

# Diatom Diversity and Community Structure Along a Thermal Gradient in the Maple River of Northern Michigan

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## Abstract

The effects of temperature on diatom diversity and community structure were investigated along a naturally occurring thermal gradient (9-19 °C) in the Maple River, Pellston, Michigan, USA, by allowing diatoms to accumulate on artificial substrates placed at 2-m intervals along a 14 m transect between 07 and 22 July 2006. Diatom species composition was examined and total species richness, relative abundance, and the Shannon-Weiner species diversity index were calculated. A Z-test showed a significant difference in mean species richness between sites 0 and 8 m, 8 and 14 m, and 0 and 14 m. Shannon-Wiener diversity indices calculated for 0 m, 8 m, and 14 m showed no increase in species diversity along the gradient. Other factors such as water chemistry, light intensity, pH, or water velocity most likely influenced species diversity and composition. As temperature increased, species richness also increased but species diversity did not.

## Introduction

Diatoms are unicellular algae that have adapted to a wide range of environments. These autotrophic organisms are highly specialized, and many taxa have specific environmental ranges that they can tolerate, such as availability of nutrients including nitrogen, phosphate and ammonia, as well as organic material.<sup>1</sup> Studies have shown that other factors affecting diatom communities include water velocity, pH, amount of light, substrate type, and temperature.<sup>2</sup> Diatom communities change species composition and abundance because of variables within a microhabitat.<sup>3</sup> Since each species has different tolerances and preferences, diatoms are good indicators of environmental conditions.<sup>3</sup>

Diatoms are present and thrive across many environments ranging from cold arctic waters to hot thermal springs. This specialization among diatom taxa is also evident over small-scale thermal gradients. One study has shown a significant increase in diatom species diversity and number over a gradient of 10°C.<sup>4</sup> The effect of temperature on algal growth has been discussed by multiple authors, but these studies primarily focus on diatom response to climatic changes over a large span of time.<sup>5,6</sup> Previous studies concerning thermal effects have focused on aquatic communities along gradients caused by hot springs or industrial runoff.<sup>7</sup> It is less clear how diatoms respond to thermal gradients created as cold waters enter a temperate stream. This experiment was implemented to assess the

degree of sensitivity diatom communities have to small-scale changes in temperature.

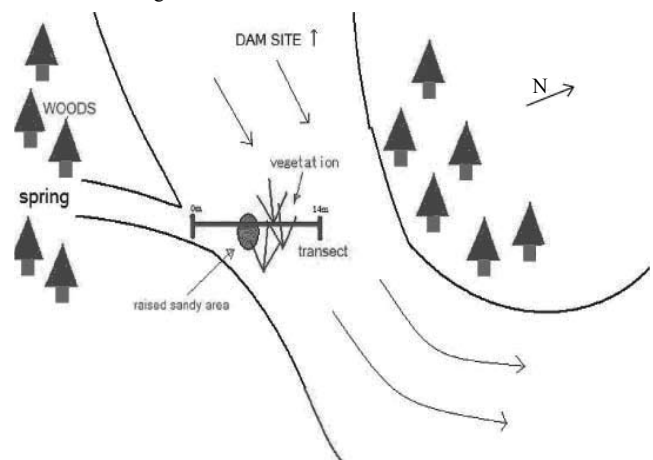
The aim of this study was to investigate benthic diatom communities along a naturally occurring thermal gradient, formed by a cold spring-fed stream flowing into the warmer Maple River. Specifically, diatom diversity and community structure were examined along this thermal gradient. It was hypothesized that diversity in the diatom community would increase with temperature and that the composition would change across the gradient.

