# Dissolved Organic Carbon Effects on Insect Emergence in Long Lake

BIOS 35502-01: Practicum in Field Biology

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## Abstract:

Increased concentrations of dissolved organic carbon (DOC) have considerable impacts on aquatic emergent insects. Previous research has shown that higher concentrations of DOC can significantly inhibit growth of many species of emergent insects due to decreased temperatures and lack of light in the water column. This study tested how the different levels of DOC in Long Lake affect emergent insects' growth, biomass, and diversity, focusing heavily on certain sub-families of *Chironomid*. The results of this study conclude that higher concentrations of DOC significantly increase body size and diversity for emergent insects. High numbers and biomass of *Chironomid* were also significantly impacted by higher DOC concentrations unlike general insect biomass which was found to be not significant.

## Introduction:

Insects play a vital role in lake and wetland ecosystems as they are a major part of the food web and provide a food source for organisms such as birds, fish, and other insects (Polis et al 1997). However, there are many factors that can inhibit or advance their growth and development while they are in their aquatic larval forms.

Dissolved organic carbon (DOC) is a compound that darkens waters and reduces light and heat penetration in the water column (Jones 1992). Varying levels of DOC affect light, oxygen, and nutrient levels which impact insects and other organisms. With higher levels of DOC, waters darken because more particles come from allochthonous sources, precipitation, acidification, and nutrient loading (Larocque et al 2006). These excess particles absorb light, preventing it from penetrating to the lower areas of the water column (Read and Rose 2013). Since light is inhibited, heat is also inhibited, resulting in lower whole lake temperatures. This attenuation of light reduces the depth of the thermocline and shrinks the epilimnion (Snucins and John 2000). A shallower epilimnion and thermocline depth will increase the volume of the anoxic hypolimnion.

Few insects are tolerant of extended periods in this low oxygenated hypolimnion which means that lakes with high DOC may have reduced insect emergence (Nebeker 1972). However, the attenuation of light and heat also means that high DOC lakes are less sensitive to climate variations because they tend to stay more stable than lakes with low DOC (Pace and Cole 2002). This stability is beneficial to certain species of emerging insects that have adapted to difficult environmental conditions and use this stability to grow. For example, certain species of midges can adapt to low temperatures in high DOC water by spending more time developing and growing, but taking longer to reach maturity which results in larger insect body size (Oliver 1971). Oxygen plays a key role in *Chironomid* development as well. Little & Smol (2001) discussed that *Chironomus* sp. are valuable indicator organisms of variable oxygen levels because they have adaptations for when anoxic conditions occur, such as possessing hemoglobin and behavioral ventilation. With this information, I expect to find more *Chironomus* sp. in higher DOC waters.

This prolonged development time also has implications for the higher trophic level organisms that feed on emergent aquatic insects. Terrestrial predators will have fewer insects to consume during their growing period which can cause changes in the trophic levels.

In Long Lake in the Upper Peninsula of Michigan, a long-term *in situ* experiment has divided the lake into two basins with an impermeable curtain. The two resulting basins have different DOC concentrations due to an in-flow located in the East basin. The East basin is the darker basin with a higher DOC concentration (11.7 mg/L) while the West basin is lighter with a lower DOC concentration (6.8 mg/L). The different DOC concentrations in the basins have altered the temperature and the thermocline depth due to difference in light penetrations (Pérez-Fuentetaja et al 1999). Prior to manipulation on Long Lake, the thermocline was at 3 meters. Now the thermocline is slightly shallower than 3 meters in the East basin and deeper than 3 meters in the West basin. Increasing DOC concentrations are becoming problematic in North American freshwater systems because it creates unpredictable consequences for the organisms that live in those systems (Monteith et al. 2007). Insect emergence research is vital to determine a solution that will benefit all major species in the different trophic levels and ensure that ecosystems will not be significantly harmed if the current DOC increases continue.

This experiment will determine if different levels of DOC in the separate basins will impact species composition, size, and growth of emerging insects in Long Lake at 3m deep. My hypothesis for this study is that the higher DOC basin (East) will have larger body sizes of emergent insects, higher numbers of *Chironomids,* more biomass, and less insect diversity due to less tolerable conditions.

