# A SURVEY OF GROUNDWATER, MACROPHYTES, AND HABITAT TYPES BELOW THE MAPLE RIVER DAM

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## Abstract:

The hyporheic zone is an important ectone that provides nutrients for algae and shelter for macroinvertebrates. Dams may affect groundwater exchange downstream. In this study, we map groundwater in the hyporheic zone of the Maple River below the Maple River Dam. Ten habitat transects were mapped in each site, where we looked predominately at substrate cover, embeddedness, groundwater seeps, and *Chara* hummocks. We mapped groundwater seeps in each site. Results suggest significant differences in average cobble cover and embeddedness downstream. Seeps mapping did not reveal a significantly negative correlation with distance from the dam. *Chara* may indicate sources of groundwater inputs in the river channel. This study provides important pre-dam removal data, which may prove useful in assessing changes following the dam removal.

*Introduction:*

The hyporeic zone is important ecotone for stream biota. Located in the streambed, the hyporheic zone is the interface between groundwater and surface water. Mixing/exchange occurs between surface water and groundwater, resulting in the exchange of nutrients for the microbes and algae living in the streambed. The hyporheic zone offers refuge for an array of benthic invertebrates (Stubbington 2012). In turn, these organisms provide food for higher trophic level organisms, such as fishes. Inputs of groundwater from the hyporheic zone may stabilize water temperatures in small sanctuaries, providing thermal refuges for fishes (Hayashi 2002).

Rate of flow and direction of groundwater inputs may be determined by underlying components of the streambed. Sediment consistency, geomorphic patterns (bedrock) underneath the streambed, and bank material can factor into influence upwelling and down- welling in streams (Brunke and Gonser 1997). Substrate composition may direct in-stream flow patterns and rates due to porosity and flow conductivity, constricting groundwater flow rates (Brunke and Gonser 1997). Grain size, shape and roughness of underlying substrate may influence porosity. Finer sediments, such as sand or silt accumulation due to stream may decrease seepage or infiltration (Beschta and Jackson 1979). Large obstructions such as large boulders may also alter upwelling patterns (White et al., 1987). In summary, finer sediments decrease groundwater flow and coarse sediments increase flow.

Macrophytes may take advantage of nutrient inputs provided by groundwater or cooler temperatures and distribute accordingly, and thus become indicators of inputs of groundwater. Some species of macrophyte such as *Potamogeton filiformis* and *P. richardsonii* occur frequently at the tail/downstream end of hyporheic zones (Fortner and White 1988), perhaps indicating presence of groundwater inputs. Similarly*, Chara*, an alga, appears to populate areas of hyporheic

groundwater input. *Chara* may form hummocks, or mounds that offer favorable conditions for plant gowth around hyporheic groundwater inputs. Spiraling groundwater inputs may contribute nutrients towards roots of the hummocks (Boulton et al. 1998). Studies have shown significant differences in hyporheic temperature beneath the head, body, and tail of *Chara* hummocks, while temperature measurements at depth both upstream and to the sides were relatively uniform (Hendricks and White, 1988). Additionally, hummock size seemed to affect magnitude of upwelling/downwelling of water (Hendricks and White, 1988).

Events that obstruct flow, such as dam construction, may alter hyporheic exchange of groundwater and surface water (Hancock 2002). Dams may create an unnatural source of pressure on the water table, shifting how groundwater flows through the hyporheic zone, perhaps by increasing groundwater flows downstream via seeps. Increased upwellings of cooler water downstream may occur as a result of (McGraw 1987). Streambed temperature may indicate the presence and extent of the hyporheic zone. Infiltration may occur at the head of riffles (White et al., 1987). Dams may also alter the flow of rivers or streams, which in turn, push certain substrates such as sand and pebbles downstream, leaving larger substrates upstream (Lignon et al. 1995).Differences in substrate composition downstream are attributed to dams altering the natural flow of rivers.

In order to understand the effects of the dam on groundwater flow downstream, we studied three stream reaches below a dam. The primary objective of this study was to map how groundwater inputs are arranged in the hyporheic zone along the Main branch of the Maple River and to determine if groundwater inputs are more abundant closer to the dam.  We predicted high discharge downstream of the caused by increased water volume from groundwater inputs, We also hypothesized that there will be  more abundant, large substrate closer to the dam and smaller

substrate further downstream, including greater embeddedness downstream from the dam. We expected to see lower embeddedness closer to potential groundwater input. In regards to biota, we expected *Chara* distribution to be related to groundwater inputs, specifically, differences in temperature outside of *Chara* hummocks deeper into the streambed. Hummocks with greater surface area were expected to show greater differences in temperature.

