The Effects of Habitat Size on Maple River Diatom Species Richness

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ABSTRACT

As the destruction and division of habitats has increased, habitat fragmentation has become a major environmental reality and concern. Multiple investigations have shown that the division of habitat area results in greatly negative consequences for the species inhabiting that area. Most widely accepted is the observation that species richness will decrease with decreasing habitat size. We designed an experiment to determine if the Maple River diatom community will adhere to this basic assumption in the concept of habitat fragmentation. Diatom colonization occurred at the University of Michigan Biological Station Stream Lab, where we submerged three different-sized groups of tile substrates of equal area in three artificial streams. The collection and identification of 500 diatom valves in each stream plot provided enough data to surmise that neither species diversity nor richness between tile size proved to be statistically significant. This withstanding, the smallest tiles consistently held the smallest mean number of species, total unique species, and the least amount of diversity as defined by the Shannon-Weiner Diversity Index. The large and medium tiles competed for greatest species richness and diversity, suggesting that the size of the medium tiles, though considerably smaller than the largest substrate, may have been enough to fill the requirements of a diatom community's minimum viable area.

INTRODUCTION

Habitat fragmentation occurs when a single habitat patch is split into two or more smaller patches. This ultimately leads to a disjointed ecosystem, oftentimes with man-made barriers

between multiple habitat areas that previously existed as one. Diverse, but equally effective, causes of habitat fragmentation include urban development, agriculture, industry, and commercial logging and grazing (Dansereau 1957). As such, the rate of habitat fragmentation has increased in proportion to the human population and, since the last half of the twentieth century, has become a major environmental reality and concern. As the destruction and division of habitats has increased, a vast amount of studies observing habitat fragmentation effects on species richness and diversity have been conducted. Their results have led most biologists to agree that habitat fragmentation has a wide range of negative effects, including those on species-area relations (Lindenmayer and Fischer 2006). Most species require a minimum viable area to thrive and survive, though specific area sizes differ between species (Schaffer 1981). In a patchy habitat, however, that need has a much smaller likelihood of being met. Studies by Preston (1962), MacArthur and Wilson (1967), and more have shown that decrease of habitat size generally equals a decrease of species richness, while larger habitat fragments will support a greater number of species.

Because habitat fragmentation poses such a threat to global biodiversity, it is important to understand its patterns and mechanisms; only then can determination of an appropriate and effective mitigation response be possible. Often, studies to this end have been conducted on a grand scale, using adjacent national parks (Rivard et al. 2000) or large sections of the rainforest (Laurance et al. 2002) as the localities upon which the long-term effects of fragmentation on a wide variety of macroscopic fauna is observed. It is certainly possible, however, to examine the effects of habitat fragmentation using a much smaller magnitude of study (Lindenmayer and Fischer 2006). Algal communities are ideal mediums by which to quickly and effectively observe the workings of habitat fragmentation without needing large amounts of space or time.

Algae of the division Bacillariophyta, in particular, are extremely well-suited subjects of a small-scale habitat fragmentation study. Commonly called diatoms, each organism is composed of two linked valves and silica walls that allow large samples to be easily preserved and studied over long temporal periods with little difficulty (Stoemer & Smol 1999). Environmentally sensitive, diatoms are present in nearly all aquatic ecosystems, usually as one of the most species-rich components, and possess one of the fastest regeneration spans of all biological indicators (Stevenson and Pan 1999). A mature community of diatoms can easily form over a few weeks' time and need very little space to do so. Diatoms have also mirrored the expected reaction to habitat fragmentation. In a previous study in diatom sensitivity to substrate size variability (1977), Patrick found that the number of species that colonized a 625 mm^2 tile was significantly greater than the number of species that colonized both a 36 mm^2 tile and a 9 mm^2 tile, with between 23 and 46 diatom species on the larger tile when compared to between 1 and 3 species on the smaller tile.

Another study into the effects of habitat fragmentation on these small organisms was initiated using the Maple River diatom community at the University of Michigan Biological Station Stream Lab. Specifically, we wanted to examine how varied substrate size would affect diatom colonization and growth on three different-sized substrates. In keeping with past research and commonly accepted suppositions, we hypothesized that, as habitat size decreased, so too would diatom species richness. The use of diatoms as our experimental subject was ideal for the amount of time we had available to conduct such a study in habitat fragmentation.

