

**STATUS AND DISTRIBUTION OF FRESHWATER MUSSELS
(BIVALVIA: UNIONOIDA) INHABITING THE SALINE RIVER WITHIN
FELSENTHAL NATIONAL WILDLIFE REFUGE**

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February 2015



INTRODUCTION

The Saline River in south central Arkansas has the most diverse and abundant mussel assemblage of any river west of the Mississippi River. Four federally protected species inhabit the Saline River including Arkansas Fatmucket (*Lampsilis powellii*), Pink Mucket (*Lampsilis abrupta*), Winged Mapleleaf (*Quadrula fragosa*), and Rabbitsfoot (*Quadrula cylindrica cylindrica*). Some of the first comprehensive mussel surveys of the Saline River (1980s – 1990s) focused on the headwater reaches, including the four forks and main stem downstream to near the Saline/Grant County line, where Arkansas Fatmucket occurs (Harris and Gordon 1988, Brown and Brown 1989, Burns and McDonnell 1992a and 1992b, Arkansas Natural Heritage Commission Database 2014). Prior to 1996, mussel survey effort in the middle and lower reaches of the Saline River was limited to a few highway crossings that provided easy river access (Arkansas Natural Heritage Commission Database 2014). Davidson (1997) surveyed and delineated mussel beds in the lower 18 km of the Saline River that lies within Felsenthal National Wildlife Refuge (NWR). Davidson and Clem (2002, 2004) provide the first comprehensive survey effort documenting mussel bed and concentration locations, species composition, and abundance for the 238 km reach of the Saline River from near Tull, Arkansas, to the northern boundary of Felsenthal NWR.

Davidson and Gosse (2004) and Peck (2010) provide quantitative data for selected mussel beds in the upper main stem Saline River. In recent years, survey efforts in the Saline River have focused on determining population estimates and community numeric standing crop for mussel beds in the middle and lower reaches near Mt. Elba, Arkansas, and between the Arkansas Game and Fish Commission (AGFC) Longview and Stillions accesses (Harris 2006, U.S. Fish and Wildlife Service [USFWS] unpublished data). These two reaches have been the focus of resource managers due to the abundant populations of Pink Mucket, Winged Mapleleaf and Rabbitsfoot.

In 2010 and 2011, AGFC and USFWS conducted post-2009 flood monitoring of selected beds in the Mt. Elba and Johnsville reaches. However, there have been no monitoring efforts to reassess the long-term (> 10 years) status of mussel beds in the Saline River. Our study presents the first long-term assessment (18 years since baseline survey) of mussel bed status in a selected reach (Felsenthal NWR) of the Saline River. We are providing this information so future conservation efforts, including land management activities at Felsenthal NWR, can better protect the mussel fauna.

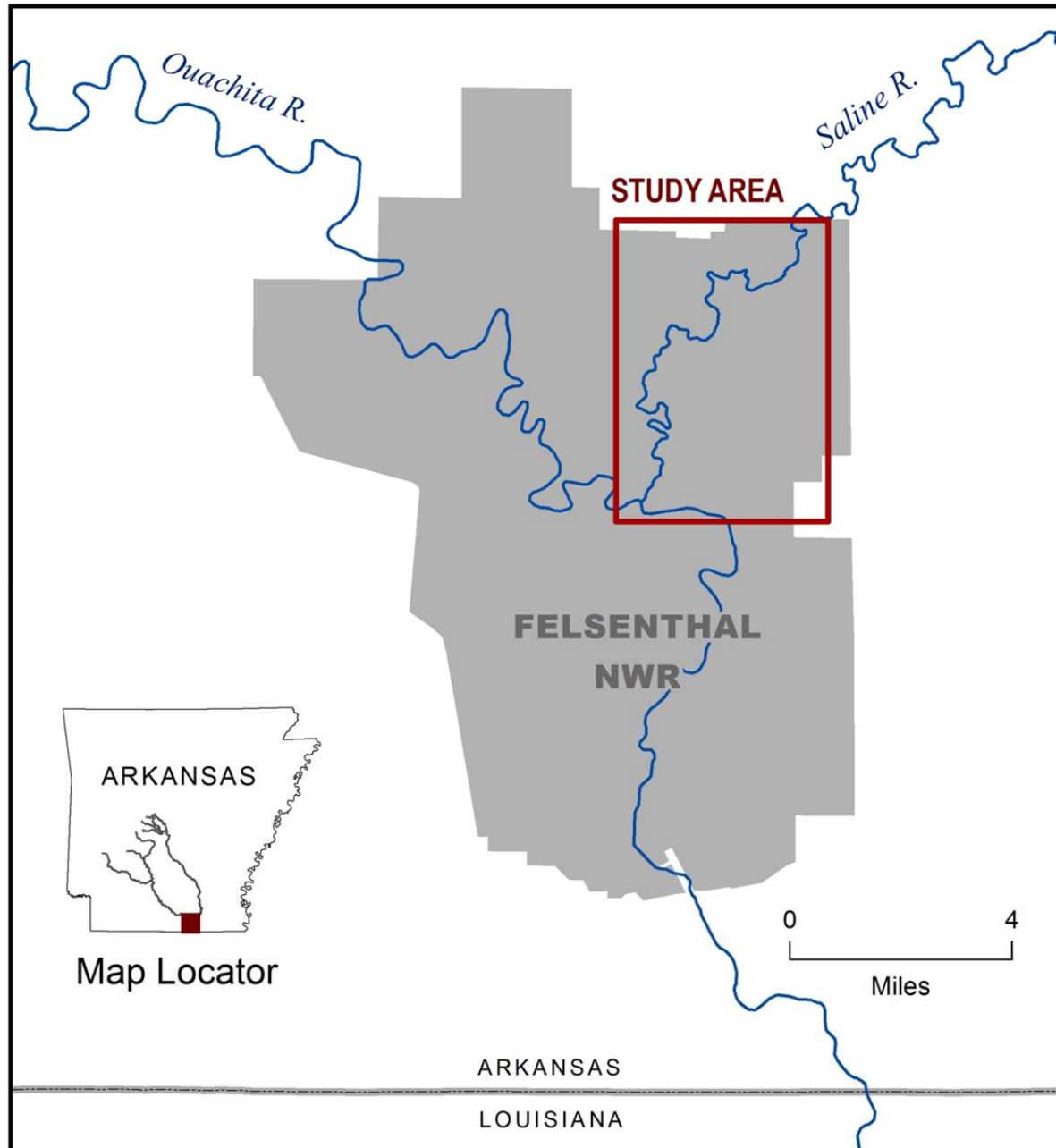
METHODS

Study Area

The Saline River is located in the South Central Plains (Level IV) Ecoregion in south central Arkansas (Woods *et al.* 2004). The Saline River flows southward before reaching its confluence with the Ouachita River near the Arkansas-Louisiana state line (Figure 1). It is the largest undammed river in the state. However, the U.S. Army Corps of Engineers operates a series of navigational structures on the lower Ouachita River. The most downstream structure occurring in Arkansas, Felsenthal Lock and Dam, is located approximately 21 km downstream of the Saline River confluence with the Ouachita River. This structure provides a six m lift for 104 km upstream in the Ouachita River and a 1.6 m fish and wildlife

pool used to manage the 163 km² Felsenthal NWR. Physical characteristics in the lower 20 – 25 km of the Saline River are affected by the lift provided by Felsenthal Lock and Dam.

Figure 1. Location of Saline River study area, 2014.



The study area for the Saline River lies within the boundary of Felsenthal NWR. The total drainage basin is 8,418 km² (USGS 1979). Channel width varies between 45 – 55 m upstream of the L'Aigle Creek confluence and becomes wider downstream of the confluence due to the prevalence of side channel mud flats. During low to moderate flows, the study area contains pools ranging from 3 – 9 m deep. The substrate is dominated by clay, sand, and gravel with large woody debris and an intact riparian area.

