PREFACE

This thematic volume is focused on recognising the role of model systems and comparative approaches over large scales in space and/or over time. Until recently, ecological research has generally been conducted on a relatively contingent and ad hoc basis, with little scope for true long-term, strategic studies or those that operate at larger spatial scales. This has often reflected the realpolitik of research funding, and also a lack of a strong scientific underpinning behind the collection of biomonitoring data that could otherwise have addressed these gaps, but which tends to be lost to the grey literature.

Sustained research over many decades in a model system (or systems) is still exceedingly rare, and is dwindling in many parts of the world due to a perceived lack of novelty, and the prevailing view that we should focus on providing answers to immediate and obvious questions, rather than building the capacity to address unforeseen problems that may arise in the future. Paradoxically, however, the very rarity of large-scale studies is that it confers uniqueness and value upon them—especially as many long-term initiatives are being wound down and the thread of continued observation is broken. Research at larger spatial scales is far more common as it is logistically more feasible within the time-limited remit of funding frameworks; it is far easier to secure funding for a study that spans 10 sites for 1 year than it is for one that spans 10 years at one site. This has increased reliance on space-for-time substitutions in correlational survey data in particular, which can be problematic when there are time lags or hystereses in biological responses to environmental change, as opposed to the instantaneous mapping of cause onto effect that is otherwise assumed.

There are some ways that such biases might be minimised, however, such as using microbial systems to shrink spatial and temporal dimensions into more tractable studies, which can address issues such as metacommunity dynamics and evolution that would not be possible with larger or longer-lived organisms. Defining what we mean by "large scale" in absolute terms is thus somewhat arbitrary. As a rule of thumb, we have used large scale to refer temporally to timescales that span at least a decade, and spatially to scales of several square kilometres and upwards within a given system or group of systems. Most cases presented in this volume represent a study that is large scale on just one of these axes, but also a few apply to both space and time.

Several of the papers, although not necessarily rooted in a model system that occupies particular physical space per se, may be considered large scale in their philosophical framework rather than simply in terms of the empirical boundaries within which they operate. In these cases the authors are searching for globally recurrent phenomena or ways to standardise data gathering at continental to global scales.

The papers in this volume are laid out in order such that they provide a conceptual thread that runs through them sequentially. The first paper by Storkey et al. (2016) opens with the longest ecological and agricultural field experiments ever conducted, which was set up in Rothamsted in the UK over a century (>170 years) ago to understand how land-use practices can alter terrestrial ecosystems. In addition, shorter but still exceptionally long-term ecological surveys have been running since the mid-1900s, expanding the focus across a range of taxonomic groups (e.g. Rothamsted Insect Survey). Arguably, long-term ecology started with the original Rothamsted studies, and the insights provided are invaluable to our understanding of agroecology. The second paper by Emmerson et al. (2016) switches the temporal and spatial scales, but stays focused on terrestrial (agro)ecosystems, by taking a snapshot of multiple sites across Europe in the EU-funded Agripopes project. This research tackles a timely and highly topical issue—contemporary increases in agricultural intensification across Europe, the subsequent decline in biodiversity across trophic levels, and the consequences of this for important ecosystem services. Ultimately this work showcases the need to consider the large-scale ecological impacts of anthropogenic landscape-use change across geopolitical boundaries.

It is followed by another large-scale EU-funded project—RivFunction—described by Chauvet et al. (2016), which sought to unravel the responses of a key ecosystem process—terrestrial leaf-litter decomposition—to environmental change via a range of stressors, but primarily focused on nutrient enrichment and riparian alteration, which are both characteristic by-products of the continental scales of agricultural intensification described in the preceding paper. The research presented in Chauvet et al. (2016) has pioneered the development of novel functional approaches to biomonitoring that have emerged over the past decade, as well as revolutionising much of the more "pure" research into Biodiversity–Ecosystem Functioning Relationships by introducing multiple new aspects of both drivers and responses that were previously unknown, but which we now know are essential for understanding how these ecosystems operate under stress at local-to-continental scales. The fourth paper, by Stamm et al. (2016), extends beyond several of the methods pioneered in the RivFunction project to take a more holistic view of how stream ecosystems respond to a complex array of micropollutants, including agricultural pesticides as well as urban pharmaceutical pollution, in multiple sites across Switzerland. At present there are many thousands of these chemicals in play in natural systems, and the task of disentangling their impacts and identifying cause-and-effect relationships is daunting to say the least, as it requires sophisticated multiscale and combined experimental and observational approaches, as clearly advocated by Stamm et al. (2016) and that moves far beyond the traditional small-scale ecotoxicological studies of dose responses of individual species in the laboratory.

