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Freshwater Mussel (Unionidae) Distribution and Demographics in Relation to Microhabitat in a First-Order Michigan Stream

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ABSTRACT

Over one-third of Michigan's native freshwater mussels (Unionidae) are classified as imperiled and a higher proportion of mussels are considered to be in need of conservation. Conservation of these species is hindered by an extensive knowledge gap about the distribution and habitat requirements of mussels in Michigan, especially in the Upper Peninsula. The objectives of our study are to examine freshwater mussel distribution and relationships between mussel population demographics and microhabitat parameters within a first-order stream in the Upper Peninsula of Michigan. To identify aggregations of mussels (n > 5 individuals), we conducted initial surveys of all wadeable reaches of Hannah Creek. Microhabitat parameters (e.g., water quality and velocity) were randomly sampled using a 1 m² grid where mussel aggregations were present and absent, and we recorded species, age, and length for all mussels found within grids. Multiple regression analysis was used to relate microhabitat parameters to mussel density. Mussel species we found included Anodontoides ferussacianus, Strophitus undulatus, Lasmigona compressa, *and* Pyganodon grandis. *All species were patchily distributed throughout the stream. The average age of all mussels was 9 years, and age structure of the mussel species suggests that some of the populations may suffer from poor reproduction. Density of all mussel species was negatively correlated with sediment size (p = 0.017) and percent aquatic vegetation (p = 0.002), but was positively correlated with percent woody debris (p = 0.023). Our study provides necessary baseline information to assess future changes to mussel populations, and suggests possible microhabitat controls on freshwater mussel populations in this region.*

INTRODUCTION

Freshwater mussels (Unionidae) play an important role in aquatic ecosystems by providing habitat and nutrients to other benthic organisms (Beckett et al. 1996; Gutierrez et al. 2003; Spooner and Vaughn 2006). Despite their important role in aquatic ecosystems, freshwater mussel populations are declining. The world's freshwater mussel (Margaritiferidae and Unionidae) diversity is highest in North America (279 species), but approximately 72% are threatened, endangered, or a species of concern (Williams et al. 1993). A similar trend is apparent in Michigan. With the April 2009 update to Michigan's list of threatened and endangered species, 27 of the 45 mussel species occurring in the state are now considered endangered (13), threatened (6), or species of special concern (8) (Michigan Administrative Code R299.1021).

Habitat degradation often is recognized as one of the major causes for decreased biodiversity in streams (Allan and Flecker 1993). Several anthropogenic activities degrade mussel habitat and are responsible for accelerating the decline of mussel populations over the past century (Watters 1999). These activities include poor logging, agricultural, and construction practices, and associated negative effects such as altered channel morphology or sediment, nutrient, and water regimes (Allan and Flecker 1993). Similarly, impoundments degrade mussel habitat by altering available habitat and flow regimes.

When attempting to preserve declining mussel populations, habitat preservation or restoration often is suggested as one of the most effective methods for increasing mussel numbers (Cope and Waller 1995). Yet state and federal resource management agencies acknowledge that recovery of these species has been hindered by an extensive knowledge gap about the distribution and habitat requirements of freshwater mussels.

To address this knowledge gap, others (e.g., Salmon and Green 1983; Howard and Cuffey 2003) have evaluated relationships between mussel metrics (e.g., density and richness) and in-stream microhabitat parameters. However, results vary among the studies. Both positive and negative correlations with specific habitat preferences by mussels have been observed (Salmon and Green 1983; Johnson and Brown 2000; McRae et al. 2004), but other research suggests that habitat preferences are non-specific (Holland-Bartles 1990; Balfour and Smock 1995; Haag and Warren 1998). For example, Johnson and Brown (2000) found that sediment size and velocity were significantly related to mussel density in Louisiana headwater streams, yet Balfour and Smock (1995) determined that sediment size and velocity were unrelated to mussel abundance in a Virginia headwater stream. Reasons for variability between results are unknown, but may simply be due to regional differences in stream habitat and mussel species examined.