Survey Approach

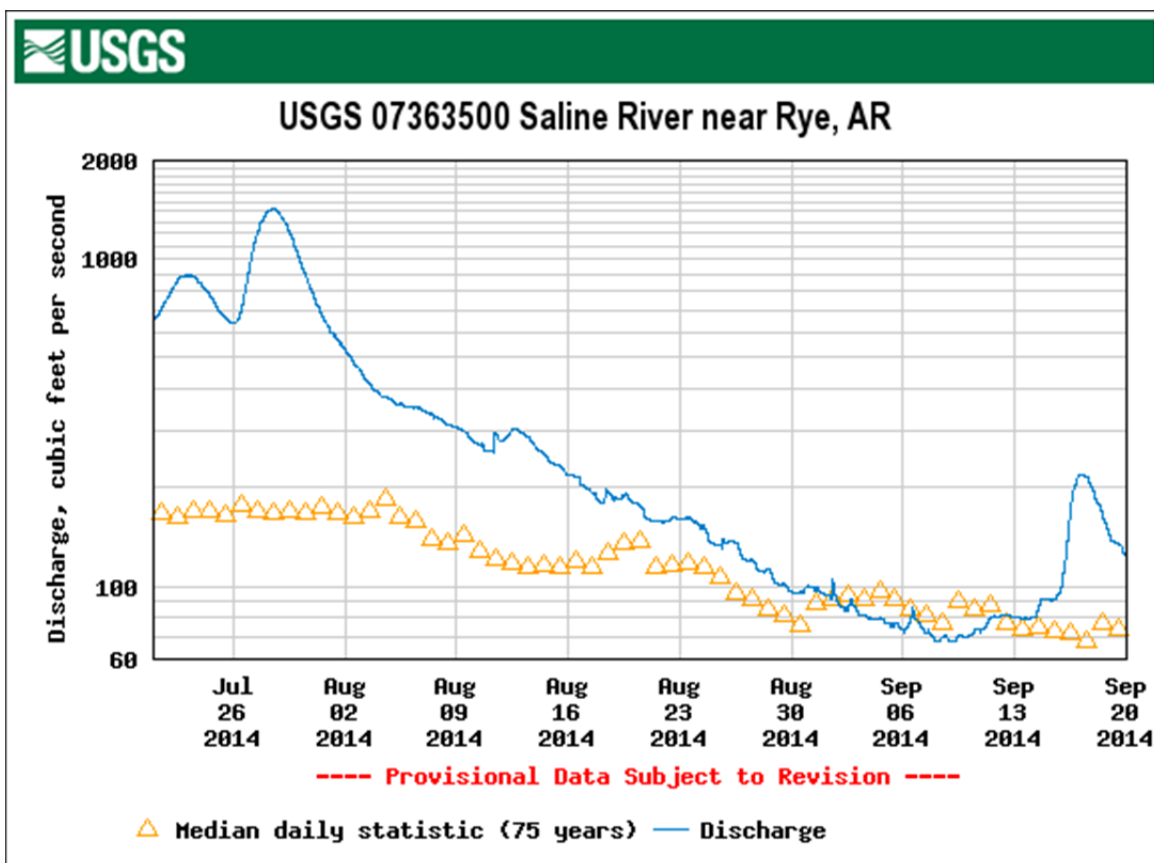
Davidson (1997) delineated existing mussel beds and provided baseline estimates of species composition, relative abundance, and population estimates and community numerical standing crop in the study area. Refuge management expressed an interest in repeating 1996 work completed by Davidson (1997) to determine status of the existing mussel assemblage. Survey sites were accessed via boat. Each survey site was sampled using dive techniques and search strategies included hand grubbing. Surveys were conducted from July 23 – September 17, 2014. Sample methodology for this monitoring effort uses methods of Harris *et al.* (1994), Christian (1995), Davidson (1997), and Christian and Harris (2005). Discharge (flow) was generally greater than the median discharge for the 75 year period of record during the survey time frame (Figure 2).

Nomenclature follows Turgeon *et al.* (1998), Inoue *et al.* (2013), Campbell and Lydeard (2012). The nomenclature for *Quadrula* is in flux at this time. We have chosen to reject changes within the *Quadrula* genus at this time until there is an empirical analysis of the *Quadrula* group as a whole.

Initial transect searches of probable mussel habitats were searched from upstream to downstream to identify and determine the limits of a potential mussel bed. Transect searches generally consisted of an area extending bank to bank (*i.e.*, wetted channel width) and approximately 60 m in length. Divers estimated the number of live mussels per m² by tactile methods. If the number of mussels was ≥ 10 mussels/m², the diver estimated the width of the bed by traversing the limits in one meter increments. Additional downstream and upstream “transects” were conducted until the substrate was uninhabited by mussels or density was < 10 mussels/m². Total length of a bed was measured using a laser range finder. Water depth, determined by a depth finder, and substrate type were recorded. Relative abundance, species composition, and general habitat information were recorded for areas with mussel densities averaging < 10 mussels/m², but with no limit as to total area.

Mussel beds were categorized as minor (< 500 m²) or major (> 500 m²). For minor beds (*m*), five samples were collected non-randomly from areas with the greatest density of mussels. For major beds (*M*), one m² quadrat sites were obtained from a random numbers table and applied in an X, Y coordinate style. Major beds with areas $< 2,500$ m² were sampled by removing one percent of the area (*e.g.*, 20 samples for a 2,000 m² bed), while 25 samples were taken from beds with $> 2,500$ m². Mussels within the quadrat were collected by excavating the substrate and tactily searching through the substrate. Mussels were placed in a mesh bag and taken to the surface where they were identified, counted, and returned to the site of collection. We calculated species population estimates and assemblage total community numeric standing crop using the methods from Sampford (1962), which were identical to Davidson (1997).

Figure 2. Saline River discharge (flow) near Rye, Arkansas, from July 20 – September 19, 2014 (USGS provisional data,
http://waterdata.usgs.gov/ar/nwis/uv/?site_no=07363500&PARAMeter_cd=00065,00060).



RESULTS

Survey of the 17.4 km of the Saline River required 36 person days to complete. Thirty-one (31) species were recorded during the survey. Five species documented by Davidson (1997) were not collected during this survey. Four species documented during this survey were not collected by Davidson (1997), including the federally endangered Winged Mapleleaf (Table 1). Davidson (1997) collected one relict Pink Mucket (federally endangered), while live Pink Mucket individuals were collected during this survey. Winged Mapleleaf and Pink Mucket were restricted to the river reach upstream of the AGFC Prairie Island Access.

A total of 13 mussel beds (11 *M* beds and 2 *m* beds) were located and delineated and 39 qualitative transect searches were searched outside of defined beds (Tables 2, 3 and 4A – 4M, Figures 3a – 3f). Three beds not identified by Davidson (1997) were delineated during this survey (Beds 0*m*, 6.5*M* and 7.5*M*). Mean bed area was 2,101 m² with a range of 200 – 9,900 m² (Table 2). Mean density for *M*beds reported by Davidson (1997) increased for four beds (Beds 1*M*, 5*M*, 8*M*, and 10*M*) and was similar for

Beds 2M, 3M and 6M. Mean density for mbeds reported by Davidson (1997) increased in Bed 9m. Except for Beds 2m, 5M, and 8M, bed area was larger than areas reported by Davidson (1997).

Table 1. Mussel species (n =35) documented from the Saline River within Felsenthal National Wildlife Refuge, Arkansas. Asterisk (*) denotes species not found during present survey. Number one (¹) denotes species found in current survey, but not reported from previous surveys.

Species	Common Name
<i>Actinonaias ligamentina</i>	Mucket
<i>Amblema plicata</i>	Threeridge
<i>Anodonta suborbiculata</i> *	Flat Floater
<i>Ellipsaria lineolata</i>	Butterfly
<i>Elliptio dilatata</i>	Spike
<i>Fusconaia flava</i>	Wabash Pigtoe
<i>Lampsilis abrupta</i>	Pink Mucket
<i>Lampsilis cardium</i>	Plain pocketbook
<i>Lampsilis</i> sp. B cf. <i>hydiana</i>	Louisiana Fatmucket
<i>Lampsilis teres</i>	Yellow Sandshell
<i>Lasmigona complanata</i> *	White Heelsplitter
<i>Leptodea fragilis</i>	Fragile Papershell
<i>Ligumia recta</i> ¹	Black Sandshell
<i>Megaloniaias nervosa</i>	Washboard
<i>Obliquaria reflexa</i>	Threehorn Wartyback
<i>Obovaria arkansasensis</i>	Southern Hickorynut
<i>Plectomerus dombeyanus</i>	Bankclimber
<i>Pleurobema sintoxia</i> ¹	Round Pigtoe
<i>Pleurobema rubrum</i>	Pyramid Pigtoe
<i>Pleurobema riddelli</i> ¹	Louisiana Pigtoe
<i>Potamilus purpuratus</i>	Bleufer
<i>Ptychobranhus occidentalis</i>	Ouachita Kidneyshell
<i>Pyganodon grandis</i> *	Giant Floater
<i>Quadrula apiculata</i> ¹	Southern Mapleleaf
<i>Quadrula fragosa</i> ¹	Winged Mapleleaf
<i>Quadrula nodulata</i>	Wartyback
<i>Quadrula metanevra</i>	Monkeyface
<i>Quadrula nobilis</i>	Gulf Mapleleaf
<i>Reginaia ebena</i>	Ebonyshell
<i>Strophitus undulatus</i>	Squawfoot
<i>Toxolasma lividum</i>	Purple Lilliput
<i>Tritogonia verrucosa</i>	Pistolgrip
<i>Truncilla donaciformis</i> *	Fawnsfoot
<i>Truncilla truncata</i>	Deertoe
<i>Utterbackia imbecillis</i> *	Paper Floater

Table 2. Mussel bed location and area in the Saline River within Felsenthal National Wildlife Refuge, 2014.

