

Vegetation Description and Data Analysis

A Practical Approach

MARTIN KENT



SECOND EDITION

 WILEY-BLACKWELL

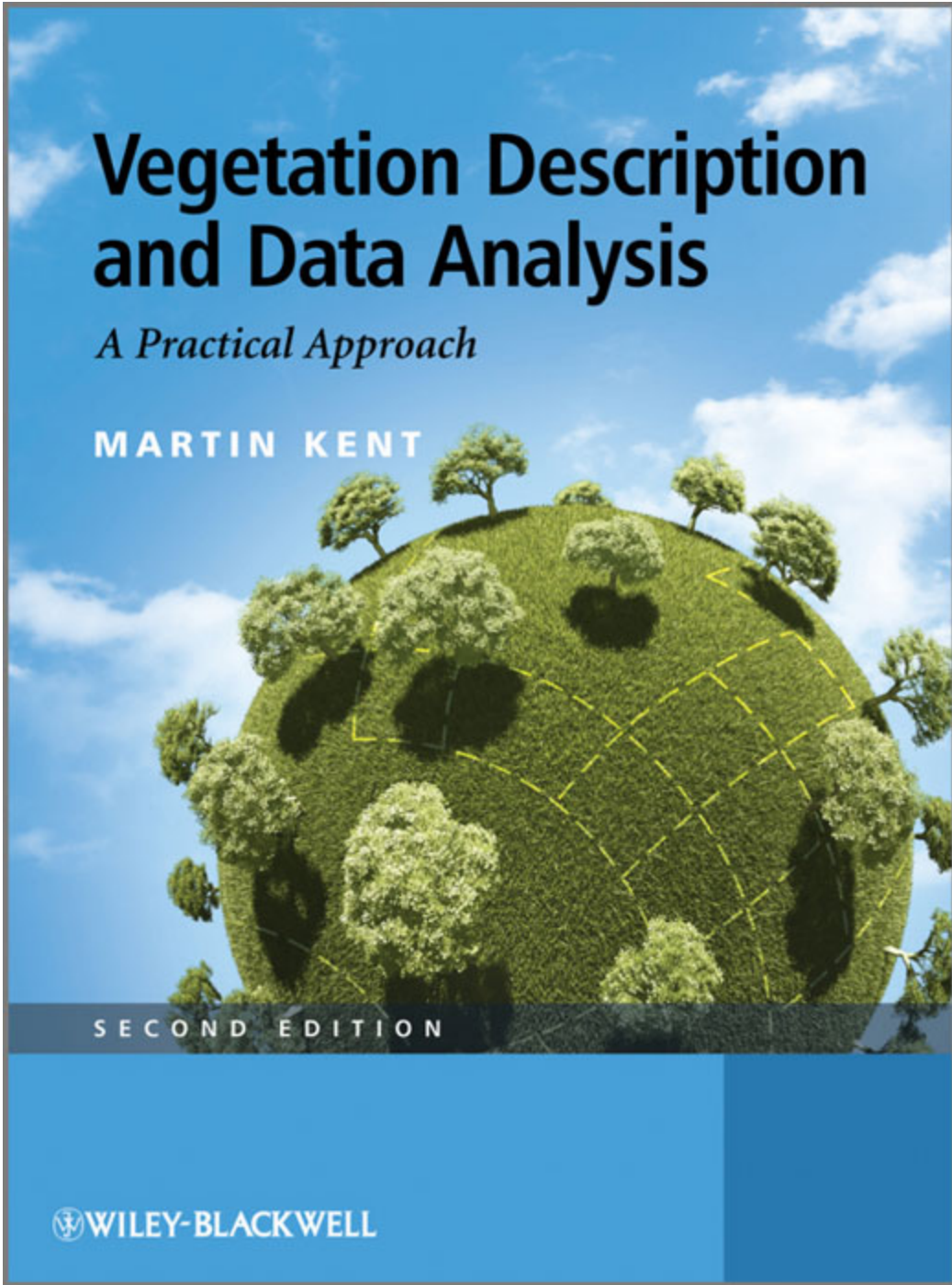
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VEGETATION DESCRIPTION AND DATA ANALYSIS

A PRACTICAL APPROACH

Second Edition

Martin Kent

University of Plymouth

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A John Wiley & Sons, Ltd, Publication

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Registered office: John Wiley & Sons, Ltd, The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ, UK

Editorial offices: 9600 Garsington Road, Oxford, OX4 2DQ, UK

The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ, UK

111 River Street, Hoboken, NJ 07030-5774, USA

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Library of Congress Cataloging-in-Publication Data

Kent, M., 1950-

Vegetation description and data analysis : a practical approach / Martin Kent. - 2nd ed.

p. cm.

Includes bibliographical references and index.

