West Fork Choctawhatchee River	04038	C	N31°24.644' W085°32.123'
East Fork Choctawhatchee River	04039	C	N31°24.645' W085°32.123'
Hurricane Creek	04040	C	N31°07.761' W085°39.397'
Yellow River	04041	Y	N31°16.432' W086°20.932'
Bottle Creek	04055	C-E	N31°16.124' W086°45.822'
Murder Creek	04056	C-E	N31°18.115' W087°00.759'
Jordan Creek (Trib. To Murder Creek)	04057	C-E	N31°20.981' W087°01.653'
Pigeon Creek	04059	C-E	N°31.28.581' W087°08.807'
Little Patsaliga Creek	04060	C-E	N31°41.155' W086°20.098'
Little Patsaliga Creek	04061	C-E	N31°43.712' W086°19.845'
Patsaliga Creek	04062	C-E	N31°46.858' W086°13.437'

second highest number of species. Judy Creek (04036) and Bottle Creek (04055) had no live species, and Hurricane Creek (04040) also had low species richness, with only two live species.

Current vs. recent historical data

Current and recent historical records of live and total taxa were reviewed to derive presence-absence data (Appendix 1). There was no significant difference between the total number of taxa found in 2004 and the total number of taxa found during all visits of a site in the 1990s for live taxa ($Z = -0.131$, $p = 0.895$) and total taxa ($Z = -0.543$, $p = 0.587$). When comparing records for live taxa from the 1990s to 2004 data for the number of taxa reported at a site, four had no change, nine had an increase in the number of taxa, and 11 showed a decrease in the number of taxa found (Fig. 2). The number of species represented by total taxa reported in 2004, when compared to the recent historical data, remained the same at three sites, increased at nine sites, and decreased at 12 sites. When the 2004 data was compared to the best effort recent historical site, the results were similar, with no significant difference between the total number of taxa represented by live taxa ($Z = -0.081$, $p = 0.935$) and total taxa ($Z = -0.445$, $p = 0.656$).

The number of candidate species represented by live taxa reported at a site was compared for 1990s records and 2004 data (Fig. 3). There was a statistically significant decrease in the number of candidate species found at a site from the 1990s to 2004 for both live taxa ($Z = -2.435$, $p = 0.015$) and total taxa ($Z = -2.946$, $p = 0.003$). Greater numbers of candidate species were found in 2004 than were reported historically at two of the 24 sites, the Yellow River (04029) and Murder Creek (04056). Twelve sites had no change, and fewer candidate species were reported in 2004 than historically at 10 of the sites. When comparing the number of candidate species reported at a site using total taxa, only the Yellow River (04029) had an increase in the number of candidate species reported in 2004. Eleven sites showed no change, and 12 sites had a decrease in the number of candidate species reported in 2004. When the number of candidate species at a site in 2004 was compared with the historically best effort visit to a site, there was also a significant difference for live taxa ($Z = -2.389$, $p = 0.017$) as well as total taxa ($Z = -2.946$, $p = 0.003$).

The number of sites at which candidate species were reported was also analyzed for both live and total taxa (Fig. 4). *Ptychobranchus jonesi* showed no change between the 1990s and 2004 in the number of sites at which it was reported. The number of sites at which *M. marrianae*, *F. escambia*, *H. australis*, *P. strodeanum*, *Q. burkei*, and *V. choctawensis* were found decreased between the 1990s and 2004. *Pleurobema strodeanum* had the largest decrease in the number of sites at which live taxa were reported, from 17 of 24 selected sites in the 1990s to 11 of 24

