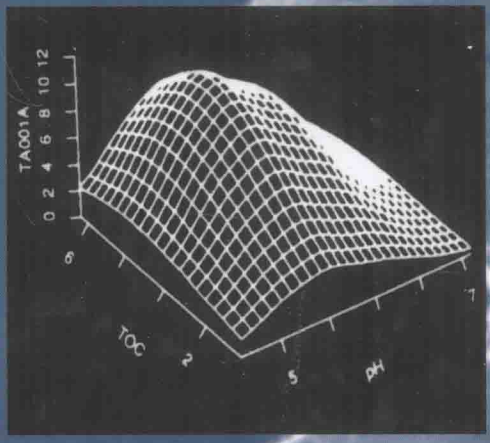
Tracking Environmental Change Using Lake Sediments

Volume 5

Data Handling and Numerical Techniques

Edited by

H. John B. Birks, André F. Lotter
Steve Juggins and John P. Smol



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Tracking Environmental Change Using Lake Sediments

Developments in Paleoenvironmental Research

VOLUME 5

Aims and Scope:

Paleoenvironmental research continues to enjoy tremendous interest and progress in the scientific community. The overall aims and scope of the *Developments in Paleoenvironmental Research* book series is to capture this excitement and document these developments. Volumes related to any aspect of paleoenvironmental research, encompassing any time period, are within the scope of the series. For example, relevant topics include studies focused on terrestrial, peatland, lacustrine, riverine, estuarine, and marine systems, ice cores, cave deposits, palynology, isotopes, geochemistry, sedimentology, paleontology, etc. Methodological and taxonomic volumes relevant to paleoenvironmental research are also encouraged. The series will include edited volumes on a particular subject, geographic region, or time period, conference and workshop proceedings, as well as monographs. Prospective authors and/or editors should consult the **Series Editor John P. Smol** for more details. Any comments or suggestions for future volumes are welcomed.

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This book is dedicated to Cajo ter Braak, whose work on quantifying species-environmental relationships underpins many of the recent advances in quantitative palaeolimnology described in this book

Preface

Palaeoenvironmental research has been thriving for several decades, with innovative methodologies being developed at a frenetic rate to help answer a myriad of scientific and policy-related questions. This burst in activity was the impetus for the establishment of the *Developments in Paleoenvironmental Research* (*DPER*) book series over a decade ago. The first four *DPER* volumes dealt primarily with methodologies employed by palaeolimnologists. Subsequent volumes addressed a spectrum of palaeoenvironmental applications, ranging from ice cores to dendrochronology to the study of sedimentary deposits from around the globe.

This book does not deal with the collection and synthesis of primary data, but instead it discusses the key role of data handling and numerical and statistical approaches in analysing palaeolimnological data. As summarised in our introductory chapter, palaeoenvironmental research has steadily moved from studies based on one or a few types of proxy data to large, data-rich, multi-disciplinary studies. In addition, there has been a rapid shift from simply using qualitative interpretations based on indicator species to more quantitative assessments. Although there remains an important place in palaeoenvironmental research for qualitative analyses, the reality is that many researchers now employ a wide range of numerical and statistical methodologies. It is time to review critically some of these approaches and thereby make them more accessible to the wider research community. We hope the 21 chapters making up this volume meet these goals.

Many people helped with the planning, development, and final production of this book. We would like to acknowledge the hard work and professionalism of our many reviewers, who provided constructive comments on earlier drafts of the manuscripts. We would also like to acknowledge the assistance we received from our publishers, and especially the efforts and encouragement from our main Springer colleagues—Tamara Welschot and Judith Terpos. We are grateful to Irène Hofmann for her work in the early stages of the book. We are particularly indebted to the enormous amount of work that Cathy Jenks has done in the processing and editing of the chapters, compiling and checking bibliographies and the glossary, and in the overall production of this book. Thanks are also due to our host institutions and our various funding sources, which helped facilitate our academic endeavours. We

also gratefully acknowledge a variety of publishers and authors who allowed us to reproduce previously published figures. Foremost, we would like to thank the authors for their hard work and especially for their patience with the delays in completing this book. We hope that the final product was worth the wait.

