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EFFECTS OF STREAM VELOCITY ON DIATOM COMMUNITY STRUCTURE

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Effects on diatom community structure under high and low current velocities over a period of ten days were observed. Artificial stream channels were supplied with water directly from the East Branch of the Maple River. One current velocity was adjusted be ambient to a point chosen in the East Branch of the Maple River at 15cm/s and a current velocity was adjusted to be 3.75cm/s (¼ of the ambient). Significant changes (p=.027) were observed in the Shannon-Wiener diversity with respect to current velocity. No significant changes were observed in the Shannon Wiener diversity with respect to time. Significant changes (p=.007) in the relative abundance of the genus *Synedra* were observed with respect to current velocity. Significant changes (p=.011) were observed with respect to time in the relative abundance of the genera *Navicula* and *Cymbella* (grouped together due to taxonomical limitations).

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Introduction

Freshwater diatoms play an extremely important role in stream and river ecosystems. Studies have shown that diatoms together with other forms of benthic algae are the primary source of energy in third to sixth order streams (Stevenson 1999, 10). Additionally, diatoms transform inorganic chemicals to organic forms and are responsible for much of the oxygenation of surface waters in streams (Stevenson 1999, 10). Given that diatoms are a primary food source in stream ecosystems, it is important to consider how diatom community structure affects stream ecosystems. Past studies have shown that herbivores prefer certain species over others in their feeding patterns (Wendeker 394). Considering that diatoms are a primary food source for many herbivores in streams, the diversity of diatom communities is inevitably linked to the balance of stream ecosystems.

The community structure of diatoms in streams varies greatly based on the complexity of their habitat (Stevenson 1999, 12). Factors influencing diatom community structure are grouped into higher level factors, such as climate and geology, and lower level factors, such as light, pH, temperature and toxic substances (Stevenson 1999,12). Higher level factors can limit the effects which lower level factors may have on diatom community structure (Stevenson 1999,12). Of the lower level factors, light, temperature and current velocity have proven to have the strongest effect on diatom community structure (Patrick 295).

This study looks at the effects of current velocity on diatom community structure. Current velocity proves to be an interesting variable because of the implications that global warming will have on freshwater streams and rivers. Future increases in temperature, induced by global warming, will cause evaporation and evapotranspiration rates to increase, resulting in decreased stream flow. Based on the results of a water balance model, one study done in the New-England/Mid-Atlantic region (assuming annual temperature increases anywhere from 3-5°C in the future) predicted a reduction of 21 and 31% in annual stream flow in autumn and winter within southern and northern sections of this region (Moore et al.).

In order to observe diatom community structure under decreased flow conditions the East Branch of the Maple River was simulated at an ambient and an a lower current velocity. Based on past studies which have increased the stream flow from ambient conditions of a fresh water stream, the diversity of diatom communities at the faster current velocity was expected to be higher than the diversity at the slower current velocity (Wendeker 387). Explanations to such findings are based on the idea that higher current velocities continuously supply diatom communities with nutrients, thus decreasing the possibility that any particular nutrient becomes limiting (Patrick 296). In addition, the continuous carrying off of excretion products in higher current velocities mitigates autoxic effects (Patrick 296). Past studies have also shown that several species are capable of tolerating mechanical stresses of high current velocities well and that species composition differs at higher velocities. Some species, such as *Desmogonium rabenhorstianum*, actually develop a more streamlined morphology at higher current velocities (Patrick 296).

This study looks at both the Shannon Wiener diversity and the relative abundance of species in diatom communities. The Shannon Wiener diversity is a diversity index for categorical data which accounts for species richness and evenness.

$$H' = -\Sigma\, p_i * \ln p_i \qquad (1)$$

Materials and Methods

The study was conducted at the Stream Research Facility in Pellston, Michigan over a period of thirteen days. Water at the Stream Research Facility is constantly pumped from the East Branch of the Maple River through various pumps and then drained back into the river. Due to the fact that the water is pumped directly from the river, such factors as temperature, pH and detritus have little affect on studies done here.

Current velocity was measured near the water intake pump of the Stream Research Facility and taken to be approximately 15cm/s. This ambient current velocity and a slower current velocity of 3.75cm/s (1/4 of the ambient) were then simulated in the Stream Research Facility. Both the high and the low current velocities were replicated three times. The project began on July 21, 2007 and ended on July 31, 2007. Samples were collected three days after the tiles were placed into the stream and two subsequent collections were done in two day intervals following this.