Site Name	Map Label	Start		End		Bed Width (m ²)	Bed Area (m ²)
		Latitude	Longitude	Latitude	Longitude		
0m*	0m	33.18907	-92.13099	33.18892	-92.13065	5	200
1M Stratum 1	1M	33.19764	-92.13303	33.19755	-92.13434	2	260
1M Stratum 2	1M	33.19755	-92.13434	33.19744	-92.13521	10	900
2M	2m	33.20490	-92.12826	33.20412	-92.12856	3	270
3M Stratum 1	3M	33.20307	-92.13119	33.20214	-92.13136	5	475
3M Stratum 2	3M	33.20214	-92.13136	33.20124	-92.13223	10	1850
4M	4m	33.20586	-92.12215	33.20628	-92.12280	10	1000
5M	5M	33.21622	-92.11717	33.21515	-92.11650	20	3200
6M Stratum 1	6M	33.22097	-92.11485	33.22029	-92.11459	20	1600
6M Stratum 2	6M	33.22029	-92.11459	33.21866	-92.11477	5	1100
6.5M*	6.5M	33.22342	-92.11577	33.22204	-92.11626	8	1560
7M	7M	33.22161	-92.11000	33.22151	-92.11076	10	1300
7.5M*	7.5M	33.22351	-92.10917	33.22294	-92.10982	10	1200
8M	8M	33.23143	-92.08829	33.23143	-92.08829	5	1900
9m	9m	33.23283	-92.08587	33.23371	-92.08556	5	600
10M	10M	33.23506	-92.09031	33.23888	-92.08618	22	9900

Asterisk (*) denotes mussel bed not identified by Davidson (1997).

Upper case "M" denotes major bed (> 500 m²); lower case "m" denotes minor bed (< 500 m²).

Table 3. Saline River qualitative mussel survey site locations within Felsenthal National Wildlife Refuge, 2014.

Site	Map Label	Latitude	Longitude
SR 09171409	14-01	33.179940	-92.12901
SR 09171408	14-02	33.182830	-92.13474
SR 09171407	14-03	33.184200	-92.13479
SR 09171406	14-04	33.182260	-92.12849
SR 09171405	14-05	33.183190	-92.12808
SR 09171404	14-06	33.189040	-92.13078
SR 09171403	14-07	33.188720	-92.13271
SR 09161406	14-08	33.187540	-92.13218
SR 09171402	14-09	33.186410	-92.13363
SR 09161405	14-10	33.186300	-92.13419
SR09141401	14-11	33.186390	-92.13512
SR 09161403	14-12	33.187870	-92.13869
SR 09161402	14-13	33.190900	-92.13570
SR 09161404	14-14	33.188740	-92.13837
SR 09161401	14-15	33.195220	-92.13651
SR 09161410	14-16	33.197640	-92.13303
SR 09161409	14-17	33.197940	-92.13267
SR 09161408	14-18	33.199960	-92.13335
SR 09161407	14-19	33.200940	-92.13354
SR 09101404	14-20	33.204700	-92.12830
SR 09101403	14-21	33.208230	-92.12885
SR 09101402	14-22	33.209350	-92.12798
SR 09101401	14-23	33.209530	-92.12718
SR 09091407	14-24	33.206330	-92.12028
SR 09091406	14-25	33.205320	-92.11730
SR 09091404	14-26	33.206100	-92.11585
SR 09091405	14-27	33.206150	-92.11575
SR 09091403	14-28	33.207200	-92.11471
SR 09091402	14-29	33.208240	-92.11399
SR 09091401	14-30	33.212930	-92.11311
SR 07311401	14-31	33.222690	-92.11637
SR 07301401	14-32	33.223190	-92.10965
SR 07251407	14-33	33.219350	-92.10452
SR 07251406	14-34	33.218630	-92.10387
SR 07251405	14-35	33.219730	-92.09998
SR 07251404	14-36	33.220820	-92.09463
SR 07251403	14-37	33.221550	-92.09338
SR 07251402	14-38	33.223920	-92.09202
SR 07251401	14-39	33.226930	-92.08798

A total of 8,385 individuals were recorded from *M* and *m* beds. Mean species richness for all beds was 16 with a range of 7 – 28 (Tables 4A – 4M), compared to a mean of 15 and range of 7 – 26 in 1996 (Davidson 1997). Mean, minimum and maximum mussel density and relative abundance for each species for *M* and *m* beds is reported in Tables 4A – 4M. Community numeric standing crop for *M* beds ranged from 13,900±2,426 (Bed 4M) – 1,004,256±271,786 (Bed 10M).

Five species comprised 80 percent of the total (Table 5). Pimpleback (*Quadrula pustulosa*) and Threeridge (*Amblema plicata*) were the two dominant species comprising 27 and 26 percent of the total, respectively. Southern Hickorynut (*Obovaria arkansensis*), Wabash Pigtoe (*Fusconaia flava*), and Gulf Mapleleaf (*Quadrula nobilis*) comprised the remainder of the 80 percent (17.7, 5.6, and 4.1 percent, respectively). Two or three species each comprised greater than 10 percent of mussel beds. The remainder of species in each mussel bed collectively comprised 70 – 89 percent of the total. Thirty-one (31) to 63 percent of species present in each mussel bed comprised less than one percent of the total. Only in one instance (Bed 2m) did a species compose greater than 50 percent of the total community.

Tables 4A – 4M. Physical parameters, species composition, and population and community estimates of minor and major mussel beds of the Saline River within the Felsenthal National Wildlife Refuge boundary, Arkansas, 1996 and 2014.

Table 4A. cont'd.

Location: 0m (see Table 2 for latitude/longitude)						
	1996			2014		
Estimated Stratum Area (m ²):	NA			1.) 5 m x 40 m = 200 m ²		
1 m ² Quadrats Sampled:	NA			5		
Min – Max Density (#/m ²):	NA			11 – 65		
Mean Density #/m ² (SD):	NA			1.) 33.0 (20.4)		
Species	1996 Number Collected	2014 Number Collected	1996 Percent of Total	2014 Percent of Total	1996 Population Estimate	2014 Population Estimate
<i>Amblema plicata</i>	NA	68	NA	41.2	NA	NC
<i>Fusconaia flava</i>	NA	4	NA	2.4	NA	NC
<i>Lampsilis sp. B cf. hydiana</i>	NA	1	NA	0.6	NA	NC
<i>Megaloniais nervosa</i>	NA	15	NA	9.1	NA	NC
<i>Obliquaria reflexa</i>	NA	2	NA	1.2	NA	NC
<i>Plectomerus dombeyanus</i>	NA	5	NA	3.0	NA	NC
<i>Pleurobema sintoxia</i>	NA	1	NA	0.6	NA	NC
<i>Quadrula apiculata</i>	NA	1	NA	0.6	NA	NC
<i>Quadrula nobilis</i>	NA	24	NA	14.5	NA	NC
<i>Quadrula pustulosa</i>	NA	42	NA	25.5	NA	NC
<i>Reginaia ebena</i>	NA	2	NA	1.2	NA	NC
Totals	NA	165	NA	99.9	NA	NC

NA – not applicable

NC – minor bed (< 500 m²), population estimate not calculated

Table 4B. cont'd.

Location: 1M (see Table 2 for latitude/longitude)						
	1996			2014		
Estimated Stratum Area (m ²):	1.) 5 m x 90 m = 450 m ² 2.) NA			1.) 2 m x 130 m = 260 m ² 2.) 10 m x 90 m = 900 m ² Total: 1160 m ²		
1 m ² Quadrats Sampled:	5			13		
Min – Max Density (#/m ²):	17 – 38			10 – 72		
Mean Density #/m ² (SD):	1.) 24.6 (8.8) 2.) NA			1.) 17.3 (7.0) 2.) 53.3 (14.9) Total: 45.0 (20.6)		
Species	1996 Number Collected	2014 Number Collected	1996 Percent of Total	2014 Percent of Total	1996 Population Estimate	2014 Population Estimate
<i>Amblema plicata</i>	58	276	47.2	47.2	NC	24773±7160
<i>Ellipsaria lineolata</i>	0	2	0.0	0.3	NC	180±396
<i>Fusconaia flava</i>	2	17	1.6	2.9	NC	1530±981
<i>Lampsilis cardium</i>	0	1	0.0	0.2	NC	90±198
<i>Megaloniais nervosa</i>	1	17	0.8	2.9	NC	1530±726
<i>Obliquaria reflexa</i>	1	0	0.8	0.0	NC	0
<i>Obovaria arkansasensis</i>	4	42	3.3	7.2	NC	3780±1409
<i>Plectomerus dombeyanus</i>	0	6	0.0	1.0	NC	540±605
<i>Pleurobema sintoxia</i>	0	13	0.0	2.2	NC	1170±784
<i>Potamilus purpuratus</i>	1	1	0.8	0.2	NC	87±233
<i>Quadrula apiculata</i>	0	1	0.0	0.2	NC	90±198
<i>Quadrula nobilis</i>	0	24	0.0	4.1	NC	2127±1351
<i>Quadrula pustulosa</i>	53	172	43.2	29.4	NC	15410±3761
<i>Reginaia ebena</i>	3	6	2.4	1.0	NC	540±845
<i>Strophitus undulatus</i>	0	1	0.0	0.2	NC	90±198
<i>Tritogonia verrucosa</i>	0	6	0.0	1.0	NC	540±528
Totals	123	585	100.0	100.0	NC	52477±9602

NA – not applicable

NC – minor bed (< 500 m²), population estimate not calculated

Table 4C. cont'd.