MATERIALS AND METHODS

Experiment location

We conducted the bulk of our experiment at the University of Michigan Biological Station Stream Lab, located on the east branch of the Maple River in Pellston, MI. The Stream Lab is a specialized facility that diverts a small but continual amount of water from the Maple River onto a research pad, where it can be pumped through one or many streams for academically exploratory purposes before being returned in a relatively unaltered state to the Maple River. The temporary diversion does not seem to have any detrimental effect on diatom species health (Edwards 2003).

Experimental design

A pre-arranged pump, barrel, and faucet system to further divert river water into several gutters was utilized on the Stream Lab research pad. We obtained three sets of different-sized tiles to act as fragmented habitat patches. The largest tile served as an unfragmented habitat, with a length and width of 10 cm x 3.5 cm. The medium-sized tiles and smallest tiles shared the same total square area as the largest tile, 35 cm^2, but that area was split evenly between two pieces and four pieces of sizes 5 cm x 3.5 cm and 3.5 cm x 2.5 cm, respectively. Three gutters served as the artificial streams into which we placed three sets of different-sized tiles. Each tile was uniformly spaced one centimeters from others of its size and 10 centimeters from tiles of a different size. The tiles were randomly ordered so that each tile size would fill a position upstream, midstream, or downstream only once, culminating in nine total plots. Between each replicate stream, we held water flow constant at approximately 115 cm^3/second, and such basic environmental conditions as natural precipitation addition and sunlight were similar enough that the only factors varied were tile size and position in stream. Two women's stockings were placed over the primary entering water pump to filter out river particulates.

Data sampling and preparation

The experiment was left undisturbed for fourteen days, beginning July 18, 2008, to allow for algal growth. No conditions or variables were altered except the pump filter, which we cleaned and changed daily. On August 1, we harvested the algae that had accumulated on the tiles using a razorblade to scrape clean the tops of each tile. Per each replicate stream, algal growth from the two medium-sized tiles and four small-sized tiles was combined into one collective sample per tile size so that only habitat size, not island proximity, would ultimately be examined. After the algae was collected, we cleaned each of the nine samples according to the Van Der Werff method (1955), and permanent diatom slides of each stream plot were made.

Data collection and analysis

Data collection involved identifying, to species-level, 500 diatom valves along a single, randomly-placed transect on a diatom slide from each plot. This was most easily accomplished using an oil immersion lens of 1000X magnification. Diatom species were identified by aid of the four-volume Bacillariophyta collection *Sußwasserflora von Mitteleuropa* (Krammer & Lange-Bertalot 1986). Once collected, data from each plot was analyzed in a variety of manners, the most significant based on tile size using the Shannon-Weiner Diversity Index. One-way ANOVA tests were then run to compare our mean SWDI values and mean species richness between tile sizes. A master list of diatom species found was also compiled to conduct an analysis of community uniqueness using the Bray-Curtis Similarity Index. All data and its analyses were compiled in the provided Appendices.

While harvesting algae, we additionally observed that a tile's position along the artificial streams seemed to have an effect on the amount of algae growing on it. Tiles downstream had a noticeably greater macroscopic amount of algae covering them than upstream tiles. This prompted us to additionally question if a tile/group of tiles' stream position may also have had an

effect on species richness. We conducted an additional Bray-Curtis Similarity Index test dependant on position in stream and independent of tile size to further examine this observation.

RESULTS

Richness and abundance of species

Using the Shannon-Weiner Diversity Index, we found that species diversity between different tile sizes remained fairly constant, varying by a maximum of 0.1094. Our greatest difference in species diversity was between the medium and small tiles (Figure 1b), which varied by 0.2008. Mean species richness decreased by 4 species between the largest and smallest tiles, which can best be visualized in the graph in Figure 1b. Table 1 summarizes the results of both computations. None of these differences, however, were statistically relevant. T-tests by means of a oneway ANOVA supported this observation; no statistical difference (where $p < 0.05$) between the three tile sizes was found in an analysis of mean SWDI values and mean species richness. That the SWDI results are larger rather than smaller do, however, indicate a higher diversity of species on each size of tile in general. No one tile size shared the highest diversity and mean number of species, but the smallest tiles collectively held both the smallest mean number of species and the least amount of diversity as defined by the Shannon-Weiner Index (Figure 1a).

