SUBLETHAL EFFECTS OF HYPOXIA IN MACROINVERTEBRATES

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Introduction

Consequences of human activities, including nutrient input from agriculture and global warming, are already impacting global ecosystems (Stocker et al. 2012, Breitburg et al. 2009). Nutrient input to aquatic ecosystems is the primary cause of hypoxia (Diaz 2001).

Hypoxia is the condition where environmental oxygen supplies are deficient, but unlike in anoxia, still present in the system.

Increasing temperatures decrease the solubility of many gases in water—including oxygen (Sander 2014); global warming is thus expected to exacerbate exposure and adverse effects of many organisms to hypoxic conditions (Vaquer-Sunyer and Duarte 2008).

Aquatic food webs largely depend on macroinvertebrate species that have a high biomass production.

In this study, we looked at sublethal effects of hypoxia on various macroinvertebrates by conducting a literature review.

Methods: literature search and data analysis

We looked for relevant published studies on Google Scholar, Scopus, and JSTOR.

Relevant studies described sublethal effects of hypoxia on the following processes: growth (changes in body length and mass), reproduction, feeding and respiration (amount of consumed oxygen). Several studies examined a range of temperature and oxygen treatments.

Data from obtained papers were digitized using Datathief III (Tummers 2008), and was compiled into an Excel spreadsheet (Microsoft 2013).

Data from different treatments were scaled to controls and experimental period lengths and oxygen measurements were standardized to partial pressure (kPa), allowing a comparison across studies and units. Effects of both temperature and oxygen on selected endpoints were analyzed using multiple regression in R (R Foundation 2015).

Results

Our literature search yielded 51 relevant studies out of which 14 investigated impacts hypoxia (and temperature) on growth, 11 on feeding, 9 on fecundity, and 17 on respiration (results not shown). We looked for both effects of oxygen (blue line) and both oxygen and temperature (red line).

Amount of oxygen has a positive effect on feeding of tested organisms ($p < 2.2 \times 10^{-16}$) (Figure 1).

Data on growth was separated to growth in length (Figure 2) and growth in mass (Figure 3). Both were significantly affected by the level of oxygen and temperature, but growth in mass much less so ($p = 0.002679$) when compared to growth in length ($p = 2.2 \times 10^{-16}$).

Fecundity was also affected significantly by oxygen and temperature ($p = 1.486 \times 10^{-9}$).

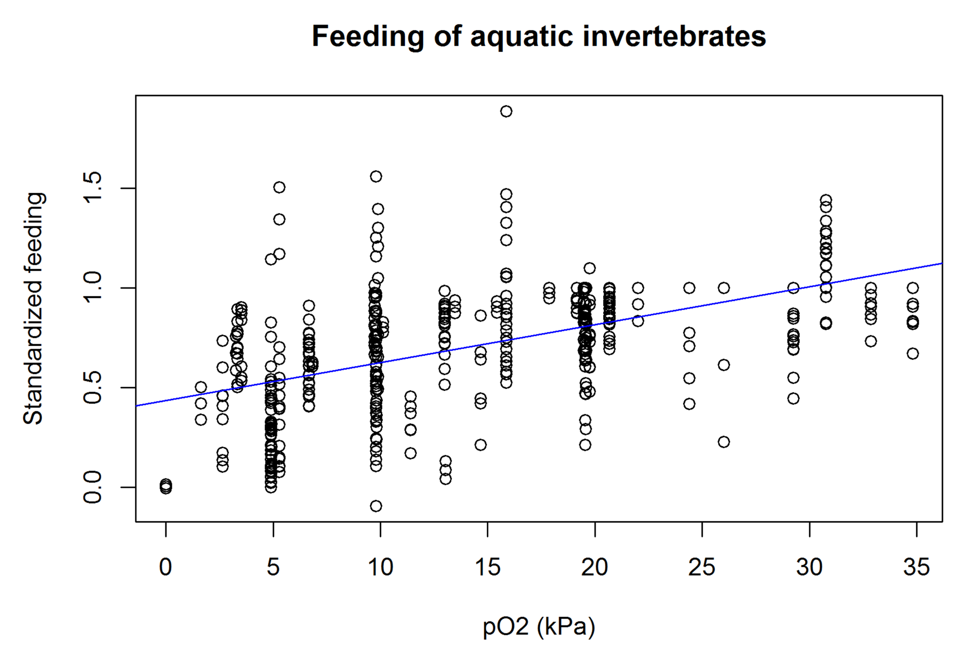

Figure 1: Feeding at a given oxygen tension—scaled to normoxia. The blue line indicates the effects of oxygen tension ($R^2 = 0.2832$, $p < 2.2 \times 10^{-16}$).

