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DIVERSITY AND ABUNDANCE OF UNIONID MUSSELS IN THREE SANCTUARIES ON THE SABINE RIVER IN NORTHEAST TEXAS

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Abstract.–Populations of freshwater mussels (Bivalvia: Unionidae) are declining for reasons that are primarily anthropogenic. The Texas Administrative Code lists 18 freshwater mussel sanctuaries ("no-take" areas) within Texas stream segments and reservoirs with three being on the Sabine River in northeast Texas. Visits to each Sabine River sanctuary were made multiple times between April and September 2007 with two goals: to establish species richness by locating rarer species not found in earlier surveys and to collect unionid data that could be used to evaluate abundances among the sanctuaries. Using timed and density surveys (0.25 meter square quadrats) 1596 individuals of 18 unionid species were recorded. Densities ranged from means of over 21 per meter square in one sanctuary to 3.6 per meter square in the sanctuary nearest the dam at Lake Tawakoni. Because a range of sizes were found for several species at the two downstream sanctuaries, recruitment evidently occurs. One of the healthiest unionid populations in these areas was *Fusconaia askewi*, which is a species of concern in the Texas Wildlife Action Plan. The mussel beds were found only in small, isolated patches in any sanctuary and silting over of beds with sand from bankfalls was evident throughout the river. Whether these sanctuaries will sustain all species within the upper Sabine River is questionable and it will be important to continue to monitor them.

It is increasingly evident that freshwater mussels (Bivalvia: Unionidae) are important components of riverine ecosystems (Christian & Berg 2000; Vaughn & Hakenkamp 2001; Howard & Cuffey 2006; Vaughn & Spooner 2006). Unionids have historically dominated lotic environments of the southeastern United States in terms of benthic biomass (Parmalee & Bogan 1998) and in undisturbed rivers may exceed other assemblages by an order of magnitude (Strayer et al. 1994). With the greatest diversity in the world, the continental United States supported nearly 300 species of unionid mussels (Neves 1993; Turgeon et al. 1998). However, their sedentary, slow-growing and long-lived (many > 25 years) life histories plus early parasitic phase usually requiring a host fish (Kat

1984; Watters 1994; Vaughn & Taylor 2000) has made them highly susceptible to human impacts such as wetland drainage, channelization, sedimentation, dredging, pollution, invasive species and impoundments (Vaughn & Taylor 1999; Howells et al. 2000; Lydeard et al. 2004). The decline of North American unionid populations has been occurring for over a century (Neves et al. 1997; Vaughn 1997) with the extinction of at least 35 species and up to 65% imperiled to some degree (Turgeon et al. 1998). For many states, including Texas, the extent of freshwater mussel decline is simply not known (Bogan 1993; Layzer et al. 1993; Neves 1993).

At least 52 species of unionids occur in Texas and yet our understanding of their conservation status is quite limited (Howells et al. 1996; 1997). Although specific data are not available, it seems likely that East Texas unionid populations have declined at least equivalent to unionids in the other regions (Neck 1986; Howells 1997; Bordelon & Harrel 2004; Ford & Nicholson 2006). The human population of the region has been growing rapidly with dramatically increasing demands on its water resources, as illustrated by the 31 large reservoirs on its rivers (Ford & Nicholson 2006). Most of the rivers of eastern Texas are isolated from each other and many drain independently into the Gulf of Mexico. For example, the Sabine River begins in North-Central Texas in Hunt, Rains and Van Zandt counties and flows southeasterly first to a large reservoir on the border with Louisiana, Toledo Bend Lake, then ends in Sabine Lake, an estuary of the Gulf of Mexico. Additionally, one reservoir was built at the headwaters of the river, Lake Tawakoni, and a second, Lake Fork, is located in Wood, Rains and Hopkins counties and contributes much initial flow to the river through Lake Fork Creek. These two reservoirs have likely changed the river downstream both in flow patterns and geomorphology (Ford & Nicholson 2007). The only recent published surveys of mussels from the Sabine River drainage are for Lake Tawakoni (Neck 1986), a study on the Old Sabine Bottom Wildlife Management Area, which has the Sabine River as its northern border (Ford & Nicholson 2006) and a number of unpublished Texas Parks and Wildlife Department (TPWD) surveys (summarized in Howells 1997; 2006).