## Methods

On July 7, 2006, a 14 m transect was laid out along a naturally occurring thermal gradient (9 °C-19 °C) from a cold spring-fed stream that enters the southeast segment of the Maple River south of the Maple River Dam (lat 45.25°N, long 84.45°W; Fig. 1). This transect was divided into 2-m intervals creating a total of eight sites. At every site, three wooden dowels, each 5 mm in diameter, were firmly placed into the sediment 3 cm from one another to act as artificial substrates for colonization. The sites varied in water depth from approximately 10-50 cm. Each dowel was immersed in different amounts of water, but all of the dowels were in at least 10 cm of water.

The substrates were left in the water for a period of 15 days to allow for sufficient establishment of diatom communities. Water temperature was taken every three days at various times during the day to account for potential diurnal fluctuations in

**Figure 1:** Transect in Maple River south of Maple River Dam, Emmet Co., Michigan, starts where a cold, spring-fed stream enters the river (left). Location of sand bar and vegetation are marked.



the thermal gradient. General observations were made concerning the aquatic flora surrounding each site as well as stream topography. Water chemistry data (dissolved nitrate, phosphate, calcium, and ammonia levels) were analyzed at the University of Michigan Biological Station Water Chemistry Lab the week of July 17, 2006. Water flow was measured by timing a blade of grass from the beginning of the transect to the end on July 19. Light intensity was measured with a photometer on July 19 and on July 25, and broad-range pH was measured using Whatman pH indicator paper (range 4.5-10; 0.5 unit increments).

On July 22, 2006 the dowels were harvested individually by placing a plastic whirl pack around the dowel to ensure that loosely attached periphyton was not lost. To prepare the diatom slides, potassium dichromate was added to 10 ml of material that came off of the dowels, in order to remove the organic material. After decanting, cover slips were prepared and mounted using Naphrax®.<sup>8</sup> Two cover slips of diatoms were prepared from every dowel except for the 14 m site, from which four cover slips per dowel were prepared due to the small amount of diatom community growth. Using a Spencer light microscope, one slide from each dowel was examined under 1000x magnification under oil immersion and the first 500 valves encountered were identified to the lowest taxonomic level (four slides from the 14 m site were needed to count a total of 500 valves). Due to time constraints, three replicate counts were only made at the 0, 8, and 14 meter sites representing the beginning, middle, and end of the transect. One count from each of the remaining six sites was made and no average calculated. Diatoms were identified to species level using Krammer and Lange-Bertalot (1986-1991), Hansmann (1973), and Patrick and Reimer (1966).<sup>8-13</sup>

Total species richness, relative abundance, and the Shannon-Weiner species diversity index,<sup>14</sup> were calculated in Microsoft Excel for Windows for the 0, 8, and 14 m sites (from the coldest to warmest site) because these had three replicates counted at each site and averages could be calculated. A Z-test was used to determine statistical significance between the mean species richness at the 0, 8, and 14 m sites.

The level of diversity in a community can be measured in different ways. Species richness is the simplest way to measure diversity. It is a count of the number of different species found in a particular sample--a sample with higher species richness has greater diversity. We can also calculate the relative abundance of each species in a sample--relative abundance refers to the percentage abundance of a particular species by comparing the number of individuals of each species to the total number of individuals in a sample. This gives information about which species are most abundant in a sample. Other diversity measures simultaneously take into account species richness and relative abundance. If two samples have the same number of species, one may be considered more diverse than the other if its species all have similar relative abundances. For example, take two samples that both have a population of 100 individuals of five different species. Sample A has 20 individuals of each species, and sample B has 96 individuals of one species and just one individual of the other four species. Sample A would be more considered to have more evenness, and therefore Sample A is more diverse than Sample B, whose evenness is lower.

