Imperial College London

CMEE MRes Project Proposal

Integrating Body Size or Temperature Scaling with the Neutral Theory of Biodiversity

(a draft title)

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9 December 2016

Proposal's Remit

This is an initial proposal, put together at an early stage in the learning process. It will develop further, as my knowledge and understanding of this exciting and intriguing area grows.

Background

Neutral Biodiversity Theory

Neutral Theory assumes that all individuals in a community are ecologically identical [Rosindell et al., 2011]. Its success at reproducing biodiversity patterns suggests that demographic stochasticity, rather than the differences among species, is the key influence on diversity [O'Dwyer et al., 2009]. Neutral Theory is a drastic simplification of reality. It provides a null model, from which to test whether the added complexity of other mechanisms can explain biodiversity.

Key parameters of a neutral model: random death, speciation, and dispersal.

Allometry and Metabolic Scaling

Body size determines an organism's metabolic rate - the rate at which it expends energy (e.g. for growth and reproduction). Thus, body size has a big impact on the structure and function of communities and ecosystems. Specifically, metabolic rate scales as a power function with body mass [Sibly, 2012].

Scaling relationships are a powerful set of generalisations, which essentially assume all species of the same size behave the same way. Like Neutral Theory, they give a quantitative starting point for understanding the structure of a complex system. Fascinated by the simplicity and success of these approaches, I am drawn to investigating the links between them, and the next layer of complexity.

Overarching Purpose

Fundamental aim: make simple assumptions about complex systems to see what can be explained by models.

Context: quantify the effects of body size/temperature on biodiversity patterns, relative to demographic stochasticity.

Method: use allometry or metabolic scaling to describe select neutral-model parameters.

Potential Avenues

1) Estimate Extinction Rates after Habitat Loss

Habitat loss is a primary threat to biodiversity, but the accurate estimation of extinction rates is unresolved [Halley and Iwasa, 2011]. The difficulty is partly due to 'extinction debt' - species are lost gradually, not immediately after habitat destruction [He and Hubbell, 2011].

In neutral models, death is a stochastic process. O'Dwyer et al (2009) instead described a size-structured simulation community, where individuals die with a size-dependent rate. The goal would be to:

- develop a time and spatially explicit hypothesis
- test whether you can generate more precise predictions of extinction rate by drawing on the methods of O'Dwyer et al.

Introducing size variation to a simulation community changes the species biomass distribution produced by a neutral model [O'Dwyer et al., 2009]. If it is too challenging to estimate extinction rates, a simpler alternative is to study changes to community structure after habitat loss.

2) Predict Altitudinal Gradients of Biodiversity

A prominent observation of biodiversity is the latitudinal diversity gradient - an increase in species richness from the poles to the equator [Tittensor and Worm, 2016]. One hypothesised explanation is higher speciation rates - a result of higher temperature and thus faster physiological rates (higher mutation rates and shorter generations) [Sibly, 2012]. This gradient can be reproduced in simulation, by applying a thermal effect to speciation rate (and, crucially, increasing community size towards the tropics) [Tittensor and Worm, 2016]. Species richness also follows elevational gradients. Temperature is the most evident factor that varies with altitude, generally decreasing at higher elevations [citation to be confirmed]. This idea of varying speciation rates is contentious and requires further evaluation. It is also unreasonable to expect the mechanisms promoting latitudinal and elevational gradients to be the same. Alternative hypotheses and ways to parametrise a neutral model will be considered. E.g., the 'out of the tropics effect' [Jablonski et al., 2006] could be examined with a 'nearly' neutral model that considers fitness.

The goal would be to:

- add thermal effects to neutral model parameters
- run spatially explicit neutral simulations, to see if altitudinal, instead of latitudinal, gradients can be reproduced.