Determining mussel habitat use is important to better understand mussel distributions. Regionally, Strayer (1983) has found mussel distributions linked to surface geology and stream size. He makes it clear, however, that it is not solely surface geology and stream size that affect the mussel distribution; it is small-scale habitat parameters linked to the large scale habitat that actually affect mussel distribution. For example, a landscape characteristic such as surficial geology affects discharge and slope, and slope ultimately affects velocity and substrate size, an in-stream habitat parameter (Strayer 1983). Flow conditions related to discharge and velocity have been found to affect mussel distributions in many studies (Salmon and Green 1983; Johnson and Brown 2000; Howard and Cuffey 2003). Also, since habitat generally varies longitudinally throughout a stream, mussel distributions may be better understood if mussel habitat use is examined longitudinally over an entire stream. Few studies have examined longitudinal mussel distribution (Howard and Cuffey 2003), most likely due to logistical difficulties, and no studies have looked at longitudinal variation in mussel habitat use over an entire stream.

Despite differing results in microhabitat studies, it is clear that continued research will be important for better understanding mussel distribution and habitat needs, and that this research may need to be species-specific and regionally focused. Although some research on freshwater mussels and their habitat use has been conducted in Michigan (e.g., Strayer 1983; Badra and Goforth 2003; McRae et al. 2004), there have been no published studies to date on mussels in streams of the Upper Peninsula of Michigan. Our study examines the relationship between freshwater mussels and various microhabitat parameters throughout a small stream in the Upper Peninsula of Michigan, providing a unique opportunity to explore longitudinal trends in mussel distribution related to microhabitat throughout an entire stream. Specifically, the objectives of our study are to map longitudinal mussel distribution throughout a first-order stream and to evaluate relationships between mussel population demographics and a variety of microhabitat parameters (e.g., water quality and velocity).

METHODS

In summer 2007, we surveyed Hannah Creek, a first-order stream in the Munuscong River watershed (eastern Upper Peninsula of Michigan; Lake Huron drainage) (Figure 1). Hannah Creek was chosen due to its size (e.g., wadeability), habitat (e.g., water clarity), access sites, and the presence of mussels.

Hannah Creek is less than 7 m wide and is mostly wadeable except for a few sections where beavers have constructed dams. The water is clear near the headwaters but becomes increasingly turbid near the mouth where there is a high percentage of clay in the stream bed. The land surrounding Hannah Creek is generally undeveloped, but a small portion is old agricultural fields. The headwater area of the stream is swampy with alders and conifers and gradually transitions into a section of thick conifer forest. The remainder of the creek is surrounded by tall grasses and a mix of coniferous and deciduous trees that have begun growing in the old agricultural fields.

