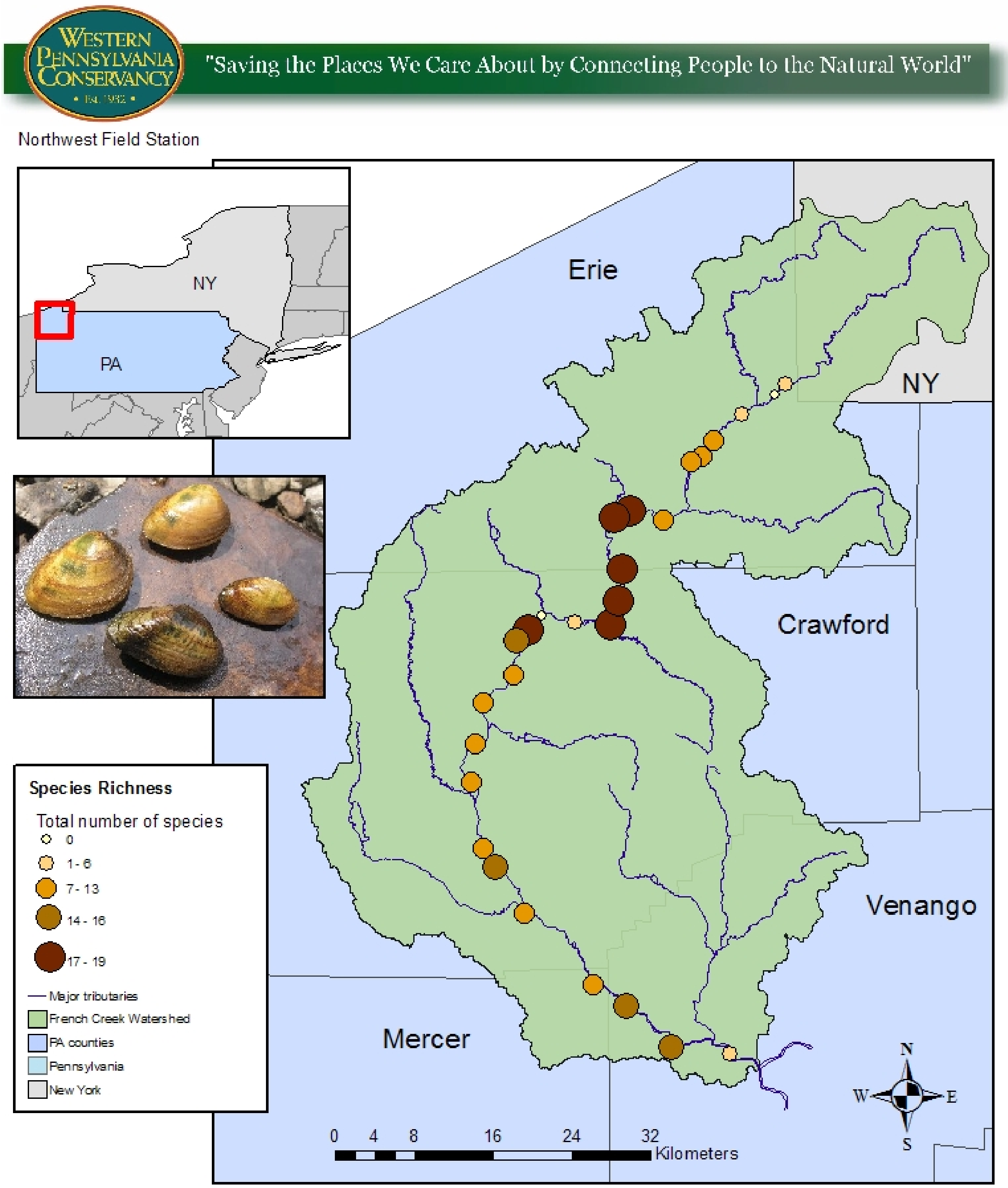

Figure 2: Freshwater Musssel Species Richness (Total number species- live)

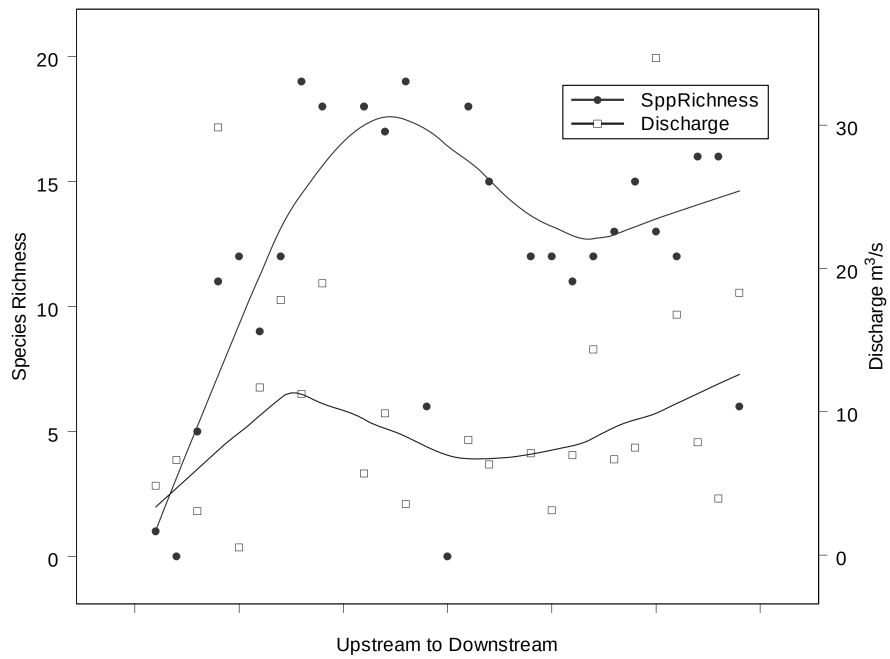

Figure 3: Species richness from upstream to downstream of French Creek. A local regression (loess) smooth line was added to help illustrate the trends (S-plus 2000). Note that discharge was measured in the field on the day of the mussel survey. Summertime mean daily discharge increases from upstream (20-30cfs) to downstream (200-300cfs) based on USGS measurements.

SPECIES SPECIFIC SUMMARIES

We wanted to characterize each species in the watershed by summarizing species-specific data across all sites. Species data is summarized in Table 6, which includes the total numbers alive, fresh dead, and weathered; total numbers male, female, and unknown sex. In addition, we calculated the mean lengths with error estimates for each species and created length frequency histograms for each species.

MUCKET (*Actinonaias ligamentina*)

Muckets were the most abundant and widely distributed species in French Creek. We found a total of 3460 live individuals distributed across 24 sites and in Erie, Mercer, Crawford and Venango counties. *A. ligamentina* made up over 45% of the total catch. At most sites where we found live specimens, we also found fresh dead specimens and/or weathered shells. Because so many live individuals were found, it was not practical to collect every fresh dead or weathered mucket shell observed at each site, therefore numbers of reported shells is considerably low. Shell length of *A. ligamentina* ranged from a minimum of 10.6mm to a maximum of 155mm with a mean of 91.2mm (88.9, 93.5). Fifteen sites had evidence of recent recruitment (specimens with lengths < 30mm, Figure 4). Two sites had a particularly high abundance of individuals less than 30 mm; both in Crawford County.

ELKTOE (*Alasmidonta marginata*)

Elktoes were widely distributed and fairly abundant in French Creek, with 320 live individuals found across 19 sites. *A. marginata* made up approximately 4.2% of the total catch and was found in Erie, Venango, Mercer, and Crawford counties. At most sites where we found live specimens, we also found fresh dead specimens and/or weathered shells. Shell length of *A. marginata* ranged from a minimum of 19.5 to a maximum of 104 mm with a mean of 64.9 mm (63.3,66.5). Three sites had evidence of recent recruitment (specimens with lengths < 30mm, Figure 4).

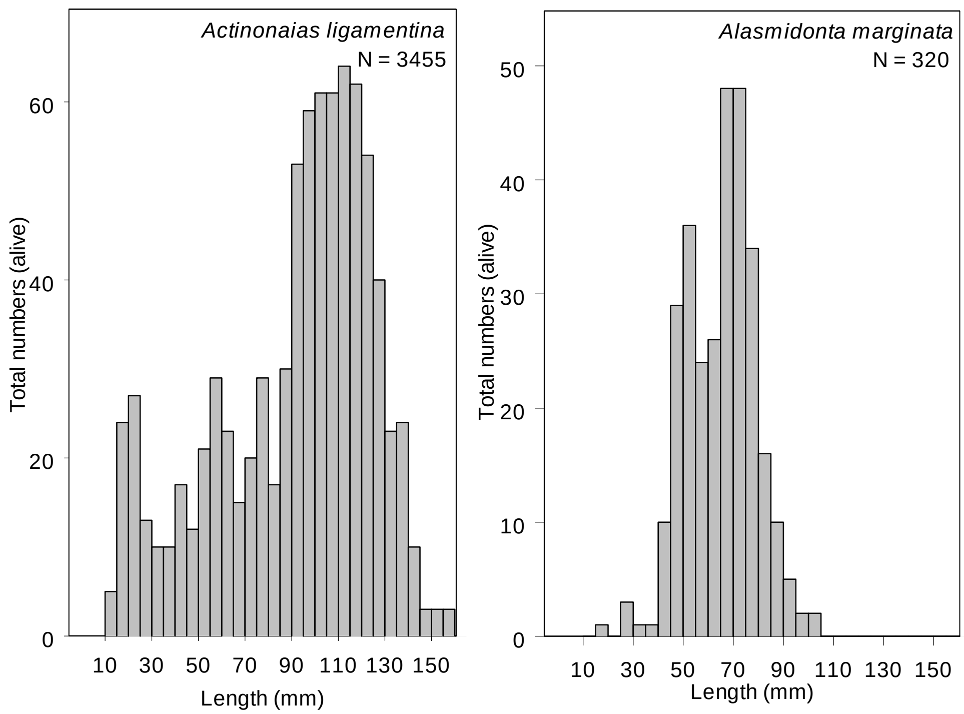

Figure 4: Length frequency histogram of mucket (*Actinonaias ligamentina*) and the elktoe (*Alasmidonta marginata*). Note the different scales of the y-axes.

Table 6: Summary statistics for each species found. Includes total numbers alive, fresh dead, and weathered dead shells. Numbers of female and male, and unknown sex are given for sexually dimorphic species. Mean lengths with the lower (LCL) and upper (UCL) 95% confidence bounds are given. Numbers given for sexes and lengths are based on live individuals only. Reported data is from snorkel/SCUBA sites and does not include midden data.

Species	Alive	Fresh Dead	Weathered Dead	Female	Male	Unknown Sex	Mean Length (mm)	LCL Length	UCL Length
Actinonaias ligamentina	3455	36	46				91.2	88.9	93.5
Elliptio dilatata	529	19	31				76.2	74.4	78.0
Villosa fabalis	439	221	78	217	218	4	26.9	26.4	27.5
Lasmigona costata	407	18	24				97.3	95.4	99.1
Alasmidonta marginata	320	21	13				64.9	63.3	66.5
Lampsilis siliquoidea	282	10	18	144	127	11	74.0	72.0	76.0
Epioblasma torulosa rangiana	274	20	31	142	119	9	45.6	43.9	47.2
Lampsilis ovata	204	6	7	41	21	142	104.2	100.0	108.5
Amblema plicata	176	5	21				93.8	89.5	98.1
Ptychobranchus fasciolaris	148	3	6				81.1	79.4	82.8
Strophitus undulatus	148	3	6				65.3	63.3	67.3
Lampsilis fasciola	70	4	4				56.3	53.0	59.6
Epioblasma triquetra	53	17	14	36	11	4	43.3	40.2	46.3
Pleurobema sintoxia	41	7	11				69.2	61.9	76.4
Quadrula cylindrica	41	7	11				91.3	82.1	100.4
Fusconaia subrotunda	39	1	9				84.8	70.4	99.3
Lampsilis cardium	32	2	1				94.6	81.9	107.2
Ligumia recta	24	8	12				125.0	114.8	135.1
Pyganodon grandis	18	5	2				61.1	45.9	76.3
Pleurobema clava	13	7	2				33.3	23.7	43.0
Anodontoides ferussacianus	11	0	0				58.8	53.1	64.4
Lasmigona compressa	6	1	0				74.4	60.5	88.4
Villosa iris	2	2	0	1		2	34.4	NA	NA
Utterbackia imbecillis	1	1	0				58.3	NA	NA
Unkown juvenile	1	0	0				22.0	NA	NA

THREERIDGE (*Amblema plicata*)

We found 176 live *Amblema plicata* individuals across 11 sites on the main-stem of French Creek and in all four counties (Erie, Crawford, Venango, Mercer). Numbers of live individuals were generally low (between 1 and 22 per site). However, live individuals from one site in Crawford County made up 66.5 % of the total *A. plicata* catch, where 117 individuals were found. In addition to the live individuals, we found a total of 5 fresh dead and 21 weathered *A. plicata* shells. At most sites where we found live specimens, we also found fresh dead specimens and/or weathered shells. Shell length of *A. plicata* ranged from a minimum of 36.5mm to a maximum of 135 mm with a mean of 93.8mm (89.5, 98.1). No sites had evidence of recent recruitment (specimens with lengths < 30mm). The length frequency histogram for *A. plicata* (Figure 5) shows bimodal distribution, indicating a size class ranging from 35-70mm with a median length of ~50mm.