Initial Timeline

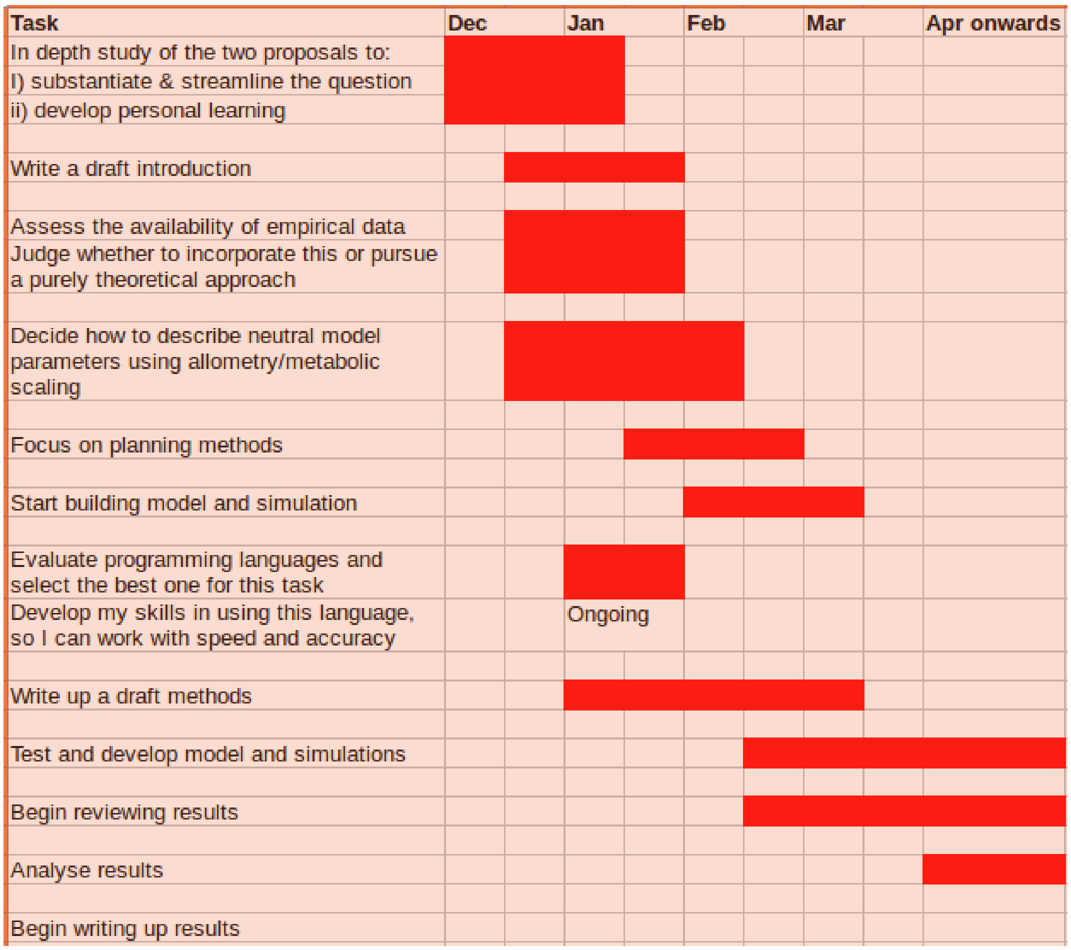

Figure 1: Timeline of initial part of project

Budget

Printing - papers for reading; dissertation (£125)

Contingency - e.g. attending a conference (£375)

References

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[Jablonski et al., 2006] Jablonski, D., Roy, K., and Valentine, J. W. (2006). Out of the tropics: Evolutionary dynamics of the latitudinal diversity gradient. *Science*, 314(5796):102–106.

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[Sibly, 2012] Sibly, R. M. (2012). *Metabolic ecology : a scaling approach*. Wiley-Blackwell, Chichester, West Sussex Hoboken, NJ.

[Tittensor and Worm, 2016] Tittensor, D. P. and Worm, B. (2016). A neutral-metabolic theory of latitudinal biodiversity. *Global Ecology and Biogeography*, 25(6):630–641.