

Simulating the origins of tropical marine diversity

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Key words:	Marine, biodiversity, ecology, evolution, palaeobiology, coral reefs, tropical, model
Research theme(s):	• Oceanography, Climate and Palaeoenvironment • Palaeobiology and Evolution
Eligible courses for this project:	• DPhil in Earth Sciences (3-4 years) • Interdisciplinary Life and Environmental Science Landscape Award (ILES�A) • Intelligent Earth (UKRI CDT)

Overview

Today, the Indo-Australian Archipelago is the global hotspot of tropical marine biodiversity, but this was not always the case (fig. 1). Various models have been suggested to explain these changes through geological time, including 'hopping hotspots' that gradually track suitable shallow-marine habitat versus 'whack-a-mole hotspots' that rise and fall independently (Yasuhara et al., 2022). Hotspots themselves have been suggested to be maintained through enhanced rates of speciation and/or low rates of extinction, high levels of overlap between ranges, or accumulation via dispersal (e.g. Bellwood et al., 2012). Understanding how biodiversity hotspots rise, endure, and fall is important in an era of rapid environmental change to inform approaches to conservation and predict how biodiversity may change in the future.

While palaeontology and biogeography are valuable for distinguishing between these different hypotheses, simulation models have also been successfully used to investigate mechanisms behind spatial and temporal shifts in diversity. For example, Saupe et al., (2019) used a cellular automaton to simulate speciation, extinction and dispersal dynamics for terrestrial fauna over a glacial cycle (fig. 2) and found evidence that the terrestrial latitudinal biodiversity gradient can be largely explained by gradients in speciation.

The goal of this project is to apply a similar approach to investigate the origins of contemporary gradients in *marine* biodiversity. The marine realm introduces several complications, including highly directional and heterogeneous dispersal potential (Álvarez-Noriega et al., 2020). Using palaeoclimate and eco-evolutionary simulations, we will investigate how habitat availability and dispersal may have changed throughout the Cenozoic for marine fauna, and will explore the plausibility of competing mechanisms for the formation of the modern hotspot of tropical marine biodiversity.