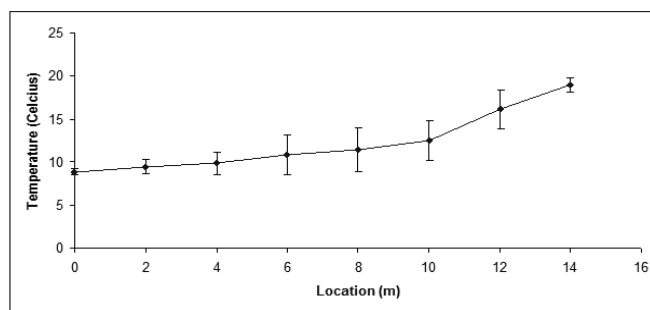
We use the Shannon-Weiner species diversity index to estimate this level of diversity, because it takes into account both species richness and evenness. The Shannon-Weiner index produces a single diversity score whereby a sample's Shannon-Weiner value will be higher with a larger number of species that are distributed with greater evenness. The higher the index value, the greater the diversity. The index is used to compare overall diversity among different communities that have been sampled.<sup>14</sup>

## Results

### *Physical and Chemical Characteristics*

Average temperature increased along the transect (Fig. 2). A definite thermal gradient occurred with the coldest temperature at 0 m (8.86 °C) and the warmest at 14 m (19 °C). Temperatures at 6, 8, 10, and 12 m had a larger standard deviation compared to the other sites (10.86 °C ± 2.34 °C; 11.43 °C ± 2.64 °C; 12.50 °C ± 2.36 °C; 16.14 °C ± 2.27 °C, respectively). The average of the 2 m site was 9.42 °C and for 4 m was 9.86 °C. According to water chemistry data, there was an overall decrease in nitrate and phosphate levels along the thermal gradient. Calcium carbonate levels remained nearly constant and ammonia levels spiked in the middle of the gradient (Fig. 3). The broad range pH taken at each site was almost neutral except at the 8 and 10 m sites where it was slightly acidic (Fig. 4). The mean light intensity was calculated and the data showed a slightly lower light intensity at the beginning of the transect (from 0-4 m) as compared to the end (Fig. 5). A faster velocity was observed at the beginning of the transect but became stagnant at the 6-8 m interval. The transect was disrupted by a sand bar where the water was most shallow. Once past the sand bar, the current increased due to the influx from the Maple River, albeit in a different direction. Water depth varied along the transect with the shallowest being at the opening of the stream and the deepest where the stream enters the Maple River. The depth varied from 10 to 50 cm. There was also varying amounts of vegetation with more occurring on and around the sand bar.