CYLINDRICAL PAPERSHELL (*Anodontoides ferussacianus*)

We found only 11 live *Anodontoides ferussacianus* individuals across 7 sites on the main-stem of French Creek in Erie and Crawford counties. Numbers of live individuals were low (between 1 and 3 per site). We found no fresh dead or weathered *A. ferussacianus* shells. Shell length of ranged from a minimum of 42.8 mm to a maximum of 73.1mm with a mean of 58.8mm (53.1,64.4). There was no evidence of recent recruitment (specimens with lengths < 30mm, Figure 5).

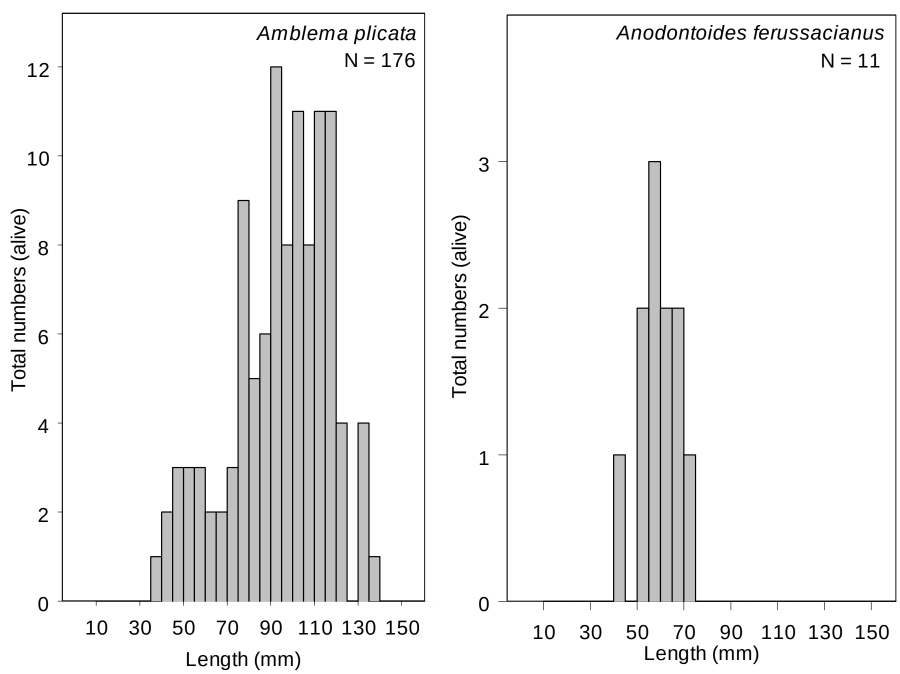

Figure 5: Length frequency histogram of threeridge (*Amblema plicata*) and the cylindrical papershell (*Anodontoides ferussacianus*) for all 27 sites surveyed in 2003. Note the different scales of the y-axes.

SPIKE (*Elliptio dilatata*)
Elliptio dilatata were widely distributed and the third most abundant freshwater mussel species in French Creek, with 529 live individuals found across 22 sites and in all four counties (Erie, Mercer, Crawford, Venango). In addition to the live individuals, we found a total of 19 fresh dead and 31 weathered *E. dilatata* shells. No dead shells were found at any sites where we did not find live individuals. Shell length of *E. dilatata* ranged from a minimum of 14.0mm to a maximum of 124.9mm with a mean of 76.2mm (74.4, 78.0). Eight sites had evidence of recent recruitment (specimens with lengths < 30mm, Figure 6).

NORTHERN RIFFLESHELL (*Epioblasma torulosa rangiana*)
We found northern riffleshell at nine sites on the main-stem of French Creek. At these sites, numbers of live individuals ranged from one to 184 individuals found per site. At only one site, we found both *E. torulosa rangiana* and *P. clava*. One site in Crawford County stood out with a very high abundance of *E. torulosa rangiana*, where 184 individuals were found, and making *E. torulosa rangiana* the 2nd most abundant species at that site. In addition to the 274 live individuals, we found a total of 20 fresh dead and 31 weathered *E. torulosa rangiana* shells. At most sites where we found live specimens, we also found fresh dead specimens and/or weathered shells. We found fresh dead but no live specimens at four sites and only one weathered shell at another site. Shell length of *E. torulosa rangiana* ranged from a minimum of 14.0 mm to a maximum of 78.1 mm with a mean of 45.6mm (44.0,47.2). Six sites had evidence of recent recruitment (specimens with lengths < 30mm, Figure 6). We found a total of 142 live female and 119 live male northern riffleshells, giving an overall female to male ratio of 1.2 to 1. Only one male and zero females were found at site 18. Conversely, site 17 had 17 females to 6 males.

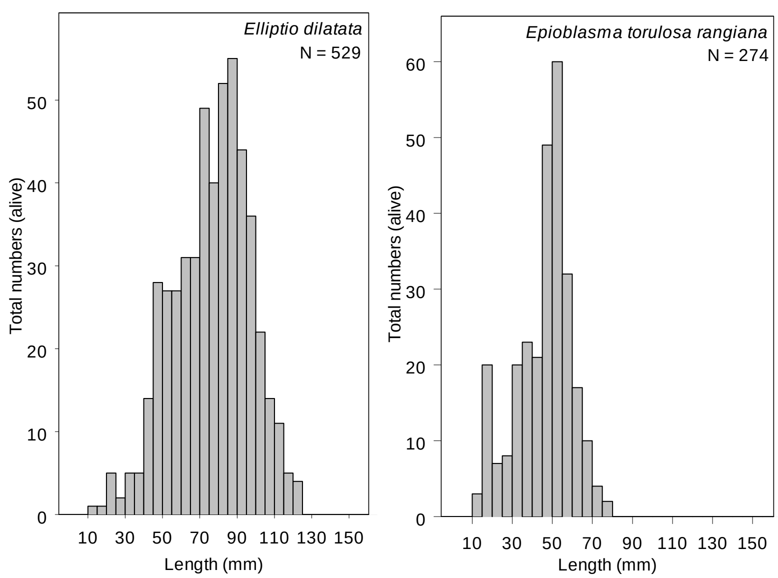

Figure 6: Length frequency histogram for spike (*Elliptio dilatata*) and northern riffleshell (*Epioblasma torulosa rangiana*) for all 27 sites surveyed in 2003. Note the different scales of the y-axes.

***S*NUFFBOX** (*Epioblasma triquetra*)
We found *Epioblasma triquetra* at 15 sites on the main-stem of French Creek, in Erie, Crawford, and Venango counties. Numbers of live individuals were generally low (between 1 and 6). *E. triquetra* from one site in Erie County made up thirty- eight percent of the total *E. triquetra* catch for the entire study, where 20 individuals were found. In addition to the 53 live individuals; we found a total of 17 fresh dead and 14 weathered *E. triquetra* shells. At most sites where we found live specimens, we also found fresh dead specimens and/or weathered shells. We found fresh dead but no live specimens at two sites in Erie County. Two sites in Crawford County had both fresh dead and weathered shells but no live specimens. Shell length of *E. triquetra* ranged from a minimum of 15.5 mm to a maximum of 67.0 mm with a mean of 43.3mm (40.2,46.3). Two sites had evidence of recent recruitment (specimens with lengths ≤ 20mm, Figure 7). We found a total of 36 live female and 11 live male snuffbox, giving an overall female to male ratio of 3.3 to 1. Site 31 had 16 female to 4 male and site 29 had 5 female and one male.

***L*ONG-SOLID** (*Fusconaia subrotunda*)
Thirty-nine live *Fusconaia subrotunda* individuals were found across 7 sites, with generally low numbers per site (1-14). All *F. subrotunda* sites were in only Erie and Crawford counties. *F. subrotunda* was most abundant at two sites in Erie County. In addition to the live individuals, we found a total of 1 fresh dead and 9 weathered *F. subrotunda* shells. We did find weathered shells at one site in Venango County, but no live individuals. Shell length of *F. subrotunda* ranged from a minimum of 11mm to a maximum of 136 mm with a mean of 84.8 mm (70.4, 99.3). Two sites had evidence of recent recruitment (specimens with lengths < 30mm, Figure 7).

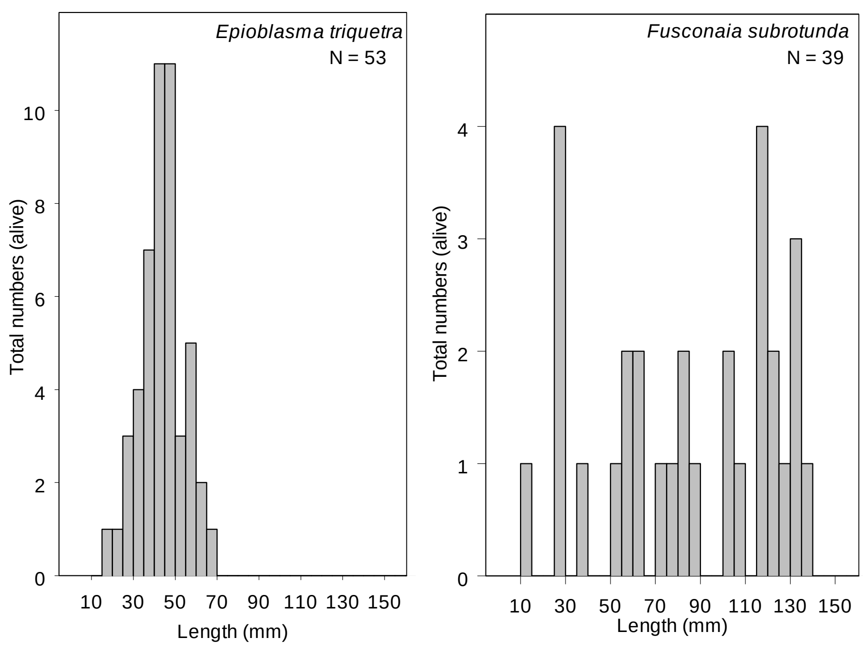

Figure 7: Length frequency histogram for snuffbox (*Epioblasma triquetra*) and long-solid (*Fusconaia subrotunda*) for all 27 sites surveyed in 2003. Note the different scales of the y-axes.

PLAIN POCKETBOOK (*Lampsilis cardium*)

We found 32 live *Lampsilis cardium* individuals found across 13 sites, with generally low numbers per site (1-8). *L. cardium* was found in Erie, Crawford, and Venango counties. In addition to the live individuals, we found a total of 2 fresh dead and 1 weathered *L. cardium* shells. No dead shells were found at any sites where we did not find live individuals. Shell length of *L. cardium* ranged from a minimum of 27mm to a maximum of 135mm with a mean of 94.6 mm (81.9, 107.3). One site had evidence of recent recruitment (specimens with lengths < 30mm). The length frequency histogram appears to separate a few size classes (Figure 8).

