THE DISTRIBUTION AND ABUNDANCE OF FRESHWATER MUSSELS IN THREE LAKE ERIE TRIBUTARIES

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Executive Summary

North America is the home of freshwater mussel (Bivalvia: Superfamily Unionoidea) diversity, with nearly 300 species known from the United States. In Ohio, a total of 78 freshwater mussel species were present historically, with 44 species occurring in the Lake Erie drainage. Five species are now extinct and 13 species extirpated from the State. The Ohio Division of Wildlife lists 54% of all Ohio unionid species as endangered, threatened, or species of concern. One species of particular interest, the Ohio endangered and federal candidate Rayed Bean (*Villosa fabalis*), still occurs in the Western Lake Erie drainage.

During the summer and fall of 2010, we conducted freshwater mussel research in three Lake Erie tributaries: the Blanchard River (Hancock County and Hardin County), Swan Creek (Lucas County), and Beaver Creek (Wood County). The purpose of our study was to establish baseline population estimates, document age class diversity, and find evidence of recent recruitment. In addition, we investigated microhabitat use, burrowing depth, and Index of Biotic Integrity development. We were particularly interested in quantifying the status and microhabitat use of the Rayed Bean (*V. fabalis*).

To achieve our objectives, two 1500m reaches (upper and middle reach) per stream were selected for study. Each reach was divided into fifteen 100m sites and three sites were randomly selected for sampling. A total of 150 quadrats (0.25m^2 each) were excavated to a depth of 6cm at each site (450 quadrats per reach). Sites within each reach were treated as replicates for the purpose of data analysis.

A total of 22 live species and 1,197 live individuals were found during our field work. Freshwater mussel abundance, density, and diversity were highest in the Blanchard River. The Upper Blanchard community was particularly speciose and robust, with 15 species found live and a mean reach density of 4.48 unionids/m^2. Rayed Bean (*V. fabalis*) was found in both the Upper Blanchard River and Middle Swan Creek. Mean population estimates were 212 *V. fabalis* per 100m in the Upper Blanchard and 88 *V. fabalis* per 100m in Swan Creek. Both populations demonstrated age class diversity and evidence of recent recruitment. In fact, we found a diversity of age classes for 15 of the 22 total species encountered during our 2010 field work – including recent recruits for 10 species.

Microhabitat conditions were analyzed for each reach. QHEI was a useful predictor of unionid species richness (R^2 = 0.66), Shannon Diversity (R^2 = 0.51), and unionid density (R^2 = 0.51). Reaches with the lowest mean QHEI scores supported the fewest number of species and lowest densities. Mean reach diversity and density increased with increasing QHEI scores, but slightly decreased where QHEI was highest. Physical habitat was most diverse in the Blanchard River, where riffles were well developed and stream substrates comprised of heterogeneous mixtures of sand, gravel, and cobble. The Blanchard River also supported the most live species and highest densities of freshwater mussels. In contrast, physical habitat was most limited in Upper Swan Creek, where habitat consisted chiefly of sandy glides littered with woody debris. Upper Swan Creek supported the fewest number of species and the lowest densities of mussels. Rayed Bean (*V. fabalis*) was most abundant in samples where small gravel dominated the surface substrates. It was found primarily in shallow glides where streambed substrates were not excessively hard or soft.

Substrate burrowing position was documented for each mussel collected. Approximately 31% of all mussels (excluding recent recruits) were not detected on the surface. Additionally, 92% of recent recruits were not detected on the surface. More than 90% of all Rayed Bean (*V. fabalis*) recovered during our field work were also not found on the surface. Burrowing characteristics varied considerably across streams, with 78% of Beaver Creek unionids found on the surface and just 38% of Swan Creek unionids found on the surface. These findings have implications for both unionid sampling and monitoring strategies, as well as habitat conservation.

Metrics for a Western Lake Erie Basin specific Unionid Index of Biotic Integrity were explored using an established framework and literature review. The metrics included number of extant species, number of indicator genera, number of species exhibiting reproductive success, and presence of burrowing species.

Overall, Middle Swan Creek and the Upper Blanchard River supported regionally and globally significant populations of the imperiled Rayed Bean (*V. fabalis*). With mean unionid densities as high as 4.48 unionids/m^2, the Upper Blanchard River supported a particularly robust unionid community as a whole. This community likely plays a significant role in the aquatic ecology of the Upper Blanchard and should be monitored to evaluate temporal changes in species richness and density. Both the Blanchard River and Swan Creek will require protection if unionid populations are to be sustained within the Western Lake Erie basin.

Acknowledgements

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Field sampling access was provided by the Metroparks of the Toledo Area, Wood County Park District, Sunshine Children’s Home, and private landowners.

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1.0 Introduction

Freshwater mussels (Bivalvia: Superfamily Unionoidea) are distributed nearly worldwide, inhabiting every continent except Antarctica. Approximately 780 species belonging to 140 genera have been identified to date, with species diversity maximized in the creeks, rivers, and lakes of North America (Graf and Cummings 2007). Nearly 300 species are known from the United States, the vast majority of which belong to the family Unionidae. While this diversity is remarkable, 70% of the North American fauna is of conservation concern (Williams et al. 1993; Master et al. 2000). This proportion of imperilment is greater within the Unionoidea (Families Unionidae, Margartiferidae, and Hyriidae) than any other group of animals in the United States.

In Ohio, a total of 78 unionid species were known to occur historically (Figure 1.1), with 44 species present in the Lake Erie drainage (Graf 2002). Five species are now extinct and 13 extirpated from the State. The Ohio Division of Wildlife lists 54% of all Ohio unionid species as endangered, threatened, or species of concern (Watters et al. 2009). Unfortunately, even unionids considered relatively common throughout their range are declining in some Ohio streams (Grabarkiewicz and Crail 2008).

In Northwest Ohio, a unionid species of particular interest is the Rayed Bean (*Villosa fabalis*) (Figure 1.2). A diminutive mussel (shell size up to 3.7 cm), *V. fabalis* has declined over the last century and is now extant in 23 of the 106 known watercourses where it formerly occurred (Butler 2002). On November 2nd, 2010, the U.S. Fish and Wildlife Service published a rule in the Federal Register proposing two freshwater mussels, the Rayed Bean (*V. fabalis*) and Snuffbox (*Epioblasma triquetra*), for listing as endangered under the U.S. Endangered Species Act (ESA) of 1973. It is also listed as endangered by the Ohio Division of Wildlife. Interestingly, several populations still occur in Lake Erie tributaries, including the Blanchard River, Fish Creek, and Swan Creek (Hoggarth et al. 2000; Grabarkiewicz 2008; Watters et al. 2009). Fresh dead Rayed Bean *(V. fabalis*) were also collected during the summer of 1996 from Tymochtee Creek (personal comm., Jamie Smith, North Carolina State Museum of Natural Sciences), although the status of this potential population remains unresolved. Clearly, these data indicate that the Rayed Bean *(V. fabalis)* is still well represented in Northwest Ohio.

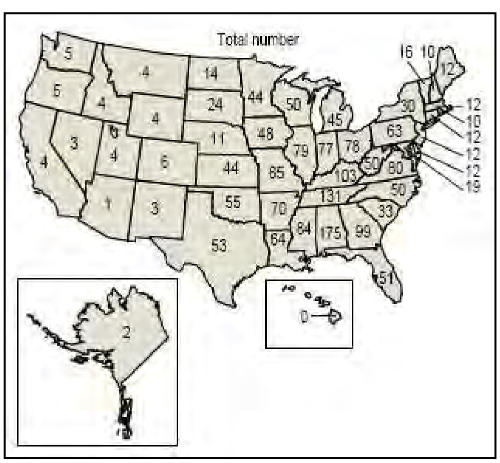

Figure 1.1 - Total number of freshwater mussel species by state. Graphic from LaRoe et al. (1995).

Figure 1.2 – A 23mm female Rayed Bean (*V. fabalis*), Swan Creek, Lucas County, OH. (Photo: Jeff Grabarkiewicz)

Ecologically, freshwater mussels play a number of important roles in aquatic ecosystems (Vaughn and Hakenkamp 2001). As sedentary suspension feeders, unionoids remove a variety of materials from the water column, including sediment, organic matter, bacteria, and phytoplankton. Mussels also interact with stream sediments. The burrowing behavior of unionoids mixes sediment pore water, releasing nutrients and oxygenating substrates (Vaughn and Hakenkamp 2001). Particularly dense assemblages of mussels may influence substrate stability while providing nutrients and microrefugia for benthic life (Vaughn and Hakenkamp 2001; Howard and Cuffey 2006; Vaughn and Spooner 2006; Zimmerman and de Szalay 2007).

Several characteristics make adult freshwater mussels useful indicators of surface water integrity. Specifically, adult unionoids are long-lived, relatively sessile, and sensitive to environmental change. The well-known early 20th century naturalist Arnold Ortmann recognized the disappearance of mussels “as one of the first and most reliable indicators of stream pollution” (Ortmann 1909). Ellis (1931a; 1931b) noted the profound influence of municipal and industrial wastes, siltation, and impoundments on freshwater mussel populations. More recently, these observations have been verified through toxilogical experiments. In fact, the early life stages of several freshwater mussel species have been found to be among the most sensitive organisms to chemical contaminants such as ammonia and copper (Augspurger et al. 2003; Wang et al. 2007a; Wang et al. 2007b). In response to these recent findings, U.S. EPA submitted new draft ammonia criteria into the federal register on December 30th, 2009.

Considering the apparent decline of freshwater mussels and their value to freshwater ecosystems, robust baseline data are needed to assess existing populations and monitor temporal changes. While some presence-absence data are available through museum collections, technical reports, and published literature (e.g. Kirsch 1895; Wilson and Clark 1912; Clark 1944; Watters 1988; 1998; Hoggarth et al. 2000; Grabarkiewicz 2008; Grabarkiewicz and Crail 2008), little to no rigorously collected quantitative data are available. Quantitative (or probability based) survey designs allow ecologists to estimate population parameters (e.g. relative abundance and density), assess changes over time, and determine uncertainty (Strayer and Smith 2003). Depending on the design, they can also be effective at locating small species (e.g. Rayed Bean) and unionids burrowed beneath the substrate surface (Obermeyer 1998).

Our objectives for this study were to (1) Establish baseline unionid population estimates for six reaches in three Lake Erie tributaries using a rigorous quantitative sampling protocol, (2) analyze community structure and evidence of recent recruitment, (3) document microhabitat use of freshwater mussels, (4) assess the burrowing tendencies of all sampled species and age classes, and (5) investigate relevant metrics for a Western Lake Erie drainage “Unionid Index of Biotic Integrity.”

2.0 Methods

The general approach used in this study was to obtain rigorous unionid, substrate, and site level data using probability based sampling design methods. A total of six reaches within three Northwest Ohio streams were selected for field work (two reaches per stream). Reaches measured 1500m in length and were subdivided into fifteen 100m sites. Three sites were randomly selected for sampling from each reach. Sites were treated as replicates for the purpose of analyzing data. Each site was first assessed for microhabitat quality by using the Ohio EPA Qualitative Habitat Evaluation Index (QHEI). A total of 150 0.25m^2 quadrats per site were then excavated for unionid mussels and substrate characteristics (2,700 quadrats total). The burrowing position of each unionid was assigned an ordinal variable dependent on approximate depth. Potential unionid IBI metrics were explored based on sampling results and scientific literature.

2.1 Description of Streams, Reaches, and Sampling Locations

Three Western Lake Erie tributaries were selected for sampling: the Blanchard River, Swan Creek, and Beaver Creek (Figure 2.1). The selection was based on a suite of factors, including driving distance from the University of Toledo, presence and absence of Rayed Bean (*V. fabalis*), stream geology, drainage area, and limited need to sample using SCUBA. The Blanchard River is a tributary of the Auglaize River and drains approximately 1,994 km^2 at the mouth south of Dupont, OH. It is located within the Central Ohio Clayey Till Plain, rising in the gently rolling terrain of the Wabash Moraine north of the City of Kenton. From its origin in Hardin County, the Blanchard meanders down through Hancock County before making an abrupt turn west towards the City of Findlay. Our middle sampling reach was located near this turn - at the intersection of Township Rd. 208 and Township Rd. 234 - just upstream of Findlay (RKM 98.5 – 99.8) (Figure 2.2). The upper sampling reach was located near U.S Route 30, approximately 4.4 km NE of Forest, OH (RKM 140.9 – 142.2). The land use of both reaches is primarily row cropped agriculture.

Swan Creek is direct tributary of the Maumee River, draining 528 km^2 at the mouth in downtown Toledo. It is primarily a low gradient (0.4 m/km), beach ridge stream best known for draining part of the Oak Openings ecoregion. While the headwaters are chiefly in agricultural land use, much of the lower watershed is suburban or intensely urbanized. Our middle sampling reach was located in Monclova Township (RKM 26.6 – 27.9) while the upper sampling reach was located within Oak Openings Metropark (RKM 45.0 – 46.3).

Beaver Creek is also a direct tributary of the Maumee River, draining 497 km^2 at the mouth in Grand Rapids, OH. The headwaters rise in the systematically drained agricultural landscape of southern Wood County and eastern Henry County, an area formerly occupied by the Great Black Swamp. Due to problems gaining access on private property, the middle and upper sampling reaches were relatively close, both located in Grand Rapids Township at RKM 2.3 – 3.5 and RKM 4.8 – 6.1.

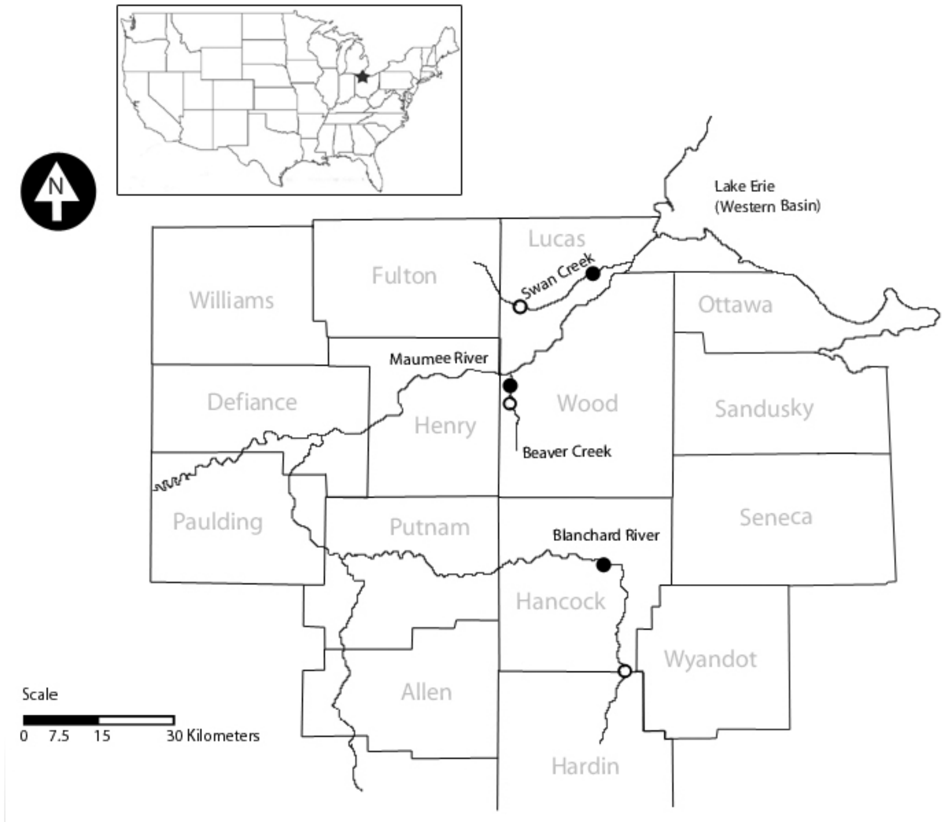

Figure 2.1 *–The location of field sampling streams and reaches. The middle reaches are denoted with bold circles (●) and upper reaches with hollow circles (○).*

Figure 2.2 *- Aerial map of the Middle Blanchard River study reach. Reaches were divided into fifteen 100m sites with three sites randomly selected for sampling.*

2.2 Site Rapid Habitat Assessment

Before transects were laid and quadrat sampling began, habitat at each site was evaluated using a multimetric protocol developed by Ohio EPA titled Qualitative Habitat Evaluation Index (QHEI) (Ohio EPA 1987; Ohio EPA 2006). QHEI assessments provide a general microhabitat score based on numerous instream and near stream variables. Example characteristics include substrate composition, instream cover, riparian zone size and quality, and channel morphology development. Final scores range from 0 to 100, with higher scores representing higher quality habitats.

