

The Effects of Golf Course Runoff on Macroinvertebrates and Nutrient Levels in the Carp Lake and Maple Rivers

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Abstract: The effect of fertilizer runoff from nonpoint sources is an issue for water quality. This study focused on two rivers in Northern Lower Michigan, the Maple River and the Carp Lake River and the possible effects of fertilizer runoff from golf courses adjacent to those rivers. The purpose was to measure the proportion of macroinvertebrates, particularly Ephemeroptera, Plecoptera, and Trichoptera, which serve as indicators of aquatic ecosystem health and also to measure nutrient levels on the rivers to determine water quality. Samples of macroinvertebrates and nutrients were taken at three locations on each river; upstream from the golf course, at the golf course, and downstream from the golf course. Temperature, pH, alkalinity, conductivity, chlorophyll A, and dissolved oxygen samples were also taken at the same sites on each river to ensure consistency. We found no significant difference between sites on the same river for the majority of our variables. There was, however, significance between the Maple River and the Carp Lake River in our variables tested. We found a significant difference in total Nitrogen levels between the two rivers and a significant difference from upstream and downstream at sites on each river, suggesting that the golf courses were sources of Nitrogen enrichment.

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Introduction

The summer tourist season in Northern Michigan provides a vital boost to the local economy with golf courses providing a major market in itself (McCool 2006). Northern Michigan has a sizable golf community with over 200 courses in the region alone; however, this popularity does not come without a cost (Tucker 2007). Golf courses, with their emphasis on flawless fairways and handsome natural settings, often pair heavily fertilized grass in close proximity to Michigan's most abundant natural resource, fresh water (Dillon and Winter 2005). Many designers attempt to improve the aesthetic qualities of a golf course by locating it next to a river or lake, often resulting in detrimental runoff from the fertilizers or pesticides used on the grass (Haines-Young and Potschin 2002).

Nitrogen, phosphorous and potassium are elements commonly used in fertilizers and when used in excess can contribute to environmental challenges such as eutrophication (Antikainen, et.al 2004). Eutrophication is the addition of nutrients to an aquatic system, and as a result can lead to an increase in algal growth and decrease in dissolved oxygen (Ayyappan, et. al 2005, Aguila et al 2004). Degradation of these ecosystems can create changes in realized niches for organisms.

To better judge the overall effect of golf course runoff of our selected rivers, we chose to examine the distribution of benthic macroinvertebrates (Zweig 2001). The benthic macroinvertebrate orders, Ephemeroptera, Plecoptera, and Trichoptera (EPT) are associated with high water quality in streams and rivers, and because they have specific life cycle requirements. They are important indicators in assessing the biological integrity and overall ecological health of the area (Rosenberg and Resh 1993). The EPT index is the number of different morphotypes observed in the orders Ephemeroptera, Plecoptera and Trichoptera as a proportion of all invertebrate morphotypes present.

These orders contain species that are hypersensitive to pollutants; hence an impacted stream should contain fewer of these taxa than a pristine stream (Kitchin 1995).

Nonpoint source (NPS) pollution, unlike pollution from industrial and sewage treatment plants, comes from many diffuse sources. NPS pollution is caused by rainfall or snowmelt moving over and through the ground. As the runoff moves, it picks up and carries away natural and human-made pollutants, finally depositing them into lakes, rivers, wetlands, coastal waters, and even underground sources of drinking water. This is the type of pollution and runoff that we will be studying in order to determine if there is a high probability of pollution from the golf courses.

Previous studies on the water quality of the Maple and Carp Lake River have drawn conflicting results. Two similar studies conducted in 2006 that studied total nitrate and ammonium showed a decrease in water quality downstream of the offset Wilderness Golf Course (Metes 2006; Boelio 2006), a 1998 study showed no decrease in water quality by measuring different nitrogen compounds downstream of the adjacent Hidden River Golf and Casting Club (Holley 1998). Our objectives were to build upon these previous studies by comparing current data obtained from both rivers to determine if golf course fertilizer runoff affects nutrient levels, chlorophyll levels and macroinvertebrate populations between the two rivers stated above.

We hypothesized that there will be an increased amount of phosphorous, nitrogen, and chlorophyll A downstream from the golf courses compared to upstream from the golf courses. We hypothesized that there would be a decrease in dissolved oxygen due to algae growth downstream from the golf courses compared to upstream from the golf courses. We predicted that a potential increase in nutrients levels will result in greater algae growth which should then be reflected in the dissolved oxygen and chlorophyll A results. We hypothesized that there will be a lower proportion of the EPT Taxa downstream from the golf courses compared to upstream from the golf courses. We predicted that the EPT Taxa will be adversely affected due to their pollution intolerance in the examined downstream sites.

