Structural Changes in Freshwater Mussel (Bivalvia: Unionidae) Assemblages Downstream of Lake Somerville, Texas

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Notes and Discussion Piece

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Abstract.—Yegua Creek, a tributary of the Brazos River, Texas has yet to be comprehensively surveyed for freshwater mussels, despite previous studies documenting high mussel abundance and richness and the occurrence of *Quadrula houstonensis*, a federal candidate species under the U.S. Endangered Species Act. We qualitatively sampled mussels at 52 sites in lower Yegua Creek to assess the status of mussel populations and provide a baseline for future monitoring efforts. In total 10,010 mussels representing 16 species were observed, including *Q. houstonensis* and *Truncilla macrodon*, which is also a federal candidate species. Mussel species richness and abundance increased with distance downstream from Lake Somerville, which corresponded with changes in assemblage structure. Recruitment was lowest near Lake Somerville and highest in reaches located in the middle sections of the study area. Taken together these results indicate that Lake Somerville may be negatively impacting the mussel fauna in Yegua Creek. Despite these impacts, mussel abundance and diversity is high in reaches located at intermediate distances from the reservoir and represents some of the largest known populations in central Texas.

Introduction

Freshwater mussels (Bivalvia: Unionidae) are among the most imperiled groups of aquatic organisms in North America (Strayer *et al.*, 2004). Destruction of habitat, loss of host fishes, introduction of invasive species (*e.g.*, zebra mussels) and river impoundments have contributed to declines in mussel populations and reductions in diversity (Williams *et al.*, 1993; Strayer *et al.*, 2004). In turn these declines have resulted in changes to assemblage structure (Haag and Warren, 2010), whereby rare species are extirpated and subadult age classes are eliminated (*e.g.,* Haag and Warren, 2010; Randklev *et al.*, 2013). This is problematic because mussels play important roles in aquatic ecosystems by facilitating nutrient cycling, stabilizing substrates and increasing habitat heterogeneity (Vaughn and Hakenkamp, 2001). Changes to assemblage structure can therefore alter the effects mussels have on aquatic ecosystems (Vaughn, 2010).

Documenting changes to species assemblages and identifying the potential causes for those changes are critical for the conservation of freshwater mussels. Although studies on mussels in the United States are increasing, knowledge of the distribution for many species is unknown (Lydeard *et al.*, 2004). This is particularly true in Texas, where species' ranges are generally known (Howells *et al.*, 1996; Howells, 2010), but detailed knowledge of the location and status of mussel populations within specific drainages is lacking. Of the 52 mussel species described in Texas, fifteen are listed as state-threatened (Texas Register 35, 2010), and six of these are on the candidate list for federal protection (Federal Register 76, 2011). Growing concern over the loss of mussel diversity has prompted increased efforts to gather baseline data from rivers for which little information exists.

To date Yegua Creek, a tributary of the Brazos River, has not been comprehensively surveyed for freshwater mussels. Previous studies within this drainage were largely opportunistic and limited to a few sites in Lake Somerville or the mainstem of Yegua Creek (Howells, 1997, 1999, 2001, 2004, 2006; Karatayev and Burlakova, 2008; Randklev *et al.*, 2010) and, although informative, provided little detail on the distribution of mussels within the drainage. Surveys performed by Karatayev and Burlakova (2008) and Randklev *et al.* (2010) in lower Yegua Creek, between its confluence with the Brazos River and Lake Somerville, revealed high mussel abundance and richness, along with adult and subadult individuals of *Quadrula houstonensis* (smooth pimpleback), a candidate for protection under the U.S. Endangered Species Act (ESA). Considering these observations, an investigation of mussel populations in lower Yegua Creek is warranted to help resolve the status of *Q. houstonensis* and expand our knowledge of mussel populations in this region. We examined the distribution, assemblage structure, and recruitment (using shell length data) of freshwater mussels in lower Yegua Creek to determine the status of mussel populations within this drainage and to provide a baseline for future monitoring efforts.

