Plant Atlas 2020

Mapping Changes in the Distribution of the British and Irish Flora

Volume 1

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O. L. Pescott & R. J. Burkmar

Dedicated to field botanists throughout Britain and Ireland, past and present, who recorded in all weathers and terrains to provide the many millions of records that underpin this Atlas, and especially to Gigi Crompton (1922–2020), a BSBI Vice-county Recorder for over 40 years, whose generous legacy helped to ensure that this book would see the light of day.

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Cover artwork: CLOCKWISE FROM TOP LEFT Stag's-horn Clubmoss *Lycopodium clavatum*, Jersey Fern *Anogramma leptophylla*, Italian Lords-and-Ladies *Arum italicum* ssp. *negelctum*, Yellow Iris *Iris pseudacorus*, Greater Bladderwort *Utricularia vulgaris*, Large-flowered Butterwort *Pinguicula grandiflora*, Deadly Nightshade *Atropa belladonna* | Chris Thorogood

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Foreword

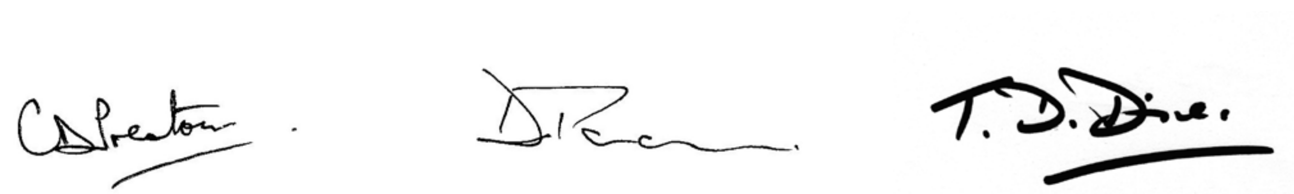
It is difficult to think of any book published in the 20th century that had a greater impact on the practice of natural history than the *Atlas of the British Flora* (Perring & Walters, 1962). Previously, the most detailed plant distribution maps showed the precise localities of species, using records derived from herbarium specimens. The 1962 *Atlas* had a completely different approach – the BSBI recruited a large band of volunteers to survey grid squares, with the aim of achieving comprehensive coverage within a limited time scale. The resulting field records were transferred to punched cards and the maps plotted mechanically. This revolutionary approach was taken up almost immediately by naturalists interested in many different groups. As one such author wrote with pardonable exaggeration, when introducing the *Second Atlas of the Breeding Birds of Maryland and the District of Columbia* (Ellison, 2010), "the atlas movement swept over the face of the earth".

The 1962 *Atlas* was planned by botanists with an interest in phytogeography, and in particular the historical and ecological factors determining the current distribution of species. It was only when the resulting maps were examined that it became clear that they also illustrated, very graphically, recent changes in the range of species. Native or long-established species in vulnerable habitats, especially wetlands and arable fields, were seen to have declined; some recently introduced species were now very widespread. As time went on, and the pressures affecting the distribution of species continued unabated, the maps published in 1962 took their place as historic documents, documenting the known range of flowering plants in the mid-20th century. The same became true of the first-generation maps of other groups, such as birds and butterflies.
A second generation of atlases appeared from the 1990s onwards, and their editors were faced with the problem of devising statistical techniques to compare the change between the two survey periods. This initiated what remains a very active field of research. The *New Atlas of the British and Irish Flora* (Preston *et al.*, 2002a) was typical in this respect, as native and long-established species were mapped much more comprehensively than before, and many newer introductions were treated for the first time.

It is a great pleasure to welcome the third atlas of British and Irish vascular plants, *Plant Atlas 2020*, with (as a bonus) the inclusion of one group of algae, the charophytes. These two volumes present the results of a survey undertaken from 2000 to 2019, mapped and analyzed with the results of the first two surveys plus many additional records collected for other recording projects. Even a cursory glance at the volumes will show how rich the resource accumulated over the years now is, and how sumptuously it is presented in this new publication. In addition to mapping the distribution of species, subspecies and hybrids, the accounts outline their altitudinal range and the distribution of records through the year, distinguishing those plants that are apparent for only a brief period from those that are identifiable over many months. Changes in the distribution of taxa are analyzed with unprecedented sophistication. The related website provides additional ways of mapping the records, and much more statistical analysis.

Just as with previous atlases, the data provided by this new publication will lead to a better understanding of why, and how rapidly, the distributions of plants are changing and how we should shape and prioritize our efforts to conserve them. In particular, bringing together thousands of taxa in an atlas allows common patterns of change, and the drivers behind them, to be identified. Using data from the *New Atlas*, *The Vascular Plant Red Data List for Great Britain* (Cheffings & Farrell, 2005) saw a fundamental shift from simply counting ten-kilometre squares to define 'rare' and 'scarce' species to a much more comprehensive analysis of threat, measured by the scale of change in range, sites and populations. This work continues and allows us not only to identify the most threatened species for urgent action, but also widespread species that are undergoing rapid declines. As we, and our ways of life, shape the landscapes and plants around us, directly and indirectly, it has never been more important to have an up-to-date picture of what is happening to our flora.

As editors of the *New Atlas* (2002), we are all too well aware of the work that goes into a publication like this. Atlases consume lives. Each of the Vice-county Recorders listed on *page 4* has undertaken a major commitment, usually extending over many years, to record in their vice-county and to synthesize the records of others. Behind them lie an untold number of individual recorders. The fact that volunteer recorders have achieved a coverage for this *Atlas* that is more complete than that of its predecessors demonstrates the healthy state of the botanical community in Britain and Ireland, disproving the oft-repeated claims that naturalists are themselves a threatened species. Although the editors of *Plant Atlas 2020* are professionals, work on such a major project inevitably expands beyond the confines of the working day, dominating not only waking hours but sometimes sleeping hours as well. A special tribute is due to Pete Stroh, who has undertaken the role of planning the publication, bringing together its individual components and seeing the book through to completion.
The project is the latest result of a collaboration between the BSBI and the Biological Records Centre (BRC) of the UK Centre for Ecology & Hydrology (UKCEH), a remarkable partnership which was initiated when the records from the 1962 *Atlas* were transferred to the BRC in 1964 and which has endured to the present day. Users of *Plant Atlas 2020* owe an enormous debt to all who have worked so hard to compile it, and thus to ensure that the distribution of our vascular plants (and charophytes) in the early 21st century has been so well documented.



Chris D. Preston David A. Pearman Trevor D. Dines

About the editors

Dr Peter Stroh is a plant ecologist with a particular interest in restoration ecology, and has been involved in various aspects of BSBI's research and monitoring programme since 2012. He previously worked at the Centre for Ecology & Hydrology (CEH) Monks Wood, Anglia Ruskin University, Natural England and the Scottish Wildlife Trust.

Dr Kevin Walker is a plant ecologist formerly based at CEH Monks Wood where he undertook research into historical and ecological changes in the British flora, agroecology, species autecology, and the management and restoration of grassland and heathland, before moving to BSBI in 2007 to become its Head of Science.

Dr Oliver Pescott has worked as a plant ecologist and data analyst at the Biological Records Centre, UKCEH Wallingford, since 2013. His research interests include understanding biases in large datasets, invasive species and ecological monitoring.

Tom Humphrey designed and maintains the BSBI's central database of botanical records. His work is focused on developing innovative tools to enhance the access to and use of biodiversity data.

Dr Richard Burkmar is a web developer at UKCEH Lancaster with a particular interest in visualizing biological records and environmental data.

The Botanical Society of Britain and Ireland (BSBI) is the leading charitable voluntary organization promoting the study, understanding, conservation and enjoyment of wild plants in Britain and Ireland. Tracing our origins back to 1836, we are one of the world's largest contributors of biological records, with our database currently holding over 50 million records, many collected by volunteer members of the Society. We provide opportunities for involvement through a range of participation projects, surveys, events, training opportunities and the production of books and other resources. We aim to build a diverse community of skilled and enthused botanists, provide data and science to help address biodiversity loss and climate change, and disseminate information to drive a passion for plants.

The Biological Records Centre (BRC), part of the UK Centre for Ecology & Hydrology (UKCEH), provides a focus for the collation, management, dissemination and interpretation of biological records. Most records are collected by volunteer recording schemes and societies, which are integral to the work of BRC. Our innovative use of technology helps to harness the enthusiasm and knowledge of naturalists, enables them to collate and analyze their records, and helps the recording community to publish atlases, data and other online resources, thus providing essential information that informs research requirements, policy development and the conservation of our heritage of wildlife.

Acknowledgements

Plant Atlas 2020 presents the results of field surveying by thousands of volunteer botanists who covered the entirety of Britain and Ireland from 2000 to 2019, submitting over 30 million records in the process and building on past atlas surveys undertaken in the mid and late 20th century. We extend our sincere thanks to everyone who has taken part in the survey. Whilst it is unfortunately not possible to list comprehensively all of those who were involved, we include on *page 4* the names of BSBI Vice-county Recorders (VCRs) who were in post between 2000 and 2019 in recognition of their time, effort and dedication with assisting in the completion of the most detailed survey of our flora ever undertaken.