*Materials and Methods:*

This study was conducted on the Main Branch of the Maple River, located near Pellston, MI, in Emmet County. The West Branch of the Maple River begins at Pleasantview Swamp; the East Maple begins at Douglas Lake. Both streams converge at Lake Kathleen, which is impounded by the Maple River Dam. Maple River Dam is a small concrete structure that impounds the Maple River at the junction point between the East and West Maple River. The Main branch of the Maple River begins at Lake Kathleen and discharges into Burt Lake . Three 100-m stretches of the Maple were selected downstream of dam. Two upstream sites were selected near the dam (Site 1: 45° 31.691, 84°. 46.434; Site 2: 45° 31.507, 84°46.531). The final site is located further downstream on Pine Trail Road (Site 3: 45° 30.890, 84.271).

**Figure 1:** Map of Maple River below dam. Sites 1 and two (above), site 3 (below). Upstream and downstream sites are enlarged.
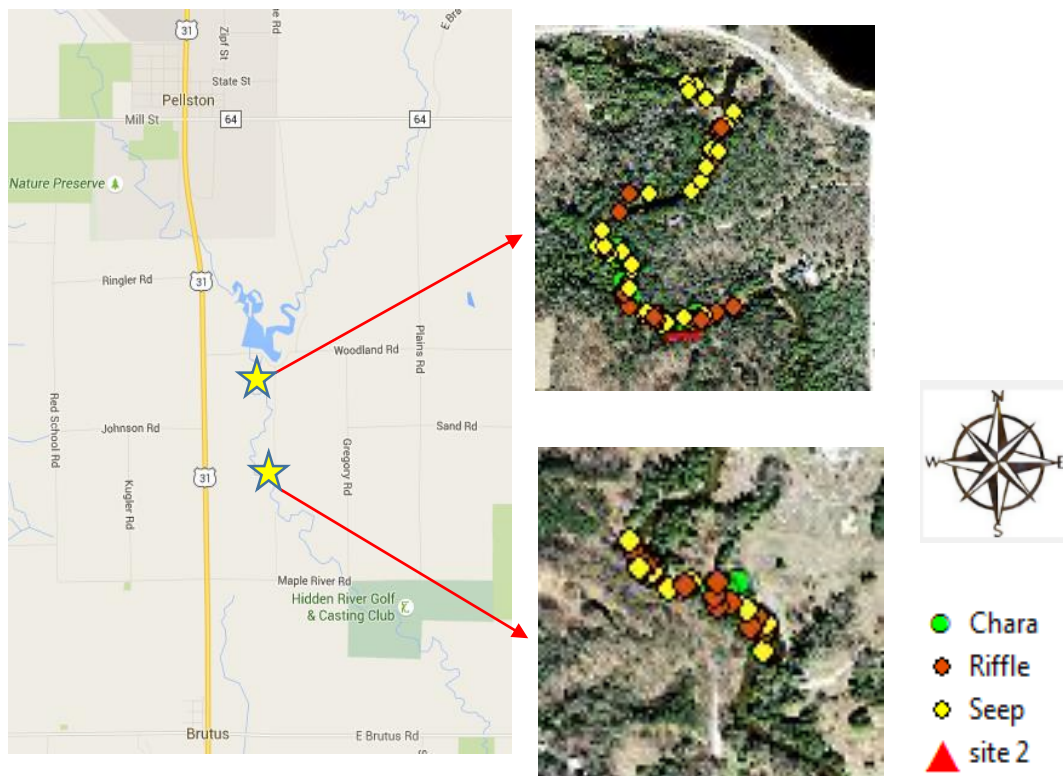
Baseline measurements were taken at each site. Discharge was measured at the furthest downstream point of each site with a flowmeter (Hach) and top set rod. We measured wetted length with a transect tape, then took flow measurements at ten locations across the stream. Discharge was calculated by multiplying width, depth, and velocity at each point across the stream. These products were summed to calculate the discharge. Dissolved oxygen and temperature were taken with a DO meter (HQ30d flexi) and conductivity was taken with a conductivity meter (YSI 30 Conductivity).