METHODS

Yegua Creek is located on the Gulf Coastal Plain and drains approximately 3407 km^2 in central Texas. Similar to other streams in this region, it is comprised of alluvial sediments with a sand and silt substrate and hard, compact clay banks. The humid subtropical climate results in average annual precipitation of 99.1 cm (Chin and Bowman, 2005). Land use in the watershed consists primarily of agriculture and cattle pastures (Chin and Bowman, 2005). Yegua Creek is impounded by a large dam that forms Lake Somerville, located approximately 34 river-km upstream from the creek's confluence with the Brazos River; this fragments the lower fourth of the Yegua Creek watershed (1012 km^2). Lake Somerville was constructed in 1965 to control flooding within the basin. The reservoir encompasses 4638 ha and is shallow, with a mean depth of approximately 4 m and maximum depth of approximately 9 m. Because Lake Somerville is shallow, thermal stratification does not occur and the reservoir is subject to frequent, complete mixing events (Roelke *et al.*, 2004).

Although impounded, Yegua Creek is classified as one of the least-disturbed streams in Texas (Twidwell and Davis, 1989; Chin *et al.*, 2002). However, there is evidence Lake Somerville's dam has had negative effects on downstream portions of the stream. Mean discharge estimated over several decades both before (8.2 m^3/s) and after (7.7 m^3/s) completion of the dam has not changed significantly (Jennings, 1999; Chin *et al.*, 2002), but the dam has homogenized downstream flow. For example, while mean annual peak flow has decreased by 85% post-impoundment (Chin *et al.*, 2002), mean low flow has increased by a magnitude of 16 times, and mean number of zero flow days per year has decreased by 70% (Chin *et al.*, 2002). The reallocation of flow in Yegua Creek has led to channel shrinkage (Chin *et al.*, 2002), changes in streamside vegetation (Jennings, 1999), and decreased transport of sediment downstream (Martinez, 2008).

At each site we qualitatively searched for mussels following methods proposed by Metcalfe-Smith *et al.* (2000). In brief, this approach maximizes the chances of finding rare species by sampling a predefined area repeatedly over multiple consecutive timed-periods. In our study, surveyors searched for mussels for a minimum of 1 person-hour (p-h) and additional 1 p-h searches were added until no new species were encountered. Surveys were conducted using tactile and visual searches by wading in the stream or snorkeling in areas >1 m deep. Mussels were identified following Howells *et al.* (1996) and Howells (2010) and counted to estimate species richness (total number of species), abundance (number of individuals) and catch-per-unit-effort (CPUE; number of mussels/p-h). Shell length measurements from anterior to posterior were recorded for each mussel using digital calipers.

We performed several analyses to examine the distribution, assemblage structure and recruitment of freshwater mussels in lower Yegua Creek. First, we used general additive models (GAMs) with a smooth spline function to explore the relationship between species richness and CPUE at different stream positions/study sites (river-km). This approach was used because of its ability to depict trends between predictor and response variables in a nonlinear fashion without the restrictions imposed on variables when using ordinary least-squares regression (Hastie and Tibshirani, 1990). Second, we estimated beta diversity using Sørensen's index (β_{SOR}) to determine the degree of dissimilarity in mussel diversity between sites. Beta diversity was plotted against study sites (river-km) using GAM to evaluate changes in species turnover in lower Yegua Creek. High and low β_{SOR} correspond to high and low degree of species turnover among sites, respectively. Third, nonmetric multidimensional scaling (NMDS) and agglomerative cluster analysis were used to evaluate mussel assemblage structure in ordinal space. NMDS is a distance-based procedure that ordinates study units based on rank dissimilarities (McCune and Grace, 2002). Dissimilarity was estimated using the Bray-Curtis index and the fit of the ordination, termed stress (*S*), was measured by comparing the rank order of pair-wise dissimilarities and the Euclidean distances of points. Stress values <0.2 are considered good fit (Quinn and Keough, 2002). Agglomerative cluster analysis, using average linkage, was then used to validate the NMDS groupings by overlaying polygons constructed from the cluster analysis within the NMDS plot. If the polygons overlapped the NMDS groupings, then the ordination can be considered a good representation of community dissimilarities. For these analyses, sites with total abundance less than 15 and species richness less than 3 were excluded from the dataset. For the six most abundant mussel species, the median shell length was plotted against study sites (river-km) to examine recruitment. All analyses were performed using R statistical package (R Development Core Team, http://www.R-project.org).