Location: 2m (see Table 2 for latitude/longitude)						
	1996			2014		
Estimated Stratum Area (m ²):	1.) 7 m x 65 m = 455 m ²			1.) 3 m x 90 m = 270 m ²		
1 m ² Quadrats Sampled:	5			5		
Min – Max Density (#/m ²):	10 – 51			10 – 72		
Mean Density #/m ² (SD):	1.) 26.6 (16.9)			1.) 27.2 (6.7)		
Species	1996 Number Collected	2014 Number Collected	1996 Percent of Total	2014 Percent of Total	1996 Population Estimate	2014 Population Estimate
<i>Amblema plicata</i>	58	27	43.6	19.8	NC	NC
<i>Fusconaia flava</i>	3	0	2.3	0.0	NC	NC
<i>Lampsilis sp. B cf. hydiana</i>	1	0	0.8	0.0	NC	NC
<i>Lampsilis cardium</i>	2	0	1.5	0.0	NC	NC
<i>Lampsilis teres</i>	2	0	1.5	0.0	NC	NC
<i>Megalonaias nervosa</i>	1	8	0.8	5.9	NC	NC
<i>Obliquaria reflexa</i>	2	0	1.5	0.0	NC	NC
<i>Obovaria arkansasensis</i>	6	2	4.5	1.5	NC	NC
<i>Plectomerus dombeyanus</i>	8	1	6.0	0.7	NC	NC
<i>Potamilus purpuratus</i>	1	0	0.8	0.7	NC	NC
<i>Quadrula nobilis</i>	0	19	0.0	14.0	NC	NC
<i>Quadrula pustulosa</i>	48	78	36.1	57.3	NC	NC
<i>Reginaia ebena</i>	1	1	0.8	0.7	NC	NC
Totals	133	136	100.2	100.6	NC	NC

NC – minor bed (< 500 m²), population estimate not calculated

Table 4D. cont'd.

Location: 3M (see Table 2 for latitude/longitude)						
	1996			2014		
Estimated Stratum Area (m ²):	1.) 18 m x 50 m = 900 m ² 2.) NA			1.) 5 m x 95 m = 475 m ² 2.) 10 m x 185 m = 1850 m ² Total: 2325 m ²		
1 m ² Quadrats Sampled:	9			23		
Min – Max Density (#/m ²):	1 – 61			5 – 73		
Mean Density #/m ² (SD):	1.) 27.2 (19.8) 2.) NA			1.) 35.6 (21.5) 2.) 26.4 (16.8) Total: 28.4 (18.2)		
Species	1996 Number Collected	2014 Number Collected	1996 Percent of Total	2014 Percent of Total	1996 Population Estimate	2014 Population Estimate
<i>Amblema plicata</i>	110	229	44.9	35.0	11000±6993	23077±7440
<i>Ellipsaria lineolata</i>	3	1	1.2	0.2	300±344	103±202
<i>Fusconaia flava</i>	14	22	5.7	3.4	1400±1338	2238±1549
<i>Lampsilis cardium</i>	0	5	0.0	0.8	0	506±494
<i>Lampsilis sp. B cf. hydiana</i>	0	2	0.0	0.3	0	198±260
<i>Lampsilis teres</i>	1	2	0.4	0.3	100±229	198±260
<i>Leptodea fragilis</i>	2	1	0.8	0.2	200±303	103±202
<i>Megaloniais nervosa</i>	3	28	1.2	4.3	300±487	2792±1311
<i>Obliquaria reflexa</i>	3	5	1.2	0.8	300±487	491±383
<i>Obovaria arkansasensis</i>	5	74	2.0	11.3	500±500	7466±3462
<i>Plectomerus dombeyanus</i>	2	28	0.8	4.3	200±303	2722±2314
<i>Pleurobema rubrum</i>	0	3	0.0	0.5	0	308±607
<i>Pleurobema sintoxia</i>	0	15	0.0	2.3	0	1526±1079
<i>Potamilus purpuratus</i>	3	1	1.2	0.2	300±487	103±202
<i>Pyganodon grandis</i>	2	0	0.8	0.0	200±303	0
<i>Quadrula apiculata</i>	0	5	0.0	0.8	0	498±379
<i>Quadrula nobilis</i>	11	31	4.5	4.7	1100±827	3124±1258
<i>Quadrula nodulata</i>	1	1	0.4	0.2	100±229	103±202
<i>Quadrula pustulosa</i>	74	186	30.2	28.4	7400±3606	18759±4137
<i>Reginaia ebena</i>	5	10	2.0	1.5	500±363	1012±770
<i>Tritogonia verrucosa</i>	4	5	1.6	0.8	400±698	498±476
<i>Truncilla truncata</i>	2	0	0.8	0.0	200±303	0
Totals	245	654	99.7	100.3	24500±13600	65832±16254

NA – not applicable

Table 4E. cont'd.

Location: 4M (see Table 2 for latitude/longitude)						
	1996			2014		
Estimated Stratum Area (m ²):	1.) 5 m x 60 m = 300 m ²			1.) 10 m x 100 m = 1000 m ²		
1 m ² Quadrats Sampled:	5			10		
Min – Max Density (#/m ²):	9 – 37			10 – 72		
Mean Density #/m ² (SD):	1.) 24.2 (13.6)			1.) 13.9 (4.2)		
Species	1996 Number Collected	2014 Number Collected	1996 Percent of Total	2014 Percent of Total	1996 Population Estimate	2014 Population Estimate
<i>Actinonaias ligamentina</i>	1	0	0.8	0.0	NC	0
<i>Amblema plicata</i>	48	36	36.7	25.9	NC	3600±1311
<i>Ellipsaria lineolata</i>	1	0	0.8	0.0	NC	0
<i>Fusconaia flava</i>	4	1	3.3	0.7	NC	100±183
<i>Lampsilis sp. B cf. hydiana</i>	1	0	0.8	0.0	NC	0
<i>Megalonaias nervosa</i>	4	12	3.3	8.6	NC	1200±710
<i>Obliquaria reflexa</i>	0	1	0.0	0.7	NC	100±183
<i>Plectomerus dombeyanus</i>	1	1	0.8	0.7	NC	100±183
<i>Potamilus purpuratus</i>	1	0	0.8	0.0	NC	0
<i>Quadrula apiculata</i>	0	1	0.0	0.7	NC	100±183
<i>Quadrula nobilis</i>	3	15	2.5	10.8	NC	1500±828
<i>Quadrula nodulata</i>	1	1	0.8	0.7	NC	100±183
<i>Quadrula pustulosa</i>	50	70	41.3	50.4	NC	7000±1981
<i>Reginaia ebena</i>	2	1	1.6	0.7	NC	100±183
<i>Tritogonia verrucosa</i>	3	0	2.5	0.0	NC	0
<i>Truncilla truncata</i>	1	0	0.8	0.0	NC	0
Totals	121	139	100.2	99.9	NC	13900±2426

Table 4F. cont'd.