We mapped groundwater seeps and heads of riffles. We walked upstream from the downstream end of each site looking for groundwater seeps and heads of riffles. Seeps were identified based on three criteria: (1) areas where bubbles on substrate were visible (2) water flow could be observed originating from the streambed after excavating a small depression into the streambed (3) if water temperature felt colder to touch than the ambient environmental temperature. We identified heads of riffles as areas between pools where (1) water moved quickly and (2) surface was choppy. Observations were made moving upstream for better visibility. One person surveyed each bank. Both seeps and heads of riffles observed were entered into a GPS. We used linear regressions to test relationships between seeps and distance from the dam.

We mapped habitat types on transects 10-m apart. At each transect, we measured water depth, periphyton index (0-3), embeddedness (0-5), substrate based on the Wentworth Scale (Wentworth 1922) of rock particle size (Table 1) in five equidistant locations within a .5x.5 meter quadrat. To calculate the distance of seeps from the dam, we used GIS to measure distance of each seeps per fifty meter transect. We then divided sums for each transect by fifty to calculate seeps per meter. These values were plotted with distance from the dam to generate a scatterplot. We used a clear bottom bucket to assist in assessing habitat mapping and identifying groundwater seeps

bubbling from the streambed. A linear regression was used to evaluate the negative relationship between seep abundance and distance to the dam. We ran one-way Post-Hoc ANOVAs to test for differences among average embeddedness and substrate percent cover in each site.

**Table 1:** Wentworth scale of rock particle study. Substrate in this study were classified as sand, gravel, cobble, or boulder. Table from: *http://www.riverhabitatsurvey.org/manual/images/*.

## WENTWORTH SCALE OF ROCK PARTICLE SIZES

| Classification | Particle size (diameter) |
|---|---|
| Boulder | Above 256 mm |
| Cobble | 64–256 mm |
| Pebble | 4–64 mm |
| Gravel (or Granule) | 2–4 mm |
| Very coarse sand | 1–2 mm |
| Coarse sand | 0.5–1 mm |
| Medium sand | 0.25–0.5 mm |
| Fine sand | 0.125–0.25 mm |
| Very fine sand | 0.062–0.125 mm |
| Silt | 0.004–0.062 mm |
| Clay | Less than 0.004 mm |

We walked upstream at each site, flagging *Chara* hummocks greater than .25m in any dimension. Flagging was done continuously from site 2 to site 1. We used a steel temperature probe to measure hummock temperature at the surface and 20 cm into the streambed in the head, middle, and foot of each hummock (Figure x). Surface and hyporheic temperature were also

measured 0.5-m outside each hummock bed in four directions. We used first used f-tests to evaluate varience in the data. All data showed unequal vaiance. T-tests assuming unequal variance were used to evaluate differences in average temperature (*Chara* surface to depth temperature, *Chara* surface to outside surface temperature, *Chara* depth temperatures to outside depth temperatures, outside surface to outside depth temperatures).
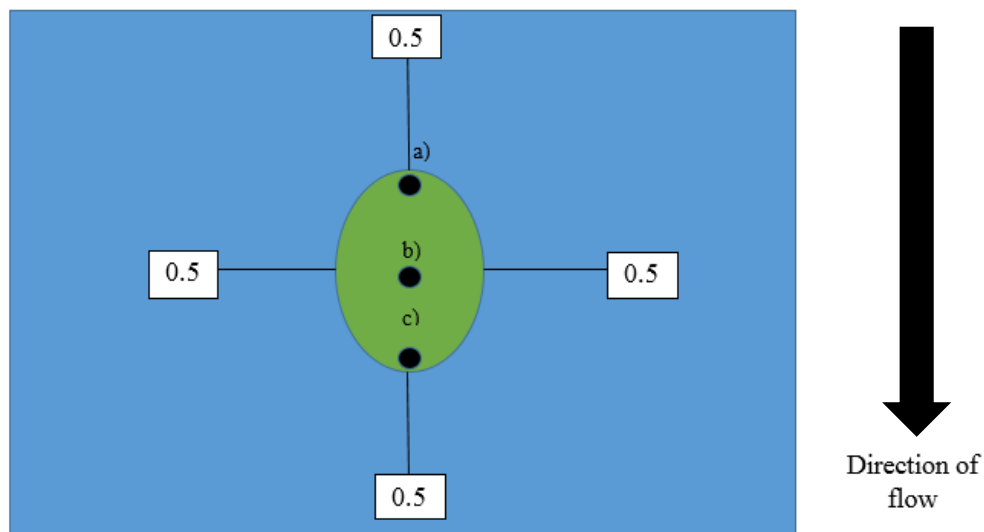


