The Freshwater Algal Flora of the British Isles

An Identification Guide to Freshwater and Terrestrial Algae

Second Edition

Building on the success of the first edition and featuring contributions from leading experts in the field, this expanded and thoroughly revised second edition provides an indispensable guide to the freshwater and terrestrial algae of the British Isles. It is an up-to-date account of, and identification tool for, more than 2400 algal species (excluding diatoms), highlighting their wider distribution around the world. Detailed descriptions are fully illustrated with clear line drawings and photographs including 193 full-page plates, eight of which are full colour. In addition, user-friendly keys enable the accurate identification of specimens to the level of genus and species.

This edition includes expanded information on ecology and the implications of recent molecular research, along with coverage of around 200 extra species. The accompanying DVD provides an updated colour photo catalogue, highly illustrated articles and video clips, making this the comprehensive reference tool for both researchers and professionals in the field.

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The Flora is dedicated to

John W.G. Lund FRS

in thanks for his outstanding contribution to the knowledge of British freshwater algae and his continuing help and encouragement to phycologists throughout the world.

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An Identification Guide to Freshwater and Terrestrial Algae

Second Edition

Edited by **David M. John**
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with an accompanying DVD prepared by Alan Donaldson, Brian A. Whitton and Peter V. York containing articles and a photo catalogue of algal images and habitats compiled by Peter V. York, David M. John and Chris F. Carter

a collaborative project of the British Phycological Society and The Natural History Museum, London

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Logos of societies and organizations which have sponsored and/or given significant support to the Flora Project.

FOREWORD

Second edition

It is now nine years since the first edition of this Flora was issued and it is no longer available. Apart from that, major changes have taken place in the classification and taxonomy of the algae. Lastly, there are some 200 verifiable additions to the flora and increased knowledge of various aspects of the ecology and distribution of many taxa. Clearly a new edition is needed, and the editors and contributors are to be congratulated on their conclusion of a major task. They have kept to what can be seen with a light microscope. This does make the identification of some species impossible (e.g. in the genus *Mallomonas*), but the vast majority of freshwater algae can still be identified in this way.

The results of investigations using electron microscopy and of phylogenetic studies have caused a major revision of the Chlorophyta, although there are some still unresolved problems, notably in *Klebsormidium*, a cosmopolitan genus containing some of the commonest soil algae. Considerable clarification has been made in the equally common aquatic genus *Scenedesmus*, pictures of which are legion. The chapter on Cyanobacteria (Cyanophyta) has been enlarged and partially revised and is an especially valuable overview based on the author's great knowledge of the group. A welcome addition is the inclusion of 'colourless' (non-photosynthetic) Euglenophyta. 'Colourless' Cryptophyta and Dinophyta are also included. The chapter on Desmids is significantly enlarged; yet less than half of the 900 British species are included. Very helpful additions are the pictures illustrating the common terms used in the description of these algae. Another welcome addition is the short yet masterly chapter on cultures of algae.

Despite the additions made, the new edition is just over 170 pages longer than the first. The CD of that volume is replaced by a DVD which includes a variety of images and articles. The photo catalogue of algae and their habitats is considerably enlarged (now over 1400 images) and the coded checklist of freshwater and terrestrial algae has been brought up to date. There are stunning pictures of desmids along all three axes. The pictures of *Vaucheria* are also to be highly commended.

The edition is a fine successor to the first and is likely to have an even larger circle of users.

J.W.G. Lund FRS
August 2010

First edition

G.S. West's 1904 account of the British freshwater algal flora was the first to be published in the twentieth century and marked a very considerable advance on earlier ones. In Fritsch's revision (West and Fritsch, 1927) of this work there were approximately 250 genera dealt with. Now over 550 genera have been recorded from the British Isles, excluding those in the Euglenophyta and Pyrrophyta, which were not included in the 1927 Flora. These figures alone show how badly needed is the new Flora.

As a result of a proposal made by David John and Brian Whitton, the British Phycological Society set up a committee in 1991 to oversee the production of a new freshwater flora. The Natural History Museum, London, supported the undertaking financially and in practical terms, by allowing members of staff to work on the project. David John and Brian Whitton became its editors, to be joined later by Alan Brook.