Table 1: Mean Shannon-Weiner Diversity Index Analysis and Mean Species Richness

Tile Size	Shannon-Weiner Index Mean Value	Mean Species Richness (spp.)
Large	2.2921	22.333
Medium	2.3626	21.333
Small	2.1618	18.333

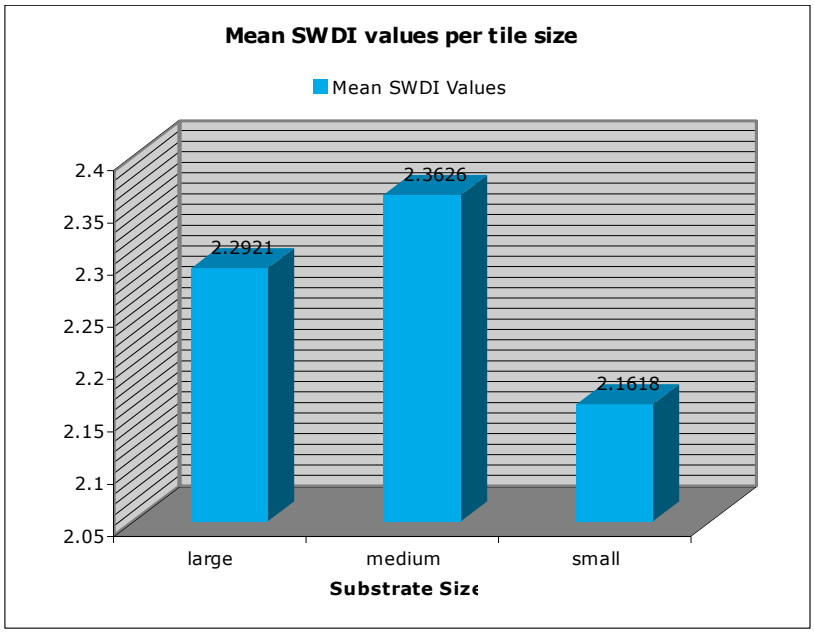


Figure 1a: Mean SWDI Values

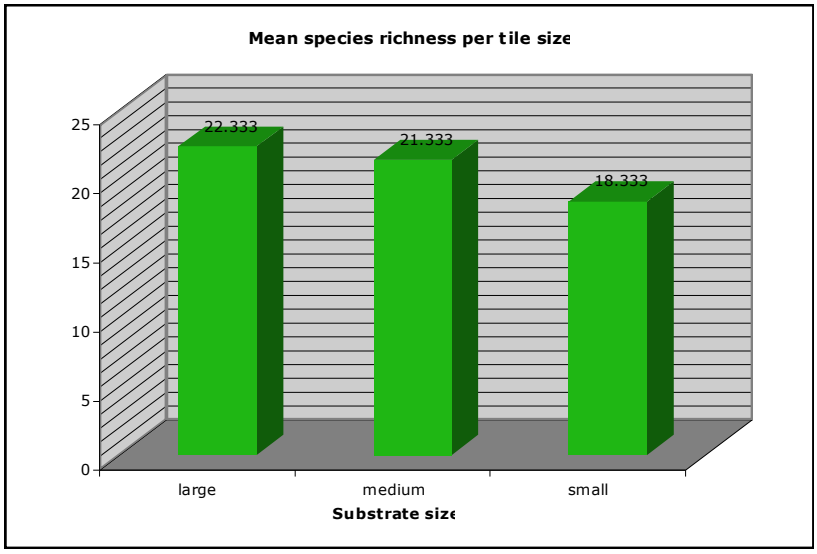


Figure 1b: Mean Species Richness

Unique species comparison

Taking into account the relative proximity of community diversity across different-sized substrata, as indicated by our SWDI results, we utilized the Bray-Curtis Similarity Index to

compare the uniqueness of species between the different tile sizes, the results of which are summarized in Table 2. In the Bray-Curtis Index, two compared tiles with a resulting value closest to zero are most dissimilar, while those closer to one are most similar. Our test results were concentrated between 0.1240 and 0.2052. The Similarity Index, therefore, revealed that uniqueness between species present on different tiles was markedly great no matter which tile sizes were compared. The greatest species contrast was between the large and medium tiles, with a value of 0.1240. The species compared between the medium and small tiles were the least dissimilar, though a value of 0.2052 is still highly dissimilar in itself.