TABLE 1.—List of species observed in lower Yegua Creek, Texas with species abbreviations, abundance (number of individuals) and species occurrence (percent of sites at which a species was present)

Species	Abbreviation	Abundance	Occurrence
Amblema plicata (threeridge)	AP	5355	85
Quadrula apiculata (southern mapleleaf)	QA	1692	89
Quadrula houstonensis (smooth pimpleback)	QH	1389	81
Lampsilis teres (yellow sandshell)	LT	740	89
Cyrtonaias tampicoensis (Tampico pearlymussel)	CT	323	74
Leptodea fragilis (fragil papershell)	LF	137	60
Pyganodon grandis (giant floater)	PG	133	47
Toxolasma texasense (Texas lilliput)	TX	83	55
Toxolasma parvum (lilliput)	TP	51	23
Quadrula verrucosa (pistolgrip)	QV	47	25
Truncilla macrodon (Texas fawnsfoot)	TM	21	2
Potamilus purpuratus (bleufer)	PP	20	15
Potamilus ohiensis (pink papershell)	PO	9	9
Arcidens confragosus (rock pocketbook)	AC	5	8
Utterbackia imbecillis (paper pondshell)	UI	4	8
Megalonaias nervosa (washboard)	MN	1	2
Total		10,010	

RESULTS AND DISCUSSION

Previous surveys in lower Yegua Creek documented relatively high mussel diversity at a limited number of sites (Howells, 1999, 2001; Karatayev and Burlakova, 2008; Randklev *et al.*, 2010). We documented 10,010 mussels representing 16 species across 53 sites between Lake Somerville and the confluence of Yegua Creek and the Brazos River (Table 1; Fig. 1), which included two candidates for protection under the ESA, *Q. houstonensis* and *Truncilla macrodon.* Overall, mussel species richness and CPUE across sites ranged from 2–11 (6.6 $\pm$ 0.3; mean $\pm$ SE) and 4.5–201.3 mussels/p-h (66.6 $\pm$ 7.3), respectively, and species occurrence was high for many species, ranging from 2–89% of sites across the study area (Table 1). In contrast to earlier studies, our estimates of mussel abundance and species richness are much higher. In fact it appears that lower Yegua Creek, particularly sites furthest downstream from Lake Somerville, harbor some of the largest known mussel populations in central Texas. For example Randklev *et al.* (2013) documented only 2081 mussels of 12 species from 44 sites on the Leon River, Texas, which is also a tributary of the Brazos River. Therefore mussel populations in lower Yegua Creek could serve as important conservation units for future monitoring and ecological studies.

Despite the high species richness and CPUE in lower Yegua Creek, we found distinct changes in both of these estimates with increasing distance from Lake Somerville. Specifically species richness (4.3 $\pm$ 0.6) and CPUE (26.1 $\pm$ 6.1 mussels/p-h) were reduced for sites located near the reservoir (0.4–9.5 river-km; Figs. 2a, b), but increased with downstream distance from Lake Somerville, peaking at approximately 11 river-km (11.0) and 28.4 river-km (201.3 mussels/p-h), respectively (Figs. 2a, b). Beta diversity also varied with distance from the reservoir such that β_{SOR} was highest at the most upstream sites (26.1 $\pm$ 6.1; 0.4–7.8 river-km; Fig. 2c) and lowest at sites further downstream (0.2 $\pm$ 0.02; 7.8–33.7 river-km; Fig. 2c), indicating high species turnover near the reservoir.