The diatom communities grew on small ceramic tiles in the PVC gutters (flumes) through which the water flowed. One tile was placed at the end of each flume to minimize effects of turbulence. The water from the Maple River was pumped into large plastic bins and then released through eight valves into eight flumes for each container. This was done across six tables, resulting in a total of fourth-eight flumes. The stream channels were placed on a large wooden stand approximately 1 meter above the ground and the three replicates for each velocity were distributed across the entire setup as evenly as possible (see *appendix*). No two replicates received water from the same container. This was done to avoid possibly confounding variables such as a difference in pH or detritus between the bins.

Originally, three velocities were to be replicated four times over a period of four time intervals. However, only three replicates of two velocities over a period of three time intervals were looked at due to time limitations.

Velocity was determined with discharge measurements according to the following formula:

$$Q = v * A \qquad (2)$$

The cross-sectional area of the gutters through which the water flowed was measured to be 26.55cm^2 on average. Setting *v* equal to 15cm/s and 3.75cm/s, one then obtains discharge in ml/s (where 1cm^3= 1ml). The discharge was calculated to be 398.25ml/sfor the high current velocity and 99.56ml/s for the low. In order to decrease human error from the time measurement (performed with a stop watch), the discharge was multiplied by a factor of four and the low discharge was multiplied by a factor of sixteen. Instead of trying to measure 398.25ml in one second one could then measure 4*398.25ml in a period of 4 seconds and 16*99.56ml in a period of 16 seconds. Due to changes in pressure and occasional accumulation of debree within the valves, all current velocities had to be calibrated on a nearly daily basis.

Upon collection, tiles were lifted slightly and horizontally placed into a zip-lock bag while remaining submerged in the water. The tiles could not be lifted out of the water because the assembled diatom communities could have fallen off. The organic matter in the bags was then brought into the lab, poured into beakers and chemically cleaned. Cleaning was done with hydrogen peroxide (approximately 40 ml per sample) and a small amount of potassium dichromate was used as a catalyst. The hydrogen peroxide liquidates all of the organic matter except for the diatom frustules. The diatom frustules were not liquidated because they are made of hydrated silicon dioxide. The remaining yellowish liquid was then poured off after a period of twelve hours, allowing the diatoms to settle at the bottom of the beaker. The process was repeated three to four times until the fluid in the beaker was clear. A pipette was used to take a small amount of frustules from the bottom of the beaker which were dripped onto microscope cover slides and allowed twenty-four hours to dry. Once the water evaporated, the cover slides were heated on a hot plate. Upon heating, the cover slips were taken and placed face down onto a small amount of Naphrax® which was poured onto the cover slides. The slides were then placed on the hotplate and taken off once the Naphrax stopped bubbling. A pair of tweezers was used to apply a gentle amount of pressure, securing the cover slip onto the slide. Pressure was applied to reduce the levels one must later focus through when looking at the diatoms, facilitating the counting process.

Once the slides were permanently mounted the diatoms were counted according to species. Due to encountered time limitations and difficulties with the identification

process of similar species within certain genera, the diatoms were ultimately counted according to genus. Counting was done on a microscopic magnification of 100x.. Keeping the y-coordinate on the slide constant and then moving from right to left across the entire slide, 600 valves were counted for each sample. All species within visibility had to be counted to obtain unbiased results.

After the diatoms were counted an ANOVA univariate statistical test was run with SPSS on all of the data to test for significant changes of Shannon-Weiner diversity and relative abundance with respect to velocity, time and velocity*time (see *appendix*). Descriptive statistics were used to obtain means and standard deviations.

Results

The study was focused on nine major genera found in the East Branch of the Maple River: *Fragilaria, Synedra, Achnanthes, Cocconeis, Cylotella, Planothidium, Cymbella and Navicula (grouped together) and Nitzschia*.

1. Shannon Wiener Diversity

Significant differences* in Shannon Wiener diversity were found between the high and low current velocities (see *appendix*). During the second sampling interval the Shannon Wiener diversity peaked for the lower current velocity and reached a minimum for the higher current velocity. The two Shannon Wiener diversity curves, however, never intersected, as the higher current velocity consistently had a higher Shannon Wiener diversity (fig. 1).