Mussel harvesting in Texas has occurred for over one hundred years, however, the intense overharvesting that occurred in the Mississippi Valley apparently did not occur in Texas (Howells et al. 1996). Although harvesting permits were required, little effort to monitor the mussel-harvesting was implemented until the increasing demand from the cultured pearl industry for American mussel shell begin in the late 1970s. In 1992, the Texas Administrative Code listed 28 freshwater mussel sanctuaries within Texas stream segments and reservoirs, but in 2006, Rule 57.157 reduced the number to 18 (Fig. 1). Harvesting is not permitted in these "no-take" areas with the intention that they will provide adult unionids producing glochidia for dispersal by fish hosts to non-protected areas.

Three of the sanctuaries occur on the Sabine River in Northeast Texas. Texas Parks and Wildlife Department conducted some limited surveys at the bridge crossings of these sanctuaries in 1993 (Howells 1995) and 1994 (Howells 1995; 1996a; 1996b) and again in 2005 and 2006 (Howells 2006). The goal of this study was to survey unionid mussels throughout the full extent of each sanctuary to establish total species richness for each and to collect data that could be used to evaluate densities of mussels within each sanctuary.

MATERIALS AND METHODS

Study areas.–The first sanctuary directly below Lake Tawakoni (hereafter called Lake Tawakoni Sanctuary) begins at the dam at Lake Tawakoni and ends downstream at State Highway 19 in Rains and Van Zandt counties. The riverbed from the dam to Highway 19 was obviously heavily impacted by scouring that occurred during high water releases. Daily discharges in this section of the river ranged from lows of 5 cfs (cubic feet per second) to high releases of