WAVY-RAYED LAMPMUSSEL (*Lampsilis fasciola*)

We found 69 live *Lampsilis fasciola* 69 individuals across 14 sites, in all four counties (Erie, Crawford, Mercer, Venango), but with generally low numbers per site (1-5). However, two sites had more individuals; one in Crawford County with 17 live individuals, while one in Erie County had 21 live individuals. In addition to the live individuals, we found a total of 4 fresh dead and 4 weathered *L. fasciola* shells. Sites 14 had no live individuals, but one weathered shell was found. Site 15 had only one fresh dead shell. Shell length of *L. fasciola* ranged from a minimum of 17mm to a maximum of 121.3mm with a mean of 56.3 mm (53.0, 59.6). Only two sites had evidence of recent recruitment (specimens with lengths < 30mm, Figure 8).

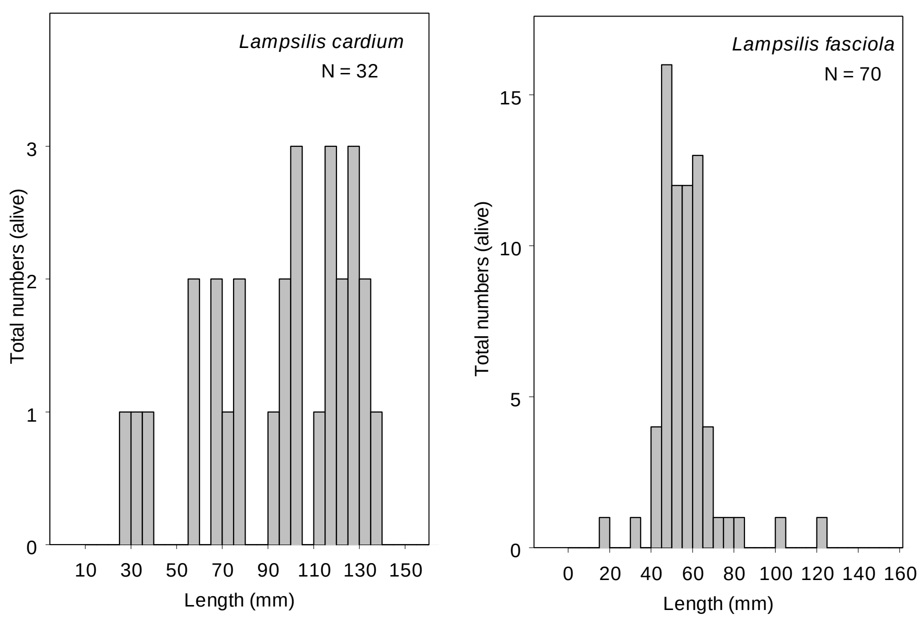

Figure 8: Length frequency histogram of plain pocketbook (*Lampsilis cardium*) and the wavy-rayed lampmussel (*Lampsilis fasciola*) for all 27 sites surveyed in 2003. Note the different scales of the y-axes.

POCKETBOOK (*Lampsilis ovata*)

We found 205 live *Lampsilis ovata* individuals found across 18 sites, with generally low to moderate numbers per site (2-21). We found *L. ovata* in all four counties (Erie, Crawford, Mercer, and Venango). *L. ovata* was most abundant at one site in Erie County, which had 66 live individuals. In addition to the live individuals, we found a total of 6 fresh dead and 7 weathered *L. ovata* shells. One site in Venango County had no live individuals, but one weathered shell was found. Shell length of *L. ovata* ranged from a minimum of 13mm to a maximum of 146.1mm with a mean of 104.2 mm (100.0, 108.5). Nine sites had evidence of recent recruitment (specimens with lengths <50mm, Figure 9).

FATMUCKET (*Lampsilis siliquoidea*)

We found a total of 282 live *Lampsilis siliquoidea* individuals across 17 sites, with generally low to moderate numbers per site (1-5). *L. siliquoidea* was widespread throughout the main-stem, but was most abundant at three sites in Erie County; with 101, 79, and 65 live individuals. *L. siliquoidea* was also found in Crawford and Venango counties. In addition to the live individuals, we found a total of 10 fresh dead and 18 weathered *L. siliquoidea* shells. We found a total of 113 live female and 131 live male fatmuckets, giving an overall female to male ratio of 1 to 1.1. The three sites with high numbers in Erie County all had slightly more females than males. At most sites where more than 1 individual was found, there was at least one male and one female. Shell length of *L. siliquoidea* ranged from a minimum of 33mm to a maximum of 121.2mm with a mean of 74.0mm (72.0,76.1). The 3 sites where *L. siliquoidea* was most abundant also had evidence of recent recruitment (<50mm). We found no individuals less than 30 mm, Figure 9).

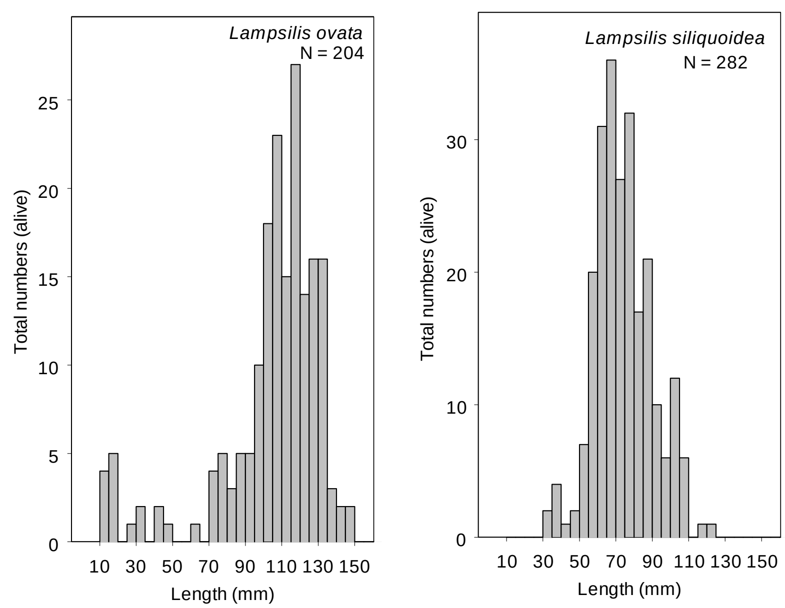

Figure 9: Length frequency histogram for pocketbook (*Lampsilis ovata*) and fatmucket (*Lampsilis siliquoidea*) for all 27 sites surveyed in 2003. Note the different scales of the y-axes.

CREEK HEELSPLITTER (*Lasmigona compressa*)
We found only 6 live *Lampsilis compressa* individuals across 6 sites. Live *L. compressa* was found in Erie and Crawford counties. One additional fresh dead shell was found in Crawford County. Shell length of *L. compressa* ranged from a minimum of 60.5mm to a maximum of 89mm with a mean of 74.4mm (60.5,88.4). No sites had evidence of recent recruitment; (specimens < 50mm, Figure 10).

FLUTED-SHELL (*Lasmigona costata*)
Lasmigona costata was our fifth most abundant species found, with a total of 407 live individuals across 22 sites. *L. costata* was found in Erie, Mercer, Crawford, and Venango counties. The only places where *L. costata* was not found were three sites in Erie County and two pool sites in Crawford County. In addition to the live individuals, we found a total of 18 fresh dead and 24 weathered *L. costata* shells. Shell length of *L. costata* ranged from a minimum of 12.8mm to a maximum of 134.9mm with a mean of 97.3 mm (95.4, 99.2). Four sites had evidence of recent recruitment; (specimens < 30mm, Figure 10).

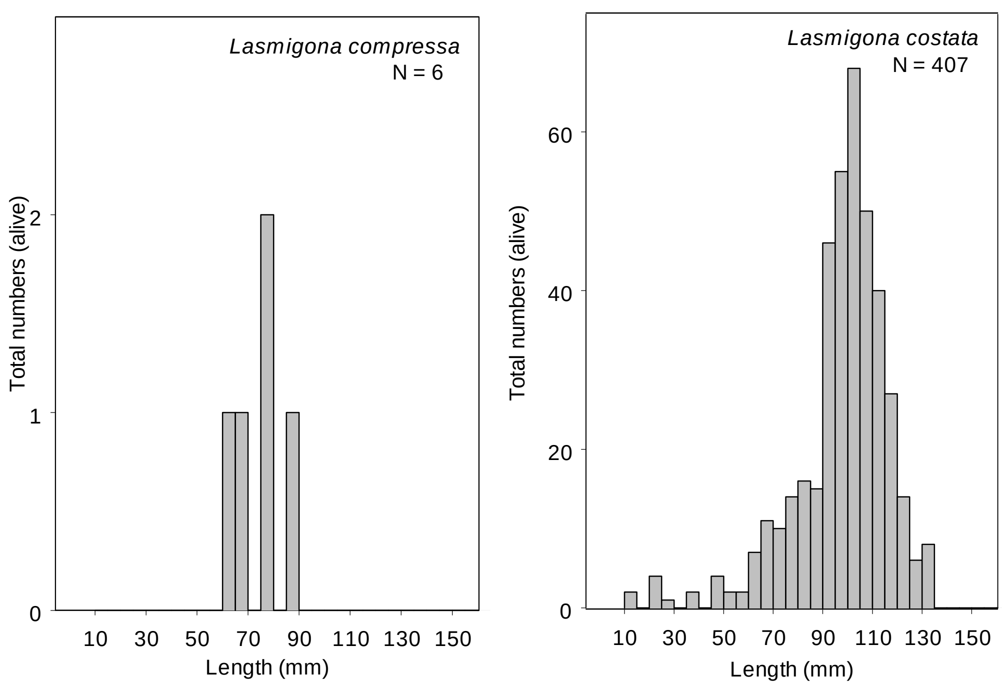

Figure 10: Length frequency histogram for creek heelsplitter (*Lasmigona compressa*) and fluted shell (*Lasmigona costata*) for all 27 sites surveyed in 2003. Note the different scales of the y-axes.

BLACK SANDSHELL (*Ligumia recta*)

Ligumia recta was found at 9 sites and in Erie, Crawford, Mercer, and Venango counties. Numbers of live individuals were very low, with only 1-5 found per site, and a total of only 24 individuals. In addition to the live individuals, we found a total of 8 fresh dead and 12 weathered *L. recta* shells. Several sites had no live individuals, however fresh dead and/ or weathered shells were found: only dead shells were found at four sites in Crawford County, and only weathered shells were found at one site in Erie County and one site in Venango County. Two sites had both freshdead and weathered shells, but no live individuals. Shell length of *L. recta* ranged from a minimum of 81mm to a maximum of 155mm with a mean of 129.4 mm (121.0, 137.9). We found no evidence of recent recruitment, and only two sites had individuals less than 100mm (Figure 11).

CLUBSHELL (*Pleurobema clava*)

We found live *P. clava* in Erie and Crawford counties at five sites on the main-stem of French Creek. Numbers of live individuals were very low, with only 1-3 found per site, and a total of only 13 individuals. In addition to the 13 live individuals, we found a total of 7 fresh dead and 2 weathered *P.clava* shells. At most sites where we found live specimens, we also found fresh dead specimens and/or weathered shells. One exception was site 7, where 3 live individuals but no empty shells were found. Another exception was site 17 (Crawford Co.), where no live individuals were found, but 1 fresh dead shell was found. This site was the lowest point in the watershed where we found evidence of *P. clava.* Clubshell ranged in lengths from a minimum of 17.5 mm to a maximum of 58.5 mm with a mean of 33.3mm (23.7, 43.0). Three of the sites had evidence of recent recruitment (specimens with lengths < 30mm, Figure 11). We were unable to sex *P. clava* in the field.

