Uniting marine and terrestrial modelling of biodiversity under climate change

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Well-documented differences between marine and terrestrial environments [1] have resulted in limited interaction between ecologists working in each of these realms [2], which has reduced our capacity to address shared research priorities such as predicting effects of climate change on biodiversity. Efforts to model impacts of climate change on compositional biodiversity are important for planning ameliorative conservation and management actions [3], yet have occurred largely independently in marine and terrestrial environments [4]. Through a workshop aimed at identifying the main differences between marine and terrestrial biodiversity modelling, we found a surprising number of commonalities, with many key challenges and their solutions being shared between realms. Acknowledging these commonalities and developing a more collaborative approach will improve predictions of climate change impacts on biodiversity, by ensuring application of the most appropriate modelling approaches and use of ‘best-practice’ methods, regardless of the environment being modelled. Here we build on broader calls for greater marine-terrestrial interaction [2] by describing specific benefits and mechanisms for achieving them.

Shared challenges confronting efforts to predict climate change impacts on biodiversity in marine and terrestrial systems include incorporating important species attributes (dispersal, life history, size, adaptation potential), accounting for interspecific interactions (trophic, competitive, mutualistic) and addressing practical modelling considerations (investigating many species, downscaling climate predictions, quantifying uncertainty). For example, there are often strong similarities in ecological attributes of marine and terrestrial species, such as for highly mobile taxa (e.g. fish, birds) where models need to incorporate short-term changes in spatial distribution, behavioural responses to environmental cues and long-distance migrations [5]. Sessile species that disperse via propagules (e.g. seaweeds, corals; land plants, fungi) require models incorporating passive propagule dispersal [6], dispersal vectors (e.g. currents, wind) and propagule establishment. Further, many organisms undergo major ontogenetic shifts (e.g. zooplankton, fish; frogs, insects) and long-lived organisms might persist in a location but be unable to successfully reproduce if environmental conditions change (e.g. corals, trees). Finally, both realms harbour
highly diverse communities (e.g. coral reefs, tropical rainforest) for which community-level modelling approaches could be more appropriate than species-level approaches [7].

Simple generic approaches incorporating interspecific interactions into models of biodiversity under climate change (e.g. Ref [8]) will be equally relevant to marine and terrestrial taxa, given strong parallels in interaction types and their importance (e.g. mutualism as exemplified by anemone-clownfish in the marine realm and plant-mycorrhiza in the terrestrial). Broader practical challenges are also shared. For example, the spatial scale of climate predictions is generally coarser than the scale at which marine and terrestrial species perceive their environment and vary in their distributions (e.g. intertidal taxa, plants). Methods to downscale climate predictions to spatial scales appropriate for focal taxa [9] are therefore relevant to both realms. Another common challenge involves integrating and quantifying uncertainty from both climate models and ecological models to better understand confidence levels for biodiversity predictions [10].

Recognition of these shared challenges in modelling biodiversity under climate change can improve the accuracy and robustness of predictions in five important ways. First, novel modelling approaches would be transferred rapidly across realms, reducing wasted effort duplicating existing approaches. Second, identification of ‘best practice’ application of existing modelling approaches would be shared, generating more accurate predictions for lower overall effort. Third, a more united approach would encourage involvement of experts in projects regardless of the ecosystem or taxa under consideration, leading to improved predictions, transfer of expert knowledge and reduced inequality between marine and terrestrial research effort [11]. Fourth, a shared approach provides greater potential to incorporate marine-terrestrial interactions at their interface in island systems and the heavily impacted coastal zone. Last, tackling research problems together will yield common theory and approaches that have predictive capability in both environments [12].
In summary, recognising common challenges in modelling biodiversity under climate change and the parallels between marine and terrestrial taxa and communities has significant potential to improve predictions in both realms. We encourage ecologists to publish more papers in interdisciplinary journals, to read relevant papers regardless of their focus (marine or terrestrial) and to look for synergies across diverse taxa and environments. Practical collaborations also need to be supported by funding mechanisms that foster greater interaction and help break down the marine-terrestrial divide. As our workshop demonstrated, unexpected benefits can emerge when marine and terrestrial biodiversity modellers collaborate to address common challenges.
References