2.3 Site Sampling Design

All sites were surveyed at low flow using a systematic sampling protocol with three random starts. This method is described in Strayer and Smith (2003) and is similar to Smith et al. (2001) with minor modifications. The protocol calls for a grid-like design that utilizes multiple random starts (Figure 2.3). Without multiple random starts, assumptions have to be made regarding the distribution of mussels in the sample area and variance cannot be calculated properly (Strayer and Smith 2003). A $0.25m^2$ PVC quadrat was used for all unionid and substrate sampling. Grid positioning was accomplished through leadcore transect lines and a 2m aluminum rod attached to the quadrat. Sampling was initiated at the furthest downstream transect and proceeded upstream.

2.31 Unionid Sampling

Unionids were sampled in each $0.25m^2$ quadrat using a snorkel or view bucket. Unionids visible on the substrate surface were first removed and given a number based on burrowing depth (2: >50% burrowed, 3: < 50% burrowed, 4: fully exposed) (Figure 2.4). After substrate measurements were made, quadrats were excavated with a metal scoop or by hand (depending on substrate composition). Any unionids collected from excavated material were given a burrowing depth of "1" (wholly burrowed). All unionids were identified to species, sexed (when possible), and measured along the x, y, and z axis. Exceptional finds were photographed. After identification and measurement, all unionids were returned to the approximate location of capture. Unionid taxonomy followed Turgeon et al. (1998).

2.32 Microhabitat Sampling

Depth, surface substrate texture, subsurface composition, penetrability, and habitat type of each $0.25m^2$ quadrat were measured. Surface substrates were evaluated visually using a rod placed diagonally across the quadrat with observations made at regular intervals. A percentage was then calculated based on 20 observations. Substrate was classified according to a modified Wentworth scale (Table 2.1). Subsurface samples were taken by driving a 7.6cm diameter polycarbonate core with beveled wall edges (wall thickness of 3mm) into the streambed. One core was taken from each quadrat along with five core penetration measurements (Figure 2.5). Core substrate was visually assessed for particle size using the modified Wentworth scale. An additional five penetration measurements were taken with a 5.0mm diameter rod and flathead. Habitat types were divided into four qualitative categories: riffle, run, pool, and glide.

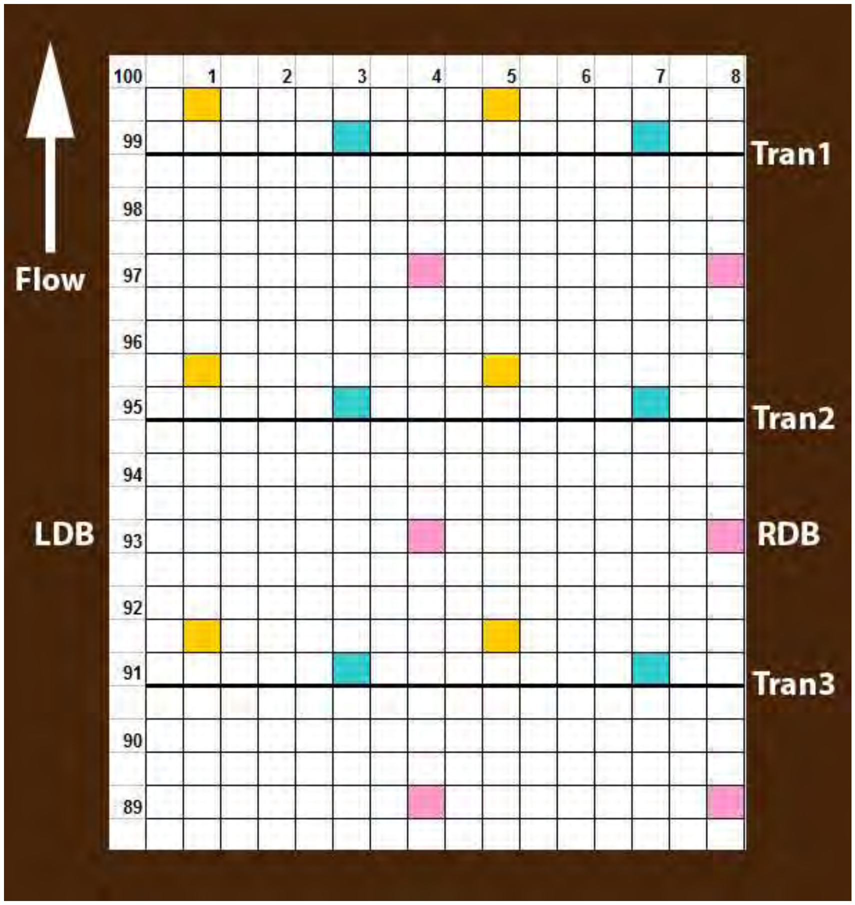

Figure 2.3 *– Sampling grid with three random starts (orange, blue, pink) and transect lines (Tran) positioned perpendicular to flow. Each square represents a single 0.25 m^2 sample. The left downstream bank (left bank when facing downstream) is labeled LDB and right downstream bank with RDB.*

Table 2.1 *- Modified Wentworth scale used to classify surface and subsurface substrate samples (Wentworth 1922).*

Size Ranges (mm)	Aggregate Class (modified Wentworth)
> 256	Boulder
64 – 256	Cobble
32 – 64	Large Gravel
2 – 32	Small Gravel
0.25 – 2	Sand
<0.25	Fines

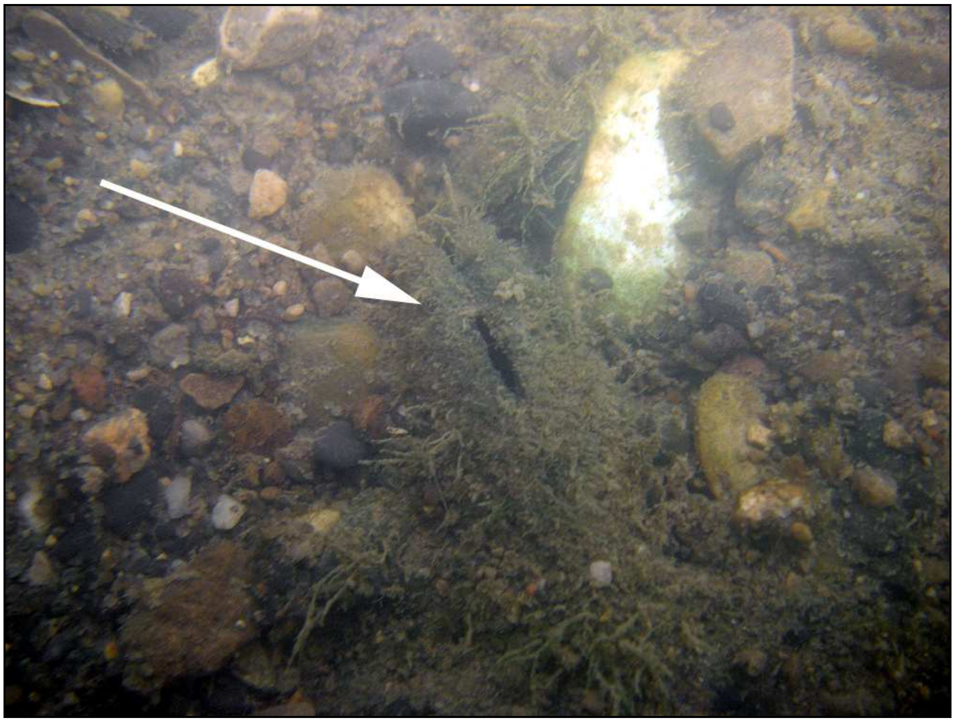

Figure 2.4 *– A Spike (<u>Elliptio dilatata</u>) burrowed in the substrate of the Blanchard River. With only a small margin of the shell exposed, this individual received a burrow ranking of "2."*

Figure 2.5 *– Driving a 7.6cm diameter core into the streambed of the Blanchard River (MBLAN1). Contents were then visually assessed for substrate composition.*

2.4 Data Analysis

2.41 Unionids

Mussel abundances, densities, and relative abundances were extrapolated for each individual site using the Mussel Estimation Program (v1.5.2, 2007) created by the U.S. Geological Survey. A website is available that hosts the software and several related scientific publications: http://www.lsc.usgs.gov/aeb/2068/. Reach abundances and densities were estimated by calculating the means of all three sites within a reach. Unionid abundance was defined as unionids per 100m of linear stream length while unionid density represented the number of individuals per m^2.

Unionid diversity at each site was described using simple species richness and the Shannon Diversity Index (H'). Shannon Diversity Index is calculated according to:

$$H' = -\sum_{i=1}^{S} p_i \ln p_i$$

Where p_i represents the importance value for species *i*. Shannon Diversity Index reach scores were calculated by pooling the abundances of all species across all sites within a particular reach.

Demographic data were analyzed to determine recent recruits, age class diversity, and male/female ratios. Recent recruits were defined for most species as individuals measuring less than 30mm except for Rayed Bean (*V. fabalis*), Slippershell (*Alasmidonta viridis*), and Lilliput (*Toxolasma parvus*). Recent recruits of these species were defined as individuals measuring less than 20mm. While this generalizes length-at-age variation among mussel species, it has been reported in the literature as an efficient and consistent field technique (Mohler et al. 2006; Smith and Crabtree 2010). Age class diversity was analyzed with shell length (x-axis) histograms and coefficient of variation using Grabarkiewicz and Crail (2008) as a guide.

The burrowing positions of unionids collected during survey activities were evaluated. Analysis was only performed on unionid species where 35 or more individuals were sampled. Recent recruits were analyzed separate from adults due to their tendency to be found after excavation.

2.42 Site Rapid Habitat Assessment

QHEI scores were compiled and means with standard deviations calculated for each reach (Ohio EPA 2006). Correlation and linear regression was used to examine the predictive power of QHEI scores for aspects of the mussel community.

2.43 Microhabitat

Reach means were generated for stream habitat variables, including riffles, runs, pools, glides, and depth. In addition, means were calculated for surface substrate textures, subsurface textures, and penetration depth. Data were explored using frequency distributions and summary statistics.

3. Results and Discussion

Approximately 800 person-hours were spent conducting field research between the months of July and November 2010. In total, three streams with six reaches containing a total 18 sites were studied. Each site was sampled using a systematic design with three random starts. Abiotic microhabitat variables were measured and unionid mussels sampled in 2,700 quadrats (450 quadrats per reach). Individual site coverage ranged from 3.2% (Beaver Creek) to 7% (Upper Swan Creek).

3.1 Site Rapid Habitat Assessment

QHEI assessments were conducted at all sites before quadrat sampling was initiated. Mean reach QHEI scores ranged from 65 (SD ±4.4) in the Middle Blanchard River to 44 (SD ±1.2) in Upper Swan Creek (Figure 3.1). In general, the Middle Blanchard scored higher than other reaches due to greater substrate diversity, the presence of well developed riffles, and overall greater habitat heterogeneity. Reaches that scored lower consisted of sites with fine substrates, homogenous channel structure (e.g. dominated by glide habitat), and indicators of instability.

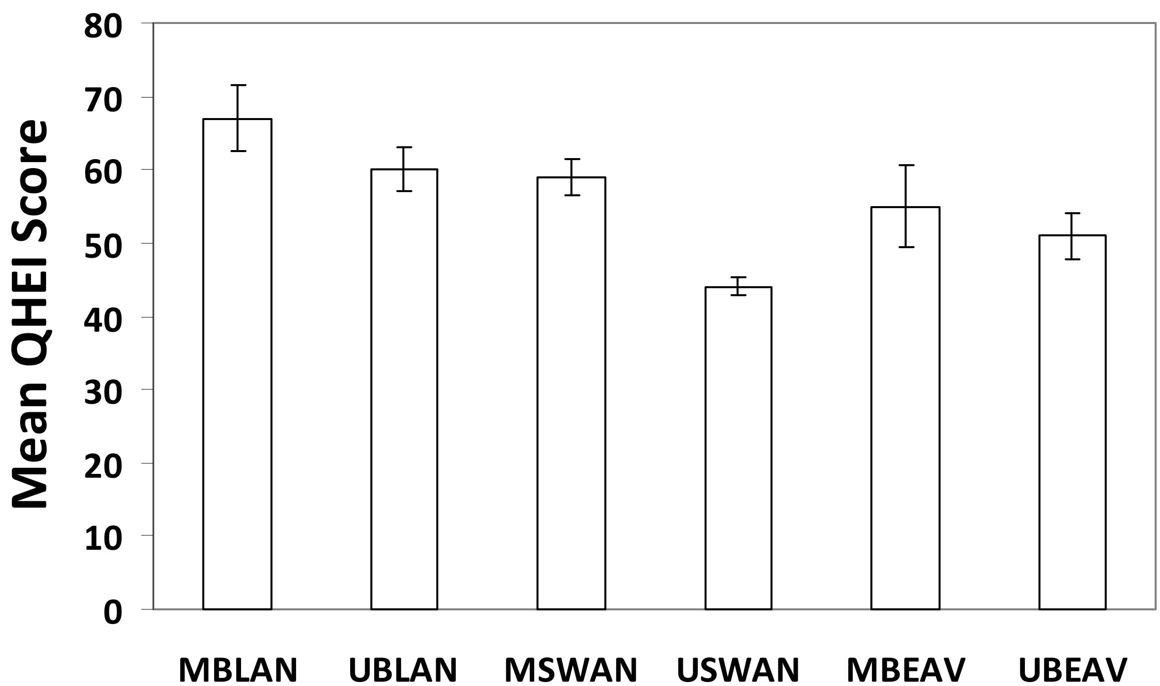

Figure 3.1 *– Mean QHEI scores (average of three sites per reach) for each sampling reach. Reach notation is as follows: MBLAN (Middle Blanchard River), UBLAN (Upper Blanchard River), MSWAN (Middle Swan Creek), USWAN (Upper Swan Creek), MBEAV (Middle Beaver Creek), and UBEAV (Upper Beaver Creek). Error bars are one sample standard deviation.*

QHEI has been positively correlated with the biological integrity of fish communities throughout Ohio (Ohio EPA 1987). If habitat quality is a useful predictor of fish community integrity, it may also be a useful predictor of unionid species richness and density. Therefore, we examined the relationship between QHEI and mean unionid species richness, Shannon Diversity, and density. A 2nd order non-linear regression was performed on reach data to examine the usefulness of QHEI as a predictor of unionid species richness (Figure 3.2), pooled Shannon Diversity values (Figure 3.3), and unionid density (Figure 3.4).