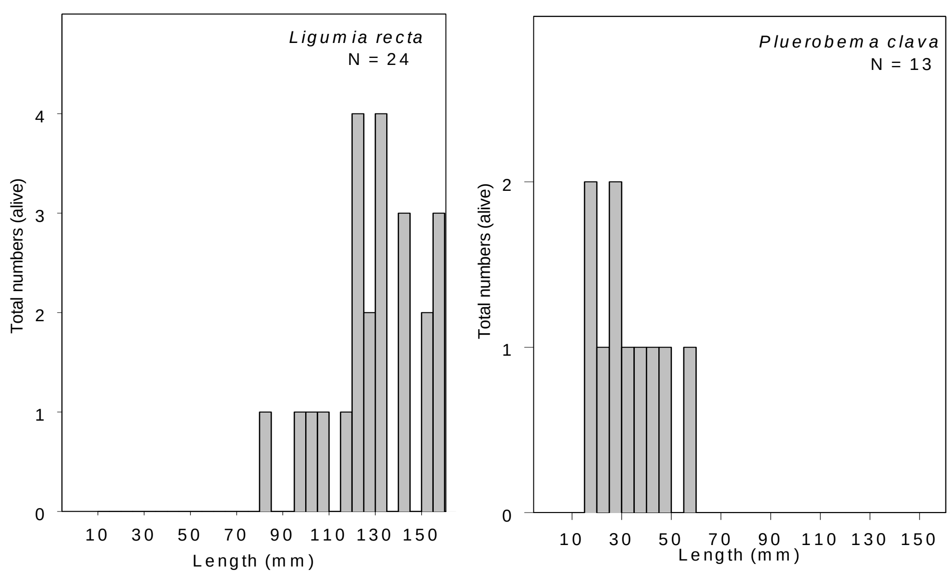

Figure 11: Length frequency histogram for black sandshell (*Ligumia recta*) and clubshell (*Pleurobema clava*) for all 27 sites surveyed in 2003. Note the different scales of the y-axes.

ROUND PIGTOE (*Pleurobema sintoxia*)

We found 74 live *Pleurobema sintoxia* individuals across 16 sites, with generally low numbers per site (1-6). Live *P. sintoxia* was found in Erie, Crawford, and Mercer counties. However, two sites in Crawford County had 12 and 17 live individuals, and one site in Erie County also had 12 live individuals. Shell length of *P. sintoxia* ranged from a minimum of 21.5mm to a maximum of 141mm with a mean of 69.2 mm (61.9, 76.4). Seven sites had evidence of recent recruitment (specimens with lengths < 30mm, Figure 12). The length frequency histogram (Figure 12) appears to be tri-modal, separating out size classes centered on 30, 70 and 130 mm. In addition to the live individuals, we found a total of 17 fresh dead and 23 weathered *P. sintoxia* shells. Three sites had no live individuals, but weathered shells were found, and one of those sites was in Mercer County.

KIDNEYSHELL (*Ptychobranchus fasciolaris*)

Ptychobranchus fasciolaris was our second most abundant species found, with a total of 1055 live individuals across 24 sites. The only sites that did not have any *P. fasciolaris* were the 2 sites highest in the watershed in Erie County, and one pool site in Crawford County. In addition to the live individuals, we found a total of 32 fresh dead and 19 weathered *P. fasciolaris* shells. Because so many live individuals were found, it was not practical to collect every fresh dead or weathered *P. fasciolaris* shell observed at each site, therefore numbers of reported shells is low.

Shell length of *P. fasciolaris* ranged from a minimum of 17mm to a maximum of 129mm with a mean of 81.1 mm (79.5, 82.8). Seven sites had evidence of recent recruitment (specimens <30mm, Figure 12).

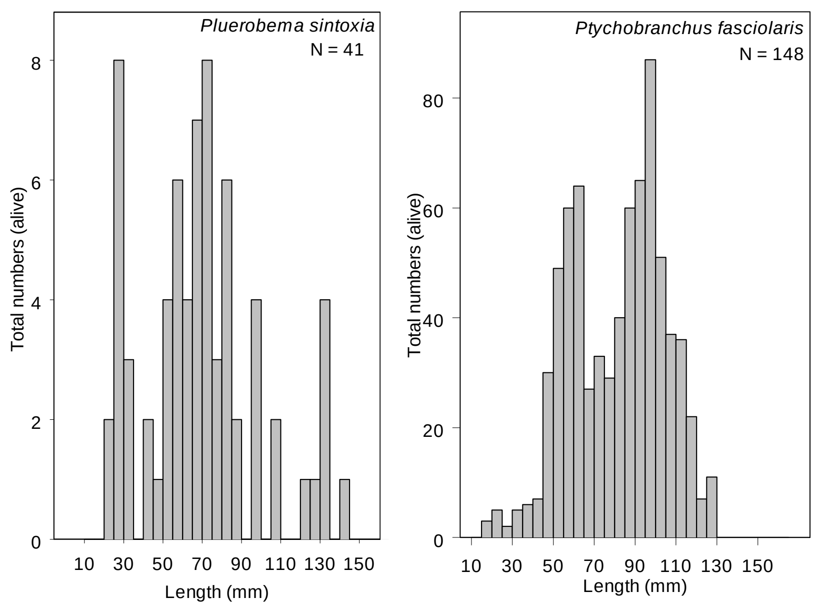

Figure 12: Length frequency histogram for round pigtoe (*Pleurobema sintoxia*) and kidneyshell (*Ptychobranchus fasciolaris*) for all 27 sites surveyed in 2003. Note the different scales of the y-axes.

GIANT FLOATER (*Pyganodon grandis*)

Pyganodon grandis was found at only 6 sites, and only in Erie and Crawford counties. Numbers of live individuals were very low, with only 1-10 found per site, and a total of only 19 individuals. In addition to the live individuals, we found a total of 5 fresh dead and 2 weathered *P. grandis* shells. Two sites had no live individuals, but each had fresh dead shells. One pool site in Crawford County had both fresh dead and weathered shells, but no live individuals. Shell length of *P. grandis* ranged from a minimum of 24.5mm to a maximum of 129mm with a mean of 81.1 mm (79.5, 82.8). Only one site in Erie County had evidence of recent recruitment (specimens < 30mm, Figure 13).

RABBITSFOOT (*Quadrula cylindrica*)

Quadrula cylindrica was found at 12 sites and in three counties; Erie, Crawford, and Venango. Numbers of live individuals were very low, with only 1-7 found per site, and a total of only 41 individuals. The site with the highest abundance of *Q. cylindrica* was in Crawford County, where 7 live individuals were found. *Q. cylindrica* ranged in size from a minimum of 37 mm to a maximum of 140mm with a mean of 91.3 (82.1,100.4). There are a few breaks in the length frequency histogram (Figure 13) that may indicate different size classes. There is evidence of recent recruitment (specimens with lengths < 50mm) at three sites. At several sites where we found live specimens, we also found fresh dead specimens or weathered shells. Only weathered shells were found at two sites; one in Crawford County, the other in Mercer County. We found a total of 7 fresh dead and 11 weathered *Q. cylindrica* shells. Also of note was a site in Crawford County, where we found 13 fresh dead and 5 weathered specimens, but only 1 live individual.

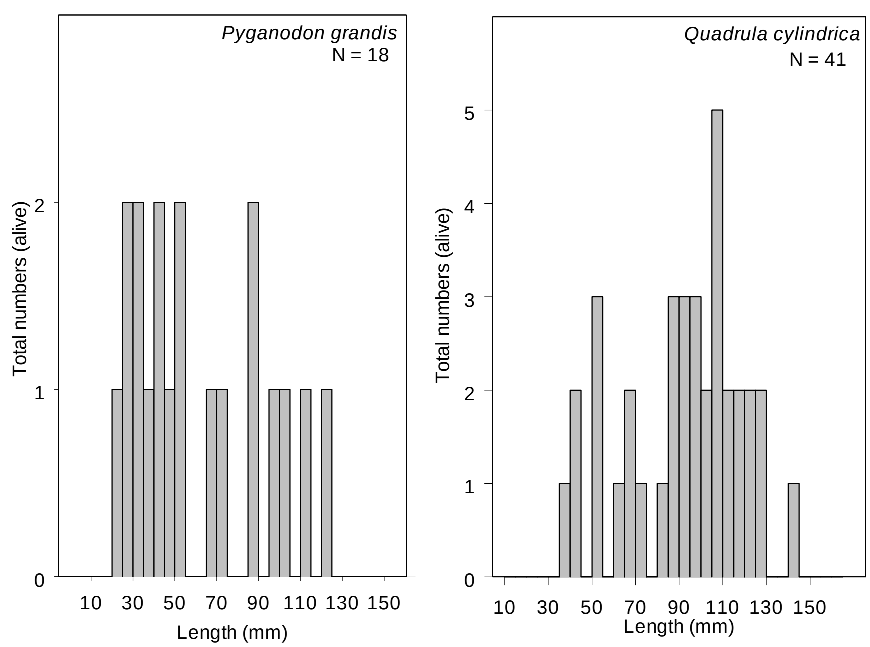

Figure 13: Length frequency histogram for giant floater (*Pyganodon grandis*) and rabbitsfoot (*Quadrula cylindrica*) for all 27 sites surveyed in 2003. Note the different scales of the y-axes.

CREEPER (*Strophitus undulatus*)

We found 149 individual live *Strophitus undulatus* across 17 sites and in all four counties (Erie, Crawford, Venango, and Mercer). *S. undulatus* was most abundant at one site in Crawford County, with 37 live individuals. In addition to the live individuals, we found a total of 3 fresh dead and 6 weathered *S. undulatus* shells. One site in Erie County had only weathered shells and another had only a fresh dead shell, but no live individuals. Shell length of *S. undulatus* ranged from a minimum of 33.5mm to a maximum of 99mm with a mean of 65.3mm (63.3, 67.3). Three sites had one individual less than 40mm; no individual *S. undulatus* under 30 mm were found (Figure 14).

PAPER PONDSHELL (*Utterbackia imbecillis*)

Only one live paper pondshell was found at a pool site in Crawford County with length of 58.3mm. One fresh dead shell was found at the same site.

RAYED BEAN MUSSEL (*Villosa fabalis*)

Villosa fabalis was found in Erie, Venango, Crawford and Mercer counties. Four-hundred and thirty nine live individuals were found across 18 sites, making up nearly 6% of the total catch. One site in Venango County had the highest abundance of *V. fabalis* with 76 live individuals found. At most sites where we found live specimens, we also found fresh dead specimens or weathered shells. We found a total of 221 fresh dead and 78 weathered *V. fabalis* shells. Also of note was a site in Crawford County, where we found 13 fresh dead and 5 weathered specimens, but only 1 live individual. The smallest adult mussels in the French Creek basin, rayed bean mussels ranged in size from a minimum of 10.5 mm to a maximum of 41.8 mm with a mean of 27 (26.4, 27.5). There is no clear break in the length frequency histogram that identifies size classes, however four sites had evidence of recent recruitment (specimens with lengths ≤ 15mm, Figure 14). We found a total of 217 live female and 218 live male-rayed bean, giving an overall female to male ratio of 1:1. Four sites had a lower than average female to male ratio, although the overall numbers at these sites were very low. Four sites had above average female to male ratios.

RAINBOW MUSSEL (*Villosa iris*)

Only 2 live rainbow mussels were found in our 2003 surveys. One live mussel was found each at two separate sites in Venango County. In addition, two fresh dead *V. iris* shells were found at one site in Venango County, but no live individuals were found. Lengths of the two live *V. iris* were 29.0 mm and 39.8mm. Both of these are adult sizes, therefore there is no evidence of recruitment. Since this species has a maximum size of 75 mm (Parmalee and Bogan 1998), we can speculate that recent recruits would be under 20mm.

