

TABLE OF CONTENTS

| | |
|---|-------|
| Preface | xiii |
| The Editor | xv |
| Aims and scope of <i>Developments in Paleoenvironmental Research</i> | |
| Book Series | xvii |
| Editors and Board of Advisors of <i>Developments in Paleoenvironmental Research</i> | |
| Book Series | xix |
| Published and Forthcoming Titles in the <i>Developments in Paleoenvironmental Research</i> Book Series..... | |
| xxi | |
| List of Contributors..... | xxiii |
| 1. An introduction to Lochnagar | |
| Neil L. Rose | 1 |
| The importance of mountains and their lakes | 1 |
| Location and site description | 4 |
| A brief history..... | 9 |
| The Royal loch..... | 11 |
| “Steep frowning glories”: The Lochnagar of artists and poets | 12 |
| The scientific ‘snowball effect’ | 14 |
| Scope of this book | 18 |
| And finally..... | 21 |
| Acknowledgements..... | 21 |
| References | 22 |
| 2. Physical characteristics of Lochnagar | |
| Michael Hughes..... | 27 |
| Introduction | 27 |
| Physical parameters | 27 |
| Light regime | 30 |
| References | 35 |
| Part I: The environmental landscape of Lochnagar | |
| 3. Geology of Lochnagar and surrounding region | |
| Sally Goodman | 39 |
| Introduction | 39 |
| Summary..... | 49 |
| Acknowledgements..... | 49 |
| References | 49 |
| 4. The shaping of Lochnagar: Pre-glacial, glacial and post-glacial processes | |
| Adrian M. Hall... | 51 |
| Introduction | 51 |
| Ancient landforms | 52 |
| Major glacial landforms..... | 53 |

| | |
|--|-----|
| The last ice sheet and its landforms | 55 |
| Periglacial landforms | 57 |
| The northeast corrie of Lochnagar..... | 57 |
| Summary..... | 60 |
| References | 61 |
| 5. Lochnagar water-temperatures, climate and weather | |
| <i>Roy Thompson, Helen Kettle, Donald T. Monteith and Neil L. Rose</i> | 63 |
| Introduction | 63 |
| Present climate..... | 66 |
| Records from the instrumental period..... | 68 |
| Reanalysis assimilation data..... | 77 |
| Water-temperature | 79 |
| Past climate..... | 85 |
| Discussion..... | 87 |
| Summary..... | 88 |
| Acknowledgements..... | 88 |
| References | 89 |
| 6. The development, distribution and properties of soils in the Lochnagar catchment and their influence on soil water chemistry | |
| <i>Rachel C. Helliwell, Allan Lilly and John S. Bell</i> | 93 |
| Introduction | 93 |
| The soils in the Lochnagar catchment | 93 |
| Factors affecting soil development in the Lochnagar catchment..... | 96 |
| Distribution of soils and their physico-chemical properties | 99 |
| Impacts of soil processes on surface water chemistry | 106 |
| The importance of soil in determining surface water nitrate concentrations | 110 |
| MAGIC modelling of soil and soil solution | 112 |
| Potential impacts of climate change on the soils of Lochnagar | 115 |
| Conclusion..... | 116 |
| Summary..... | 116 |
| References | 117 |
| 7. Flora and vegetation of Lochnagar – past, present and future | |
| <i>H. John B. Birks</i> | 121 |
| Introduction | 121 |
| Present-day flora and vegetation..... | 126 |
| Past flora and vegetation..... | 136 |
| Future flora and vegetation | 139 |
| Discussion and conclusions | 143 |
| Summary..... | 145 |
| Acknowledgements..... | 145 |
| References | 146 |

| | |
|--|-----|
| Part II: The contemporary physical and biological status of Lochnagar | |
| 8. The sediments of Lochnagar: Distribution, accumulation and composition <i>Neil L. Rose</i> | 155 |
| Introduction | 155 |
| Estimating the boundary of sediment accumulation | 156 |
| Sediment distribution and movement | 158 |
| Sediment accumulation rates | 164 |
| The influence of climate change on future sediment accumulation rates | 166 |
| Sediment description | 168 |
| Sediment composition and sources | 168 |
| Summary | 173 |
| Acknowledgements | 173 |
| References | 174 |
| 9. Hydrology and hydrochemistry of Lochnagar <i>Alan Jenkins, Nick Reynard, Mike Hutchins, Muriel Bonjean and Martin Lees</i> | 177 |
| Introduction | 177 |
| Hydrology | 177 |
| Hydrochemistry | 183 |
| The future? | 189 |
| Summary | 195 |
| Acknowledgements | 196 |
| References | 196 |
| 10. The aquatic flora of Lochnagar <i>Roger J. Flower, Donald T. Monteith, Jonathan Tyler, Ewan Shilland and Sergi Pla</i> | 199 |
| Introduction | 199 |
| Aquatic plants in acidic Scottish Highland lochs | 201 |
| The aquatic plants of Lochnagar | 202 |
| The history of aquatic vegetation | 215 |
| Discussion | 218 |
| Summary | 224 |
| Acknowledgements | 225 |
| References | 225 |
| 11. Pattern and process in the Lochnagar food web <i>Guy Woodward and Katrin Layer</i> | 231 |
| Introduction | 231 |
| Methods | 232 |
| Results | 233 |
| Discussion | 239 |
| The prospects for biological recovery | 246 |
| Future directions | 247 |