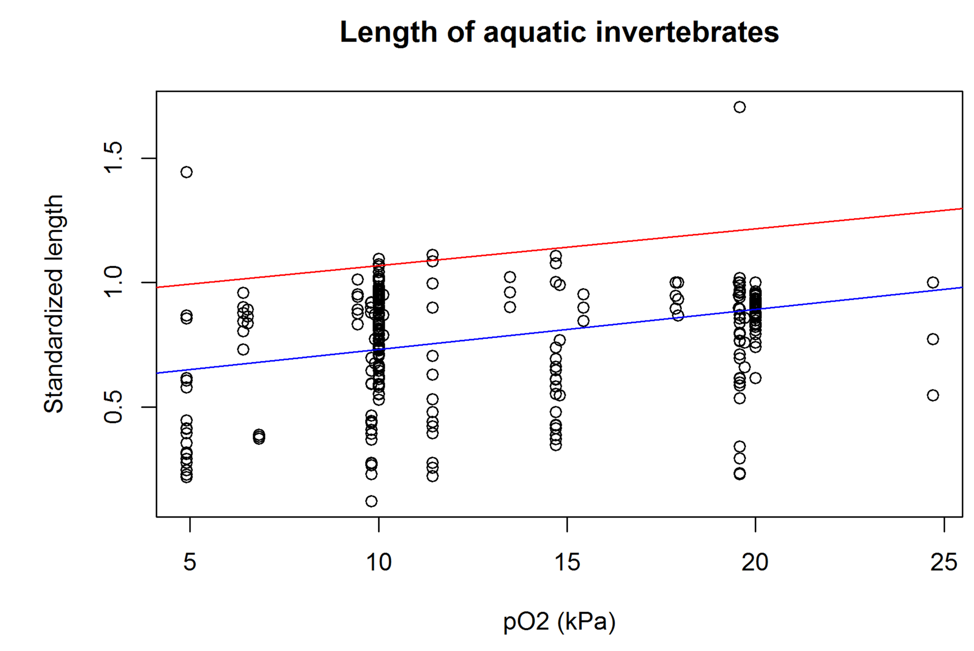

Figure 2: Length at a given oxygen tension—scaled to normoxia. The blue line indicates the effects of oxygen tension ($R^2 = 0.1374$, $p = 4.708 \times 10^{-12}$), and the red line oxygen tension and temperature ($R^2 = 0.2557$, $p = 2.2 \times 10^{-16}$).