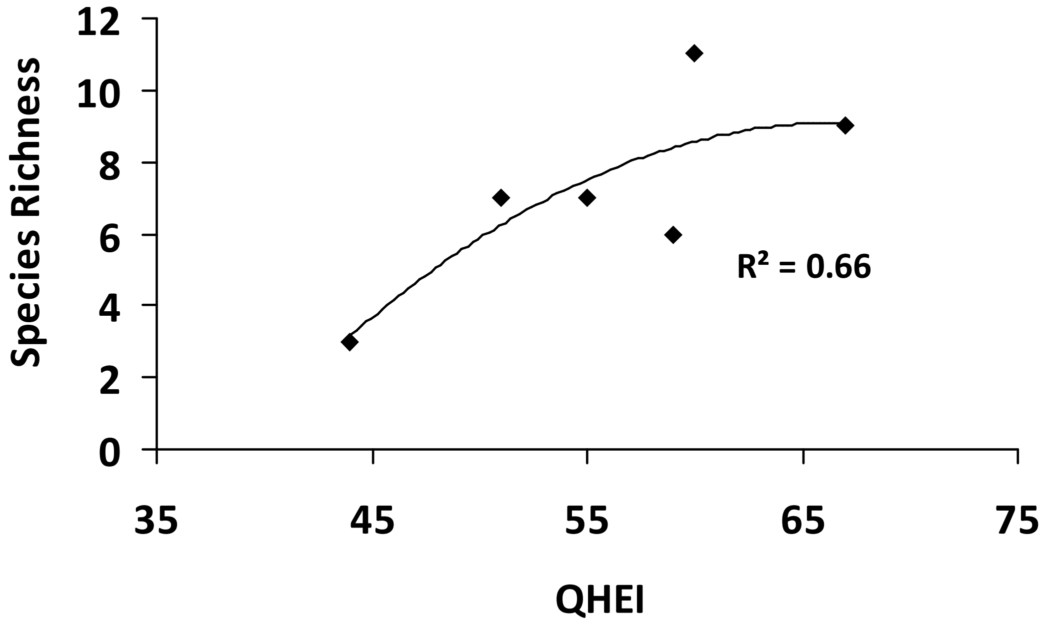

Figure 3.2 – *Non-linear regression of mean QHEI scores and mean species richness per reach. R^2 value estimates goodness-of-fit.*

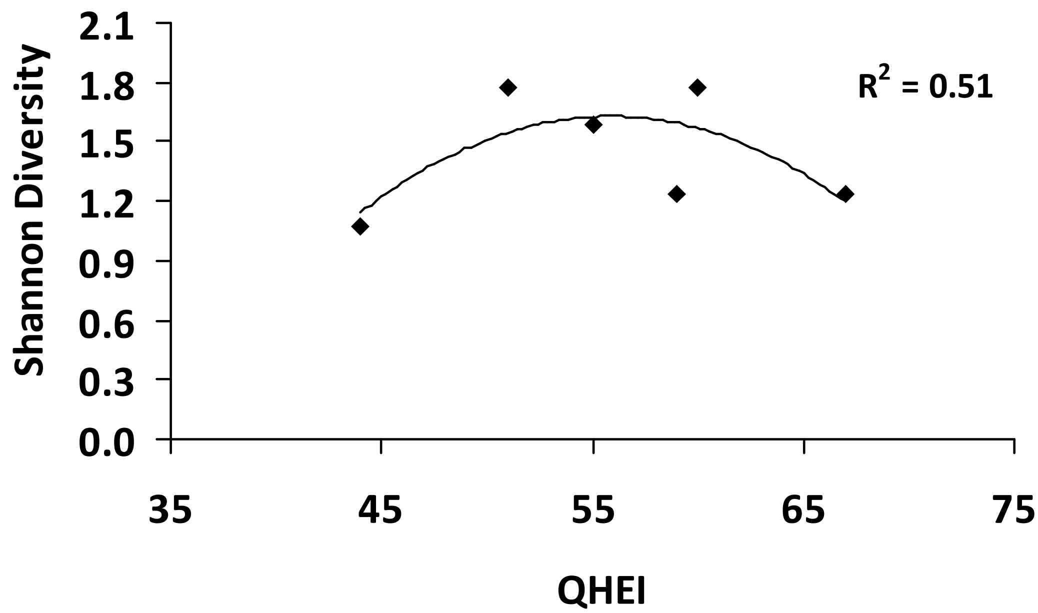

Figure 3.3 – *Non-linear regression of mean QHEI scores and pooled Shannon Diversity scores per reach. R^2 value estimates goodness-of-fit.*

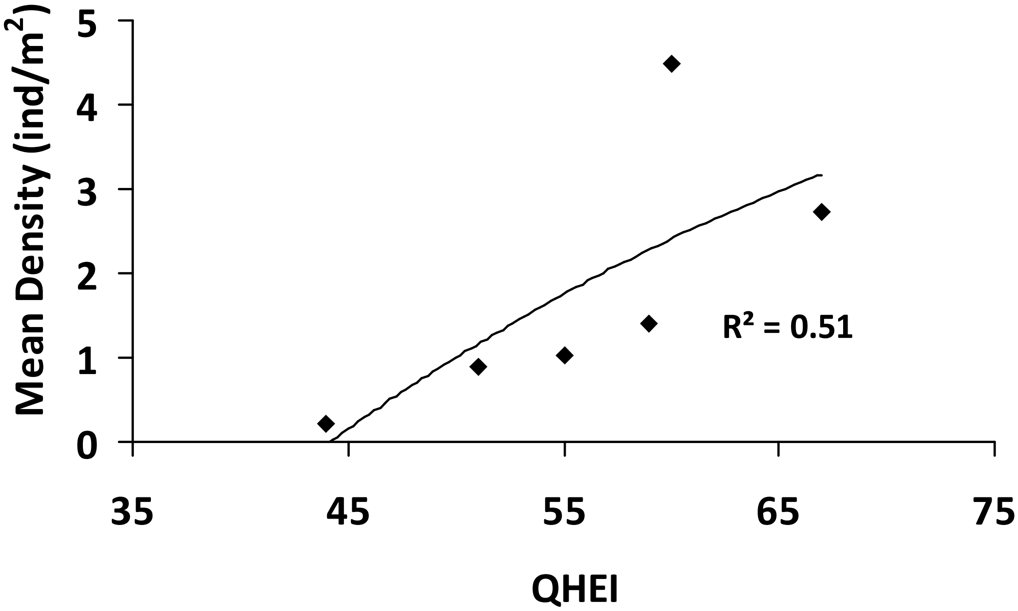

***Figure 3.4** – Non-linear regression of mean QHEI scores and mean density per reach. R^2 value estimates goodness-of-fit.*

Although our study possessed a limited number of data points, the initial results suggest a relationship between QHEI scores and unionid richness ($R^2 = 0.66$), Shannon Diversity ($R^2 = 0.51$), as well as unionid density ($R^2 = 0.51$). Although more samples are needed from Ohio creeks and rivers to determine the predictive ability of QHEI, our preliminary results seem to make intuitive sense. A "humped" shaped curve may result from the combination of two factors: the impact of habitat quality on unionid mussels and QHEI scoring methodology. When QHEI scores are low (e.g. Upper Swan Creek), habitat is limited for unionid mussels and fishes; consequently unionid diversity and density are low. As QHEI scores increase, habitat suitability for fishes and mussels also increases - resulting in increased unionid diversity and density. However, streams that score highest may possess characteristics less suitable for mussels, such as large substrates and high gradients. These sites may be most suitable for fish communities but perhaps not for unionid mussels. Some of the highest quality mussel beds left in the Maumee watershed are found in low-gradient, small gravel dominated creeks with well-developed structural habitat (riffles and pools). Many of these sites would likely receive a QHEI score in the range of 55 – 65 – much like the Upper Blanchard reach during this study.

3.2 Unionid Community

A total of 22 live species and 1,197 live individuals were sampled at all sites combined. Estimated mean reach abundance ranged from 3,267 unionids (per 100m) in the Middle Blanchard River to 137 unionids (per 100m) in Upper Swan Creek. Estimated mean reach densities varied from 4.48 unionids/m^2 in the Upper Blanchard River to 0.22 unionids/m^2 in Upper Swan Creek. Pooled reach Shannon Diversity scores were highest in the Upper Blanchard River at 1.77 and lowest in Upper Swan Creek at 1.07. Calculating uncertainty for reach means is problematic without making assumptions regarding habitat conditions and mussel distributions through each 100m site. However, 90% confidence levels (CL) were calculated for all site abundances and densities (e.g., Figure 3.5). The magnitude of these confidence levels is the result of several factors: site unionid densities, the patchy distribution of mussels at multiple spatial scales, and site coverage (area sampled vs. total sample-able area). The number of samples required to generate more accurate estimates of low density unionid populations may be quite high and can be cost prohibitive (Strayer and Smith 2003).

Several state listed species were found live during this study, including the Ohio species of concern Kidneyshell (*Ptychobranchus fasciolaris*), Creek Heelsplitter (*Lasmigona compressa*), Deertoe (*Truncilla truncata*), and Round Pigtoe (*Pleurobema sintoxia*). In addition, State endangered and federal candidate Rayed Bean (*V. fabalis*) were found in the Upper Blanchard River and Middle Swan Creek. Within both of these reaches, *V. fabalis* was present at each site – suggesting that it is well distributed throughout the Upper Blanchard and Middle Swan Creek.

3.21 Blanchard River

Our Blanchard River field sampling documented a total of 17 live species and 813 live individuals. Mean reach unionid abundance estimates (unionids per 100m) were 3,627 unionids in the Middle Blanchard and 3,275 in the Upper Blanchard. Mean reach densities (individuals/m^2) were 2.74 in the Middle Blanchard and 4.48 in the Upper Blanchard. Site abundances and estimates were also calculated with 90% CL and are presented in Figure 3.5. Because surveys designed to estimate unionid population sizes have not been published for Ohio streams, these data are difficult to compare with nearby streams. However, all six sites sampled within the Blanchard River supported higher population sizes and densities compared to Swan Creek and Beaver Creek.

The Middle Blanchard River was found to support a total of 12 live species, with Shannon Diversity scores ranging from 0.94 to 1.49 and a pooled reach score of 1.24. The most abundant species in the Middle Blanchard were Spike (*Elliptio dilatata*) (66.3%), Fatmucket (*Lampsilis siliquoidea*) (9.7%), Kidneyshell (*P. fasciolaris*) (8.8%), Creeper (*Strophitus undulatus*) (5.7%), and Fragile Papershell (*Leptodea fragilis*) (4.7%) (Table 3.1). Recent recruits were documented for Spike (*E. dilatata*) and Rainbow (*Villosa iris*) (Table 3.2). In addition, Flutedshell (*L. costata*), Fatmucket (*L. siliquoidea*), Fragile Papershell (*L. fragilis*), and Creeper (*S. undulatus*) did exhibit some age class diversity ($C_V \geq 0.15$) – while Spike (*E. dilatata*) and Kidneyshell (*P. fasciolaris*) exhibited a considerable amount of age class diversity ($C_V \geq 0.25$). Histograms are helpful to illustrate the diversity of shell lengths found for these two species (Figures 3.6 and 3.7). The species found as dead shell only included Slippershell (*A. viridis*), Threeridge (*Amblema plicata*), Wavyrayed Lampmussel *(Lampsilis fasciola*), and Rayed Bean (*V. fabalis*).

While not exceptional, the Middle Blanchard does support a relatively diverse and dense assemblage of mussels considering its size and regional biogeography. Age class diversity and recruitment were documented for several species, including Ohio species of concern Kidneyshell (*P. fasciolaris*) (Table 3.2; Figures 3.7). In addition to our results, a recent study conducted in 2009 documented a total of 17 live unionid species in the vicinity of Findlay (Hoggarth and Burgess 2009). The survey area of this study was just west of our lowest site (MBLAN1) downstream through the City of Findlay and west approximately 8.0 km. Interestingly, just four live Spike (*E. dilatata*) were reported by Hoggarth and Burgess (2009) after searching six reaches. Spike was by far the most abundant species during our study, accounting for 66.3% of all mussels sampled. Densities were as high as 16 per $0.25m^2$ (potentially up to 64 per m^2) in the gravelly riffles of MBLAN3 (Figure 3.8). Such an abrupt change in distribution and density may be a result of barriers to dispersal (impounded sections through Findlay), changes in host fish distributions, or water quality issues.

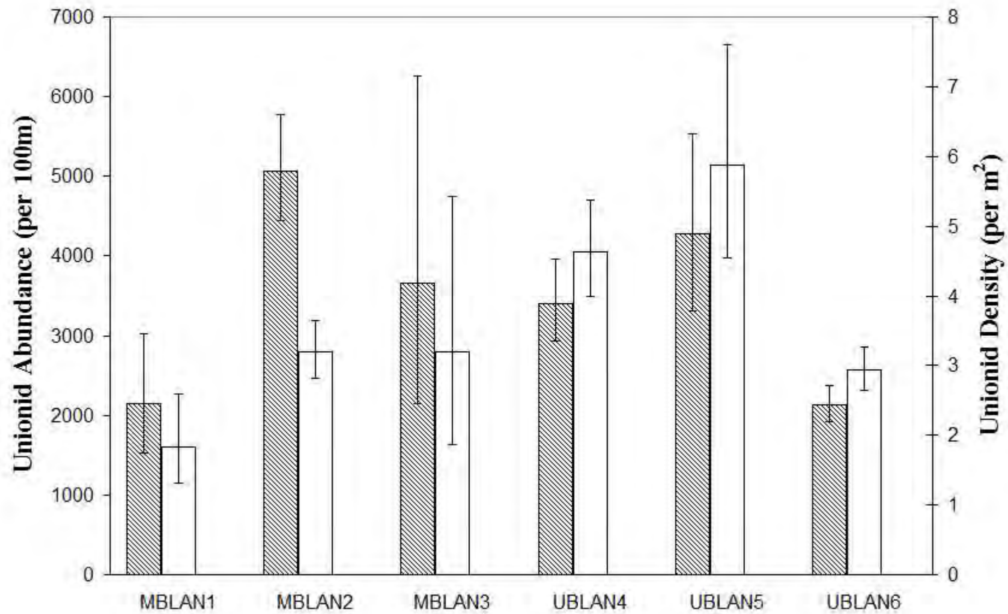

***Figure 3.5** – Unionid abundance (per 100m) and density (per m^2) estimates for three Middle Blanchard River (MBLAN) sites and three Upper Blanchard River (UBLAN) sites, Hancock County and Hardin County, OH. Hatched bars represent abundance and white bars density. Error bars indicate 90% confidence levels.*

***Table 3.1** – Mean unionid abundances (per 100m) and densities (individuals/m^2) for the middle reach of the Blanchard River, Hancock County, OH (based on the average of three 100m sites per 1,500m reach).*

Common Name	Scientific Name	Mean Abundance (per 100m)	Mean Density (per m^2)	Relative Abundance (%)	Site Occurrence
Cylindrical Papershell	*Anodontoides ferussacianus*	10	0.01	0.3	MBLAN3
Spike	*Elliptio dilatata*	2403	1.83	66.3	ALL
Wabash Pigtoe	*Fusconaia flava*	14	0.01	0.4	MBLAN2
Fatmucket	*Lampsilis siliquoidea*	353	0.27	9.7	ALL
White Heelsplitter	*Lasmigona complanata*	34	0.03	0.9	MBLAN1/2
Creek Heelsplitter	*Lasmigona compressa*	14	0.01	0.4	MBLAN2
Flutedshell	*Lasmigona costata*	45	0.04	1.2	ALL
Fragile Papershell	*Leptodea fragilis*	172	0.12	4.7	ALL
Kidneyshell	*Ptychobranchus fasciolaris*	319	0.24	8.8	ALL
Giant Floater	*Pyganodon grandis*	24	0.02	0.7	MBLAN1/2
Creeper	*Strophitus undulatus*	208	0.16	5.7	ALL
Rainbow	*Villosa iris*	31	0.03	0.9	MBLAN1/3
	All Unionids	3627	2.74		

***Table 3.2** – Shell length data for unionid species found in the middle reach of the Blanchard River. Higher coefficients of variation (C_v) indicate greater variation in shell lengths relative to the mean. Individuals identified as "recent recruits" measured less than 30mm on the x-axis (≤ 20mm for Slippershell, Rayed Bean, and Lilliput).*

Common Name	Scientific Name	Min Length (mm)	Max Length (mm)	Mean Length (mm)	C_v	Recent Recruits
Cylindrical Papershell	*Anodontoides ferussacianus*	52	52	52	N/A	0
Spike	*Elliptio dilatata*	21	122	77	0.25	4
Wabash Pigtoe	*Fusconaia flava*	73	73	73	N/A	0
Fatmucket	*Lampsilis siliquoidea*	39	125	91	0.19	0
White Heelsplitter	*Lasmigona complanata*	97	119	110	0.10	0
Creek Heelsplitter	*Lasmigona compressa*	87	87	87	N/A	0
Flutedshell	*Lasmigona costata*	81	129	110	0.19	0
Fragile Papershell	*Leptodea fragilis*	48	98	72	0.22	0
Kidneyshell	*Ptychobranchus fasciolaris*	36	101	75	0.31	0
Giant Floater	*Pyganodon grandis*	33	53	43	N/A	0
Creeper	*Strophitus undulatus*	50	82	61	0.15	0
Rainbow	*Villosa iris*	27	74	54	N/A	1