Coverage in Ireland was enhanced immeasurably by the efforts of Paul Green, who not only oversaw recording in two vice-counties but also worked tirelessly across the length and breadth of the island and led numerous field meetings and workshops. In Scotland, Andy Amphlett played a key role as a VCR and also created coverage maps which were periodically supplied to all VCRs, identifying progress and highlighting areas that were under-recorded relative to past surveys. Both Andy and Paul also assisted in the validation of a subset of taxa that were largely restricted in distribution to their respective countries, and helped many recorders to navigate the BSBI database for the purpose of validating records.

We sincerely thank all BSBI taxon referees in post during the atlas project, who assisted BSBI members in the determination of many of the more challenging groups of taxa mapped here.

We thank Alex Lockton for encouraging recorders to update records for their own vice-counties during the early years of this project, and Bob Ellis for providing support on MapMate and other recording issues.

We also thank the BSBI country officers who were instrumental in organizing field meetings and plant identification workshops in their respective areas, namely Maria Long, Sarah Pierce and Paul Green in Ireland, Polly Spencer-Vellacott, Barbara Brown and Paul Green in Wales, and Jim McIntosh in Scotland.

Much of the text that accompanies the distribution maps was written by expert volunteers, each of whom is named as an author under the relevant taxon mapped. Thanks are due to all, but most especially to David Pearman, without whom the task would have been considerably more onerous. For the alien taxa mapped, we were able to update many of the first dates of discovery in the wild originally published in Preston *et al.* (2002a) thanks to the generous provision of ongoing research by Chris Preston and David Pearman. David also provided an updated list of the most recent maximum and minimum altitudinal records, whilst Chris provided valuable comments on a draft of Chapter 6. Rob Boyd also provided helpful comments on Chapter 6. Special mention should go to John Poland who provided the unpublished leafing months for over 1,000 taxa. The opportunity to include charophytes in this *Atlas* is due to the efforts of Nick Stewart, who led numerous workshops and field meetings, validated many thousands of records in order to provide us with a clean dataset for mapping, and also wrote the text that accompanies each map.

At Princeton University Press (PUP) we thank Robert Kirk and the design team of Rob Still, Andy Swash and Martin Jones, who throughout the process of steering this book to publication have been endlessly helpful, hardworking and professional. David Roy at the Biological Records Centre (BRC) was instrumental in organizing and funding website design and data analysis. We are indebted to Chris Preston, Alan Leslie, Chris Cheffings and David Barden for proofreading the text within these pages; any errors that remain are entirely the responsibility of the editors.

The BSBI is grateful for the generosity demonstrated by BSBI members in supporting the *Plant Atlas* project through their many financial donations. The Wild Flower Society and The Finnis Scott Foundation funded field surveying in areas of Scotland and Ireland identified as being under-recorded leading up to the final four years of the project. Natural Resources Wales, NatureScot and the National Parks & Wildlife Service supported the work of BSBI Country Officers, and Natural England provided funds for the completion of record validation by BSBI science staff. The BRC, organized and funded by the UK Centre for Ecology & Hydrology (UKCEH) and the Joint Nature Conservation Committee (JNCC), was pivotal in the analyses of the *Atlas* dataset and the design and production of the associated website. This work was supported through Natural Environment Research Council award number NE/R016429/1 as part of the UK-SCAPE programme delivering National Capability. Assistance towards publication costs was provided by the Royal Society of Wildlife Trusts, the Wildlife Trust for Bedfordshire, Cambridgeshire and Northamptonshire, the Centre for Environmental Data and Recording (National Museums Northern Ireland), the National Parks & Wildlife Service, the British Pteridological Society, and the Naturesave Trust. Grant support for the project was received from the Chapman Charitable Trust, the D'Oyly Carte Charitable Trust, the Lennox Hannay Charitable Trust, the Lindeth Charitable Trust, the Nineveh Trust the Nora Smith Charitable Settlement, the Seven Pillars of Wisdom Trust and the Thriplow Charitable Trust.

Vice-county Recorders (2000–19)

Britain

1a **West Cornwall** (Colin French)
1b **Isles of Scilly** (Rosemary Parslow)
2 **East Cornwall** (Ian Bennallick, Rose Murphy)
3 **South Devon** (Roger Smith)
4 **North Devon** (Bob Hodgson, Jeremy Ison)
5 **South Somerset** (Stephen Parker, Simon Leach, Paul Green)
6 **North Somerset** (Helena Crouch, Liz McDonnell, Rob Randall, Ian Green)
7 **North Wiltshire** (Sharon Pilkington, Richard Aisbitt)
8 **South Wiltshire** (Sharon Pilkington, Richard Aisbitt)
9 **Dorset** (Robin Walls, David Pearman, Bryan Edwards)
10 **Isle of Wight** (Colin Pope)
11 **South Hampshire** (Martin Rand, Pete Selby)
12 **North Hampshire** (Tony Mundell)
13 **West Sussex** (Mike Shaw, Matthew Berry, Alan Knapp, Mary Briggs)
14 **East Sussex** (Paul Harmes, Arthur Hoare)
15 **East Kent** (Geoffrey Kitchener, Sue Buckingham, Eric Philp)
16 **West Kent** (Geoffrey Kitchener, Eric Philp)
17 **Surrey** (Ann Sankey, Barry Phillips)
18 **South Essex** (Ken Adams)
19 **North Essex** (Ken Adams)
20 **Hertfordshire** (Trevor James, Ian Denholm, Alla Mashanova)
21 **Middlesex** (Mark Spencer, Rodney Burton)
22 **Berkshire** (Mick Crawley)
23 **Oxfordshire** (David Morris, Sue Helm, John Killick)
24 **Buckinghamshire** (Roy Maycock, Andy McVeigh)
25 **East Suffolk** (Martin Sanford, Francis Simpson)
26 **West Suffolk** (Martin Sanford, Francis Simpson)
27 **East Norfolk** (Bob Ellis)
28 **West Norfolk** (Richard Carter, Sarah Harmer, Kenneth Beckett, Gillian Beckett)
29 **Cambridgeshire** (Alan Leslie, Jonathan Shanklin, Nick Millar, Gigi Crompton)
30 **Bedfordshire** (Chris Boon, John Wakely)
31 **Huntingdonshire** (Terry Wells, David Broughton)
32 **Northamptonshire** (Rob Wilson, Gill Gent, Alyson Freeman, Brian Laney)
33 **East Gloucestershire** (Chris Dixon, Mark Kitchen, Clare Kitchen)
34 **West Gloucestershire** (Clive Lovatt, Mark Kitchen, Clare Kitchen)
35 **Monmouthshire** (Stephanie Tyler, Elsa Wood ,Trevor Evans)
36 **Herefordshire** (Stuart Hedley, Peter Garner, Heather Davies, Steph Thomson)
37 **Worcestershire** (John Day, Paul Reade, Bert Reid)
38 **Warwickshire** (John Walton, Monica Walton, James Partridge, Pam Copson)
39 **Staffordshire** (John Hawksford, Ian Hopkins)
40 **Shropshire** (Sarah Whild, Alex Lockton)
41 **Glamorganshire (West)** (Barry Stewart, Quentin Kay)
41 **Glamorganshire (East)** (Julian Woodman, David Bardon, Karen Wilkinson)
42 **Breconshire** (Mike Porter, John Crellin)
43 **Radnorshire** (Liz Dean, Sue Spencer, David Humphreys)
44 **Carmarthenshire** (Richard Pryce, Kath Pryce)
45 **Pembrokeshire** (Stephen Evans)
46 **Cardiganshire** (Steve Chambers, Arthur Chater)
47 **Montgomeryshire** (Kate Thorne, Gill Foulkes, Mark Duffell)
48 **Merionethshire** (Jo Clark, Sarah Stille, Peter Benoit)
49 **Caernarvonshire** (Wendy McCarthy, Geoff Battershall)
50 **Denbighshire** (Delyth Williams, Jean Green)
51 **Flintshire** (Emily Meilleur, Gail Quarterly-Bishop, Goronwy Wynne)
52 **Anglesey** (Ian Bonner, Nigel Brown)
53 **South Lincolnshire** (Sarah Lambert, Malcolm Pool, Irene Weston)
54 **North Lincolnshire** (Paul Kirby, Irene Weston)
55 **Leicestershire** (Geoffrey Hall, Russell Parry, Steve Woodward, Michael Jeeves)
56 **Nottinghamshire** (David Wood, Mark Woods)
57 **Derbyshire** (Alan Willmot)
58 **Cheshire** (Graeme Kay)
59 **South Lancashire** (David Earl)
60 **West Lancashire** (David Earl, Eric Greenwood)
61 **South-east Yorkshire** (Rohan Lewis, Richard Middleton, Peter Cook)
62 **North-east Yorkshire** (David Barlow, Vincent Jones, Jill Magee, Tom Medd)
63 **South-west Yorkshire** (Kay McDowell, Louise Hill, Geoffrey Wilmore)
64 **Mid-west Yorkshire** (David Broughton, Phyl Abbott)
65 **North-west Yorkshire** (Linda Robinson, Kevin Walker, Deborah Millward)
66 **County Durham** (Keith Robson, John Durkin)
67 **South Northumberland** (John Richards, Megs Rogers, Quentin Groom, George Swan)
68 **North Northumberland** (Chris Metherell, George Swan, Quentin Groom)
69 **Westmorland** (Mike Porter, Jeremy Roberts, Phill Brown, Geoffrey Halliday)
70 **Cumberland** (Mike Porter, Jeremy Roberts, Phill Brown, Geoffrey Halliday)
71 **Isle of Man** (Philippa Tomlinson, Linda Moore, Larch Garrad)
72 **Dumfriesshire** (Chris Miles)
73 **Kirkcudbrightshire** (David Hawker)
74 **Wigtownshire** (Alan Silverside)
75 **Ayrshire** (David Lang, Gill Smart, Carol Crawford, Alan Stirling)
76 **Renfrewshire** (Keith Watson)
77 **Lanarkshire** (Michael Philip, Peter Wiggins, Peter Macpherson)
78 **Peeblesshire** (Luke Gaskell, Kathy Velander, David McCosh)
79 **Selkirkshire** (Rod Corner, Jeff Waddell)
80 **Roxburghshire** (Rod Corner, Jeff Waddell)
81 **Berwickshire** (Michael Braithwaite)
82 **East Lothian** (Helen Jackson, Marion Moir)
83 **Midlothian** (Barbara Sumner, Douglas McKean)
84 **West Lothian** (Jay Mackinnon, Jackie Muscott)
85 **Fifeshire** (Sandy Edwards, George Ballantyne)
86 **Stirlingshire** (Philip Sansum, Matt Harding, Edna Stewart, Ruth McGuire)
87 **West Perthshire** (Liz Lavery, Jane Jones, Neil Taylor, Paul Stanley)
88 **Mid Perthshire** (Alistair Godfrey, Jim McIntosh)
89 **East Perthshire** (Martin Robinson, Ros Smith)
90 **Angus** (Robin Payne, Theo Loizou, Mark Tulley, Barbara Hogarth)
91 **Kincardineshire** (David Welch, David Elston)
92 **South Aberdeenshire** (Ian Francis, Ruth Mitchell, Kathy Fallowfield)
93 **North Aberdeenshire** (David Welch, David Elston)
94 **Banffshire** (Andy Amphlett)
95 **Moray** (Ian Green)
96 **East Inverness-shire** (Adam Fraser, Sarah Smyth, Andy Amphlett, Margaret Barron)
97 **West Inverness-shire** (Ian Strachan, Ian Bonner)
98 **Main Argyll** (Gordon Rothero, Carl Farmer)
99 **Dunbartonshire** (Pam Murdoch, John Holland, Alison Rutherford)
100 **Clyde Isles** (Angus Hannah)
101 **Kintyre** (David Batty, Pat Batty)
102 **South Ebudes** (Simon Smart, Malcolm Olgilvie, Richard Gulliver)
103 **Mid Ebudes** (Lynne Farrell)
104 **North Ebudes** (Stephen Bungard, Catriona Murray)
105 **West Ross** (Duncan Donald, James Fenton)
106 **East Ross** (Brian Ballinger, Barbara Ballinger, Peter Wortham)
107 **East Sutherland** (Mick Crawley, Morven Murray)
108 **West Sutherland** (Ian Evans, Pat Evans)
109 **Caithness** (Francis Higgins, Margaret Higgins, Ken Butler, Helen Crossley)
110 **Outer Hebrides** (Paul Smith, Richard Pankhurst)
111 **Orkney** (John Crossley, Elaine Bullard)
112 **Shetland** (Walter Scott, Paul Harvey)
113j **Jersey** (Anne Haden, Margaret Long, Joan Banks)
113a **Alderney** (Brian Bonnard)
113g **Guernsey** (Helen Litchfield, Jane Gilmour, Charles David)
113s **Sark** (Susan Synott, Roger Veall)

