Manuscript

Faster growth rates and higher mortality but similar size-spectrum in heated, large-scale natural experiment

Max Lindmark[a,1], Malin Karlsson[a], Anna Gårdmark[b]

[a] Swedish University of Agricultural Sciences, Department of Aquatic Resources, Institute of Coastal Research, Skolgatan 6, 742 42 Öregrund, Sweden

[b] Swedish University of Agricultural Sciences, Department of Aquatic Resources, Box 7018, 750 07 Uppsala, Sweden

[1] Author to whom correspondence should be addressed. Current address:
Max Lindmark, Swedish University of Agricultural Sciences, Department of Aquatic Resources, Institute of Marine Research, Turistgatan 5, 453 30 Lysekil, Sweden, Tel.: +46(0)104784137, email: max.lindmark@slu.se

Dear Editor,
I am submitting the manuscript '*Faster growth rates and higher mortality but similar size-spectrum in heated, large-scale natural experiment*' for consideration to be published as an article in *Nature Communications*. A previous version of this manuscript has been submitted to *Nature Ecology and Evolution*. Since then, we have expanded the discussion to better link to the previous literature, changed the analysis of the size-spectrum and also changed the title.

Global warming is often predicted to lead to faster growth rates, but overall shrinking of ectotherm species (e.g., reduced mean body size due to declines in adult size-at-age). These predictions generally stem from small-scale and short-term experiments, and to a lesser degree, observational analysis. Semi-controlled ecosystem-scale warming experiments, are, however, extremely rare. Yet, they provide unique insight into potential impacts of climate change.

In this study, we use an enclosed coastal bay heated by cooling water from a nuclear power plant for more than two decades (resulting in temperatures ~+8°C) and its reference area as a large-scale experimental study system. We analyze time series of growth-increment biochronologies and catch data of a common freshwater fish (12658 length-at-age measurements from 2426 individuals in 256 net deployments), to quantify differences in key individual- and population level parameters, such as body growth, asymptotic size, and mortality rates.

Contrary to common predictions on the effects of warming on size-at-age and body growth, we found that body size was larger for all ages and growth faster for all sizes in the heated area, compared to the reference area. However, despite these changes in growth and size, the size-spectrum was only slightly larger in the heated area, which we showed was due to elevated mortality rates.

Our findings reveal that universal predictions about the shrinking of ectotherm organisms may be too simplistic since they typically focus on individual-level changes (body growth rates) and not population-level processes (mortality and demography). It also suggests that mortality may be similarly important as a driver of size structure-changes with warming as body growth rates.

Population size-distributions determine ecological functions, interactions, and dynamics, and understanding their responses to climate change is therefore paramount. Our results demonstrate that to understand warming-induced changes in the size-structure of species, it is critical to account for how climate change alters *both* mortality and growth rate, and how these changes may depend on each other. This knowledge is critical for mechanistic climate assessments of aquatic ecosystems.

We are grateful for your consideration of our manuscript, and we look forward to hearing from you.

Sincerely,

Max Lindmark, on behalf of all co-authors
Swedish University of Agricultural Sciences, Department of Aquatic Resources, Institute of Marine Research, Turistgatan 5, Lysekil 453 30, Sweden, Tel.: +46(0)104784137, **email**: max.lindmark@slu.se