The Flora Committee had a difficult decision to make. British marine phycologists started a comprehensive and now highly regarded series of volumes some 50 years ago, but it is still not yet quite complete. It was obvious that, no matter how urgent the need for a comprehensive replacement of the West and Fritsch volume, one on a similar scale to the marine Flora would take very many years to complete. Nevertheless, it was decided to include all genera containing photosynthetic taxa, apart from a few of doubtful validity. For some genera containing a relatively large number of species, a representative sample is described and figured and the others merely listed. In particular, only about 300 of the commonest of the 800 or so desmid species are described in full. This seems to me to be a sensible decision. Even so, it has taken some 10 years to complete the present work. This may seem a long gestation time to some people, but not to those who, from experience, are able

to appreciate the amount of work involved in and the complexities of producing multi-authored books. Moreover, the Flora is accompanied by a CD-ROM of photo-images.

Our knowledge of the distribution of the British freshwater algae has greatly increased since 1927 and there have also been some marked changes in taxonomy. Modern advances in taxonomy have been incorporated, even though the practical use of the Flora depends on light microscopy. Knowledge of the distribution and ecology of some species has also increased greatly, although there are still many about which little is known. Hopefully, the Flora will help to correct this.

The representation of some groups has been enlarged as a consequence of studies made especially for the Flora, including the Euglenophyta by Konrad Wołowski and *Vaucheria* by Leslie Johnson and Roy Merritt. The much-needed account of the Rhodophyta by Robert Sheath and Alison Sherwood benefited from a large number of collections at sites ranging widely over parts of the British Isles. Many illustrations have been drawn especially by Hilary Belcher and Erica Swale, who also added much floristic information. David Williamson has produced many original desmid figures. He and Alan Brook have continued the interest in and indeed love for desmids, which was pioneered so brilliantly by William and George West. It is noteworthy that over 10% of the descriptive part of the latter's 1904 Flora was devoted to desmids.

David John's account of the Ulotrichales and Chaetophorales is particularly useful for a different reason: namely, it gives us conclusions by someone with special experience and knowledge of groups in which the taxonomy is often in an unsatisfactory, or even very unsatisfactory state. A prime example is *Stigeoclonium*, a very common and abundant genus. Despite or as a result of a diversity of past studies, what he says about the difficulties of identifying species of this genus is only too true.

The diatoms are introduced by Martyn Kelly and Elizabeth Haworth, but otherwise are not included here. Their account contains useful references to introductory guides and Floras. There is also a valuable overview of the many taxonomic revisions and nomenclatural changes made in recent times at the level of genus. In view of the importance of diatoms in the British Isles, and their widespread use for a variety of purposes, we hope that it will not be long before there is also a diatom Flora of the British Isles. As in the case of the Chlorophyta referred to above, it is surely better to have even an imperfect account than no account at all.

It was decided to include only photosynthetic (pigmented) taxa, although there are references to one or two non-photosynthetic (colourless) genera. This lacuna is particularly large for the Euglenophyta, where there are at least as many colourless as pigmented genera. Perhaps an account of such algae or protozoa can be produced by cooperation between our phycological and protozoological societies?

Is there amongst us a phycologist who has specialized knowledge of all groups of freshwater and terrestrial algae? Probably not, so all phycologists can be grateful to those who have made this Flora possible. The book will also be invaluable to anyone who wants to know something about our freshwater algae or wishes to learn how to identify the algae they find. The Flora is much needed and will, I believe, be much used.

J.W.G. Lund FRS
March 2001

PREFACE

First edition

An increasing awareness of the importance of freshwater algae in environmental management and monitoring has led to an increased demand for their accurate naming. However, when two of us started to run an annual training course at the University of Durham for biologists in the water industry and water management, a number of problems about which we were already partially aware became very obvious. In order to make reliable identifications of all the species present in a range of mixed samples, well over 40 publications were needed including identification guides, Floras, monographs and research papers. Many of these are written in languages other than English and, even for the better linguists, are not always easy to use, since they are mostly written for professional taxonomists. Almost all focus on regions other than the British Isles, many are expensive and some are frequently difficult to obtain. The only comprehensive guide for the British Isles remains West and Fritsch's *A Treatise on the British Freshwater Algae*, first published in 1927.

It was evident that non-specialists require a user-friendly, well-illustrated identification guide written in English that should describe as many of the British freshwater algae as possible. Unfortunately, knowledge of the British freshwater algal flora remains far from complete. Many species recorded in the nineteenth century or early years of the twentieth century have not been recorded again. In a few cases this may be because of environmental changes, but more often than not it is simply because no one has resampled the localities and regions where these species grow. As a result of having no guide, we approached specialists in algal taxonomy and ecology with a proposal to produce a new and modern Flora dealing with all British freshwater algae. Everyone approached was very encouraging and offered strong support, despite a recognition that it was inevitable that the Flora would have many shortcomings.