The fifth paper, by Nedwell et al. (2016), moves downstream from the headwaters covered in the preceding two chapters to focus on long-term and large-scale (particularly in relation to the microbial taxa investigated) studies on a single model system, the Colne Estuary in southern England, which has pioneered much of our modern understanding of in situ microbial ecology and biogeochemistry. This system, which is a useful general model for many estuaries in the temperate zone, has been key for unlocking novel pathways within the major macronutrient cycles that fuel the planet's ecosystems, and the role microbes play in regulating these. The importance of microbes as model organisms is pursued further in the subsequent chapter by Maček et al. (2016), which makes the case for studying their ecology in extreme environments—natural CO_2 vents known as "mofettes"—across the globe as an ideal test bed for understanding how environmental and biogeographical filters in general, and proxies of climate change in particular, shape natural communities and their associated ecosystem processes. Moreover, terrestrial mofette systems are also used as proxies to assess if Carbon Capture Storage (CCS) solutions are a viable method for reducing global CO_2 levels. However, the microbial ecology of mofette systems demonstrates that any escape of CO_2 from CCS may promote local soil hypoxia and shift the microbial communities to dominance by anaerobic methane producing Archaea, highlighting the role long-term extreme environments may play in providing evidence for landscape management.

Climate change is the main theme of the next collection of chapters, which starts with a paper by Mieszkowska and Sugden (2016), moving into the marine realm to consider how large-scale range shifts have been triggered across a transitional zone. Species abundance data have been gathered since the 1950s, across 120 intertidal and subtidal sites from northern Africa to northern UK, making this one of the longest-term and largest-scale marine datasets in existence. The theme is extended further still in the subsequent chapter by Torossian et al. (2016), which aims to unify differing predictive approaches that forecast ecological changes to climate change. A better understanding of the mechanistic drivers of change can be achieved by combining physiological (small-scale) and biogeographical (large-scale) modelling approaches, which will improve our ability to develop a more accurate global perspective on the ecology of climate change. The paper by Andresen et al. (2016) then explores the impacts of the main driver of climate change—elevated atmospheric CO_2—on long-term terrestrial plant experiments by examining a large-scale network of Free Air Carbon Dioxide Exchange projects. Indeed, the research presented by Andresen et al. (2016) clearly highlights the importance of considering space and time in the analysis of a key response variable—biomass—when considering how plants respond to elevated CO_2, demonstrating clear spatiotemporal scale dependencies on how we perceive these responses.

The next group of three chapters returns to the aquatic realm, and each has a distinct conservation and biomonitoring flavour. The first of these, by Gray et al. (2016), like the preceding paper of Andresen et al. (2016), covers large scales in both space and time, but here the focus is on very different drivers and responses, namely tracking food-web responses to reversals in acidification following several decades of strong regulation on emissions. This set of >20 streams and lakes from across the UK, which have been tracked since the 1980s, generated >400 food webs in total—by far the largest standardised suite of trophic networks published to date for any ecosystem. This unique dataset unearths some unexpected results and also compelling evidence that space-for-time proxies are far from perfect matches for true chronosequences, with many systems showing marked lags or hysteresis in their ecological recovery that do not match the much faster and clearer rates of chemical recovery. The penultimate chapter remains in the freshwater realm but moves beyond simply anticipating and predicting stressor impacts, to consider the scope for active restoration across a large number of European rivers. Here, Friberg et al. (2016) demonstrate clearly how carrying out manipulations at appropriate temporal and spatial scales is one of the major determinants of the success (or failure) of such interventions. The final paper in the volume, by Jackson et al. (2016), looks forward to gauge future prospects for meeting the urgent need for a new generation of freshwater biomonitoring approaches that can track changes in biodiversity and also ecosystem processes and services at global scales. At present these tools are poorly developed for application at large scales, but this paper highlights some existing approaches that could be adapted and harnessed relatively quickly, as well as novel ones that could potentially be better placed to address the needs of the emerging monitoring or regulatory frameworks (e.g. IPBES) which are driving much of the biomonitoring research agenda around the world.

In conclusion, we hope the diverse set of studies highlighted here and drawn from both the aquatic and terrestrial realms provide some stimulating and novel insights into the challenges—and potential rewards—of carrying out large-scale ecological research. One of the strongest themes to emerge from this volume is the invaluable, and often unexpected, new insights that can be gleaned from supporting long-term research in model systems—just as developmental biologists have *Caenorhabditis elegans*, geneticists have *Drosophila melanogaster*, and plant biologists have *Arabidopsis* spp. as core study systems, ecologists need comparable long-term observational systems that can complement experimental and comparative space-for-time approaches. Contrary to the perception of many Governmental agencies that fund the majority of these programmes, the very fact that they do the same thing repeatedly over long periods of time is their great strength and not a weakness reflecting a supposed lack of novelty, which means that funding is constantly under threat. Once the data series is interrupted, however, its value is hugely diminished and we would be well advised to protect these unique observational platforms for both current and future generations.

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