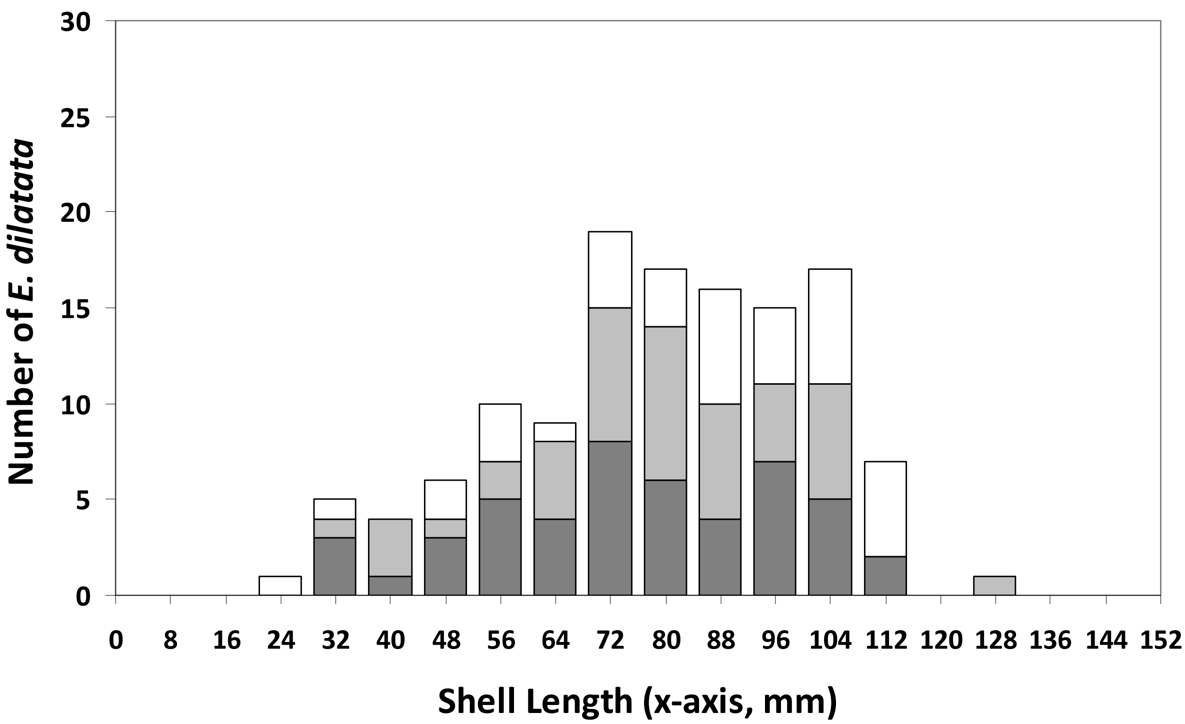

***Figure 3.6** – Shell length histogram of Spike (E. dilatata) sampled in the Middle Blanchard River. Sites are shaded as follows: MBLAN1 (☐), MBLAN2 (☐), and MBLAN3 (☐).*

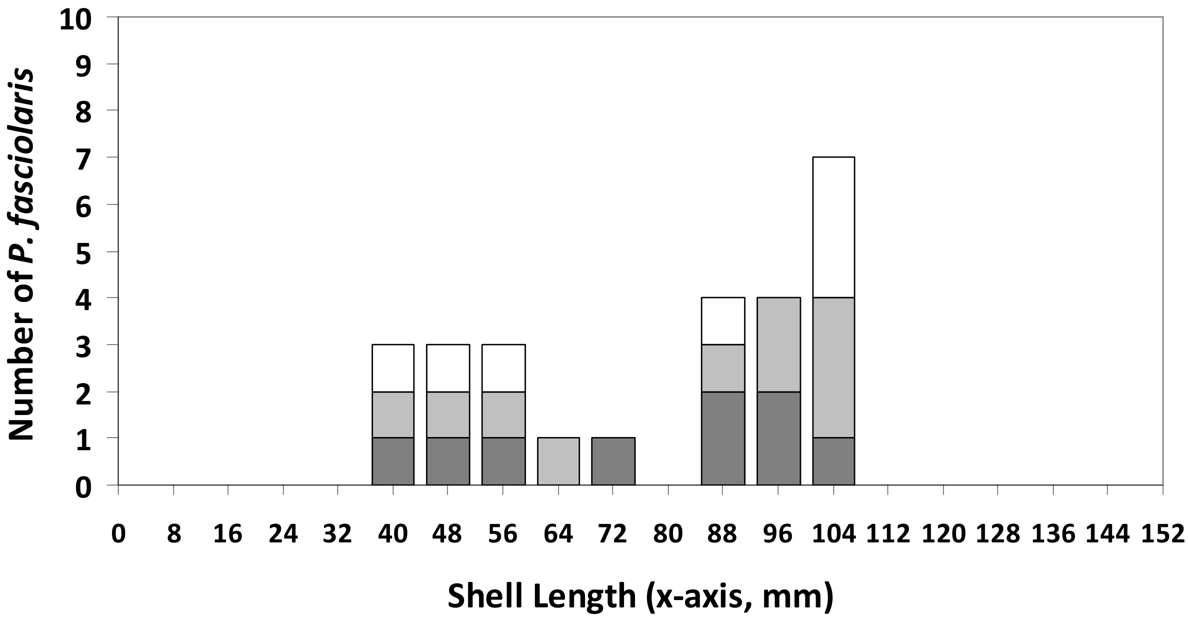

Figure 3.7 ***–*** *Shell length histogram of Ohio species of concern Kidneyshell (P. fasciolaris) sampled in the Middle Blanchard River. Sites are shaded as follows: MBLAN1 (☐), MBLAN2 (■), and MBLAN3 (■).*

The Upper Blanchard River (Figure 3.9) was found to support a total of 15 live species, with Shannon Diversity scores ranging from 1.52 to 1.84. The most abundant species were Spike (*E. dilatata*) (41.5%), Fatmucket (*L. siliquoidea*) (23.7%), Giant Floater (*P. grandis*) (9.9%), Wabash Pigtoe (*Fusconaia flava*) (7.3%), and Rayed Bean (*V. fabalis*) (6.5%) (Table 3.3). Recent recruits were documented for Slippershell (*A. viridis*), Cylindrical Papershell (*A. ferrusacianus*), Spike (*E. dilatata),* Wabash Pigtoe (*F. flava*), Fatmucket (*L. siliquoidea*), Giant Floater (*P. grandis*), and Rayed Bean (*V. fabalis*). In addition, all species except White Heelsplitter (*Lasmigona complanata*) exhibited age class diversity ($C_V \geq 0.20$) (Table 3.4). The presence of recent recruits, numerous young individuals, and a diversity of age classes suggests that the Upper Blanchard unionid community has been stable over the past two decades.
From 1994 to 1996, a survey was conducted of the Upper Blanchard by Hoggarth et al. (2000). Two sites were located near our Upper Blanchard reach, although the precise location of the sites was difficult to determine. Hoggarth et al. (2000) reported a large and diverse mussel community from these sites, including substantial numbers of Rayed Bean (*V. fabalis*). Although methods differ greatly between the two studies (quantitative quadrat-based survey vs. qualitative search), the five most abundant species reported by Hoggarth et al. (2000) were the same five species found during our study. Two species were found during the previous study that we did not encounter, however. These two species were the Ohio endangered Purple Lilliput (*Toxolasma lividus*) and Lilliput (*T. parvus*). It should be noted here that quadrat surveys may not be as efficient at detecting low density species ($\leq$ 0.01 per m^2) as qualitative surveys (Strayer et al. 1997; Vaughn et al. 1997; Obermeyer 1998; White and Gangloff 2008). We also randomized our sites to replicate our effort and therefore were not necessarily expending effort sampling the most suitable habitat. Therefore, both of the *Toxolasma* species reported by Hoggarth et al. (2000) may still occur in the Upper Blanchard despite not being found during our sampling efforts.

Our most productive site during 2010 was UBLAN5. It supported both the greatest density of unionids (5.88 unionid/m^2, 90% CL 4.55 – 7.61) and the most species (Figure 3.10). Two species found at MBLAN5 were not found elsewhere in the Blanchard River: the Slippershell (*A. viridis*) and Plain Pocketbook (*Lampsilis cardium*). Both individuals were quite small ($\leq$ 40 mm) and signaled that *A. viridis* and *L. cardium* had recently reproduced.

The Upper Blanchard River ecosystem is particularly valuable to Northwest Ohio due to its diverse and robust unionid population. It not only maintains many species that are declining statewide (e.g. *P. sintoxia*), but also one of the last remaining global populations of Rayed Bean (*V. fabalis*).

Figure 3.8 – *(Top) A young 39mm Kidneyshell (P. fasciolaris) collected at MBLAN2, 8/17/2010. (Right) Unionids found in a single 0.25m²quadrat at MBLAN3, 7/8/2010. (Photos: Jeff Grabarkiewicz)*

Figure 3.9 *– The Upper Blanchard River site UBLAN4 (left) and UBLAN5 (right), 8/20/2010, Hancock County, OH. (Photos: Jeff Grabarkiewicz)*

***Table 3.3** – Mean unionid abundances (per 100m) and densities (individuals/m^2) for the upper reach of the Blanchard River, Hancock County and Hardin County, OH (based on the average of three 100m sites per 1,500m reach).*

Common Name	Scientific Name	Mean Abundance (per 100m)	Mean Density (per m^2)	Relative Abundance (%)	Site Occurrence
Slippershell	*Alasmidonta viridis*	13	0.02	0.4	UBLAN5
Threeridge	*Amblema plicata*	46	0.06	1.4	UBLAN4/5
Cylindrical Papershell	*Anodontoides ferussacianus*	52	0.07	1.6	UBLAN4/5
Spike	*Elliptio dilatata*	1360	1.86	41.5	ALL
Wabash Pigtoe	*Fusconaia flava*	240	0.33	7.3	ALL
Plain Pocketbook	*Lampsilis cardium*	6	0.01	0.2	UBLAN5
Fatmucket	*Lampsilis siliquoidea*	777	1.06	23.7	ALL
White Heelsplitter	*Lasmigona complanata*	39	0.05	1.2	UBLAN4/5
Flutedshell	*Lasmigona costata*	64	0.09	2.0	UBLAN5/6
Round Pigtoe	*Pleurobema sintoxia*	39	0.05	1.2	ALL
Kidneyshell	*Ptychobranchus fasciolaris*	65	0.09	2.0	UBLAN4/5
Giant Floater	*Pyganodon grandis*	324	0.44	9.9	ALL
Creeper	*Strophitus undulatus*	7	0.01	0.2	UBLAN4
Rayed Bean	*Villosa fabalis*	212	0.29	6.5	ALL
Rainbow	*Villosa iris*	19	0.03	0.6	ALL
	All Unionids	3275	4.48		

***Table 3.4** – Shell length data for unionid species found in the upper reach of the Blanchard River. Higher coefficients of variation (C_v) indicate greater variation in shell lengths relative to the mean. Individuals identified as "recent recruits" measured less than 30mm on the x-axis ($\leq$ 20mm for Slippershell, Rayed Bean, and Lilliput).*

Common Name	Scientific Name	Min Length (mm)	Max Length (mm)	Mean Length (mm)	C_v	Recent Recruits
Slippershell	*Alasmidonta viridis*	16	18	17	N/A	2
Threeridge	*Amblema plicata*	32	121	74	0.40	0
Cylindrical Papershell	*Anodontoides ferussacianus*	18	72	51	0.31	1
Spike	*Elliptio dilatata*	13	106	82	0.23	5
Wabash Pigtoe	*Fusconaia flava*	10	101	59	0.28	1
Plain Pocketbook	*Lampsilis cardium*	35	35	35	N/A	0
Fatmucket	*Lampsilis siliquoidea*	17	115	90	0.20	1
White Heelsplitter	*Lasmigona complanata*	98	131	111	0.13	0
Flutedshell	*Lasmigona costata*	43	131	106	0.25	0
Round Pigtoe	*Pleurobema sintoxia*	40	100	69	0.33	0
Kidneyshell	*Ptychobranchus fasciolaris*	61	111	83	0.22	0
Giant Floater	*Pyganodon grandis*	23	119	88	0.27	1
Creeper	*Strophitus undulatus*	64	64	64	N/A	0
Rayed Bean	*Villosa fabalis*	12	29	21	0.24	8
Rainbow	*Villosa iris*	34	46	39	N/A	0

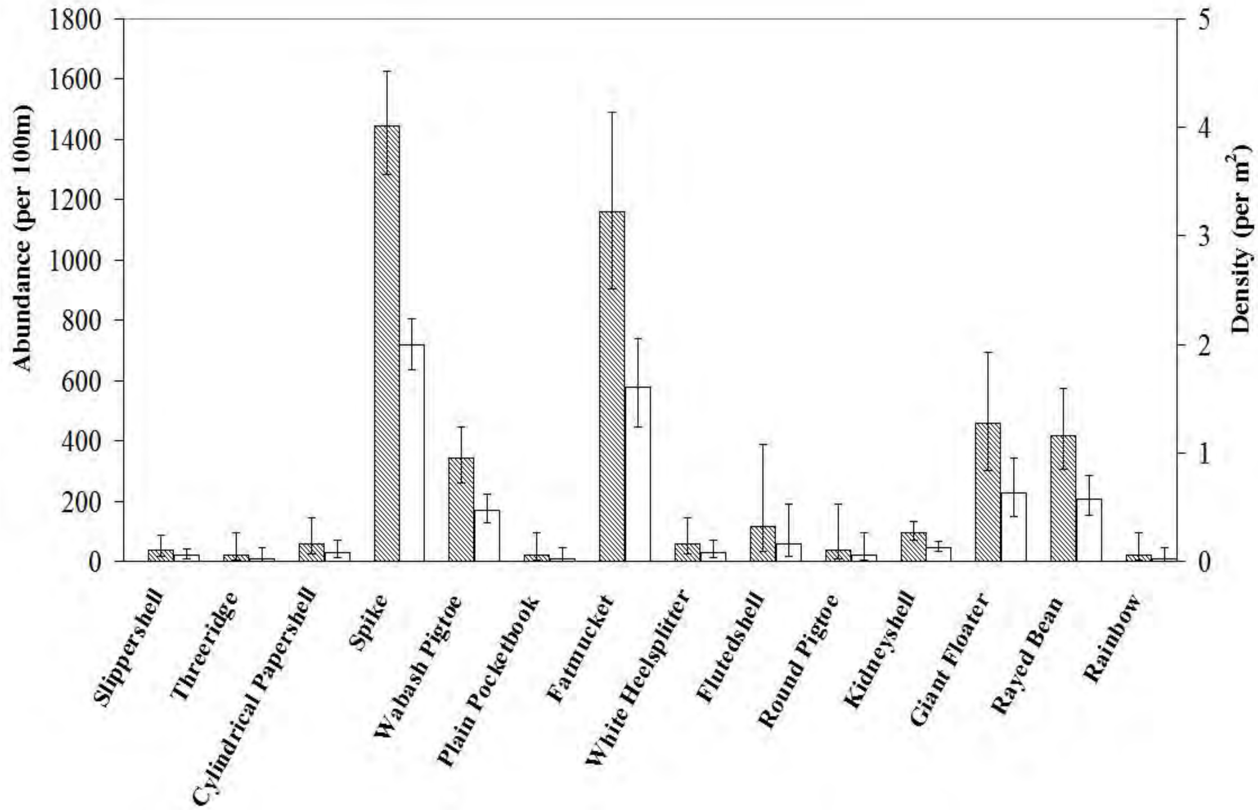

Figure 3.10 – *Species abundance (per 100m) and density (per m^2) estimates for UBLAN5, Hancock County, OH. Hatched bars represent abundance and white bars represent density. Error bars indicate 90% confidence levels.*

3.22 Swan Creek

Our Swan Creek field work documented a total of eight live species and 181 live individuals. Mean reach unionid abundance estimates (unionids per 100m) were 867 unionids in Middle Swan Creek and 137 in Upper Swan Creek. Mean reach densities (individuals/m^2) were 1.38 in Middle Swan Creek and 0.22 in Upper Swan Creek. Site abundances and estimates were also calculated with 90% CL and are presented in Figure 3.11. Overall, unionid diversity and density within Swan Creek was lower than the Blanchard River but similar to Beaver Creek.

Middle Swan Creek (Figure 3.12) was found to support a total of six live species, with Shannon Diversity scores ranging from 1.04 to 1.43. The most abundant species in Middle Swan Creek were Spike (*E. dilatata*) (60.9%), Fatmucket (*L. siliquoidea*) (11.8%), Rayed Bean (*V. fabalis*) (10.2%), Rainbow (*Villosa iris*) (8.9%), and Wabash Pigtoe (*F. flava*) (5.6%) (Table 3.5). Recent recruits were documented for Slippershell (*A. viridis*), Fatmucket (*L. siliquoidea*), and Rayed Bean (*V. fabalis*) (Table 3.6). Although we did not detect recent recruits for Spike (*E. dilatata*), Wabash Pigtoe (*F. flava*), and Rainbow (*V. iris*), each of these species did exhibit some age class diversity ($C_V \geq 0.15$). Several species were also found as dead shell only, including Threeridge (*Amblema plicata*), Cylindrical Papershell (*A. ferrusacianus*), Plain Pocketbook *(L. cardium*), Fragile Papershell (*L. fragilis*), and Pink Heelsplitter (*Potamilus alatus*).