In June 1991, the council of The British Phycological Society agreed to support the proposal submitted by two of us (DMJ, BAW) to prepare a modern synoptic account and identification guide to the freshwater and terrestrial algae of the British Isles. A committee was given the task of planning and organizing the 'Flora Project' and its first meeting took place at Durham on 25 September 1991. The Natural History Museum in London agreed to play a leading role by making staff time, workspace and other resources available. Because many of the experts required to produce such an authoritative work reside overseas, an early priority was to seek financial support to enable some overseas collaborators to visit the British Isles to collect material and to work with phycologists here. The first invitations were sent in 1993 and new specialists continued to join the project up until 1998. The successful outcome owes much to the contributors, who have given so freely of their time in preparing keys, descriptions and illustrative material. In 1996 it was decided to broaden the project to include a CD-ROM of mainly colour images. P.V. York agreed to be mainly responsible for compiling this photo catalogue.

Initially the committee hoped to cover all algal groups within a single volume, but it soon became clear that this was unrealistic. The decision about what to do was resolved in 1998 when the diatomists on the committee withdrew, believing it impossible to include diatoms until much further taxonomic research had been carried out. Fortunately, diatoms are one of the few algal groups for which there already exist fairly comprehensive identification guides. These guides and other useful literature on diatoms are introduced here by M.G. Kelly and E.Y. Haworth. Even with the omission of diatoms, there was still a problem over volume length, so the present deal with only about one-third of the 1000 or so desmids recorded for the British Isles.

David John, Brian Whitton, Alan Brook
London, Durham, Buckingham
June 2001

Second edition

This new edition of the Flora is a response to the number of species reported for the first time in the British Isles and also important taxonomic changes, many of which result from molecular studies which have shifted understanding of phylogenetic

relationships. The more than 200 new species include a few overlooked in the first edition, but are mostly new records. Some of the new records are in lists sent by agencies such as the Scottish Environment Protection Agency (SEPA), Environmental Protection Agency (EPA) of Ireland and the Centre for Ecology and Hydrology (CEH), and usually identified by overseas consultants. In most cases we know nothing about the experience and expertise of those identifying the material, making it difficult to know just how reliable the records are. These new records are mentioned and only accepted if they can be verified. Otherwise they are accompanied by a note that they require further verification. This is a slight shift from the first edition, where records for the British Isles were accepted only if published or provided by experienced and well-respected professional or amateur phycologists.

Many molecular studies in the past decade have revealed marked discrepancies between phylogeny based on morphology compared to molecular genetic data, indicating that many characters traditionally used for species identification have little or no phylogenetic significance. It is clear that various organizational levels have arisen on a number of occasions by convergent and parallel evolution and certain key characters have therefore lost their importance for distinguishing taxonomic groups. As a result, some new taxonomic re-alignments are proposed, cryptic species recognized and well-known genera redefined and split into two or more genera. Due to the uncertainties still existing and sometimes the failure to arrive at a concensus, the authors have adopted a fairly conservative approach and only to accept taxonomic changes if the evidence is very strong.

Newly acquired information on habitats and distribution patterns within and outside Europe have been taken into account in preparing this new edition. It seems likely that many algae have an almost cosmopolitan distribution, although in most cases are not present in polar regions.

The most enlarged chapter is that dealing with desmids, which now includes descriptions and illustrations of over 400 of the almost 900 desmid species known from the British Isles. The revised chapter includes 12 additional plates of more than 250 new line drawings prepared by David Williamson. Other expanded chapters include the blue-green algae (Cyanobacteria) chapter with more than 60 additional entries of species newly recorded for the British Isles and the one on euglenophytes that now includes colourless forms.

The new contributors are Dr Fabio Rindi (Chlorophyta: Klebsormidiales, Prasiolales, Trentepohliales), David Williamson (Chlorophyta: Zygnematales, desmids), Dr Alan Donaldson (DVD preparation), Dr John Day (Culture Collections), Dr Jan Krokowski (Water Framework Directive) and Dr Chris Carter (photo catalogue images, plates, articles).

The accompanying CD has been replaced by a DVD that contains articles and video clips in addition to a much expanded photo catalogue of images of freshwater algae. The DVD has been assembled by Peter York and David John, the articles have been edited by Brian Whitton, Alan Donaldson and David John, and the Photo Catalogue compiled by Peter York, David John and Chris Carter.