Three mussel assemblages were apparent in the study area. At sites located immediately downstream of the reservoir (0.4–9.5 river-km), species composition was dominated by *Quadrula apiculata* and *Pyganodon grandis,* which commonly occur in lentic habitats and are tolerant of impoundments (Williams *et al.*, 2008; Fig. 2d; Assemblage I). At sites located in the middle portion of the study area (9.9–31.9 river-km), *Amblema plicata* and *Q. houstonensis* were the dominant species (Fig. 2d; Assemblage II). Both species are considered riverine generalists and have life-history traits that are favored in stable habitats (Haag, 2012). Lastly the two most downstream sites (33.4 and 33.7 river-km), located at the confluence, shared

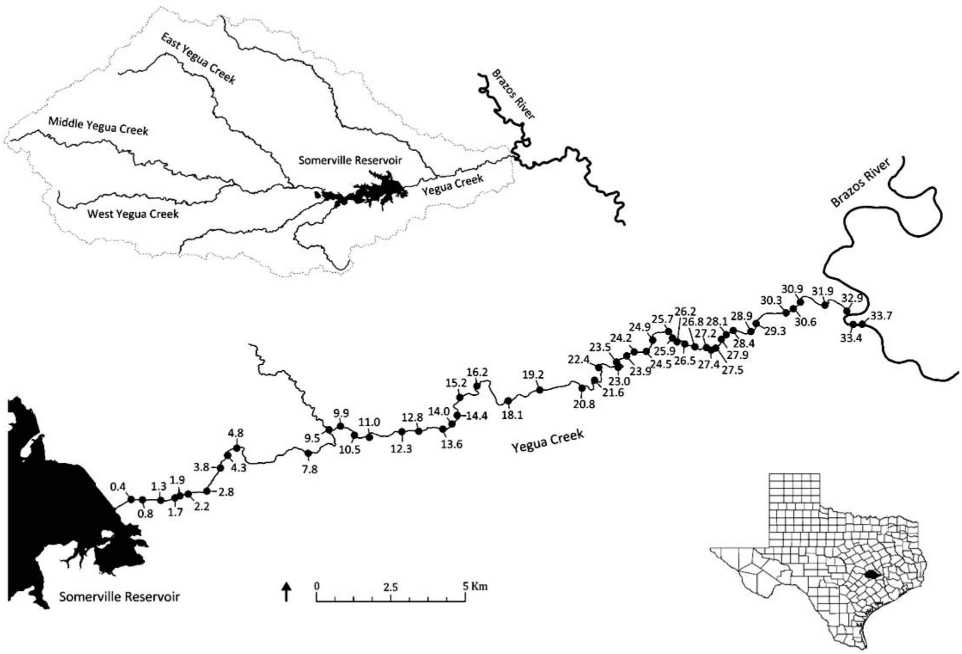

FIG. 1.—Map of sites sampled for freshwater mussels in lower Yegua Creek, Texas downstream of Lake Somerville

similar species composition (Fig. 2d, Assemblage III) and were dominated by *Cyrtonaias tampicoensis* and *T. macrodon*. The dominance of *C. tampicoensis* at these sites and the presence of *T. macrodon* is expected given that both species occur in the Brazos River (Randklev *et al.*, 2014).

Shell length data for the six most abundant species appeared to vary with proximity to Lake Somerville. Median shell lengths for most of the species were highest near Lake Somerville and generally decreased with distance downstream (Figs. 3a–d). However, there were several notable exceptions. For *L. fragilis*, median shell length was highest at sites located upstream near the reservoir and downstream near the confluence and lowest in reaches located in the middle portion of the study area (Fig. 3f). Median shell length for *Amblem plicata* revealed a similar pattern, although individuals were generally larger near the reservoir compared to those from sites at the confluence with the Brazos River (Fig. 3a). In contrast median shell length for *L. teres* was generally the same regardless of stream position (Fig. 3e). Taken together, these results indicate that recruitment for most species may be reduced in reaches near Lake Somerville, with the exception of *L. fragilis,* which is considered tolerant of environmental perturbations (Haag, 2012). We realize that the sampling methods used in this study may be biased against the detection of small individuals (Vaughn *et al.*, 1997). However, sampling effort was similar throughout the study area and smaller individuals (<30 mm in shell length) were successfully sampled at 70% of sites.