| | |
|--|-----|
| Summary..... | 248 |
| Acknowledgements | 249 |
| References | 249 |
| | |
| 12. Brown trout in Lochnagar: Population and contamination by metals and organic micropollutants <i>Bjørn Olav Rosseland, Sigurd Rognerud, Peter Collen, Joan O. Grimalt, Ingrid Vives, Jean-Charles Massabuau, Reinhard Lackner, Rudolf Hofer, Gunnar G. Raddum, Arne Fjellheim, Ron Harriman and Benjamin Piña.</i> | 253 |
| Introduction | 254 |
| The fish population in Lochnagar | 255 |
| Physiological status and osmoregulation in relation to water chemistry | 262 |
| Metal concentration in fish organs | 263 |
| Persistent organic pollutants (POPs) in liver and muscle and polycyclic aromatic hydrocarbons (PAH) in liver | 274 |
| Liver histology as an indicator of oxidative stress..... | 278 |
| Summary..... | 281 |
| Acknowledgements..... | 283 |
| References | 283 |
| | |
| Part III: Anthropogenic impacts from atmospheric pollutant deposition | |
| | |
| 13. National, international and global sources of contamination at Lochnagar <i>Neil L. Rose, Sarah E. Metcalfe, Anna C. Benedictow, Martin Todd and Jim Nicholson.</i> | 289 |
| Introduction | 290 |
| Modelling source attribution..... | 291 |
| Scottish sources | 292 |
| UK sources | 295 |
| European sources | 300 |
| Intercontinental and global sources | 306 |
| Discussion..... | 307 |
| Summary..... | 310 |
| Acknowledgements..... | 311 |
| References | 311 |
| | |
| 14. Acidification of Lochnagar and prospects for recovery <i>Donald T. Monteith, Chris D. Evans and Catherine Dalton</i> | 317 |
| Introduction | 317 |
| The chemical composition of lake water and its acidification by acid Pollutants..... | 318 |
| The importance of acidity for lake ecosystems..... | 319 |
| Palaeolimnological reconstruction of lake acidity | 321 |
| Evidence for recovery from acidification from environmental monitoring ... | 327 |
| Future prediction..... | 336 |

| | |
|---|-----|
| Summary..... | 338 |
| Acknowledgements..... | 340 |
| References | 340 |
| 15. Trace metals in the catchment, loch and sediments of Lochnagar: Measurements and modelling | |
| <i>Edward Tipping, Handong Yang, Alan J. Lawlor, Neil L. Rose and Laura Shotbolt</i> | 345 |
| Introduction | 346 |
| Methods | 347 |
| Trace metals in atmospheric deposition..... | 347 |
| Trace metal inputs from weathering | 348 |
| Trace metals in soil..... | 350 |
| Trace metals in biota..... | 350 |
| Trace metals in loch water..... | 351 |
| Trace metals in loch sediments..... | 354 |
| Trace metal toxicity | 356 |
| Dynamic modelling | 358 |
| Discussion..... | 365 |
| Summary..... | 369 |
| Acknowledgements..... | 370 |
| References | 370 |
| 16. Persistent organic pollutants in the sediments of Lochnagar | |
| <i>Derek C.G. Muir and Neil L. Rose</i> | 375 |
| Introduction | 375 |
| Methodology..... | 378 |
| Results and discussion | 380 |
| Summary..... | 395 |
| Acknowledgements..... | 396 |
| References | 396 |
| 17. Temporal and spatial patterns of spheroidal carbonaceous particles (SCPs) in sediments, soils and deposition at Lochnagar | |
| <i>Neil L. Rose and Handong Yang</i> | 403 |
| Introduction | 403 |
| Atmospheric deposition of SCPs | 404 |
| SCPs in sediments and sediment traps..... | 407 |
| SCPs in catchment soils..... | 414 |
| A SCP number balance..... | 416 |
| Impacts of climate change | 419 |
| Summary..... | 419 |
| Acknowledgements..... | 420 |
| References | 421 |

Part IV: Future impacts

| | |
|--|-----|
| 18. Future climate predictions for Lochnagar | |
| <i>Helen Kettle and Roy Thompson</i> | 427 |
| Our changing climate..... | 427 |
| Projecting anthropogenic climate change | 430 |
| Future climate projections at Lochnagar..... | 434 |
| Predicting water temperatures at Lochnagar..... | 437 |
| Predicting ice cover at Lochnagar | 439 |
| Summary..... | 442 |
| Acknowledgements..... | 443 |
| References | 443 |
| 19. Past and future environmental change at Lochnagar and the impacts of a changing climate | |
| <i>Neil L. Rose and Richard W. Battarbee</i> | 445 |
| Introduction | 445 |
| Past environmental change and present status | 446 |
| Direct effects of climate..... | 450 |
| Indirect effects of climate | 452 |
| Other impacts..... | 457 |
| Conclusions | 458 |
| Summary..... | 459 |
| Acknowledgements..... | 460 |
| References | 460 |
| Glossary, acronyms and abbreviations | 465 |
| Index | 493 |