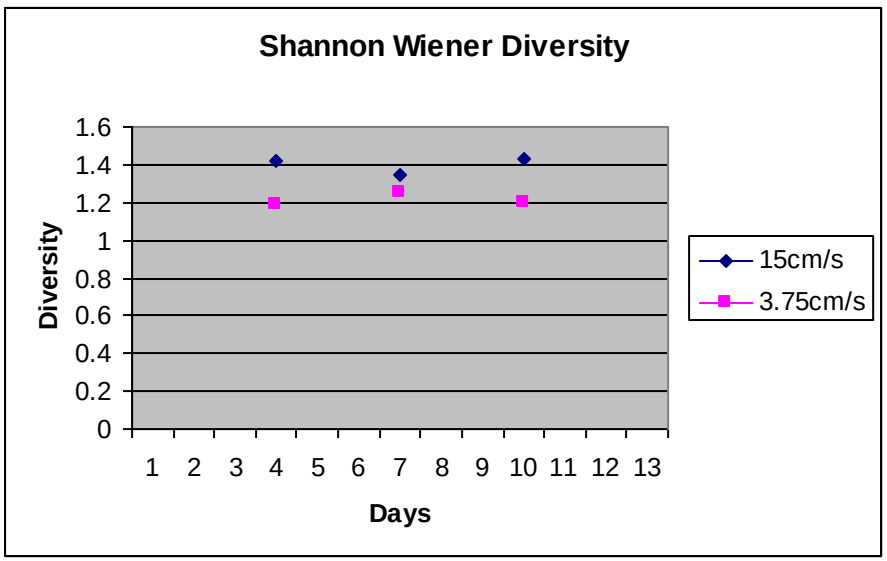

Figure 1

2. Relative Abundance

Out of the eight major groupings only *Synedra* and the group of *Navicula* and *Cymbella* showed significant changes in relative abundance. Synedras were significantly more abundant* in the faster current velocity than in the lower current velocity (see *figure 2*). *Naviculas* and *Cymbellas* were more abundant in the first sampling interval than in the second or third (see figure 2).