Methods

For our study we collected samples at three locations along both the Maple River and the Carp Lake River. The two locations we examined were the Hidden River Golf and Casting Club, located northeast of Brutus in Cheboygan County, Michigan and the Wilderness Golf Course located northeast of Bliss in Emmet County, Michigan. The Hidden River Golf and Casting Club is located directly on the Maple River while the Wilderness Golf course is several hundred meters away from the Carp Lake River. Both sites are located in temperate forest with the dominant tree species varying between oak, aspen, maple, and pine.

Three samples of each test at each transect were taken in order to obtain an average for that portion of the river (Fig. 1). The upstream samples acted as the control for this experiment since they should not have any runoff associated with the golf course. At the rivers, we sampled one site upstream of the golf course in question, one perpendicular from the golf course, and one downstream from the golf course (Fig. 11). At each sample point we took three samples for every test we conducted; one sample from the center of the river and the other two approximately two meters from each riverbank (Fig. 1). We attempted to choose sites that would be far enough upstream to avoid any contamination from the golf course and far enough downstream to catch any significant runoff (Fig. 11). Each river site was similar in that there were no visible algae blooms and had rocky cobble substrate interlaid with sandy patches. All sites were also similar in being undeveloped with forested riverbanks and a strong current.

Nutrient and Water Chemistry Analyses

In order to compare nutrients within and between streams, we tested the water temperature, dissolved oxygen, chlorophyll content, and nutrient levels. The nutrients that we tested for were total nitrogen, total phosphorous and soluble reactive phosphorous. Water temperature and dissolved oxygen were measured on site using the Hydrolab (Hach Environmental 2009). Chlorophyll A samples were taken using a kit that involved a syringe and a filter system (Michigan Department of

Environmental Quality 2008). Nutrient levels were collected in 250 milliliter acid washed plastic bottles to be later tested at the Lakeside Lab at The University of Michigan Biological Station (UMBS). We rinsed the bottles and caps in the river water before filling and to screw the caps on while submerged in order to keep as much air out as possible and have a viable sample.

Macroinvertebrate Index Sampling

To analyze water quality using benthic macroinvertebrate index we collected three samples at each in stream site using a 30-centimeter square surber sampler. After each sample the collected material was transferred to a large pan by turning the net inside out and then using a spray bottle to rinse the net clean and capture all invertebrates. Forceps were used to remove organisms from the sand and debris and then to deposit them into a sample bottle filled with river water. The collected macroinvertebrates were later identified in the laboratory using hand-lenses and microscopes and then counted to perform an EPT index (Kitchin 1995; Watson-Ferguson 2006).

Results

Temperature

The Maple River was significantly warmer than the Carp Lake River ($p=0.000$, Fig. 2). A significant interaction between river and site exists for temperature ($p=0.011$, Fig. 2).

Dissolved Oxygen

The Carp Lake River has significantly higher dissolved oxygen levels than the Maple River ($p=0.000$, Fig. 3) There is a significant interaction between site and river with an increase in downstream sites of dissolved oxygen in the Carp Lake River ($p=0.000$, Fig. 3)

Chlorophyll A

There was significant difference in chlorophyll A between the Maple River and the Carp Lake River ($p=0.047$, Fig. 4). There was an upward trend in Chlorophyll A levels in both the Maple River and the Carp Lake River (Fig. 4). There was no significant difference between sites ($p=0.133$, Fig. 7).

Total Nitrogen

There was an upward trend in Nitrogen levels in both the Maple River and the Carp Lake River (Fig. 5). And there was a significant difference in Nitrogen levels between the Maple River and the Carp

Lake River ($p=0.000$, Fig. 5). There was a significant difference in Nitrogen levels between sites ($p=0.001$, Fig. 5).

Total Phosphorous

There was no significant difference in total Phosphorous levels between the Maple River and the Carp Lake River ($p=0.080$, Fig. 6). There was no significant difference in total Phosphorous levels between sites ($p=0.984$, Fig. 6). There was an upward trend in total Phosphorous levels in the Carp Lake River and a downward trend in the Maple River (Fig. 6). There was a significant interaction between river and site ($p=0.040$, Fig. 6).