Location: 5M (see Table 2 for latitude/longitude)						
	1996			2014		
Estimated Stratum Area (m ²):	1.) 20 m x 90 m = 3200 m ² 2.) 10 m x 50 m = 500 m ² Total: 2300 m ²			1.) 20 m x 160 m = 3200 m ² 2.) NA		
1 m ² Quadrats Sampled:	23			25		
Min – Max Density (#/m ²):	6 – 60			12 – 116		
Mean Density #/m ² (SD):	1.) 29.1 (12.2) 2.) 32.0 (19.3) Total: 29.7 (13.6)			1.) 53.4 (26.1) 2.) NA		
Species	1996 Number Collected	2014 Number Collected	1996 Percent of Total	2014 Percent of Total	1996 Population Estimate	2014 Population Estimate
<i>Actinonaias ligamentina</i>	1	0	0.1	0.0	100±207	0
<i>Amblema plicata</i>	282	294	41.2	22.0	28200±6678	37632±8057
<i>Ellipsaria lineolata</i>	11	18	1.6	1.3	1100±770	2304±1145
<i>Elliptio dilatata</i>	0	1	0.0	0.1	0	128±224
<i>Fusconaia flava</i>	52	75	7.6	5.6	5200±2103	9600±2929
<i>Lampsilis cardium</i>	4	6	0.6	0.4	400±639	768±1545
<i>Lampsilis sp. B cf. hydiana</i>	0	1	0.0	0.1	0	128±224
<i>Lampsilis teres</i>	0	1	0.0	0.1	0	128±224
<i>Leptodea fragilis</i>	3	2	0.4	0.2	300±335	256±310
<i>Ligumia recta</i>	0	1	0.0	0.1	0	128±224
<i>Megalonaias nervosa</i>	15	36	2.2	2.7	1500±719	4608±1413
<i>Obliquaria reflexa</i>	5	25	0.7	1.9	500±402	3200±1294
<i>Obovaria arkansasensis</i>	10	360	1.5	27.0	1000±570	46080±14135
<i>Plectomerus dombeyanus</i>	7	38	1.0	2.8	700±541	4864±3884
<i>Pleurobema riddellii</i>	0	18	0.0	1.3	0	2304±1666
<i>Pleurobema rubrum</i>	1	13	0.1	1.0	100±207	1664±863
<i>Pleurobema sintoxia</i>	0	82	0.0	6.1	0	10496±2921
<i>Potamilus purpuratus</i>	6	2	0.9	0.2	600±443	256±310
<i>Pyganodon grandis</i>	2	0	0.3	0.0	200±283	0
<i>Pytchobranhus occidentalis</i>	2	0	0.3	0.0	200±283	0
<i>Quadrula apiculata</i>	0	1	0.0	0.1	0	128±224
<i>Quadrula nobilis</i>	18	34	2.6	2.5	1800±838	4352±1581
<i>Quadrula nodulata</i>	0	3	0.0	0.2	0	384±372
<i>Quadrula pustulosa</i>	168	279	24.6	20.9	16800±3782	35712±4010
<i>Reginaia ebena</i>	71	38	10.2	2.8	7100±4640	4864±1715
<i>Tritogonia verrucosa</i>	21	3	3.1	0.2	2100±945	384±372
<i>Truncilla truncata</i>	5	3	0.7	0.2	500±502	384±372
Totals	684	1334	99.9	99.8	24500±13600	170752±29259

NA – not applicable

Table 4G. cont'd.

Location: 6M (see Table 2 for latitude/longitude)						
	1996			2014		
Estimated Stratum Area (m ²):	1.) 5 m x 85 m = 450 m ² 2.) NA			1.) 20 m x 80 m = 1600 m ² 2.) 5 m x 220 m = 1100 m ² Total: 2700 m ²		
1 m ² Quadrats Sampled:	5			25		
Min – Max Density (#/m ²):	9 – 28			4 – 84		
Mean Density #/m ² (SD):	1.) 21.6 (7.4) 2.) NA			1.) 25.6 (21.4) 2.) 19.2 (18.1) Total: 22.9 (19.9)		
Species	1996 Number Collected	2014 Number Collected	1996 Percent of Total	2014 Percent of Total	1996 Population Estimate	2014 Population Estimate
<i>Amblema plicata</i>	43	191	39.8	34.7	NC	21619±7700
<i>Ellipsaria lineolata</i>	1	3	0.9	0.5	NC	334±743
<i>Fusconaia flava</i>	6	16	5.6	2.9	NC	1816±1611
<i>Lampsilis cardium</i>	2	3	1.9	0.5	NC	343±326
<i>Leptodea fragilis</i>	1	0	0.9	0.0		0
<i>Megalonaias nervosa</i>	3	9	2.8	1.6	NC	1016±700
<i>Obliquaria reflexa</i>	1	1	0.9	0.2	NC	114±204
<i>Obovaria arkansasensis</i>	7	84	6.5	15.3	NC	9403±8013
<i>Plectomerus dombeyanus</i>	3	20	2.8	3.6	NC	2247±2259
<i>Pleurobema riddellii</i>	0	3	0.0	0.5	NC	330±420
<i>Pleurobema sintoxia</i>	0	5	0.0	0.9	NC	567±657
<i>Potamilus purpuratus</i>	0	6	0.0	1.1	NC	673±663
<i>Quadrula nobilis</i>	4	43	3.7	7.8	NC	4841±1292
<i>Quadrula nodulata</i>	0	1	0.0	0.2	NC	114±647
<i>Quadrula pustulosa</i>	33	147	30.6	26.7	NC	16573±2957
<i>Reginaia ebena</i>	2	17	1.9	3.1	NC	1934±1197
<i>Tritogonia verrucosa</i>	2	0	1.9	0.0	NC	0
<i>Truncilla truncata</i>	0	1	0.0	0.2	NC	110±197
Totals	108	550	100.2	99.8	NC	62034±19445

NA – not applicable

NC – Minor bed (< 500 m²), population estimate not calculated

Note: one Winged Mapleleaf was collected from Bed 6M while delineating bed area.

Table 4H. cont'd.

Location: 6.5M (see Table 2 for latitude/longitude)						
	1996			2014		
Estimated Stratum Area (m ²):	NA			1.) 8 m x 195 m = 1560 m ²		
1 m ² Quadrats Sampled:	NA			16		
Min – Max Density (#/m ²):	NA			9 – 33		
Mean Density #/m ² (SD):	NA			1.) 18.9 (6.6)		
Species	1996 Number Collected	2014 Number Collected	1996 Percent of Total	2014 Percent of Total	1996 Population Estimate	2014 Population Estimate
<i>Amblema plicata</i>	NA	100	NA	33.1	NA	9750±2339
<i>Ellipsaria lineolata</i>	NA	2	NA	0.7	NA	195±237
<i>Fusconaia flava</i>	NA	1	NA	0.3	NA	98±173
<i>Megalonaia nervosa</i>	NA	17	NA	5.6	NA	1658±691
<i>Obovaria arkansasensis</i>	NA	2	NA	0.7	NA	195±237
<i>Plectomerus dombeyanus</i>	NA	5	NA	1.7	NA	488±332
<i>Quadrula apiculata</i>	NA	2	NA	0.7	NA	195±237
<i>Quadrula nobilis</i>	NA	28	NA	9.3	NA	2730±820
<i>Quadrula nodulata</i>	NA	2	NA	0.7	NA	195±237
<i>Quadrula pustulosa</i>	NA	133	NA	44.0	NA	12968±2926
<i>Reginaia ebena</i>	NA	8	NA	2.6	NA	780±759
<i>Tritogonia verrucosa</i>	NA	2	NA	0.7	NA	195±237
Totals	NA	302	NA	100.1	NA	29445±4574

NA – not applicable

Table 4I. cont'd.

Location: 7M (see Table 2 for latitude/longitude)						
	1996			2014		
Estimated Stratum Area (m ²):	1.) 10 m x 100 m = 1000 m ²			1.) 10 m x 130 m = 1300 m ²		
1 m ² Quadrats Sampled:	10			13		
Min – Max Density (#/m ²):	5 – 74			11 – 47		
Mean Density #/m ² (SD):	1.) 29.1 (12.2)			1.) 28.1 (11.8)		
Species	1996 Number Collected	2014 Number Collected	1996 Percent of Total	2014 Percent of Total	1996 Population Estimate	2014 Population Estimate
<i>Amblema plicata</i>	114	131	34.8	35.9	11400±7174	13100±5072
<i>Ellipsaria lineolata</i>	6	0	1.8	0.0	600±600	0
<i>Elliptio dilatata</i>	0	1	0.0	0.3	0	100±180
<i>Fusconaia flava</i>	16	5	4.9	1.4	1600±835	500±421
<i>Lampsilis cardium</i>	5	0	1.5	0.0	500±503	0
<i>Lampsilis teres</i>	2	0	0.6	0.0	200±300	0
<i>Leptodea fragilis</i>	2	0	0.6	0.0	200±300	0
<i>Ligumia recta</i>	0	0	0.0	0.0	0	0
<i>Megalonaias nervosa</i>	11	12	3.4	3.3	1100±783	1200±769
<i>Obliquaria reflexa</i>	3	5	0.9	1.7	300±481	500±563
<i>Obovaria arkansasensis</i>	4	2	1.2	0.5	400±368	200±243
<i>Plectomerus dombeyanus</i>	4	1	1.2	0.3	400±368	100±180
<i>Quadrula apiculata</i>	0	6	0.0	0.6	0	600±336
<i>Quadrula nobilis</i>	4	53	1.2	14.5	400±368	5300±1840
<i>Quadrula nodulata</i>	0	5	0.0	1.7	0	500±563
<i>Quadrula pustulosa</i>	117	128	35.6	35.1	11700±5231	12800±2560
<i>Reginaia ebena</i>	24	15	7.3	4.1	2400±1813	1500±910
<i>Tritogonia verrucosa</i>	9	1	2.7	0.3	900±708	100±180
<i>Truncilla truncata</i>	7	0	2.1	0.0	700±825	0
Totals	328	365	99.8	99.7	24500±13600	36500±7638

Table 4J. cont'd.