ISBN 978-0-471-49092-0 (cloth) - ISBN 978-0-471-49093-7 (paper)

1. Plant ecology. 2. Plant communities. 3. Vegetation surveys. 4. Plant ecology-Data processing. 5. Plant communities-Data processing. 6. Vegetation surveys-Data processing. I. Kent, M., 1950- Vegetation description and analysis. II. Title.

QK901.K37 2011

581.7-dc23

2011030218

A catalogue record for this book is available from the British Library.

This book is published in the following electronic format:
ePDF 9781119944782; ePub 9781119962397; Mobi
9781119962403

This second edition is dedicated to my dear friend, academic colleague and former co-author, Paddy Coker, who sadly died in July 2005. His enthusiasm for and enjoyment of the subjects of plant ecology, vegetation science and computing are greatly missed.

Preface to the second edition

The success of the first edition of this text was as much of a surprise to the authors as it was to both the publishers and its academic and scientific audience. The enthusiastic response demonstrated that there was a very clear need for a book that sought to simplify the complexities of vegetation description and multivariate analysis in the context of vegetation data and plant ecology. The first edition went through eight reprints and only went out of print in 2005. A second edition has been at the proposal stage for over ten years and it is only now, following retirement from mainstream academic life, that the author has found the time to develop the project further. Nevertheless, the need for such a text appears to be as great as ever.

In the 19 years since the publication of the first edition, a great deal has changed in the world of vegetation science and plant ecology. What is now one of the key journals in the subject, *Journal of Vegetation Science*, was only founded in 1990, two years before the publication of the first edition of this book in 1992. The sister journal *Applied Vegetation Science* only appeared in 1997. Numerous other journals relevant to the subject have evolved during the intervening years and the whole field of multivariate analysis has extended its application across the full range of ecological sciences. While actual methods and techniques have evolved only relatively slowly over this time, far more significant changes have occurred in the world of computer hardware and software. As the review of software in Chapter of this new edition demonstrates, there are now numerous quite sophisticated packages available for vegetation data analysis, and a whole new approach has emerged at the

research frontier using the R language and related packages.

Over the past 20 years, the use of methods of vegetation description and analysis has extended globally. Originally the province of a relatively small group of academics in the United Kingdom, Europe, North America and Australia, examination of the range of research locations of scientific papers published in *Journal of Vegetation Science* and *Applied Vegetation Science* clearly demonstrates that the scope and application of vegetation description and analysis by scientists and academics is now truly worldwide. One of the paradoxes of this is that during that same period, both plant ecology and vegetation science can only be described as having taken a back seat in the author's home country of the UK. This is partly because many of the most exciting avenues for research and exploration in vegetation science lie elsewhere on the globe, particularly in the tropics. A key theme of the new edition is to demonstrate and foster this worldwide perspective of the subject. This is a perspective that is all the more important because of the universal threats to biodiversity and the limited success of the numerous valiant efforts at biological conservation across the globe in the face of human exploitation and so-called development.

Lastly, the author would like to thank all those students, particularly those who have completed his Masters course in ecology and multivariate analysis at the University of Plymouth over the past 12 years, for their enthusiasm for and commitment to this subject. While the greater range and complexity of methods and of computer software today means that this text cannot possibly cover every aspect of the subject of vegetation science at the research level, ultimately, the purpose of this book is to introduce, simplify and explain quite complex things for the improvement of understanding and to assist with learning. I have never

forgotten the comment of a very well-known vegetation research scientist, who came up to me at a conference after the publication of the first edition and told me in no uncertain terms that '*you should never have published that book - it makes things too easy for students and removes the mystique*'!! I knew from that moment onwards that the book had every potential to achieve its objectives and it is my fervent hope that this second edition manages to build even more successfully upon that achievement.

*Martin Kent
Plymouth, UK
March 2011*

Acknowledgements

Many people assisted in writing the first edition of this book. In particular Martin Kent would once again like to thank Dr Tom Dargie (private ecological consultant, Boreas Ecology - <http://www.boreasecology.com/>), who has always shared his enthusiasm and interest for the subject, Professor David Gilbertson (School of Geography, Earth and Environmental Sciences, University of Plymouth), Dr Ken Thompson (formerly of the Department of Biological Sciences, University of Sheffield) and Dr Peter Wathern (formerly of the Department of Biological Sciences, University of Aberystwyth, Wales), all of whom gave their support and encouragement. A good number of years ago, Dr Nicholas J. Cox of the Department of Geography at the University of Durham read the first edition of the text with an exceptionally trained and critical eye, noting the many small errors therein, and his corrections have helped greatly with this revision. I thank him for his efforts.

