On the importance of behavioural adaptations in thermally challenged intertidal ectotherms: implications for climate change studies

Coraline Chapperon

BSc, MSc

Thesis submitted to the Faculty of Sciences and Engineering, School of Biological Sciences of Flinders University in total fulfilment of the requirements of the degree of Doctor of Philosophy of Flinders University

June 2012

Supervisor: Prof. Laurent Seuront
Co-supervisor: Assoc. Prof. Jim Mitchell

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To my mother (Marie), brother (Luc) and grand-mother (Emilienne),
To my son Bastian, the apple of my eye.

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SUMMARY

The recent integration of physiological responses of ectotherms in climate change models has provided a greater insight into the species thermal window of adaptation, hence future distribution ranges. However, there are still fundamental gaps in these climate change models. In the present thesis, intertidal ecosystems were used as outdoor laboratories and valuable models, which used invertebrates as bio-indicators to bridge the gaps between the thermal ecology of ectotherms and climate change models. Intertidal invertebrates already live at or near to the upper edge of their thermal tolerance window, hence have limited physiological abilities to adapt to further warming. Their behavioural adaptations to mean temperature increase and especially to extreme events are then likely to play a major role in the maintenance of individuals' fitness in the warming climate. Nevertheless, the behaviour is still absent from climate change models. In addition, the local environmental context, especially the spatial environmental thermal heterogeneity, is overlooked in climate change models. Yet, this appears critical since mobile ectotherms living in heterogeneous environments such as the intertidal might behaviourally take advantage of thermal mosaics when facing new environmental conditions by, for example, relocating into thermally favourable microhabitats. The large scale approach used in climate change studies also leads to erroneous measurements of ectotherm body temperatures that largely contribute to distribution patterns. Indeed, they usually consider air temperature measured at large spatial scale to be a good proxy for animal body temperatures. Nonetheless, organism thermal properties are determined by multiple non-climatic and biotic variables which interact at the niche level. In this context, the present work aimed to investigate (i) the primary factor(s) that determine body

temperature, displacement and distribution patterns of mobile intertidal ectotherms at the individual scale, (ii) the space-time heterogeneity in environmental and invertebrate body temperatures at a range of scales by using thermal imaging, and (iii) the potential adaptive behavioural capacity of intertidal ectotherms to compensate for climate change. The main results show that substratum temperature could be used as a primary determinant for mobile intertidal ectotherms in climate change models, instead of air temperature. I also highlight a high substratum thermal heterogeneity at centimeter scale in different habitats, *i.e.* tropical mangroves and temperate rocky shores. This contributes to the growing evidence that small spatial scale variability in thermal environmental properties can surpass the thermal variability measured at large spatial scales. Besides this evidence for the importance of thermal variability, I have demonstrated that the gastropod species *Littoraria scabra*, in tropical mangroves, and *Nerita atramentosa*, on temperate rocky shores, were able to select thermally favourable microhabitats or substrata to behaviourally thermoregulate. I also emphasise the buffering role of aggregation behaviour under cold, hot and desiccation stresses. In conclusion, the present work shows the need to integrate small spatial scale heterogeneity found in environmental conditions and thermoregulatory behaviours that appeared to be species and habitat-specific into climate change models. This small spatial scale heterogeneity constitutes a fundamental prerequisite to make prediction about ectotherm distribution ranges in the changing climate.

DECLARATION

'I certify that this thesis does not incorporate without acknowledgment any material previously submitted for a degree or diploma in any university; and that to the best of my knowledge and belief it does not contain any material previously published or written by another person except where due reference is made in the text'.

Coraline Chapperon

June 2012

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