Effect of DOC levels on aquatic insect growth, distribution and emergence patterns.

BIOS 569: Practicum in Environmental Field Biology

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Abstract

DOC has many influences in aquatic systems, from abiotic factors like acidity, nutrient availability and temperature, to aquatic community distribution. Aquatic insects are the most common type of macroinvertebrates and emergent adults represent the connection between aquatic and terrestrial systems. The purpose of this study was to evaluate if DOC levels affect aquatic insect distribution between shallow and deep sites, emergence timing and body size. The research was conducted in Bay lake and Morris lake (low and high DOC level, respectively) at UNDERC. There was a significant and constant preference for shallow sites in both lakes ($P<0.01$). Biomass emergence and dominance of adult emergent insect changed over time and between lakes. In week 1 biomass emergence was significantly ($P= 0.008$) higher in Morris and was compromised majorly of chironomid emergence. Week 2 showed a peak emergence of chaoborus and biomass emergence was significantly higher in Bay ($P= 0.001$). Chironomids were found to grow larger in Morris ($P<0.01$).

Introduction and hypotheses

Depending on different amounts sources of allochthonous (comes from outside the system) inputs, lakes vary in their dissolved organic carbon (DOC). In general, DOC is defined as fine organic compounds small enough to pass through a filter - size range between 0.7 and 0.45 micrometers (um) - and result from naturally-occurring organic carbon forms found in plants, animals and soil organic matter (Schumacher 2002). Contamination is also a source of dissolved organic carbon by increasing the total carbon content in the soil through spills and other anthropogenic activities, although this represents a small contribution compared to the total organic carbon content in the soil (Schumacher 2002). DOC is a measurable component of natural waters and ranges from yellow, brown and in some instances black in color. DOC concentrations in aquatic environments vary greatly and can range from <1 mg liter^{-1} to 50 mg liter^{-1} or more (Williamson et al.1999). Due to its color, DOC 'stains' the water and the higher the concentration the darker the body of water is.

DOC is an important component by its many influences in aquatic ecosystems such as contributing to acidification (Eshleman and Hemond,1985), formation and transportation of metal complexes (Lawlor and Tipping, 2003) and food/nutrient availability (Stewart and Wetzel, 1981; Wetzel, 1992). Also, DOC exhibits light attenuation which in turn has an effect on the water temperature.

Macroinvertebrates live in numerous aquatic environments which include, but are not limited to rivers, streams and lakes. They include mollusks, arachnids, crustaceans, and insects which are the most common type of macroinvertebrates. Aquatic insects spend most of their time underwater as juveniles and, after metamorphosis, emerge as adults to breed and lay eggs back in the water (Hansen et al). These insects disperse around the body of water and are important food source for terrestrial predators, compromising as much as 90% of a spider's diet (Kato et al. 2003) and more than 60% of flycatchers and gleaner's diets (Iwata et al. 2003). Burdon and Harding (2008) showed that spider density near the stream declined when the number of emerging insects was experimentally decreased. There is an intricate connection between aquatic and adjacent terrestrial ecosystems (Jackson and Fisher 1986) and emerging insects play an important role in the movement of energy from aquatic to terrestrial systems (Hansen et al).

Macroinvertebrates communities are generally sensitive to environmental changes and have been used in numerous biological monitoring studies since they respond to chemical and physical disturbances in water (Mustow 2002, Soldner et al. 2004). The light attenuation properties of DOC and its effect on phytoplankton and zooplankton community structure have been previously studied. It was found that with increasing light attenuation ecosystem production decreased (Karlsson et al. 2009). Moreover, decreased light affected phytoplankton community distribution by restricting autotrophic organisms to the top-most water layer (Christensen et al. 1996). However, the effect of DOC on macroinvertebrate community distribution wasn’t studied. This study intends to show how DOC levels affect aquatic insect distribution, growth and emergence patterns.

Numerous lakes at University of Notre Dame Environmental Research Center (UNDERC) exhibit different DOC levels. Available data of the DOC levels in Bay Lake (6.2mg/l) and Morris Lake (15.5mg/l) will enable us to: (1) evaluate if DOC levels have an effect on aquatic insect distribution between shallow and deep sites; (2) evaluate if there’s a difference in timing of emergence between sites and lakes; and (3) compare mean body size of mature insects captured at shallow sites to evaluate if there’s significant difference in growth between high and low DOC lakes.