Martin Kent wishes to offer very special thanks to Professor Robin Pakeman of The James Hutton Research Institute (formerly the Macaulay Land Use Research Institute), Craigiebuckler, Aberdeen, Scotland, for his kindness and patience in carefully reading and correcting the manuscript of this new edition and making a number of very helpful suggestions for its improvement. Very particular thanks also go to Jamie Quinn of the Cartographic Resources Unit in the School of Geography, Earth and Environmental Sciences at the University of Plymouth, who redrew most of the original figures and diagrams, as well as many new ones. The volume of work became far more than either of us originally realised but, as the quality of the diagrams demonstrate, he has succeeded admirably. Dr Rana Moyeed of the Department of Statistics, Computing and Mathematics at

the University of Plymouth deserves special mention for his tolerance of my many questions concerning statistical analysis relevant to the writing of the revision.

My very good friends, Professor Liquan Zhang of the State Key Laboratory for Estuarine and Coastal Research (SKLEC) and Dr Xihua Wang of the Department of Environmental Science, both from East China Normal University, Shanghai, kindly funded a study visit to China in September–October 2010, which acted as a catalyst for embarking on this second edition. I thank them both very warmly indeed. The University of Plymouth and particularly the School of Geography, Earth and Environmental Science have also provided invaluable support throughout the revision and in particular I would wish to thank my colleague Dr Ruth Weaver.

In truth, this edition would never have appeared at all, were it not for the dogged perseverance of a succession of editors at John Wiley and Sons (now Wiley-Blackwell), Keily Larkins, Rachael Ballard and most especially Fiona Woods. Fiona was the one who finally succeeded, and I offer very grateful thanks to you, Izzy Canning, Sarah Karim and your colleagues for all your hard work in seeing this second edition through to publication.

Finally, I owe an enormous debt of gratitude to my wife Gay for her infinite patience and support during the writing and revision of the book. It is also dedicated to our children Jonathan, Joseph, Holly and Kitty and her husband Ben, and to our grandchildren Sam and Tom.

Copyright and authorship of all figures and tables are acknowledged in the appropriate captions. The authors are grateful to Routledge publishers for permission to include diagrams from P. Gould and R. White (1986) *Mental Maps* in Chapter .

The author also wishes to thank Professors Bruce McCune and James Grace and MjM Software Design for permission to

include material from McCune, B. and Grace, J.B. (2002) *Analysis of Ecological Communities*, MjM Software Design in Figures 4.1 and 6.23 and the 'Landscape Analogy' text for non-metric multidimensional scaling in Chapter 6. Dr. Peter Henderson of Pisces Conservation Ltd. is thanked for permission to present the data in Table 6.5. Dr. Jane Robbins (School of Animal, Rural and Environmental Sciences, Nottingham Trent University, UK) and Professor John Matthews (Department of Environment and Society, Swansea University, UK) kindly gave permission to use their research published in *Journal of Vegetation Science* and in *Arctic, Antarctic and Alpine Research* as a case study and Plate 1.2.

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Martin Kent
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University of Plymouth, UK
March 2011

Safety in the field

All fieldwork is potentially dangerous, even when carried out in local, well-known areas. Precautions should always be taken and local safety codes adhered to. The following recommendations are important:

- 1.** Always obtain an up-to-date weather forecast.
- 2.** Take advice from local experts if in doubt.
- 3.** Be aware of potential health problems of any members of the party.
- 4.** Collect the addresses and telephone numbers of family or friends of every member of the party.
- 5.** Leave this information and details of the route to be followed with a responsible person at the base and an expected time of return.
- 6.** If possible, carry a mobile phone and a geographical positioning system (GPS) device but bear in mind that signals and reception may be weak or non-existent in remote areas.
- 7.** Never, ever, carry out fieldwork alone: a group of three or four leaves one or two people free to go for help, while a second person can stay with an injured or ill colleague.
- 8.** All members of the party should have had a tetanus injection. Always take note of travel advice relating to preventative inoculations and medicines in the fieldwork locality.
- 9.** Be extra careful in certain habitats such as wetlands, bogs and swamps. Working in the tropics carries special potential dangers.
- 10.** Be prepared for the worst that can happen in terms of bad weather or an accident. Responsible members of the party must be familiar with basic first aid and safety

procedures. The following equipment is essential, depending on environment:

suitable footwear (usually stout boots), appropriate clothing, waterproofs with hood, over-trousers, warm hat and gloves, sunhat and sunscreen, water, first aid kit, insect repellent, torch with batteries, whistle, emergency rations including glucose sweets, spare warm clothing and socks, survival blanket or lightweight tent, map and compass.

11. The standard SOS signal for torches or whistles is three short signals, three long and three short.

In the United Kingdom, all those responsible for organising fieldwork and research overseas should be aware of the British Standard 8848 (2007) + Amendment 1 (2009) which provides clear guidelines for good practice. Similar documents and information exist in many other countries.

ACCESS

Always obtain permission from landowners, farmers and other relevant agencies before carrying out fieldwork on their land. By far the majority will gladly give permission provided it is requested before going onto their land.