**Figure 2:** Diagram of *Chara* hummock temperature mapping. Temperature was measured at the surface and 20cm depth in the hummock at the a) head b) body c) tail; similar procedures were used to measure temperature outside the hummock in four directions.

*Results:*

Water quality values also were similar both upstream and downstream for our total study area. Conductivity (difference= 4.3 µS) and discharge (difference= .45 m$^3$/sec) were slightly higher downstream (Table 2). Temperature measurements were equal at site 1 and site 3.

**Table 2:** Water quality data and or all three sites. Discharge and conductivity increase from upstream to downstream.

|  | DO (mg/L) | pH | Conductivity (µS) | Temperature (°C) | Discharge (m$^3$/sec) |
|---|---|---|---|---|---|
| Site 1 | 9.04 | 8.51 | 336.2 | 18.5 | 1.20 |
| Site 2 |  |  |  |  | 1.30 |
| Site 3 | 8.93 | n/a | 340.5 | 18.5 | 1.65 |

Substratum cover was similar from site 1 to site 3, except for cobble. Cobble was greatest closest to the dam, then decreased downstream. Only cobble cover varied significantly from site different among all three sites (F= 8.09, df=149, p < 0.00). There was no significant difference in averages of sand cover (F=1.77, df=149, p=.174) and gravel cover (Figure 3,F=0.759, df=149, p=0.470) in our sites, however, proportions tended to increase from upstream to downstream. Pebble cover was fairly similar in all three sites (Figure 3; F=.569, df=149, p= 0.567).

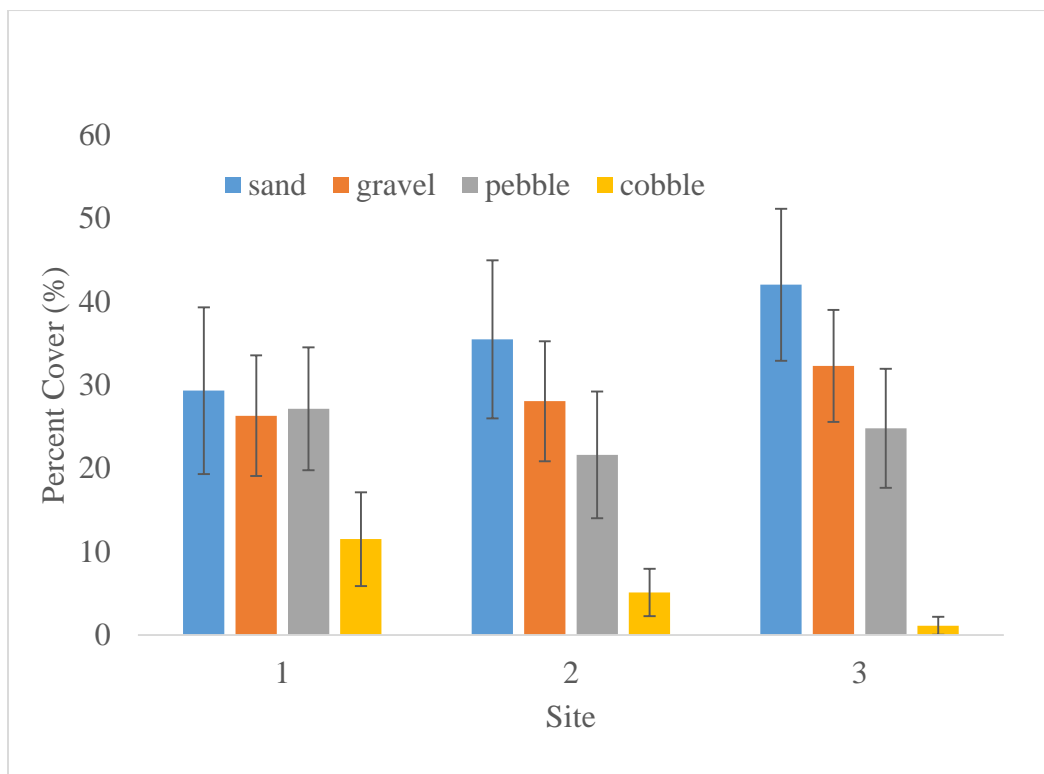**Figure 3:** Percent cover of substratum for sand, gravel, pebble, and cobble for three sites downstream of the Maple River Dam. **S**and (F=1.77, df=149, p=.174) and gravel (F=0.759, df=149, p=0.470) increased from site 1 to site 3 while cobble (F= 8.09, df=149, p < 0.00) was most abundant at site 1. Pebble (F=.569, df=149, p=0.567) composition was similar among all three sites. Graph shows bars with error bars to 2 standard errors.