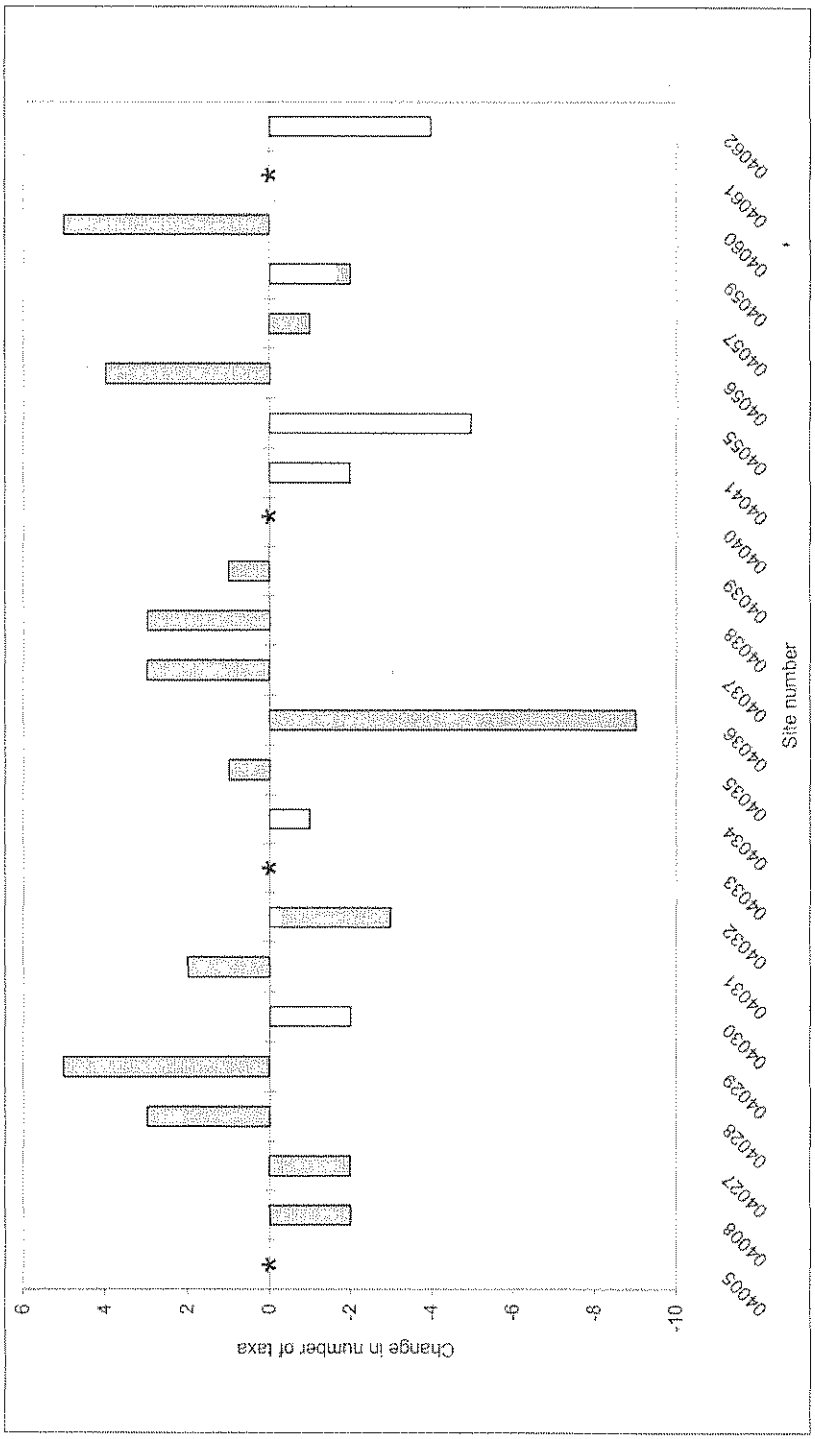

Figure 2. Change in the number of mussel species (represented by live taxa) reported at a site from the 1990s (zero line) to 2004; * = no change.