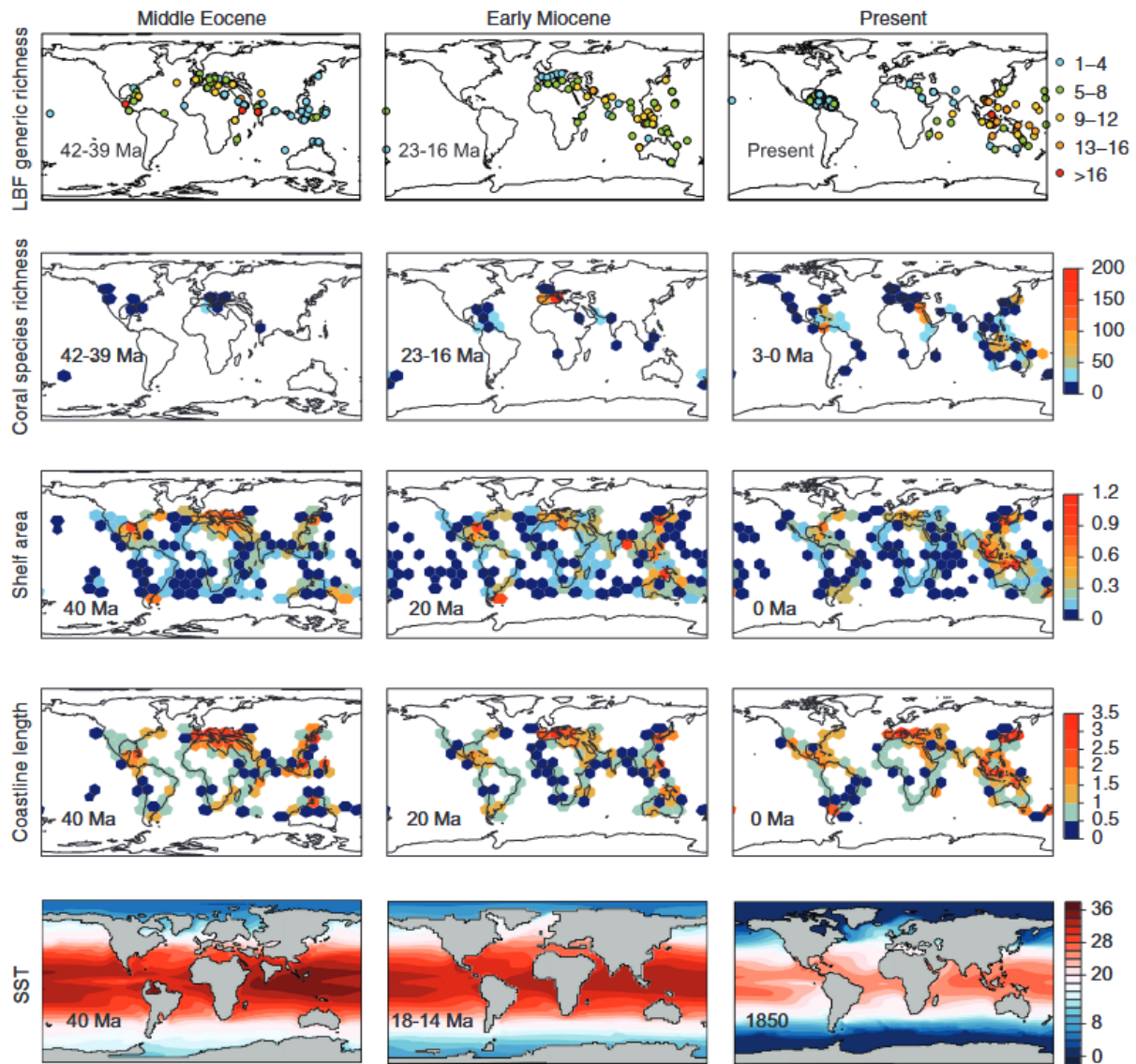


Figure 1: Cenozoic shifts in larger benthic foraminifera (LBF) and coral species richness, contrasted against potential tectonic and climate drivers. Figure from Yasuhara et al., 2022.

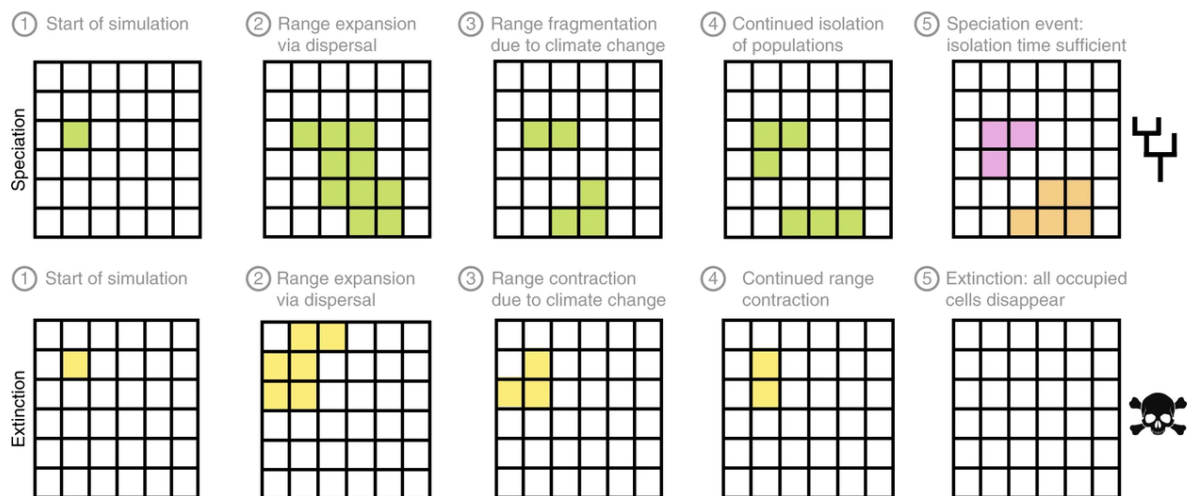


Figure 2: Schematic of the cellular automaton-based simulation used by Saupe et al., 2019.

Methodology

You will begin by building a simple eco-evolutionary model for marine biodiversity (e.g. based on Saupe et al., 2019). You will then use palaeoclimate models to simulate how marine dispersal patterns may have changed throughout the Cenozoic. These 'palaeo-dispersal' data will then be combined with environmental data from the palaeoclimate models to drive the eco-evolutionary model, simulating biodiversity dynamics throughout the Cenozoic. By assessing the model against modern and palaeobiological biodiversity data, we will investigate the drivers of marine biodiversity change across space and time.

Timeline

Year 1: Training and rotation projects (ILESIA/Intelligent Earth).

Years 2 and 3: Constructing the eco-evolutionary model, palaeo-dispersal simulations, and full eco-evolutionary simulations.

Year 4: Model assessment against modern and palaeobiological data, publishing papers and presenting results at conferences, thesis write-up.

Training & Skills

You will be provided training in eco-evolutionary and dispersal modelling, (palaeo)climate model data analysis, and statistical methods for palaeobiology and ecology. The project would suit a student with strong quantitative skills and interests in (palaeo)ecology and climate/marine science, but a background in palaeobiology is not required.

References & Further Reading

Álvarez-Noriega, M., Burgess, S.C., Byers, J.E., Pringle, J.M., Wares, J.P. and Marshall, D.J. (2020). Global biogeography of marine dispersal potential. *Nature Ecology & Evolution*, 4(9), pp.1196–1203. doi:10.1038/s41559-020-1238-y.

Bellwood, D.R., Renema, W. and Rosen, B.R. (2012). Biodiversity hotspots, evolution and coral reef biogeography. *Biotic Evolution and Environmental Change in Southeast Asia*, pp.216–245. doi:10.1017/cbo9780511735882.011.

Saupe, E.E., Myers, C.E., Townsend Peterson, A., Soberón, J., Singarayer, J., Valdes, P. and Qiao, H. (2019). Spatio-temporal climate change contributes to latitudinal diversity gradients. *Nature Ecology & Evolution*, 3(10), pp.1419–1429. doi:10.1038/s41559-019-0962-7.

Yasuhara, M., et al. (2022). Hotspots of Cenozoic Tropical Marine Biodiversity. CRC Press, pp.243–300. doi:10.1201/9781003288602-5.

Further Information

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