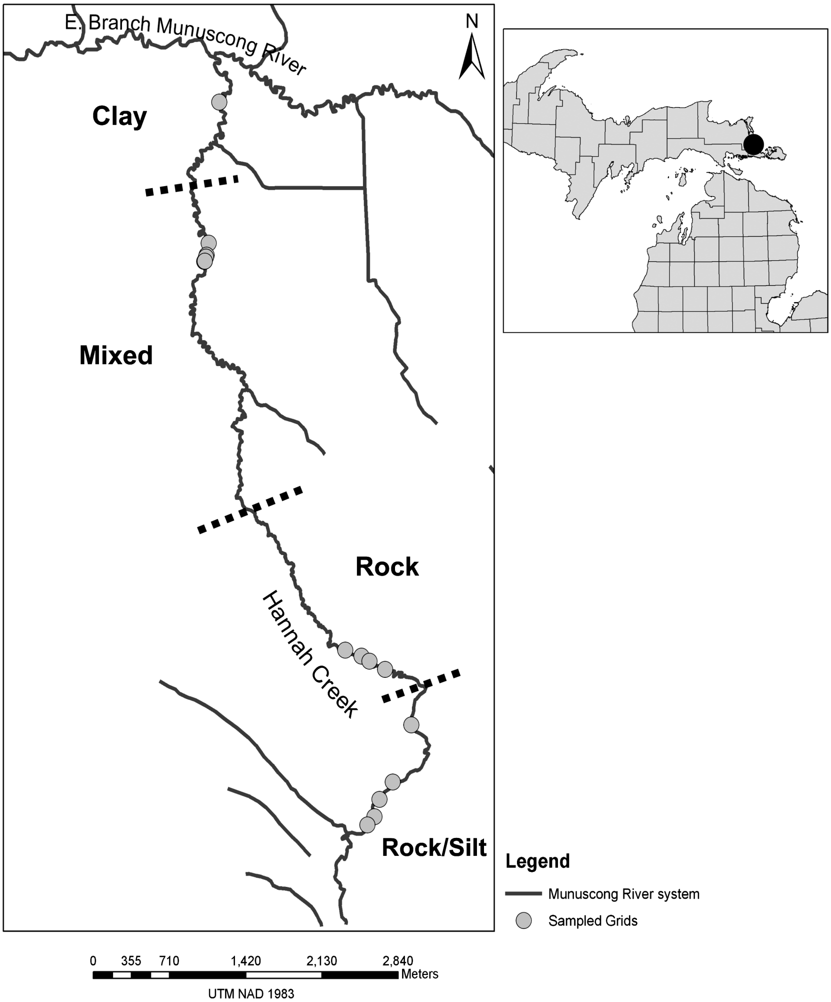

FIGURE 1. Map of Hannah Creek, Michigan, including the four stream reaches (clay, mixed, rock, rock/silt) used to stratify mussel sampling and the locations of sampled grids. Inset illustrates location of Hannah Creek in the eastern Upper Peninsula, Michigan.

We conducted an initial survey throughout the stream because no previous studies had identified mussel species or densities for Hannah Creek. Approximately 6 miles of Hannah Creek less than 0.7 m deep were waded during an initial survey in order to determine the location of mussel aggregations and to stratify the stream by habitat type. Approximately 80% of the stream bottom was surveyed over 5 days. We surveyed the creek for mussels in a zig-zag motion across all wadeable sections of the stream using an 18.9 L (5 gal) glass-bottom bucket. Mussel aggregations were marked with a GPS unit and were defined as groups of 5 or more individuals separated by more than 1 meter of unoccupied stream bed (Howard and Cuffey 2003). The general habitat of the area was mapped and included overhead canopy, land use, and sediment types. We used this information to divide the stream into four longitudinal reaches based on sediment type (clay, clay/sand/silt (mixed), rock and rock/silt) to distribute quantitative mussel sampling effort among the reach types.

An objective of our study is to relate mussel demographics to microhabitat parameters; therefore we chose to focus sampling efforts on mussel aggregations to increase our sample sizes for statistical analysis. We sampled three to four mussel aggregations from each of the four reaches of the stream (except the downstream clay reach) for mussel habitat using a 1x1 m grid containing 25 square quadrats, each side of the quadrat being 20 cm (Figure 1; Strayer and Ralley 1993). This method was sufficient for sampling all mussel species found during the initial survey. Generally one grid was sampled for every aggregation (aggregations tended to occupy less than 10 m of stream reach), but if the aggregation spanned more than 10 m, one grid was sampled every 10 m. Within each grid, we sampled 8 randomly chosen quadrats using a random number table (Piette 2005). We also sampled one grid in each of the 4 reaches of the creek where no mussels were located to compare to habitat where mussels were present. Temperature, pH, dissolved oxygen, and specific conductivity were measured at the center of each grid using a Hydrolab® multi-probe meter. Percent aquatic vegetation and woody debris within each quadrat were visually estimated. Depth (cm) and velocity (m/s) were measured at the center of each quadrat using a Marsh-McBirney flowmeter. We used a gravelometer to collect twenty pieces of sediment from each sampled quadrat and calculated mean sediment size. For quadrats containing mussels, we recorded each mussel's species, condition (live or dead), length, and age. Age was determined by counting annuli (i.e., growth rings; Day 1984) because the method is quick and easy to conduct in the field, although it often underestimates mussel age (Neves and Moyer 1988; Kesler and Downing 1997). Mussels were collected by hand from the substrate, and small mussels were located within substrate by manually sifting through sediment up to 5 cm in depth. Although data were collected for dead mussels, we only analyzed data collected from live mussels.

