How are dragonflies responding to climate change?
An investigation of thermal effects on *Anax junius* nymph growth

Background:

Earth's climate is changing, and scientists are already observing impacts on biota across many taxonomic groups.[1] Odonata are known to be useful biological indicators of environmental change at a macro-scale, including climate change.[2] Odonata are highly temperature-sensitive, with direct effects on their physiology (e.g., developmental rate) and other life-history traits (e.g., phenology).[1] Additionally, distributional and phenological records for Odonata are extensive, so they are excellent model organisms for studying the impacts of climate change on animal distributions, life history strategies, and development. Finally, the fossil record and historic data show that Odonata have survived rapid and dramatic climatic transitions in the past. However, present-day rates of climate change are substantially greater due to anthropogenic causes.[3] Historically, Odonata have proven to be resilient and adaptable, but their current response is unknown. In sum, Odonata are considered sentinels of climate change, and there is growing interest in examining changes in their phenology and physiology as the climate warms.

Odonata have been closely researched in the field. Studies using Odonates in applied research areas, such as climate change, are beginning to gain attention, but overall, research in this area is lacking.[4] I believe that Odonata would be an exceptional research subject to help us understand how freshwater organisms are responding to warming temperatures. Shifts in air temperatures will influence lentic water temperatures through convection and by changing evaporation rates.[5] Odonata are likely to reflect the mismatches between water and air temperatures due to climate change, demonstrating a potential temporal decoupling between aquatic and terrestrial species.[5] Understanding this response in Odonates is particularly important, because they play an important role in structuring food webs, especially in fishless ponds which harbor unique biodiversity among macroinvertebrates, and are quite numerous across the landscape in many glaciated regions.[6]

Research Proposal:

I propose an investigation to examine the effects of warming temperatures on larval dragonflies using the species *Anax junius* (the common green darner dragonfly, Order: Odonata, Family: Aeshnidae), in laboratory experiments. Although lab and field observations of temperature effects on larval Odonate development have been done independently, this proposed study will allow for a comparison between the lab experiment and data collected in the field in order to see if the lab findings in the lab hold up in real ecosystems. This proposal aims to **1)** determine a range of temperatures that allow for optimal growth conditions for *A. junius* nymphs, and **2)** compare the laboratory results to water temperature and *A. junius* emergence timing observed in the field by students and citizen scientists in order to better understand the effects that climate change has on aquatic ecosystems.

Preliminary Work:

For the past three summers, I have worked with my mentor Dr. Emily Schilling at Augsburg University on projects studying dragonflies from the family Aeshnidae. Our studies have focused on species showing evidence of modified life history strategies as an adaptive response to climate change. Through this research, we have developed relatively simple, cost effective and trustworthy sampling methods for nymphs, exuviae, and adults, that can easily be replicated by others.

Methods and Materials:

Aim 1) For this study, I have selected *Anax junius,* because this species is common throughout North America and adults are easily identified in the field (as opposed to other Aeshnids), which need to be observed in hand for species identification. Additionally, *A. junius* is known to be migratory, meaning that this species' distribution covers a large geographic area. For the laboratory component of my study, I will set up fifteen 20-gallon tanks (30"x12"x12"), each containing ten *A. junius* nymphs. Each tank will have a heater to regulate the temperature and a HOBO Dissolved Oxygen Data Logger to monitor the dissolved oxygen differences amongst the temperature treatments. Tanks will be supplied with emergence supports and covered with mesh to capture emerging adults. There will be five temperature treatments (10°C, 15°C, 20°C, 25°C, and 30°C), with three replicates of each. Nymphs will be measured for their head-width-to-wing-sheath ratio three times per week in order to monitor growth, the number of days it takes each nymph to emerge will also be recorded. All molts, deaths, and emergences will be documented each measuring period.

Aim 2) In order to get students and the general public more involved in STEM, I am going to enlist the help of volunteer scientists to broaden the scope of my data set. I will do this by contacting high schools and universities with NSF grants, and by posting ads on social media. I will also contact the Dragonfly Society of the Americas to enroll citizen scientists. For the recruited volunteers, I will let them choose a pond to sample and send them a temperature logger that continuously records water temperature, dip-nets for sampling dragonfly nymphs, and a guide on nymph and adult identification for *A. junius*. Lastly, I will create a web page where volunteers can easily upload their data and observations from their field sites. By using citizen scientists, I will be able to sample a larger geographic area than would be possible on my own, and collect data from multiple regions simultaneously.

Broader Impact:

By examining the data I receive from citizen scientists around the country, I will be able to gain insight as to which regions in North America are seeing the most dramatic changes in water temperature and gain a better understanding of the biological response to this environmental change. It is important to determine regions of concern so conservation planning can be prioritized in those areas. All humans and a large proportion of earth's biodiversity require fresh water to survive. That is why research focusing on freshwater ecosystems is essential. Since climate change is a global issue, it is important to involve people in climate-related research that can ultimately inform how we protect freshwater ecosystems, arguably our most precious ecological resource. By engaging students and citizens in science, by allowing them to be a part of the data collection process, I hope to get more individuals interested in helping preserve and conserve the limited resources we have on Earth for generations to come.

References:

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