**Figure 2:** Mean temperature (°C, n=5) along transect in Maple River (± standard deviation).



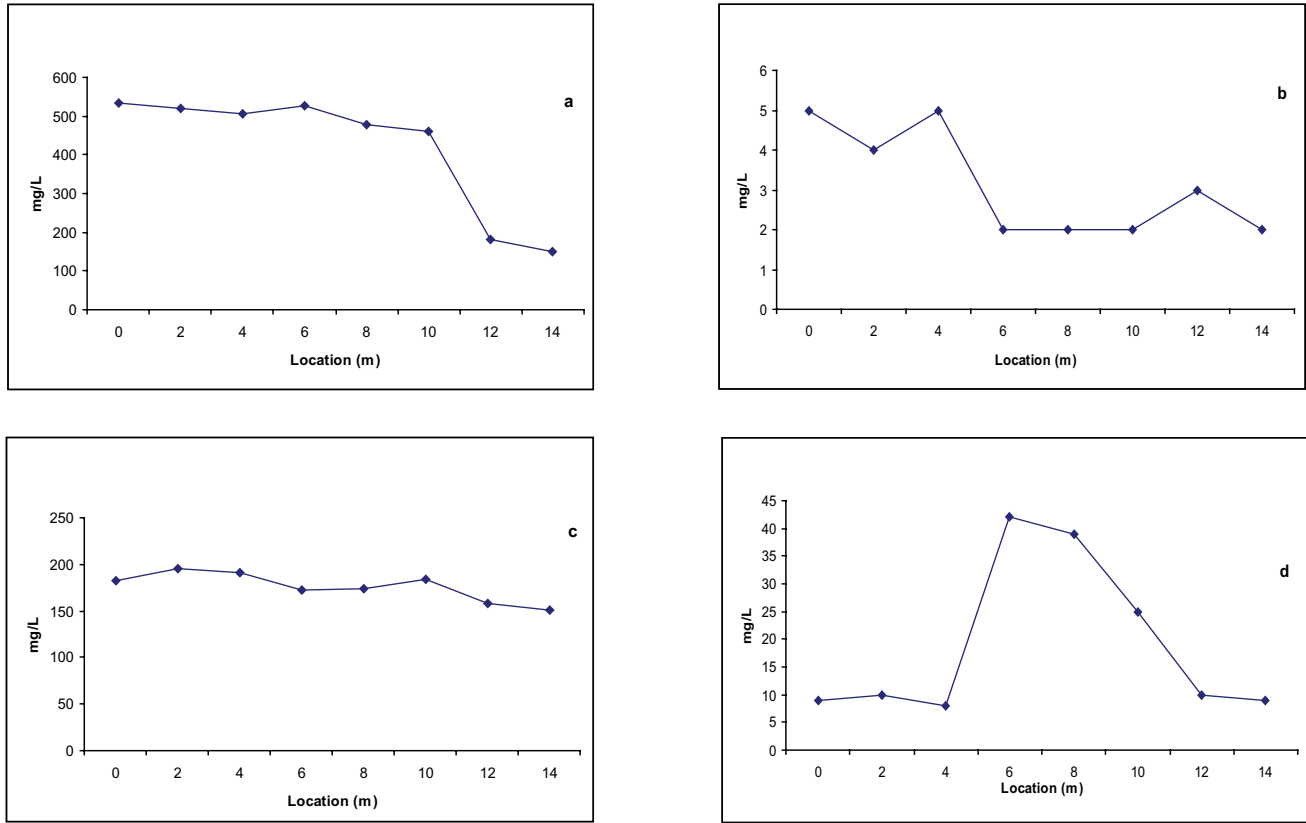
### *Species Composition*

The five dominant species at 0 m were *Martyana ansata* (17.9%), *Fragilaria pinnata* (15.8%), *Melosira varians* (13.4%), *Diatoma hiemale* var. *mesodon* (10.6%), and *Meridion circulare* (7.91%). At 8 m, those dominating were *Fragilaria construens* f. *venter* (22.3%), *Fragilaria pinnata* (12.6%), *Achnanthyidium minutissimum* (12.1%), *Martyana ansata* (10.8%), and *Fragilaria vaucheriae* (7.01%). At 14 m, the dominant species were

*Achnanthydium minutissimum* (9.57%), *Cocconeis pediculus* (9.06%), *Martyana ansata* (8.41%), *Gomphonema intricatum* (6.31%), and *Gomphonema parvulum* (5.93%) (Fig. 6). For each of the dominant species from 0, 8, and 14 m, the change in relative abundance was graphed over the entire gradient (Fig. 6).

the mean temperatures at these sites. However, there were no individuals of this species in the surrounding sites. One study showed that the rarer a species, the more likely it is to have a clumped distribution.<sup>15</sup> The environmental conditions at 8 m, including factors other than temperature, such as habitat complexity and nutrients, could have been precisely what *F. construens f. venter* needed, and thus encouraged its growth.