## Methods:

In Long Lake, 6 insect emergence traps were placed in each basin (East and West) above water that is 3 meters deep. The emergence traps consisted of mesh netting attached to upright piping kept afloat by pool noodles. A bottle of ethanol was attached at the top of the trap to contain the insects. The insects in the traps were collected daily for two weeks and identified to subfamily. Collecting daily allowed for a comparison between the two basins to determine differing timings of insect emergence. The length of the insects was recorded to determine if size differed between the East and West basin. Mass was calculated from lengths using regression equations from Benke et al 1999, Sabo et al 2002, Sample et al 1993, & Sage 1982 to see if the emerging biomass was different between the basins. To compare body sizes and emergent biomass between the two basins, t-tests were performed. Diversity was recorded to determine which basin had the most emergent insect families.

## Results:

Mean body length of insects caught was significantly higher in the East basin than the West basin (6.2mm compared to 4.5mm, t=2.921, df=95.963, p=<0.01; Figure 1). Mean *Chironomid* length was also significantly higher in the East basin at 5.0mm compared to the West basin which was 4.0mm (t=4.505, df=110.7, p=<0.0001; Figure 2). Emergent biomass (Figure 3) was higher in the darker East basin (40.3 mg/m$^2$) compared to the west basin (4.0 mg/m$^2$) but this difference was not significant (t=1.798, df=80.4, p=0.08). The emergent biomass of *Chironomids* was significantly higher in the East basin 0.008 mg/m$^2$ compared to 0.005 mg/m$^2$ in the West basin, (t=4.222, df=97.996, p=<0.0001; Figure 4). Finally, the East basin had significantly more families of insects, and thus was more diverse, than the West basin (Figure 5 and Figure 6).

**Discussion:**

The original hypothesis that higher levels of DOC would increase insect body length, increase *Chironomid* body length, and increase biomass was supported. The assumption that diversity would decrease with higher DOC concentrations was not supported.

My data suggested that emergent insect body length at 3m depth was significantly higher in high DOC environments. This basin might be prone to produce larger insects due to the abundance of nutrients from increased DOC concentration. Allochthonous nutrients may land on the sediments and promote growth by facilitating access to key nutrients. Insects might also be larger in the East basin due to the difference in temperatures between the two basins. Sibly and Atkinson (1994) suggest that juvenile mortality rate can increase with increasing temperatures. Since the West basin has a lower DOC level which allows more light to penetrate the water column, it can be assumed that the West basin has a higher temperature. This higher temperature may be too severe for juvenile insects that are adapted to colder conditions for most of the year.

A possible explanation for the large numbers of Chironomidae in both basins is due to the adaptations that they have from being in an anoxic environment. For example, there are a few species of *Chironomid* that use hemoglobin to obtain oxygen when oxygen is otherwise at low concentrations (Panis et al 1995). From the results, we know that there are higher abundances of *Chironomids* in the East basin versus the West basin. This anoxic environment does not appear to inhibit their growth like it does for other insects that are more sensitive to light or oxygen changes in the water column. It is also assumed that *Chironomids* thrive in the East basin because there are fewer predator encounters due to lack of light and oxygen.

The results of my diversity calculation did not support my initial hypothesis. The East basin had more families of emergent insects than the West basin. I had hypothesized that the lower temperatures and anoxic conditions would not be beneficial for insects not in the *Chironomidae* family. My results, however, show that significant diversity can occur despite these adverse conditions. It is possible that East basin produced more diverse insects because there may be fewer predators in this basin. The colder temperatures and decreased dissolved oxygen levels are not conducive to insect predators such as fish and amphibians (Carpenter et al 2001).

Although West Long had a lower average biomass of emergent insects, there were actually higher numbers of insects emerging from this basin. This could be because larger insects emerged from the East basin than the West basin. There were more Trichopterans that exceeded 15mm in length in the East basin. There was also an Odonata that was collected in the East basin that contributed to the large biomass mean.