Ireland

H1 **South Kerry** (Caroline Mac Daeid, Rory Hodd)
H2 **North Kerry** (Caroline Mac Daeid, Rory Hodd, Peter Wyse Jackson, Mike Wyse Jackson)
H3 **West Cork** (Clare Heardman, Maura Scannell, Tony O'Mahony)
H4 **Mid Cork** (John Wallace, Maura Scannell, Tony O'Mahony)
H5 **East Cork** (Edwina Cole, Finbarr Wallace, Tony O'Mahony, Maura Scannell)
H6 **Co. Waterford** (Paul Green)
H7 **South Tipperary** (Rosaleen Fitzgerald)
H8 **Co. Limerick** (Sylvia Reynolds)
H9 **Co. Clare** (Sharon Parr, Stephen Ward, Fiona Devery)
H10 **North Tipperary** (David Nash)
H11 **Co. Kilkenny** (Roger Goodwillie)
H12 **Co. Wexford** (Paul Green, Paula O'Meara, Ro FitzGerald)
H13 **Co. Carlow** (Lisa Dowling, Mark McCorry, Fiona McGowan, Betsy Hickey, Sharon Parr)
H14 **Co. Laois** (Mark McCorry, Fiona McGowan, Evelyn Moorkens)
H15 **South-east Galway** (Micheline Skeffington)
H16 **West Galway** (John Conaghan)
H17 **North-east Galway** (Chris Peppiatt, Cilian Roden)
H18 **Offaly** (Fiona Devery, Aideen Austin)
H19 **Co. Kildare** (Declan Doogue)
H20 **Co. Wicklow** (Catríona Brady, Pauline Hodson)
H21 **Co. Dublin** (David Nash)
H22 **Meath** (Margaret Norton)
H23 **West Meath** (Con Breen)
H24 **Co. Longford** (Shaun Howard, Rosemary Goode)
H25 **Co. Roscommon** (John Earley)
H26 **East Mayo** (Gerry Sharkey, Eamonn Delaney)
H27 **West Mayo** (Gerry Sharkey)
H28 **Co. Sligo** (Don Cotton, Michael Archer, Sharon Parr)
H29 **Co. Leitrim** (Don Cotton, Michael Archer, Eamon Gaughan, Aoife Delaney)
H30 **Co. Cavan** (Robert Northridge, Jonathan Shackleton, Paddy Reilly)
H31 **Co. Louth** (Donal Synnott, Melinda Lyons, Cliona Byrne, Kate Harrington)
H32 **Co. Monaghan** (Alexis FitzGerald, Alan Hill, Pat Lenihan)
H33 **Fermanagh** (Ralph Forbes, Robert Northridge)
H34 **East Donegal** (Oisín Duffy, Mairéad Crawford, Pauline Hodson)
H35 **West Donegal** (Ralph Shepherd, David McNeill)
H36 **Tyrone** (Ian McNeill)
H37 **Co. Armagh** (John Faulkner)
H38 **Co. Down** (Graham Day)
H39 **Co. Antrim** (David McNeill, Wesley Semple, Neville McKee, Stan Beesley)
H40 **Co. Londonderry** (Dave Riley)

Chapter 1: Introduction

The first *Atlas of the British Flora* (Perring & Walters, 1962) pioneered the use of grid-based recording, and since its publication this approach has been widely adopted for mapping plants and animals, especially birds, at both national and regional scales, particularly in Europe and North America (Preston, 2013). Its successor, the *New Atlas of the British and Irish flora* (Preston *et al*., 2002a), was equally ground-breaking, providing alongside each map information and expert commentary on status, altitude, history, ecology and trends in distribution using a novel method to measure relative change since the first *Atlas* recording period (Telfer *et al*., 2002). The results of these analyses were far-reaching, and in particular highlighted the dramatic loss of species associated with arable land and open habitats on infertile soils (*e.g.* species-rich grasslands, bogs, heaths), as well as increases in the ranges of introduced species, generalists associated with nutrient-enriched soils, and southerly distributed species (Preston *et al*., 2002b).

The *New Atlas* dataset has been used extensively by scientists to address a range of issues affecting ecosystems and wildlife populations, most notably the atmospheric deposition of nutrients, especially nitrogen (McClean *et al*., 2011), climate change (Hill & Preston, 2015; Suggitt *et al*., 2018), declines in pollinators (Biesmeijer *et al*., 2006) and the spread of non-native species (Seebens *et al*., 2016). The dataset has also been used by plant conservationists to produce lists of threatened (IUCN Red Data) species for Great Britain (Cheffings & Farrell, 2005), Wales (Dines, 2008), England (Stroh *et al*., 2014) and Ireland (Wyse-Jackson *et al*., 2017), and to estimate the overall status of Britain's wildlife (Burns *et al.,* 2016). Its legacy has been profound, improving our knowledge of the British and Irish flora and how it has changed, and also influencing the ways in which it has been managed, protected and restored.