Soluble Reactive Phosphorous (SRP)

There was a significant difference in SRP between the Maple River and the Carp Lake River ($p=0.000$, Fig. 7), however, there were no trends in the Maple River or Carp Lake River. There was no significant difference between sites on the Maple River and sites on the Carp Lake River ($p=0.972$, Fig. 7). There was no interaction between site and river ($p=0.657$, Fig. 7).

Macroinvertebrates and EPT

At both the Maple River and Carp Lake River, the downstream site's EPT comparisons are higher than the upstream control site (Fig. 8, Fig. 9). At the Maple River and Carp Lake River there was a consistent trend of a lower EPT index at the control site upstream, followed by a notable increase at the site closest to the golf course, with a slight percent drop in the EPT index for the last site (Fig. 8, Fig. 9). The Carp Lake River has a noticeably higher EPT index than the Maple River at all sites tested (Fig. 8, Fig. 9).

Discussion

Contrary to what we predicted, Maple River temperatures were significantly higher than the Carp Lake River. We expected the Maple River to be colder because it was a deeper river than Carp Lake River. These results did not support our hypothesis. Reasons for these results may be contributed to the weather during sampling of the rivers. When we collected our samples from the Maple River the temperature was 17.7° Celsius and it had only rained .127cm in the three preceding days. This is

contrasted with the weather when we collected samples on the Carp Lake River; 13.3° and 2.3cm of rain in the preceding three days.

We originally predicted that there would be a decrease in dissolved oxygen downstream from the golf course. We thought that an increase in nutrients would result in extra algae growth, which would be reflected in lower dissolved oxygen levels. Contrary to our predictions, we found a significant increase in dissolved oxygen downstream from the golf course on Carp Lake River, suggesting that the increased growth of algae actually added dissolved oxygen to the river.

For our chlorophyll A levels we also did not observe any significant difference between sites at both rivers, however there was a sizable increase for the second site on the Carp Lake River and an upward trend for the Maple River. This does not support our hypothesis as we expected a significant increase in chlorophyll A levels as a result of increased algae growth from nutrient runoff from the golf courses.

We did not observe a significant difference between sites for both rivers for total phosphorous or TSRP, which we expected to find significant increase in these nutrients downstream from the golf courses as a result of fertilizer runoff. This may be attributed to testing by the golf courses to access the soil content of phosphorous before adding these nutrients. Also, the local plant life may have taken up any extra phosphorous before it reached the river. Our data did find a significant increase in nitrogen between the up and downstream sites on the Carp Lake River. This supports our hypothesis of an increase of nitrogen levels downstream from the golf courses. There was an increasing trend of nitrogen for the Maple River, though never enough to be statistically significant. This implies that nitrogen from golf course fertilizers do runoff into rivers if used in excess.

Our EPT index data showed an interesting trend in both rivers; there was a large increase between the first site and the second, with a smaller difference between the second and third. There

was a 30% and 15% increase respectively in the proportion of EPT index between the first and second site in both the Carp Lake River and Maple River. The change between the second and third sites was less dramatic, dropping only 17% and 2% for the Carp Lake and Maple River. This data does not support our hypothesis as we expected to see a decrease in the EPT proportion due to the nutrient and pesticide runoff from the golf courses. A possible explanation for our data could be that the runoff from the golf course is significant enough to increase the algae growth (as our data showed) but not enough to adversely affect the EPT benthic macroinvertebrates. This theory is reinforced by findings from a study conducted in Wisconsin, which concluded that macroinvertebrate measures were significantly correlated with phosphorus and nitrogen concentrations (Garrison et al. 2006) although this could be attributed to a variety of factors. More sampling is needed to further test this.

Previous studies that were conducted here at the University of Michigan Biological Station found some similar results. There were significant increases in nitrogen levels between sites upstream, at the Wilderness Golf Course and slightly lower at the downstream site on the Carp Lake River (Metes 2006 and Boelio 2006). Data from the previous study also showed there was an increased proportion of EPT between the site upstream from the golf course and at the golf course proper on Carp Lake River (Metes 2006). Since there were no statistical tests ran to compare EPT index data in our study, it can only be said that there was an upward trend between upstream samples and the site nearest to the Wilderness Golf Course.

A previous study on the effects of golf courses on the Maple River also showed similar data as our findings. There were no significant differences in nitrogen levels between sites upstream, at the Hidden River Golf and Casting Club and downstream from the golf course (Holley 1998). This was consistent with our findings.