DISCLAIMER

While every reasonable care has been taken, neither the author nor the publisher accept any liability for any injury, accident, loss or consequent damage, however caused, arising from this book or any information contained therein.

Chapter 1

The nature of quantitative plant ecology and vegetation science

THE NATURE OF VEGETATION

Dictionary definitions usually describe vegetation as 'plants collectively' or 'plant growth in the mass'. To the plant ecologist and vegetation scientist, this definition is completely inadequate and perhaps conforms to the view of many students (and teachers and lecturers!), who see it as 'a frightening and unknown mass of green, shrouded in technical terms and Latin Names' (Randall, 1978: p. 3). This book is concerned with the techniques for both collecting and analysing data on vegetation with the primary aim of making sense of the 'frightening and unknown mass of green'. As such, it is a text on quantitative plant ecology, which is a clearly recognisable subdiscipline of ecology and biogeography. The field of quantitative plant ecology is also related to an area of research known as vegetation science, which in addition to vegetation description and analysis, also includes plant population biology, species strategies and vegetation dynamics (successional processes and vegetation change) (van der Maarel, 1984a, 2005a,b). Most researchers and students take the phrase 'vegetation description and data analysis' to mean the collection of vegetation data, followed by analysis, usually using complex mathematical methods. However, in the 1980s and 1990s, there was a distinct tendency for the processes of analysis to become an end in themselves. An important aim of the previous edition of this book was to show that quantitative

plant ecology and vegetation description and data analysis can and perhaps should be primarily ecological rather than mathematical in emphasis. The only way that variations in vegetation and plant species distributions can be properly understood and explained is within an ecological framework. This introduces the fundamental point that vegetation is always an integral part of an ecosystem (Tansley, 1935; Waring, 1989; Willis, 1997; Dickinson and Murphy, 1998; Leuschner, 2005) and can only be studied by fully exploring its role within that ecosystem. Vegetation cannot be isolated as a separate entity from the ecosystem within which it exists.

The building blocks of vegetation are individual plants. Each plant is classified according to a hierarchical system of identification and nomenclature using carefully selected criteria of physiognomy and growth form. The individuals of a species, taken together, form a species population, and within the local area of a few square metres to perhaps as much as a square kilometre, groups of plant species populations that are found growing together are known as plant communities or plant species assemblages. Much more will be said of plant communities and species assemblages later in Chapter 2, but within plant communities, the presence or absence of particular species is of primary importance. After this, the amount or abundance of each species present is of interest. Although most vegetation data are still collected at the species level, one of the more interesting developments of the past 20 years has been in alternative methods of describing vegetation, such as plant functional types and taxonomic, morphological and structural surrogates (Ramsay *et al.*, 2006). This book is concerned with reasons and methods for collecting data of these kinds, and with techniques for their analysis.

The importance of vegetation within ecology is three-fold. Firstly, in most terrestrial parts of the world, with the exception of the hot and cold deserts, vegetation is the most obvious physical representation of an ecosystem. When ecologists talk about different ecosystem types, they usually equate these with different vegetation types and the dominant species life-forms within them. Secondly, most vegetation is the result of primary production, where solar energy is transformed through photosynthesis by different plant species into green plant tissue. The net primary production, which is the amount of green plant tissue accumulated within the area of a particular vegetation type over a given period of time, represents the base of the trophic pyramid. All other organisms in both the grazing and detrital food webs are ultimately dependent upon that base for their food supply. Thirdly, vegetation also acts as the habitat within which the organisms live, grow, reproduce and die. In the case of the grazing food web, it is among the above-ground parts of plants. With the detrital web, it is on the surface and below ground among the roots. Taken together, these three points show the central importance of vegetation to ecology and demonstrate the need for methods to assist with both description and data analysis (Anderson and Kikkawa, 1986; Cherrett, 1989; Barbour *et al.*, 1999; van der Maarel, 2005a,b).

WHY STUDY VEGETATION?

There are many situations where vegetation merits study. The commonest examples of the use of vegetation description are in the recognition and definition of different vegetation types and plant communities, which is known as the science of phytosociology, the mapping of vegetation communities and types, the study of relationships between plant species distributions, environmental controls and their

interactions with humans and animals, and the study of vegetation as a habitat for animals, birds and insects. Change in vegetation over time may also need to be described using concepts of succession and climax.

Information on vegetation may be required to help to solve an ecological problem, for biological conservation and management purposes, as an input to environmental impact statements, to monitor management practices, or to provide the basis for prediction of possible future changes in plant species distributions and linked to both human impacts on habitats via land use practices and also climate.

A useful distinction is into aspects of study that are academic, as opposed to those which can be termed applied. In the academic case, vegetation may be described and data analysed largely for their own sake. Applied studies are where vegetation data are collected and analysed with the aim of providing information of relevance to some ecological problem, often to do with environmental conservation and ecosystem management or the prediction of future environmental and ecological change. Many examples of research include elements of both.