Location: 7.5M (see Table 2 for latitude/longitude)						
	1996			2014		
Estimated Stratum Area (m ²):	NA			1.) 10 m x 120 m = 1200 m ²		
1 m ² Quadrats Sampled:	NA			12		
Min – Max Density (#/m ²):	NA			16 – 84		
Mean Density #/m ² (SD):	NA			1.) 43.8 (19.7)		
Species	1996 Number Collected	2014 Number Collected	1996 Percent of Total	2014 Percent of Total	1996 Population Estimate	2014 Population Estimate
<i>Amblema plicata</i>	NA	109	NA	20.7	NA	10900±4044
<i>Ellipsaria lineolata</i>	NA	9	NA	1.7	NA	900±541
<i>Fusconaia flava</i>	NA	56	NA	10.6	NA	5600±2615
<i>Lampsilis cardium</i>	NA	6	NA	1.1	NA	600±421
<i>Megaloniais nervosa</i>	NA	9	NA	1.7	NA	900±659
<i>Obliquaria reflexa</i>	NA	9	NA	1.7	NA	900±603
<i>Obovaria arkansasensis</i>	NA	35	NA	6.6	NA	3500±2071
<i>Plectomerus dombeyanus</i>	NA	5	NA	1.0	NA	500±562
<i>Pleurobema riddellii</i>	NA	9	NA	1.7	NA	900±659
<i>Pleurobema rubrum</i>	NA	2	NA	0.4	NA	200±243
<i>Pleurobema sintoxia</i>	NA	14	NA	2.7	NA	1400±954
<i>Quadrula apiculata</i>	NA	1	NA	0.2	NA	100±180
<i>Quadrula nobilis</i>	NA	22	NA	4.2	NA	2200±1216
<i>Quadrula pustulosa</i>	NA	197	NA	37.5	NA	19700±4174
<i>Reginaia ebena</i>	NA	40	NA	7.6	NA	4000±2532
<i>Tritogonia verrucosa</i>	NA	3	NA	0.6	NA	300±283
Totals	NA	526	NA	100.0	NA	52600±12343

NA – not applicable

Table 4K. cont'd.

Location: 8M (see Table 2 for latitude/longitude)						
	1996			2014		
Estimated Stratum Area (m ²):	1.) 10 m x 230 m = 2300 m ²			1.) 5 m x 380 m = 1900 m ²		
1 m ² Quadrats Sampled:	23			19		
Min – Max Density (#/m ²):	5 – 39			10 – 70		
Mean Density #/m ² (SD):	1.) 15.3 (9.8)			1.) 34.9 (20.8)		
Species	1996 Number Collected	2014 Number Collected	1996 Percent of Total	2014 Percent of Total	1996 Population Estimate	2014 Population Estimate
<i>Amblema plicata</i>	134	184	38.2	27.7	13400±4648	18400±5421
<i>Ellipsaria lineolata</i>	0	7	0.0	1.1	0	700±639
<i>Fusconaia flava</i>	42	32	12.0	4.8	4200±2526	3200±1358
<i>Lampsilis abrupta</i>	0	1	0.0	0.2	0	100±176
<i>Lampsilis sp. B cf. hydiana</i>	3	0	0.9	0.0	300±341	0
<i>Lampsilis cardium</i>	4	2	1.1	0.3	400±486	200±250
<i>Megaloniais nervosa</i>	10	28	2.8	4.2	1000±720	2800±1157
<i>Obliquaria reflexa</i>	6	7	1.7	1.1	600±612	700±459
<i>Obovaria arkansasensis</i>	10	117	2.8	17.6	1000±720	11700±5218
<i>Plectomerus dombeyanus</i>	11	4	3.1	0.6	1100±782	400±322
<i>Pleurobema sintoxia</i>	0	1	0.0	0.2	0	100±176
<i>Ptychobranhus occidentalis</i>	2	0	0.6	0.0	200±285	0
<i>Pleurobema rubrum</i>	2	0	0.6	0.0	200±285	0
<i>Quadrula fragosa</i>	0	1	0.0	0.2		100±176
<i>Quadrula nobilis</i>	5	23	1.4	3.5	500±418	2300±979
<i>Quadrula nodulata</i>	0	3	0.0	0.5	0	300±288
<i>Quadrula pustulosa</i>	102	243	29.1	36.7	10200±3934	24300±4780
<i>Reginaia ebena</i>	10	9	2.8	1.4	1000±780	900±647
<i>Strophitus undulatus</i>	1	0	0.3	0.0	100±205	0
<i>Tritogonia verrucosa</i>	4	1	1.1	0.2	400±486	100±176
<i>Truncilla truncata</i>	5	0	1.4	0.0	500±486	0
Totals	351	663	99.9	100.3	35100±9762	66300±16001

Table 4L. cont'd.

Location: 9m (see Table 2 for latitude/longitude)						
	1996			2014		
Estimated Stratum Area (m ²):	1.) 5 m x 90 m = 450 m ²			1.) 5 m x 120 m = 600 m ²		
1 m ² Quadrats Sampled:	5			6		
Min – Max Density (#/m ²):	26 – 50			11 – 115		
Mean Density #/m ² (SD):	1.) 39.2 (10.6)			1.) 71.7 (45.8)		
Species	1996 Number Collected	2014 Number Collected	1996 Percent of Total	2014 Percent of Total	1996 Population Estimate	2014 Population Estimate
<i>Actinonaias ligamentina</i>	0	1	0.0	0.2	NC	NC
<i>Amblema plicata</i>	93	69	47.4	16.0	NC	NC
<i>Ellipsaria lineolata</i>	0	4	0.0	0.9	NC	NC
<i>Fusconaia flava</i>	20	15	10.2	3.5	NC	NC
<i>Lampsilis cardium</i>	3	1	1.5	0.2	NC	NC
<i>Leptodea fragilis</i>	2	0	1.0	0.0	NC	NC
<i>Megaloniais nervosa</i>	6	2	3.1	0.5	NC	NC
<i>Obliquaria reflexa</i>	4	5	2.0	1.2	NC	NC
<i>Obovaria arkansasensis</i>	2	167	1.0	38.8	NC	NC
<i>Plectomerus dombeyanus</i>	4	3	2.0	0.7	NC	NC
<i>Pleurobema riddellii</i>	0	9	0.0	2.1	NC	NC
<i>Pleurobema rubrum</i>	0	1	0.0	0.2	NC	NC
<i>Pleurobema sintoxia</i>	0	6	0.0	1.4	NC	NC
<i>Quadrula apiculata</i>	0	2	0.0	0.5	NC	NC
<i>Quadrula fragosa</i>	0	1	0.0	0.2	NC	NC
<i>Quadrula nobilis</i>	2	13	1.0	3.0	NC	NC
<i>Quadrula pustulosa</i>	53	131	27.0	30.5	NC	NC
<i>Reginaia ebena</i>	1	0	0.5	0.0	NC	NC
<i>Tritogonia verrucosa</i>	2	0	1.0	0.0	NC	NC
<i>Truncilla truncata</i>	4	0	2.0	0.0	NC	NC
Totals	196	430	99.7	99.9	NC	NC

NC – minor bed (< 500 m²), population estimate not calculated

Table 4M. cont'd.

Location: 10M (see Table 2 for latitude/longitude)						
	1996			2014		
Estimated Stratum Area (m ²):	1.) 20 m x 130 m = 2600 m ² 2.) 20 m x 170 m = 3400 m ²			1.) 22 m x 450 m = 9900 m ²		
1 m ² Quadrats Sampled:	25			25		
Min – Max Density (#/m ²):	16 – 94			8 – 386		
Mean Density #/m ² (SD):	1.) 31.0 (10.2) 2.) 46.1 (21.3); Total: 39.5 (18.6)			1.) 101.4 (78.2)		
Species	1996 Number Collected	2014 Number Collected	1996 Percent of Total	2014 Percent of Total	1996 Population Estimate	2014 Population Estimate
<i>Actinonaias ligamentina</i>	7	19	0.7	0.7	1694±1283	7524±3657
<i>Amblema plicata</i>	203	446	20.5	17.6	48781±10435	176616±68560
<i>Ellipsaria lineolata</i>	17	22	1.7	0.9	4077±2627	8712±3662
<i>Elliptio dilatata</i>	3	84	0.3	3.3	729±795	33264±12408
<i>Fusconaia flava</i>	167	229	16.9	9.0	40096±9070	90684±34642
<i>Lampsilis abrupta</i>	0	1	0.0	0.0	0	396±695
<i>Lampsilis sp. B cf. hydiana</i>	8	2	0.8	0.1	1936±1296	792±1391
<i>Lampsilis cardium</i>	15	18	1.5	0.7	3630±2435	7128±3096
<i>Lampsilis teres</i>	9	1	0.9	0.0	2186±1573	396±695
<i>Leptodea fragilis</i>	4	0	0.4	0.0	971±876	0
<i>Megaloniais nervosa</i>	28	48	2.8	1.9	6722±3422	19008±13830
<i>Obliquaria reflexa</i>	10	11	1.7	0.4	2422±1789	4356±2027
<i>Obovaria jacksoniana</i>	14	600	1.4	23.7	3394±2048	237600±58695
<i>Plectomerus dombeyanus</i>	44	109	4.4	4.3	10627±4555	43164±14045
<i>Pleurobema sintoxia</i>	0	65	0.0	2.6	0	25740±14884
<i>Pleurobema riddellii</i>	0	190	0.0	7.5	0	75240±41070
<i>Pleurobema rubrum</i>	69	91	7.0	3.6	16621±7582	36036±12326
<i>Potamilus purpuratus</i>	5	1	0.5	0.0	1214±1183	396±695
<i>Ptychobranchus occidentalis</i>	6	1	0.6	0.0	1457±1591	396±695
<i>Quadrula apiculata</i>	0	6	0.0	0.2	0	2376±1817
<i>Quadrula fragosa</i>	0	3	0.0	0.1	0	1188±1153
<i>Quadrula metanevra</i>	12	6	1.2	0.2	2901±1950	2376±1817
<i>Quadrula nobilis</i>	4	13	0.4	0.5	971±876	5148±3635
<i>Quadrula nodulata</i>	1	0	0.1	0.0	243±498	0
<i>Quadrula pustulosa</i>	257	469	26.0	18.5	61765±16316	185724±42638
<i>Reginaia ebena</i>	48	73	4.9	2.9	11495±4853	28908±12887
<i>Strophitus undulatus</i>	2	3	0.2	0.1	479±679	1188±1153
<i>Toxolasma lividum</i>	0	1	0.0	0.0	0	396±695
<i>Tritogonia verrucosa</i>	24	16	2.4	0.6	5809±3779	6336±3310
<i>Truncilla donaciformis</i>	4	0	0.4	0.0	971±876	0
<i>Truncilla truncata</i>	27	8	2.7	0.3	6544±2911	3168±1935
<i>Utterbackii imbecillis</i>	1	0	0.1	0.0	236±486	0
Totals	989	2536	99.8	99.7	237486±42385	1004256±271786