Our data showed that while there are some significant differences in chemical analyses between the three sites along the two sample rivers. This result could advocate for increasing the sample size for future research. Furthermore, the Hidden River Golf and Casting Club is advertised as a casting club and this is reflected in their attempt to mitigate the effects of the golf course's impact on the river by reducing the amount of nutrients that enter the river system by utilizing buffer zones of at least 90 meters between fertilized grass and the river (Davies and Nelson 1994, Holly 1998). These buffer strips might explain the absence of a dramatic effect from the runoff as buffer strips have been shown to effectively reduce both the movement of nutrients and sediments into stream water (Karr and Schlosser 1978). Another conclusion that could be drawn is that the Wilderness Golf Course is far enough away from the Carp Lake River to have no effect on its water quality.

The major limitation to our study is our inability to properly account for specific site variation, which is mostly related to our low number of sample size. We did not have an effective mean to account for variations in our data that we did find between the sites because we could not be completely sure that it was associated with runoff from the golf course. Another limitation was our temporal restriction of sample collection, as we would have preferred to collect all of our samples under similar conditions.

Some improvements that we could make to our study would be increasing the number and distribution of our samples and sites. To properly observe any trends in our data, it would be better to measure water quality along our chosen rivers at specific intervals from a location farther ahead and below our tested sites. Furthermore, we could have taken soil samples to attempt to track the progression of runoff from the golf courses and see if there was a gradient.

With the popularity of golf courses in Northern Michigan likely to increase, it is important to fully understand the effect that these attractions will have on the water quality of the neighboring streams and rivers. We found that neither the Wilderness Golf Course nor the Hidden River Golf Course had a significantly adverse effect on the water quality of the nearby streams; however, there were some

impacts. We can only relate this minimal impact to the forested buffers that exist between both courses and the respected river. This data could be useful in regulations regarding new construction of golf courses and should be further studied to better understand the dynamic that buffer zones play mitigating the affect of runoff on water quality.