Higher biomass in the East basin is an unexpected result, but in this case, it could be beneficial for terrestrial predators. Since there were more insects that emerged in the East basin, there may be more food for terrestrial predators to eat. The increase in nutrients may have been helpful for emergent insect growth and allowed for the large biomass that was produced in the East basin. These excess nutrients may have supported the prey for the emergent insects as well as the base of the food web. It has been suggested that there is a threshold of DOC (around 15mg/l) below which nutrients limit productivity of the lake and above which light limits productivity (Karlsson et al. 2009; Kelly et al. 2014; Solomon et al. 2015). East Long is currently under this threshold and so the increase in nutrients appears to have been beneficial. If the lake continues to brown, light limitation may become too great and over-ride the effect of excess nutrients and we may expect a decline in the biomass of emergent insects.

Unfortunately, there was not enough data to conclude if timing of emergence is being seriously affected by the different DOC concentrations. Also, there is no definitive proof from my research to suggest that emergence is delayed because of DOC. This would be a great study to further explore with a longer collection period. Other potential experiments to perform would be to examine how an excess of nutrients, such as phosphorous and nitrogen, affect aquatic insect growth. To improve upon this experiment, I would have collected for a longer period and observed how the temperature differed between the two basins daily. It would also have been beneficial to put more traps on each side to increase sample size.

DOC is an increasing problem in many temperate lakes and strongly affects the organisms that live in them (Solomon et al 2015). More research needs to be performed concerning DOC to understand how trophic cascades may continue to alter and change. Key terrestrial predator species of insects could be negatively affected due to lack of food available for them to eat during their growing period. Research, such as this, is vital to ensure that we better understand future implications of high DOC concentrations.

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**Figures:**

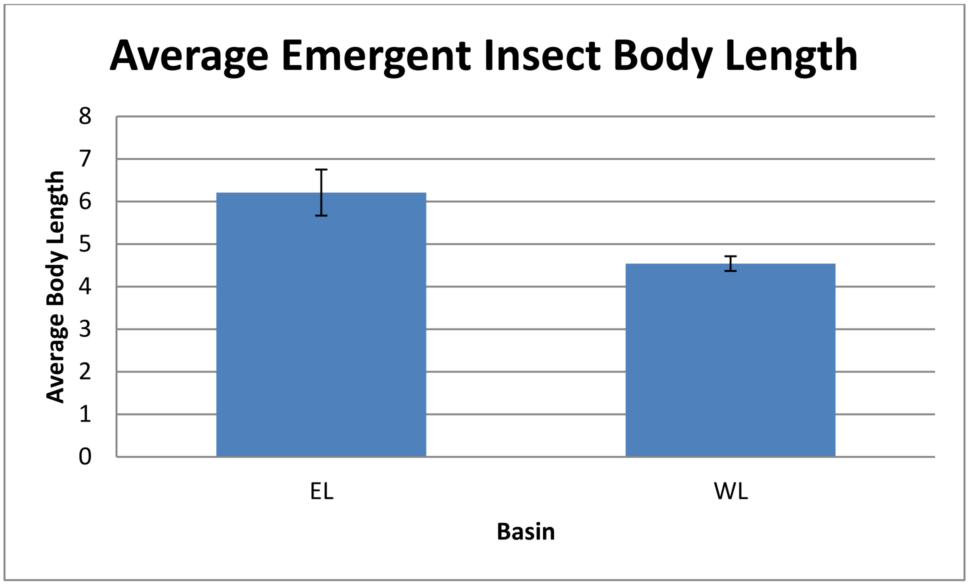

Figure 1. Average Insect Body Length According to Basin. The East basin had significantly greater average body length than the West basin ($p<0.01$). Error bars represent standard error.