Table 5. Relative abundance, in percent of total, of species from the Saline River, within Felsenthal National Wildlife Refuge, major and minor mussel beds, 1996 and 2014.

Species	1996		2014	
	Number of Individuals	Percent of Total	Number of Individuals	Percent of Total
<i>Actinonaias ligamentina</i>	9	0.3	20	0.2
<i>Amblema plicata</i>	1143	34.9	2160	25.8
<i>Ellipsaria lineolata</i>	39	1.2	68	0.8
<i>Elliptio dilatata</i>	3	0.1	86	1.0
<i>Fusconaia flava</i>	326	9.9	473	5.6
<i>Lampsilis abrupta</i>	0	0.0	2	0.0
<i>Lampsilis sp. B cf. hydiana</i>	13	0.4	6	0.1
<i>Lampsilis cardium</i>	35	1.1	42	0.5
<i>Lampsilis teres</i>	14	0.4	4	0.0
<i>Leptodea fragilis</i>	14	0.4	3	0.0
<i>Ligumia recta</i>	0	0.0	1	0.0
<i>Megalonaias nervosa</i>	82	2.5	241	2.9
<i>Obliquaria reflexa</i>	35	1.1	71	0.8
<i>Obovaria arkansasensis</i>	62	1.9	1485	17.7
<i>Plectomerus dombeyanus</i>	84	2.6	226	2.7
<i>Pleurobema sintoxia</i>	0	0.0	187	2.2
<i>Pleurobema riddellii</i>	0	0.0	244	2.9
<i>Pleurobema rubrum</i>	72	2.2	110	1.3
<i>Potamilus purpuratus</i>	17	0.5	10	0.1
<i>Ptychobranhus occidentalis</i>	10	0.3	1	0.0
<i>Pyganodon grandis</i>	4	0.1	0	0.0
<i>Quadrula apiculata</i>	0	0.0	26	0.3
<i>Quadrula fragosa</i>	0	0.0	5	0.1
<i>Quadrula metanevra</i>	12	0.3	6	0.1
<i>Quadrula nobilis</i>	51	1.6	343	4.1
<i>Quadrula nodulata</i>	3	0.1	16	0.2
<i>Quadrula pustulosa</i>	955	29.1	2275	27.1
<i>Reginaia ebena</i>	167	5.1	220	2.6
<i>Strophitus undulatus</i>	3	0.1	4	0.0
<i>Toxolasma lividum</i>	0	0.0	1	0.0
<i>Tritogonia verrucosa</i>	69	2.1	37	0.4
<i>Truncilla donaciformis</i>	4	0.1	0	0.0
<i>Truncilla truncata</i>	51	1.6	12	0.1
<i>Utterbackii imbecillis</i>	1	0.0	0	0.0
Totals	3278	100.0	8385	99.6

Figures 3a– 3f. Location of major and minor mussels beds in the Saline River, Felsenthal National Wildlife Refuge, Arkansas (2014).

Figure 3a. continued.



Figure 3b. continued.



Figure 3c. continued.



Figure 3d. continued.



Figure 3e. continued.



Figure 3f. continued.



A total of six Winged Mapleleaf and two Pink Mucket individuals were collected from Beds 6M, 8M, 9m, and 10M (Appendix 1). Mean length of Winged Mapleleaf was 38.6 mm with a range of 29.0 – 46.2 mm. Length of Pink Mucket individuals were 63.5 and 65.1 mm.

DISCUSSION

The taxonomy for *Quadrula*, *Fusconaia*, and *Pleurobema* species is currently in flux. Davidson (1997) lumped Round Pigtoe (*P. sintoxia*) and Louisiana Pigtoe (*P. riddelli*) with Wabash Pigtoe and Pyramid Pigtoe (*P. rubrum*) due to taxonomic uncertainty at the time. Southern Mapleleaf (*Q. apiculata*) may have been lumped with Gulf Mapleleaf in 1996. Gulf Mapleleaf was identified as Mapleleaf (*Q. quadrula*) in 1996. While these three species appear as new records of occurrence for Felsenthal NWR, they likely were present, but not identified (due to lumping of taxa), during the 1996 survey.

Mussels vary considerably with respect to their habitat preferences. Four of five species not collected during this survey prefer sluggish silt (mud) substrate areas in creeks, rivers, and reservoirs. It is not surprising these species were absent from our survey given our focus on mussel beds in the main channel. Mussel bed substrate was comprised of gravel with sand. Fawnsfoot (*Truncilla donaciformis*) was the only species typically found in gravel dominant substrates not collected during this survey. Fawnsfoot also was rare ($n = 4$) in 1996 (Davidson 1997). Black sandshell (*Ligumia recta*) is widely distributed throughout the Saline River, but is a new occurrence record for Felsenthal NWR. Winged

Mapleleaf is common in the Saline River between AGFC's Longview and Stillion accesses. Its presence in Felsenthal NWR is not surprising given the close proximity of the study area to a sizeable population upstream of the refuge.

Mussel assemblages typically consist of a few dominant, common species and many more less abundant or rare species (Vaughn 1997). The majority of mussel species (approximately 80%) make up less than 10 percent of mussel beds and a substantial number (approximately 35%) comprise less than one percent. It is rare for a single species to compose greater than 50 percent of a mussel bed (Haag 2012). We observed similar results in the 13 mussel beds delineated during this survey.

The five dominant species in this survey comprised 80 percent of the total mussel community. Compared to Davidson (1997), these same five species comprised 75 percent of the total (Table 5). A noteworthy increase (approximately 14 percent) in relative abundance occurred with Southern Hickorynut since 1996. In 1996, Southern Hickorynut was common near the periphery of mussel beds, typically occurring on descending banks in areas with a greater prevalence of fine substrate particles (e.g., sand and silt). During this survey, Southern Hickorynut was common throughout the entire bed. It seems unlikely that fish host abundance played an important role in restructuring the mussel assemblage since potential fish hosts for Southern Hickorynut include common species such as Bluegill (*Lepomis macrochirus*). The substantial increase in Southern Hickorynut abundance may be attributable to changes in microhabitat conditions (i.e., increase in fine substrate particles), but empirical data is lacking at this time to support this hypothesis.

Species dominance has been documented to shift in medium to large rivers (e.g., White, Ouachita, Saline, and Buffalo Rivers) from upstream to downstream reaches as physical characteristics (e.g., microhabitat and macrohabitat variables) of the river and host fish presence and abundance change (Christian 1995; Posey 1997; Davidson and Clem 2002, 2004; Matthews *et al.* 2010). We observed a similar community composition shift for species in our study area compared to the river reach immediately upstream of the refuge (i.e., Johnsville to Stillion). Species routinely collected in the Saline River between AGFC's Longview and Stillion accesses (e.g., Spike [*Elliptio dilatata*], Mucket [*Actiononaias ligamentina*], Western Fanshell [*Cyprogenia* sp. A cf *aberti*], Monkeyface [*Q. metanevra*], and Rabbitsfoot [*Q. cylindrica cylindrica*]), are notably rare to absent in the study area.