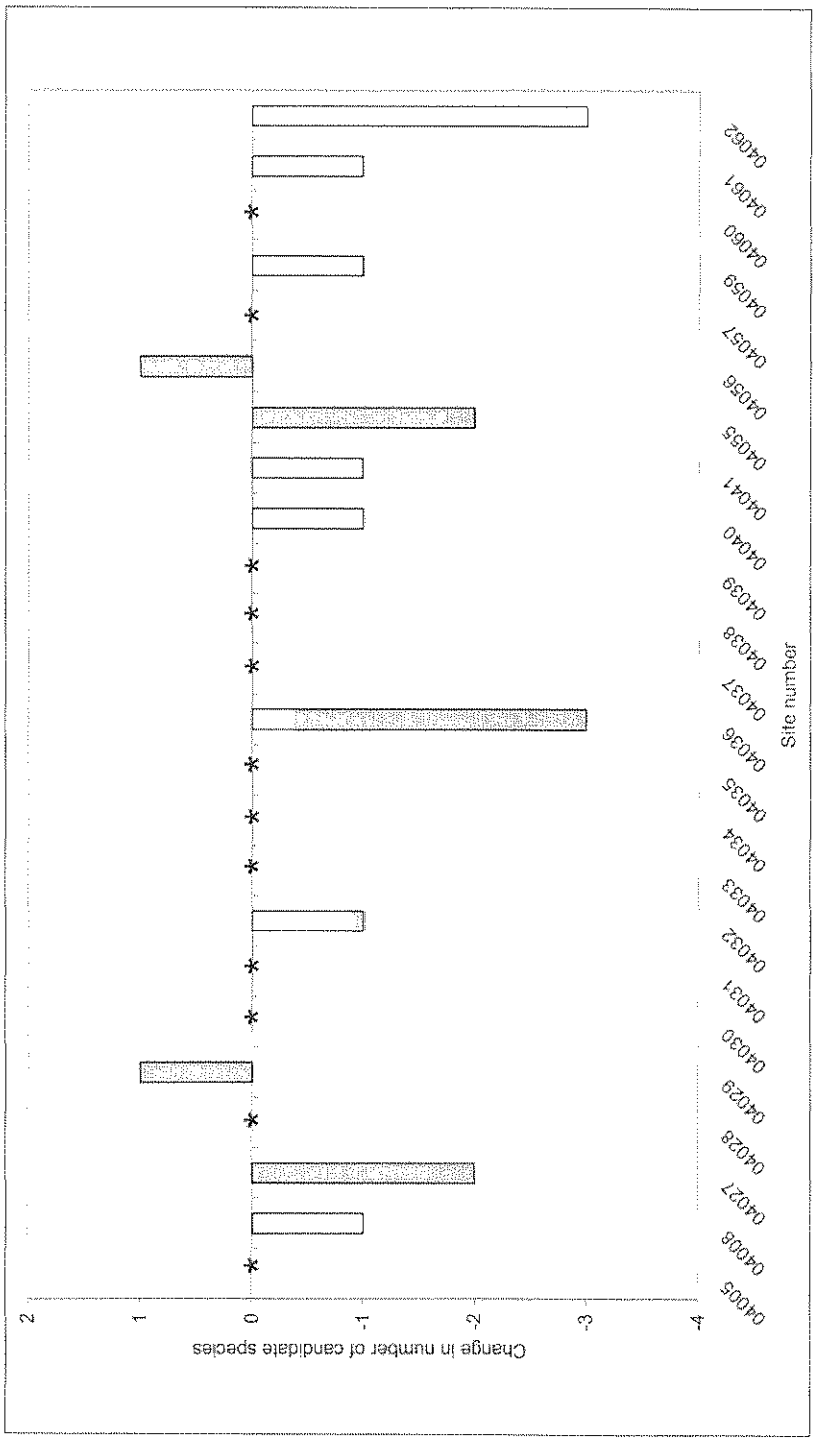

Figure 3. Change in the number of candidate species (represented by live taxa) reported at a site from the 1990s (zero line) to 2004; * = no change.

selected sites in 2004. There were significantly fewer candidate species reported at a site in 2004 than in the 1990s for both live taxa ($Z = -2.226$, $p = 0.026$) and total taxa ($Z = 2.214$, $p = 0.027$).

Candidate Species Accounts

The total number of individuals for each species found at a site is available for the 2004 survey data. As mentioned previously, the recent historical records did not always report the total number of individuals at each site. Recent historical records are reported below in a presence-absence format that includes both live taxa and shell material.

