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COMMENTARY

# Macroecology as a hub between research disciplines: Opportunities, challenges and possible ways forward

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Macroecology aims to explain the distribution of and the process underlying biodiversity patterns in space and time, through the analysis of large-scale and multi-species data (Brown & Maurer, 1989). Deeply rooted in biogeography, community ecology and evolutionary biology, macroecology is an intrinsically inclusive branch of ecology, which relies on the integration of various kinds of data and methodological approaches. As a science, it has matured from its descriptive incipient form (Brown & Maurer, 1989), and now strives to explicitly understand the mechanisms that shape species patterns and ecological processes (Beck et al., 2012). Typically, macroecology, and environmental and Earth system sciences, in general, deal with very complex systems, which often requires knowledge from across different disciplines (Hicks, Fitzsimmons, & Polunin, 2010).

Through their ecological and global focus, macroecological approaches are central in identifying the main drivers and understanding the fundamental mechanisms that determine responses of species as well

as ecosystems to rapid ongoing environmental changes (Kerr, Kharouba, & Currie, 2007). Due to its central position within the spectrum of ecological and evolutionary disciplines, we envisage macroecology as a hub of integrated research, capable of answering urgent and complex questions relating to global biodiversity change as a result of global environmental change. The ongoing biodiversity crisis and its global change drivers, with their multifaceted, systemic impacts, are indeed raising important ecological and social challenges which need to be addressed by macroecological research. This paper calls for interdisciplinary efforts to develop more accurate future scenarios to inform strategic biodiversity conservation (Ledford, 2015). On the one hand, integrating the past into macroecological research, using phylogenetic information or reconstructions of past human impact, will improve the understanding of the underlying processes that determine the contemporary biodiversity patterns and trends (Beck et al., 2012). On the other hand, predictions of the future distribution of biodiversity based on projections of climate, land use and resource exploitation will provide an important tool to assess the potential consequences of interactions between environmental and social changes for biodiversity. The implementation of conservation measures based on such predictions requires an interdisciplinary perspective that integrates natural and social sciences.

According to the definition of interdisciplinarity by Kötter and Balsiger (1999), interdisciplinarity is considered a form of multidisciplinary collaboration where two (or more) disciplines keep their autonomy, and jointly solve a problem which cannot be solved by one discipline alone. Transdisciplinary approaches, in turn, include the joint collaboration between scientists and practitioners (Kötter & Balsiger, 1999). However, when one discipline becomes a serving discipline (i.e. a product provider, e.g. of a provider of a remote sensing product or climate data) to another one, the multidisciplinary endeavour cannot be considered truly interdisciplinary. Although not all macroecological questions necessarily need multi-disciplinary approaches, combining knowledge and tools from different disciplines allows seeing problems in a wider context. This is often a promising approach to find innovative answers to long-standing scientific questions, which is clearly corroborated by the advent of recent multidisciplinary research initiatives such as DIVERSITAS or Future Earth and the establishment of synthesis centres such as the National Center for Ecological Analysis and Synthesis (NCEAS) and the Socio-Environmental Synthesis Center in the USA, or the Synthesis Centre for Biodiversity Sciences (sDiv) in Germany. Multidisciplinary approaches are particularly relevant in the current age of big data, where a rapidly increasing pool of data and methods is becoming available enabling scientists to tackle more complex problems (Franklin, Serra-Diaz, Syphard, & Regan, 2017). A good illustration of this is the work of the NCEAS working group on prospects and priorities for satellite monitoring of global terrestrial biodiversity, which identified the ecological priorities for future monitoring and imagery from space (Jetz et al., 2016).

Interdisciplinary science faces a number of obstacles. A consequence of disciplinary academic programmes is that each discipline develops their own perspective, with a specific terminology and even understanding of common problems (Campbell, 2005). The further two disciplines are apart (e.g. coming from the natural vs. the social sciences), the more divergent are their perspectives, and the greater are the challenges for integrative work. This means that interdisciplinary research requires time dedicated to understanding the other discipline, to agree on semantics, to develop a common language and protocols, and to clarify problem definitions and outputs. This additional time needs to be accounted for within the research (project) schedule (Campbell, 2005). Also, there is a general lack of interdisciplinary journals, let alone editors or reviewers, which makes publishing interdisciplinary research more challenging. Finally, most funding programmes are structured into disciplines with clearly defined disciplinary panels, which lowers the chances of awarding funding to interdisciplinary research projects (Bromham, Dinnage, & Hua, 2016). Some recent research programmes have opened calls for interdisciplinary research (such as the calls under the Research for Sustainable Development Framework of the German Federal Ministry of Education and Research—BMBF, the Sinergia Program from the Swiss National Fund, or the US Global Change Research Program), though these funding options still remain scarce. However, such research calls are typically either restricted to specific topics or questions, or they are so broad that they are restricted to researchers with a high reputation and a curriculum of excellence (like the Synergy Grants of the European Research Council).