CASE STUDIES

Throughout this book, many different examples of the application of methods for the description and analysis of vegetation will be presented. A brief introduction to four contrasted case studies serves to demonstrate the diversity of situations where vegetation may need to be surveyed and data collected and analysed.

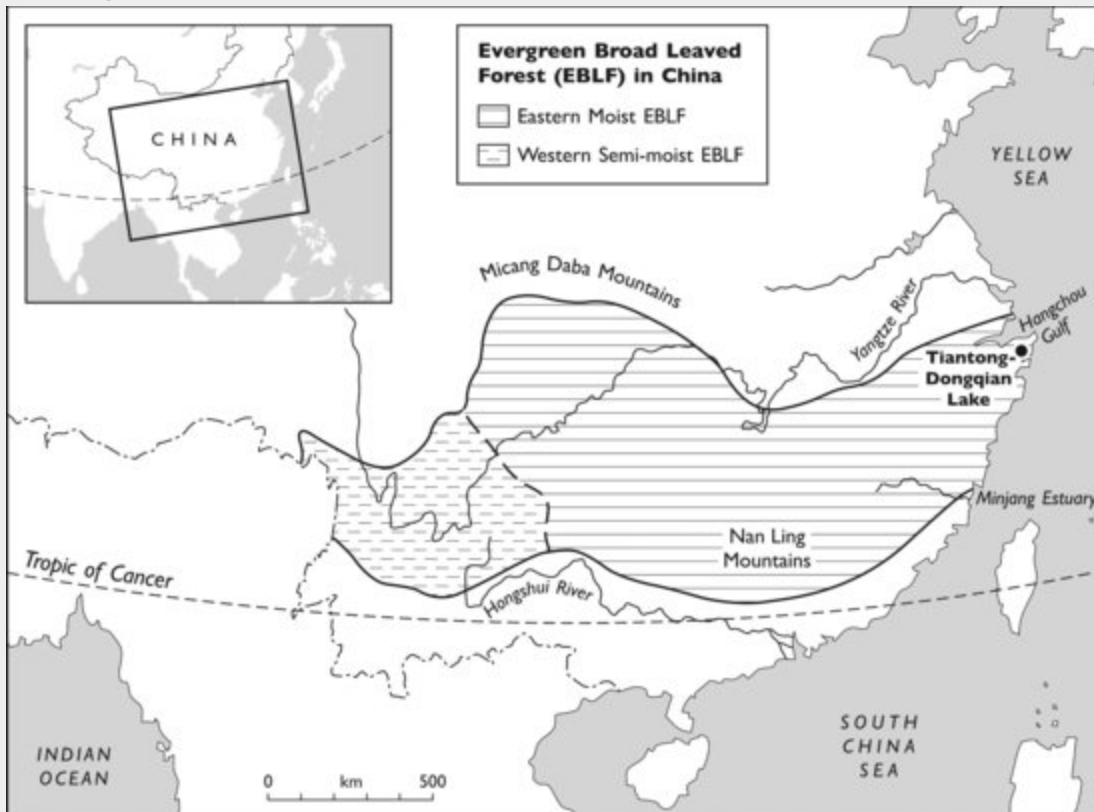
Case Study 1: Evergreen broad-leaved forest in Eastern China: its ecology and conservation and the importance of

resprouting in forest restoration (Wang et al., 2007)

Evergreen broad-leaved forest (EBLF) is now recognised as an important global vegetation formation type that contributes to both the biodiversity and the sustainable development of the subtropical regions of China. Discussion of the forests is omitted in Archibold (1995), although they are mapped as EBLF in the more recent overview of world vegetation types by Box and Fujiwara (2005). While its biogeographical status in China still remains a matter of debate, unfortunately, the extent of the EBLF has decreased very significantly due to long-term anthropogenic disturbance, including deforestation, logging and fire, and much of the forest is now degraded to plantation, secondary forests, shrub and grassland communities. Song (1988, 1995) provided the most valuable review in English of both the position of the Chinese EBLF within the world vegetation formation types and the overall characteristics of the forest. In China, it occurs between 24°–32°N and 99°–123°E and formerly covered around 25% of the area of the country ([Figure 1.1](#)). It lies within areas dominated by a subtropical monsoon climate and the forests occupy mountainous and hilly areas across the south and east of China ([Plate 1.1](#)). The forests are extremely diverse, particularly in terms of tree and shrub species (phanerophytes 50–80% of species – see Chapter 3), ranging from over 100 vascular plant species/400 m² in the south, to 30–45 species in the north of its distribution (Song, 1988). The dominant species of the EBLF come from only a few genera, together with some ancient coniferous species, many of which have ‘broad leaves’.