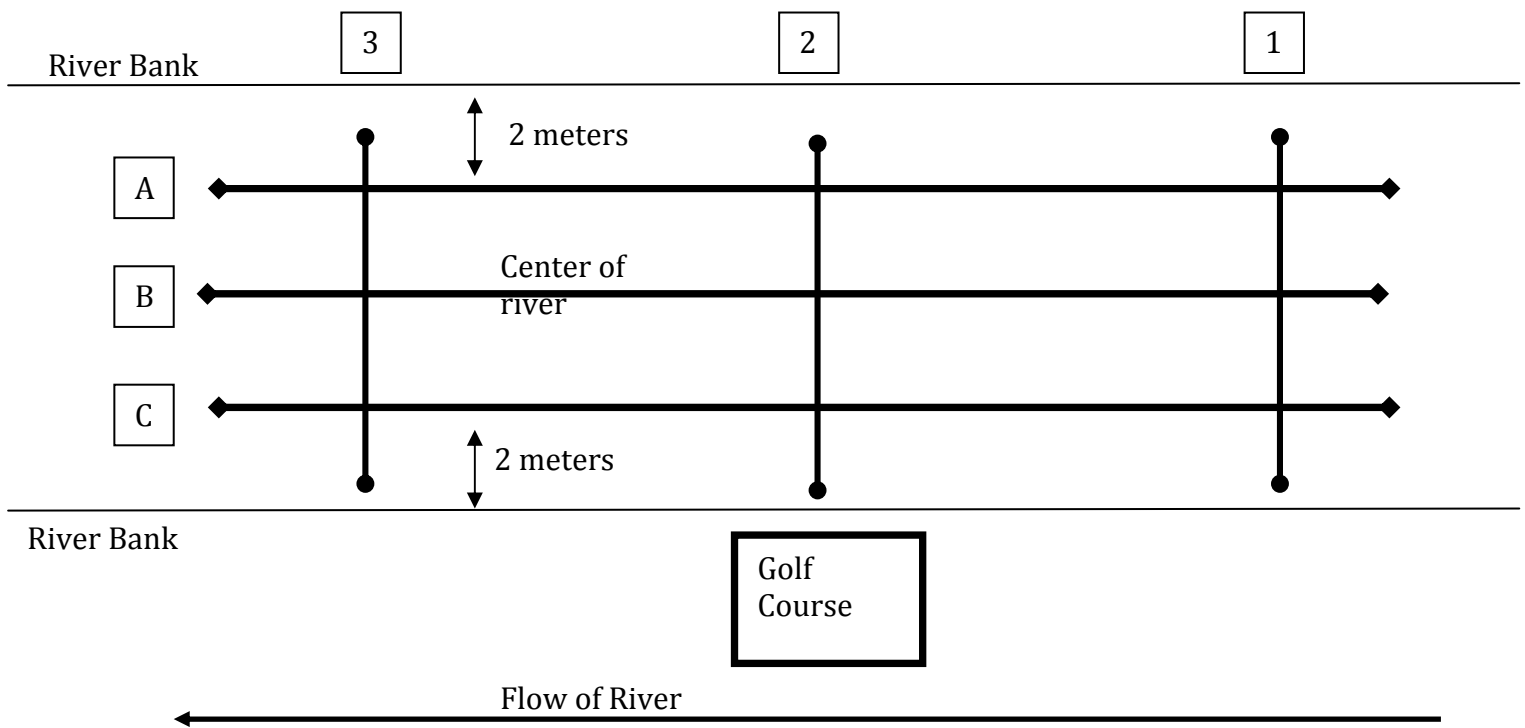


Figure 1: *River Sampling Sites*- Samples were taken for each variable at the line intersections in the diagram. Line 1 is upstream from the golf course, line 2 is at the golf course, and line 3 is downstream. Line A is two meters from shore, line B is in the center of the river, and line C is two meters from the other shore. Line C was determined to always be closest to you when the river is flowing from right to left. There were nine sampling sites for each river.

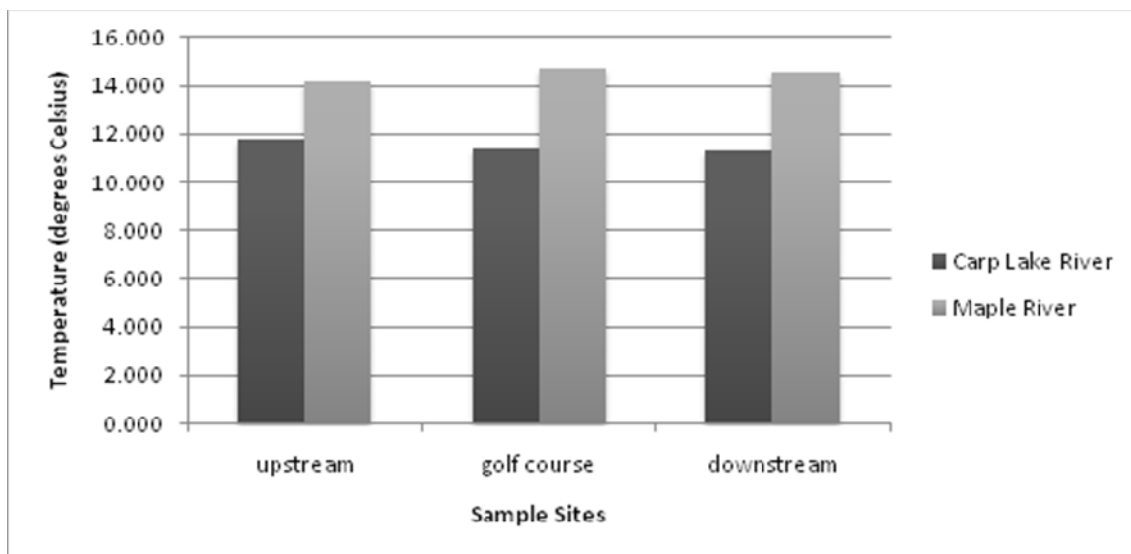


Figure 2: The Maple River had a significantly higher temperature at all sites when compared to those of the Carp Lake River. There is a downward trend in temperature in the Carp Lake River and an upward trend in temperature in the Maple River. Standard deviation bars greater than zero are shown. This graph is representative of the ANOVA test ran on data.