Seep abundance did not change with distance downstream from the dam (Figure 4; t= 1.63, df= , p=0.22).  Average embeddedness was significantly different among three sites on along the Maple River  (F= 6.793, df=149. p=0.002). We saw greater embeddedness downstream from the dam than upstream (Figure 5). Significant differences in average embeddedness were observed in site 1&2 (df= 149, p= 0.007) and 1&3 (df= 149, p=0.003).
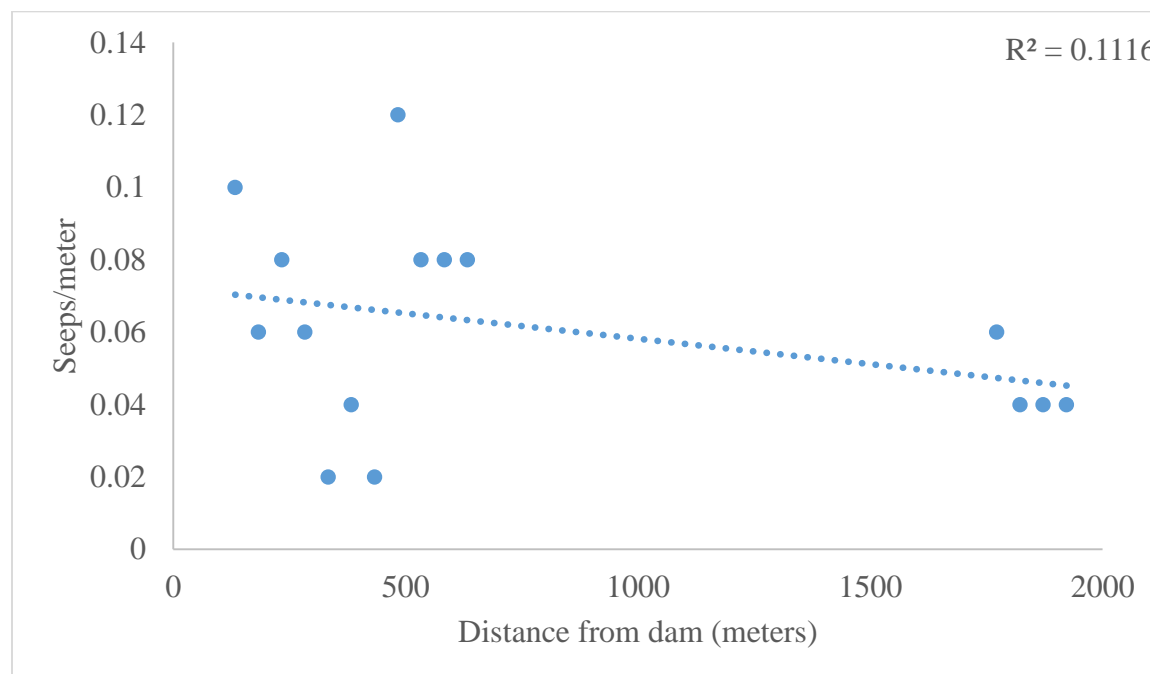


