Ecological-Economic Modelling for Biodiversity Conservation

Both ecologists and economists use models to help develop strategies for biodiversity management. The practical use of disciplinary models, however, can be limited because ecological models tend not to address the socioeconomic dimension of biodiversity management, whereas economic models tend to neglect the ecological dimension. Given these shortcomings of disciplinary models, ecological and economic knowledge need to be combined into ecological-economic models. Gradually guiding the reader into the field of ecological-economic modelling by introducing mathematical models and their role in general, this book provides an overview of ecological and economic modelling approaches relevant for research in the field of biodiversity conservation. It discusses the advantages and challenges associated with ecological-economic modelling, together with an overview of useful ways of integrating ecological and economic knowledge and models. Although this is a book about mathematical modelling, ecological and economic concepts play an equally important role, making the book accessible for readers from very different disciplinary backgrounds.

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ECOLOGY, BIODIVERSITY AND CONSERVATION

The world's biological diversity faces unprecedented threats. The urgent challenge facing the concerned biologist is to understand ecological processes well enough to maintain their functioning in the face of the pressures resulting from human population growth. Those concerned with the conservation of biodiversity and with restoration also need to be acquainted with the political, social, historical, economic, and legal frameworks within which ecological and conservation practice must be developed. The new Ecology, Biodiversity, and Conservation series will present balanced, comprehensive, up-to-date and critical reviews of selected topics within the sciences of ecology and conservation biology, both botanical and zoological, and both 'pure' and 'applied'. It is aimed at advanced final-year undergraduates, graduate students, researchers, and university teachers, as well as ecologists and conservationists in industry, government, and the voluntary sectors. The series encompasses a wide range of approaches and scales (spatial, temporal and taxonomic), including quantitative, theoretical, population, community, ecosystem, landscape, historical, experimental, behavioural, and evolutionary studies. The emphasis is on science related to the real world of plants and animals rather than on purely theoretical abstractions and mathematical models. Books in this series will, wherever possible, consider issues from a broad perspective. Some books will challenge existing paradigms and present new ecological concepts, empirical or theoretical models and testable hypotheses. Other books will explore new approaches and present syntheses on topics of ecological importance.

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Preface

Despite various efforts to halt or reverse the current trend, biodiversity is being lost at an alarming rate across the world. At first sight, biodiversity may be regarded as an ecological issue and a topic of ecological research. However, its loss has economic causes and economic consequences, and economists are increasingly interested in the economic dimension of the loss and the conservation of biodiversity. To encompass the full complexity of biodiversity, both its ecological and economic dimensions must be considered in an integrated manner, ideally even together with other scientific disciplines such as hydrology, climatology, sociology, psychology and philosophy. Among various concepts for interdisciplinary integration, ecological-economic modelling has proven very fruitful and is gaining relevance and popularity both among ecologists and economists.

The present book provides an overview of the state of the art of ecological-economic modelling. The focus here is on mechanistic process models that model the relationships between causes and consequences through mathematical rules or equations. Statistical models such as habitat suitability and species distribution models that explain species presence from biotic and abiotic conditions, or econometric models that for instance explain human behaviour through environmental and socioeconomic variables, are not covered in this book. This is not because statistical models cannot be used for ecological-economic modelling – in fact there are a number of ecological-economic models that contain statistical models as components – but, in the author's view, to date mechanistic process models form the majority of ecological-economic models, and a fair consideration of statistical models would be beyond both the author's knowledge and the scope of this book.

To build integrated ecological-economic models, both conceptual knowledge (about what to integrate and for what purpose) and formal mathematical methods (how to integrate the available knowledge) are required. This book tries to address both dimensions of the integration

process by considering both conpceptual thinking and mathematics on intermediate levels. The book thus contains more mathematics and less conceptual thinking than standard books on ecology or on environmental or ecological economics, but it contains less mathematics and more conceptual thinking than standard books on mathematical and complex-systems modelling. In this way, the book is integrative not only with regard to the disciplines of ecology and economics but also with regard to the mediation between concepts and their formal mathematical implementation. A particular feature of the book is the employment of numerous modelling examples from the literature whose selection is, of course, subjective but carried out in an attempt to be instructive and to cover a wide range of concepts and methods.

Although generally not stated explicitly, the focus of the book – especially the literature examples – is on terrestrial biodiversity conservation. Some of the modelling approaches addressed here can also be applied to marine and freshwater ecosystems, but the inclusion of these ecosystems would be beyond the book's scope.

Furthermore, in most of the conservation problems considered biodiversity has no market value, and the conservation of biodiversity requires particular policies and strategies that differ from those applicable to marketable natural resources such as timber and fish.

Since biodiversity often has no market value, the economic valuation of biodiversity (and the environment in general) is a major research field in environmental and ecological economics, covered in various books. In economic terms, valuation deals with society's demand for biodiversity. In contrast, much of the literature on ecological-economic modelling deals with the supply of biodiversity and, in particular, the question of how limited financial resources should be spent cost-effectively to maximise biodiversity levels for a given cost or budget. Most of the present book focuses on that supply side of biodiversity, although a few sections address the demand side, as well. It will be argued that the combined consideration of both sides is very fruitful.

Before proceeding to an outline of the structure of the book, some remarks should be added concerning the book's intended readership. Because this is book about mathematical modelling, some mathematical knowledge is required to understand the models presented. However, it is not necessary to understand all the equations in detail to capture their meaning and the modelling concepts behind them. The primary audience of the book is researchers and graduate students who already have a proficient knowledge base in mathematical modelling, quantitative ecology and

economics, or at least one of these three disciplines, and who wish to broaden their knowledge beyond their own discipline in order to work with researchers from other disciplines, or even develop integrated models on their own. This is not a textbook in the narrow sense but, rather, a compendium of relevant ecological-economic models, concepts and approaches. However, it can also be used as a textbook for graduate courses, and in fact some of its content is based on a lecture about ecological-economic modelling held by the author regularly over the past few years.

The book is organised into four parts. Part I introduces mathematical modelling in general, describing in particular the various purposes models can have, as well as typical model features. Modelling examples are considered from the disciplines of physics, ecology and economics.

Part II provides an overview of ecological models relevant for biodiversity conservation. After an introductory chapter, three important model features are addressed: stochasticity, spatial structure and individual variability and behaviour. In a final chapter the modelling approaches of the previous chapters are combined to discuss one of the central questions of biodiversity research: why and how can different species coexist?

The economic side of ecological-economic modelling is presented in Part III, which starts with basic concepts of environmental economics, such as biodiversity loss as a market failure and policy instruments for mitigating that market failure. As a fundamental approach for policy analysis, the following chapter presents basics of game theory, which is followed by a chapter on incentive design and a chapter on the modelling of human behaviour and decisions. The final chapter applies concepts derived in the previous chapters to discuss recent research on the agglomeration bonus – a policy instrument for incentivising spatially coordinated conservation efforts by landowners.

The final section, Part IV on ecological-economic modelling, starts with a brief summary of the history of economic thought, including the foundations of environmental economics and ecological economics, to derive recommendations for the design of ecological-economic models. The following chapter deals with the advantages of ecological-economic modelling compared with disciplinary research, as well as associated difficulties and challenges. After a chapter about major approaches for the integration of ecological and economic models, two examples are presented in which ecological-economic models are used to analyse policy instruments for the conservation of species. Part IV concludes with an outlook on the possible future of ecological-economic modelling.

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