We observed longitudinal changes in species richness and turnover, CPUE, assemblage structure and median shell length with distance from Lake Somerville. These changes indicate that Lake Somerville is likely impacting the mussel fauna in Yegua Creek and mirrors results from previous studies that have examined the effects of impoundments on downstream mussel communities (Vaughn and Taylor, 1999; Haag and Warren, 2010; Randklev *et al.*, 2013). For example Vaughn and Taylor (1999) assessed the influence two reservoirs had on downstream mussel populations in southeastern, Oklahoma. They observed that species richness and abundance increased with distance downstream from the reservoirs. They also found rare species were only present at sites furthest downstream from the impoundments,

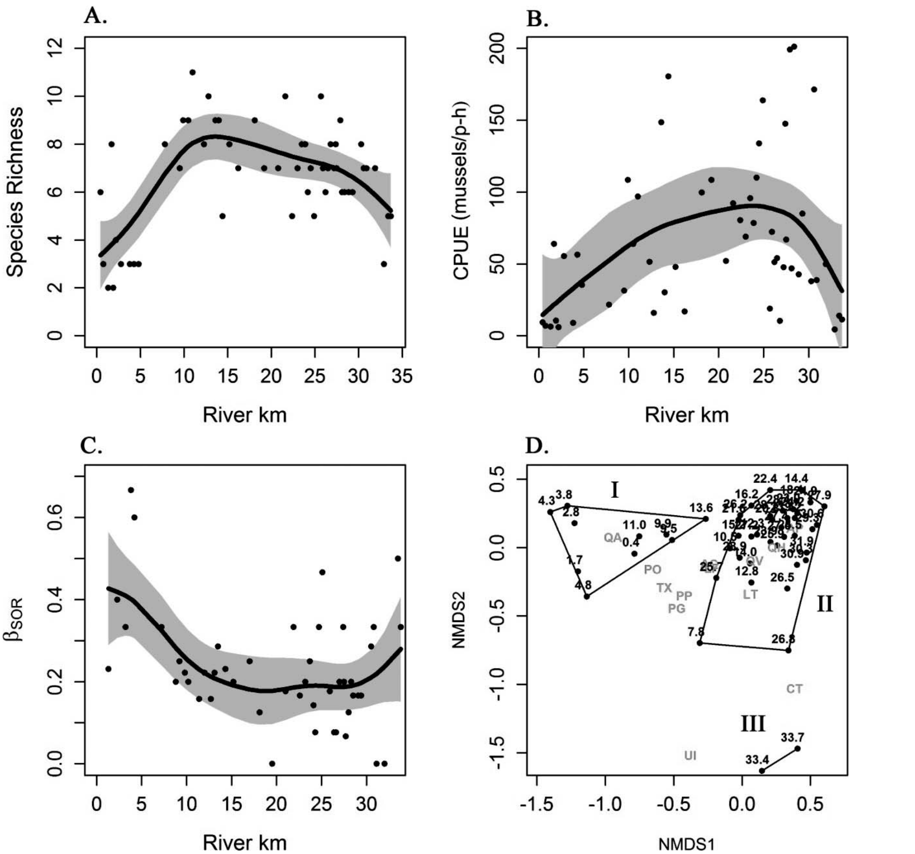

FIG. 2.—**(A)** General additive models (GAM) representing the relationship between species richness (number of species), **(B)** catch-per-unit-effort (CPUE; mussels/person-hours of search effort), and **(C)** beta diversity (β_{SOR}) of mussels with the distance (river-km) of study sites downstream from Lake Somerville in Yegua Creek, Texas. Shaded areas indicate 95% confidence intervals. **(D)** NMDS biplot of mussel assemblage structure ($S = 0.10$, $k = 2$). Sites and species are represented by black points and species abreviations (red text; Table 1), respectively. Lines connecting site clusters were derived from the agglomerative cluster analysis. Mussel assemblages in lower Yegua Creek are labeled the following: (I) reservoir-influenced (lentic), (II) lotic, and (III) Brazos River assemblages

and that mussel assemblages were nested such that the number of species shared between any two sites increased with distance from the impoundments.

