Different Types **of Tea**

Keiko Wilkins

Importance of dissolved organic matter from a native and an invasive plant species in determining freshwater zooplankton success

The effects of increasing dissolved organic matter

Materials from terrestrial plants can have important impacts on organisms living within lakes. Lakes have been experiencing increases in dissolved organic matter (DOM) in the northeastern United States and western Europe. This DOM is often composed of brown, tea-colored substances (Figure 1) that can strongly impact a lakes' suitability as a habitat for organisms. DOM can alter both temperature and light due to its tea-colored materials that absorb light leading to warmer surface waters, stable thermal stratification, and alteration of the vertical gradients of dissolved oxygen and other chemicals (Solomon et al. 2015). These changes in habitat availability could have significant effects for freshwater zooplankton species that have specific temperature optima and tolerances to hypoxia (low oxygen) or anoxia (no oxygen). The complex roles of DOM in freshwater systems makes it difficult to determine the continued effects that it may have on aquatic organisms.

The effects of DOM on freshwater organisms has been widely debated with both beneficial and harmful effects suggested. It is thought that a unimodal relationship between DOM concentration and primary production (phytoplankton) helps to explain these contrasting results (Figure 2). At low DOM concentrations, positive effects are seen on primary production through the addition of nutrients to systems that are often nutrient-limited. However, at high DOM concentrations, negative effects are seen on primary production through the shading of visible light that is needed for photosynthesis. The concentration where DOM switches from the positive to negative effects appears to vary among systems. These effects are also thought to transfer to higher trophic levels such as zooplankton, an important consumer of planktonic algae and important prey for fish, and fish through effects on their food resources. However, DOM concentration does not appear to directly affect zooplankton, as they have been found to tolerate DOM at concentrations far above the proposed threshold concentrations (Nova et al. 2019). This raises questions about the potential importance of DOM quality that might be related to the origin of the DOM. Is DOM quality perhaps more important than DOM concentration?

Figure 1. Dissolved Organic Matter (DOM) derived from a variety of plant sources with different colors of tea seen from the different plant species compared to distilled water. Photo: Craig Williamson.

Inputs of DOM into lakes include a diverse group of materials that originate from different types of terrestrial plants which are then partially broken down in the soils by microbes and sunlight before entering aquatic ecosystems (Solomon et al. 2015). The specific plant species from which the DOM is derived could have a strong influence on its possible effects on freshwater zooplankton. It has been found that not all terrestrial plant species have the same effects on algal or zooplankton abundance in wetlands (Stoler and Rylea 2011), suggesting that this may also be true in lakes. For my thesis research, I tested the hypothesis that the effects of DOM on zooplankton varies with the