Table 2: Bray-Curtis Similarity Index Results; Habitat Size

Tile Size Comparison	**Bray-Curtis Index value**
Large vs. Medium	0.1240
Medium Vs. Small	0.2052
Large vs. Small	0.1729

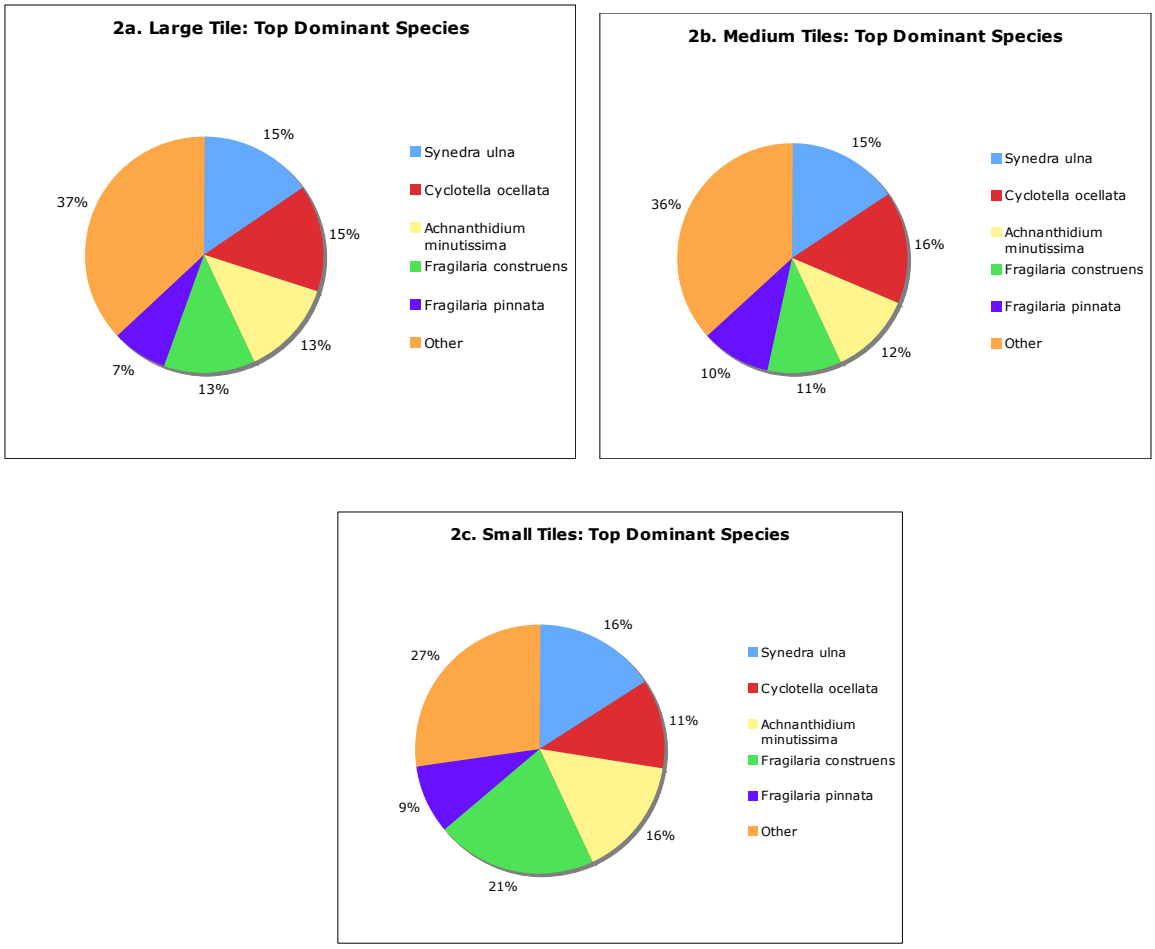
Initial diatom presence observations

We observed 56 diatom species total between the different-sized tiles, a complete list of which can be found in Appendix III. Twenty of these species, including the top dominant species, were found on all tiles regardless of their size; 36 species were unique to one or two different-sized tiles. An eclectic collection of nine species, including *Achnanthes laevis, Cymbella microcephala, Eucocconeis flexella, Fragilaria constricta, Stauroneis phoenicenteron, Navicula capitata,* and *Reimeria sinuata* were collectively found on the largest blocks. The medium-sized tiles held ten unique species, including a multiple *Amphora* and *Achnanthes* species and a few larger species such as *Nitszchia frustulum, Neidium ampliatum, Frustulia rhomboids,* and *Amphipleura pellucida*. The smallest tiles held the fewest amount of unique

species, with the five species concentrated between two *Navicula* species, *Gomphonema intricatum, Fragilaria ulna,* and *Caloneis bacillum.*

Species dominance

Our most dominant species across the large, medium, and small tiles were *Synedra ulna, Cyclotella ocellata, Achnanthidium minutissima, Fragilaria construens,* and *Fragilaria pinnata.* As Figures 2a - c show, relative abundances of the most dominant species were most similar between the large and medium-sized tiles, while the smaller tiles held a lesser amount of *Cyclotella ocellata* and a greater number of *Fragilaria construens. Syndra ulna* maintained top dominance across all tile sizes.



Figures 2a-c: Relative amounts of dominant species on the large, medium and small tiles

The combined amount of these fives species made up 63% of the total diatom community on the large tiles, 63% on the medium tiles, and 73% on the smaller tiles. The presence of some species varied greatly. *Cymbella cistula* was among the most abundant species on the large and medium tiles, its presence alone making up 5.5% and 4.8% of the total abundance on the large and medium tiles, respectively. On the small tiles, however, only one *Cymbella cistula* frustule was recorded, encompassing only 0.14% of the total diatom population.

Stream position