**Figure 3:** Dissolved nutrient levels along gradient a) Nitrate b) Phosphate c) Calcium carbonate d) Ammonia.



*Species Diversity*

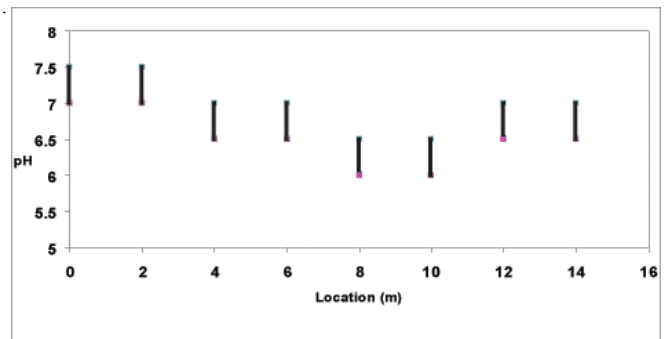
Species richness increased with increasing temperature. A Z-test showed a significant difference in mean species richness between sites 0 and 8 m, 8 and 14 m, and 0 and 14 m ( $p = 0.007$ ,  $Z = 1.64$ ;  $p = 0.001$ ,  $Z = 1.64$ ;  $p < 0.0001$ ,  $Z = 1.64$ , respectively). The Shannon-Wiener diversity indices calculated for 0, 8, and 14 m showed a higher species index value at 0 and 14 m and lower at the 8 m site. The index was 2.61 at 0 m, 1.97 at 8 m, and 3.12 at 14 m (Fig. 7).

**Discussion**

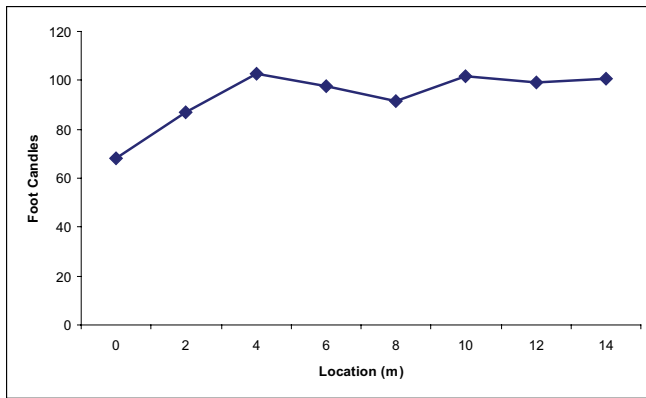
Species diversity is characterized by species richness and evenness, the influence of both factors overall diversity is determined using the Shannon-Weiner index. Since the Shannon-Weiner index did not follow the same trend as the species richness at 8 m, this suggests that the diatom communities among sampling locations were uneven. *Fragilaria construens f. venter* was the dominant species at 8 m and present only at 6 and 8 m, causing a drop in species evenness and the diversity index compared to the 0 and 14 m sites. The optimal temperature range for *F. construens f. venter* could be from 10.9 °C to 11.4 °C,

These other factors could have all had an effect on which species colonized each location, as well as how diverse the community became. For example, the influx from the Maple River allowed for a greater variety of immigrants to potentially colonize the artificial substrates. The presence of the sand bar and increased vegetation is likely to also have had an impact on the concentration of nutrients, pH, and habitat availability, due to water recharge and plant metabolism.