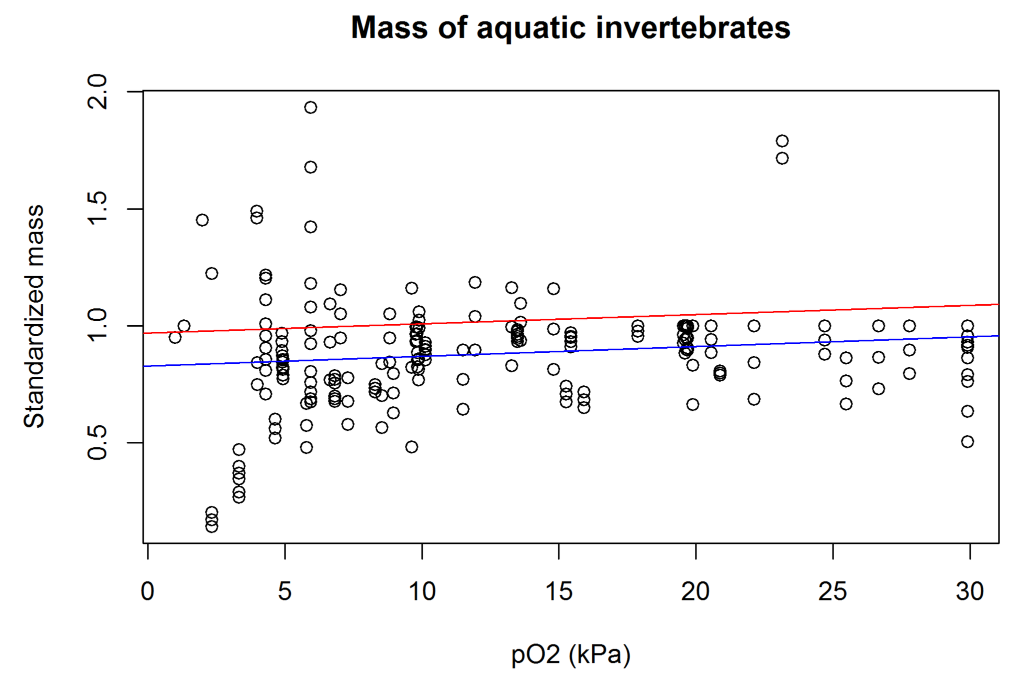

Figure 2: Mass at a given oxygen tension—scaled to normoxia. The blue line indicates the effects of oxygen tension ($R^2 = 0.01848$, $p = 0.05434$), and the red line oxygen tension and temperature ($R^2 = 0.05807$, $p = 0.002679$).

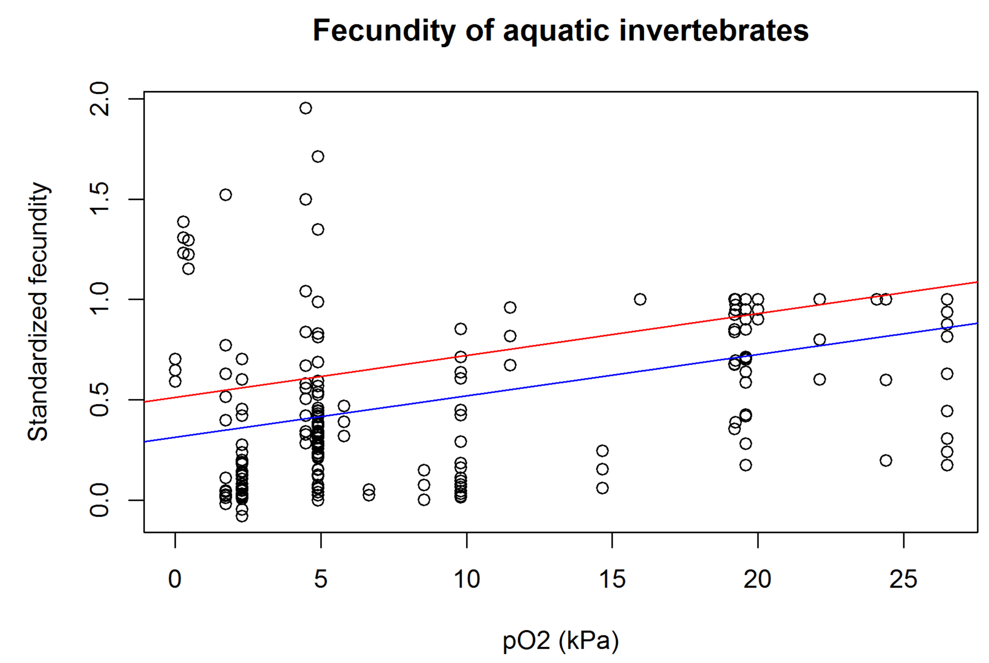

Figure 2: Fecundity at a given oxygen tension—scaled to normoxia. The blue line indicates the effects of oxygen tension ($R^2 = 0.1632$, $p = 4.372 \times 10^{-10}$), and the red line oxygen tension and temperature ($R^2 = 0.1701$, $p = 1.486 \times 10^{-9}$).

Conclusion

All tested processes were adversely impacted by decreasing oxygen availability. Organisms in hypoxic conditions were feeding less, grew and reproduced less than organisms in normoxic conditions.

We expect increasing temperatures in aquatic ecosystems to adversely affect a number of important processes and life history traits through their impact on oxygen availability.

Anthropogenic changes in global ecosystems have potential to adversely impact survival and life history of many species. Consequences for populations in the field still need to be tested.

Next steps
Evaluating impacts of 1.5-4.5˚ C (Stocker et al. 2012) increase on the amount of oxygen in freshwater systems and on relevant processes.

Through population modeling, we aim to quantify impacts for a population of freshwater amphipods.

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