As DOC taints water and attenuates light, insects in Morris Lake may be restricted to shallow sites due to low oxygen, low temperatures and other unfavorable conditions in deeper sites. Clear waters may allow for a more dispersed distribution of aquatic insects whereas dark waters may impose a more clumped distribution in shallow sites. We may find evidence of this in greater abundance of insects in shallow sites of Morris Lake compared to shallow sites of Bay Lake. For emergence rates we may observe a peak of emergence over time; insects in deep sites of clear lakes may adopt a mass emergence strategy. Invertebrates in shallow zones are likely to be preyed upon so they may try and find refuge in deeper sites where there are less fish. However, they have to travel further up the water column to emerge. As a strategy to minimize predation risk we may expect to find evidence of mass emergence in traps at deep sites of clear lakes, compared to more steady rates of emergence at shallow sites.

For the third part of the study we may find a difference in body size, with insects in dark lakes having larger average body size. Even though insects in dark lakes may be restricted to shallow sites due to unfavorable conditions in deeper waters, they should be better ‘hidden’ from visual predators as the dark water provides protection, compared to low DOC lakes with clearer waters. Darker lakes thus present a low predation-risk environment compared to higher predation-risk environment in clear lakes. With likely refuge and a more stable environment in dark waters, insects manage to spend more time foraging for food and as a result manage to allocate more energy towards development. We would expect to find that adult insects in the shallow zone of the dark lake may have a larger average body size compared to the clear lake, since they can afford to grow larger without risking predation.

Methods

The study sites will be Morris Lake and Bay Lake, which are well known examples of high and low DOC levels, respectively. We will construct and place emergence traps in order to compare data from shallow and deep sites in both lakes. In a random pattern, 5 emergence traps of 0.25 m^2 will be placed in shallow waters at 1.5m and 5 traps in deep waters at 5m for each of the lakes, for a total of 10 emergence traps per lake. The traps will remain in place for 2 weeks and the samples will be collected every 24h. Captured insects will be preserved in 70% ethanol and sorted. We will then proceed to count and identify the mature aquatic insects in the laboratory to family level. We will use time series data to look at how emergence patterns change over time at the shallow and deep sites in both the clear (Bay) and dark (Morris) lakes.

Also, body size (mm) will be measured for insects caught at shallow sites of both lakes. T-tests will then be used to compare mean body size to evaluate if there is significant difference in growth between insects emerging from clear and dark lakes.

Results

Emergence sampling of the lakes was divided in 2 weeks. Emergence samples were collected mid-June (week 1) and early July (week 2). Biomass emergence was significantly different between shallow and deep sites for Bay, as well as Morris (P= values< 0.01). A trend of higher biomass emergence at shallow sites compared to deep sites was observed, as expected. However, the average biomass emergence at shallow sites between Bay (mean= 103.17 mg) and Morris (mean= 80.84 mg) did not differ greatly (*P*= 0.40), nor did the biomass emergence at deep sites (*P*= 0.18; Fig. 1).

Both biomass emergence and individual family contribution differed greatly between week 1 and week 2 of sampling. Morris exhibited a significantly higher average biomass emergence in week 1, while the opposite was observed for Morris in week 2 (P= 0.008, P= 0.001; Fig. 2). Chironomids dominated emergence in week 1 and, in general, Morris had a higher abundance and diversity of emerging adults (Fig. 3). The emerging patterns appear to have changed over time as chaoborus became more abundant in week 2 and Bay accounted for a higher average biomass emergence (Fig. 4).

Based on mean body size comparisons of emerging insects in the shallow zones of Bay Lake and Morris Lake, adult chaoborus were found to significantly (P< 0.01) grow larger in Bay (mean= 2.33 mg) compared to Morris (mean= 1.79 mg; Fig.5). Chironomids were significantly (P< 0.01) larger in Morris (mean= 1.72 mg) than in Bay (mean= 0.73 mg; Fig.5).