Twenty years on, the need for a new atlas seems even more urgent. All ten of the UK's hottest years have occurred since 2002. Whereas air and water quality have improved since the late 20th century, our soils appear to be the most degraded they have ever been due to prolonged intensive management and the unprecedented use of fertilizers, pesticides and other chemicals for agriculture (Environment Agency, 2019). The number of introduced pathogens is increasing and those that are already here continue to devastate some native tree populations, most notably Ash Dieback Disease first reported in the UK in 2012 (Mitchell *et al*., 2014). Since 2000, housing, road and rail developments have reached levels not seen since the mid-20th century, often to the detriment of habitats that are important for wildlife and human well-being. On a more positive note, public spending on conservation and the environment has increased steadily, as has membership of conservation charities and awareness of environmental issues. Mass participation in citizen science schemes has demonstrated their effectiveness and value in providing the evidence required by scientists and land managers, and has influenced government thinking and spending on environmental issues (Pescott *et al*., 2015).

By 2010, it was clear that a comprehensive update of the hectad (10 × 10 km) scale maps for the entire British and Irish flora would be possible, following the success of the *Atlas Updating Project* (AUP) that began a few years after the publication of the *New Atlas* (Pearman *et al.,* 2005). The BSBI therefore committed to producing a third atlas based on records collected between 2000 and 2019. *Plant Atlas 2020* summarizes the results of this endeavour. From the outset, it was clear that this publication would differ from its precursors in a number of important respects. First, it would be possible to publish online, free to access by anyone with a computer and internet connection. The possibility of a physical book of maps only became a practical reality later following the interest of funders and support from Princeton University Press. Second, virtually all the records used to produce the maps in this *Atlas* could be submitted to the BSBI database electronically by BSBI recorders, mainly via the computer package MapMate. This proved to be a highly efficient means of collating, checking and editing records and maps centrally. Most importantly, however, it meant that the maps were derived from the underlying records themselves, rather than summary lists for hectads. Whilst this substantially increased the volume of data to validate, it also provided a wealth of extra information on which decisions could be based, especially the likelihood that a record was correct, and in some cases its local status, habitat, and abundance.

Arrangement of the book and the *Online Plant Atlas*

Chapters 2 and 3 provide, respectively, the historical background to the current project, the aims and scope of *Plant Atlas 2020* and the methods used to achieve adequate coverage and to determine status at the hectad scale. The criteria used to select the species mapped, and preparation of the species maps and accounts, are described in Chapter 4. The results of the project are summarized in Chapters 5 and 6, including the coverage achieved by the survey and an analysis of the changes in distribution since the first *Atlas* (long-term trends) and the *New Atlas* (short-term trends). The detailed results for the 2,863 taxa included in this book (Table 1.1), consisting of distribution maps with accompanying text and information on trends, phenology, apparency, and altitudes, are presented in Chapter 7. All the material in Chapter 7 is also available to view in the *Plant Atlas 2020* website (plantatlas2020.org), together with maps and accounts for an additional 634 taxa. The online *Atlas* also includes interactive maps, photographs for most taxa, and information on country-level trends and status, national rarity and conservation designations.

Table 1.1. A summary of the taxa mapped in this book and the online *Atlas* site. For the criteria used for the selection of species to be mapped, and definitions of each of the status categories, see Chapter 3. Aggregates are genera or aggregates of similar species or hybrids used for recording purposes when identification of the component species or segregates is particularly difficult. In counting the totals, an aggregate of six species is counted as one aggregate and six species, and a species with two subspecies as one species plus two subspecies. The two generations of *Trichomanes speciosum* (gametophyte and sporophyte) are mapped separately but are only counted as a single species in the total presented here. Hybrids have been mapped without status.

	Species		Subspecies		Aggregates		Hybrids		Total	
	Book	**Web**	**Book**	**Web**	**Book**	**Web**	**Book**	**Web**	**Book**	**Web**
Native	1,388	1,388	129	129	37	37	—	—	1,554	1,554
Native or alien	45	45	0	0	0	0	—	—	45	45
Archaeophyte	152	152	6	6	3	3	—	—	161	161
Neophyte	820	1,435	22	37	14	15	—	—	856	1,487
Spontaneous hybrid	133	134	1	2	3	3	138	139	138	139
Cultivated hybrid	109	109	0	0	0	0	109	109	109	109
Total	2,647	3,263	158	174	56	58	246	248	2,863	3,495

Chapter 2: Recording the British and Irish flora 1962–2019

A comprehensive account of recording for the 1962 *Atlas* and the *New Atlas* is given in Preston *et al.* (2002a), and so here we simply provide a summary of the surveys, projects and recording developments that have had a major influence on our understanding of plant distribution in Britain and Ireland over the past 60 years.

National and local scale recording projects

As noted above, the 1962 *Atlas* was the first to utilize grid-based mapping, made possible by the publication of the Ordnance Survey National Grid that appeared on the sixth edition Ordnance Survey maps published for Britain in 1945–47 and extended to Ireland by Webb by 1955. The potential for using the 10 × 10 km squares (hectads) of this grid to produce national distribution maps was realized almost immediately by the BSBI, and by 1954 it had been adopted as the basis for mapping the entire native flora of Britain and Ireland, as well as the most frequent non-natives (Walters, 1954). This was achieved over six field seasons and published as the *Atlas of the British Flora* in 1962, with dot-distribution maps for all 'generally accepted native British species (excluding critical segregates) and most well-established introductions' (Perring & Walters, 1962). Each dot indicated presence within a hectad, and maps for species in 100 or fewer vice-counties distinguished recent records (made from 1930 onwards) from older records. Species known from 100 or more vice-counties were mapped as 'all records', with no distinction between pre- and post-1930 records. Microspecies in the critical genera *Alchemilla*, *Euphrasia*, *Hieracium* (including *Pilosella*), *Limonium*, *Rosa*, *Rubus*, *Sorbus* and *Taraxacum* were excluded from the *Atlas*, as were other 'difficult' species and most hybrids and infraspecific taxa. The majority of these were mapped subsequently in the *Critical Supplement to the Atlas of the British Flora* (Perring & Sell, 1968), with occurrences based on herbarium specimens, literature references and field records determined by experts. It proved possible to provide a full treatment of all critical genera except for *Taraxacum*, where three aggregates were mapped, and *Rosa*, which was excluded entirely.

One of the enduring legacies of the 1962 *Atlas* was the stimulus that it provided to local plant recording and, most notably, the resultant increase in the publication of county Floras. The experience of grid-based recording combined with post-war prosperity, and the increased leisure time and car use that this allowed, had the effect of boosting the number of recorders able to take part. As a result, the number of county Floras published rose from 1·2 and 1·6 per year in the 1950s and 1960s, to 3·4 and 4·4 per year in the 1970s and 1980s (Fig. 2.1). Remarkably, these rates have been maintained to the present day.

Not surprisingly, many counties began to employ grid-based recording following the 1962 *Atlas*. The first, published for Cambridgeshire in 1964, was at 10 km square scale (Perring *et al.*, 1964) but mapping at 2 × 2 km square precision (tetrad) subsequently became the norm. E.S. Edees was the first botanist to start recording at this scale in 1956, although J.G. Dony's *Flora of Hertfordshire* (1967) was the first to reach publication, with Edees' *Flora of Staffordshire* (1972) appearing five years later. Since then, around 60 tetrad Floras have been published, mainly in lowland counties where there are usually sufficient botanists to attempt coverage at such a fine scale. Notable exceptions include Floras for Assynt (Evans *et al.*, 2002), Rum (Pearman *et al.*, 2004) and Cardiganshire (Chater, 2010), all of which include large areas of challenging upland terrain with few resident botanists. Despite the greater effort involved, 1 × 1 km grid squares (monads) have become the preferred scale of recording in recent years; 16 county Floras have been published at this scale since the first monad Flora appeared in 1978 – W.H. Jowsey's (1978) *Botanical Atlas of the Harrogate District*. By far the most ambitious, however, has been the recent *Flora of Cornwall*, for which Cornish botanists surveyed an astonishing 3,800 monads between 2000 and 2019 (French, 2020).