**Figure 4:** Broad range pH along gradient



**Figure 5:** Light intensity by location.



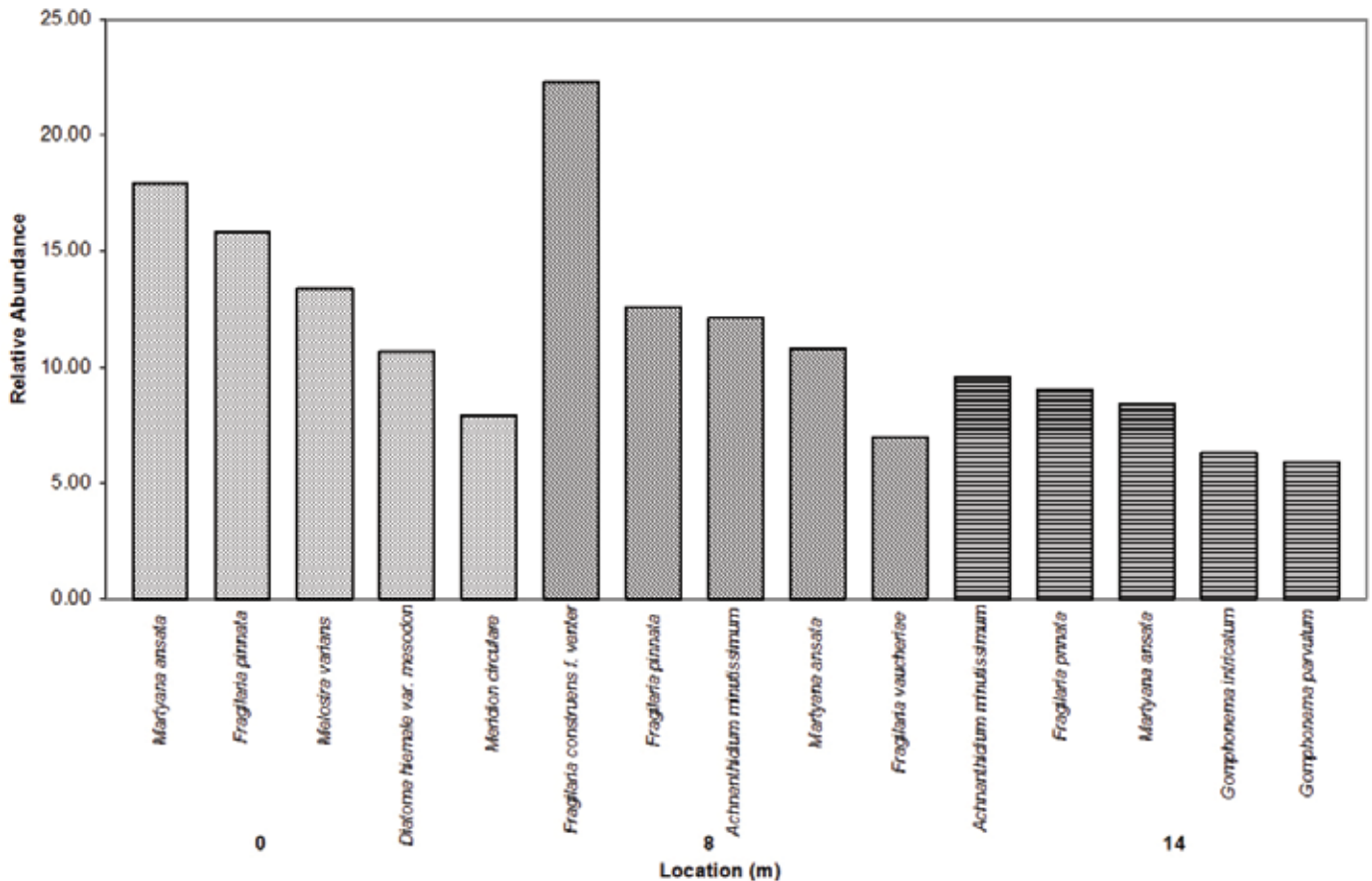
Regarding the water chemistry, calcium carbonate did not change significantly over the gradient, so it was unlikely to influence differences in community structure. Dissolved nitrate and phosphate levels both decreased over the gradient and ammonia levels spiked around the 6 to 8 m interval. These nutrients could have had an effect on the diatom communities, especially nitrogen and phosphate, which can both be limiting to the growth of diatom communities.

Another factor that could have an effect on the diatom communities was the amount of light available at each location. There was a lower light intensity at the beginning of the transect, which was also the coldest area. Temperature and light intensity are closely related with one often being a direct result

of the other; if more light is available, then more energy can be absorbed, thus increasing temperature. *Gomphonema parvulum*, *Synedra ulna*, and *Fragilaria vaucheriae* have been known to proliferate with more light.<sup>16</sup> In this experiment, *G. parvulum* and *S. ulna* follow this trend, but *F. vaucheriae*, which was more dominant at the 0 m site, does not. This could be due to any of the variables mentioned earlier, or perhaps this species prefers colder water. At 0 m there was more shade due to tree coverage, which could have made the water temperature colder. *Cocconeis pediculus* may have responded to temperature as well, showing a dominance later in the transect. According to Lowe et al. (1986), *Meridion circulare* has been shown to associate with colder temperatures.<sup>16</sup> The data showed that *M. circulare* was most abundant at the 0 m site and *Melosira varians* showed this same trend. This could be because both of these species prefer colder water.

