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The relative importance of intraspecific and interspecific effects to temperature–size relationships in diatom communities

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Summary

Climate warming has been linked to an apparent general decrease in body sizes of ectotherms, both across and within taxa, especially in aquatic systems. We tested the hypothesis that diatoms are smaller at warmer temperatures using a system of geothermally heated streams in Iceland. To do this we examined both community and species levels of organization simultaneously, and developed a statistical method that calculates the proportion of size differences between communities that are due to intraspecific and interspecific effects. We found that there was no consistent relationship between size and temperature at either the population or community level. Therefore, these data provide important counterexamples to both James' and Bergmann's temperature–size rules, respectively, undermining the widely held assumption that warming favours the small. In addition, we show that interspecific effects were a bigger contributor to whole-community size differences, and are probably more ecologically important than more commonly studied intraspecific effects. These findings highlight the need for multispecies approaches in future studies of climate warming and body size.

Introduction

Numerous studies have linked temperature and climate warming with changes in body size across taxa, with an apparent trend that warmer conditions tend to favour smaller organisms (Daufresne *et al* 2009, Sheridon and Bickford 2011). Since body size is a key determinant of organism physiological traits and functional roles within an ecosystem, these temperature-size relationships have ramifications for ecological interactions and the structure and functioning of communities. Recent work suggests that, for ectotherms in aquatic environments, the trend of smaller sizes at warmer temperatures is sufficiently widespread that it may be a universal rule across many biological scales. We tested temperature-size relationships at both the population (James' rule) and community (Bergmann's rule) levels in diatom assemblages from a series of geothermally heated streams in Iceland. Diatoms are found in almost all aquatic systems and account for around 23% of the world's total primary productivity, so warming-induced body size changes in diatoms could have large impacts on aquatic food web structure.

Materials and Methods

Study system and sampling

The study was done in the geothermal Hengill region of Iceland. The area contains multiple indirectly heated streams that are tributaries to the same main stem, all within 2 km of one another. These features enable us to isolate the effects of temperature on diatom community composition and size structure. Diatom sampling took place in August 2008; algal scrapes were taken from five randomly selected rocks in each of 14 streams in the system. Relative abundance of diatom species was calculated, and within each stream, for every species in the top 95% abundant species, ten individuals were selected for size measurement. We used valve area as the measure of body size for the diatoms.

Statistical methods

We first tested for population level (intraspecific) effects by carrying out linear regressions of temperature against body size for each diatom species that was present in two or more streams. We then tested for community level effects by calculating average diatom size for each stream using a simple weighted mean, with confidence intervals determined using resampling methods. To partition the causes of community level size change into intraspecific effects (body size differences within species) and interspecific effects (compositional changes between communities), we considered pairwise comparisons between the 14 streams. We defined the proportional contribution of intraspecific effects as the size difference we would expect if there were no compositional differences between two streams, and compared this to the observed size differences between those streams in order to calculate the relative contribution of interspecific effects.

Results and Discussion

In a comprehensive study of diatoms in a natural community, we provide evidence that commonly reported temperature-size relationships do not hold universally for diatoms. At the population level, temperature had a significant effect on the body size of some diatoms, but the direction of slopes varied and there was no overall tendency for species to decrease in size with increasing temperature. There was also no clear relationship between temperature and body size at the community level. Therefore our results do not support the hypothesis of smaller body size under warmer conditions, contradicting both Bergmann's and James' rules. The results also undermine claims that reduced body size is a universal ecological response to warming in aquatic systems (Daufresne *et al.* 2009), suggesting that diatoms are a very important exception to these general tendencies.

Our results also showed that community-level body-size shifts across gradients of temperature are determined largely by interspecific effects. Of 91 pairwise comparisons between average community body size in the fourteen streams, 51 showed that the observed difference in average community body size was solely due to compositional shifts and only four showed that the difference was solely due to intraspecific effects. The rest were due to a mixture of the two mechanisms, with an average contribution of intraspecific effects to community differences in body size of 21.8%. Thus intraspecific size changes, which are commonly studied in single-species laboratory experiments, played a much smaller role in the field, highlighting the need for whole-community studies for understanding the effects of climate change in natural multispecies systems (Woodward *et al.* 2010).

More recently, other studies have started to test the proposed universal rule of Daufresne *et al*. (2009) that there is a shift towards smaller species with increased warming in aquatic communities, with some studies showing further exceptions. Future studies should build on the population- and community-level responses of body size to warming demonstrated here, in order to help disentangle the most important factors determining differences in community structure under warming. Only by understanding the mechanisms underpinning the exceptions to general rules in ecology can we hope to promote true predictability of future climate warming responses.

References

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