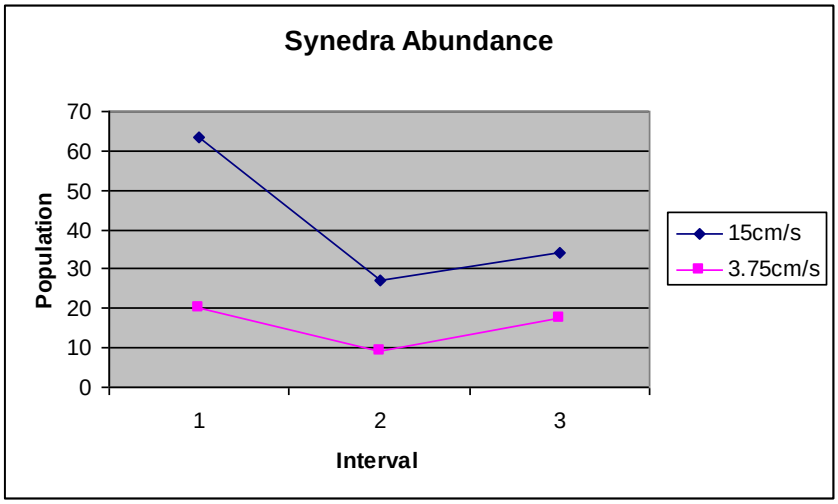

Figure 2

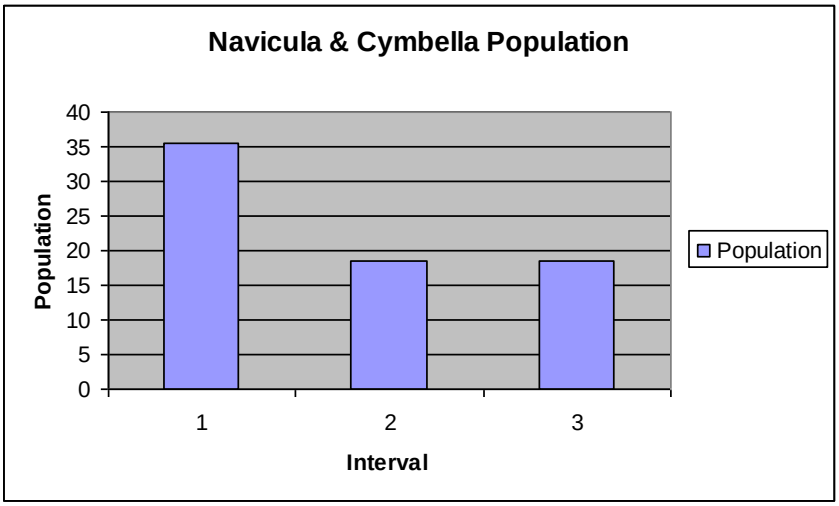

Figure 3

Discussion

The Shannon Wiener diversity of the faster current velocity was higher than that of lower current velocity. This most likely has much to do with nutrient availability and the carrying off of excretion products as previously discussed. While the predicted hypothesis of decreased diversity under decreased stream flow conditions held true, not much insight on the actual community structure can be extrapolated from the findings since they were done on a genus level. Much of the statistical inference power was lost by moving down one classification level. Some studies suggest that most of the variations within community structure can be seen by observing the behavior of those species which are less abundant. Such approaches clearly emphasize the importance of a species-specific data set. Indirectly, this study somewhat confirms such an approach due to the fact that the dominant genus, Fragilaria, showed no significant change in relative abundance with respect to velocity or time.

The fact that there is not a significant change in Shannon Wiener diversity with respect to time is closely related to the distribution of the sampling periods. Perhaps collecting samples at the beginning of the study would have provided a more insightful look into the community behavior of diatoms over time and across the different velocities. Early communities are particularly interesting because of the difference in growth patterns. Diatom communities first develop in a two-dimensional array with a different species composition than at later points in the development stage. With an increasing number of diatoms colonizing the substrate, competition for space increases. Consequently, those diatoms capable of standing on one end and attaching themselves with mucilage pads become more abundant and begin to form a three-dimensional community. Following the development of this three dimensional community, new habitats become available and species diversity is increased (Patrick 292). Certain species, such as *Gomphonema*, are rarely present until this three-dimensional community is developed (Patrick 293).

Being that *Synedras* are impart responsible for the early vertical development of diatom communities and that this particular genus does better in slower current velocities (provided there are hard substrates to which it can attach itself to), the significant

increased presence of Synedras at higher current velocities is an unexpected result (Patrick 291). However, other studies may have referred to current velocities significantly higher than 15cm/s and possibly therefore obtained different results.

Little should be interpreted about the significance of an increased *Navicula* and *Cymbella* population at earlier periods in the community development. The grouping together of these two rather different genera brings forth much uncertainty.