Discussion

In this research we observed that DOC levels may affect aquatic insect communities by direct or indirect relationships. We evaluated whether invertebrate distribution was affected by DOC levels by placing emergence traps in shallow and deep sites at both lakes and comparing average biomass emergence. The study showed a significantly higher emergence in shallow sites at both lakes. We also wanted to evaluate if insects in Morris were limited to shallow sites due to unfavorable conditions deeper in the lake; we compared biomass emergence at shallow sites of both lakes. With no significant difference in average biomass emergence at the sites, we couldn’t conclude that insects inhabiting darker waters are restricted to shallow sites compared to lakes with clearer waters (low DOC). In general, Bay showed a higher average biomass emergence for shallow and deep sites (Fig. 1). Temperature profiles show that during the sampling weeks Bay had warmer waters at both depths compared to Morris; low temperatures in Morris Lake result due to the light-attenuating properties of high levels of DOC. The obtained result of higher emergence in warmer waters goes in hand with a previous study by Jackson & Fisher (1986) where rapid insect development in warm water temperatures of a desert stream resulted in high annual production (121 x 10^3 mg m^{-2} $year^{-1}$ dry mass) and emergence (23 x 10^3 mg m^{-2} $year^{-1}$).

Another aspect we studied was emergence patterns over time. This was done in order to determine if insects in deep sites of clear lakes adopt a mass emergence strategy to avoid predation. We compared time series data to look for evidence of mass emergence (shown as a peak) in deep sites compared to more steady rates in shallow sites. Time series between shallow and deep site in Bay showed a similar emergence pattern throughout week 1 and week 2 of sampling with no significant difference, therefore the mass emergence hypothesis was not supported.

We found however, that emergence patterns and species composition greatly differed between week 1 and week 2. This difference in average biomass emergence found between the lakes may be as a result of differences in emergence timing and contributions of different families. Morris showed a significantly higher biomass emergence in week 1 and was compromised primarily by chironomids (Fig. 3), while in week 2 the biomass emergence was higher in Bay dominated by emergence of adult chaoborus (Fig. 4). Previous research have also found that emergence of adult insects vary in time (Corbet, 1964), spatially (Iwata, 2003) and may be related to differences in behavior among insect taxa. It was also observed that chaoborus emergence was much higher in Bay Lake during the second week and this appears to be the main driver in Bay having a higher biomass of emergence than Morris. For both chironomids and chaoborus, a significant difference in body size was found between both lakes. However, a relationship between darker water color and larger adult body size couldn't be determined because the trend varied between families -chaoborus and chironomids-.

Chironomids and chaoborus were abundant and greatly dominated emergent biomass on both lakes, the rest being damselflies and caddisflies. Several studies on benthic secondary production and emergence have shown that adult Diptera generally compromise 60-99% of biomass emergence (Jackson and Fisher, 1986).

DOC is potentially having an effect on emergence timing and understanding its effect on aquatic insect communities is of great importance. Aquatic insects are critical components of aquatic, as well as, terrestrial food webs and significant changes in their emergence will have an impact on the distribution and population biology of terrestrial predators. If increasing levels of DOC were to cause a decrease in emergence, this could be detrimental to shoreline predators that prey on these insects such as spiders, bats, birds and lizards. DOC effect on emergence timing could be important to predators that have coevolved with prey availability and need the food at a certain time. If DOC fluctuations cause a difference in emergence timing, absence or deficiency of prey could heavily affect terrestrial predators that rely on periods of emergence. Further experiments across lakes should be done in order to clearly determine that the results obtained were due to DOC effect rather than a lake effect. Also, emergence difference at family levels could be thoroughly studied to better understand the differences in emergence timing and what factors drive it.