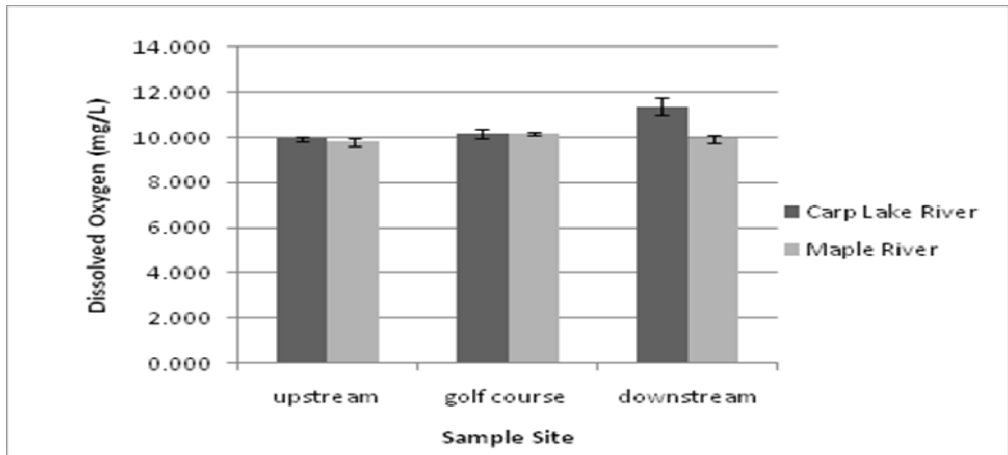


Figure 3: There was a slight upward trend of dissolved oxygen levels on the Maple River. The Carp Lake River had a major increase in dissolved oxygen downstream. Standard deviation bars greater than zero are shown. This graph is representative of the ANOVA test ran on data.

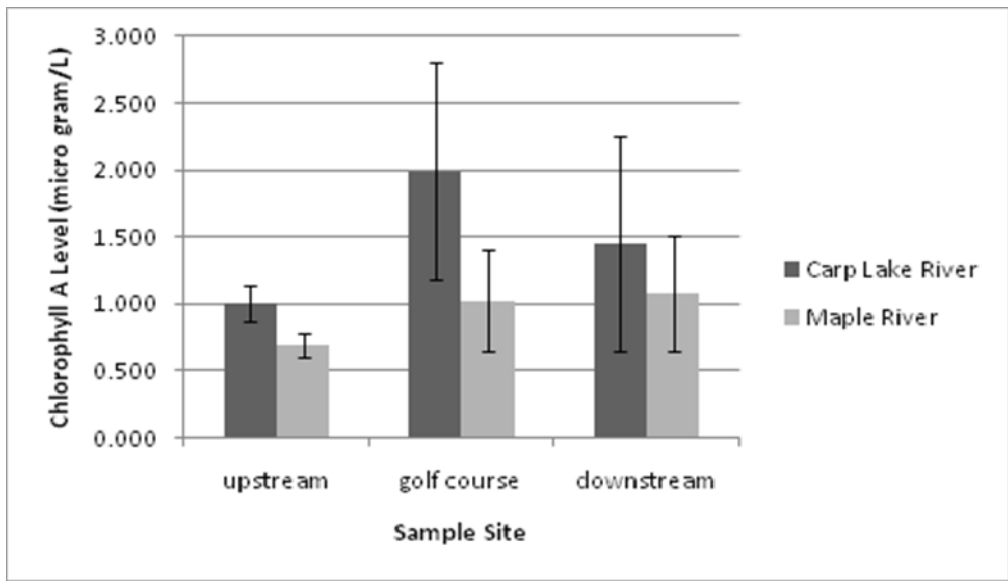


Figure 4: There was a difference in chlorophyll A levels between the Maple River and the Carp Lake River. There was an upward trend in the amount of chlorophyll A at the golf course and downstream from the golf course on both the Maple and Carp Lake Rivers. Standard deviation bars greater than zero are shown. This graph is representative of the ANOVA test ran on data.

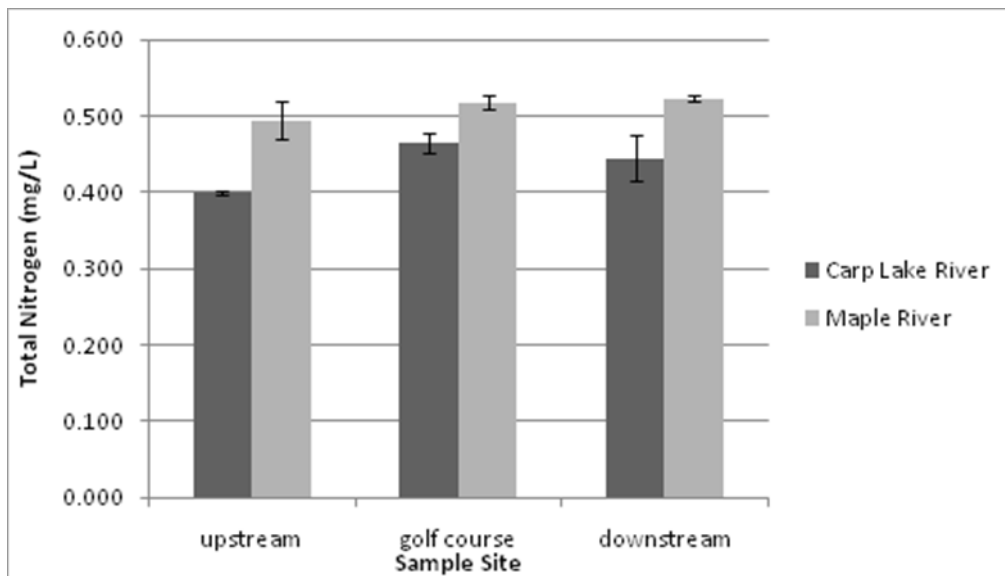


Figure 5: There was a difference in total Nitrogen levels between the Maple River and the Carp Lake River. There was an upward trend in total Nitrogen on both the Carp Lake River and the Maple River. Standard deviation bars greater than zero are shown. This graph is representative of the ANOVA test ran on data.