**Figure 4:** Regression of seep abundance per meter to distance from dam. Relationship between seeps and distance from the dam does is not significantly negative ($R^2 = 0.112$, p= 0.224).
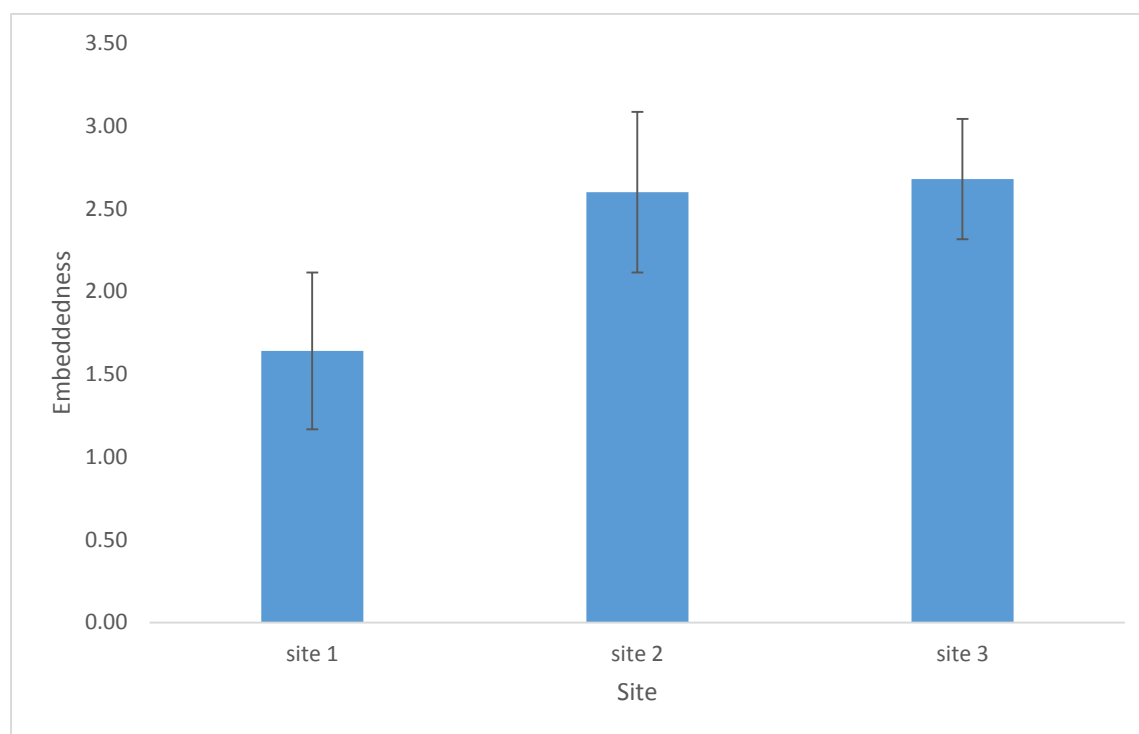
**Figure 5:** We found average embeddedness at three sites along the Maple River were significantly different. Two-standard error bars were used for 95% confidence. Embeddedness was significantly different sites 1 & 2 (df= 149, p= 0.007) and sites 1& 3 (df= 149, p=0.003).

We found that mean temperature at the substrate surface on *Chara* hummocks was not significantly different than mean surface substrate temperature outside *Chara* hummocks (T (two-tailed) = 0.023, df = 56, p = 0.982).Similarly, mean temperature at   20cm depth underneath *Chara* hummocks was not significantly different from  temperature at 20cm depth in the substrate outside *Chara* hummocks (T=-0.596, df=37, p(two-tail)=0.555).