Figures

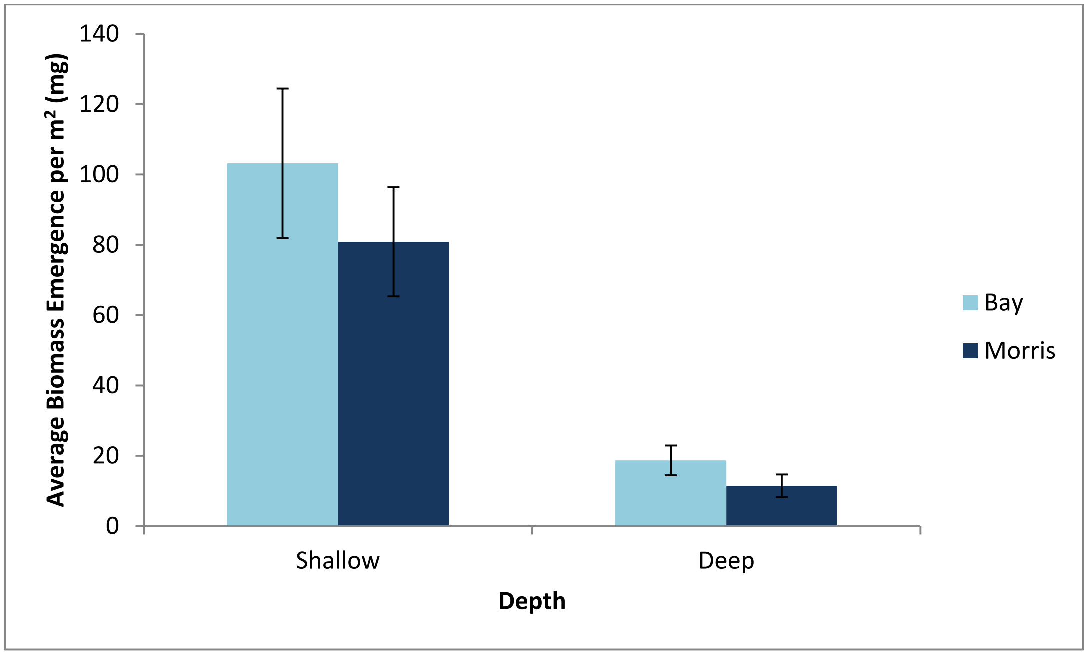

Fig. 1. Comparison of average biomass emergence per m^2 at shallow and deep sites between Bay Lake and Morris Lake. Biomass emergences at the shallow and deep sites were not significantly different between Bay and Morris (*P*= 0.40 and *P*= 0.18, respectively).