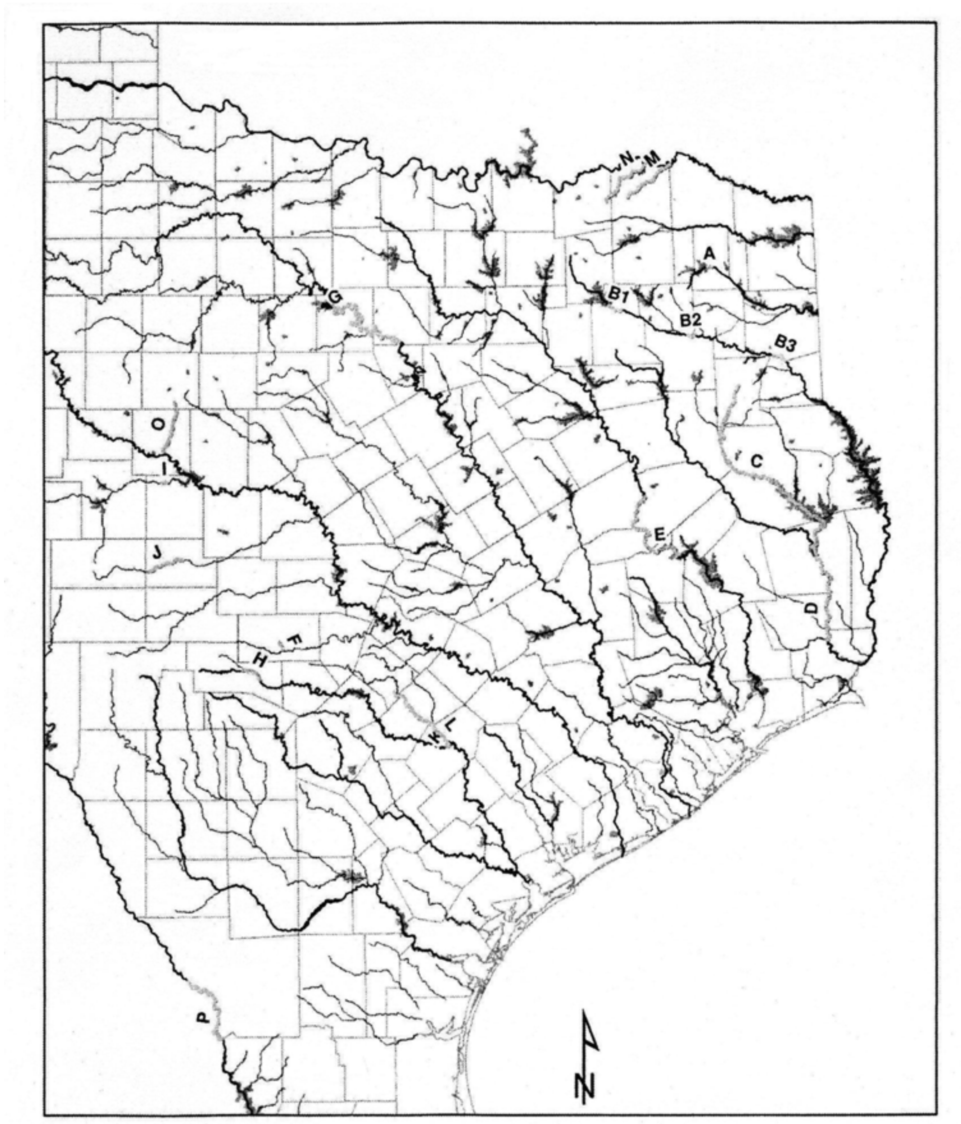

Fig. 1. Texas Mussel Sanctuaries (Texas Administrative Code Title 31, part 2, Ch. 57, subch. B, rule 57.157); A. Big Cypress Creek in Camp County; B1. Sabine River in Rains and Van Zandt counties; B2. Sabine River in Smith, Upshur and Wood counties; B3. Sabine River in Harrison and Panola counties; C. Angelina River in Angelina, Cherokee, Jasper, Nacogdoches, Rusk, San Augustine, and Tyler counties; D. Neches River in Hardin, Jasper, Orange and Tyler counties; E. Trinity River in Houston, Leon Madison, Trinity and Walker counties; F. Live Oak Creek in Gillespie County; G. Brazos River in Palo Pinto and Parker counties; H. Guadalupe River in Kerr County; I. Concho River in Concho County; J. San Saba River in Menard County; K. Guadalupe River in Gonzales County; L. San Marcos River in Hays, Guadalupe and Gonzales counties; M. Pine Creek in Lamar and Red River counties; N. Sanders Creek in Fannin and Lamar counties; O. Elm Creek in Runnels and Taylor counties; P. Rio Grande in Webb County.

over 7000 cfs in just one day (United States Geological Survey [USGS] 2007). The initial first km is channelized and deep. The rest consists of mud and silty substratum with large amounts of detritus and nonorganic trash (plastic and styrofoam).

The second sanctuary below the bridge at Highway 14 (hereafter called Highway 14 Sanctuary) is located from Farm to Market Road 14 to State Highway 155 in Smith, Upshur and Wood counties. In this section, the river was relatively wide (20-30 m at low water) and so a number of shallow sites with mussels and shells were evident. Some exposure of rocky outcrops of Cretaceous origin occurred with areas of small cobble. However, a large percentage of the sanctuary had severe erosion of the steep riverbanks, including numerous bankfalls. Daily discharges in this section of the river ranged from a low of 45 cfs to a high of 18,500 cfs in the year of the study (USGS 2007). This part of the river normally experiences flooding several times in the winter but during the year of the survey the high flows occurred during midsummer.

The third sanctuary below the bridge at Highway 43 (hereafter Highway 43 Sanctuary) is located from State Highway 43 downstream to U. S. Highway 59 in Harrison and Panola counties. The river in this section was also relatively shallow and wide. However, daily discharges in this section of the river were more dramatic and ranged from lows of 11 cfs to high releases of 20,400 cfs (USGS 2007). It also had some areas of bedrock and extremely large boulders. Few reaches of any length with smaller rocks and cobble were evident.

Sampling techniques.–Each sanctuary was surveyed multiple times between April and September 2007 using two methods. The total extent of each sanctuary was initially explored by kayaking during low water with reconnaissance for shells and stream characteristics appropriate for mussels such as current and the presence of cobble (Vaughn et al. 1997; Strayer et al. 1997; Strayer & Smith 2003). Five to seven sites spaced throughout the length of each sanctuary were sampled. At selected sites, timed surveys were conducted and in areas with adequate mussel numbers, density surveys were performed. Both methods are necessary as timed surveys are useful for locating rare species but cannot be used for statistical comparison between areas (Strayer & Smith 2003).