David John and Brian Whitton
London and Durham
April 2011

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First edition

The first edition would not have been possible without the generous support of the British Phycological Society and The Natural History Museum in London. Financial support provided by the former covered the expenses of the Flora Committee, a 'Flora Workshop' held in July 1999 at the University of Durham helped to employ research assistants for a few months, supported several visits by overseas collaborators and defrayed some of the production costs of the book. Special thanks go to all members of the 'British Freshwater Algal Flora Committee' who assisted in planning, organizing and running the project: B.S.C. Leadbeater, E.J. Cox, J.P.C. Harding, E.Y. Haworth, D.G. Mann and R.G. Sheath. Many others helped the project: J.F. John, G.W. Lawson and D. Rose assisted in compiling information and edited key groups; B. Williamson, D. Page, M. Sadka, D. Sutton, J. Benfield and V. Noble gave advice, helped to develop the software or assisted in the production of the CD-ROM photo catalogue; M.D. Guiry and F. Rindi provided unpublished data and hosted a collecting trip to Clare Island; S.C. Hardiman redrew and scanned illustrations of blue-green algae, D.M. Balbi and P.J. Robinson also assisted in the preparation of these figures; P. Rye prepared the plates and labels for most drawings of eukaryotic algae, B. Steiner-Gafner did the same for the haptophytes; S. Blackmore and R.M. Bateman (Keeper of Botany, NHM) supported the Flora project by allowing one of us (DMJ) to devote considerable time to it; J.P.C. Harding maintained contacts with colleagues, initially in The National Rivers Authority and subsequently The Environment Agency; R.V. Smith and S.I. Heaney sought support for the project in Northern Ireland, R.A. Sweeting and J.T. Krokowski similarly obtained financial support from The Environment Agency (England and Wales). Contacts and help from algal specialists in addition to those listed on the contents page were very important. Among those from the British Isles who commented on text, keys and illustrations were A.E. Bailey-Watts, J.H. Belcher, J.A. Brodie, G. Eaton, B.S. C. Leadbeater, J.W.G. Lund, B. Moss, E.M.F. Swale and J.R. Young. Researchers from overseas who have rendered similar assistance were P.A. Broady (Department of Plant and Microbial Sciences, University of Canterbury, New Zealand), P.F.M. Coesel (Department of Aquatic Ecology, University of Amsterdam, The Netherlands), T.J. Entwisle (Royal Botanic Gardens, Sydney, Australia), O.M. Skulberg (Norwegian Institute for Water Research, Oslo, Norway) and C.G. Velez (Departamento de Ciencias Biologicas, Universidad de Buenos Aires, Argentina). Many others assisted with providing material, literature, and taxonomic advice, including D.M. Balbi, S.J. Brierley, J. Ellaway, J.E. Florey, M.D. Guiry, L.M. Irvine, J.P.C. Harding, J. Jamieson, S. Pritchard, W. Purvis, F. Rindi, N. Robson, F. Rumsey, L.E. Shubert, G.E. Stevens (fomerly Douglas) and R. Woods.

We owe special thanks to Hilary Belcher and Erica Swale, who contributed many new records, original illustrations, ecological data and showed great patience in revising and refereeing manuscripts. Another key person is David B. Williamson, who prepared about one-third of the plates, provided many new desmid illustrations, and redrew many pencilled illustrations from the Wests' archive of illustrations housed at The Natural History Museum, London. He has made many valuable contributions to the text of the desmid section and edited many of the illustrations. Throughout, John Lund has given us much valued advice and assistance especially during visits to the Freshwater Biological Association at Windermere to consult his card index of British freshwater algae. Special mention goes to Judith John, who has not only been a very patient wife during the long hours of preparing the Flora, but has also carried out a considerable amount of the literature research, edited text, produced the standardized list of author abbreviations and prepared the taxonomic index.

To Maria Murphy and Ward Cooper at Cambridge University Press we are indebted for the patient and efficient manner in which they have dealt with the many and varied problems encountered during production; special thanks go to Jane Bulleid for copy-editing the manuscript.

We are indebted to all those who have contributed to this book for their time, enthusiasm and patience. The name of each contributor is given under the heading of the taxonomic group(s) or section for which they are responsible. All introductory chapters are co-authored by the editors who also prepared the glossary.

Finally, we remember Dr T. Christensen ('Tyge'), who was to have prepared text and illustrations for the genus *Vaucheria* (p. 262), but sadly died before he could complete the task.