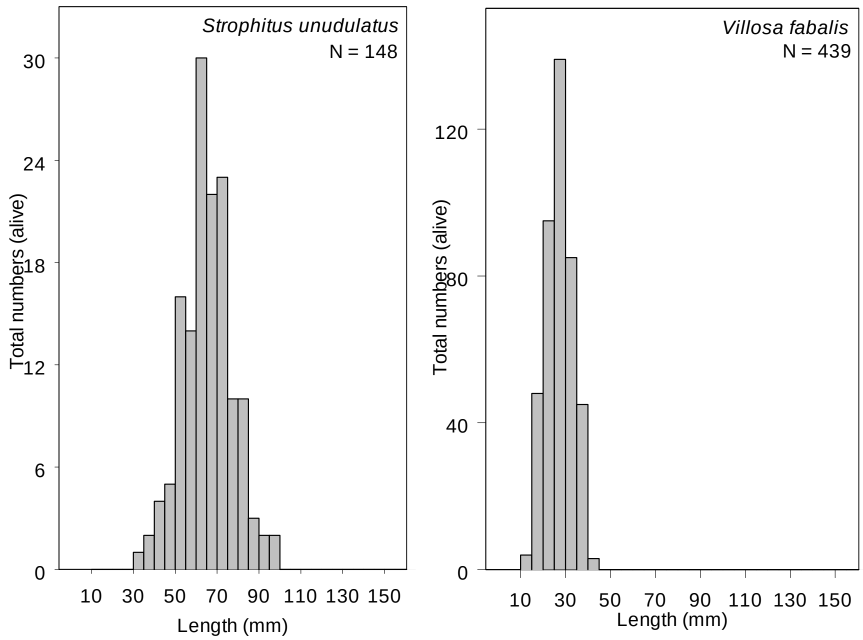

Figure 14: Length frequency histogram for creeper (*Strophitus undulatus*) and rayed bean mussel (*Villosa fabalis*) for all 27 sites surveyed in 2003. Note the different scales of the y-axes.

MUSSEL –HABITAT RELATIONSHIPS

HABITAT VS. SPECIES RICHNESS

We tested for relationships between habitat data and mussel species richness. We used simple regression analysis to see if there were any significant relationships between habitat variables and species richness. Significance for all tests were assessed at the $\alpha = 0.05$ level. Results of the regressions show significant linear relationships between species richness and aquatic vegetation (p-value = 0.175). No other significant relationships were found, however, we did find some trends in the data (Appendix C). An increase in the following parameters scores showed an increasing trend in species richness: sorting, temperature, riparian vegetation thickness score, channel modification score, in-stream cover score, and embeddedness score. An increase in the following parameter scores showed a decreasing trend in species richness: bank stability, water path, bank vegetation thickness, bank vegetation type, and aquatic vegetation. Remember that higher scores for these parameters indicate "better" quality habitat.

For categorical variables, we tested for significant relationships to species richness using Kruskal-Wallis rank sum tests. Significance for all tests were assessed at the $\alpha = 0.05$ level. Results of the Kruskal-Wallis tests show that habitat type (riffle, riffle-run, run, or pool) showed a significant relationship with species richness (p-value=0.01). It is not surprising that riffle, riffle-run, and run habitats had higher species diversity than pool habitats. A significant relationship between species richness and substrate type was also found (p-value =0.047, Figure 15). Sites with boulders as the dominant substrate had a significantly lower species richness than other types of substrates.

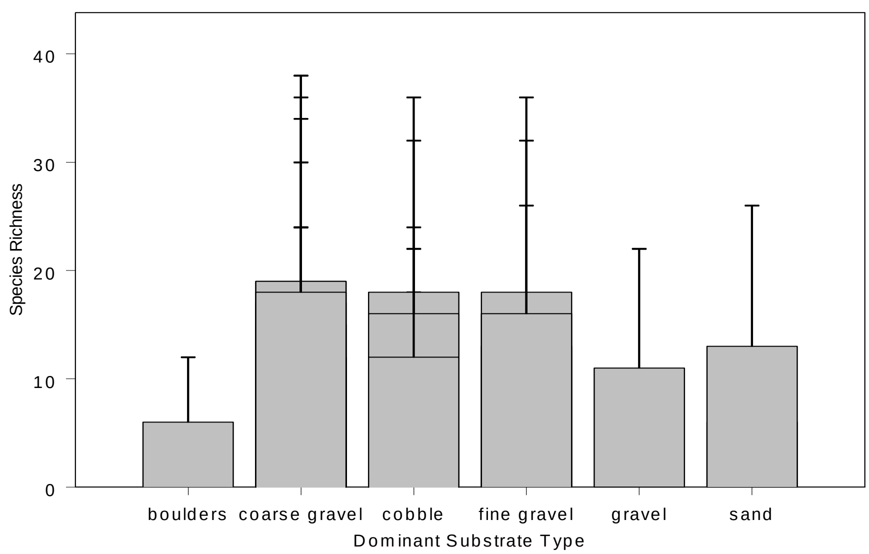

Figure 15: Bar graph with upper 95% confidence interval error bars indicating a significant relationship between species richness and substrate type (p-value =0.047).

Cluster analysis (Morans I) was performed on species diversity to see if the clustered patterns shown in Figure 2 are a result of random chance (ESRI 2003). This tool measures spatial autocorrelation (feature similarity) based on both feature locations and feature values simultaneously. Given a set of features (sites) and an associated attribute (species richness), it evaluates whether patterns are clustered, dispersed, or random. A Moran's Index value near +1.0 indicates clustering; an index value near -1.0 indicates dispersion. A z score is also calculated to assess whether or not the observed clustering or dispersion is statistically significant. Results of the cluster analysis gave a Moran's Index of 0.139, indicating that while there may be some clustering, the pattern may be due to random chance. The z score was 2.62, which is statistically significant at the α =0.05 level.

INDIVIDUAL SPECIES VS. HABITAT AND OTHER SPECIES

We tested the relationships of CPUE of each mussel species with habitat parameters using simple regression techniques. Significance for all tests were assessed at the α = 0.05 level for each of the following variables: dissolved oxygen, temperature, pH, conductivity, habitat type, substrate type, shear stress, wetted perimeter, sorting, sediment load, riparian buffer width, riparian vegetation type, riparian vegetation thickness, bank vegetation type, bank vegetation thickness, bank stability, water pathways, channel modification, canopy cover, in-stream cover, embeddedness, and aquatic vegetation (Schneir 2003, Appendix A). Results are reported for the individual species below. Our investigations showed a strong correlation between bankful velocity and shear stress (r =0.964, p-value =0.00), as well as between bankful discharge and sheer stress (r =0.776, p-value =0.00). Therefore, we left bankful velocity, bankful discharge out of the following analyses, but we included shear stress.

Additionally, we were interested in basic associations between mussel species, so we tested the correlations of CPUEs for each species with each other species using standard Pearson correlation methods (Mathsoft 1999). Significance for all tests were assessed at the α = 0.05 level. Most species were significantly correlated to at least one other species. Interestingly, no species had a negative correlation with another species. Results are reported for the individual species below.

Mucket (*Actinonaias ligamentina*)

We found a significant positive relationship between *A. ligamentina* CPUE and embeddedness (p-value =0.049); *A. ligamentina* CPUE increased with embeddedness scores (Figure 16). We found a significant negative relationship between *A. ligamentina* CPUE and aquatic vegetation scores (p-value =0.049); *A. ligamentina* CPUE decreased with increasing aquatic vegetation scores.

We found significant correlations between CPUE of *A. ligamentina* and *A. marginata* (r=0.642, p-value = 0.000), *A. ferussacianus*(r = 0.531, p-value = 0.003), *E. dilatata* (r = 0.620, p-value = 0.000), *E. torulosa rangiana* (r=0.599, p-value = 0.001), *L. cardium* (r = 0.378, p-value = 0.043), *L. costata* (r = 0.667, p-value = 0.000), *Q. cylindrica* (r=0.548, p-value =0.002), and *S. undulatus* (r=0.679, p-value = 0.000).

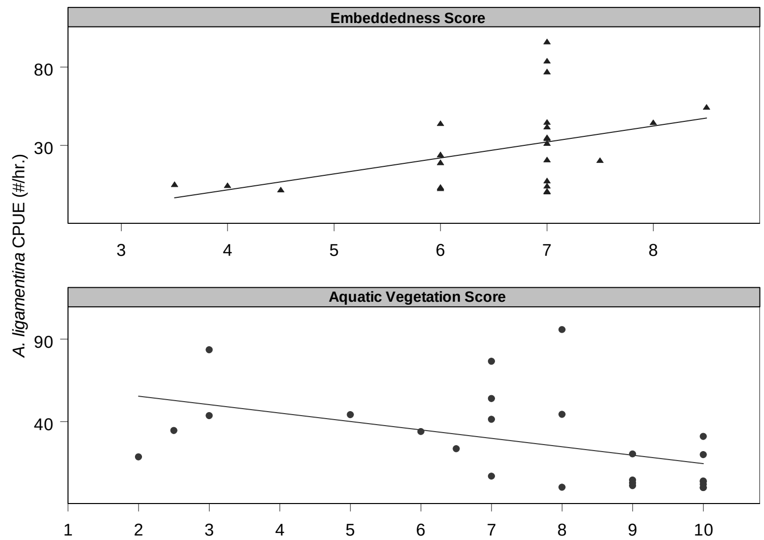

Figure 16: CPUE (total numbers/hour) of *A. ligamentina* versus embeddedness and aquatic vegetation.

Elktoe (*Alasmidonta marginata*)
We found significant relationships between *A. marginata* CPUE and aquatic vegetation (p-value = 0.038). *A. marginata* CPUE decreased with increasing aquatic vegetation scores (Figure 17). We found significant correlations between *A. marginata* and *L. recta* (r = 0.579, p-value =0.001), *L. fasciola* (r = 0.472, p-value = 0.010), and *L. cardium* (r = 0.487, p-value = 0.010), *L. costata* (r = 0.557, p-value = 0.003), *E. torulosa rangiana* (r = 0.435, p-value = 0.003), *A. ligamentina* (r = 0.635, p-value = 0.000), and *A. ferussacianus* (r = 0.469, p-value = 0.000).

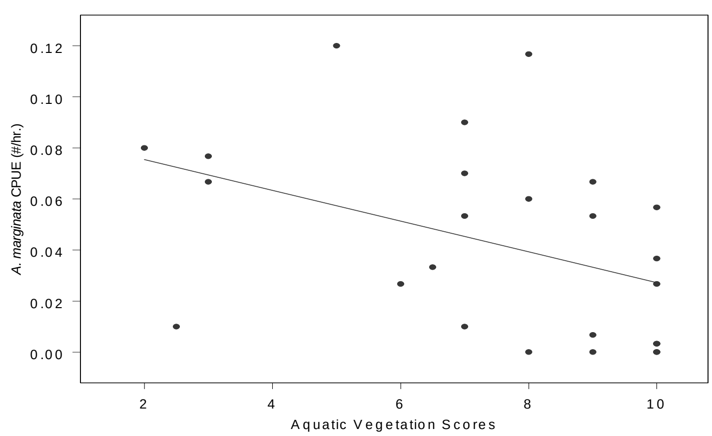

Figure 17: CPUE (total numbers/hour) of *A. marginata* versus aquatic vegetation.

Threeridge (*Amblema plicata*)
We found significant relationships between *A. plicata CPUE* and wetted perimeter (p-value = 0.012) and shear stress (p-value = 0.001). *A. plicata* CPUE increased with increasing wetted perimeter and increasing shear stress (Figure 18). We found significant correlations between *A. plicata* and *A. ferussacianus* (r = 0.700, p-value =0.000), and *L. compressa* (r = 0.664, p-value = 0.002).

Cylindrical papershell (*Anodontoides ferussacianus*)
We found a significant relationship between *A. ferussacianus* CPUE and bank stability (p-value = 0.047) and shading (p-value =0.018). *A. ferussacianus* CPUE increased with shading scores and decreased with increasing bank stability scores. We found significant correlations between *A. ferussacianus* and (r =0.874, p-value = 0.000), *L. compressa* (r =0.405, p-value = 0.036), *A. marginata* (r = 0.469, p-value = 0.014), *E. torulosa rangiana* (r=0.645, p-value = 0.000), *F. subrotunda* (r= 0.553, p-value = 0.003), *P. clava* (r = 0.431, p-value = 0.025), *P. sintoxia* (r = 0. 395, p-value = 0. 042), *Q. cylindrica* (r = 0.544, p-value = 0.003), *S. undulatus* (r=0.564, p-value = 0. 002), and *A. ligamentina* (r = 0.570, p-value = 0.002).

