Preface

This volume serves as an introduction, reference, and survey both of the profound transformation experienced in the last decade by ecology's fast-growing field of biodiversity and ecosystem functioning and of the economics of ecosystem services. Motivated in the early 1990s by environmental concerns over worldwide declines in biodiversity, the biodiversity and ecosystem functioning research area originated as a synthesis of the relatively disparate fields of community and ecosystem ecology. Neither discipline by itself could adequately describe the wide array of possible ecological consequences of biodiversity loss (Loreau *et al.* 2001, Naeem *et al.* 2002, Hooper *et al.* 2005). The first generation of research on biodiversity and ecosystem functioning rapidly grew into a discipline that can be characterized by several features (Loreau *et al.* 2002). First, species or functional group richness was the primary way of operationally defining and manipulating biodiversity. Second, many studies often worked within a single trophic level (usually plants), though microcosm and mesocosm studies using microbes and invertebrates proved exceptions. Third, research efforts considered only biogeochemical processes, especially primary productivity, as ecosystem functions. Fourth, the prevailing mechanisms were limited to niche complementarity (i.e. niche differences lead to greater exploitation of available resources that lead to greater levels of ecosystem functioning) and selection effects (i.e. higher diversity communities invariably contain one or a few dominant species with disproportionate influences over ecosystem function) that were often viewed as opposing hypotheses vying for supremacy. Fifth, local extinction or biodiversity loss was largely considered a random process and experiments focused on producing as many randomly constructed species combinations as possible to explore how biodiversity loss influenced ecosystem functioning. Sixth, the research was largely experimental, complex, abstract, and confirmatory in nature (i.e. simply confirming that changes in biodiversity did indeed change ecosystem functioning). Finally, work on biodiversity and ecosystem functioning was colored by a tremendous debate over interpretation of its findings.

Over the last few years, however, biodiversity and ecosystem functioning research has evolved dramatically. This volume provides a thorough review of the new face presented by the second generation of biodiversity and ecosystem functioning research. Its 21 chapters are written by more than 60 authors who have been at the forefront of this transition. Virtually everything that characterized the first generation of biodiversity and ecosystem functioning research has changed. First, rather than species or functional group richness, the new focus is on trait-based, functional biodiversity, as well as on community composition. Second, biodiversity and ecosystem functioning studies are increasingly multi-trophic and span both terrestrial and marine ecosystems in comparison to the dominance of terrestrial plant studies that typified earlier biodiversity and ecosystem functioning work. Third, trait-based mechanisms of ecosystem functioning have become a major thrust for contemporary biodiversity and ecosystem functioning research, while niche complementarity and selection effects are considered to be co-occurring (not conflicting) mechanisms. Fourth, rather than assuming random local extinctions, much new work on biodiversity and ecosystem functioning employs trait-based extinction probabilities or increasingly uses empirical extinction scenarios to establish its biodiversity gradients. Fifth, compared to the more abstract deliberations of the first generation of biodiversity and ecosystem functioning research, there is now much more attention to

the role of biodiversity and ecosystem functioning in restoration ecology, agriculture, invasions, disease, pollination, climate change, and other ecosystem-service-related environmental issues. Finally, consensus has been achieved (Loreau *et al.* 2001, Hooper *et al.* 2005) and the debate that once clouded the interpretation of biodiversity and ecosystem functioning findings has largely abated.

There are also entirely new features of the second generation of biodiversity and ecosystem functioning research as well. Enough studies have now accumulated to allow meta-analyses, which obviate the sometimes subjective interpretation of trends in biodiversity and ecosystem functioning experiments expressed during the earlier contentious period. Second, *in silico*, trait-based simulation modeling of biodiversity and ecosystem functioning relationships at larger scales has augmented the complex and costly combinatorial experimental approach and represents an entirely new and promising method for large-scale biodiversity and ecosystem functioning research. Third, metacommunity theory applied to biodiversity and ecosystem functioning provides additional understanding of ecosystem complexity and stability.

Beyond the basic science of biodiversity and ecosystem functioning, this volume also explores the current state of the economics of biodiversity and ecosystem services. With antecedents in both natural resource and ecological economics, this field of economics incorporates insights from ecology to build an understanding of the ways in which biodiversity and ecosystem functioning contribute to human wellbeing. The field received a major stimulus from the Millennium Ecosystem Assessment's (2005b) focus on ecosystem services – the benefits that people derive from the processes and functioning of both 'natural' and 'managed' ecosystems. By conceptualizing ecosystem processes and functioning as factors in the production of ecosystem services that directly or indirectly benefit people, the Millennium Ecosystem Assessment has brought many ecological questions within the realm of economics. For example, it has made it natural to analyze the trade-offs (in terms of ecosystem services) of alternative ecological configurations. At the same time it has compelled economists to pay serious attention to the ecological stocks and flows that underpin the production of many ecosystem services. This volume explains and expands upon the ways in which the new face of biodiversity and ecosystem functioning research is interfacing with research into the decisions that people make about how to use the resources of the environment.