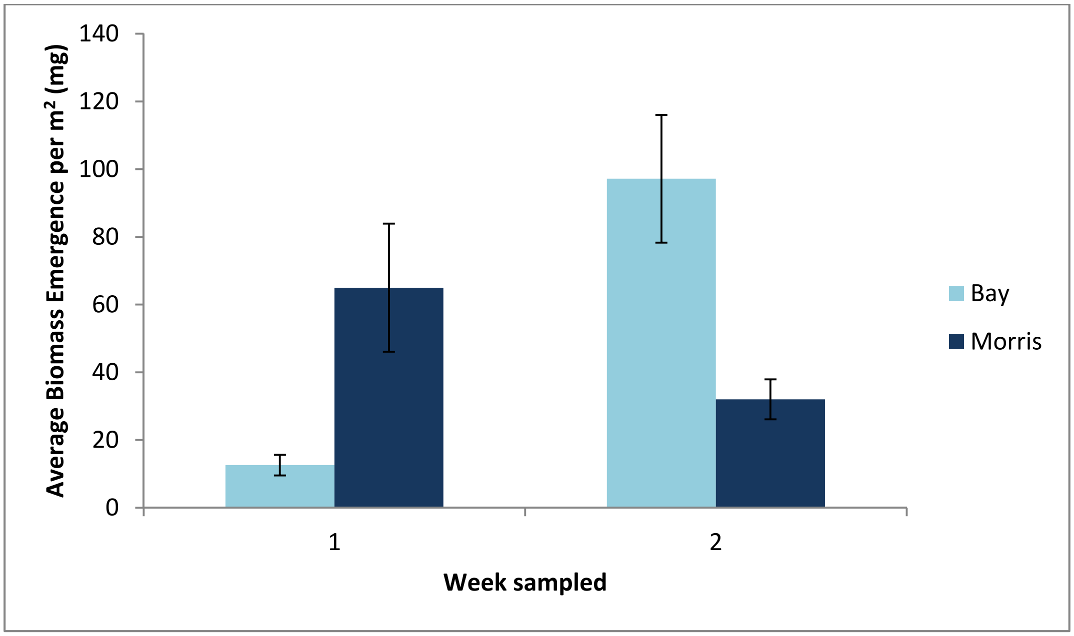

Fig. 2. Average biomass emergence per week at Bay Lake and Morris Lake

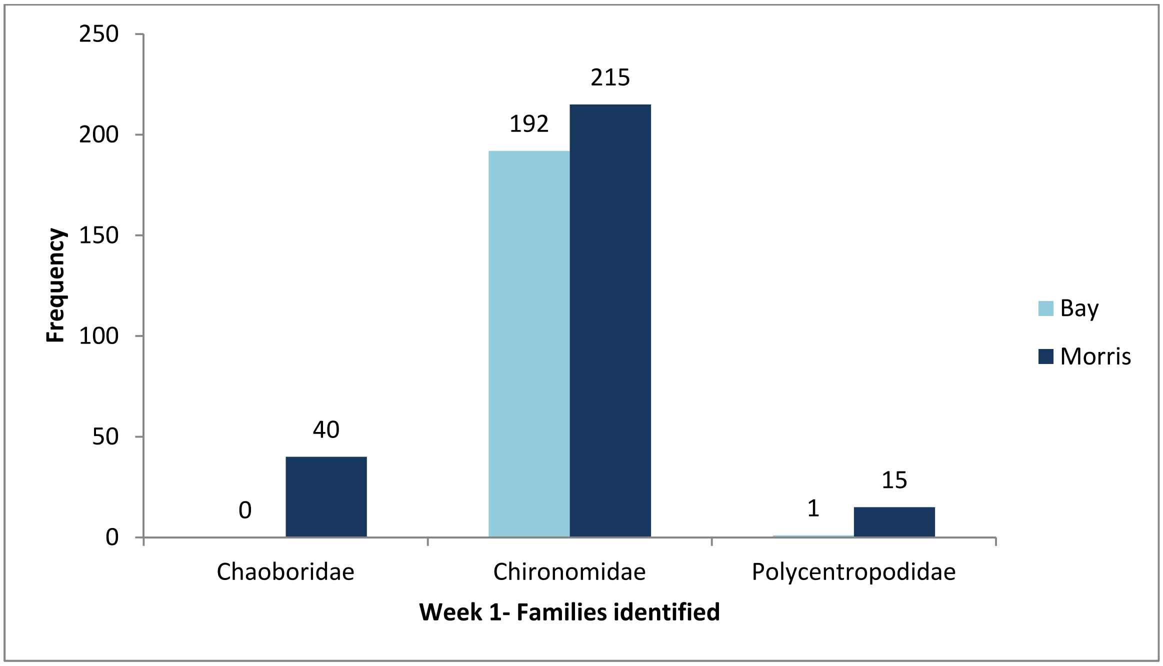

Fig. 3. Frequency (counts) of emergence by family at Bay Lake and Morris Lake in week 1.