Grabarkiewicz and Crail (2007) and Grabarkiewicz (2008) reported results of qualitative unionid surveys from Swan Creek conducted during 2006 to 2008. Five sites were located near or within our 1500m Middle Swan Creek sampling reach. Several species, including Flutedshell (*L. costata*), Pink Heelsplitter (*P. alatus*), Creeper (*S. undulatus*), and Deertoe (*T. truncata*), found during those surveys were not found during our study in 2010. However, all of the missing species sampled between 2006 and 2008 were at very low abundances (< 5 individuals per site). As previously stated in the discussion of the Upper Blanchard, qualitative searches are generally more efficient at locating species than quadrat-based, quantitative sampling methods. Considering these species were rare during 2006-2008, it is reasonable that our quadrat sampling did not detect them considering site coverage was generally less than 7%.

The Middle Swan Creek reach sampled during our study is the “jewel” of the system as described by Grabarkiewicz (2008). However, it should be noted that this study randomized sampling sites with the purpose of replicating sampling effort and collecting representative data. This randomization removed effort from some of the most optimal locations. Despite this, it also led us to a new high quality site (MSWAN2) where we found many Rayed Bean (*V. fabalis*).

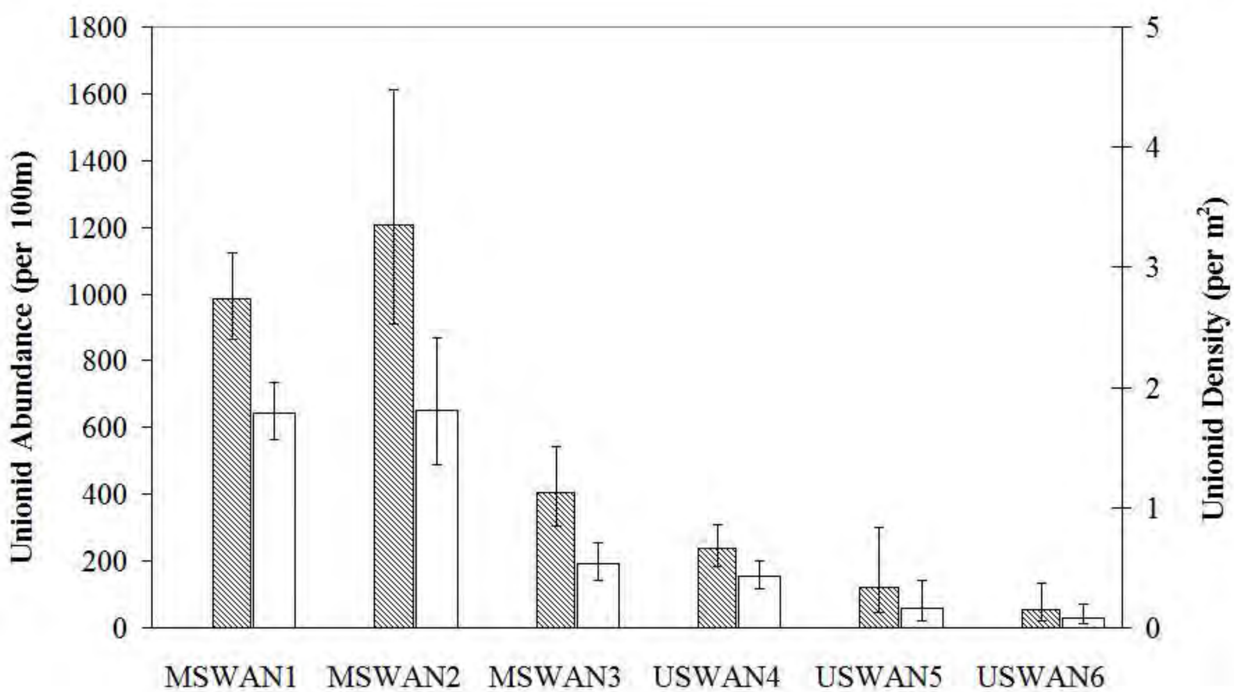

Figure 3.11 *- Unionid abundance (per 100m) and density (per m^2) estimates for three Middle Swan Creek (MSWAN) sites and three Upper Swan Creek (USWAN) sites, Lucas County, OH. Hatched bars represent abundance and white bars represent density. Error bars indicate 90% confidence levels.*

Table 3.5 *- Mean unionid abundances (per 100m) and densities (individuals/m²) for the middle reach of Swan Creek, Lucas County, OH (based on the average of three 100m sites per 1,500m reach).*

Common Name	Scientific Name	Mean Abundance (per 100m)	Mean Density (per m^2)	Relative Abundance (%)	Site Occurrence
Slippershell	*Alasmidonta viridis*	24	0.04	2.7	ALL
Spike	*Elliptio dilatata*	528	0.85	60.9	ALL
Wabash Pigtoe	*Fusconaia flava*	48	0.08	5.6	MSWAN1/2
Fatmucket	*Lampsilis siliquoidea*	102	0.15	11.8	ALL
Rayed Bean	*Villosa fabalis*	88	0.13	10.2	ALL
Rainbow	*Villosa iris*	77	0.12	8.9	ALL
	All Unionids	867	1.40		

Table 3.6 *- Shell length data for unionid species found in the middle reach of Swan Creek. Higher coefficients of variation (C_v) values indicate greater variation in shell lengths relative to the mean. Individuals identified as "recent recruits" measured less than 30mm on the x-axis ($\leq$ 20mm for Slippershell, Rayed Bean, and Lilliput).*

Common Name	Scientific Name	Min Length (mm)	Max Length (mm)	Mean Length (mm)	C_v	Recent Recruits
Slippershell	*Alasmidonta viridis*	14	29	23	0.28	1
Spike	*Elliptio dilatata*	40	105	65	0.20	0
Wabash Pigtoe	*Fusconaia flava*	46	67	54	0.20	0
Fatmucket	*Lampsilis siliquoidea*	15	85	56	0.45	6
Rayed Bean	*Villosa fabalis*	20	33	25	0.14	1
Rainbow	*Villosa iris*	36	63	48	0.17	0

Upper Swan Creek was found to support a total of three live species, with Shannon Diversity scores ranging from 0.64 to 1.02. The species encountered were Fatmucket (*L. siliquoidea*) (38.6%), White Heelsplitter (*L. complanata*) (31.6%), and Giant Floater (*P. grandis*) (29.9%) (Table 3.7). Recent recruits were not documented for any of the three species and each species exhibited low age class diversity ($C_v \leq 0.13$) (Table 3.8). Several species were present as shell only, including Cylindrical Papershell (*A. ferrusacianus*), Threeridge (*A. plicata*), Wabash Pigtoe (*F. flava*), and Creeper (*S. undulatus*).

Upper Swan Creek supported the fewest mussels and least number of species. These results concur with those reported by Grabarkiewicz (2008) for sites near our sampling reach. Sampling activity was difficult throughout Upper Swan Creek due to large amounts of woody debris – the worst of which was found at USWAN6 (Figure 3.13). While our reach was located within Oak Openings Metropark, QHEI scores were consistently poor at all three sites.

Indicators of channel instability were widespread, with many areas of scour down to hardpan, abundant woody debris, and bank erosion.

Table 3.7 *- Mean unionid abundances (per 100m) and densities (individuals/m^2) for the upper reach of Swan Creek, Lucas County, OH (based on the average of three 100m sites per 1,500m reach).*

Common Name	Scientific Name	Mean Abundance (per 100m)	Mean Density (per m2)	Relative Abundance (%)	Site Occurrence
Fatmucket	*Lampsilis siliquoidea*	53	0.06	38.6	USWAN1/2
White Heelsplitter	*Lasmigona complanata*	43	0.10	31.6	ALL
Giant Floater	*Pyganodon grandis*	41	0.06	29.9	ALL
	All Unionids	137	0.22		

Table 3.8 *- Shell length data for unionid species found in the upper reach of Swan Creek. Higher coefficients of variation (C_v) indicate greater variation in shell lengths relative to the mean. Individuals identified as "recent recruits" measured less than 30mm on the x-axis ($\leq$ 20mm for Slippershell, Rayed Bean, and Lilliput).*

Common Name	Scientific Name	Min Length (mm)	Max Length (mm)	Mean Length (mm)	C_v	Recent Recruits
Fatmucket	*Lampsilis siliquoidea*	90	112	100	0.06	0
White Heelsplitter	*Lasmigona complanata*	67	95	79	0.12	0
Giant Floater	*Pyganodon grandis*	70	86	77	0.08	0

Figure 3.12 – *Middle Swan Creek (MSWAN2), 9/12/2010, Lucas County, OH. (Photo: Jeff Grabarkiewicz)*

Figure 3.13 – *Upper Swan Creek (USWAN6), 10/15/2010, Lucas County, OH. (Photo: Jeff Grabarkiewicz)*

3.23 Beaver Creek
Our Beaver Creek field sampling documented a total of 10 live species and 205 live individuals. Mean reach unionid abundance estimates (unionids per 100m) were 907 unionids in Middle Beaver Creek and 769 in Upper Beaver Creek. Mean reach densities (individuals/m^2) were 1.03 in Middle Beaver and 0.89 in Upper Beaver Creek. Site abundances and estimates were also calculated with 90% CL and are presented in Figure 3.14. Overall, unionid diversity and density within Beaver Creek was lower than the Blanchard River but similar to Swan Creek. We also had little distance between our middle and upper reach due to limited creek access.

Middle Beaver Creek was found to support a total of nine live species, with Shannon Diversity scores ranging from 1.24 to 1.50. The most abundant species were Wabash Pigtoe (*F. flava*) (44.9%), Fragile Papershell (*L. fragilis*) (17.8%), Pink Heelsplitter (*P. alatus*) (14.4%), White Heelplitter (*L. complanata*) (7.2%), and Mapleleaf (*Quadrula quadrula*) (4.6%) (Table 3.9). Recent recruits were documented for Wabash Pigtoe (*F. flava*) and Pimpleback (*Quadrula pustulosa*) (Table 3.10). Considerable age class diversity was exhibited by Fragile Papershell (*L. fragilis*) and Pink Heelsplitter (*P. alatus*) ($C_V \geq 0.15$).

To our knowledge, the mussels of Beaver Creek have not been studied prior to our field sampling. Middle Beaver Creek was found to support a medium to low density mussel assemblage noticeably different in composition than Swan Creek or the Blanchard River. Many of the species found in Middle Beaver Creek, such as Fragile Papershell (*L. fragilis*), Pink Heelsplitter (*P. alatus*), Pimpleback (*Q. pustulosa*), and Mapleleaf (*Q. quadrula*), are commonly associated with "big river" or lake habitats. Such species are abundant in the Maumee River just downstream of our Beaver Creek sites (Grabarkiewicz, unpublished data). Due to the proximity of our sites to the Maumee River (~2.3 RKM), the current Maumee fauna probably has a strong influence on the species assemblages of our Beaver Creek sampling sites.

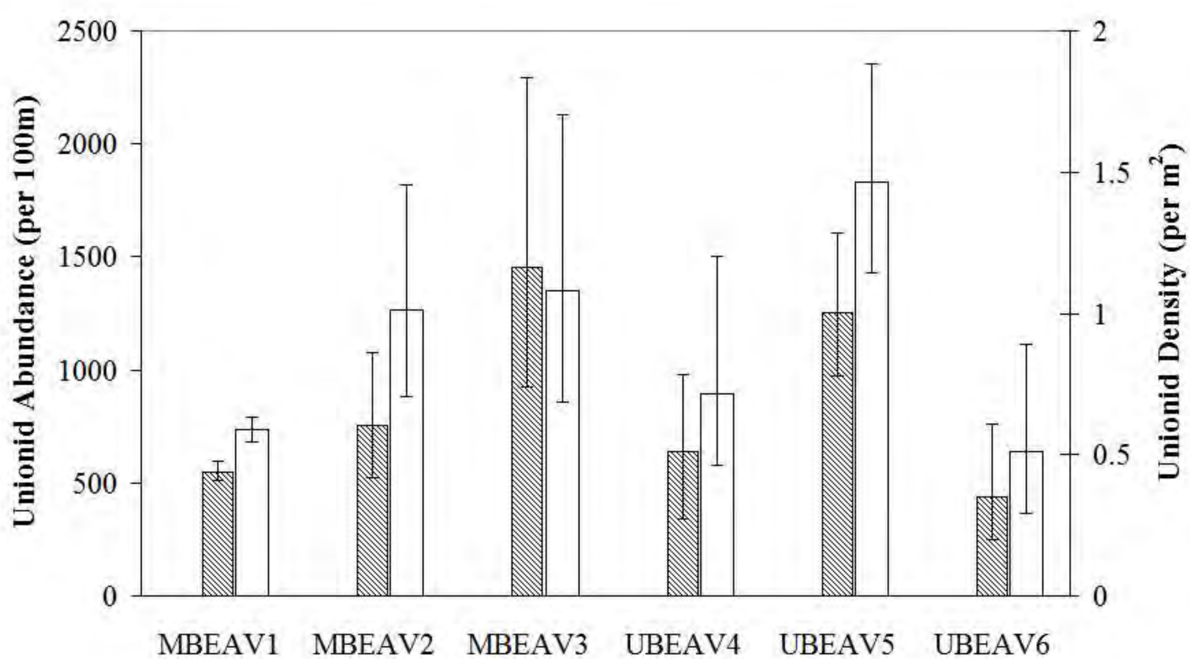

Figure 3.14 *- Unionid abundance (per 100m) and density (per m^2) estimates for three Middle Beaver Creek (MBEAV) sites and three Upper Beaver Creek (UBEAV) sites, Wood County,*

OH. Hatched bars represent abundance and white bars represent density. Error bars indicate 90% confidence levels.

Table 3.9 *- Mean unionid abundances (per 100m) and densities (individuals/m^2) for the middle reach of Beaver Creek, Wood County, OH (based on the average of three 100m sites per 1,500m reach).*

Common Name	Scientific Name	Mean Abundance (per 100m)	Mean Density (per m2)	Relative Abundance (%)	Site Occurrence
Wabash Pigtoe	*Fusconaia flava*	407	0.54	44.9	ALL
White Heelsplitter	*Lasmigona complanata*	66	0.05	7.2	MBEAV2/3
Creek Heelsplitter	*Lasmigona compressa*	12	0.01	1.3	MBEAV3
Fragile Papershell	*Leptodea fragilis*	161	0.18	17.8	ALL
Pink Heelsplitter	*Potamilus alatus*	131	0.12	14.4	ALL
Giant Floater	*Pyganodon grandis*	38	0.04	4.2	MBEAV1/2
Pimpleback	*Quadrula pustulosa*	39	0.04	4.3	MBEAV2/3
Mapleleaf	*Quadrula quadrula*	42	0.04	4.6	MBEAV2/3
Lilliput	*Toxolasma parvus*	12	0.01	1.3	MBEAV3
	All Unionids	907	1.03		

Table 3.10 *– Shell length data for unionid species found in the middle reach of Beaver Creek. Higher coefficients of variation (C_v) values indicate greater variation in shell lengths relative to the mean. Individuals identified as "recent recruits" measured less than 30mm on the x-axis (≤ 20mm for Slippershell, Rayed Bean, and Lilliput).*

Common Name	Scientific Name	Min Length (mm)	Max Length (mm)	Mean Length (mm)	C_v	Recent Recruits
Wabash Pigtoe	*Fusconaia flava*	24	96	66	0.28	2
White Heelsplitter	*Lasmigona complanata*	90	108	99	0.06	0
Creek Heelsplitter	*Lasmigona compressa*	93	93	93	N/A	0
Fragile Papershell	*Leptodea fragilis*	31	101	68	0.28	0
Pink Heelsplitter	*Potamilus alatus*	72	140	100	0.23	0
Giant Floater	*Pyganodon grandis*	67	85	76	0.11	0
Pimpleback	*Quadrula pustulosa*	15	67	51	N/A	1
Mapleleaf	*Quadrula quadrula*	74	114	91	N/A	0
Lilliput	*Toxolasma parvus*	28	28	28	N/A	0

Upper Beaver Creek was found to support a total of nine live species, with Shannon Diversity scores ranging from 1.51 to 1.68. The most abundant species were Wabash Pigtoe (*F. flava*) (40.8%), Fragile Papershell (*L. fragilis*) (23.0%), White Heelplitter (*L. complanata*) (10.7%), Pink Heelsplitter (*P. alatus*) (7.7%), and Giant Floater (*P. grandis*) (5.2%) (Table 3.11). Recent recruits were documented for Ohio species of concern Deertoe (*T. truncata*) (Table 3.12). Some diversity of age classes was documented for Wabash Pigtoe (*F. flava*), Fatmucket (*L. siliquoidea*), White Heelsplitter (*Lasmigona complanata*), and Fragile Papershell (*Leptodea* *fragilis*) ($C_V \geq 0.15$).