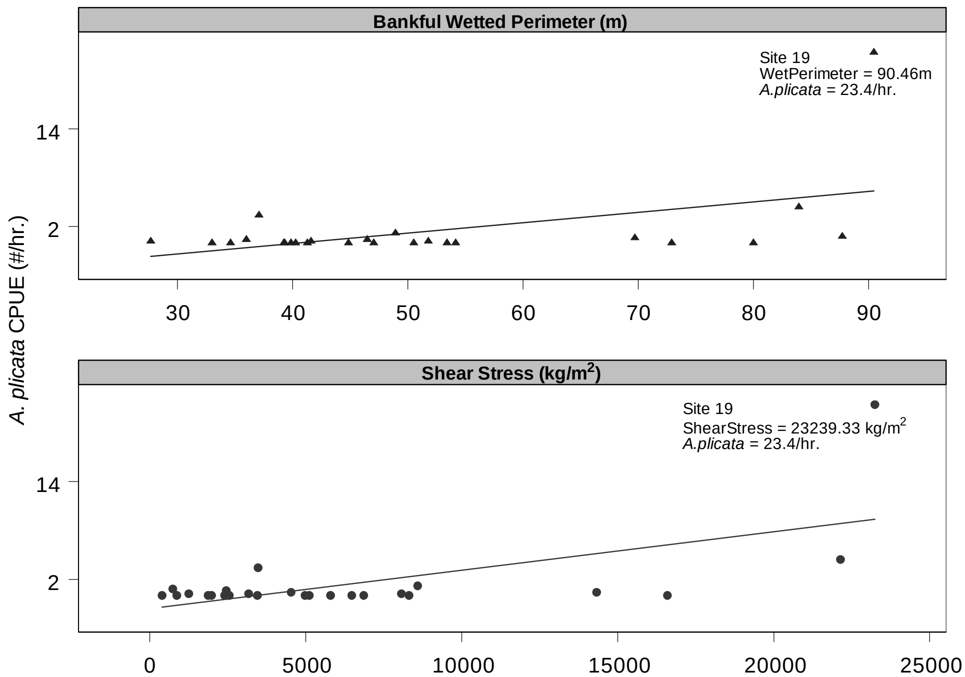

Figure 18: CPUE (total numbers/hour) of *A. plicata* versus wetted perimeter and shear stress.

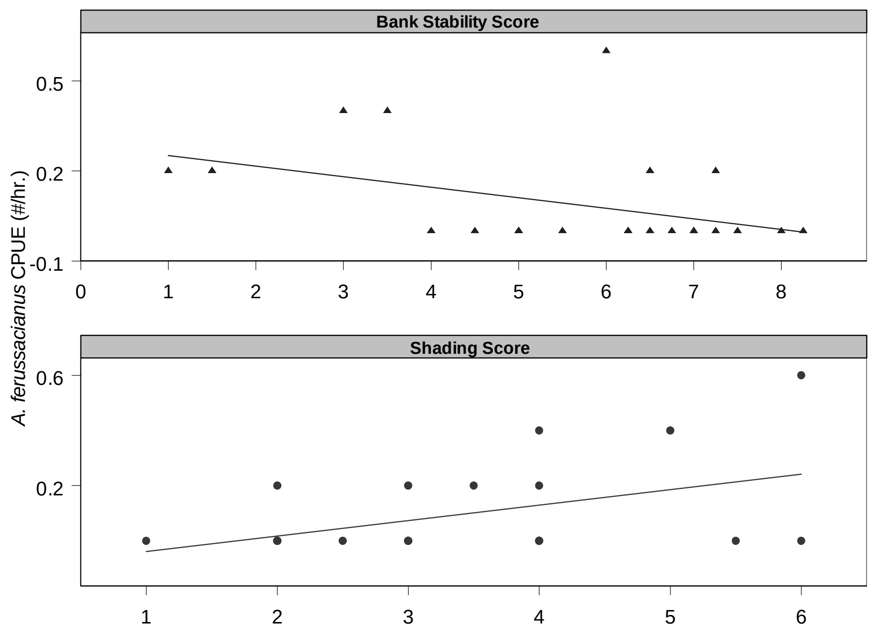

Figure 19: CPUE (total numbers/hour) of *A. ferussacianus* versus bank stability and shading.

Spike (*Elliptio dilatata*)
We found no significant relationships between *E. dilatata* CPUE and habitat parameters. We found significant correlations between *E. dilatata* and *A. ligamentina* (r =0.613, p-value = 0.001), *E. torulosa rangiana* (r= 0.538, p-value = 0.004), *L. costata* (r = 0.486, p-value = 0.010), *P. fasciolaris* (r = 0.514, p-value = 0.006), *Q. cylindrica* (r =0.570, p-value = 0.002), *S. undulatus* (r = 0.531, p-value = 0.004), and *V. fabalis* (r = 0.511, p-value = 0.007).

Northern riffleshell (*Epioblasma torulosa rangiana*)
We found a significant relationship between *E. torulosa rangiana* CPUE and dissolved oxygen (p-value =0.001), conductivity (p-value =0.005), and riparian vegetation type (p-value =0.034). *E. torulosa rangiana* CPUE increased with increasing dissolved oxygen and decreased with increasing conductivity (Figure 20). In fact, it seems that site 29 has driven all of these relationships. We found significant correlations between *E. torulosa rangiana* and *L. cardium* (r =0.674, p-value = 0.000), *Q. cylindrica* (r =0.497, p-value = 0.008), and *S. undulatus* (r =0.779, p-value = 0.000).

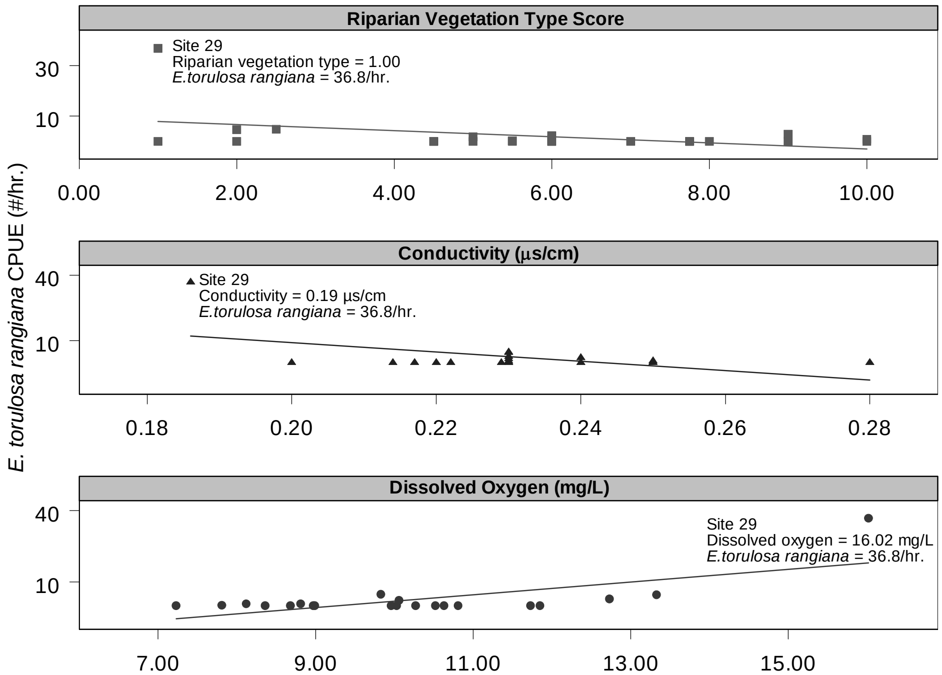

Figure 20: CPUE (total numbers/hour) of *E. torulosa rangiana* versus conductivity, dissolved oxygen and riparian vegetation type.

Snuffbox (*Epioblasma triquetra*)

We found a significant relationship between *E. triquetra* CPUE and in-stream cover (p-value =0.013); *E. triquetra* CPUE increases with in-stream cover (Figure 21). We found significant correlations between *E. triquetra* and *L. cardium* (r= 0.394, p-value =0.042), *L. siliquoidea* (r =0.456, p-value = 0.017), *L. compressa* (r =0.491, p-value = 0.009), *P. sintoxia* (r =0.426, p-value = 0.027), and *P. fasciolaris* (r = 0.747, p-value =0.000).

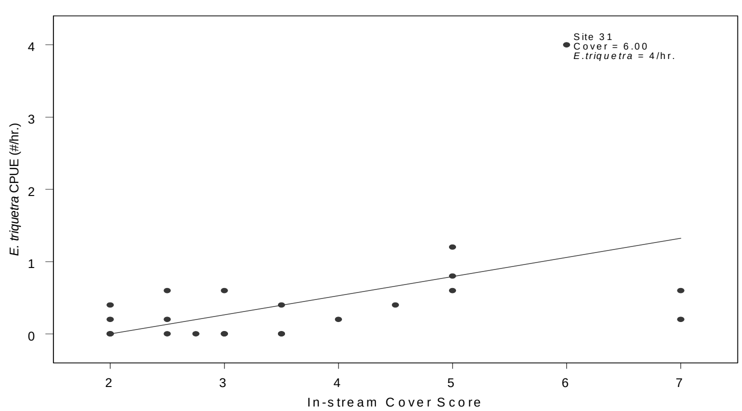

Figure 21: CPUE (total numbers/hour) of *E. triquetra* versus in-stream cover.

Long-solid (*Fusconaia subrotunda*)
We found no significant relationships between *F. subrotunda* CPUE and habitat variables. We found significant correlations between *F. subrotunda* and *A. ferussacianus* (r = 0.553, p-value =0.003), *L. ovata* (r = 0.641, p-value = 0.003), *P. sintoxia* (r = 0.781, p-value =0.000), and *P. clava* (r = 0.791, p-value =0.000).

Plain pocketbook (*Lampsilis cardium*)
We found no significant relationships between *L. cardium* CPUE and habitat variables. We found significant correlations between *L. cardium* and L. ovata (r= 0.600, p-value = 0.001), *E. triquetra* (r = 0.394, p-value = 0.042), *E. torulosa rangiana* (r = 0.397, p-value =0.042), *Q. cylindrica* (r=0.454, p-value = 0.017), and *S. undulatus* (r = 0.505, p-value =0.007).

Wavy-rayed lampmussel (*Lampsilis fasciola*)
We found a significant relationship between *L. fasciola* CPUE and in-stream cover (p-value =0.026) and aquatic vegetation (p-value = 0.004). *L. fasciola* CPUE increased with increasing in –stream cover, and decreased with increasing aquatic vegetation scores (Figure 22). We found significant correlations between *L. fasciola* and *L. recta* (r = 0.436, p-value = 0.003), *L. costata* (r = 0.535, p-value = 0.004), and *A. marginata* (r = 0.472, p-value = 0.010).

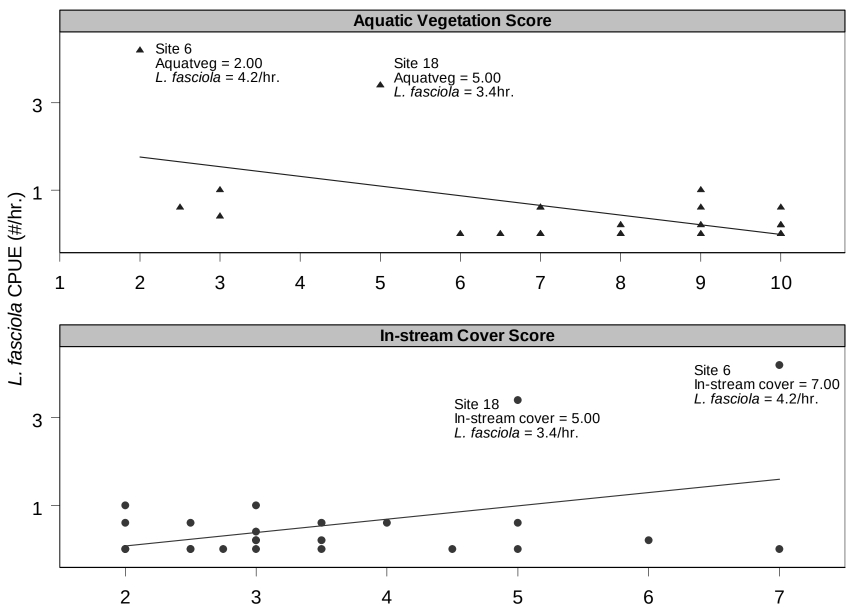

Figure 22: CPUE (total numbers/hour) of *L. fasciola* versus aquatic vegetation and in-stream cover.