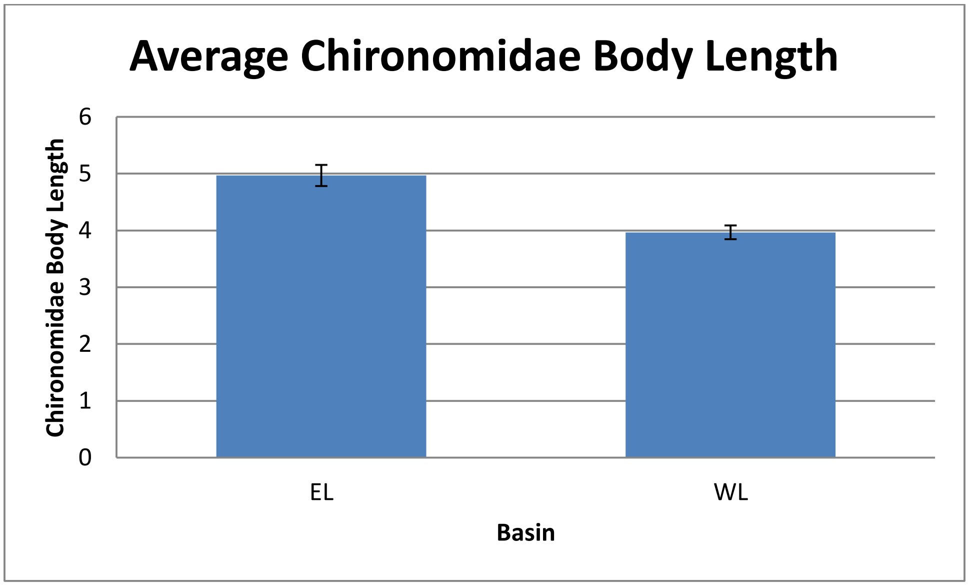

Figure 2. Average Chironomidae Body Length According to Basin. The East basin had significantly greater average body length than the West basin ($p<0.0001$). Error bars represent standard error.

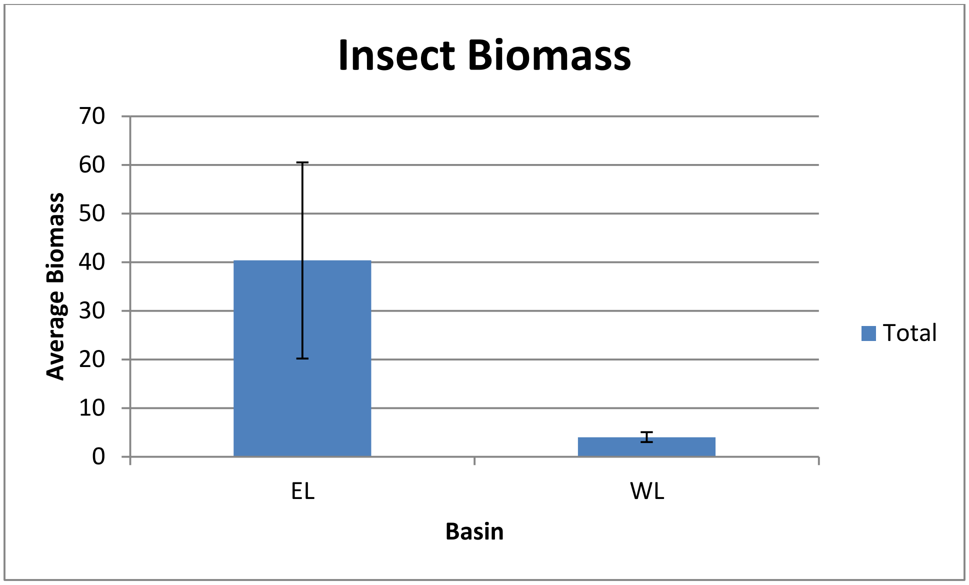

Figure 3. Insect Biomass According to Basin.  The East basin had greater average biomass than the West basin ($p<0.08$), but was not significant.  Error bars represent standard error.