Margaritifera marrianae (Alabama pearlshell)

Margaritifera marrianae is endemic to south-central Alabama, where populations are found in the headwaters of the Conecuh-Escambia River drainage and a tributary of the lower Alabama River (Mott and Hartfield 1994, Shelton 1997). This species was encountered historically at two of the 24 sites selected for resurvey (Appendix 1). Individuals were found at Bottle Creek (04055) in 1993, 1995, and 1999, and at Jordan Creek (04057) in 1991, 1992, 1993, and 1995 (J.D. Williams, unpubl. data). In 2004, *M. marrianae* was found at only one site, Jordan Creek (04057),

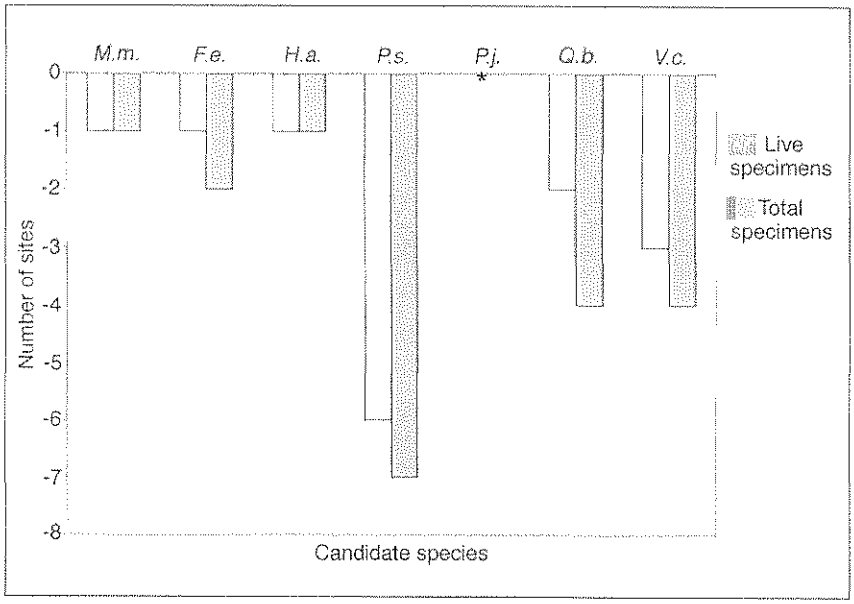

Figure 4. Change from 1990s to 2004 in the number of sites at which candidate species (represented by live and total taxa) were found; *M.m* = *Margaritifera marrianae*; *F.e.* = *Fusconaia escambia*; *H.a.* = *Hamiota australis*; *P.s.* = *Pleurobema strodeanum*; *P.j.* = *Ptychobranchus jones; Q.b.* = *Quincuncina burkei*; *V.c.* = *Villosa choctawensis*;* = no change.

where 13 live individuals, three FD shells, and one WD shell were found upstream of the US Highway 31 Bridge, and one live specimen was found downstream of the bridge.

***Fusconaia escambia* (narrow pigtoe)**

The native range of *F. escambia* is the Conecuh-Escambia and Yellow river drainages (Johnson 1969, Williams and Butler 1994), though it is no longer present in the Yellow River drainage (J.D. Williams, unpubl. data). *Fusconaia escambia* was reported during the 1990s at three of the 24 sites resurveyed for this study (Appendix 1). This species was found in 1993 at Bottle Creek (04055), and in 1995 at Patsaliga Creek (04030, 04062) (J.D. Williams, unpubl. data). During the 2004 survey, *F. escambia* was found at only one site, Patsaliga Creek (04030), where two live *F. escambia* were found upstream of the Alabama Highway 106 Bridge.

***Hamiota australis* (southern sandshell)**

The distribution of *Hamiota australis* includes the Conecuh-Escambia, Yellow, and Choctawhatchee river drainages in Alabama and Florida (Blalock-Herod et al. 2002). During the 1990s, *H. australis* was reported at six of the 24 recent historical sites selected for resurvey (Appendix 1). Individuals of this species were found at the West Fork Choctawhatchee River (04005) in 1993, at Patsaliga Creek (04062) in 1995, at Flat Creek (04027), Eightmile Creek (04028), and Pea Creek (04032) in 1998, and at the East Fork Choctawhatchee River (04035) and the West Fork Choctawhatchee River (04005) in 1999 (Blalock-Herod et al. 2005; J.D. Williams, unpubl. data).