Table 3.11 *- Mean unionid abundances (per 100m) and densities (individuals/m²) for the upper reach of Beaver Creek, Wood County, OH (based on the average of three 100m sites per 1,500m reach).*

Common Name	Scientific Name	Mean Abundance (per 100m)	Mean Density (per m²)	Relative Abundance (%)	Site Occurrence
Wabash Pigtoe	*Fusconaia flava*	314	0.36	40.8	ALL
Fatmucket	*Lampsilis siliquoidea*	38	0.04	4.9	UBEAV4/5
White Heelsplitter	*Lasmigona complanata*	82	0.10	10.7	ALL
Fragile Papershell	*Leptodea fragilis*	177	0.21	23.0	ALL
Pink Heelsplitter	*Potamilus alatus*	59	0.08	7.7	UBEAV4/5
Giant Floater	*Pyganodon grandis*	40	0.02	5.2	UBEAV4/6
Pimpleback	*Quadrula pustulosa*	15	0.02	2.0	UBEAV5
Mapleleaf	*Quadrula quadrula*	23	0.03	3.0	UBEAV5
Deertoe	*Truncilla truncata*	21	0.03	2.7	UBEAV4/5
	All Unionids	769	0.89		

Table 3.12 *– Shell length data for unionid species found in the upper reach of Beaver Creek. Higher coefficients of variation (C_v) indicate greater variation in shell lengths relative to the mean. Individuals identified as "recent recruits" measured less than 30mm on the x-axis (≤ 20mm for Slippershell, Rayed Bean, and Lilliput).*

Common Name	Scientific Name	Min Length (mm)	Max Length (mm)	Mean Length (mm)	Cv	Recent Recruits
Wabash Pigtoe	*Fusconaia flava*	36	99	69	0.24	0
Plain Pocketbook	*Lampsilis cardium*	110	110	110	-	0
Fatmucket	*Lampsilis siliquoidea*	78	92	78	0.18	0
White Heelsplitter	*Lasmigona complanata*	89	145	112	0.19	0
Fragile Papershell	*Leptodea fragilis*	56	114	91	0.17	0
Pink Heelsplitter	*Potamilus alatus*	112	141	124	0.11	0
Giant Floater	*Pyganodon grandis*	70	74	72	-	0
Pimpleback	*Quadrula pustulosa*	46	61	54	-	0
Mapleleaf	*Quadrula quadrula*	66	73	70	-	0
Deertoe	*Truncilla truncata*	29	29	29	-	1

3.24 Rayed Bean

Rayed Bean (*V. fabalis*) was well distributed in both the Upper Blanchard River and Middle Swan Creek. We did not find live Rayed Bean (*V. fabalis*) in the other four study reaches, although subfossil shell was present in the Middle Blanchard River. Within the Upper

Blanchard, Rayed Bean (*V. fabalis*) was the fifth most abundant species (6.5%), while in Middle Swan Creek it was the third most abundant species (10.2%). Female to male ratios in the Upper Blanchard were exactly 1:1 (n=30), while ratios in Middle Swan Creek were 1:2.75 (n=15). Inequities in the numbers of female to male in Middle Swan Creek may be due to the small sample size. Recruitment and considerable age class diversity were documented for both the Upper Blanchard River (Figure 3.15) and Middle Swan Creek (Figure 3.16). Approximately 24.2% of the total Rayed Bean (*V. fabalis*) sampled in the Upper Blanchard were less than 20mm and deemed "recent recruits." This percentage is nearly identical to that reported by Smith and Crabtree (2010) during recent quantitative surveys of French Creek, PA (24.1%). French Creek is nationally recognized as one of the most ecological intact aquatic ecosystems in the Upper Ohio River drainage.

From 2006 to 2008, Grabarkiewicz (2008) sampled sites near the Middle Swan Creek reach. The position of Middle Swan Creek was selected to reduce the probability of overlap with sites reported by Grabarkiewicz (2008). This removed the densest known populations of *V. fabalis* from our study area. Therefore, results from our 2010 Middle Swan Creek sampling should be interpreted with care when comparing them to Grabarkiewicz (2008).

During our 2009 Blanchard River reconnaissance, we documented live *V. fabalis* as far south as State Route 81 (RKM 151.8), approximately 10.9 RKM upstream of our Upper Blanchard sampling reach. To our knowledge, this is the most upstream known record of live *V. fabalis* in the Blanchard River. Hoggarth et al. (2000) recorded Rayed Bean (*V. fabalis*) as far north as County Road 26 (RKM 118.7). If *V. fabalis* still persists at this site, the distance between these two populations is approximately 33.1 RKM. This is a considerable stretch, with several reaches of suitable habitat and extant populations in between. Therefore, the Upper Blanchard will require protection if it is to play a role in the recovery of the Rayed Bean (*V. fabalis*).

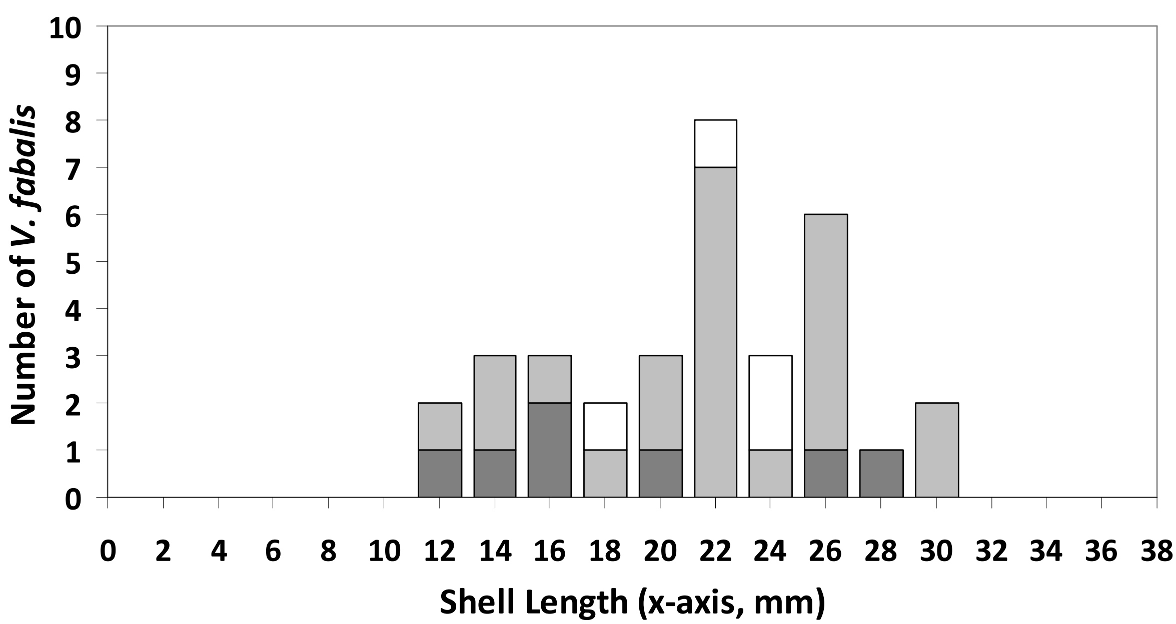

Figure 3.15 *– Shell length histogram of Rayed Bean (V. fabalis) sampled in the Upper Blanchard River. Sites are shaded as follows: UBLAN4 (☐), UBLAN5 (☐), and UBLAN6 (☐).*

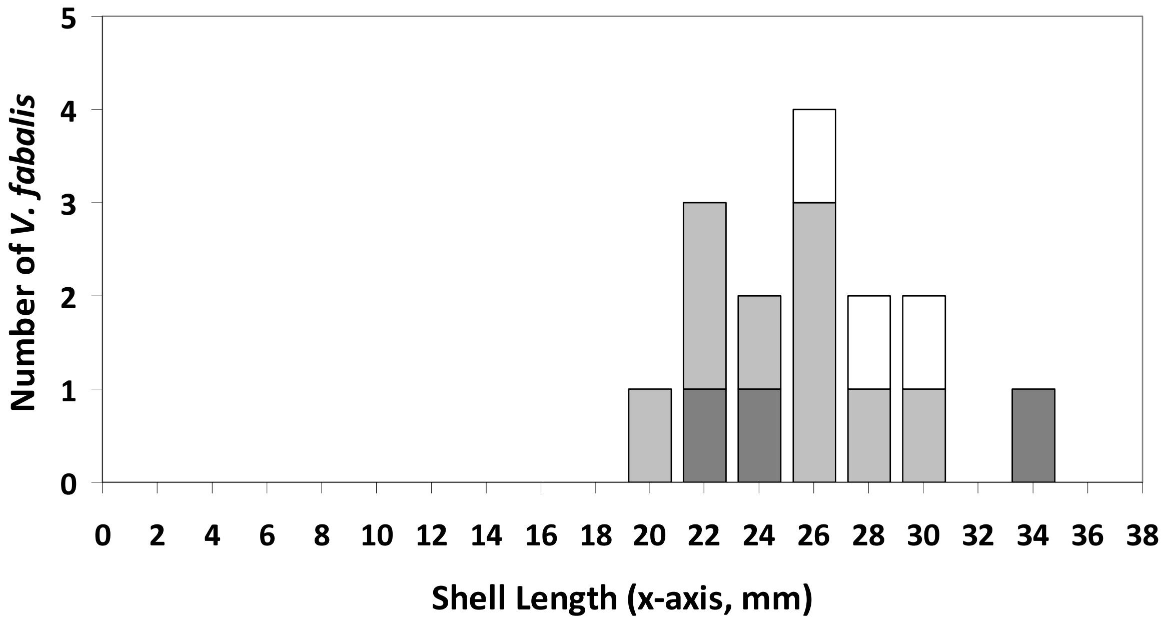

Figure 3.16 – *Shell length histogram of Rayed Bean (<u>V. fabalis</u>) sampled in Middle Swan Creek. Sites are shaded as follows: MSWAN1 (☐), MSWAN2 (☐), and MSWAN3 (■).*

3.25 Burrowing Analysis
Approximately 69% of all live mussels measuring > 30mm were found on the substrate surface during 2010 sampling. The remaining individuals (> 30mm) were collected from excavated substrate. In contrast, 92% of all recent recruits (≤ 30mm, ≤ 20mm for Slippershell, Rayed Bean, and Lilliput) were collected from excavated material. In the Blanchard River and Beaver Creek approximately 73% and 78% of mussels measuring > 30mm were found at the substrate surface, respectively. In Swan Creek, fewer unionids were visible at the surface, with just 38% collected from surface sampling. Differences between species were also observed across all streams and reaches. Wabash Pigtoe (*F. flava*) and Rayed Bean (*V. fabalis*) were more common in excavated material than in surface samples (Figure 3.17). In fact, none of our eight most common species were most abundant in the "entirely exposed" or the ">50% exposed" positions. Approximately 40% of Ohio Species of Concern Kidneyshell (*P. fasciolaris*) were found in excavated substrate. Interestingly, Smith and Crabtree (2010) reported 41% of *P. fasciolaris* in excavated substrate during quantitative surveys of French Creek, PA. It should be noted, however, that Smith and Crabtree (2010) included recent recruits in their data.

Drawing conclusions regarding the burrowing tendencies of different unionid species may be confounded by a number of variables. First, smaller individuals are often difficult to detect due to their size and propensity for burrowing. Laboratory studies and field collections have documented the recovery of juvenile mussels (up to three years old) from zero to eight centimeters below the substrate surface (Neves and Widlak 1987; Yaeger et al. 1994). Therefore, if a large number of young individuals comprise a population, the recovery of that species from surface samples may be predictably lower. To reduce this effect, we removed "recent recruits" from our burrowing analysis. In addition to size, there may be differences between streams. For example, during our 2010 sampling, we found that far more unionids burrowed into the substrate in Swan Creek. This could be related to flow, substrate stability and texture, or other habitat variables. Last, temporal variation in burrowing position may occur due to changes in environmental conditions such as temperature, flow, or food supply.

In addition to burrowing position, we noted the number of mussels that were found under flat stones (i.e. large gravel, cobble, and boulder) but were not wholly buried. Across all sites, this number totaled 44 individuals that would have gone undetected in a surface survey of mussels. Most of these mussels were found in the Middle Blanchard River where substrates were relatively large and heterogeneous.

These results underscore the need to disturb and investigate sediments when sampling freshwater mussels both quantitatively as well as qualitatively. During this study, 62% of the unionid community in Middle Swan Creek was not found on the surface. Conversely, in Beaver Creek, only 22% of unionids were not found on the surface. As such, the need for excavation will depend on the characteristics of the target population, habitat attributes, and goal of the study (Strayer and Smith 2003).

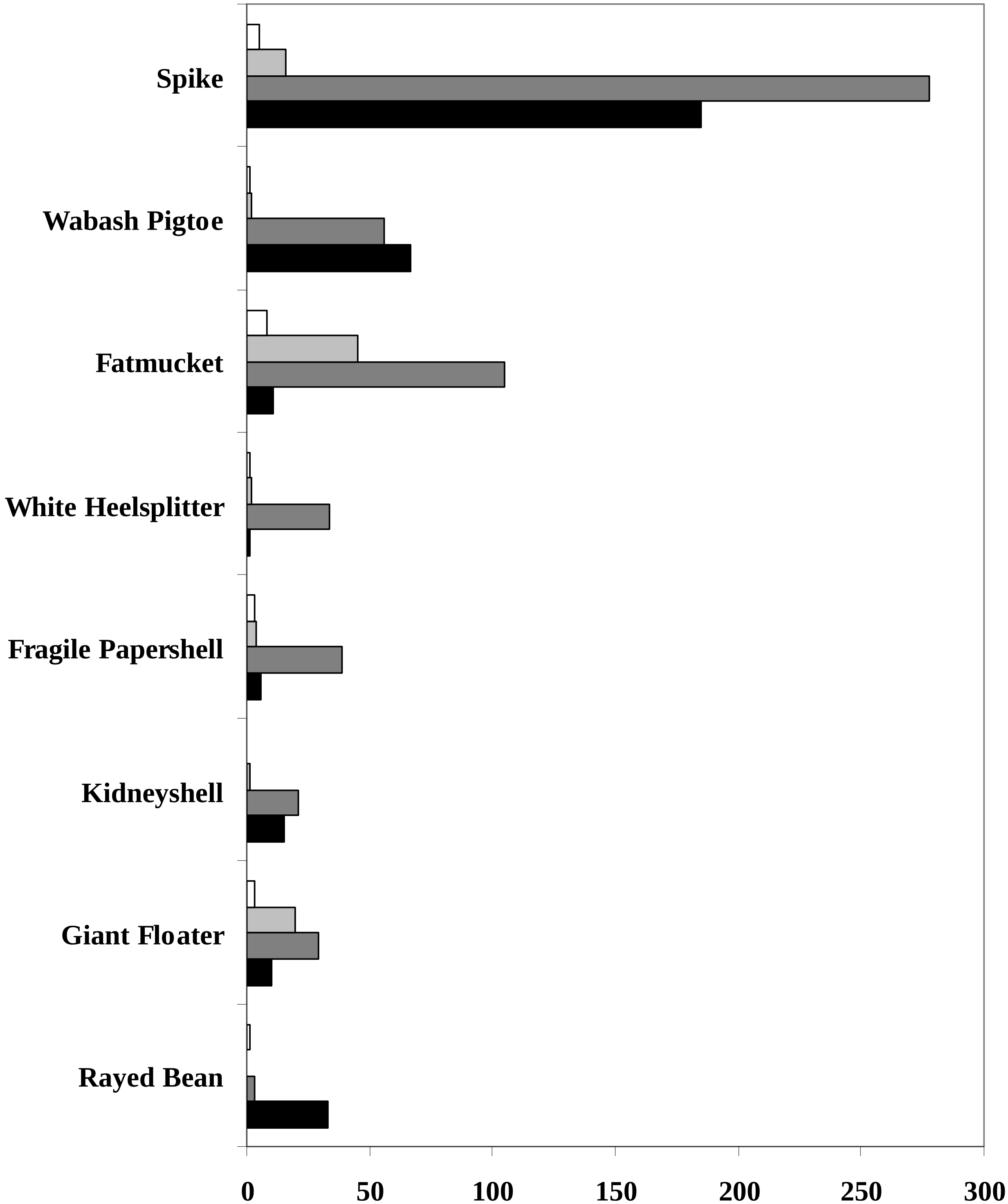

Figure 3.17 *- Total number of individuals found in each burrowing position across all reaches and streams (minimum n=35). Positions were assigned ordinal ranks based on the percentage of mussel visible at the substrate surface: entirely exposed (☐), >50% exposed (☐), ≥ 50% burrowed (☐), and not visible at substrate surface (■).*

3.3 Microhabitat

3.31 Blanchard River

The Middle Blanchard River (Figure 2.5) supported a variety of habitats. Riffles (20%), glides (75%), runs (2%), and pools (3%) were all present within our sampling locations (Table 3.13). The dominant surface particle size was small gravel (35%), followed by bedrock (18%), sand (16%), large gravel (12%), and cobble (11%). Subsurface samples were comprised mostly of small gravel (61%) and sand (31%) (Table 3.14). Although we performed only limited core and rod sampling within the Middle Blanchard, we experienced more core refusals (substrate too hard to get a sample) in the Middle Blanchard than all other reaches. Despite this and extensive patches of exposed bedrock, mussels were relatively abundant where small and large gravel substrates dominated the streambed.