Although Lake Somerville appears to have impacted the mussel fauna in lower Yegua Creek, its presence may partially explain why this small creek in central Texas continues to harbor such high mussel richness and CPUE. In 2011 Texas experienced one of the worst droughts on record, resulting in low water levels for many streams and rivers in central and west Texas. In lower Yegua Creek river discharge declined but flow did not become intermittent, in part because of periodic releases from Lake Somerville, which possibly benefited some populations impacted by the drought. However, because flows in lower Yegua Creek were episodic and not specific to the mussels themselves, channel shrinkage and the subsequent loss of habitat continued to be a problem (E.T. Tsakiris unpublished data). These observations suggest environmental flow studies in this basin are needed in order for dam operators to better manage

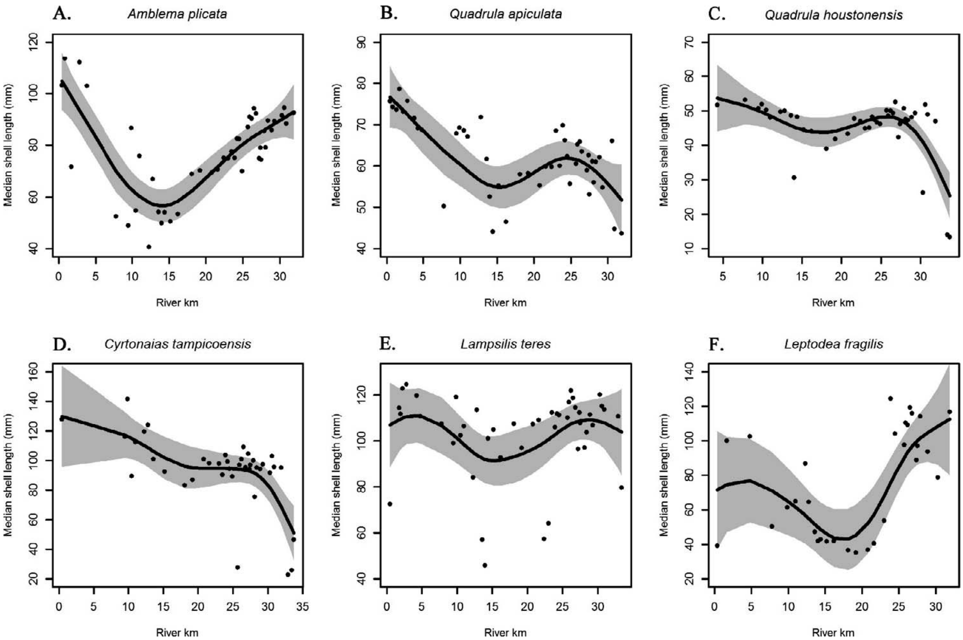

FIG. 3.—General additive models (GAM) of median shell length (mm) and the distance (river-km) of study sites downstream from Lake Somerville in Yegua Creek, Texas. Models are for the 6 most abundant species in Yegua Creek: **(A)** *Amblema plicata*, **(B)** *Quadrula apiculata*, **(C)** *Quadrula houstonensis*, **(D)** *Crytonaias tampicoensis*, **(E)** *Lampsilis teres* and **(F)** *Leptodea fragilis*. Shaded areas indicate 95% confidence intervals

flows during periods of drought. Our results are consistent with previous work suggesting that the ecological impacts of large impoundments vary at multiple spatio-temporal scales (Poff and Hart, 2002).

Yegua Creek contains one of the most diverse and abundant mussel faunas in central Texas and sustains some of the largest remaining populations of *Q. houstonensis*, a species presently considered for listing under the ESA. Consequently, lower Yegua Creek downstream of the reservoir should be protected, and populations with high abundance, richness, and recruitment should be monitored to ensure that changes in water management or land-use practices do not negatively impact the mussel fauna. In addition to monitoring, Texas Parks and Wildlife Department, in cooperation with the Brazos River Authority and the Army Corps of Engineers, should initiate environmental flow and contaminant studies in Yegua Creek to ensure that impoundment releases are sufficient for maintaining aquatic habitat and tolerable levels of water quality for mussels.

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