Structure of the Book

This book consists of 21 chapters arranged in four parts. Part I is introductory and Chap. 1 considers the rapid development and ever-increasing application of numerical and statistical techniques in palaeolimnology. Chapter 2 provides an overview of the basic numerical and statistical approaches used in palaeolimnology in the context of data collection and assessment, data summarisation, data analysis, and data interpretation. Many of these techniques are described in more detail in chapters in Parts II and III but some important approaches such as classification, assignment and identification, and regression analysis and statistical modelling are described in Chap. 2 as they are not specifically covered elsewhere in the book. Chapter 3 describes the modern and stratigraphical data-sets that are used in some of the later chapters.

Part II considers numerical approaches that can be usefully applied to the two major types of palaeolimnological data, namely modern surface-sediment data-sets and core sediment data-sets. These approaches are exploratory data analysis and data display (Chap. 5), assessment of uncertainties associated with laboratory methods and microfossil analysis (Chap. 6), clustering and partitioning (Chap. 7), classical indirect and canonical direct ordination (Chap. 8), and a battery of techniques grouped together as statistical-learning methods in Chap. 9. These include classification and regression trees, multivariate regression trees, other types of tree-based methods, artificial neural networks and self-organising maps, Bayesian networks and genetic algorithms, principal curves, and shrinkage methods. Some other numerical techniques are not covered in these five chapters (e.g., estimating compositional turnover, richness, and species optima and tolerances, and comparing clusterings and ordinations) because the topics are not sufficiently large to warrant individual chapters. They are outlined in Chap. 4 as an introduction to Part II.

Part III contains seven chapters. They describe numerical techniques that are only applicable to the quantitative analysis of stratigraphical data-sets. Chapter 11 discusses numerical techniques for zoning or partitioning stratigraphical sequences and for detecting patterns within stratigraphical data-sets. Chapter 12 considers the essential task of establishing age-depth relationships that provide the basis for estimating rates of change and temporal patterns within and between stratigraphical

sequences. Chapter 13 discusses an important but rarely used approach to core correlation by sequence-slotting. Chapter 14 discusses the quantitative reconstruction of environmental variables such as lake-water pH from, for example, fossil diatom assemblages. This general topic of environmental reconstruction has been a central focus of many palaeolimnological investigations in the last 20 years and Chap. 14 highlights the assumptions and limitations of such reconstructions, and the testing, evaluation, and validation of reconstructions. Chapter 15 considers modern analogue methods in palaeolimnology as a procedure for quantitative environmental reconstructions and for comparing fossil and modern assemblages as a tool in lake restoration and management. Chapter 16 concludes Part III by presenting new approaches to assessing temporal patterns in palaeolimnological temporal-series where the major assumptions of conventional time-series analysis are not met. Other numerical techniques such as palaeopopulation analysis, stratigraphical changes in richness, and approaches to temporal-series analysis such as LOESS smoothing and the SiZer (Significant Zero crossings of the derivative) approach and its relatives BSiZer and SiNos that are not discussed in Chaps. 11, 12, 13, 14, 15 and 16 are outlined briefly in Chap. 10, which also provides an overview and introduction to Part III.

Part IV consists of five chapters. Chapter 17 provides an introduction and overview to this Part. Three chapters (Chaps. 18, 19, 20) describe case studies where some of the numerical methods presented in Parts II and III are used to answer particular palaeolimnological research questions and to test palaeolimnological hypotheses. Chapter 18 considers limnological responses to environmental changes at inter-annual to decadal time-scales. Chapter 19 reviews the application of numerical techniques to evaluate surface-water acidification and eutrophication. Chapter 20 discusses tracking Holocene climatic change using stratigraphical palaeolimnological data and numerical techniques. The last chapter, Chap. 21, discusses eight areas of research that represent future challenges in the improved numerical analysis of palaeolimnological data.

Data-sets, figures, software, and R scripts used or mentioned in this book, links to important websites relevant to this book and its contents are available from Springer's Extras website (http://extras.springer.com).

About The Editors

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