Hamiota australis was found at five of the 24 sites resurveyed in 2004. At the West Fork Choctawhatchee River (04005), 13 live individuals were found upstream of the Alabama Highway 10 Bridge, and six live individuals were found downstream of the bridge. At Eightmile Creek (04028), four live specimens were encountered upstream of the Florida Highway 181 bridge, and seven were found downstream of the bridge. One live *H. australis* individual was encountered downstream of the bridge at each of the following sites: the Yellow River (04029), the East Fork Choctawhatchee River (04035), and Jordan Creek (04057).

***Pleurobema strodeanum* (fuzzy pigtoe)**

Pleurobema strodeanum is endemic to the Conecuh-Escambia, Yellow, and Choctawhatchee river drainages in Alabama and Florida (Blalock-Herod et al. 2005). In the 1990s, *P. strodeanum* was found at 18 of the 24 recent historical sites selected for resurvey (Appendix 1). This species was reported in 1991 at Murder Creek (04056), in 1993 at Bottle Creek (04055) and the West Fork Choctawhatchee River (04005), and in 1995 at Patsaliga Creek (04030, 04062), Pigeon Creek (04059), Jordan Creek (04057), and Little Patsaliga Creek (04061) (Blalock-Herod et al. 2005; J.D. Williams,

unpubl. data). This species was also found at Flat Creek (04027), Eightmile Creek (04028), the Pea River (04031), and Pea Creek (04032) in 1998 (Blalock-Herod et al. 2005). In 1999, it was reported at Bottle Creek (04055), the West Fork Choctawhatchee River (04005, 04037), a tributary to Lindsey Creek (04008), the East Fork Choctawhatchee River (04035, 04039), Judy Creek (04036), and Hurricane Creek (04040) (Blalock-Herod et al. 2005; J.D. Williams, unpubl. data).

During the 2004 survey, *P. strodeanum* was found at 11 of the 24 resurveyed sites. At the West Fork Choctawhatchee River (04005), 47 live individuals were found upstream, and 71 live individuals were encountered downstream of the Alabama Highway 10 Bridge. One *P. strodeanum* individual was found upstream of the Alabama Highway 153 Bridge at Flat Creek (04027). At Eightmile Creek (04028), 27 live specimens were found upstream of the Florida Highway 181 Bridge, and 74 live individuals were found downstream of the bridge. Upstream of the Alabama Highway 106 Bridge at Patsaliga Creek (04030), two live *P. strodeanum* were found. At the Pea River (04031), four live specimens and one FD shell were encountered upstream of the Alabama Highway 10 Bridge, and two live individuals were found downstream of the bridge. Five live and two WD specimens were found at Pea Creek (04032) upstream of the County Road 9 Bridge. At the East Fork Choctawhatchee River (04035), one live individual was found downstream of the County Road 54 Bridge. Two live *P. strodeanum* were found downstream of the bridges at both the West Fork Choctawhatchee River (04037) and the East Fork Choctawhatchee River (04039). At Murder Creek (04056) and Patsaliga Creek (04062), one live individual was found upstream of each of the bridges.

***Ptychobranchus jonesi* (southern kidneyshell)**

The distribution of *P. jonesi* is reported as the Conecuh-Escambia, Yellow, and Choctawhatchee River systems of Alabama and Florida (Burch 1975, Butler 1989), with recent records indicating the presence of this species in the West Fork Choctawhatchee River (Blalock-Herod et al. 2005). *Ptychobranchus jonesi* was found during the 1990s at only one of the 24 sites selected for resurvey (Appendix 1). In 1999, this species was reported at the West Fork Choctawhatchee River (04005) (Blalock-Herod et al. 2005). Recently, in 2004, two live individuals were found downstream of the Alabama Highway 10 Bridge at this same site (04005).