ArcGIS 9 was used to map the distribution and density of mussel aggregations throughout Hannah Creek. Calculating mussel densities from aggregations, however, artificially inflates the densities of mussel species throughout the stream. Mussel densities calculated for Hannah Creek, therefore, can be more accurately described as aggregation densities (referred to hereafter as "grid density"). To examine the relationship between mussel grid density and habitat parameters (e.g., sediment size and percent woody debris), we used stepwise regression analysis. Grid densities from grids with and without mussels were used in the regression analyses. We did not calculate densities for mussels in the clay section of Hannah Creek since no mussels were found in that section. Also, since a low number of mussels were found throughout the study ($n = 49$), grid density was calculated for all mussels species together but was heavily influenced by *Anodontoides ferussacianus,* which comprised over 75% of the individuals collected. We used a Student's t-test to determine whether there was a difference between habitat parameters with and without mussels, and an ANOVA was used to determine whether there was a difference in mussel grid density between stream reaches. Multiple regression analysis also was used to determine whether there was a relationship between mussel age and habitat. Highly correlated habitat parameters (Pearson's correlation, $p < 0.05$) were not included in the regression analysis. When appropriate, we transformed data using SYSTAT to meet the normality assumption of parametric statistics. Raw data from our study are available electronically from Lake Superior State University's Department of Biological Sciences.

RESULTS

Mussel Distribution and Demographics

Four species of mussels were found throughout Hannah Creek with cylindrical papershells (*Anodontoides ferussacianus*) occurring most frequently (in approximately 85% of the grids sampled) and giant floaters (*Pyganodon grandis)* occurring least frequently (in less than 5% of the grids sampled; Table 1).

TABLE 1. Frequency of occurrence and mean species density of freshwater mussels for each habitat type throughout Hannah Creek, MI, 2007.

Name	Frequency of occurrence (%)	Mean species density (number/m^2)			
		Clay	Mixed	Rock	Rock/Silt
Anodontoides ferussacianus (Cylindrical papershell)	85.42	0	10.16	6.25	11.25
Strophitus undulatus (Strange floater)	8.33	0	1.56	0	0
Lasmigona compressa (Creek heelsplitter)	4.17	0	0	2.08	0.63
Pyganodon grandis (Giant floater)	2.08	0	0	0	0.63

Anodontoides ferussacianus were found throughout the stream, creek heel-splitters (*Lasmigona compressa)* were near the headwaters, strange floaters (*Strophitus undulatus)* near the mouth, and a single *Pyganodon grandis* was located near the headwaters (Figure 2). The range of total mussel grid