Moreover, the curved structure of *Cocconeis pediculus* allows it to strongly attach to substrates in faster moving water. There is a slight trend in the data showing this genus to be more prominent at the 0 and 14 m sites, where the velocity was greater than the 8 m site. Lowe et al. (1986) supported the idea that *Achnanthes minutissimum* prefers high-velocity water.<sup>16</sup> Yet in the current study, *A. minutissimum* was dominant in the 14 m site, which had a slower velocity than the opening of the stream. One possible explanation is that *A. minutissimum* may have been absent from the pool of available immigrants around the colder end, whereas merging with the Maple River allowed the warmer end to contact many more species.

**Figure 6:** Relative abundance of the five most dominant species at 0, 8, and 14 m.

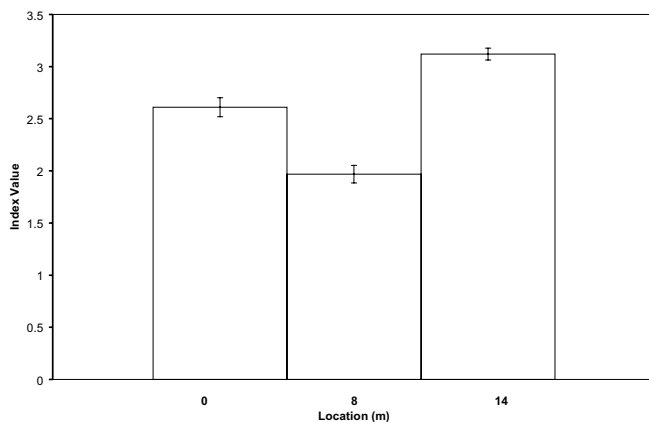


Along with the possible influx of species from the Maple River, the current may have also brought other organisms that could have affected the diatom communities present. Grazers prefer diatoms because they are very nutritious and grazers may influence the composition and diversity of a diatom community.<sup>17</sup> If grazing can keep diatom populations small enough that individual species are not competing for limiting resources, then a larger variety of species can exist in the same area due to less interspecific competition.<sup>18</sup>

The choice of substrates in this experiment was an important factor. Since the dowels were not part of the natural environment, it was not expected that they would yield an exact representation of the natural diatom communities present across the thermal gradient. Nevertheless, it has been shown that representative communities will form on artificial substrates.<sup>19</sup>

This experiment tested the effect of temperature, a single variable, on diatom communities in their natural environment. There were many other parameters besides temperature that varied along the gradient, making it difficult to attribute specific change in the community to temperature alone. Despite the difficulty in testing a single variable, it was important to consider how the variables affected the diatom community structure, and more importantly, to examine what effect they have on diversity. Although the diatom communities at different points along the thermal gradient shifted in species composition, it was hard to identify the direct cause of these shifts.

**Figure 7:** Shannon Diversity index ( $\pm$  standard deviation) calculated for 0, 8 and 14 m.



A controlled experiment could be designed to minimize other variables and focus directly on temperature, but this approach could potentially produce diatom communities that are not representative of the Maple River.

Temperature was an interesting factor to look at because even though the thermal gradient was only 10°C, there was a significant change in diatom community structure over a short distance. Changes in structure of an ecosystem start at the microhabitat level and a slight change in a single environmental factor like temperature could restructure an entire diatom community. Investigating the nature of these small scale ecosystem changes may offer insights into the dynamics of human-environment interactions at a local scale.

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