When we compared surface substrate temperature to hyporheic substrate temperature outside *Chara* hummocks, there was no significant difference in mean temperature (T=0.515, df=33, p(2-tail)=0.610). However, we found the mean temperature among *Chara* surface temperature and *Chara* 20cm depth temperature was significant among all *Chara* hummocks (T=3.135, df=51, p(two tail)=0.003).
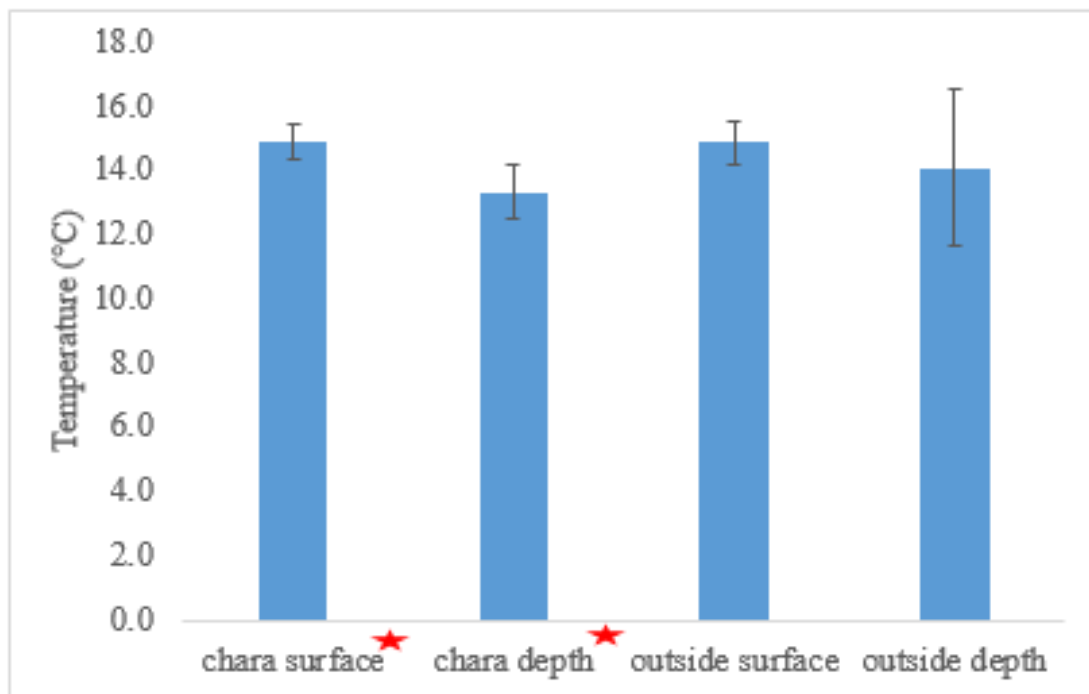


**Figure 6:** Average *Chara* temperatures in and outside of hummocks. Surface temperature was greater at the surface than at 20cm depth both within and outside hummocks. Stars indicate significant differences in mean temperature among surface and 20cm depth *Chara* temperature (T=3.135, df=51, p(two tail)=0.003).
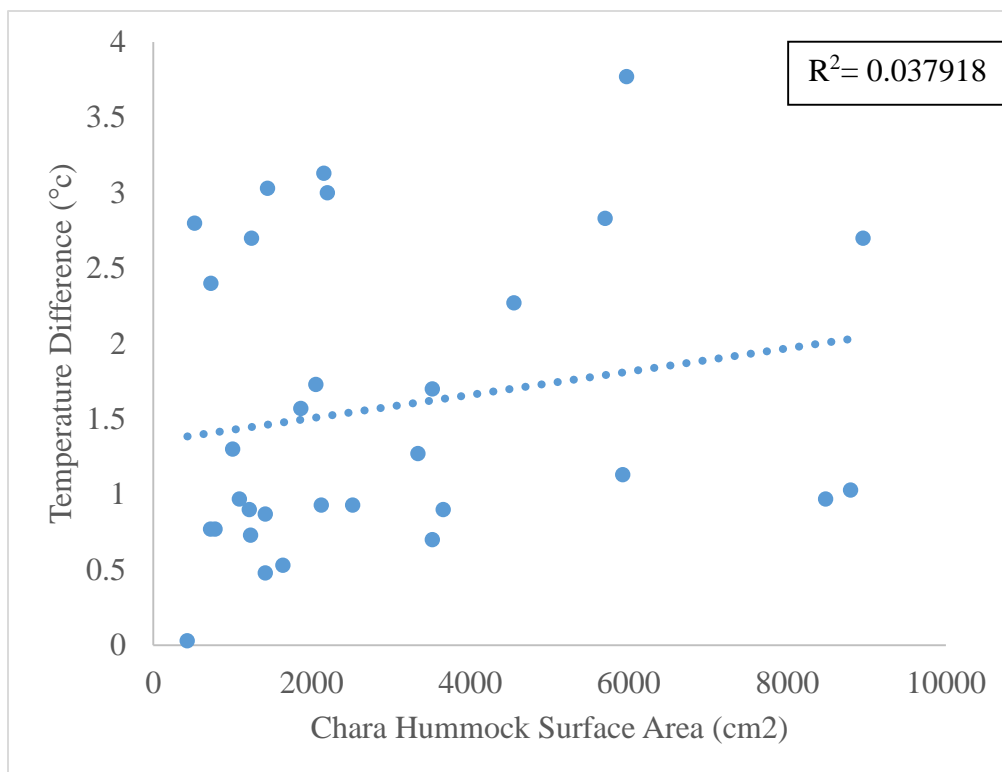
**Figure 7:** Scatterplot of *Chara* surface area to temperature difference between average head/body/foot surface and 20cm depth measurements ($R^2$ =.0379, p= 0.294).