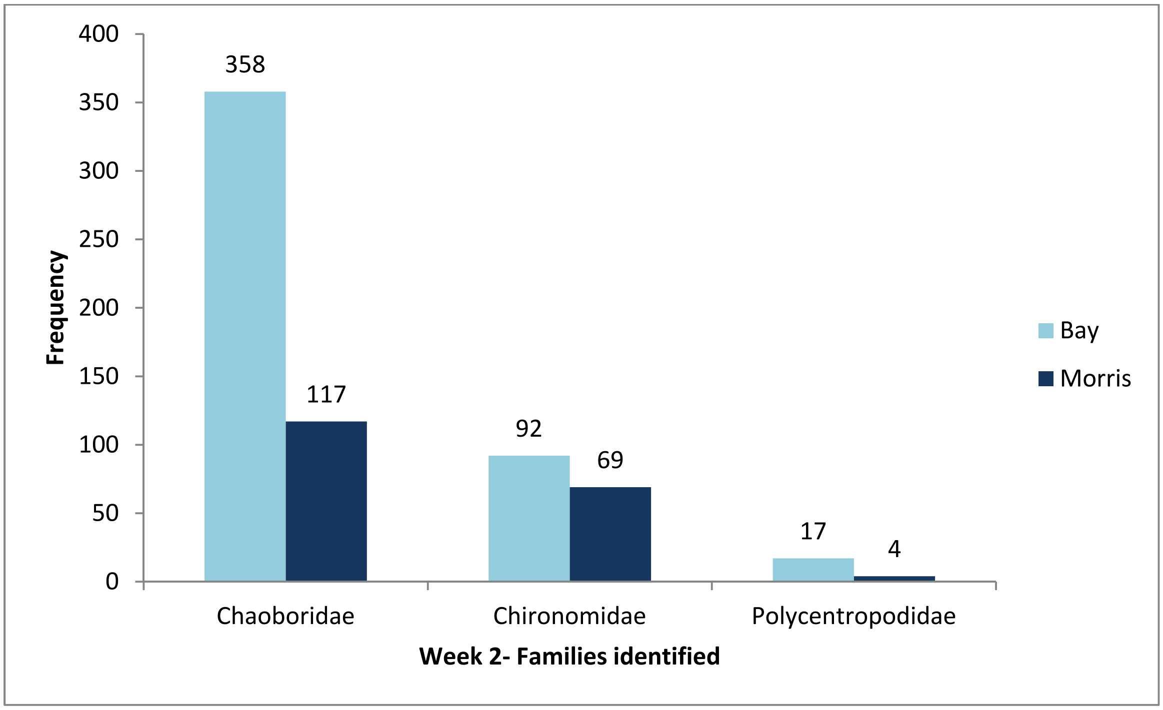

Fig. 4. Frequency (counts) of emergence by family at Bay Lake and Morris Lake in week 2.

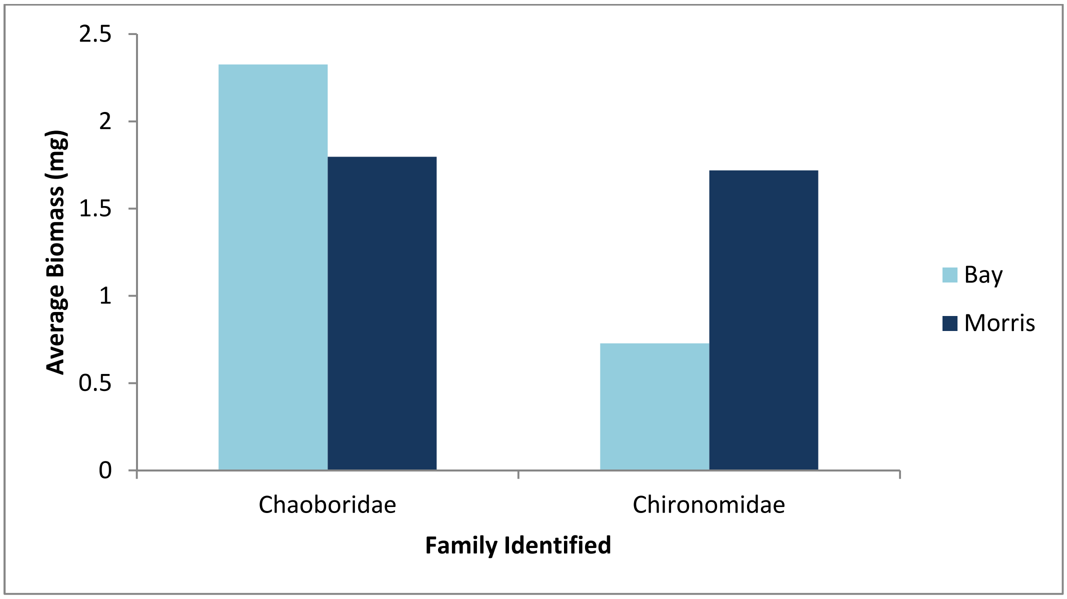

Fig. 5. Body size comparison of adult insects at shallow sites from Bay Lake and Morris Lake.

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