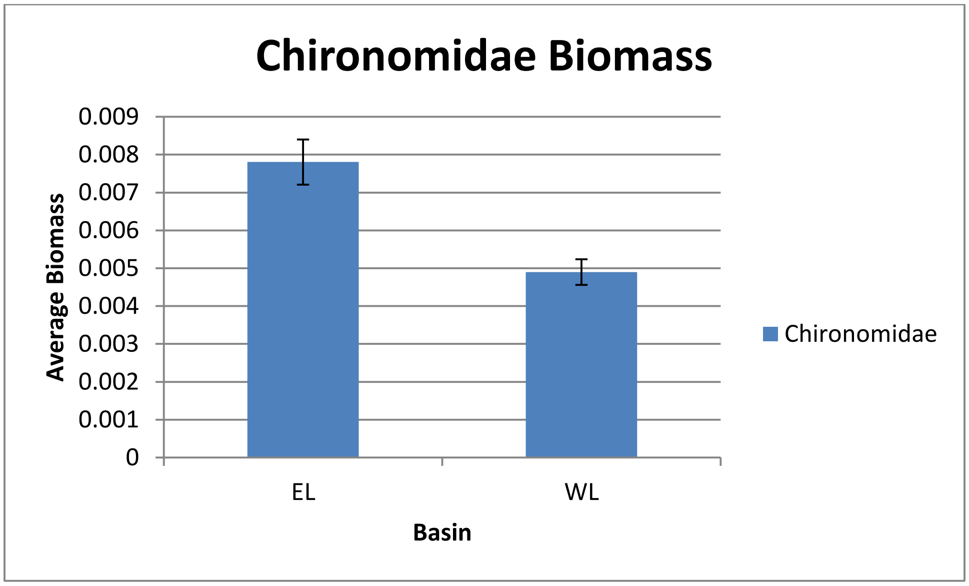

Figure 4. Chironomidae Biomass According to Basin.  The East basin had significantly greater biomass than the West basin ($p<0.0001$).  Error bars represent standard error.