Timed surveys.–Time searches were conducted by surveying a 100m stretch of the river visually and tactilely for live and recently dead mussels in shallow areas and along the banks. Each site was sampled for a total of one-person hour. All live unionids and shells that were complete with both valves were collected, identified and counted. Live specimens were returned to the river. One voucher of each species was retained in the University of Texas at Tyler collection and any questionable specimens were collected and sent to Robert Howells of TPWD for identification.

Density surveys.–In timed survey sites where unionids were abundant (at least 12 per 1 person hour), nearby areas were sampled using 0.25 meter square quadrats to estimate density (expressed as mussels per square meter). A random plot design was used $\left(\frac{L*W}{n/k}\right)^2$ with three starting points (k) and a sample total of 10 quadrats (n) (Strayer & Smith 2003). An approximate width of river of 20 m (W) and 100 m for the reach sampled (L) was used. This produced a distance of three meters between samples. Two surveyors searched the substratum by hand and excavated all mussels to a depth of 15 cm until no more specimens were found. Both live and recently dead (complete with both valves) were identified and counted. Measurements of length, width and height were taken only on living unionids.

Data analysis.–All individuals counted in the timed surveys were used to calculate a Shannon-Wiener species diversity (H' base e) and evenness (J') indices. Rank abundance was determined for unionids for both methods. A Jaccard's Coefficient of Community was used to compare species similarity between sanctuaries for the timed surveys (Brower et al. 1997). Richness and densities were

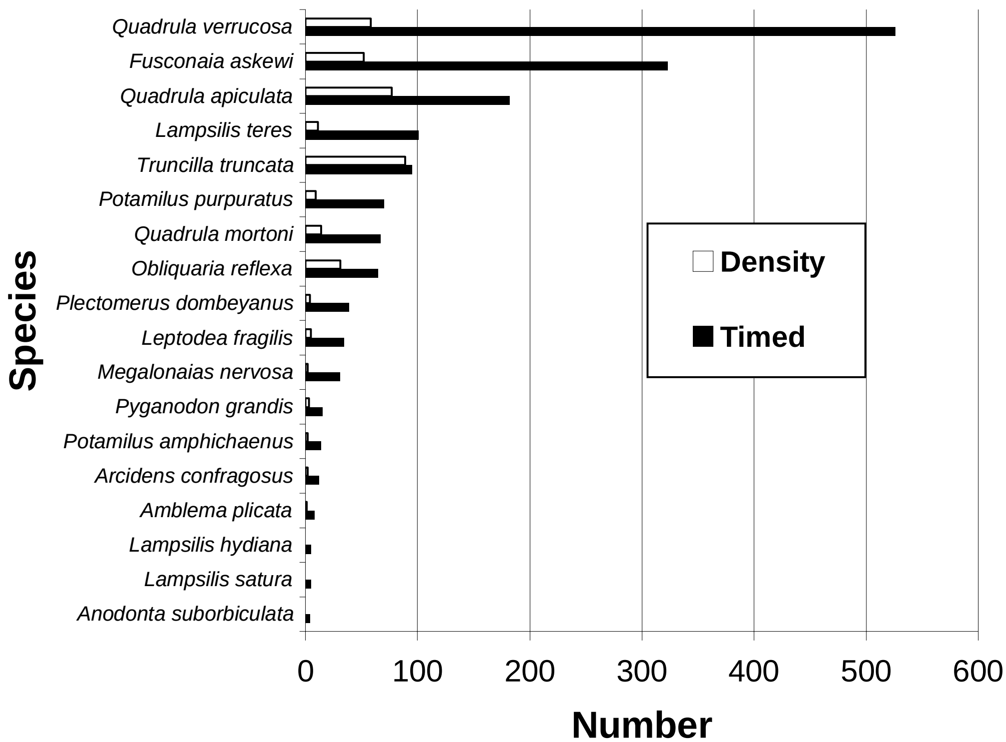

Figure 2. Comparison of the number of unionid mussels collected at the three sanctuaries of the Sabine River by sampling technique. The species are ranked by their abundances in the timed surveys.

compared for the density surveys using a single classification nested *ANOVA* with the sanctuary and sites nested with sanctuary as effects to be tested (SYSTAT®11 2004).