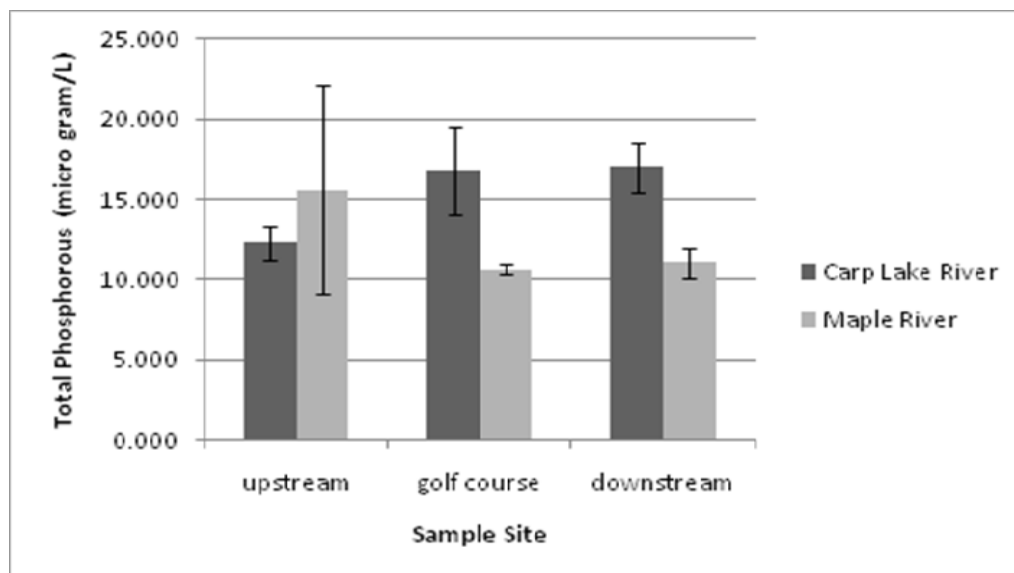


Figure 6: There was a difference in total Phosphorous levels between sites on the Maple River and Carp Lake Rivers. There was an upward trend of total Phosphorous levels on the Carp Lake River. There was a downward trend of total Phosphorous levels on the Maple River. Standard deviation bars greater than zero are shown. This graph is representative of the ANOVA test ran on data.

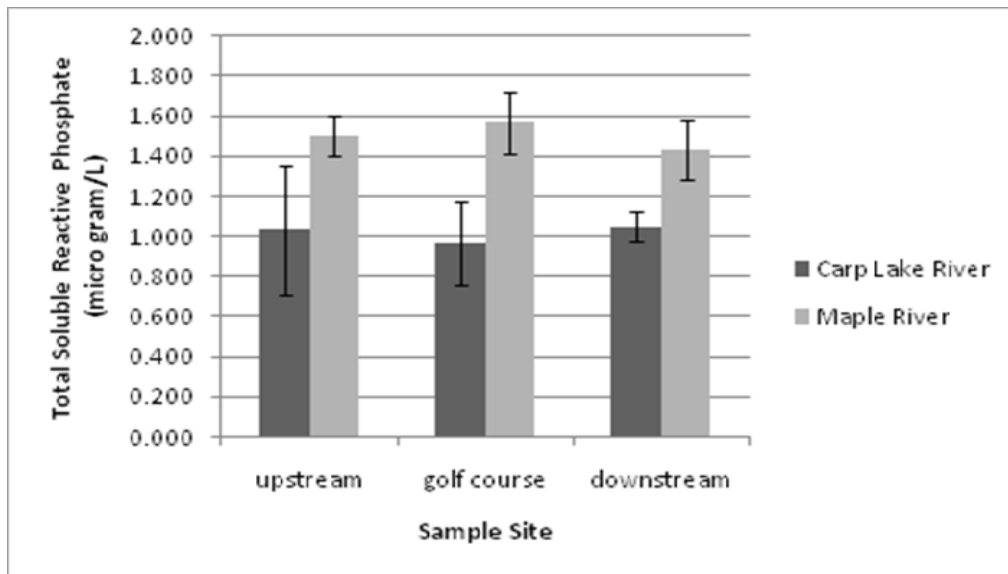


Figure 7: There was a major difference in total soluble reactive phosphate levels between the Maple River and Carp Lake River. Levels on the Maple River were lower downstream than upstream. On the Carp Lake River, levels were higher downstream than upstream. Standard deviation bars greater than zero are shown. This graph is representative of the ANOVA test ran on data.