Literature Cited

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Appendix

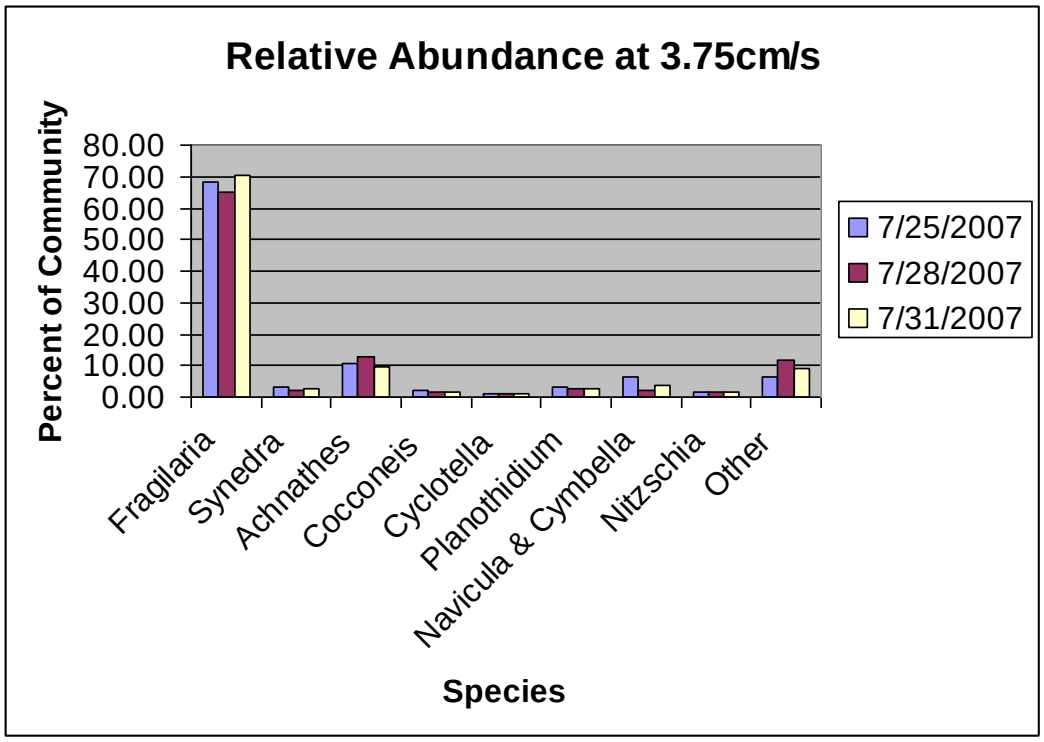

Figure 4

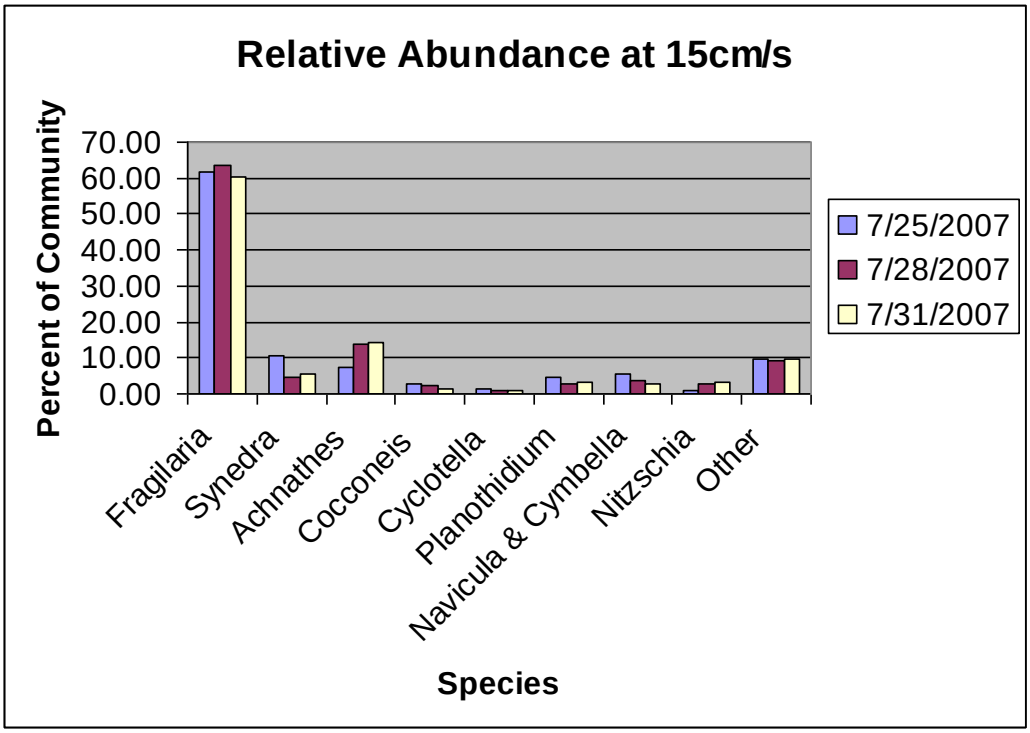

Figure 5

Velocity Time Distribution

	Bins					
Gutters	I	II	III	IV	V	VI
1	A1	B1	C1	A1	B1	C1
2	B2	C2	A2	B2	C2	A2
3	C3	A3	B3	C3	A3	B3
4	A4	B4	C4	A4	B4	C4
5	B1	C1	A1	B1	C1	A1
6	C2	A2	B2	C2	A2	B2
7	A3	B3	C3	A3	B3	C3
8	B4	C4	A4	B4	C4	A4

Figure 6

Letter indicates velocity
Number indicates time (week)
Example: A2 = Velocity A at second week