RESULTS

Eighteen unionid species totaling 1596 individuals were found in the survey of 19 sites in the three sanctuaries on the Sabine River (Figure 2). Only one species, *Anodonta suborbiculata,* was found in this study that was not recorded in Howells' surveys of these sanctuaries (Table 1). In the timed survey all 18 unionid species were found (Table 2) whereas in the density survey only 15 were recorded (Table 3). Four species were abundant in both timed and density surveys (Fig. 2). These species were *Quadrula verrucosa, Fusconaia askewi, Q. apiculata* and *Truncilla truncata*. Several other species were abundant in the time surveys, but less so in the

Table 1. Totals of unionids collected by various methods including visual examination, wading and snorkeling with hand collection recorded by the Texas Parks and Wildlife Department at three sanctuaries in the Sabine River. Collections occurred in 1993 and 1994 at the Lake Tawakoni sanctuary, in 1994 also at the Highway 14 sanctuary and in 1994, 1995 and twice in 2005 at the highway 43 sanctuary (Howells 1995; 1996a; 1996b; 2006).

	Lake Tawakoni	Highway 14	Highway 43	Total
Fusconaia askewi	0	0	88	88
Quadrula verrucosa	0	0	74	74
Lampsilis teres	3	0	63	66
Leptodea fragilis	28	1	19	48
Quadrula mortoni	0	0	47	47
Obliquaria reflexa	0	0	37	37
Quadrula apiculata	4	0	24	28
Potamilus purpuratus	17	0	10	27
Potamilus amphichaenus	1	0	11	12
Amblema plicata	3	0	8	11
Plectomerus dombeyanus	0	0	10	10
Truncilla truncata	2	0	7	9
Lampsilis satura	0	0	6	6
Pyganodon grandis	6	0	0	6
Lampsilis hydiana	0	0	5	5
Megalonaias nervosa	1	0	4	5
Utterbackia imbecillis	0	0	3	3
Arcidens confragosus	0	1	1	2
Toxolasma texasiensis	2	0	0	2
Total Number	67	2	417	486
Species Richness	10	2	17	19

density surveys. Timed surveys are generally more successful at locating rare species but tend to record more of the large species (Strayer et al. 1997; Vaughn et al. 1997). Seven species were relatively rare in both methods (Table 2 & 3). Measurements of live specimens found during the density survey are shown in Table 4. A few species, including *Fusconaia askewi*, exhibited a wide range of sizes in the Highway 14 and 43 Sanctuaries.

Jaccard's Coefficient of Community index indicated fewer species in common between the Lake Tawakoni Sanctuary and the other sanctuaries (CC_J 14 vs. Tawakoni = 0.44%; CC_J 43 vs.

Table 2. Totals of the species collected by the timed method at the three sanctuaries in the Sabine River.

	Lake Tawakoni	Hwy 14	Hwy 43	Total
Quadrula verrucosa	0	397	129	526
Fusconaia askewi	0	169	154	323
Quadrula apiculata	24	117	41	182
Lampsilis teres	1	24	76	101
Truncilla truncata	2	66	27	95
Potamilus purpuratus	6	32	32	70
Quadrula mortoni	0	11	56	67
Obliquaria reflexa	0	39	26	65
Plectomerus dombeyanus	0	17	22	39
Leptodea fragilis	2	15	17	34
Megalonaias nervosa	0	22	9	31
Pyganodon grandis	13	1	1	15
Potamilus amphichaenus	6	3	5	14
Arcidens confragosus	0	8	4	12
Amblema plicata	1	0	7	8
Lampsilis hydiana	0	0	5	5
Lampsilis satura	0	0	5	5
Anodonta suborbiculata	1	0	3	4
Total number	56	921	619	1596
Species richness	9	14	18	18
Shannon diversity	1.63	1.82	2.27	2.13
Evenness	0.74	0.69	0.78	0.73

Tawakoni = 0.50%; CC_J 14 vs. 43 = 0.78%). Lake Tawakoni Sanctuary had the fewest individuals and lowest species richness (Table 2). The highway 14 had the greatest number of individuals but the highway 43 sanctuary had the greatest richness (Table 2).