A mean species richness analysis to test our question of stream position on diatom species richness and diversity did not reveal any large or seemingly relevant differences between number of species and stream position. Tiles upstream, midstream, and downstream held mean numbers of species of 19.3, 19.6, and 22.6, respectively, the only noteworthy difference being between the tiles in a downstream and upstream position. Use of the Bray-Curtis Similarity Index, however, indicated that actual species uniqueness between downstream and upstream tiles was more similar than dissimilar, with a value of 0.5514. The test additional revealed that all comparisons between stream position, though dissimilar, was not as distinctive as the Bray-Curtis test of species uniqueness across tile size, with values ranging between 0.2967 and 0.5514.

Table 3: Bray-Curtis Index Results Comparing Tile Stream Position

Tile Position in Stream	**Bray-Curtis Index Value**
Upstream vs. Midstream	0.3144
Midstream vs. Downstream	0.2967
Upstream vs. Downstream	0.5514

DISCUSSION

Richness and abundance of species, including unique species comparisons

Our results indicate that substrate size had no significant effect on diatom species richness, therefore not statistically agreeing with previous studies into the effects of fragment size on species richness and diversity (Fahrig 2003). This withstanding, our data did, however, show a pattern in which the smallest-sized tiles consistently held the smallest mean number of species, total number of unique species, and the least amount of diversity as defined by the Shannon-Weiner Diversity Index. In contrast, species richness and diversity was fairly interchangeable between the large and small tiles; where the large tile had the greatest mean number of species, the medium tile had the highest level of diversity. This suggests that the medium tile, though half the size of the biggest substrate, may still have possessed a large enough surface area to fill the requirements of a diatom community's minimum viable area. It is entirely possible that, when compared to the average size of a diatom, the 17.5 cm^2 area of one medium tile may not seem fragmented at all.

In fact, some studies postulate that habitat fragmentation effects will only become truly apparent when dealing with significantly smaller patches that make up just 20 – 30% the average habitat on the landscape (Fahrig 2003), possibly clarifying why only our smallest tiles held the most noticeable differences in species richness and diversity. In a study completed in fragmented Australian territories, however, a pattern was suggested in that, although the larger land patches held a greater number of species, every patch, regardless of size, recorded a different mix of species (Freudenberger 2001). This could explain why even the smallest tiles held several

species that did not inhabit the other tile sizes and emphasize the importance of even the smallest habitat patches in conservation efforts.