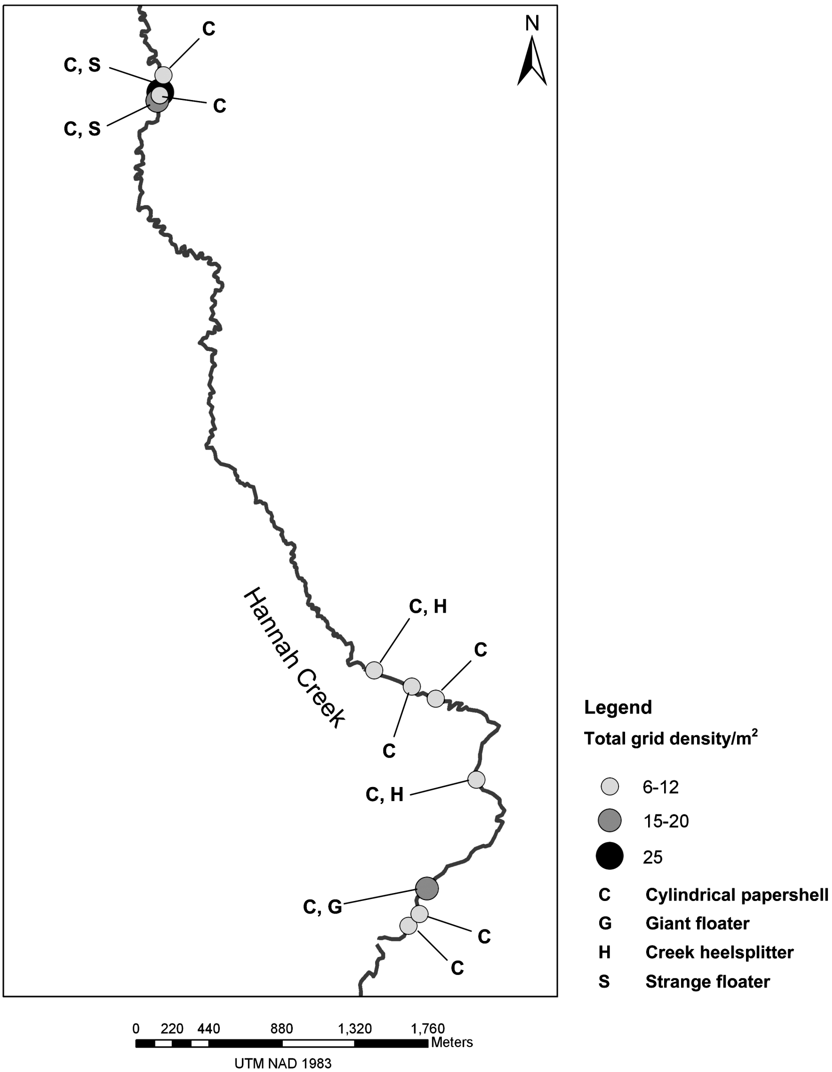

FIGURE 2. Grid density of all freshwater mussels (only where mussels were present) and the distribution of freshwater mussel species throughout Hannah Creek, Michigan, 2007.

densities (from all grids sampled) was 0–25 individuals/m^2. Total mussel grid densities did not show any longitudinal patterns (Figure 2). Densities (from grids with mussels) were not found below 5/m^2 due to the requirements for aggregations to be five or more individuals within one meter of each other.

There was no longitudinal trend in mussel age throughout Hannah Creek. Ages of *Anodontoides ferussacianus*, *Strophitus undulatus*, and *Lasmigona compressa* ranged from 3 to 16 years of age (Figure 3A), but no individuals less than 3 years old were found. *Anodontoides ferussacianus* age structure was similar to the age structure of all of the mussel species together, with 12 classes represented (Figure 3B). *Lasmigona compressa* and *Strophitus undulatus* had an abnormal distribution centered on older individuals with only 3 age classes represented (Figure 3C–D).

Mussel-Habitat Relationships

Sediment size, percent vegetation and percent woody debris were all significant predictors of total mussel grid density ($F = 7.148$; adjusted $R^2 = 0.552$; $p = 0.005$). Sediment (coeff $= -0.779$, $t = -2.775$, $p = 0.017$) and aquatic vegetation (coeff $= -4.111$, $t = -3.995$ $p = 0.002$) had a negative relationship with mussel grid density, whereas woody debris (coeff $= 6.313$, $t = 2.611$, $p = 0.023$) had a positive relationship with mussel grid density. *Anodontoides*