To inform forest conservation and management, Wang *et al.* (2007) described research into major plant community types and underlying environmental gradients (see Chapter 2) of degraded EBLF around Tiantong and Dongqian Lake near Ningbo in Eastern China ([Figure 1.1](#); [Plate 1.1](#)), and examined the importance of vegetative resprouting as a key mechanism in secondary succession following forest clearance. Species composition was described from 199 10 m × 10 m plots (Chapter 3) and analysed using various methods presented later in this book (Two-Way Indicator Species Analysis [TWINSpan] – Chapter 8; and canonical correspondence analysis [CCA] ordination – Chapter 6). Some 22 degraded and mature forest community types were identified, while CCA indicated that a primary vegetation gradient was related to the distance of sample plot from mature forest, which was closely linked to altitude and slope. The secondary gradient corresponded to successional stage and disturbance. The roles of resprouting and reseedling characteristics in forest regeneration were researched firstly by 10 m × 10 m plots taken from selected TWINSpan groups, and secondly by 20 m × 20 m plots in representative areas of forest at different ages – 1, 20, 43 and 60 years, and in an area of mature forest – 100+ years.

Figure 1.1 The distribution of evergreen broad-leaved forest (EBLF) in China and the separation of forest into the Western semi-moist and Eastern moist forest types (after Song, 1988; Wang *et al.*, 2007: reproduced with kind permission of Elsevier).



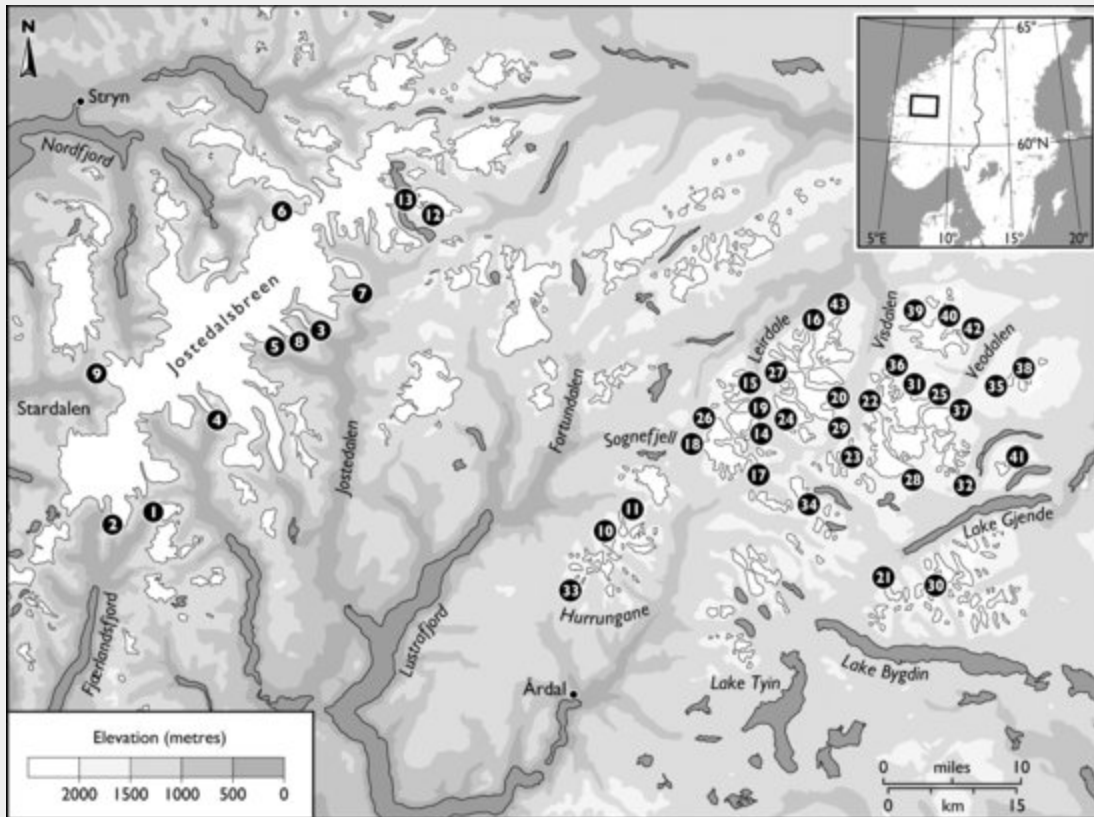
The importance of resprouting in the regeneration of many EBLF tree and shrub species was demonstrated, a process linked to ideas of the persistence niche - resprouting from stumps is an important means of persistence for many species. Existing remnant forests should be conserved, but forest restoration is also essential and will benefit from understanding of the importance of tree/shrub resprouting, as well as seedling recruitment in forest regeneration. Further work is in progress on seedbanks, germination success and both inter- and intra-specific competition within Chinese EBLF to assist with successful conservation and management of this rare forest type (Chapter 6 - Case studies).