Pocketbook (*Lampsilis ovata*)
We found no significant relationship between *L. ovata* CPUE and habitat variables. We found significant correlations between *L. ovata* and *L. cardium* (r = 0.600, p-value =0.001).

Fatmucket (*Lampsilis siliquoidea*)
We found no significant relationship between *L. siliquoidea* CPUE and habitat variables. We found significant correlations between *L. siliquoidea* and *E. triquetra* (r= 0.456, p-value = 0.017).

Creek heelsplitter (*Lasmigona compressa*)
We found no significant relationship between *L. compressa* CPUE and habitat variables. We found significant correlations between *L. compressa* and *A. ferussacianus* (r = 0.405, p-value =0.036) and *E. triquetra* (r = 0.491, p-value = 0.009).

Fluted-shell (*Lasmigona costata*)
We found a significant relationship between *L. costata* CPUE and embeddedness (p-value =0.023) and aquatic vegetation (p-value =0.002). *L. costata* CPUE increased with increased embeddedness scores, and decreased with increasing aquatic vegetation scores (Figure 23). We found significant correlations between *L. costata* and *L. fasciola* (r = 0.535, p-value =0.004), *E. dilatata* (r= 0.486, p-value = 0.010), *A. ligamentina* (r= 0.660, p-value = 0.000), and *A. marginata* (r = 0.557, p-value = 0.003).

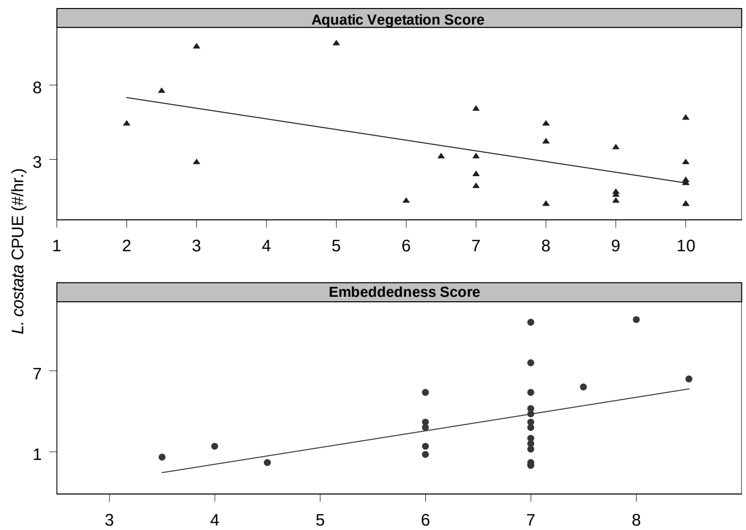

Figure 23: CPUE (total numbers/hour) of *L. costata* versus aquatic vegetation and embeddedness.

Black sandshell (*Ligumia recta*)
We found a significant relationship between *L. recta* CPUE and riparian buffer (p-value =0.010), riparian vegetation type (p-value = 0.014), aquatic vegetation (p-value =0.013), and sorting (p-value =0.016). *L. recta* CPUE increased with riparian buffer, riparian vegetation type, and aquatic vegetation score (Figure 24). As sorting increased, *L. recta* increased. We found significant correlations between *L. recta* and *L. fasciola* (r = 0.436, p-value =0.003).

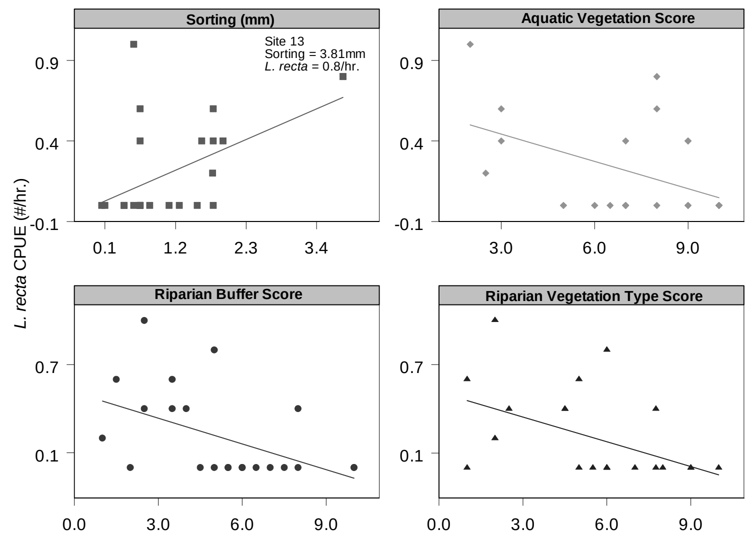

Figure 24: CPUE (total numbers/hour) of *L. recta* versus sorting, aquatic vegetation, riparian buffer, and riparian vegetation type.

Clubshell (*Pleurobema clava*)
We found a significant relationship between *P. clava* CPUE and wetted perimeter (p-value = 0.046) and channel modification (p-value =0.049). As channel modification scores increase, so does *P. clava* CPUE (Figure 25). As wetted perimeter increases, *P. clava* CPUE decreases. We found significant correlations between *P. clava* and *A. marginata* (r = 0.561, p-value =0.002), *F. subrotunda* (r =0.791, p-value = 0.000), and *A. ferussacianus* (r = 0.431, p-value = 0.025).

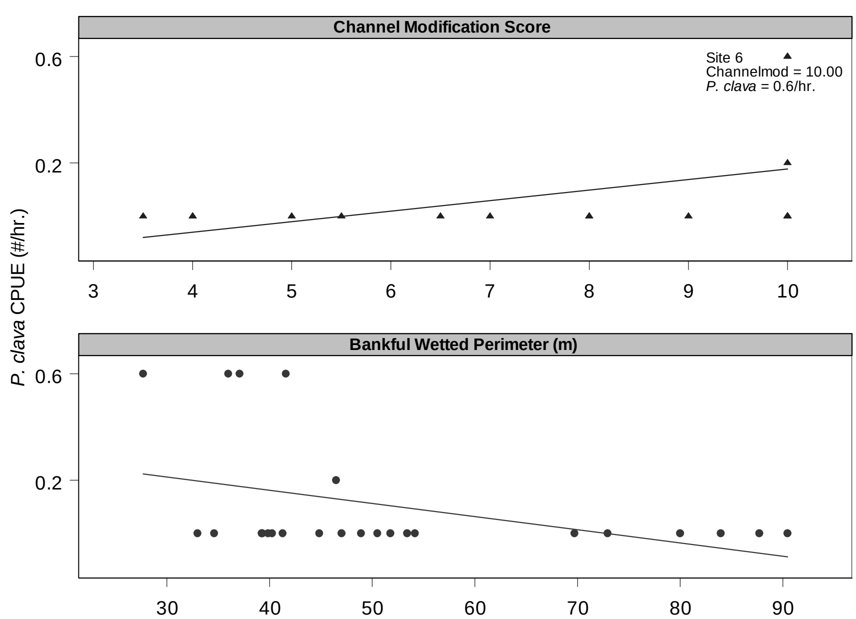

Figure 25: CPUE (total numbers/hour) of *P. clava* versus channel modification and wetted perimeter.

Round pigtoe (*Pleurobema sintoxia*)
We found a significant relationship between *P. sintoxia* CPUE and wetted perimeter (p-value =0.043), dissolved oxygen (p-value 0.038), and riparian buffer (p-value=0.037). As riparian buffer scores increase, so does *P. sintoxia* CPUE (Figure 25). As bankful wetted perimeter and dissolved oxygen increases, *P. sintoxia* CPUE decreases. We found significant correlations between *P. sintoxia* and *E. triquetra* (r = 0.426, p-value = 0.027), *F. subrotunda* (r = 0.781, p-value = 0.000), *A. ferussacianus* (r= 0.395, p-value = 0.042), and *L. compressa* (r = 0.405, p-value = 0.036). It should be noted that dissolved oxygen (as well as temperature) fluctuates temporally, so direct relationships between species and dissolved oxygen should be viewed with caution.

Kidneyshell (*Ptychobranchus fasciolaris*)
We found a significant positive relationship between *P. fasciolaris* CPUE and in-stream cover (p-value = 0.003); as in-stream cover scores increases so does *P. fasciolaris* (Figure 27). We found significant correlations between *P. fasciola* and *E. triquetra* (r = 0.747, p-value = 0.000), *E. dilatata* (r= 0.514, p-value = 0.006), and *L. siliquoidea* (r = 0.474, p-value = 0.013).

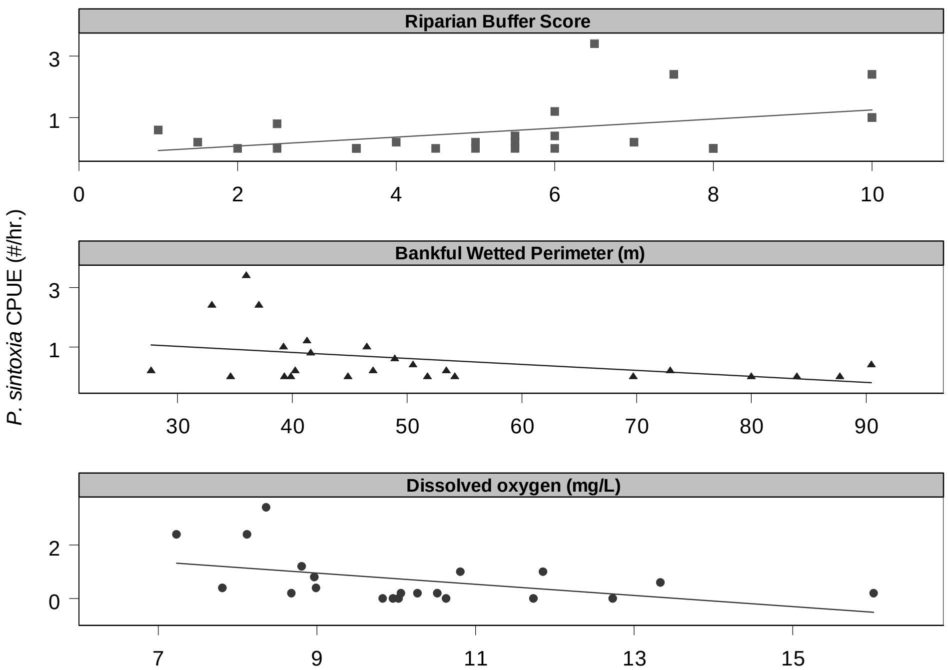

Figure 26: CPUE (total numbers/hour) of *P. sintoxia* versus wetted perimeter and dissolved oxygen.

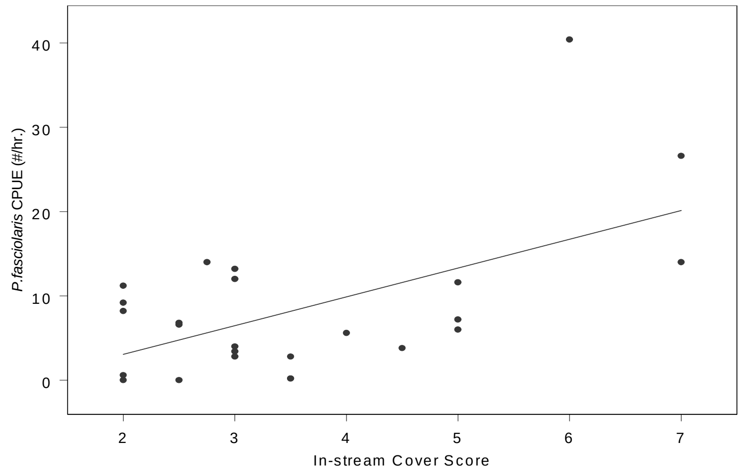

Figure 27: CPUE (total numbers/hour) of *P. fasciolaris* versus in-stream cover.

Giant floater (*Pyganodon grandis*)
We found a significant negative relationship between *P. grandis* CPUE and pH (p-value =0.000); as pH increased, *P. grandis* CPUE decreased (Figured 28). We found no significant correlations between *P. grandis* and other mussel species.