The shift in mussel community composition occurs near the northern boundary of Felsenthal NWR. Shallow shoal areas common upstream of Felsenthal NWR are absent within the refuge. Construction and operation of Felsenthal Lock and Dam may partially explain this notable and rather abrupt change in hydrology. However, it should be noted historical descriptions (e.g., water depth, channel width, maps of shoals, etc.) of the Saline River within the study are lacking; thus, making it impossible to ascertain hydrology of the area prior to dam construction.

Bed 4M was the only bed to show a substantial decrease in mean density of mussels compared to Davidson (1997). Bed 4M was delineated by Davidson (1997) as a *m*bed. Differences in sampling methodology for *m*beds and *M*beds likely accounts for the difference observed in mean density of Bed 4M. Bed area increased in 70 percent of the beds primarily due to two factors: 1) use of improved

(laser) range finders, and 2) more experience by the author delineating mussel beds. While beds may have expanded or constricted to some degree since 1996, beds appear generally stable with most differences between 1996 and 2014 bed areas accounted for by the aforementioned factors.

MANAGEMENT CONSIDERATIONS AND MONITORING RECOMMENDATIONS

Protection or improvements in the status of mussels in the Saline River requires proper management of the watershed and cooperative efforts of stakeholders. The following management and monitoring recommendations are provided to assist with future refuge management.

1. U.S. Army Corps of Engineers operation and management of Felsenthal Lock and Dam appears to have altered species richness and abundance in the lower 20 – 25 km of the Saline River. Efforts focused on summer drawdowns of pool elevation may restore some shoals and increase species richness and abundance of mussels within the refuge.
2. Collection of baseline sediment composition in mussel beds followed by periodic monitoring of sediment composition may provide insights into whether influxes of fine sediment loading in the river are affecting the mussel community.
3. Implementation of best management practices to reduce sediment runoff from construction sites, county road maintenance, and other land use activities (*e.g.*, forestry) will further improve water quality and habitat availability in the Saline River. Execution of these management strategies should improve and/or sustain the quality and quantity of vegetative cover in riparian areas, decrease siltation, and subsequently improve habitat quality for mussels.
4. Proper management of native mussel resources includes periodic monitoring. Implementation of a “mussel monitoring program” is needed at Felsenthal NWR to establish and track population size, demography, recruitment, and status of threatened and endangered mussels (*e.g.*, Winged Mapleleaf and Pink Mucket), as well as “at-risk” species. Selected mussel beds should be quantitatively assessed and monitored at a 10 year interval.

ACKNOWLEDGEMENTS

I thank T. Inebnit, E. Knoll, D. Andrews, and C. Cox for their assistance in the field. R. Eastridge, J. Ertel, and T. Fotinos helped secure funding for this project. This project was funded by the Service’s Southeast Region Inventory and Monitoring Network in partnership with Felsenthal NWR and the Arkansas Ecological Services Field Office. R. Eastridge, M. Stroeh and T. Fotinos provided peer review of this report.

LITERATURE CITED

Brown, A.V. and K.B. Brown. 1989. Stream inventory of *Lampsilis powelli* populations on National Forest lands. Final report submitted to U.S.D.A. Forest Service, Ouachita National Forest, Hot Springs, AR. 70pp.

- Burns & McDonnell, Inc. 1992a. Report on surveys for the Arkansas fatmucket mussel.
Prepared for Hope Engineers and the Saline County Rural Development Authority,
Benton, AR.
- Burns & McDonnell, Inc. 1992b. Distribution of Arkansas fatmucket mussel (*Lampsilis powelli*)
in the North Fork of the Saline River. Prepared for Hope Engineers, Benton, AR.
- Campbell, D.C. and C. Lydeard. 2012. The genera of Pleurobemini (Bivalvia: Unionidae: Ambleminae).
American Malacological Bulletin 30(1):19-38.
- Christian, A.D. 1995. Analysis of the commercial mussel beds in the Cache and White rivers in Arkansas.
Unpublished M.S. thesis, Arkansas State University, Jonesboro. 197pp.
- Christian, A.D., and J.L. Harris. 2005. Development and assessment of a sampling design for mussel
assemblages in large streams. Am. Midl. Nat. 153:284-292.
- Davidson, C.L. 1997. Analysis of mussel beds in the Little Missouri and Saline Rivers, Blue Mountain,
Ozark and Dardanelle Lakes, Arkansas. Unpublished M.S. thesis, Arkansas State University,
Jonesboro. 156pp.
- Davidson, C.L., and S.A. Clem. 2002. The freshwater mussel (Bivalvia: Unionacea) resources in a
selected segment of the Saline River: location, species composition and status of mussel beds.
Unpublished report, Arkansas Tech University, Russellville, for The Nature Conservancy, Little Rock,
Arkansas, and Arkansas Game and Fish Commission, Little Rock. 48pp.
- Davidson, C.L., and S.A. Clem. 2004. The freshwater mussel (Bivalvia: Unionacea) resources in a selected
segment of the Saline River: location, species composition and status of mussel beds. Addendum 2.
Unpublished report, Arkansas Tech University, Russellville, for the Arkansas Game and Fish
Commission, Little Rock. 23pp.
- Davidson, C.L. and D. Gosse. 2004. Status and distribution of freshwater mussels (Unionacea) inhabiting
the Saline River/Holly Creek bottoms area, Saline County, Arkansas. Journal of the Arkansas
Academy of Science 57 (2003):187-192.
- Haag, W.R. 2012. North American freshwater mussels: natural history, ecology, and conservation.
Cambridge University Press, New York, New York.
- Harris, J.L. 2006. *Quadrula fragosa* population estimates at 10 sites in the Ouachita River drainage,
Arkansas. Unpubl. Report submitted to U.S. Fish and Wildlife Service, Arkansas Ecological Services
Field Office. 14pp. + appendix.
- Harris, J.L., and M.E. Gordon. 1988. Distribution and status of rare and endangered mussels (Mollusca:
Margaritiferidae, Unionidae) in Arkansas. Journal of the Arkansas Academy of Science 41 (1987):49-
56.

- Harris, J.L., P. Rust, S.W. Chordas III, and G.L. Harp. 1994. Distribution and population structure of freshwater mussels (Unionidae) in Lake Chicot, Arkansas. *Proceedings Arkansas Academy of Science* 47 (1993):38-43.
- Inoue, K., D.M. Hayes, J.L. Harris, and A.D. Christian. 2013. Phylogenetic and morphometric analyses reveal ecophenotypic plasticity in freshwater mussels *Obovaria jacksoniana* and *Villosa arkansasensis* (Bivalvia: Unionidae). *Ecology and Evolution* open access. 14pp.
- Matthews, M., F. Usrey, S.W. Hodges, J.L. Harris, and A.D. Christian. 2010. Species richness, distribution, and relative abundance of freshwater mussels (Bivalvia: Unionidae) of the Buffalo National River, Arkansas. *Journal of the Arkansas Academy of Science* 63 (2009):113-130.
- Peck, A.J. 2010. Evaluation of freshwater mussel conservation strategies at multiple scales: macro-molecules, behavior, habitat, and policy. Unpubl. p.H.D. dissertation, Arkansas State University, Jonesboro. 439pp.
- Posey, W.R., Jr. 1997. Location, species composition, and community estimates for mussel beds in the St. Francis and Ouachita rivers in Arkansas. Unpublished M.S. thesis, Arkansas State University, Jonesboro. 178pp.
- Sampford, M.R. 1962. An introduction to sampling theory with applications to agriculture. Oliver and Boyd Ltd., Edinburgh.
- Turgeon D.D., J.F. Quinn, Jr, A.E. Bogan, E.V. Coan, F.G. Hochberg, W.G. Lyons, P.M. Mikkelsen, R.J. Neves, C.F.E. Roper, G. Rosenberg, B. Roth, A. Scheltema, F.G. Thompson, M. Vecchione, and J.D. Williams. 1998. Common and scientific names of aquatic invertebrates from the United States and Canada: mollusks, 2nd edition. American Fisheries Society, Special Publication 26, Bethesda, Maryland. 526pp.
- U.S. Geological Survey. 1979. Drainage areas of streams in Arkansas in the Ouachita River basin. U.S. Geological Survey open file report, Little Rock. 87pp.
- Vaughn, C.C. 1997. Regional patterns of mussel species distributions in North American rivers. *Ecography* 20:107-115
- Woods A.J., Foti, T.L., Chapman, S.S., Omernik, J.M., Wise, J.A., Murray, E.O., Prior, W.L., Pagan, J.B., Jr., Comstock, J.A., and Radford, M., 2004, Ecoregions of Arkansas (color poster with map, descriptive text, summary tables, and photographs): Reston, Virginia, U.S. Geological Survey (map scale 1:1,000,000).

Appendix 1



Photo 1: Female Pink Mucket collected from Saline River, Felsenthal National Wildlife Refuge, Arkansas (2014).



Photo 2: Winged Mapleleaf collected from Saline River, Felsenthal National Wildlife Refuge, Arkansas (2014).