David John, Brian Whitton, Alan Brook
London, Durham, Buckingham
June 2001

Second edition

We are indebted to all authors for readily agreeing to update and revise their original contributions and give special thanks to our new contributors.

Thanks go to the many who assisted us during preparation of this volume including: Bryan Kennedy (EPA, Ireland) for arranging laboratory facilities at Castlebar and accompanying us during field excursion to western Ireland; Dr Mary Kelly-Quinn (University College Dublin, Ireland) and Dr Trevor Champ (Central Fisheries Board, Ireland) for advice on collecting sites in Co. Westmeath and elsewhere in Ireland; Dr Tracey Begg (Scottish Natural Heritage) for assistance during sampling in the Outer Hebrides; Dr Christian Boedeker (National Herbarium of The Netherlands, Leiden) and Dr Frederik Leliaert (Ghent University, Belgium) for information to DMJ on *Aegagropila*; Elaine Monaghan (FBA, Windermere, UK) and Dr Elizabeth Haworth (FBA, Windermere, UK) for providing information from the Fritsch Collection; Dr Chris Carter for photomicrographs and preparation of plates; Dr Wayne Trodd (EPA, Ireland), Dr Jan Krokowski (SEPA, Scotland), Dr Stephen Maberley (CEH, Lancaster, UK), Dr Shelley Doe (Northern Ireland Environment Agency), for providing us with new records for Ireland and Scotland; Drs Fabio Rindi, Dagmar Stengel, Robin Govier, Zoe Popper and Ciaran Loughnane who accompanied DMJ on field collecting excursions and helped to make his stay in Ireland such a pleasant one; Dr Paul Gainey for providing collections and distribution records for red algae; Olena Bilous for assisting Prof. P. Tsarenko and DMJ in preparing the text and illustrations for the Chlorococcales *sensu lato*; the late Alan Joyce who provided DMJ with records and maps on the distribution of desmids in Sutherland. Many others assisted us with the literature, sent specimens or gave us advice including Dr Hilary Belcher and Dr Erica Swale, Dr Martin McGarrigle (EPA), Ruth Little (EPA), Prof. Maurice Moss (University of Surrey), Dr Thomas Pröschold (SAMS), Dr Frans Kouwets, Dr P.F.M. Coesel (University of Amsterdam), Dr Mary Kelly-Quin (UCD), Derek Stevens, Ray Woods, Sally Donaldson (SEPA), Dr Pauline Lange (SEPA), Dr Dominic Hicks (SEPA), Dr Trevor Champ, Richard Lansdown (Ardeola Environmental Services), Dr Janina Kwandrans (Institute of Nature Conservation, Kraków), Sara Pritchard (Beacon Biological), Graham Burgess, June Bell (SEPA), Anne Webster, Richard Bassett (APEM), John Kelcey, Elaine Monaghan, Dr Lawrence Carvalho (CEH), Malcolm Storey (FBA), and Dr Bernadette Ní Chatháin (RPS, Meuve, Ireland) and Professor Michael Guiry (MRI). One of us (DMJ) would like to specially thank Professor Michael Guiry for all his friendship and assistance as well as providing facilities at the Martin Ryan Institute (National University of Ireland, Galway) during his two-year stay as a Marie Curie Fellow, and Dr Johannes Vogel for allowing him the use of facilities in the Department of Botany at the Natural History Museum, London, as a Scientific Associate.

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In addition to the support from the British Phycological Society and The Natural History Museum, financial support for the first edition came from several sources. Unfortunately, the Flora Project never succeeded in obtaining finance to carry out the basic research needed to answer important taxonomic and ecological questions. We were both disappointed and surprised at the lack of support from most water companies and by some of the bizarre responses they provided to our correspondence. Grants from Northumbrian Water (then plc), Thames Water and the Department of Agriculture and Rural Development (Northern Ireland) received at an early stage were especially welcome and helped to get the project under way. We are also most grateful to a number of other organizations and individuals for supporting the first edition. The Royal Society provided a research microscope for BAW and helped to finance visits by Prof. K. Wołowski, while The Linnean Society of London and The Natural Environment Research Council contributed towards the preparation of illustrations. Plantlife and the Freshwater Biological Association assisted by promoting the Flora while support towards the costs of publication has been provided by The Environment Agency, The British Phycological Society, The Natural Environment Research Council, The Systematics Association, The Countryside Council for Wales, English Nature, Scottish Natural Heritage, Accrofab Ltd, C. Wright (Director of Accrofab Ltd) and an anonymous donor.

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David John and Brian Whitton
London, Durham
April 2011