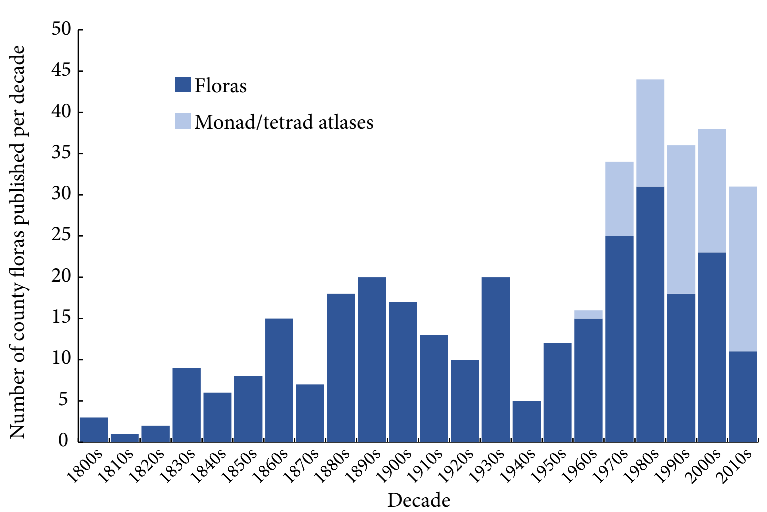


Figure 2.1. The number of county Floras published for British and Irish vice-counties in each decade from 1800 to 2019. The numbers of atlases produced at 1 × 1 km (monad) and 2 × 2 km (tetrad) scale are also displayed. These figures are based on an unpublished compilation of 376 county Floras including complete Floras, supplements and checklists covering single or multiple vice-counties, and also local Floras covering substantial parts of vice-counties, whole islands and major cities.

During the 1980s, it became increasingly apparent that the maps in the 1962 *Atlas* (at that time in its third edition) were out of date and a new atlas survey was needed. Fearing that there were insufficient volunteers to complete such a mammoth undertaking, the BSBI decided instead to resurvey a sample of hectads (1 square in 9 or 11% of the total) in Britain and Ireland, recording in detail the same three tetrads in each hectad—the 'A', 'J' and 'W' tetrads using the 'DINTY' system for naming tetrads within a hectad (Fig. 2.2). Fieldwork for the *BSBI Monitoring Scheme* took place in 1987–88, with the results suggesting that many native species had declined since the 1960s, thereby confirming the need for a more comprehensive atlas survey (Rich & Woodruff, 1990). This recommendation was accepted by the BSBI in 1992 but fieldwork did not commence until funding was secured for the project from the Department for Environment, Food and Rural Affairs in 1995. Following the appointment of a full-time coordinator, surveying was undertaken from 1996–99, although the date-class for mapping was extended back to 1987 so that records collected for the *BSBI Monitoring Scheme* could be included (Preston *et al.*, 2002a). Around five million records were submitted for the project and the excellent taxonomic and geographic coverage achieved meant that 2,412 taxa were mapped at hectad scale in the book, with an additional 942 neophytes included on the CD-ROM that accompanied it. The maps revealed dramatic declines in the range of many native taxa associated with species-rich habitats on infertile soils, and native and archaeophyte plants associated with arable land. In comparison, the range of many non-natives and natives associated with nutrient-enriched soils had increased, as had a handful of coastal halophytes that had spread inland along salt-treated road verges since the 1970s.

Although there was no official BSBI recording project immediately following the completion of fieldwork for the *New Atlas*, recorders were encouraged to resurvey hectads within their own vice-counties to update the maps produced, which in turn led to several new county Floras. In addition, the *BSBI Monitoring Scheme* tetrads were resurveyed in Britain (but not in Ireland) from 2002 to 2004 as part of the *BSBI Local Change* project. This was the first BSBI project where most recorders submitted records electronically, and it was also instrumental in showing recorders how more standardized approaches could be used to monitor change more effectively (Braithwaite *et al.*, 2006), as had previously been exemplified by Rich *et al.*'s (1996) innovative botanical survey of Ashdown Forest. The lessons learned are well summarized in Rich & Woodruff (1992) and Rich & Smith (1996) and heavily influenced the design of the *National Plant Monitoring Scheme* that was launched in 2015 following several years of development and piloting by a partnership of organizations, including the BSBI, Plantlife, JNCC and UKCEH (Pescott *et al.*, 2015, 2019a).

Rare, scarce and threatened species

The maps in the 1962 *Atlas* showed, for the first time, how rare some species were at a national scale, with the number of hectads providing an objective measure of range size. From 1968 onwards, information on the rarest species, represented in 15 or fewer hectads, was updated through targeted surveys and by collating records from VCRs. This led to the production of a *Red Data Book* for Britain (Perring & Farrell, 1977, 1983) and revisions to the distribution maps for rarer species produced for the second and third editions of the *Atlas of the British Flora* (Perring & Walters, 1976, 1982). A complete revision of the *Red Data Book*, including hectad maps, was published in 1999 (Wigginton, 1999). Work on nationally scarce species, represented in 16–100 hectads, was carried out from 1990 to 1992, with recorders asked to provide details of records they held and to check as many populations as possible (Stewart *et al.*, 1994). In Ireland, rare and scarce species are those represented in ten or fewer hectads and 11–25 hectads respectively, and lists have been produced by Curtis & McGough (1988) and Neff (2000). Following the publication of the *New Atlas*, lists for both rare and scarce species were revised for Britain using hectad counts for the period 1987–99 (Cheffings & Farrell, 2004), and this process has been repeated for *Plant Atlas 2020* using records for the period 2000–19 for Britain and Ireland separately.

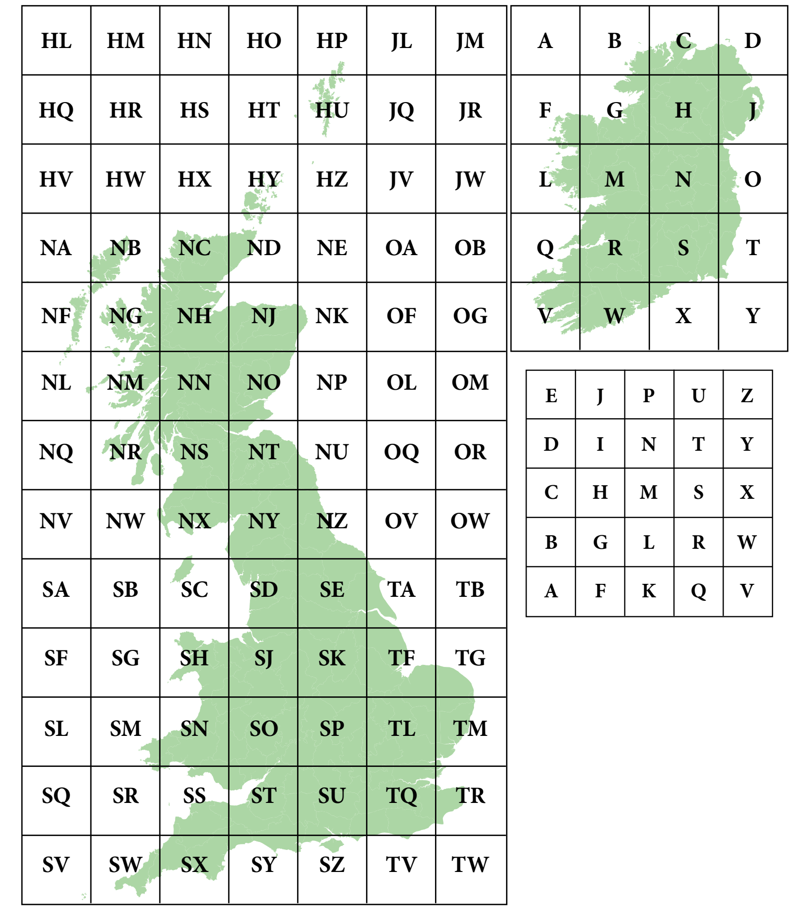


Figure 2.2. Map of Britain and Ireland showing the conventional naming of the 100 × 100 km grid cells of the British and Irish National Grids and the 2 × 2 km grid cells within 10 × 10 km grid cells using the 'DINTY' scheme for naming tetrads. When recording at tetrad scale these letters are added to the grid reference for the hectad, for example SE35U.

In Scotland, populations of the rarest arctic-alpine species present in Sites of Special Scientific Interest (SSSI) were surveyed during successive cycles of 'Common Standards Monitoring', with baseline surveys undertaken in the 1990s (Sydes, 2008). Since the early 2000s, many of these populations have been resurveyed, often by BSBI volunteers with funding from Scottish Natural Heritage (now NatureScot), thereby ensuring that high-quality records for many under-recorded taxa have been available to BSBI recorders and have been included in this *Atlas*.

The concept of compiling lists of sites for the rarest species in a vice-county appears to have emerged from discussions between D.G. Jones and A.O. Chater in 1978. They envisaged a register of populations of national and local rarities that would be useful in assessing the local significance of sites for conservation and survey (Chater, 1990). Since then, many County Rare Plant Registers have been published, most notably in Wales, which now has complete coverage at the vice-county level. Often based on targeted surveys, these registers have improved substantially the conservation and protection of many species, especially regional rarities that were often overlooked or ignored in the past because they were not included on national listings of rare or scarce species.