***Quincuncina burkei* (tapered pigtoe)**

Quincuncina burkei is endemic to the Choctawhatchee River drainage in southern Alabama and western Florida (Blalock-Herod et al. 2005). During the 1990s, *Quincuncina burkei* was found at eight of the 24 recent historical sites selected for resurvey (Appendix 1). *Quincuncina burkei* specimens were reported at Flat Creek (04027), Eightmile Creek (04028), the Pea River (04031), Pea Creek (04032), and Big Creek (04033, 04034) in 1998

(Blalock-Herod et al. 2005). In 1999, this species was found at the West Fork Choctawhatchee River (04005) and Judy Creek (04036) (Blalock-Herod et al. 2005).

Quincuncina burkei was found at only four sites during the 2004 survey. At the West Fork Choctawhatchee River (04005), two live *Q. burkei* were encountered upstream of the Alabama Highway 10 Bridge, and three live individuals were found downstream of the bridge. Thirteen live specimens were found upstream and 16 individuals were found downstream of the Florida Highway 181 Bridge at Eightmile Creek (04028). At Pea Creek (04032), four live individuals were found upstream and one live individual was found downstream of the County Road 9 Bridge. One live specimen was encountered downstream of the County Road 3 Bridge at Big Creek (04034).

***Villosa choctawensis* (Choctaw bean)**

Villosa choctawensis is endemic to the Choctawhatchee, Conecuh-Escambia, and Yellow river drainages in Alabama and Florida (Butler 1989, Williams and Butler 1994). During the 1990s, *V. choctawensis* was reported at seven of the 24 recent historical sites selected for resurvey (Appendix 1). This species was reported in 1995 at Patsaliga Creek (04062), in 1996 at the Yellow River (04041), and in 1998 at the Pea River (04031) and Pea Creek (04032) (Blalock-Herod et al. 2005; J.D. Williams, unpubl. data). In 1999, *V. choctawensis* was found in the West Fork Choctawhatchee River (04005), the East Fork Choctawhatchee River (04035), and Judy Creek (04036) (Blalock-Herod et al. 2005).

Villosa choctawensis was found at three of the 24 sites resurveyed in 2004. At the West Fork Choctawhatchee River (04005), 18 live individuals were encountered upstream of the Alabama Highway 10 Bridge, and 13 live individuals were found downstream of the bridge. Ten live *V. choctawensis* were found upstream from the County Road 9 Bridge at Pea Creek (04032). At the East Fork Choctawhatchee River (04035), three live individuals were found downstream of the County Road 54 Bridge.

Discussion

There was no statistically significant decline in the overall mussel assemblages at the 24 sites in the Choctawhatchee, Yellow, and Conecuh-Escambia river drainages for which recent historical data were available. However, presence-absence designs typically have a low to moderate statistical power to detect modest and uniform decreases (< 20–50%) in a population (Strayer 1999). In particular, surveys based on a small number of sites, as is the case with the present study, were shown to have a low power for all but the most severe (≥ 70%) declines (Strayer 1999). Thus, it is possible that, due to the presence-absence design of this study, a low-to-moderate uniform decrease in the mussel populations that was not statistically detectable may have occurred among the sites.

The number of candidate species found at a site as well as the number of sites at which candidate species were found did show a statistically significant decrease from the 1990s to 2004. These data suggest that candidate species are not at low and stable population levels; rather, there has been a decrease in the number of locations where candidate species were found. Since presence-absence designs often have much higher power to detect local extirpations than uniform declines in population, it is likely that such is the case for these candidate species (Strayer 1999).

It is often difficult to discuss population trends using recent historical data since a variety of collection and reporting methods are used. This study's 2004 survey followed the Carlson et al. (2003) draft freshwater mussel survey protocol, which establishes important collection and reporting criteria, such as a set collection distance both upstream and downstream of the bridge crossing. The need for standardized reporting methods is evident when attempting to compare current survey data with recent historical records. In order to be a useful analysis tool now and in the future, mussel survey reports and databases should classify mussels as live/wet specimens, FD, or WD, and should include total number of species found, number of man-hours spent at a site, and detailed location information. Additionally, recording the total number of individuals may be helpful in analyzing even qualitative surveys. It may be possible to estimate abundance, or catch per unit effort, using the total number of individuals found and the total number of man-hours expended or the distance/area searched at a site.