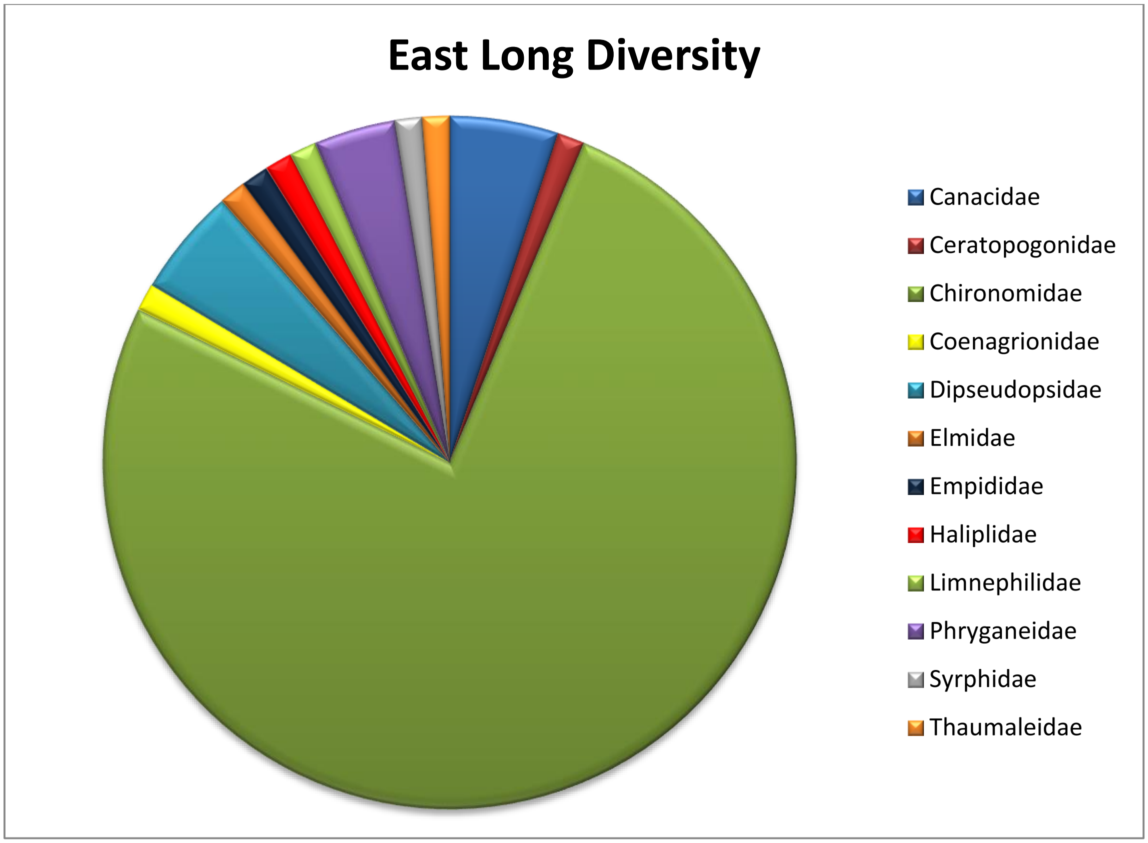

Figure 5. Insect Diversity in the East basin. The East basin had a larger amount of families collected.

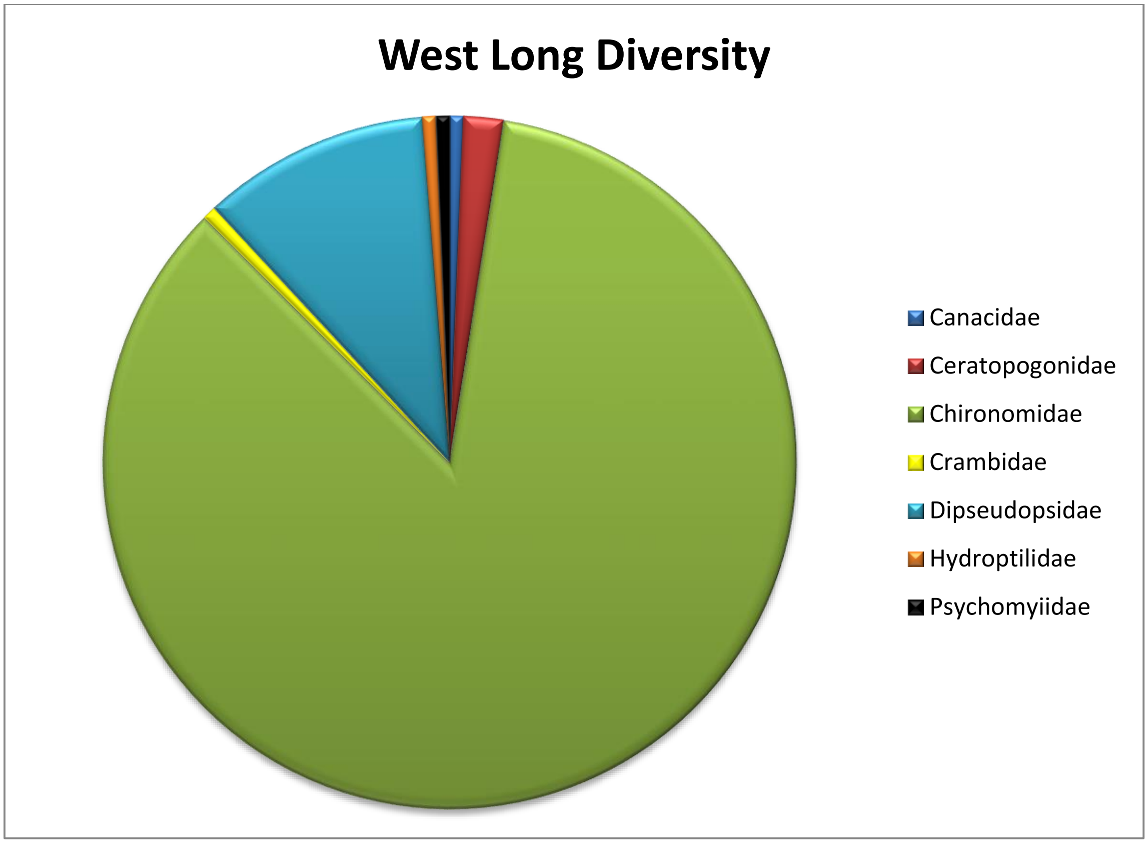

Figure 6. Insect Diversity in the West basin. There were fewer families collected, but more Chironomidae that were collected.