One of the key findings of the *New Atlas* was to highlight declines of species still present in more than 100 hectads, and therefore not classed as either nationally rare or scarce. From 2008–13 the BSBI undertook a sample survey of 50 of these 'widespread decliners' as part of its *Threatened Plants Project*. The main aim of this project was to revisit a random sample of historic locations for these species and, where still present, collect information on their population sizes, habitats, management and threats using a standardized methodology (Walker *et al.*, 2017). The findings showed that upland species had fared better than those in the lowlands since the 1970s, with lowland losses mainly due to neglect or a lack of appropriate management over several years and the subsequent spread of more competitive species. Many of the worst-affected species had life-histories poorly adapted to withstand prolonged periods with no grazing or disturbance due to their inability to disperse or recover from seed banks and/or spread by vegetative means. An equivalent survey was undertaken in Ireland, focusing on eight threatened species (Long *et al.*, 2017).

Since the early 1990s, many national rarities, too numerous to mention individually here, have been the subject of targeted surveys to assess their current status, often with recommendations then provided to help to plan or monitor conservation interventions. Many of these surveys have been undertaken by the staff and volunteers of conservation charities such as Plantlife, the Freshwater Habitats Trust and the Species Recovery Trust under the guise of various national partnership projects such as 'Back from the Brink', run by Natural England and the Partnership for Species Conservation. In England, much local survey work on rarities has also been undertaken by active county rare plant groups, such as in Somerset, Oxfordshire and Norfolk, whereas in Wales and elsewhere Dr Tim Rich and co-workers have undertaken numerous surveys of endemic whitebeams. In Scotland, many montane species have been surveyed and monitored, in some cases as part of reintroduction programmes, by staff and volunteers of the Royal Botanic Garden Edinburgh and the National Trust for Scotland, especially on the Cairngorms and Ben Lawers ranges. Another important survey, run by the Nevis Landscape Partnership, brought together botanists, geologists and mountaineers to survey inaccessible areas of the north face of Ben Nevis, leading to the discovery of many nationally important populations of arctic-alpine species (Skyring, 2019). In the Republic of Ireland, many rarities have been surveyed under the auspices of the National Parks and Wildlife Service. Such surveys have greatly enhanced our understanding of the distribution, abundance and ecological requirements of our rarest species.

Other surveys

Since the 1970s, surveys of specific groups of plants have contributed to our knowledge of their distribution in our area. The distribution maps for ferns in the 1962 *Atlas* were far less complete than for other species, but this situation was much improved as a result of fieldwork for the *Atlas of Ferns of the British Isles* (Jermy *et al.*, 1978). This not only updated previously published maps but also included additional segregates, subspecies and hybrids for the first time. Subsequent work by members of the British Pteridological Society has continued to improve our understanding of the British and Irish fern flora, in particular the evolution and delineation of taxa within the *Dryopteris affinis* complex (Trewren, 2014).

Our knowledge of the distribution of aquatic plants was vastly improved by both the *SNH Scottish Loch Survey* carried out between 1984–97, the Northern Ireland lake survey from 1982 to 1994, and the updating of maps for around 200 aquatic species under the auspices of the *Aquatic Plants Project* (Preston & Crofts, 1997). BSBI handbooks were also published for charophytes (Moore, 1986), pondweeds (Preston, 1995b) and water-starworts (Lansdown, 2008). Survey work for other BSBI handbooks presented opportunities to improve our understanding of the distribution of many difficult groups included in *Plant Atlas 2020*, most notably sedges (Jermy *et al.*, 1982, 2007), eyebrights (Metherell & Rumsey, 2018), fumitories (Murphy, 2009), roses (Graham & Primavesi, 1993), grasses (Cope & Gray, 2009), whitebeams (Rich *et al.*, 2010) and violets (Porter & Foley, 2017).

Orchids have long been one of the most studied groups of plants and our understanding of their taxonomy and distribution has advanced greatly in recent decades, largely due to molecular studies (Bateman, 2022). Most notable have been reassessments of British and Irish *Epipactis* (helleborine) species (Bateman, 2020c) and *Dactylorhiza* (marsh-orchid) species (Bateman, 2011a, 2019). A recent project to survey the orchids of Ireland has also generated many new records (Curtis & Thompson, 2009), and orchid Floras have been produced for a number of counties and regions, in some cases based on comprehensive surveys of the constituent species, as for example took place in Bedfordshire (Revels *et al.*, 2015).

Hybrids

Although maps for some hybrids were included in the *Critical Supplement to the Atlas of the British Flora* (Perring & Sell, 1968), it was not until the publication of *Hybridisation and the flora of the British Isles* (Stace, 1975), and subsequently the inclusion of all known wild hybrids in Stace (1991), that they were more routinely identified and recorded by botanists in our area. The practical result was that the *New Atlas* project was able to cover all hybrids listed by Stace (1997) that were recorded in 50 or more 10 km squares. In 2005, a major new project began to update these maps, and the accounts of rare hybrid taxa published in Stace (1975), and also included all the additional hybrid taxa discovered growing in the wild since 1975 (Pearman & Preston, 2005). This ultimately led to the publication of the *Hybrid Flora of the British Isles* (Stace *et al.*, 2015) which presented detailed accounts for 909 taxa, with maps for many hybrids showing their hectad distributions superimposed over those of their parents. All the records compiled for the *Hybrid Flora* were examined critically and included many that were previously unpublished, having been sourced by the authors from grey and peer-reviewed literature, major herbaria and databases held by experts on particular genera, as well as from records submitted to the BSBI as part of routine recording.

Introduced species

One of the most striking aspects of the *New Atlas* was the number of non-native taxa mapped for the first time, as well as the increases in the 10 km range of some of those included in the 1962 *Atlas*. Whilst some non-natives did genuinely spread during the second half of the 20th century, the apparent increase for many taxa was largely due to the more widespread and systematic recording of non-natives, especially trees and shrubs planted in wild locations. The main stimulus for this evolution in recording habits was the publication of C.A. Stace's (1991) *New Flora of the British Isles* and its abridged *Field Flora* (Stace, 1999). This was the first national Flora to include all non-natives "that the plant-hunter might reasonably be able to find 'in the wild' in any one year". This greater interest and enthusiasm for recording non-native species was encapsulated in attempts to catalogue the occurrence of such taxa at the vice-county level, with summaries for our area as a whole (Clement & Foster, 1994), for Ireland (Reynolds, 2002) and for individual vice-counties (*e.g.* Wilmore, 2000). A further stimulus was provided by the growing concern since the 1980s of the negative impacts of some non-natives on native biodiversity. This ultimately led to the use of BSBI data and expertise to track and assess the scale and nature of these biological invasions at a national scale (Roy *et al.*, 2015), as well as to identify species that might become problematic in the future (Roy *et al.*, 2014). In addition, over the last decade there have been several citizen science initiatives to help record the presence of invasive species, with a view to improve their management and control, leading to an increased understanding of their spread, habitats and abundance (Groom *et al.*, 2019a).

One exception to this trend in recording aliens concerns weeds formerly associated with wool waste ('shoddy'), used as a manure to improve agricultural soils. Historically, these shoddy weeds were associated with mills that imported wool from North and South America, railway sidings where the wool or shoddy was transferred, and areas where it was spread on arable land (*e.g.* rhubarb fields in West Yorkshire, market gardens in Bedfordshire). The exotic plant species that were present as contaminants in the shoddy and germinated from this waste were recorded obsessively by a small coterie of botanists during the early to mid-20th century (Hayward & Druce, 1919; Dony, 1953; Lousley, 1961). However, due to the increased importation of cleaned (scoured) wool, the practice of using shoddy had virtually died out by the late 20th century, and the last mills producing wool waste finally closed in 2005 (Shimwell, 2006). Consequently, the recording of shoddy weeds also declined in the late 20th century as the species themselves became increasingly rare.

Chapter 3: Scope of the *Plant Atlas 2020* project

There were four main aims of the *Plant Atlas 2020* project:

- To complete a comprehensive survey of the vascular plant flora at the 10 km square scale in Britain and Ireland for the period 2000–19.
- To develop a BSBI database designed to implement efficient data flows and to act as a functioning repository for all botanical records in Britain and Ireland.
- To encourage the digitization of historic pre-2000 data sets not captured and mapped previously.
- To summarize the 21st century distribution of our native and alien flora in a published atlas, and make available this information to a wide range of organizations and individuals for the purposes of enjoyment, research and conservation.