Case Study 2: Pioneer vegetation on glacier forelands in southern Norway (Robbins and Matthews, 2009, 2010)

Climate change and its ecological impact is one of the most important and also controversial environmental topics at the present time. A widely observed phenomenon in Europe and Scandinavia over the past

100 years has been the retreat of mountain glaciers in response to increased summer temperatures and relatively low winter precipitation, and Nesje *et al.* (2008) have predicted that up to 98% of Norwegian glaciers may have disappeared by 2100. Robbins and Matthews (2009) saw the retreat of such glaciers as a valuable opportunity to study the earliest stages of vegetation colonisation (primary succession) and the manner in which plant species are responding to the availability of new terrain on glacier forelands ([Plate 1.2](#)). They were concerned firstly to examine the species composition of early pioneer stages, and secondly to see whether these highly disturbed sites are colonised by consistent sets of species or whether species composition is more dependent on chance (stochastic) factors that tend to produce more random and variable collections of species. McCook (1994), Walker and del Moral (2003), Pickett and Cadenasso (2005) and Pickett *et al.* (2008) present the most recent reviews of processes of primary succession.

Figure 1.2 The locations of the 43 glacier forelands in southern Norway studied by Robbins and Matthews (2009, 2010). Redrawn and reproduced with kind permission from Wiley-Blackwell.

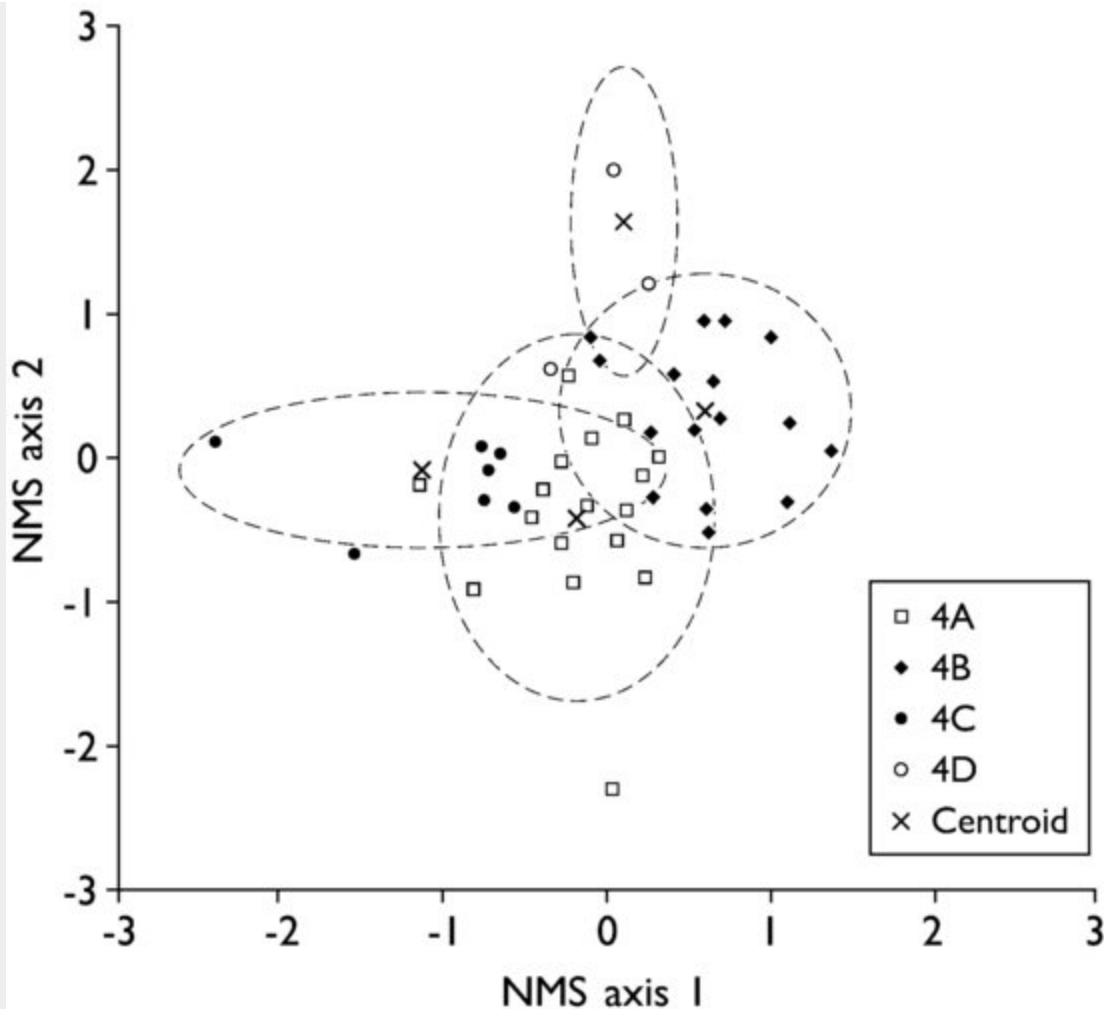


A total of 43 glacier forelands in the Jotunheim and Jostedalsglaciaren regions of southern Norway, with an altitudinal range of 80–1860 m,