Densities of unionids were significantly different among all three sanctuaries (F = 7.93; df = 7,102; P < 0.0001). The density for Lake Tawakoni Sanctuary was the lowest, Highway 43 sanctuary a little higher and the Highway 14 sanctuary was the highest (Table 3).

DISCUSSION

The Sabine River historically supported approximately 33 unionid species (Howells et al. 1996). Recent surveys have

Table 3. Totals of the species collected by quadrate sampling method (for density measurement) at all three sanctuaries in the Sabine River.

	Lake Tawakoni	Hwy 14	Hwy 43	Total
Truncilla truncata	0	81	8	89
Quadrula apiculata	5	61	11	77
Quadrula verrucosa	0	51	7	58
Fusconaia askewi	0	28	24	52
Obliquaria reflexa	0	22	9	31
Quadrula mortoni	0	2	12	14
Lampsilis teres	0	2	9	11
Potamilus purpuratus	1	7	1	9
Leptodea fragilis	1	3	1	5
Plectomerus dombeyanus	0	4	0	4
Pyganodon grandis	1	2	0	3
Arcidens confragosus	0	2	0	2
Megalonaias nervosa	0	2	0	2
Potamilus amphichaenus	1	0	1	2
Amblema plicata	0	1	0	1
Number	9	268	83	360
Mean per square meter	3.60	21.44	7.60	
Standard error	1.64	3.56	1.08	
Species richness	5	14	10	15

recorded only a portion of those (Neck 1986; Ford & Nicholson 2006; Howells 1997; 2006). Ford & Nicholson's (2006) study on the Old Sabine Bottom Wildlife Management Area (OSBWMA) used timed searches and found 13 unionid species in that limited section of the Sabine River. The major substratum was sand and clay, neither of which are stable habitats for unionids and may explain the lower richness at the OSBWMA. The TPWD surveys involved visual, tactile and some snorkeling searches at the bridges bordering these sanctuaries in 1993 (Howells 1995) and 1994 (Howells 1995; 1996a; 1996b) and again in 2005 and 2006 (Howells 2006). In those surveys, TPWD found 486 live and recently dead individuals of 19 species (Table 1). Nearly all these specimens were from the sanctuary furthest downstream at the bridges on Highways 43 and 59. The addition to the current survey of the two species (*Utterbackia imbecillis* and *Toxolasma texasiensis*) that TPWD recorded in their surveys means that the

Table 4. Measurements on live unionids collected during density surveys in the three sanctuaries in the Sabine River. Mean Length and Standard Deviation given with the Range in parenthesis.

		Lake Tawakoni		Hwy 14		Hwy 43	
	Max Length (mm) in TX (Howells et al. 1996)	Number of Live Individuals	Mean Length (Range) (mm)	Number of Live Individuals	Mean Length (Range) (mm)	Number of Live Individuals	Mean Length (Range) (mm)
Fusconaia askewi	70 (95 in OK)			19	56.7+/-14.19 (28-82)	3	61.4+/-25.76 (32-80)
Lampsilis teres	145			1	32	3	122.6+/-12.95 (112.5-137.2)
Megalonaias nervosa	230			1	154		
Obliquaria reflexa	46 (80 in MO)			16	46.5+/-8.66 (30-59)	2	44.5+/-7.71 (39-49.9)
Plectomerus dombeyanus	132			3	89.3+/-23.12 (75-116)		
Potamilus amphichaenus	177	1	127.7				
Potamilus purpuratus	178	1	120	4	118.8+/-39.14 (63-146)		
Pyganodon grandis	170	1	98	2	65.0+/-16.97 (53-77)		
Quadrula apiculata	118	3	53.4+/-6.12 (46.3-57)	55	54.9+/-10.06 (32-71)	1	70.2
Quadrula mortoni	67			2	46.0+/-7.07 (41-51)	6	47.1+/-9.18 (32-57)
Quadrula verrucosa	170			41	106.6+/-28.44 (41.5-160)	2	92.3+/-8.13 (85.6-98)
Truncilla truncata	60			21	39.8+/-9.85 (19-59)	3	49.3+/-9.01 (40-58)

mussel fauna of the sanctuaries of the Sabine River currently exhibits 69.7% of the total species that historically occurred in the Sabine River.