Geographical scope, recording method and resolution of recording

The *Plant Atlas* project covered the whole of Britain and Ireland as well as the Isle of Man and the Channel Islands. For the sake of brevity, this area is referred to as 'Britain and Ireland', or 'our area', in the text of this *Atlas*. Recorders were asked to survey all 10 km grid squares (hectads) that contained any land or fresh water, and any coastal waters supporting marine vascular plants, which in our area includes only the sea-grasses (*Zostera marina* and *Z. noltei*). Recorders were asked to submit individual records at 2 km square (tetrad) or higher resolution rather than simply confirming the presence of a taxon within a given hectad as was sometimes the case in previous *Atlas* surveys (see Preston *et al.*, 2002a, page 15). Although a few counties achieved complete coverage at 1 km square (monad) or 2 km square scale from 2000 to 2019 as part of published county Flora surveys (*e.g.* Devon, Cornwall), most employed a sampling approach based on guidance issued at the start of the project (Groom *et al.*, 2011). This approach was essential in areas where most squares were remote and/or few botanists were available to help survey them. The guidance encouraged recorders to survey a minimum of three tetrads per hectad, focusing on those that were most accessible and biodiverse. However, a few VCRs used a more structured approach, selecting squares systematically or at random in order to reduce the biases introduced by self-selection, accessibility, availability of recorders and terrain (*e.g.* Groom *et al.*, 2015).

Most of the records collected for this *Atlas* were supplied electronically as species lists for monads or tetrads (Fig. 3.1). Recorders were, however, asked to provide more precise details (100 m resolution or better) for nationally rare and scarce taxa, county rarities and conservation priority taxa (*e.g.* UK Biodiversity Action Plan, Red Data Book, Schedule 8 species of the Wildlife and Countryside Act 1981), as well as for new county records and rediscoveries of taxa thought to have been lost from a vice-county. Since 2000, the availability of affordable and accurate hand-held GPS units, together with recent innovations in field recording technology such as the iRecord phone app, has resulted in a dramatic increase in the number of high precision records available for mapping purposes, as shown in Figure 3.1. This figure updates those presented in Pescott *et al.* (2019b), which display the numbers of records submitted at monad, tetrad and hectad scale by country.

Botanists were asked to record all native and non-native taxa that were found growing *in the wild* (Walker *et al.*, 2016b) which, for the purposes of this *Atlas*, referred to all locations up to and including the boundaries of private parks and gardens and sown field crops, as well as native plants naturalized within these boundaries. Crop plants were recorded only where regenerating, either as relics of cultivation ('volunteers') or where seed had been spilt, for example alongside roads or under bird feeders, or if they had arisen as a contaminant of seed, raw materials or waste products. As in the *New Atlas*, botanists were encouraged to record both native and non-native tree and shrub species wherever planted in wild locations for forestry, amenity, conservation, ornament and landscaping (*e.g.* shelterbelts, hedgerows, dune stabilization), regardless of whether they were regenerating or not. Similarly, recorders were encouraged to record native and non-native wild-flowers that had been deliberately sown in wild locations. Such seed mixes often included cornfield annuals such as *Agrostemma githago*, *Centaurea cyanus* and *Glebionis segetum* as well as recently arrived neophytes such as *Cota austriaca*. Recorders were asked to note the relevant status of occurrences where species were known or suspected to have been deliberately or accidentally introduced, although the response was very patchy and most recorders submitted records with no status assigned.

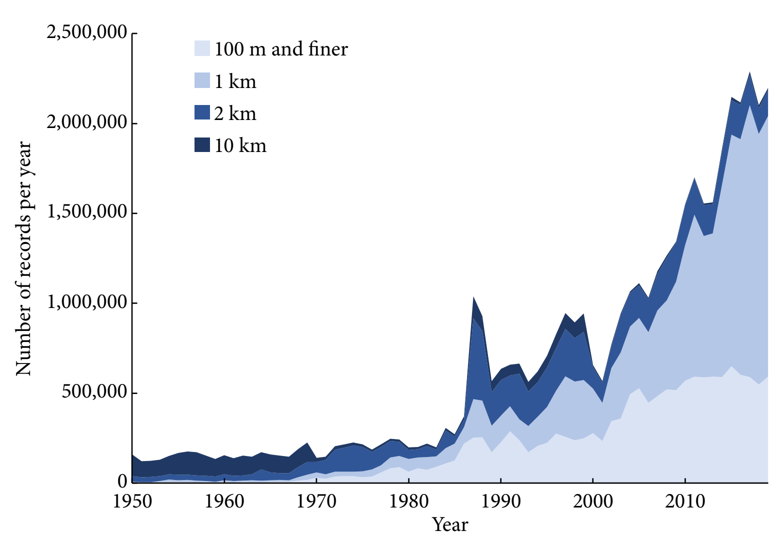


Figure 3.1. The resolution of records for vascular plants and charophytes held in the BSBI central database for the years 1950–2019. The 100 m records combine records collected at the 100 m, 10 m and 1 m resolutions. Records attributed to date ranges rather than individual years have been included by averaging numbers across years within BSBI date-classes (1950–69, 1970–86, 1987–99, 2000–19).

Taxonomic scope

Plant Atlas 2020 follows previous *Atlases* in covering all terrestrial and aquatic vascular plants comprising pteridophytes (clubmosses, quillworts, horsetails, ferns), and flowering plants (gymnosperms, angiosperms). We also include, for the first time, charophytes (stoneworts), multicellular green algae and the only non-vascular plants included in the remit of the BSBI.

The list of vascular plant taxa covered by the project was based on the species and subspecies treated *in full* in the third edition of the *New Flora of the British Isles* (Stace, 2010) (*i.e.* included in the main keys and provided with a numbered entry). Taxa that were mentioned in the text but not included within the formal numbering system were excluded.

As in the *New Atlas*, the aim of *Plant Atlas 2020* was to collect data on the occurrence in the wild of the following taxa:

- All native vascular plant species, with the exception of the numerous microspecies in the large genera *Hieracium* (hawkweeds), *Rubus* (brambles) and *Taraxacum* (dandelions).
- All established introductions (including of native taxa) or frequently recurrent casuals as listed by Stace (2020) occurring in the wild, regardless of whether introduced deliberately or accidentally by humans.
- All forestry and ornamental trees and shrubs planted on a small or large scale.
- The more distinctive native and non-native subspecies and hybrids.

A fourth edition of the *New Flora* was published in 2019 (Stace, 2019) and we have mapped a number of additional native species included in that work that were discovered as new to Britain or Ireland since the third edition was published (*e.g. Carex cespitosa*), or were newly described (*e.g. Sorbus herefordensis*), or whose historical presence was confirmed following the examination of historical specimens (*e.g. Bolboschoenus laticarpus*). All native taxa mapped here for the first time are listed in Table 3.1. It should be noted that this list includes four taxa not included in Stace (2019): the

Table 3.1. Native taxa discovered or first recognized in Britain and Ireland since 2000 and therefore not previously mapped for our area. New native subspecies are not included.

Species	Details
Asplenium fontanum	Possibly a chance colonist with historic records but long extinct
Bolboschoenus laticarpus	A possible native with records dating back to the 1800s
Botrychium nordicum	A cryptic taxon first described in 2017
Carex cespitosa	First found in 1960 but not correctly identified until 2008
Carex salina	First found in Scotland in 2004
Centaurium intermedium	Known since the late 1800s but only recognized as distinct in 2019
Cystopteris alpina	Formerly in Essex (introduced) and Yorkshire (native) where last seen in 1911
Cystopteris diaphana	Discovered in 2000 but with records dating back to the 1700s
Diphasiastrum tristachyum	An overlooked taxon recorded from a single site in the 1800s
Epipactis dunensis	Formerly included and mapped within *Epipactis leptochila s.l.*
Erythranthe peregrina	An amphidiploid first recorded from Lanarkshire in 2011 and Orkney in 2014
Lycopodium lagopus	An over-looked native taxon first reported in 2007
Myosotis stricta	An overlooked native taxon with a few historic records
Potentilla cryeri	Recently described as distinct from *P. crantzii*
Senecio eboracensis	A amphidiploid found in 1979 and described in 2003
Serapias lingua	Recorded from two sites historically and from a new site in Essex in 2017
Sorbus admonitor	Described as a new taxon in 2009 (Rich & Proctor, 2009)
Sorbus arvonicola	Described as a new taxon in 2014 (Sell & Murrell, 2014)
Sorbus cambrensis	Described as a new taxon in 2009 (Rich & Proctor, 2009)
Sorbus cheddarensis	Described as a new taxon in 2009 (Houston *et al.*, 2009)
Sorbus cuneifolia	Described as a new taxon in 2009 (Rich & Proctor, 2009)
Sorbus eminentiformis	Described as a new taxon in 2009 (Rich & Proctor, 2009)
Sorbus eminentoides	Described as a new taxon in 2009 (Houston *et al.*, 2009)
Sorbus evansii	Described as a new taxon in 2014 (Rich *et al.*, 2014)
Sorbus greenii	Described as a new taxon in 2014 (Rich *et al.*, 2014)
Sorbus herefordensis	Described as a new taxon in 2014 (Rich *et al.*, 2014)
Sorbus leighensis	Described as a new taxon in 2010 (Rich *et al.*, 2010)
Sorbus margaretae	Described as a new taxon in 2009 (Rich & Proctor, 2009)
Sorbus parviloba	Described as a new taxon in 2010 (Rich *et al.*, 2010)
Sorbus pseudomeinichii	Described as a new taxon in 2010 (Rich *et al.*, 2010)
Sorbus richii	Described as a new taxon in 2014 (Rich *et al.*, 2014)
Sorbus rupicoloides	Described as a new taxon in 2009 (Houston *et al.*, 2009)
Sorbus saxicola	Described as a new taxon in 2010 (Rich *et al.*, 2010)
Sorbus scannelliana	Described as a new taxon in 2009 (Rich & Proctor, 2009)
Sorbus sellii	Described as a new taxon in 2014 (Rich *et al.*, 2014)
Sorbus spectans	Described as a new taxon in 2014 (Rich *et al.*, 2014)
Sorbus stenophylla	Described as a new taxon in 2009 (Rich & Proctor, 2009)
Sorbus stirtoniana	Described as a new taxon in 2009 (Rich & Proctor, 2009)
Sorbus whiteana	Described as a new taxon in 2010 (Rich *et al.*, 2010)
Stenogrammitis myosuroides	A neotropical fern discovered in south-west Ireland in 2019
Utricularia bremii	Known from the New Forest since the 1990s
Utricularia ochroleuca	Formerly included and mapped within *U. intermedia s.l.*
Utricularia stygia	Formerly included and mapped within *U. intermedia s.l.*
Zannichellia obtusifolia	Possibly an overlooked native, discovered in North Essex in 2016

