PREFACE

Editorial Commentary: Global Change in Multispecies Systems Part 1

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Evaluating the consequences of global change is a major challenge in current research, especially in the light of rising concerns over anthropogenic impacts in general and climate forcing and its potential impacts on ecosystems in particular (Daufresne et al., 2009; Parmesan, 2006; Parmesan and Yohe, 2003; Raffaelli, 2004; Sarmiento et al., 2004; Walther et al., 2002; Woodward et al., 2010a,b). To address how multispecies systems might change over the next century, ecologists need to focus on how their properties will be affected by the main drivers behind global change that have already been identified (Sala et al., 2000; Thomas et al., 2004), as well as dealing with emerging and potentially synergistic multiple stressors (e.g. Feuchtmayr et al., 2009; McKee et al., 2003; Memmott et al., 2007; Moss et al., 2003). This collection of papers in Volume 46 of *Advances in Ecological Research* represents the first of a set of three under the theme of *Global Change in Multispecies Systems*, each of which contains a different blend of papers from both empirical and theoretical approaches: this commentary is concerned primarily with the papers appearing in this and the two subsequent volumes, while briefly placing them in the wider context of recent advances in the field, rather than giving an in-depth review.

Global ecological change is driven by a suite of environmental parameters that control the structure and dynamics of multispecies systems (Thomas et al., 2004; Tylianakis, 2009; Woodward et al., 2010a). The main drivers investigated in Volumes 46–48 include land use change and habitat fragmentation (Hagen et al., 2012), drought (Ledger et al., 2012a,b) and other components of climate change (Meerhoff et al., 2012; Mintenbeck et al., 2012; Möllmann and Diekmann, 2012; O'Gorman et al., 2012; Peck et al., 2012), eutrophication (Jeppesen et al., 2012), and resource overexploitation (Peck et al., 2012; Rossberg, 2012). Other aspects of global change that are touched on in the papers published here and in

other recent volumes in the series include invasive species (Jacob et al., 2011; Woodward et al., 2010a,b), marine and freshwater acidification (Layer et al., 2010; Mintenbeck et al., 2012; Peck et al., 2012), and agricultural intensification (Feld et al., 2011; Hladyz et al., 2011a,b; Mulder et al., 2011, 2012). There is also considerable potential for synergies to arise from different combinations of these stressors, as it is rare that a single driver will be operating in isolation, but these interactive effects are still poorly understood (Feld et al., 2011; Friberg et al., 2011; Woodward et al., 2010a,b).

In terms of response variables, the six papers in this volume are concerned primarily with populations, communities and ecosystems over ecological timescales, whereas some of those in the two subsequent volumes encompass an even wider range of organisational levels (e.g. genes, individuals: Moya-Laraño et al., 2012; O'Gorman et al., 2012) and spatiotemporal scales (e.g. eco-evolutionary dynamics of food webs: Moya-Laraño et al., 2012).

Habitat fragmentation is one of the key threats to both global and local biodiversity, as species and higher-level responses will be determined by their spatial context and source-sink dynamics within the landscape (Raffaelli, 2004). Surprisingly, though, very little attention has been paid to gauging how ecological networks (e.g. food webs, mutualistic networks) might be affected by habitat size or fragmentation, despite the fact that the configuration and strength of interactions between species may be just as important as the identity and number of species themselves (Hagen et al., 2012; McLaughlin et al., 2010). Even less attention has been paid to how potential synergistic effects of additional stressors, such as climate change, may amplify or mitigate the effects of habitat fragmentation. Here, Hagen et al. (2012) make a first attempt at considering how best to integrate spatial and ecological networks, to explore the effects of dispersal, colonisation, extinction and habitat fragmentation on network structure and dynamics. They also make the first steps towards embedding network approaches more explicitly within applied and landscape ecology and ideas arising from metacommunity theory, highlighting the great potential for improving on the current species-based or habitat-centric approaches to management and conservation of biodiversity in the face of global change. Hagen et al.'s paper reflects a growing realisation within the applied ecology fraternity that effective monitoring, management and conservation of multispecies systems must move beyond the spatial and temporal boundaries that are typically used to delimit them at present. The potential for eco-evolutionary dynamics to create feedbacks in

fragmented food webs are also touched on, with species both responding to and shaping their biotic and abiotic environment over a range of timescales. These points are covered in greater depth in the preceding and subsequent volumes by Melian et al. (2011) and Moya-Laraño et al. (2012), which represent pioneering attempts to bridge the gap between ecology and evolution in multispecies systems.