The Upper Blanchard River (Figure 3.9) was comprised of riffles (17%), glides (74%), and pools (9%) (Table 3.13). The dominant surface particle size was small gravel (39%), followed by sand (25%), woody debris (16%), and silt (11%). Subsurface samples were comprised mostly of small gravel (40%), sand (34%), woody debris (12%), and silt (7%) (Table 3.14). Core depth penetration measurements demonstrated that sediments were generally softer in the Upper Blanchard when compared with the Middle Blanchard (Figure 4.1). Extensive areas of our Upper Blanchard reach were covered with silt, although this didn't seem to impact unionid distributions or densities (Figure 4.2). Riparian areas within the Upper Blanchard were generally wide and packed with native herbaceous vegetation as well as common floodplain trees. We also observed high quality pools with excellent in-stream rootwad cover (Figure 4.3).

3.32 Swan Creek

Middle Swan Creek was comprised mainly of glide habitat (82.3%), with some riffles (10.3%) and pools (7.3%) (Table 3.13). Surface substrates were dominated by small gravel (48%) and sand (26%), with smaller amounts of woody debris (10%) and silt (5%). Subsurface substrates were found to contain small gravel (49%), sand (36%), and some woody debris (7%) (Table 3.14). Core sampling suggested that substrates were softer in Middle Swan Creek than both the Middle and Upper Blanchard River. Adjacent to the channel, the riparian corridor was wide and supported several native herbaceous and woody species, including Green-headed Coneflower (*Rudbeckia laciniata*), Ironweed (*Vernonia altissima*), American Sycamore (*P. occidentalis*), Eastern Cottonwood *(Populus deltoides)*, and Paw-Paw (*Asimina triloba*). In-stream vegetation included Water Willow (*Justicia americana*) and Lizard's Tail (*Saururus cernuus*).

Upper Swan Creek was substantially different than Middle Swan Creek. Stream habitat was comprised solely of glides (89%) and pools (11%) (Table 3.13). The large amount of small gravel sampled in Middle Swan Creek was replaced in Upper Swan Creek with sand (40%) and woody debris (35%). Smaller quantities of silt (13.3%) and small gravel (6.2%) were present. Subsurface samples were comprised mainly of sand (52%) and woody debris (24%) (Table 3.14). Penetration measurements were similar to Middle Swan Creek, although slightly softer (Figure 4.4). A wide floodplain was present, although substantial damage from the Emerald Ash Borer (*Agrilus planipennis*) and a recent tornado was observable. Very little in-stream cover and vegetation were present.

3.33 Beaver Creek

Our Middle Beaver Creek reach was positioned just 2.3 river kilometers upstream of the confluence with the Maumee River. Stream habitat was mostly glide (91%), with some riffle areas (3%) and pools (6%) (Table 3.13). Surface sediments were comprised of small gravel (37%), sand (22%), woody debris (15%), silt (12%), and large gravel (11%). Subsurface samples were comprised of small gravel (44%), sand (35%), woody debris (9%), and silt (8%) (Table 3.14). The riparian corridor of Middle Beaver Creek was wide and forested with some smaller areas of row cropped agricultural fields.

The habitat of Upper Beaver Creek was similar to Middle Beaver Creek. The reach was primarily glide (92%), with some riffle areas (3%) and pools (5%) (Table 3.13). Surface sediments were comprised of small gravel (49%), sand (26%), silt (13%), and woody debris (5%). Subsurface samples were comprised of small gravel (57%), sand (27%), silt (6%), and woody debris (5%) (Table 3.14). Core depth penetration data were similar for both the Upper and Lower Beaver Creek (Figure 4.5). Overall, penetration data indicated that Beaver Creek substrates were softer than the Blanchard River yet harder than Swan Creek. The riparian corridor of Beaver Creek was primarily forested and wide.

3.34 Rayed Bean

At the microhabitat level, *V. fabalis* was found in riffle, glide, and shallow pool habitats. We collected Rayed Bean (*V. fabalis*) from quadrats ranging in water depth from 1cm to 38cm (n=48, mean =19cm) at low flow. Small gravel (2-32mm) was the dominant surface particle size in 87% of the quadrats with Rayed Bean (*V. fabalis*) and 61% of the subsurface samples. The occurrence of small gravel within reaches that supported extant *V. fabalis* populations was investigated in relation to the occurrence of *V. fabalis* within those quadrat samples (Figure 4.6). Streambed penetrability varied widely, with mean core penetration measurements ranging from 0cm to 7.4cm. Frequency distributions were generated to examine the occurrence of Rayed Bean (*V. fabalis*) in relation to study area core penetrability (Figures 4.7 and 4.8). In both streams, Rayed Bean were more common in moderately soft substrates and less common or absent in the hardest and softest extremes. This pattern of habitat use was postulated recently by Strayer (2008) who expected "excessively soft and excessively hard sediments probably often limit the spatial distribution of mussel populations."

Table 3.13 – *Mean habitat categories (%), depth (cm), and surface substrate composition (%) for each sampling reach. Abbreviated column headings are as follows: sgrav (small gravel), lgra (large gravel), cobb (cobble), bldr (boulder), bedr (bedrock), and orga (organic debris).*

Reach	Glide (%)	Riffle (%)	Run (%)	Pool (%)	Depth (cm)	Clay (%)	Silt (%)	Sand (%)	Sgra (%)	Lgra (%)	Cobb (%)	Bldr (%)	Bedr (%)	Orga (%)
MBLAN	75	20	2	3	19.0	0	3	16	34	12	11	1	17	4
UBLAN	74	17	0	9	16.7	1	10	25	39	4	3	1	0	16
MSWAN	82	10	0	7	19.0	4	5	26	48	2	3	0	1	10
USWAN	89	0	0	11	19.7	5	13	40	6	0	0	0	0	35
MBEAV	91	3	0	6	21.2	2	12	22	37	11	5	0	0	15
UBEAV	92	3	0	6	21.0	3	13	26	49	2	2	0	0	5

***Table 3.14** – Mean substrate subsurface composition for each sampling reach. Abbreviated column headings are as follows: sgrav (small gravel), lgra (large gravel), cobb (cobble), bldr (boulder), bedr (bedrock), and orga (organic debris).*

Reach	Clay (%)	Silt (%)	Sand (%)	Sgra (%)	Lgra (%)	Cobb (%)	Bldr (%)	Bedr (%)	Orga (%)
MBLAN	0	1	30	61	0	0	0	4	2
UBLAN	6	7	34	40	1	0	0	0	12
MSWAN	2	1	36	49	1	0	0	0	7
USWAN	5	12	52	6	0	0	0	0	24
MBEAV	3	8	35	44	1	0	0	0	9
UBEAV	4	6	27	57	0	0	0	0	5

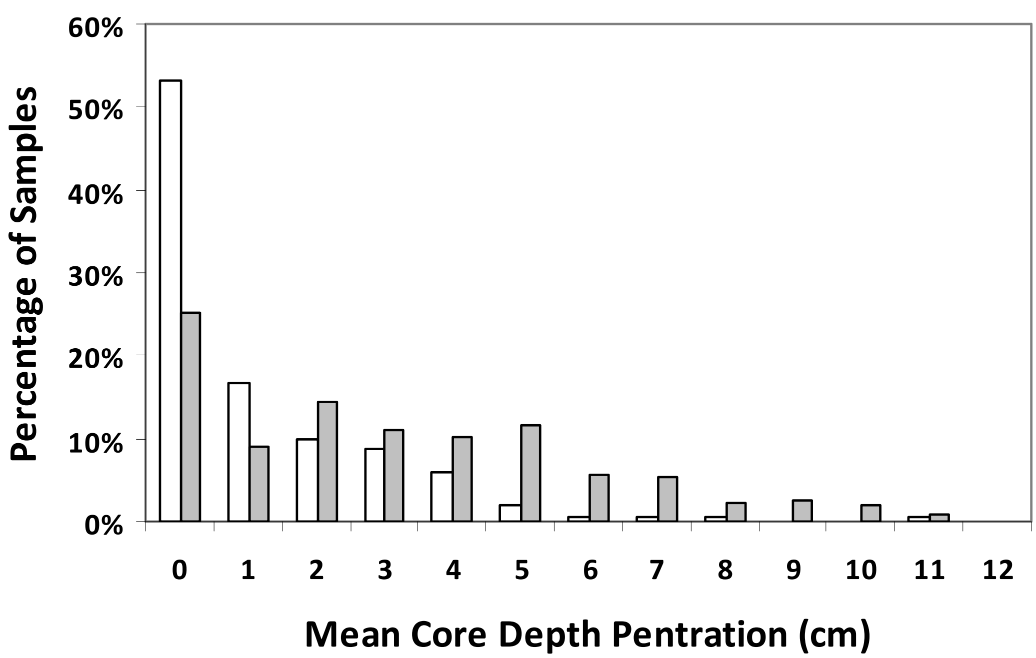

***Figure 4.1** – Frequency distribution of mean core depth penetration measurements in the Middle Blanchard River (n= 150) and Upper Blanchard River (n= 415). Reaches are shaded as follows: Middle Blanchard River (☐) and Upper Blanchard River (☐).*

***Figure 4.3** – A large American Sycamore (Platanus occidentalis) rootwad under the water line during low flow conditions at UBLAN5, 9/6/2010, Hancock County, OH. (Photo: Jeff Grabarkiewicz)*

***Figure 4.2** – Silt deposited on a shallow, sand and gravel glide within UBLAN4, 8/20/2010, Hancock County, OH. (Photo: Jeff Grabarkiewicz)*

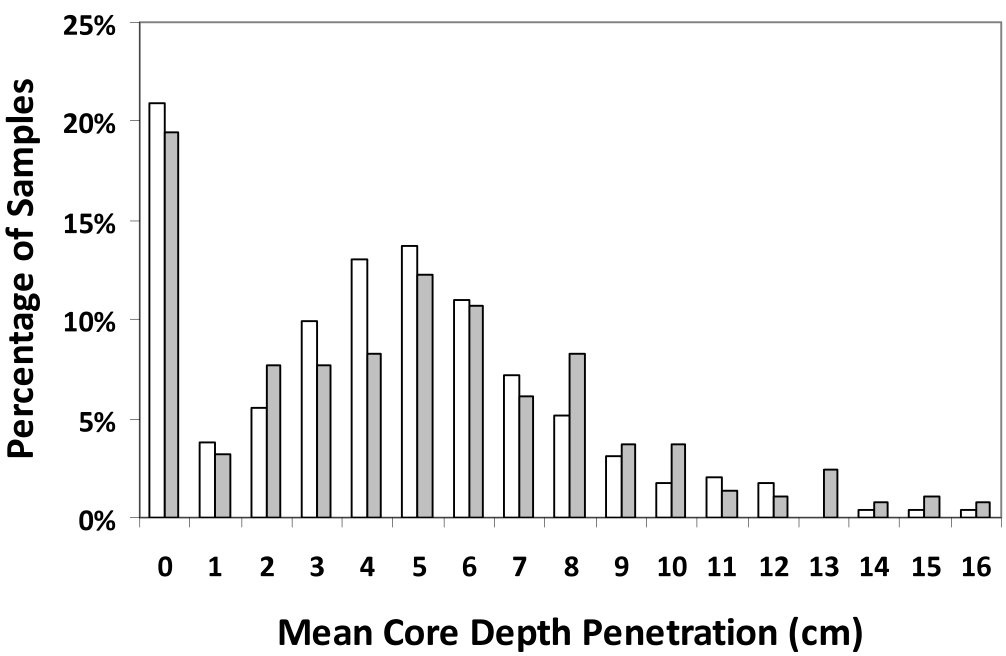

***Figure 4.4** – Frequency distribution of mean core depth penetration measurements in Middle Swan Creek (n= 290) and Upper Swan Creek (n= 373). Reaches are shaded as follows: Middle Swan Creek (☐) and Upper Swan Creek (■).*

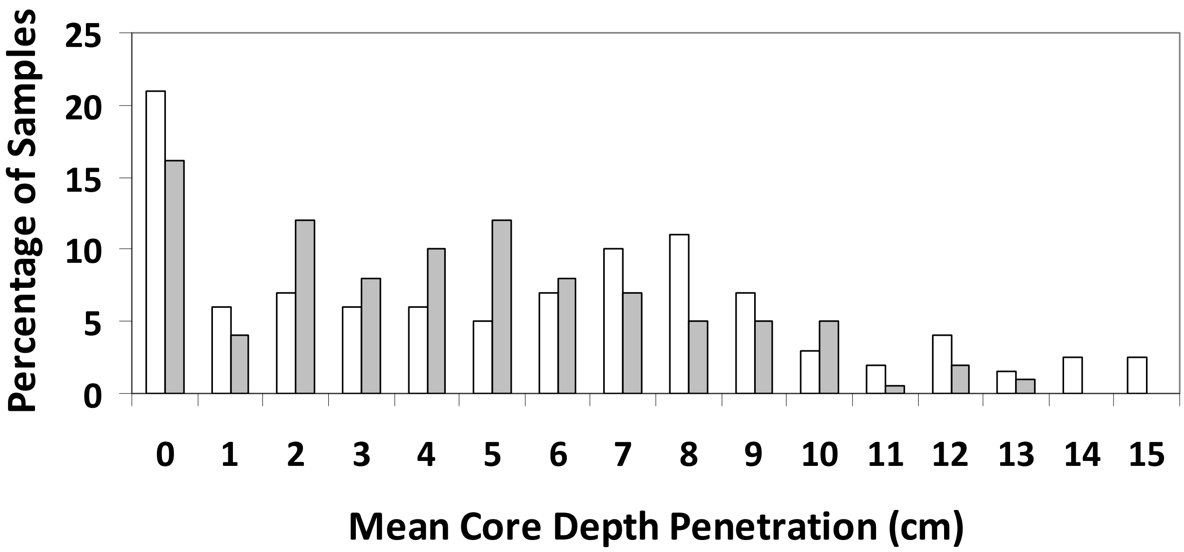

Figure 4.5 – *Frequency distribution of mean core depth penetration measurements in Middle Beaver Creek (n= 402) and Upper Beaver Creek (n= 411). Reaches are shaded as follows: Middle Beaver Creek (☐) and Upper Beaver Creek (■).*