Conclusions

The 2004 survey of 24 sites in the Choctawhatchee, Yellow, and Conecuh-Escambia river drainages found 23 taxa, 21 of which were represented by live individuals, and two of which (*A. radiatus* and *M. nervosa*) were represented by FD shells. While there was no significant difference in the total number of species found at a site in the 1990s and in 2004, it is likely that the presence-absence design of the study limited the statistical power to detect smaller and more uniform population declines. This study has documented a decline from the 1990s to 2004 in the number of candidate species reported at a site and the number of sites at which candidate species were reported. There was a decrease from the 1990s to 2004 in the number of sites at which *M. marrianae*, *F. escambia*, *H. australis*, *P. strodeanum*, *Q. burkei*, and *V. choctawensis* were reported, with *P. strodeanum* showing the greatest decrease in the number of sites at which it was reported in 2004 relative to the 1990s.

Several of the candidate mussel taxa discussed in this paper are highly imperiled. *Margaritifera marrianae* and *P. jonesi* are nearly extinct, while *Q. burkei* and *F. escambia* are not far behind. Life history information,

improved propagation technology, and other related research are imperative if these species are to be recovered.

Future mussel surveys should follow standardized protocols in order to assess mussel conservation status. Information regarding collection date and time, site location, distance surveyed, number of live, FD, or WD specimens, total number of species found, total number of individuals found, and number of man-hours expended at a site should be included in survey reports if they are to be relevant now and useful in the future. Studies should address factors such as population size, status and trends in population demographics, and recruitment success by presence of juveniles. Using survey data in conjunction with other information such as habitat and landuse change data, a concentrated effort can be made to create detailed plans for recovery that address various factors that have led to the decline in freshwater mussel diversity.

Acknowledgments

We thank Will Heath, Jonathan Miller, Jonathan Shelton, Ashley Shelton, Matthew Shelton, Nicholas Shelton, Michael Mullen, and Vanessa Pruitt for their field assistance. Financial support for this project was provided by the US Fish and Wildlife Service Panama City Field Office Contract #401214G049 and the ALFA Fellowship at Troy University.

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Appendix 1. Current (2004) and recent historical (1990s) mussel data for 24 survey sites; current data reports number of live individuals collected and recent historical data reports presence (X) of taxa (represented by both live individuals and dead shells). * = candidate species.

	04005		04008		04027		04028		04029		04030	
	2004	1990s	2004	1990s	2004	1990s	2004	1990s	2004	1990s	2004	1990s
Margaritifera marrianae Johnson*												
Anodontoides radiatus (Conrad)						X						
Elliptio cf. *arctata* (Conrad)					24							
Elliptio cf. *complanata* (Lightfoot)					3				4			
Elliptio crassidens (Lamarck)						X						
Elliptio cf. *icterina* (Conrad)	156	X			55	X	306	X	78		7	X
Elliptio mcmichaeli (Clench and Turner)	9	X			276	X						
Unidentified *Elliptio*		X										
Fusconaia escambia Clench and Turner*											2	X
Hamiota australis (Simpson)*	19	X				X	11	X	1			
Lampsilis ornata (Lea)												
Lampsilis straminea claibornensis (I. Lea)	10	X				X	1		5	X	2	X
Lampsilis teres (Rafinesque)						X						
Megalonaias nervosa (Rafinesque)												X
Pleurobema strodeanum (Wright)*	118	X		X	1	X	101	X			2	X
Ptychobranchus jonesi (van der Schalie)*	2	X										
Pyganodon cf. *grandis* (Say)				X								X
Quadrula succissa (Lea)	7	X			1				68	X	6	X
Quincuncina burkei (Walker)*	5	X				X	29	X				
Toxolasma sp.	8	X	2	X	8		10	X	20	X		X
Uniomerus sp.												
Utterbackia peggyae (Johnson)					1	X			1			
Villosa choctawensis Athearn*	31	X										
Villosa lienosa (Conrad)	56	X	4	X	14	X	164	X	14		5	
Villosa vibex (Conrad)	26	X	2	X	5	X	59	X	22	X		