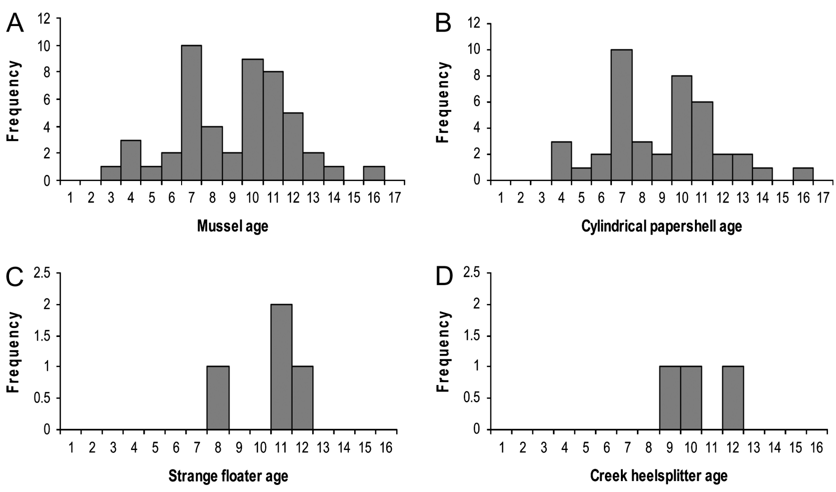

FIGURE 3. Age histograms of (A) all mussels, (B) cylindrical papershell *Anodontoides ferussacianus*, (C) creek heelsplitter *Lasmigona compressa*, and (D) strange floater *Strophitus undulatus*.

ferussacianus grid density also was significantly related to measured habitat parameters (F = 7.528; adjusted R^2 = 0.566; p = 0.004) including sediment (coeff = −0.746, t = −2.859, p = 0.014), aquatic vegetation (coeff = −3.904, t = −4.0852, p = 0.002) and woody debris (coeff 6.045, t = 2.693, p = 0.020).

With the exception of specific conductivity, microhabitat parameters (i.e., percent woody debris, velocity, sediment size, and water temperature) did not differ between grids with mussels present versus absent (Table 2). Grids containing mussels had a higher specific conductivity than grids without mussels. The difference in mean specific conductivity between the grids, however, was small (34 μS/cm), and likely not biologically significant. Total mussel grid density also did not differ among the 3 stream reaches where mussels were present.

DISCUSSION

Hannah Creek, a headwater stream in the Upper Peninsula of Michigan, possessed four mussel species, which were patchily distributed throughout the stream. There were no longitudinal trends in mussel density, species, or age distribution throughout the stream. Three of the four species appear to have poor recruitment (i.e., only older individuals were found), which may emphasize the need for protection and restoration of Hannah Creek. A few in-stream habitat parameters were significant predictors of mussel grid density and may mean that restoring habitat could improve their future status in the eastern Upper Peninsula.

TABLE 2. Mean habitat values for grids with and without mussels sampled in Hannah Creek, MI, 2007.

Habitat parameter	Mussels present	Mussels absent
Percent vegetation	6	41
Percent woody debris	11	4
Depth (cm)	28.4	19.8
Velocity (m/s)	0.03	0.06
Sediment size (mm)	5.3	12.7
Temperature (°C)	18.5	20.6
pH	8.23	8.17
Dissolved oxygen (mg/L)	4.04	4.49
Specific conductivity (μS/cm)*	527	493

*Significant difference at $\alpha = 0.05$

The age structure and densities of three of the four mussel species in Hannah Creek indicate that they may suffer from poor reproduction. The *Anodontoides ferussacianus* populations in Michigan appear stable (Badra and Goforth 2003), as do those in Hannah Creek. However, *Strophitus undulatus*, *Pyganodon grandis*, and *Lasmigona compressa* populations in Hannah Creek could potentially be in more danger. The three populations are small and dominated by older individuals. No juveniles were found which may indicate that reproduction has not been successful in the last 3 years (youngest mussel found was 3 years old). However, the lack of juvenile mussels observed in our study also may be explained by sampling error. Balfour and Smock (1995) found that juvenile mussels were rarely located compared to older mussels, even when sampling a large amount of sediment.

Further investigation of the mussel populations is needed to create a long term data set for Hannah Creek which will better explain the status of the unionid mussels. The mussel populations in Hannah Creek appear to suffer from decreased reproduction recently, but more effective methods for locating juvenile mussels are needed to accurately assess the status of the mussel populations and any need for protection or restoration.