In the light of these pending challenges, we urge the scientific community (including the respective funding and publishing bodies), to take steps towards further support of interdisciplinary science. Here, we identify five avenues that will likely help to achieve or at least support such development.

First, a stronger inclusion of socio-environmental elements into biogeographical or macroecological education could prepare a new generation of interdisciplinary scientists (McBride, Brewer, Bricker, & Machura, 2011). Additionally, dedicated education programmes (like e.g. the Graduate Teaching Fellows in K-12 Education of the National Science Foundation, or the European School of Sustainability Science and Research inter-university consortium) could play a key role in integrated research teams and NGOs. To be able to deal with the interwoven challenges of a complex world, increasing the awareness for the importance of integrative thinking and acquiring the necessary skills to interpret interdisciplinary reports (IPCC, IPCCD and IPBES) will complement disciplinary study programmes.

Second, interdisciplinary communication could be fostered by thematic conferences and workshops that do not only host parallel sessions covering different disciplines, but rather focus on answering specific questions by integrating various disciplines. An important component of such meeting should be a conference (synthesis) report. The Gordon Research Conferences, the conference series 'Species On The Move' or the 'European Conference on Biodiversity and Climate Change', for instance, cover biodiversity and climate change with its causes and consequences from genetics via ecology, evolution and conservation to political and ethical considerations. Also, macroecological conferences, such as those of the International Biogeographical Society or the dedicated Special Interest Groups, could benefit from, for example, integrating terrestrial, freshwater and marine sciences in a single conference. A further step forward would also be to actively 'invite' other disciplines to macroecology events (e.g. Macroecology meets economy or the social sciences, etc.).

Third, the inclusion of macroecological research in integrative journals (such as e.g. Nature Sustainability or Frontiers in Ecology and Evolution), as well as the inclusion of an interdisciplinary section or special issues in macroecological journals may facilitate publishing interdisciplinary research outputs. New publishing formats, such as Open Science and popular science initiatives, which are on the rise in general and which complement the traditional publication system, may facilitate this development.

Fourth, opportunities for acknowledging the value of integrative research are provided by establishing more (or larger) funding programmes covering multidisciplinary science, such as the joint actions of the Belmont Forum partnership, the EU BiodivERsA network or Future Earth's Program for Early-stage Grants Advancing Sustainability Science. Efforts should be made to reduce the existing geographical bias in integrated research funding programmes, which mostly concentrated in the United States and Europe (though cf. the Collaborative Adaptation Research Initiative in Africa and Asia – CARIAA). This requires the establishment of new integrated research centres, such as the recently created Centro de Síntese em Biodiversidade e Serviços Ecossistêmicos (SinBiose) in Brazil but also securing the long-term funding of existing synthesis centres, which is often not the case as the example of the Australian Centre for Ecological Analysis and Synthesis (funded from 2009 to 2014) clearly demonstrates. However, to thoroughly address global challenges, a higher willingness to support interdisciplinary research is also required from the large funding institutions at the national or international level. In this respect, it is worth noting that the establishment of interdisciplinary research will require more time. Therefore, funding bodies may focus on supporting interdisciplinary (synthesis) phases of long-term projects or on supporting more interdisciplinary projects. Directly addressing the synthesis of previous disciplinary outcomes will facilitate a more precise description of the proposed framework and analyses. Here, partly breaking up the rather disciplinary structure of evaluation panels, widening the spectrum of reviewer pools, and incentives to fund unconventional, integrative proposals may be useful steps forward.

Finally, if academia and politics really aim to better acknowledge the complexity of environmental and societal challenges by fostering interdisciplinary research, they need to adequately acknowledge interdisciplinary engagement in their reward system, for example, in academic career pathways.

While many of these avenues may appear challenging, following them should significantly contribute to more interdisciplinarity—to provide solutions to complex problems in macroecology, global change research and beyond.

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## DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no new data were created or analysed in this study.

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