were sampled ([Figure 1.2](#)). The vegetation data were collected in a particularly interesting manner, using rectangular quadrats for contiguous (adjacent) sampling along transects away from the glacier snout in each case. The detail of this is presented in a case study at the end of Chapter 3. In addition to the vegetation data, two regional explanatory environmental variables were collected at each quadrat, altitude and distance eastwards from a fixed reference point, representing a continentality index. Earlier surveys had also examined more local habitat factors, such as snow distribution, microsite conditions, and measures of the randomness of points of initial colonisation (stochasticity) (Whittaker, 1989, 1991).

As with the Chinese case study above, data analysis involved techniques of multivariate analysis – numerical classification using a form of similarity analysis known as flexible- β followed by use of a multi-response permutation procedure (MRPP) (see Chapter 8) and ordination using non-metric multidimensional scaling (NMS) (McCune and Grace, 2002) (see Chapter 6). An example NMS ordination plot, displaying the results for 42 sites, with four classification groups superimposed is shown in [Figure 1.3](#). This type of plot is fully explained in Chapter 6.

[Figure 1.3](#) Non-metric multidimensional scaling (NMS) ordination plot of the 42 glacier foreland sample sites with four numerical classification groups superimposed. One site was removed due to a complete absence of vegetation in the pioneer zone. Redrawn and reproduced with kind permission from Wiley-Blackwell.



The key result of the research was that the vegetation could be seen as one broad vegetation type characterised by *Poa alpina* (Alpine meadow grass) and *Oxyria digyna* (Mountain sorrel), indicated in general terms by the overlapping of the classification group circles on [Figure 1.3](#) (see Chapter 8). Nevertheless, within this overall group, there was a high degree of variability, but two emerging subcommunities could be identified and these were shown to be linked to both site altitude and continentality. Whereas the very earliest stages of colonisation could be said to be highly stochastically determined (i.e. by randomness and chance), the beginnings of the organisation of changes in species composition into two successional pathways could be observed. There are many interesting features to this work, including the regional scale of vegetation description, the underlying model of vegetation change and dynamics, the sampling design and its relevance to the topic of vegetation response to climate change.

Case Study 3: Vegetation description and data analysis to inform the conservation

of a rare plant species - Lobelia urens L. (the heath lobelia) in southern England (Dinsdale et al., 1997, 2000)

The successful conservation of rare plant species usually requires a range of information and scientific research linked to both the autecology (the study of a single species in relation to its ecology and environment) and synecology (the study of a community of species in relation to their ecology and environment) of the species involved in order to assist with management practice. *Lobelia urens* L. (the heath lobelia) ([Plate 1.3](#)) is a perennial rhizomatous herb that shows a Lusitanian distribution in Europe and North Africa extending from Morocco, Madeira and the Azores in the south, along the Atlantic coast through Portugal, Spain and France, as far north as Belgium. However, in the UK, at the extreme north of its range, *L. urens* is today limited to six locations in the southern coastal counties of England, although historical records indicate that it may have been found on 19 sites altogether. Dinsdale *et al.* (1997) surveyed the historical and documentary evidence for its distribution and completed extensive botanical surveys to try to understand the plant communities and species assemblages within which it grows (its phytosociology) and to assess both environmental controls and limitations on the species.

At the six remaining sites in southern England, a total of 95 0.5 m × 0.5 m quadrats, containing 122 plant species, were recorded, using a Domin abundance scale and a carefully devised sampling strategy (see Chapter 3). Data on 16 environmental variables were also collected ([Table 1.1](#)) in order to summarise the environmental variability and the factors possibly limiting its distribution. Analysis of the data for phytosociological purposes involved using the numerical classification method called Two-Way Indicator Species Analysis (TWINSpan: Hill, 1979b) (see Chapter 8), while the floristic variation and correlations with the environmental variables in the 95 quadrats were assessed using the method of ordination known as canonical correspondence analysis (CCA) (ter Braak, 1986a, 1987, 1988a,b) (see Chapter 6).

Table 1.1 The 16 environmental variables measured in the survey of *Lobelia urens* L. (the heath lobelia) at six sites in southern England (Dinsdale *et al.*, 1997). Reproduced with kind permission of Wiley-Blackwell.

Microclimate and habitat	Soil variables
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