*Discussion:*

Results showed discharge downstream from the dam was greater than discharge upstream (Table 2). Increases in discharge may be due to inputs from groundwater sources contributing additional water volume to the stream channel, increasing the volume of water flowing per second downstream.

Substrate cover was similar for all three sites. Moving downstream, we saw insignificant differences in average sand, gravel, and pebble cover while larger substrate, such as cobble, were significantly more abundant closer to the dam, which supports our hypothesis. Alternatively, significantly higher cover of cobble upstream may be attributed to human activities during dam construction, perhaps to control erosion. Cobble is more resistant to downstream movement due

to greater mass. While smaller substrates are washed downstream, cobble remains stationary. Remaining cobble may increase pore space for groundwater to flow through. On the other hand, downstream deposition of finer sediment downstream may decrease pore space. Embeddedness was significantly greater in in site 1&2 and 1&3, where higher embeddedness was present downstream (Figure 6). This may decrease hyporheic exchange by dampening upwelling or downwelling with decreased porosity (Beschta and Jackson 1979).

We saw no significant negative correlation between groundwater seeps and distance from the dam. Hyporheic flow patterns may be too variable to make generalized assumptions of seep locality due to unknown variables such as bedrock and sediment composition altering pathways for groundwater along the river channel (Brunke and Gonser 1997). Bedrock constrained streams may limit hyporheic exchange (Kasahara and Wondzell 2003). This may necessitate geomorphic studies to be done around the Maple River. Peizometers and seepage meters may also be utilized to comprehensively study rates of seepage near the Maple River Dam down to our upstream study sites (Lee and Cherry 1979).

*Chara* distribution may be affected by these inputs of groundwater. Our results suggested no difference in average surface and depth temperature at different locations of the hummock. This contradicts results of past studies, which suggested lower temperature occurs at the body and foot of the hummock (Henricks and White 1988). Perhaps taking measurements 0.5m outside hummocks was not enough to escape the influence of upwellings caused by hummocks. The same study also showed significant interaction between temperature and length, suggesting the longer the hummock is, the greater the resulting magnitude of upwelling. Our results revealed no significant relationship between hummock surface area and mean temperature difference. Perhaps length plays a larger role in determining magnitude of groundwater upwelling than overall surface

area. Future studies may involve evaluating different *Chara* dimensions to assess magnitude of upwelling.

Our results suggest significant differences between average surface and 20cm depth hyporheic temperature within hummocks. *Chara* hummocks may still be a plausible source of hyporheic groundwater input. Other studies found significant differences in mean temperature of *Chara* hummocks at the body and tail (Hendricks and White, 1998). Perhaps more detailed temperature measurements should be made and at different depths, such as 5cm below the surface.

This study presents pre-dam removal data of groundwater and habitat. The implications of dam removal may initiate cascading changes that affect hyporheic exchange patterns within the Maple River may change as a result of dam removal, specifically for the distribution of *Chara* and other macrophytes and the dispersal of sediment that groundwater inputs may influence. Groundwater mapping following dam removal will be necessary to illustrate an accurate picture of how the river may change in regards to the context of this study and many others.

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*Work-log Summary:*

| Name | Work Description | Percent |
|---|---|---|
| Brendan Nee | Habitat mapping, seeps/riffleheads *Chara* temperature probing/mapping, statistics, data entry | 25% |
| Kirk Acharya | Habitat mapping, seeps/riffleheads, *Chara* temperature probing/mapping, statistics, data entry | 28% |
| Allie Birkbeck | Habitat mapping, *Chara* temperature probing/mapping, statistics | 19% |
| Kerry Fingerle | Habitat mapping, *Chara* temperature probing/mapping | 10% |
| Taine Stoll | Habitat mapping, data entry | 10% |
| Amy Schrank | Habitat mapping, consoler, wizard | 12% |
| Donna Hollansworth | Moraler | 1% |

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