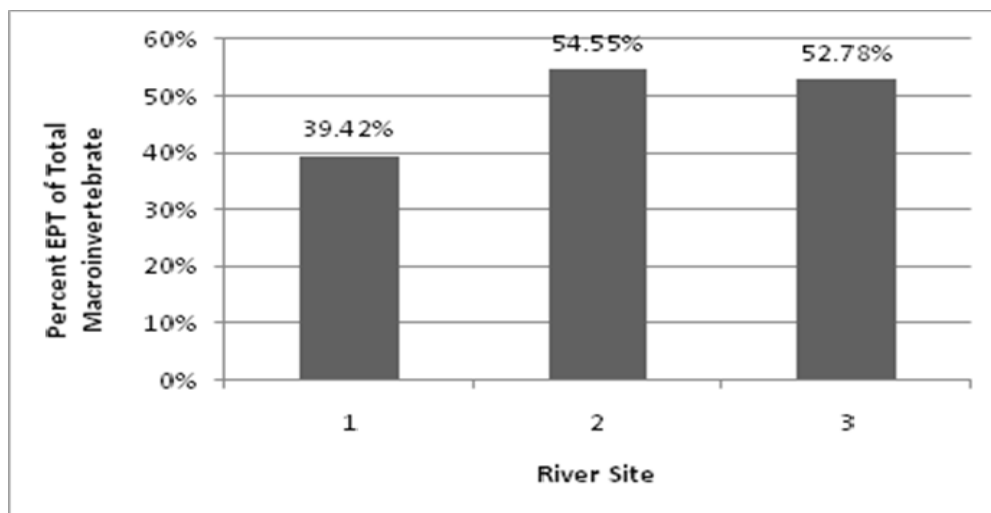


Figure 8: Maple River-There was a higher percentage of EPT in downstream samples than in the upstream samples. There is a trend upward in EPT percentages.

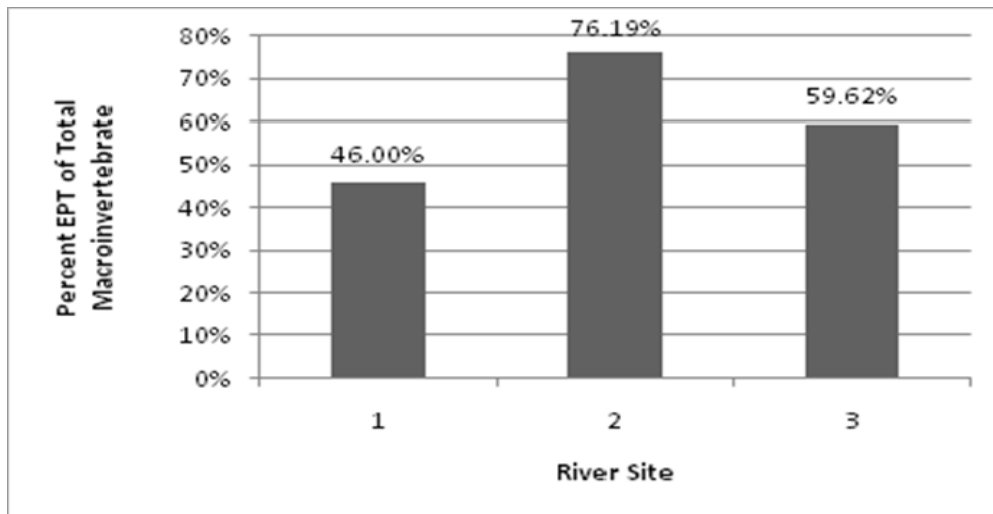


Figure 9: Carp Lake River-River-There was a higher percentage of EPT in downstream samples than in the upstream samples. There is a trend upward in EPT percentages.



Figure 11: The red arrows indicate the location on each river that we sampled at. Site one being upstream from the golf course. Site 2 near or at the golf course. And site 3 is downstream from the golf course

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