It appears that, as in other east Texas rivers, anthropogenic impacts are likely reducing unionid diversity and abundance in the upper Sabine River. Near the dam at Lake Tawakoni the scouring impact of high water releases on the river substrate was very evident. The substrate was silt and sand, with only one very small site (30 m) of cobble where a few unionids were found. Further downstream, the riverbanks were relatively low and erosion was not evident but debris from the reservoir was abundant. The most apparent factor that could be impacting the mussels in other two sanctuaries was erosion. The Highway 14 Sanctuary had a number of shallow reaches with cobble, which produced riffles where live unionids were abundant. This sanctuary also had steep banks and surrounding agricultural land often came adjacent to the river. A number of recent bankfalls, which released large amounts of sand downstream were evident. Highway 43 Sanctuary was also shallow and wide, but had areas with extremely large boulders and little cobble. Mussels were not found in reaches with solid bedrock. The greatest densities were found just downstream of the bridge at Highway 43, which had stable geomorphology but where smaller rocks and cobble were present. During the time of this survey, construction was occurring near the bridge that released sand into the river. Then a rare summer flood occurred, which shifted the sand downstream covering much of one of the study sites.

Timed surveys can be used to examine species richness and ranked species abundances and the unionids in the sanctuaries were comparable to recent surveys in other east Texas rivers (Howells et al 2000; Bordelon & Harrel 2004). As is typical of unionid diversity studies, the rank abundance curve exhibited a few very abundant species with several intermediately abundant species and a large number of rare species (Fig. 2). The highest density of unionids of over 21 per square meter was found in the Highway 14

Sanctuary (Table 2). This density compares favorably to those in Little River (17 unionids per square meter) and the Kiamichi river (20 unionids per square meter) in southeastern Oklahoma (Vaughn & Spooner 2004). However, it is important to point out that these sites in the Sabine River were chosen particularly due to the presence of abundant unionids. Observations made during this study were that such optimal sites were relatively limited in each sanctuary. Indeed, there was significant variation among sanctuary mussel density. The Highway 43 Sanctuary had a mean density of only 7.6 unionids per square meter and the Lake Tawakoni Sanctuary had a much lower mean density of 3.6 unionids per square meter.

It does appear that recruitment of young is occurring in both Highway 14 and Highway 43 Sanctuaries since a range of sizes were found for several species (Table 4). One of the healthiest populations was *Fusconaia askewi*, which is a species of concern in the Texas Wildlife Action Plan (TPWD 2006). This population had very large individuals as well as very small specimens.

Unionid beds were found only in the sanctuaries below Highway 14 and 43 with only one very small area in the Lake Tawakoni Sanctuary with enough mussels to do a density survey. Although some of these beds in the downstream sanctuaries appeared to have significant numbers of unionids, it is evident that the beds do not extend for any length but rather are very sporadic. From limited observations made elsewhere and the literature (Neck 1986; Ford & Nicholson 2006; Howells 1997; 2006), it is likely that this pattern is true throughout the extent of the upper Sabine River. To understand the species composition as is exists today in the sanctuaries would require a landscape level approach detailing the various habitats that support the different species of unionids.

The impact of high water releases on erosion of the banks and covering of beds with sand was obviously a problem for these unionid populations. This was most evident by the lowest density of mussel occurring in the sanctuary near the dam. Even though this area had less erosion of banks (probably because bank-full level was relatively low and water likely spread over the surrounding wetlands), there were no mussels in most of the samples. The scouring effect of high water releases is known to impact mussels near reservoirs. Recruitment of mussels from this sanctuary is probably limited and it is unlikely that the small areas of dense mussels in the other sanctuaries will sustain all species within the upper Sabine River. It will be important to monitor these sanctuaries in the future.

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