Preface

We have written this book primarily for two kinds of target audiences. The first one consists of those ecologists and evolutionary biologists who may not be very experienced with mathematical and statistical modelling yet, but who are interested in learning more about modelling approaches in order to integrate them with data. The second audience consists of those mathematicians, statisticians, and computer scientists who are interested in ecological and evolutionary questions, and thus wish to see how the mathematical, statistical, and computational tools that they already master can be applied in these fields of sciences. We have intended the book for researchers and graduate students, as well as advanced master students. We also hope it will be useful as a textbook for graduate-level courses in ecological modelling, statistical ecology, theoretical ecology, and spatial ecology.

After an introductory chapter, we devote one chapter to movement ecology, one to population ecology, one to community ecology, and one to genetics and evolutionary ecology. We have followed the same structure in each chapter. We start with a conceptual section, which provides the necessary biological background and motivates the modelling work. The next three sections present mathematical modelling approaches, followed by one section devoted to statistical approaches. We end each chapter with a perspectives section, where we summarize some of the key messages of the chapter, discuss some limitations of the approaches we have considered, and mention some alternative approaches.

We assume that the reader is familiar with the basics of calculus and probability. These are covered in good depth in the context of ecological modelling, e.g., in the books of Otto and Day (2007), Mangel (2006), and Hastings (1996). From the statistical side, we expect the reader to have basic knowledge of linear models (e.g., ANOVA and regression), covered, e.g., by the book by Grafen and Hails (2002) or that of Zuur et al. (2007). Some parts of this book utilize rather advanced mathematical and statistical methods compared with the background typical for graduate students in ecology and evolution. Therefore, we finish the book with two appendices, one related to mathematical and the other to statistical methods. In these appendices, we summarize a wide range of methods that are utilized in this book and that we expect to be useful for the reader more widely.

In a single book, it is not possible to present a comprehensive review of all the mathematical and statistical approaches developed for movement ecology, population ecology, community ecology, population genetics, and evolutionary biology.

Therefore, the selection of approaches and models we present is necessary limited, and biased by our own research interests. The reason why we cover such a broad range of topics rather than focusing on a more limited scope is that one key aim of this book is to link modelling approaches used in different fields of ecology and evolutionary biology to each other. With this aim, we have constructed the models in a stepwise manner, starting from simple baseline models, and then adding gradually new components. As one example, in Chapter 2 we start from a random walk model in homogeneous space. We then extend the model to heterogeneous space by considering how moving individuals may respond to spatial variation in their environments, after which we model movements in a highly fragmented landscape as a particular case study. In Chapter 3, we add to the movement model the births and deaths of individuals, resulting in a model that we will call the butterfly metapopulation model. As another example, in Chapter 2 we link dispersal kernels to movement models. In Chapter 3, we utilize dispersal kernels to construct a model for the ecological dynamics of sessile organisms, which we call the plant population model. In Chapter 4, we add to the plant population model competition among heterospecifics, resulting in what we call the plant community model. Finally, in Chapter 5 we extend the plant population model into an eco-evolutionary model by letting the individuals carry genes that influence the dispersal of their propagules.

While our aim is to integrate models with data, we discuss real data only in the context of few motivating examples. All the data analysed in the statistical sections have been generated by the mathematical models of the same chapter. We have decided to do so because with simulated data the reader has the full knowledge of the process that has generated the data, which would be never the case with real data. Therefore, knowing the underlying process enables one to pinpoint the potentials and pitfalls of different kinds of statistical methods more effectively than would be the case with real data.

As our starting point is movement ecology, much (though not all) of our emphasis is on the spatial aspects of ecology and evolution, especially on the interplay between environmental heterogeneity and ecological processes. In particular, each chapter has one section that applies the mathematical modelling approaches to study the consequences of habitat loss and fragmentation. In addition to presenting perspectives to ecological modelling, we thus hope to provide some insights on how habitat loss and fragmentation influence the movements of individuals, the dynamics of populations and communities, and evolutionary dynamics.

Writing this book would not have been possible without the support we have obtained from many people. First of all, working with the publisher has been as smooth as one could hope for. We would therefore like to thank Charles Godfray for taking the initiative of inviting us to write this book, Ian Sherman for guiding us with the initial planning, and Jennifer Dunne for providing feedback. Lucy Nash has worked as an excellent editor; her help has been invaluable through the writing process. For permission to reproduce copyrighted material, we would like to thank the National Academy of Sciences USA (Figures 2.2A–C and 4.2A–C), the Ecological

Society of America (Figure 2.2D), Oxford University Press (Figure 3.2CD), Nature Publishing Group (Figure 3.2E), and John Wiley and Sons (Fig. 5.2A,B,C).

Most importantly, the book has benefited greatly from comments that we have received from several colleagues. We would thus like to thank Nerea Abrego, Florian Hartig, Arild Husby, Jussi Jousimo, Etsuko Nonaka, Iñaki Odriozola, Bart Peeters, Johannes Signer, Tord Snäll and Eugenia Soroka for providing a large number of suggestions and corrections that greatly improved the contents. We thank Kaisa Torppa for helping us to compile the index, Sami Ojanen for producing the maps of Figures 2.2 and 3.2., and Juha Merilä for permission to use the photo of Fig. 5.2D. Our warmest thanks go to Ilkka Hanski, the leader of the Metapopulation Research Centre, where this book has been written. This is not only for the feedback and encouragement that he has provided during the writing process, but also and especially for sharing with us his passion for science.

The research that resulted in the development of the modelling approaches presented in this book, as well as the writing of this book, has been supported by grants from the European Research Council (Grant 205905), Academy of Finland (Grants 12424, 129636, and 25044), the Kone Foundation (Grant 44-6977), The Netherlands Organisation for Scientific Research (Rubicon Grant 825.11.009), and the Research Council of Norway (CoE Programme Grant 223257).