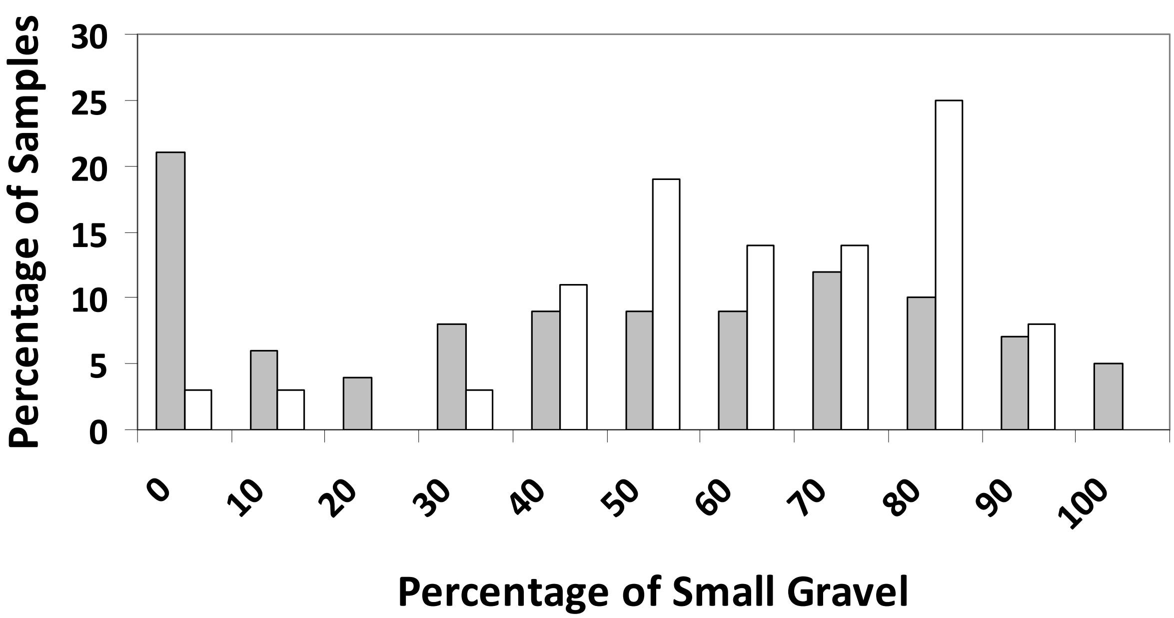

Figure 4.6 – *Frequency distribution of small gravel within the Upper Blanchard River and Middle Swan Creek where live V. fabalis was found. The x-axis is the surface percentage of small gravel within quadrat samples. The y-axis represents the percentage of samples (■) and the percentage of live Rayed Bean (V. fabalis) (☐).*

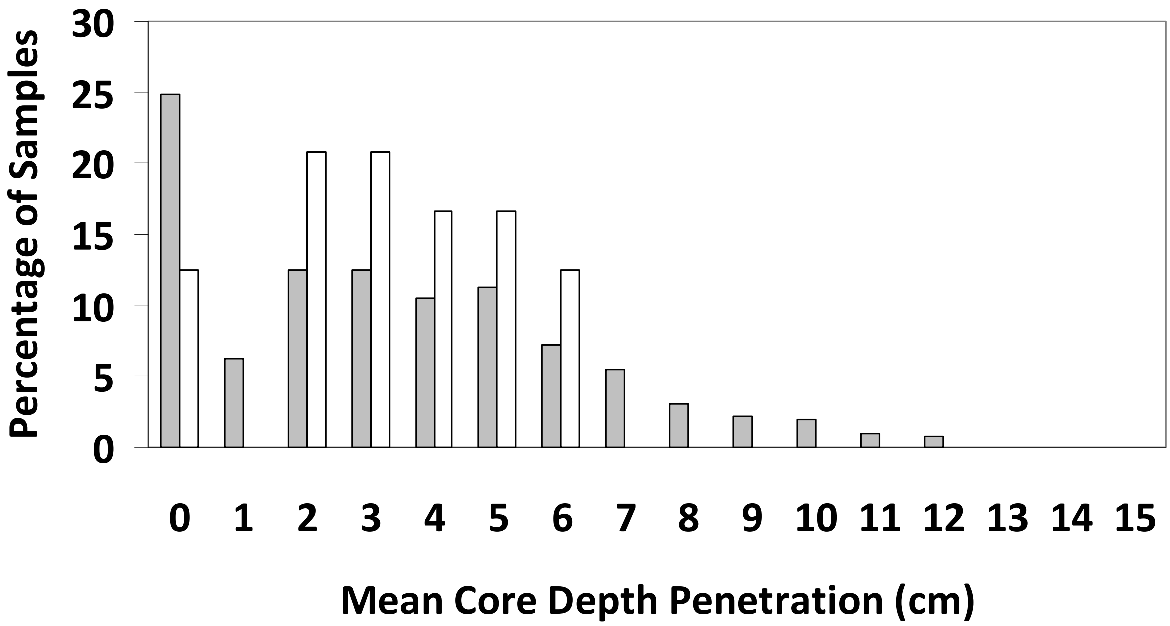

Figure 4.7 *- Frequency distribution of core penetration measurements in the Upper Blanchard River. The x-axis is the mean (average of five core attempts) depth of penetration (cm). The y-axis represents the percentage of samples (n=415) (■) and the percentage of live Rayed Bean (V. fabalis) (□).*

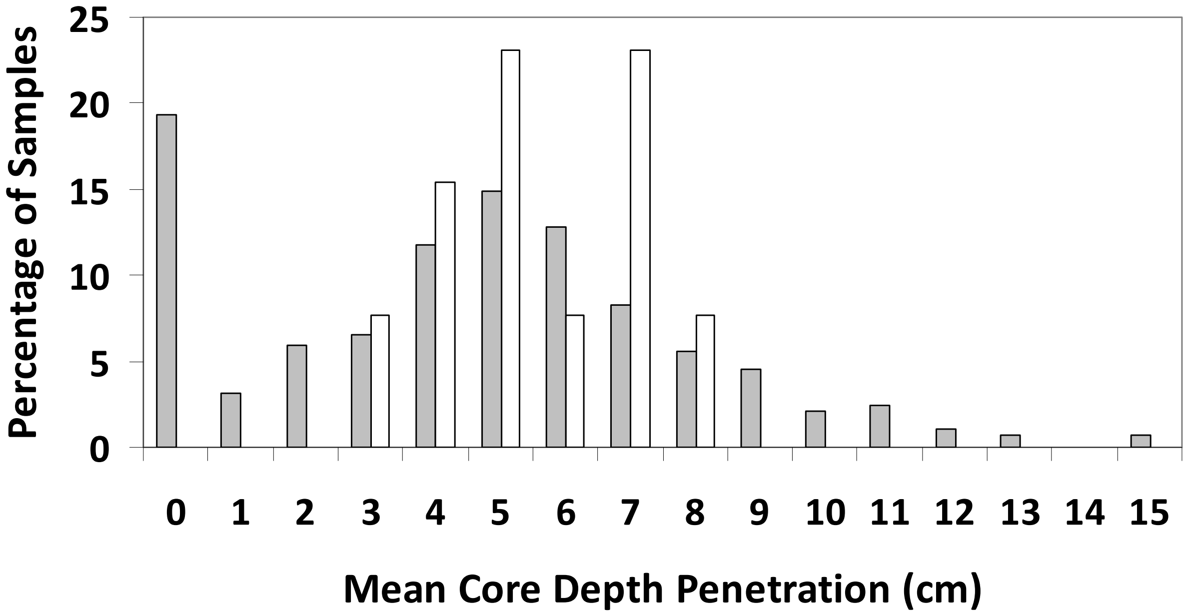

Figure 4.8 *- Frequency distribution of core penetration measurements in Middle Swan Creek. The x-axis is the mean (average of five core attempts) depth of penetration (cm). The y-axis represents the percentage of samples (n=290) (■) and the percentage of live Rayed Bean (□).*

3.4 Unionid Index of Biotic Integrity

Starting in the early 1900s, scientists were using fish communities as indicators of relative ecological health (Simon 1999). During the past 30 years, several states and regional water quality organizations have developed multimetric indexes to evaluate changes in surface water biological communities over time. The first "Index of Biotic Integrity" was developed for fishes by Karr (1981). Today, numerous multimetric indices exist to measure the quality of surface waters and habitats throughout the United States (Simon 1999).

The formal use of freshwater mussels as indicators of biological integrity within a multimetric framework has been limited. Kearns and Karr (1994) developed a "Benthic Index of Biotic Integrity" for rivers of the Tennessee Valley that utilized mussels from the genus *Epioblasma* (Riffleshells) as "intolerant species." More recently, Hoggarth and Goodman (2007) utilized a multimetric "Mussel Index of Biotic Integrity" developed by Goodman (2007) to measure changes in mussel communities within the Little Miami River, OH.

Freshwater mussels possess a number of characteristics that make them suitable indicators of biological integrity (Melhop and Vaughn 1994; Grabarkiewicz and Davis 2008), which are reproduced here:

Unionoidean Attributes

1. Long-lived: some species may reach 70+ years.
2. Sedentary: juvenile and adult mussels move little during their entire lifetime.
3. Burrowers: some species and juveniles burrow deep into the streambed.
4. Filter feeders: mussels obtain food and oxygen from the water column and via interstitial flow.
5. Fairly large: mussels contain ample soft tissue for chemical analysis.
6. Spent valves: dead mussels leave a historical record.
7. Established taxonomy.

Sensitivity to Environmental Perturbations

1. Unionoids demonstrate a gradient of tolerances to both chemical contaminants and physical alterations.
2. Exhibit sensitivity to habitat or watershed changes that alter flow regimes, reduce substrate stability, or cause siltation.
3. Vulnerable to periods of low dissolved oxygen.
4. Sensitive to exotic species invasions, such as the zebra mussel (*Dreissena polymorpha*).

Sampling and Monitoring

1. Unionoids are widespread throughout the United States, and are particularly speciose in the eastern United States.
2. Protocols have been developed to survey mussels, although sampling techniques have not been standardized.
3. Freshwater mussels are relatively easy to tag and monitor.

With the characteristics described above as context, we investigated IBI metrics for a Unionid Index of Biotic Integrity for Western Lake Erie Basin tributaries. The metrics below build off the publications cited above and utilize data from this study as well as data collected by Grabarkiewicz and Crail (2007; unpublished data) and Grabarkiewicz (2008; unpublished data), in addition to the review by Grabarkiewicz and Davis (2008). We followed the framework established by Karr (1981) in his foundational paper and Ohio EPA (1987).

Species Composition and Richness

1. **Number of Extant Species.** A simple but fundamental measure of biological communities, species richness is the enumeration of species within a certain geographic area. Karr (1981) and Ohio EPA (1987) both reported the use of native species richness in fish IBI programs due to the well-documented pattern of fish community richness decline with increasing environmental disturbance. Like many freshwater fishes, freshwater mussels are also sensitive to environmental disturbance and have been impacted by habitat destruction, pollution, exotic species, and changes in land use (Watters 2000; Lydeard et al. 2004; Poole and Downing 2004; Strayer et al. 2004). As such, temporal losses to unionid community species richness may result from environmental disturbance. Mussels are particularly useful in this regard due to the presence of shell that documents their former occurrence at a site.

   This metric must be weighted to waterbody size and biogeography. However, unlike fish communities, seasonal calibration is not needed due to the non-migratory nature of freshwater mussels.

2. **Number of Indicator Genera.** Similar to the metric proposed by Kearns and Karr (1994), some genera of freshwater mussels have demonstrated greater sensitivity to environmental disturbance than others. In extreme cases, such as the *Epioblasma* (Riffleshells), entire genera have been driven to the brink of extinction. Unfortunately, the three *Epioblasma* species once found in Northwest Ohio have not been found live in two decades and are most likely extirpated from the region. Their extreme rarity (if they are still present) would not allow for much utility as indicator species.

   Trends of population decline within the Western Lake Erie Basin tributaries can be detected through analyzing museum voucher records, published studies, and survey data. While statewide Ohio Division of Wildlife listings may be helpful, many State endangered species are currently extirpated or were not historically known from the Lake Erie drainage. Therefore, a basin-wide specific list is required to be useful for an Index of Biotic Integrity. Recommended genera from our work in Western Lake Erie tributaries over the past five years include *Alasmidonta*, *Amblema*, *Obovaria*, *Pleurobema*, *Ptychobranchus*, and *Villosa*. All of these genera were widespread in the basin historically and are still present to various extents. Some of the genera (e.g., *Amblema*) may be common in other areas of Ohio, but seem to be sharply declining within the tributary waters of Western Lake Erie.

Reproductive and Ecological Factors

3. **Number of Species Exhibiting Reproductive Success.** Age class diversity is an indicator of reproductive success over time. Due to the complex reproductive biology of freshwater mussels, reproductive success requires both suitable environmental conditions and suitable host fishes. Through our 2010 field research and previous studies (e.g., Grabarkiewicz and Crail 2008; Grabarkiewicz 2008), a threshold value (or gradient of values) could be established as an indicator of age class diversity. For example, we utilized coefficient of variation (C_v) during this study as an indicator of shell length variation. With an adequate sample size, a C_v value of > 0.20 provided a reliable indicator of age class diversity.

4. **Presence of Burrowing Species**. The tendency of some species to burrow has been speculated on by a number of naturalists and malacologists over the past century. For example, the early 20th century naturalist Ortmann (1919) stated that Rayed Bean (*V. fabalis*) in West Virginia were "deeply buried in the sand and gravel..." Burrowing increases the contact that mussels have with sediments and may act as an indicator of sediment and interstitial pore water quality. Although more samples are needed, our field research during 2010 observed differences between species burrowing behavior. Our burrowing list includes Spike (*E. dilatata*), Wabash pigtoe (*F. flava*), Kidneyshell (*P. fasciolaris*), and Rayed Bean (*V. fabalis*). Ex-situ studies have also noted differences in species burrowing behavior and explored the relationship between community structure and sediment position (Allen and Vaughn 2009). A "healthy" riverine community is likely one that is comprised of species that have both a propensity for burrowing and those that do not.

4. Conclusions

Despite the unexceptional reputation of Northwest Ohio streams, our research found locally and globally significant populations of freshwater mussels within our three study streams. Overall, mussel diversity and density were highest in the Upper Blanchard River. Swan Creek supported a moderately dense population of mussels in the middle reach and a depauperate community in the upper reach. The community found in Beaver Creek resembled a big river fauna more than a small creek fauna. This was likely due to the proximity of sampling reaches to the Maumee River. Age class diversity was apparent for many species in both the Upper Blanchard and Middle Swan Creek, with many recent recruits found in the Upper Blanchard. Upper Swan Creek and Beaver Creek were found to support few recent recruits, although some age class diversity was present.

Rayed Bean (*V. fabalis*) was found in both the Upper Blanchard and Middle Swan Creek. It was most abundant in samples where small gravel dominated the surface substrates and was found primarily in shallow glides where streambed substrates were not excessively hard or soft. The populations in the Upper Blanchard and Middle Swan Creek have successfully reproduced within the past few years and were relatively abundant throughout each sampling reach.

We found QHEI was a useful predictor of unionid community attributes such as species richness and density. However, the relationship between QHEI and unionid community metrics is likely non-linear due to the habitat use by freshwater mussels and QHEI methodology. Overall, physical habitat was most diverse in the Blanchard River, where riffles were well developed and stream substrates comprised of heterogeneous mixtures of sand, gravel, and cobble. In contrast, physical habitat was most limited in Upper Swan Creek, where habitat consisted chiefly of sandy glides littered with woody debris. Upper Swan Creek also supported the fewest number of species and the lowest densities of mussels. There was also little evidence of recent recruitment and age class diversity within Upper Swan Creek.

The burrowing behavior of different mussel species has an important implication for both monitoring and conservation. We observed that burrowing does not vary only by species, but may have observable differences among streams. Sampling methods should be designed to meet survey goals and provide reliable estimates of population density and recruitment. These results underscore the need to investigate sediments when sampling freshwater mussels both quantitatively as well as qualitatively.

Suggested preliminary metrics for a unionid-based IBI included number of extant species, number of indicator genera, number of species exhibiting reproductive success, and presence of burrowing species. The development of a full index would be a complex and time-consuming task, but would be a valuable tool to monitor surface water integrity.

Finally, we would like to further highlight the Upper Blanchard River that supported a particularly high density and speciose unionid community. On-the-ground conservation practices (wetland restoration, riparian buffers, etc.) and stream protection will be required if this community is to persist long-term.

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6. Appendix 1: Listing of community outreach activities undertaken

<u>Jeff Grabarkiewicz</u>

June 2011 - Advanced Wonders of Watersheds Workshop, Freshwater Mussels of the Portage River (15 secondary school teachers)

June 2010 - Advanced Wonders of Watersheds Workshop, Freshwater Mussels of the Portage River (20 secondary school teachers)

October 2010 – Ohio Certified Volunteer Naturalist Program, Aquatic Biology of Northwest Ohio (12 area environmental educators)

Grabarkiewicz, J.D. and J.F Gottgens. 2011. Microhabitat Use and Community Structure of Unionid Mussels in Three Lake Erie Tributaries. Oak Opening's Research Symposium, Toledo, Ohio.

Krajeski, C, J.D Grabarkiewicz and J.F. Gottgens. 2011. Freshwater Mussel Diversity in the upper and middle reaches of the Blanchard River, Swan Creek, and Beaver Creek in Northwest Ohio 'Posters on the Capitol'; Undergraduate student research in NW Ohio. Columbus, Ohio