Understanding the likely cause-and-effect relationships behind global change in natural systems requires an understanding of how they change through both time and space. These themes recur throughout these three volumes, especially in those papers focused on fresh waters (Jeppesen et al., 2012; Ledger et al., 2012a,b; Meerhoff et al., 2012; O'Gorman et al., 2012). These seemingly fragile ecosystems cover only a tiny percentage of Earth's surface, yet they are disproportionately important, especially in terms of the biodiversity they hold and the ecosystem goods and services they provide. They are also fragmented islands of water in a predominantly terrestrial landscape (Hynes, 1975), and as such, they are vulnerable to an array of anthropogenic stressors (Hladyz et al., 2011a,b), especially as much of the world's human population lives clustered close to their shores or on their floodplains. In the context of climate change, the analysis of flood and drought risks is critically important for preserving the structure and functioning of fresh waters (Milly et al., 2006). Unfortunately, our ability to make accurate and predictive assessments is still severely constrained by the current lack of data and understanding, with most examples to date being limited to correlational studies (Lake, 2003). Here an attempt to help redress this balance is made by the Ledger et al. (2012a,b) paper, which presents a comprehensive set of results building from earlier studies (Ledger and Hildrew, 2001; Ledger et al., 2008, 2009) in one of the first mesocosm field experiments to measure the effects of drought on replicate macroinvertebrate communities, providing a rare experimental test of community resilience in aquatic ecosystems at intergenerational scales. The communities were resilient to relatively low-frequency disturbance (quarterly droughts), but the capacity for recovery was soon exceeded as disturbance frequency increased (monthly droughts), skewing community structure and functioning. This highlights how multispecies responses to climate change may be highly non-linear, with marked thresholds and tipping points, rather than a simple progressive and gradual erosion of ecological integrity.

The Ledger et al. (2012a,b) study isolates a single component of climate change (drought), as does the O'Gorman et al. (2012) study in Volume 47,

although the latter focuses on the effects of warming on stream ecosystems. Climate change is among the most important but also most complex drivers of global change, and quantifying and anticipating its effects on the structure and functioning of multispecies systems are daunting. This is especially challenging because climate change represents an amalgam of changes in both the abiotic (atmospheric and hydrological) and the biotic (invasions, extinctions and evolution) environments, in addition to the enormous scope for unexpected feedbacks to arise between these components.

Identifying correlations between climate variables and the biota is therefore only a beginning, and we need to move rapidly beyond the species-centric bioclimatic envelope approach to address responses in multispecies systems (Pearson and Dawson, 2003). A deeper mechanistic understanding is needed urgently, and considerable effort is being devoted to achieving this goal via the use of increasingly sophisticated experiments and models. While this gap in our knowledge is being bridged, correlational data continue to provide invaluable insights and help guide further studies by providing the wider context within which to search for likely mechanisms (e.g. Konig et al., 2002; Milner et al., 2000, 2008, 2009; Rawcliffe et al., 2010), as shown here in a new synthesis by Meerhoff et al. (2012), even though they cannot demonstrate causality unequivocally. Community or ecosystem responses to climate change are likely to be complex, because species populations interact within their respective ecological networks at both ecological and evolutionary timescales (Melian et al., 2011; Moya-Laraño et al., 2012; Olesen et al., 2010; Woodward et al., 2010a). Competition, natural enemies, and physiological constraints (among many others) influence species distributions, and these will change with both the climate and shifts in local communities on a global scale (Möllmann and Diekmann, 2012; Walther, 2010; Woodward et al., 2010a,b). Here, Meerhoff et al. (2012) provide an overview of multispecies responses to climatic change, as detected using space-for-time substitutions in lake ecosystems. They consider not only structural properties (species richness, biomass, density, body size) but also processes (e.g. reproduction, the intensity of trophic interactions and potential for top-down control of resources by consumers) for the major taxonomic and functional groups within food webs across a broad latitudinal range. This approach is complemented in the subsequent volume by O'Gorman et al. (2012), who also employ space-for-time substitution, but within a single catchment, to assess the effects of warming in fresh waters.