Mussels in Hannah Creek do appear to have habitat preferences, which may prove to be important for protecting mussel populations. In particular, percent vegetation, percent woody debris, and sediment size are significant predictors of total mussel grid density in Hannah Creek. Several studies have examined the importance of different habitat parameters yet no consensus exists across regions or species. Our study suggests that mussel grid density is greater in the presence of finer substrate, as does McRae et al. (2004), but contradicts others (Salmon and Green 1983; Johnson and Brown 2000) who found greater abundances and increased occurrence of mussels in coarser, more stable substrates. In our study, the mussels may be associated with finer substrate if it is difficult to burrow among larger substrate in Hannah Creek. Similarly, we found a negative relationship between percent aquatic vegetation, whereas Salmon and Green (1983) suggested a positive relationship when mussels are located at a preferable depth. Variation in vegetation relationships between the studies could be related to different densities and species of aquatic plants. For example, in Hannah Creek aquatic vegetation is very dense, and this may reduce mussels' ability to burrow. Percent woody debris has a positive relationship with mussel density in our study, but Haag and Warren (1998) found no relationship between mussels and percent woody debris. Two situations may explain positive mussel relationships with wood in Hannah Creek. One is that wood may stabilize sediment in Hannah Creek, allowing mussels to persist in areas with higher concentrations of wood. The second situation is that a mussel may be located near wood if it falls off a host fish that is associated with wood as habitat. However, Haag and Warren (1998) suggest that mussel distribution in headwater streams may not be affected by host fish numbers as host fish populations tend to be less stable in headwater streams. Interestingly, we did not find velocity to be an important habitat parameter, yet several other studies have found both positive and negative relationships (Salmon and Green 1983; Johnson and Brown 2000; Holland-Bartels 1990). In Hannah Creek, the velocity is relatively similar in all stream sections sampled (0.00–0.16 m/s), which may explain why velocity is not a significant predictor of mussel density in Hannah Creek. The lack of consensus in microhabitat results is most likely due to regional variation in mussel species and microhabitat, which reinforces the need to determine mussel habitat preferences locally.

Although mussel density in Hannah Creek is significantly related to microhabitat parameters (e.g., sediment, aquatic vegetation, and woody debris) throughout the stream, there is no difference in habitat of grids with mussels present versus grids where mussels were absent. This suggests that our data are limited to predicting habitat that would support low versus high densities of mussels, and it is unable to predict presence or absence of mussels based on habitat. Additional habitat parameters, such as sediment compaction and sediment stability, in future analyses could strengthen our understanding of environmental factors controlling presence-absence of freshwater mussels in this region.

Many mussel populations are declining across North America and are in need of protection. Our study, along with several others, suggests that microhabitat parameters may be important for management of freshwater mussels. Cope and Waller (1995) emphasized the notion that the ability to restore appropriate mussel habitat is important for preserving mussel populations, but more studies need to be conducted at a local scale to identify habitat management needs. Studies also need to be conducted to determine the amount of variation in mussel habitat needs among streams within watersheds and regions. It is unclear whether patterns found in Hannah Creek can be safely extrapolated to other area streams for management of mussel populations. Further research to determine the importance of habitat relative to other factors such as host fish needs and landscape-level habitat preferences will also be important. In some streams, microhabitat may not be as important to mussels as fish species present since fish hosts are often necessary to complete the mussel life cycle (Haag and Warren 1998). McRae et al. (2004) found surficial geology to be an important reach-scale variable affecting mussel distributions, but also mentioned that a combination of reach and catchment-scale variables together seem to explain a large amount of the variability in mussel distributions in their study.

Freshwater mussel populations in Hannah Creek may be impaired, but continued research (e.g., on variation between streams, the importance of fish host species, and landscape influences relative to microhabitat) is still needed to fully understand the dynamics of freshwater mussel populations in Hannah Creek and other streams throughout the eastern Upper Peninsula. Our results will provide important baseline data that can be used to monitor and protect future mussel populations in Hannah Creek and will provide a comparison for other regional mussel studies.

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