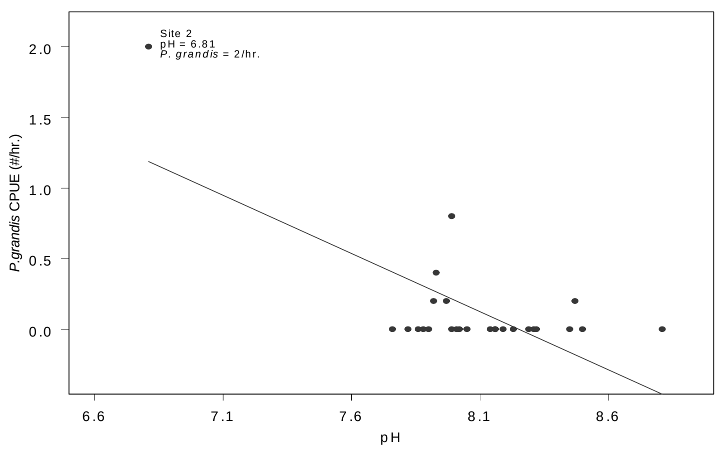

Figure 28: CPUE (total numbers/hour) of *P. grandis* versus pH.

Rabbitsfoot (*Quadrula cylindrica*)
We found no significant relationships between *Q. cylindrica* CPUE and habitat parameters. We found significant correlations between *Q. cylindrica* and *S. undulatus* (r =0.445, p-value = 0.039), *L. cardium* (r = 0.454, p-value =0.017), *A. ferussacianus* (r= 0.544, p-value = 0.003), *E. dilatata* (r= 0.570, p-value = 0.002), *E. torulosa rangiana* (r=0.497, p-value= 0.008), and *A. ligamentina* (r =0.534, p-value = 0.004).

Creeper (*Strophitus undulatus*)
We found a significant relationship between *S. undulatus* CPUE and shading (p-value =0.017) and conductivity (p-value = 0.043). *S. undulatus* CPUE increased with increased shading scores and decreased with increasing conductivity (Figure 29). We found significant correlations between *S. undulatus* and *A. ferussacianus* (r=0.564, p-value = 0.002), *E. dilatata* (r=0.531, p-value =0.004), *E. torulosa rangiana* (r = 0.779, p-value =0.000), *L. cardium*, (r=0.505, p-value = 0.007), and *Q. cylindrica* (r=0.445, p-value =0.039).

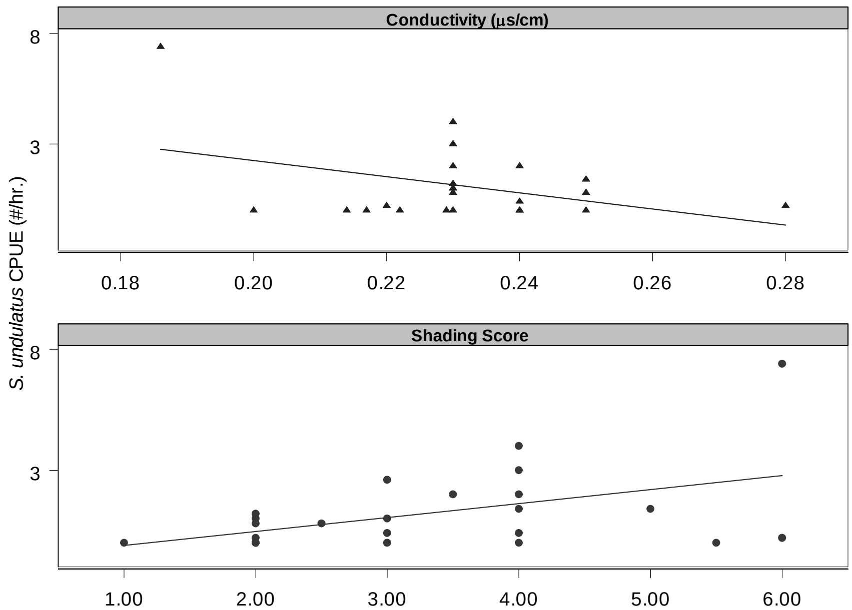

Figure 29: CPUE (total numbers/hour) of *S. undulatus* versus conductivity and shading.

Paper pondshell (*Utterbackia imbecillis*)
We found a significant relationship between *U. imbecillis* CPUE and sheer stress (p-value =0.008), riparian vegetation thickness (p-value =0.007), bank vegetation type (p-value =0.022), bank vegetation thickness (p-value = 0.025), bank stability (p-value =0.021), and waterpath (p-value = 0.002). We found significant correlations between *U. imbecillis* and *A. plicata* (r = 0.809, p-value = 0.000), *A. ferussacianus* (r = 0.8736, p-value = 0.000), and *L. compressa* (r = 0.8554, p-value = 0.000).

Rayed bean mussel (*Villosa fabalis*)
We found a significant positive relationship between *V. fabalis* CPUE and temperature (p-value = 0.022, Figure 30), riparian vegetation type (p-value = 0.044), and embeddedness (p-value = 0.044). We found a significant negative relationship between *V. fabalis* and aquatic vegetation (p-value =0.000). We found significant correlations between *V. fabalis* and *L. costata* (r = 0.748, p-value =0.000), *S. undulatus* (r = 0.399, p-value = 0.039), and *E. dilatata* (r=0.511, p-value = 0.007).

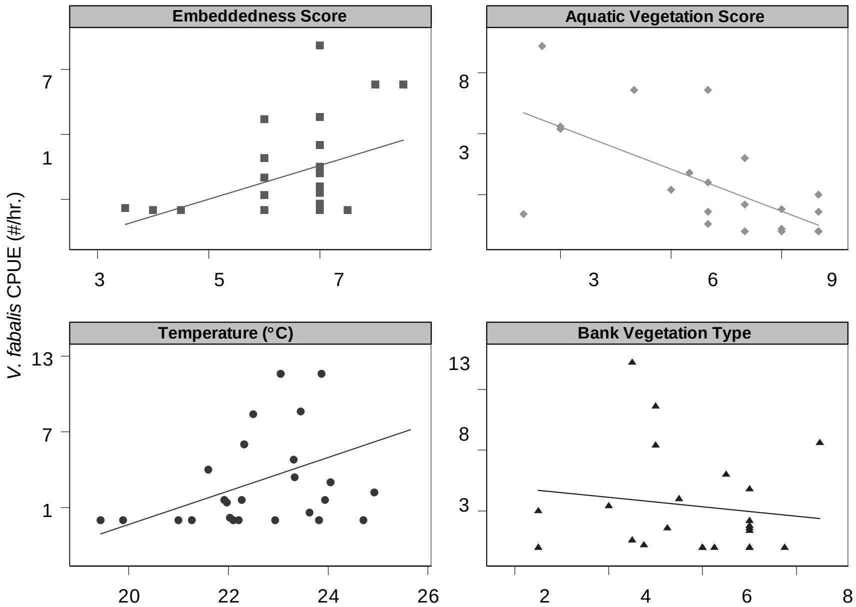

Figure 30: CPUE (total numbers/hour) of *V. fabalis* versus embeddedness, aquatic vegetation, temperature, and bank vegetation type score.

Rainbow mussel (*Villosa iris*)
We found significant relationship between *V. iris* CPUE and bank vegetation type (p-value =0.013). We found significant correlations between *V. iris* and *L. fasciola* (r = 0.477, p-value =0.012) and *E. dilatata* (r =0.7303, p-value =0.000).

MUSKRAT MIDDEN COLLECTIONS

We compared species composition data from the midden collections with data from corresponding mussel survey sites. Specifically, we looked at species composition, relative abundances, and lengths. Ultimately, muskrat midden research may be used an alternative to in-stream sampling techniques.

We looked at presence/absence of mussel species within muskrat middens for two reasons; to see if there were any species found in the middens that were not found during our snorkel surveys and to see if there were species not documented in the middens that we did find in our surveys. In addition, we wanted to compare the relative abundances of species between the middens and the snorkel surveys to see if the muskrats had any bias in which species they consume.

To further assess differences between our snorkel survey and midden data, we compared comparing mean lengths of each species found at five sites. To test if length means were different, we compared 95% confidence intervals between midden and snorkel survey data. These analyses were done to determine if there is a size bias in muskrat diets. In other words, we wanted to see if muskrats favor younger and smaller specimens or do they have a bias for older and larger individuals. Standard two sample t-tests were used to determine if the mean lengths for each species were the same in both the middens and survey data at each site. Significance was tested at the $\alpha = 0.05$ level.

A total of 22 middens was collected in 2002, and 5 additional middens were collected in 2004. Species richness ranged from 6 to 20, with a mean of 11.8 (10.5, 13.0). Midden locations were mapped using GPS technology. Figure 31 illustrates midden species richness.

Nine midden collection sites were within 200m of a 2003 snorkel survey site. Shell lengths of all species were measured at five of these middens, which were compared to 2003 snorkel survey length data. At two sites, a midden was collected in both 2002 and 2004. We compared the data from each of these two sites between both years to see if there were any noticeable changes in species relative abundances in the middens. If the sample had 20 or more individuals of one species, statistical significance of lengths was assessed.

Tables 7-10 show the total numbers and relative abundances of each species found in the 2002 midden collections versus the 2003 in-stream snorkel surveys. Tables 11-13 show the total numbers, relative abundances, mean lengths and 95 % confidence intervals on the mean lengths of each species found in the 2004 midden collection versus the 2003 in –stream mussel survey at sites 17 and 22. Tables 14 and15 show the total numbers, relative abundances, mean lengths, and confidence intervals on the mean lengths of each species found in the 2002 and 2004 midden collections versus the 2003 in-stream mussel survey. Mean lengths of *A. ligamentina* are consistently significantly smaller in the middens than what was observed in the 2003 snorkel surveys. The maximum size of muskrat predation on A. ligamentina was xxmm. *P. fasciolaris* had significantly smaller lengths in the middens from site 15, 17, and 29. Lengths of *E. dilatata* were significantly smaller in middens at sites 17, 22, 24, and 29. At site 17, both *A. marginata* and *S. undulatus* had significantly smaller lengths in middens than in the 2003 snorkel survey. Interestingly, *E. torulosa rangiana* shells were smaller in the middens than in the snorkel survey data for site 24, but larger in site 29.

Twelve species were found in the 2002 midden at site 9 and sixteen were found during the 2004 midden collection (Table 7). Six species found in the 2003 snorkel survey (*A. plicata, A. ligamentina, E. triquetra, L. cardium, Q. cylindrica,* and *V. fabalis*) were not found in the 2002 midden, and two species found in the 2002 midden (*E. torulosa rangiana* and *L. fasciola*) were not found in 2004 midden collection. The fact that zero *A. ligamentina* were collected in the 2002 midden is suspicious, and the collection should be investigated for error. *V. fabalis* comprised 6.2% of the snorkel survey, but was absent from the midden collection. Relative abundances of *E. dilatata, P. sintoxia, P. fasciolaris,* and *S. undulatus* were all much higher in the midden collection than in the snorkel survey.

Table 7: Total numbers and relative abundance of each species found in the 2002 midden collection versus the 2003 in-stream snorkel survey at site 9.

Site 9	**2002 Midden Survey**		**2003 Snorkel Survey**	
	Total Number	**Relative Abundance (%)**	**Total Number**	**Relative Abundance (%)**
A. ligamentina		0.00%	170	62.27%
A. marginata	2	2.47%	8	2.93%
A. plicata			2	0.73%
E. dilatata	22	27.16%	15	5.49%
E. torulosa rangiana	1	1.23%		
E. triquetra			3	1.10%
F. subrotunda	3	3.70%	6	2.20%
L. cardium			2	0.73%
L. fasciola	1	1.23%		
L. siliquoidea	1	1.23%	2	0.73%
L. compressa	3	3.70%	1	0.37%
L. costata	1	1.23%	1	0.37%
P. clava	5	6.17%	1	0.37%
P. sintoxia	11	13.58%	5	1.83%
P. fasciolaris	18	22.22%	34	12.45%
Q. cylindrica			2	0.73%
S. undulatus	13	16.05%	4	1.47%
V. fabalis			17	6.23%
Total	**81**		**273**	