Diatom presence and species dominance

In a 2003 study of Maple River diatoms, *Fragilaria* and *Achnanthidium* species were among the most abundant genera near the Stream Lab (Edwards), keeping in consistence with our results. Additionally abundant in headwater streams are *Fragilaria* species (Biggs 1996), which accounts for their presence in the Maple River. *Synedra ulna* is also common to a variety of freshwater aquatic habitats in which attachment to a substrate is necessary (Patrick 1966). In the same 2003 Maple River study, however, the *Cyclotella* genus was identified on only one collection date, and it was not nearly as abundant as it was on our tiles. *Cyclotella ocellata* is typically a common planktonic lake alga not commonly found in streams (Canter-Lund & Lund 1995). Its dominant presence in the Maple River samples is intriguing and would require further studies.

The presence of *Cocconeis placentula, Achnanthes species,* and *Planothidium* species on each substrate regardless of size is fairly typical in representations of early-colonizing diatom communities (Patrick 1977). In such cases, the first substrate colonies are two-dimensional and include flatter species like those aforementioned. Competition for space encourages the subsequent growth of a three-dimensional community that includes vertically-growing species like *Synedra ulna.* Additionally, *Gomphonema* species only become plentiful in a fully matured community (Patrick 1977). From the dominant amounts of *Synedra ulna* and *Fragilaria* species in our results, as well as *Gomphonema*'s presence in most of the plots, it seems that the diatom community was already moving into the stages of a three-dimensional community when we collected samples. That *Cymbella cistula* had such apparent difficulty colonizing the smallest tile

size, appearing only twice in comparison to 86 and 76 times on the large and medium tiles, respectively, could perhaps be explained in terms of habitat area competition in an increasingly three-dimensional colony.

Stream Position

Though we ultimately did not determine a large difference in species richness and diversity between tiles upstream, midstream, and downstream, some discussion of the distinctly visible differences between the tiles pre-collection that prompted such an additional query is necessary. Past studies have shown that current does have an effect on the microdistribution of algae in streams. Diatoms, in particular, are somewhat susceptible to disturbance by current, and some researchers even hold that current is the leading factor affecting algal community dissimilarities among subtrata in the same habitat (Stevenson 1996). It is possible that the current was flowing most intensely at the initial outpour of water into the artificial streams, therefore washing the macroscopic algae and some diatom species down the stream to a point where they could more easily settle the farthest tiles. As our results show, this may not ultimately lead to a great level of species uniqueness, because the same diatom species would have the opportunity to settle all three stream positions. It could, though, possibly affect species richness if a strong enough current was present.

Experiment Limitations

Several factors beyond habitat size could have influenced our results. While gathering data, we only recorded 500 diatom valves along a single transect for each tile plot, but it was easy to see a number of additional species present that did not fall along the transect. Therefore, they were not considered in cumulative species richness and diversity assessments, while they in fact may have had a significant effect on these variables in the diatom community. Substrate size

was another major experiment limitation. 35 cm^2 is to a diatom what a 4.8 mi^2 area of forest approximately is to a deer. The exception between the comparison is that diatoms likely covered every square centimeter of the tile substrates. Though the tile fragments may have seemed small by human standards, even the smallest tiles may in actuality have been too unrealistically large to have many effects on a community of diatoms.

Another limitation of the study was the amount of samples that were ultimately taken. We only observed one point in the newly-formed diatom community's story. In doing so, it was impossible to examine the dynamics of habitat fragmentation on species richness. Over time, competition for resources and space affects diatom species richness and diversity on various-sized substrata (Patrick 1977). Had we had the opportunity, additional colonization time and sample days would have added valuable insight into the study.

Conclusions and looking forward

From our experiment, we were able to observe and explore various patterns that habitat size and restriction produce in species richness, diversity, and dominance. In the future, however, I would recommend more studies be done into the matter. Aside from Patrick's experiments, seemingly little research has been conducted into the specific effects of substrate size on diatom communities. Just because our results were ultimately statistically insignificant in no way implies that those of the future will be the same.

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APPENDICES: See Excel spreadsheets.