The contents of this volume

In 2000, the National Science Foundation (NSF) funded a Research Coordinating Network (RCN) entitled 'Biotic Mechanisms of Ecosystem Regulation in the Global Environment' (BioMERGE) to foster collaboration and usher biodiversity and ecosystem functioning research through its maturation phase (Naeem *et al.* 2007). The relationship between biodiversity and ecosystem functioning is also the central theme of the ecoSERVICES core project of DIVERSITAS (http://www.diversitas-international.org/), an international programme that promotes biodiversity science and aims to bridge the science and policy interface. This volume is the final product of a five-year collaboration between BioMERGE and DIVERSITAS.

The volume is divided into four sections. The first section, *Introduction, Background, and Meta-Analyses*, provides the background for the volume. The editors provide the background, historical context, and an overview of the volume's content in Chapter 1, followed by a meta-analysis by Schmid *et al.* (Chapter 2) that quantitatively tests several biodiversity and ecosystem functioning hypotheses using the enormous body of published experimental studies. The last chapter in this section is an historical and quantitative analysis of the impact of biodiversity and ecosystem functioning research by Solan *et al.* (Chapter 3) that quantitatively tests several biodiversity and ecosystem functioning hypotheses using the enormous body of published experimental studies.

The second section, *Natural Science Foundations*, consists of seven chapters. In Chapter 4, Petchey *et al.* describe one of the major contributions of biodiversity and ecosystem functioning research to ecology: an increasing emphasis on functional diversity. Petchey *et al.* illustrate both the advantages and challenges of focusing on functional diversity by

reviewing how authors have attempted to quantify functional diversity. Duffy *et al.* (Chapter 5), consider how functional diversity has transformed biodiversity and ecosystem functioning research from a largely confirmatory science to one that is increasingly predictive.

The remaining chapters of the second section address universal challenges for all of ecology, in the context of biodiversity and ecosystem functioning. These are stability and complexity (Chapter 6 by Griffin *et al.*), identifying the mechanisms generating ecological relationships (Chapter 7 by Hector *et al.*), the importance of trophic structure (Chapter 8 by Cardinale *et al.*), microbial ecology (Chapter 9 by Bell *et al.*), and the importance of the spatial dimension and metacommunities in determining the effects of diversity on ecosystem functioning (Chapter 10 by Gonzalez *et al.*).

The third section takes research on biodiversity and ecosystem functioning further than it has ever gone into the human dimension. The first six chapters cover the most pressing environmental challenges humanity faces. Notably, these chapters also highlight a new emphasis on ecosystem services that go beyond the historic focus on primary productivity. Díaz *et al.* consider the effects of biodiversity on the carbon cycle (Chapter 11) as a way to shed light on anthropogenic climate change that has been largely devoid of considerations of biodiversity. Wright *et al.* consider the role that diversity may play in fostering the restoration of degraded or abandoned habitats (Chapter 12). Jackson *et al.* (Chapter 13) consider the importance of biodiversity in the agricultural ecosystems that now cover one third of Earth's terrestrial surfaces, and focus on biological control as a case study. Klein *et al.* (Chapter 14) discuss the critical ecosystem service of pollination, which is equally important for many crops as well as unmanaged or restored systems. The mitigation of disease (Chapter 15 by Ostfeld *et al.*) and biological invasions (Chapter 16 by Engelhardt *et al.*) are two other biotic ecosystem services that are strongly influenced by biodiversity.

What truly makes this volume unique are the chapters of Section 3, which consider the economic perspective. Perrings *et al.* (Chapter 17) provide a synthesis of the economics of ecosystem services and biodiversity, and the options open to policy-makers to address the failure of markets to account for the loss of ecosystem services. Barbier *et al.* (Chapter 18) examine the challenges of valuing ecosystem services and, hence, to understanding the human consequences of decisions that neglect these services. Brock *et al.* (Chapter 19) examine the ways in which economists are currently incorporating biodiversity and ecosystem functioning research into decision models for the conservation and management of biodiversity.

The fourth and final section consists of two chapters, one describing the new, ambitious direction of biodiversity and ecosystem functioning research to become a global science (Chapter 20) and a synthesis of this volume (Chapter 21) by the editors that describes the nature of the progress made thus far and the future directions and challenges that have been covered by the many authors of this volume.