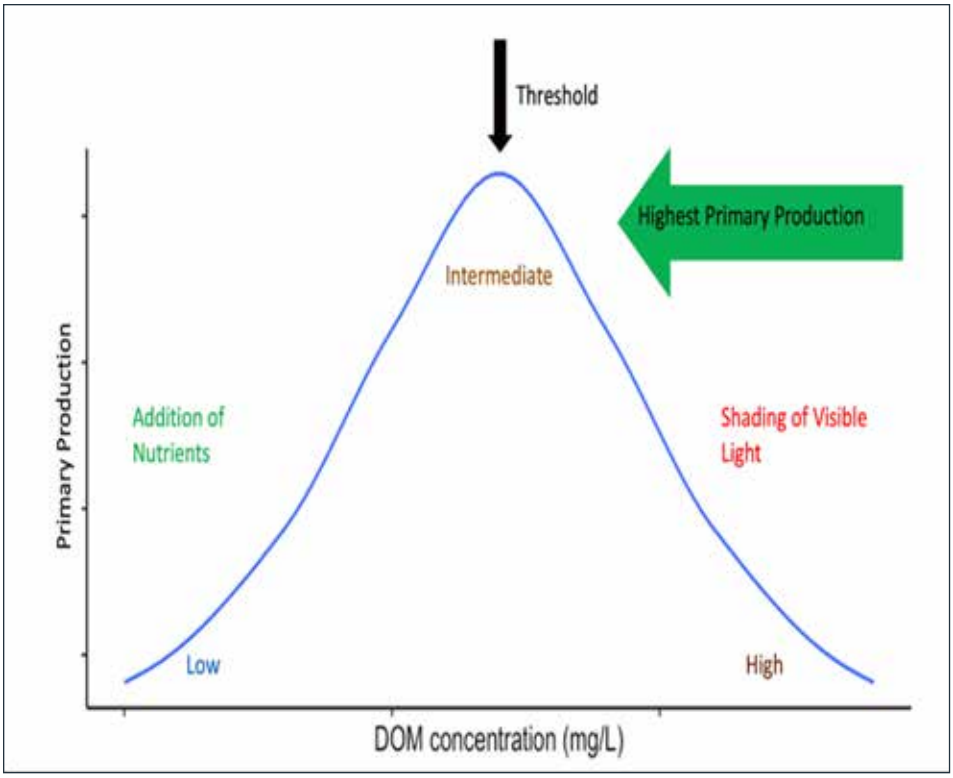

Figure 2. Unimodal relationship between DOM concentration and primary production where the relationship between DOM concentration and primary production is positive (green) at low DOM concentration below a threshold DOM concentration and negative (red) at high DOM concentrations above the threshold.

source of the plants from which it is derived.

The importance of DOM source

Both red maple (*Acer rubrum*), a native plant species and Amur honeysuckle (*Lonicera maackii*), an invasive plant species are common in forests in the eastern United States and contribute DOM inputs into aquatic systems. Amur honeysuckle is known to have only a few herbivore predators (McNeish and McEwan 2016). In addition, negative effects of Amur honeysuckle have been found on both terrestrial and aquatic organisms. In the terrestrial environment, Amur honeysuckle contains important plant secondary compounds used for plant defenses to deter herbivores and suppress germination of native plant species and aide in its invasion. Due to the highly successful invasion of Amur honeysuckle, the riparian zone of streams can become near monocultures with potentially significant negative effects on aquatic biota. In streams, DOM derived from Amur honeysuckle has been found to reduce amphibian larvae survival likely due to harmful compounds in the Amur honeysuckle leaves (McNeish and McEwan 2016). In contrast, red maple did not have any negative effects on algal or zooplankton abundance in wetlands (Stoler and Rylea 2011). This suggests that Amur honeysuckle may have more direct negative effects on freshwater zooplankton than red maple.

For my research I used juvenile *Daphnia* (Figure 3), an important zooplankton grazer, in a series of bioassays to explore the importance of the source of the DOM in determining the survival and growth of zooplankton. Juvenile *Daphnia* were exposed to DOM derived from either red maple or Amur honeysuckle leaves in the presence or absence of algae for five days. I hypothesized that DOM derived from Amur honeysuckle would have a more negative effect on *Daphnia* survival and growth than DOM derived from red maple. In contrast with expectations, I found that DOM derived from Amur honeysuckle had only indirect negative effects on growth through decreasing *Daphnia*'s food source (phytoplankton), while red maple had direct negative effects on *Daphnia* survival and even greater indirect negative effects than Amur honeysuckle on growth. Plant secondary compounds used to defend plants from herbivores could explain the direct negative effects of red maple on *Daphnia* survival. Both Amur honeysuckle and red maple likely decreased growth rates due to phytotoxicity reducing their phytoplankton resources. Phytotoxicity occurs in DOM when the derived plant species have high DOM concentrations, and high C:N ratios which are associated with plant secondary compounds. These secondary compounds include phenols, quinones, and lignin phenols which can act as natural biocides (Nielen et al. 2017).

Implications for management

My research stresses the importance of considering the composition of the terrestrial plant community surrounding a freshwater system when considering lake management. The terrestrial environment can play a key role in determining what is happening in aquatic systems. DOM derived from terrestrial plants can have negative effects on *Daphnia*, which are important consumers of phytoplankton that can help control algae blooms. In addition, invasive plant species in terrestrial environments have the potential to strongly impact aquatic systems. The plant source and chemical composition of DOM is an important determinant of the effects DOM will have on freshwater biota.

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Figure 3. (a) Miami University graduate students Oluwaseun Olubodun (left) and Keiko Wilkins (right) collecting zooplankton from Lake Lacawac, Pennsylvania, USA (b) Daphnia an important zooplankton grazer of primary production and prey for fish.

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Keiko Wilkins is a recent graduate of Miami University (Oxford, Ohio). She completed both her bachelor's of science and master's of science with an applied statistics certificate from Miami University. Since completing her master's thesis research project looking at the effects of dissolved organic matter on freshwater zooplankton, she has transitioned to Southern Cross University (Lismore, Australia), where she is taking part in the Association for the Sciences of Limnology and Oceanography: Limnology and Oceanography Research Exchange. Her research there will focus on the effects of climate change on coral reef feeding rates.

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