	04031		04032		04033		04034		04035		04036	
	2004	1990s	2004	1990s	2004	1990s	2004	1990s	2004	1990s	2004	1990s
*Margaritifera marrianae**												
Anodontoides radiatus				X								X
Elliptio cf. *arctata*				X								
Elliptio cf. *complanata*									1			
Elliptio crassidens												
Elliptio cf. *icterina*	173	X	150	X	1			X	19	X		X
Elliptio mcmichaeli	1											
Unidentified *Elliptio*												
*Fusconaia escambia**												
*Hamiota australis**				X					1	X		
Lampsilis ornata												
Lampsilis straminea claibornensis	1	X	1	X					1	X		
Lampsilis teres												
Megalonaias nervosa												
*Pleurobema strodeanum**	6	X	5	X					1	X		X
*Ptychobranchus jonesi**												
Pyganodon cf. *grandis*												
Quadrula succissa	6	X	2	X								X
*Quincuncina burkei**		X	5	X		X	1	X				X
Toxolasma sp.					1	X	5	X	15	X		X
Uniomerus sp.	13	X	23	X			12	X				
Utterbackia peggyae												
*Villosa choctawensis**		X	10	X					3	X		X
Villosa lienosa	4	X	42	X	2	X	11	X	28	X		X
Villosa vibex	13	X	38	X		X	4	X	1	X		X

	04037		04038		04039		04040		04041		04055	
	2004	1990s	2004	1990s	2004	1990s	2004	1990s	2004	1990s	2004	1990s
*Margaritifera marrianae**												X
Anodontoides radiatus												
Elliptio cf. *arctata*	6											
Elliptio cf. *complanata*												
Elliptio crassidens												X
Elliptio cf. *icterina*	20	X	1		1	X			1	X		X
Elliptio mcmichaeli	226	X		X		X						
Unidentified *Elliptio*												
*Fusconaia escambia**												X
*Hamiota australis**												
Lampsilis ornata												X
Lampsilis straminea claibornensis			12	X						X		
Lampsilis teres			3									
Megalonaias nervosa												
*Pleurobema strodeanum**	2	X			2	X		X				X
*Ptychobranchus jonesi**												
Pyganodon cf. *grandis*												
Quadrula succissa	4	X		X	18	X				X		X
*Quincuncina burkei**												
Toxolasma sp.	42	X			40	X	2					
Uniomerus sp.												X
Utterbackia peggyae	2											
*Villosa choctawensis**										X		
Villosa lienosa	2		18		2		6	X	1			X
Villosa vibex	3	X			4				1	X		X

	04056		04057		04059		04060		04061		04062	
	2004	1990s	2004	1990s	2004	1990s	2004	1990s	2004	1990s	2004	1990s
*Margaritifera marrianae**			14	X								
Anodontoides radiatus												
Elliptio cf. *arctata*												
Elliptio cf. *complanata*												
Elliptio crassidens	8	X			9	X						X
Elliptio cf. *icterina*			10	X			2				23	X
Elliptio mcmichaeli												
Unidentified *Elliptio*				X								
*Fusconaia escambia**												X
*Hamiota australis**			1									X
Lampsilis ornata												
Lampsilis straminea claibornensis						X			13	X	1	X
Lampsilis teres												X
Megalonaias nervosa												
*Pleurobema strodeanum**	1	X		X		X				X	1	X
*Ptychobranchus jonesi**												
Pyganodon cf. *grandis*											3	
Quadrula succissa	11	X			9	X	1		16	X	4	X
*Quincuncina burkei**												
Toxolasma sp.	20		2	X		X	3		13	X	8	X
Uniomerus sp.											1	X
Utterbackia peggyae												
*Villosa choctawensis**												X
Villosa lienosa				X			2		4	X	8	X
Villosa vibex	12		5	X	4		2		4	X	5	X