Bin Setup

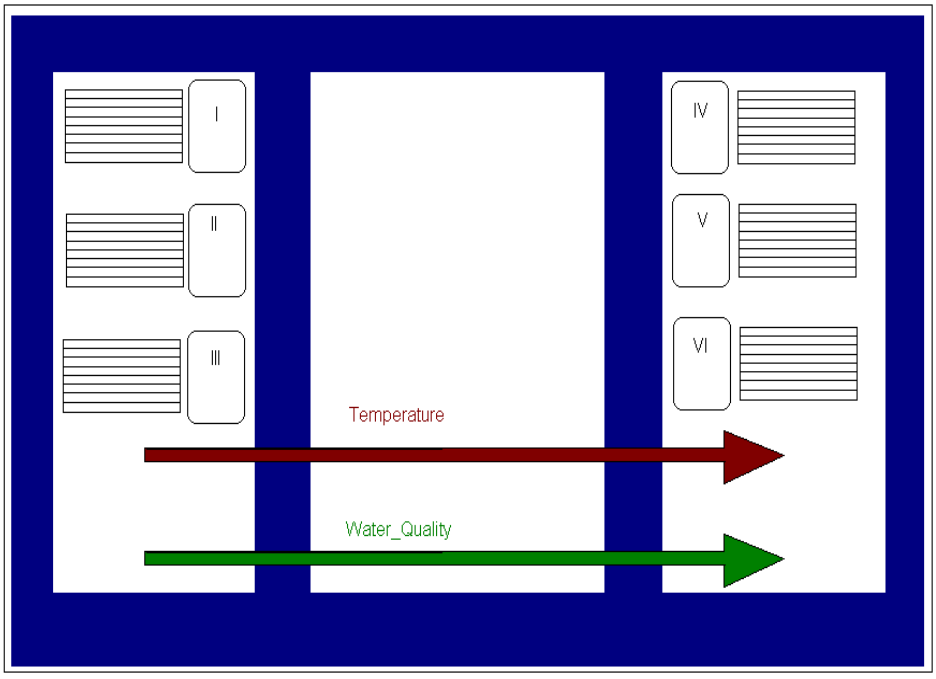

Figure 7

Tests of Between-Subjects Effects

Dependent Variable: Shannon-Weiner Diversity

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.161(a)	1	.161	7.150	.016
Intercept	32.099	1	32.099	1428.702	.000
Velocity	.161	1	.161	7.150	.016
Error	.382	17	.022		
Total	32.971	19			
Corrected Total	.543	18			

a R Squared = .296 (Adjusted R Squared = .255)

Table 1.

Tests of Between-Subjects Effects

Dependent Variable: Shannon-Weiner Diversity

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.001(a)	2	.000	.008	.992
Intercept	32.265	1	32.265	952.333	.000
Interval	.001	2	.000	.008	.992
Error	.542	16	.034		
Total	32.971	19			
Corrected Total	.543	18			

a R Squared = .001 (Adjusted R Squared = -.124)

Table 2.

Tests of Between-Subjects Effects

Dependent Variable: Shannon-Weiner Diversity

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.187(a)	5	.037	1.369	.298
Intercept	31.960	1	31.960	1169.042	.000
Velocity	.169	1	.169	6.192	.027
Interval	.001	2	.000	.017	.984
Velocity * Interval	.025	2	.012	.454	.645
Error	.355	13	.027		
Total	32.971	19			
Corrected Total	.543	18			

a R Squared = .345 (Adjusted R Squared = .093)

Table 3.

Tests of Between-Subjects Effects

Dependent Variable: Synedra

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	2505.789(a)	1	2505.789	6.940	.017
Intercept	15390.000	1	15390.000	42.625	.000
Velocity	2505.789	1	2505.789	6.940	.017
Error	6138.000	17	361.059		
Total	24739.000	19			
Corrected Total	8643.789	18			

a R Squared = .290 (Adjusted R Squared = .248)

Table 4.

Tests of Between-Subjects Effects

Dependent Variable: Navicula & Cymbella

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1181.075(a)	2	590.538	6.522	.008
Intercept	11059.886	1	11059.886	122.148	.000
Interval	1181.075	2	590.538	6.522	.008
Error	1448.714	16	90.545		
Total	13478.000	19			
Corrected Total	2629.789	18			

a R Squared = .449 (Adjusted R Squared = .380)

Table 5.