remarkable discovery of the neotropical fern *Stenogrammitis myosuroides* in south-west Ireland in 2019 (Hodd & Rumsey, 2020), *Botrychium nordicum*, first described by Stensvold & Farrar (2017) and reported new to our area in 2019 following molecular work performed on samples collected from Glen Shee (South Aberdeenshire), and *Centaurium intermedium* and *Potentilla cryeri*, described in recent years (Sell & Murrell, 2014; Rich & McVeigh, 2019) but not considered sufficiently distinct to be treated in full by Stace (2019). In addition to these natives, we have mapped a number of non-natives mentioned for the first time in Stace (2019) that have been widely planted and have subsequently naturalized (*e.g. Ginkgo biloba*) or appear to have been established in Britain for some time (*e.g. Cotula alpina*; Walker *et al*., 2020).

The publication of the *Hybrid Flora* (Stace *et al*., 2015) has greatly improved our knowledge of the ecology and distribution of hybrids in our area, and we have therefore included maps for all taxa recorded in 50 or more hectads. In comparison, the microspecies in the large critical genera of *Hieracium*, *Rubus* and *Taraxacum* can only be identified by a small number of specialists and therefore were excluded from this *Atlas*. There have been numerous nomenclatural changes since 2000 and so we follow the most recently published names in Stace (2019); therefore, for example, *Anagallis arvensis* becomes *Lysimachia arvensis*, *Mimulus guttatus* becomes *Erythranthe guttata* and *Sedum rosea* becomes *Rhodiola rosea*. We have made exceptions in only a few cases. For the *Dryopteris affinis* complex, views differ as to the best approach to the taxonomic ranking of the discrete entities within this complex, the evolutionary history of which is still largely uncertain, although hypotheses as to the genomic constitution of the three main recognized entities, *D. affinis*, *D. borreri* and *D. cambrensis*, have long existed. While Stace (2010) considered the approach of recognizing variants as (agamo)species to be desirable, he subsequently reverted to a single species concept (Stace, 2019). Here we follow the earlier view of Stace (2010) and Fraser-Jenkins (2007) which we feel is most consistent with treatments of other apomicts and reflects the genetic and evolutionary distinctiveness of these taxa. We have followed Bateman & Ruddall (2018), and others, in reassigning *Coeloglossum viride* to *Dactylorhiza viridis*, a change in nomenclature that is not included in Stace (2019).

The nomenclature of charophytes covered by the project follows John *et al.* (2021).

Separation of records into date-classes

The hectad maps for the 1962 *Atlas* displayed two date-classes (pre- and post-1930) for all taxa occurring in fewer than 100 vice-counties. Records for taxa occurring in more than 100 vice-counties were amalgamated and mapped under the umbrella term 'all records' (*i.e.* without distinct date-classes). The *New Atlas* mapped three date-classes for all taxa; pre-1970 (inclusive of all records dating back to the 16th century and the first botanical publications), 1970–86 (bridging the gap between the first and second *Atlases*), and 1987–99. Recording for this *Plant Atlas* project covered the years 2000–19, which is treated as a single date-class. For the book, we have chosen to follow the *New Atlas* in mapping the date-classes pre-1970, 1970–86 and 1987–99, alongside 2000–19. These are distinguished on the maps presented here by increasing the strength of the fill within each dot so that the most recent are a solid colour. We considered mapping earlier date-classes but concluded that the dots for these would be so faint on a map as to not add substantially to the visual interpretation offered to the reader, and a dot for a hectad that was last occupied before 1930 may easily be missed amongst a sea of neighbouring dots from later date-classes. However, it has been possible to map a more complete range of date-classes in the online *Atlas*, as the flexibility that comes with digital publications means that date-classes can be viewed independently.

Identifying native and introduced plants at a national level

Our definition of native and introduced species follows Macpherson *et al.* (1996), who define a native species as one which arrived in our area naturally, without the intervention of humans, having come from an area in which it is native, or one which has arisen *de novo* in the study area. The latter category includes many apomictic taxa that probably evolved in our area during the post-glacial period, such as the endemic whitebeams (*Sorbus* spp.) listed in Table 3.1, and amphidiploids derived from hybridization between native and non-native parents (*e.g. Senecio eboracensis*, *Spartina anglica*) or exclusively non-native parents (*e.g. Erythranthe peregrina*; Vallejo-Marín, 2012). Stace & Crawley (2015) describe such taxa as 'neo-natives'. Introduced species (also known as aliens, or non-natives) are defined as those taxa that were brought to our area by humans, either intentionally or unintentionally, even if native in the source area, or those which arrived without the intervention of humans but came from an area in which they were known to have been introduced. This category includes a small number of species that went extinct before or during the last glacial period but were reintroduced by humans during the current post-glacial period (*e.g. Abies alba*, *Diplotaxis tenuifolia*, *Euphorbia cyparissias*, *Picea abies*, *Rhododendron ponticum*; West, 2000).

Most species mapped in this *Atlas* are easily classified as either native or introduced in our area. This is because many native species have a well-documented and continuous pollen or macrofossil record spanning the last glacial period (Godwin, 1975; West, 2000), as well as distributions and ecological niches that correspond closely with their wider distribution in Europe and elsewhere where they are unequivocally native. Many other species are known to have been introduced to our area by humans from the Neolithic period onwards, either deliberately for food, forestry, or horticulture, or transported accidentally within imported goods and raw materials (Stace & Crawley, 2015). There are, however, 45 species which cannot be classified so easily and, even on the balance of available evidence, their categorization as native in Britain and Ireland remains largely speculative (Table 3.2). As in the *New Atlas* we have classified these taxa as 'native or alien' but have attempted to map the status of individual hectad occurrences, with the exception of four taxa where it has proved impossible to differentiate native from alien occurrences (*Berberis vulgaris*, *Bolboschoenus laticarpus*, *Brassica nigra*, *Ribes rubrum*).

Our categorization of national status follows the *New Atlas* save for sixteen species where further research and survey has indicated that a change in status was required (Table 3.2). These include ornamentals that were formerly considered to be native in semi-natural habitats but are considered much more likely to be modern introductions (neophytes) based on the current published evidence *e.g. Aconitum napellus*, *Euphorbia stricta*, *Fritillaria meleagris*, *Leucojum aestivum*, *Muscari neglectum*, *Symphytum tuberosum*. The change in status has proven particularly contentious for *Fritillaria meleagris* due to its importance as a flagship for the conservation of floodplain grasslands. Similarly, *Cynodon dactylon* and *Laphangium luteoalbum* are now categorized as neophytes. The two Irish heaths, *Erica erigena* and *E. mackaiana*, formerly considered to be native, are now thought to have been transported to Ireland as packaging by pilgrims and smugglers (Sheehy Skeffington & Van Doorslaer, 2015) and so have been reclassified as ancient introductions (*i.e.* archaeophytes – see *opposite*).

Four former neophytes have been reassessed as native following research into their history, distribution and/or habitats (*Lathyrus hirsutus*, *Stachys alpina*, *Teucrium chamaedrys*, *Valerianella eriocarpa*), although the evidence remains equivocal, and it is entirely possible that their status may again change if new information comes to light. More straightforward is the change in status of the garden plant *Angelica archangelica*. Whilst *A. archangelica* subsp. *archangelica* is certainly a neophyte in our area, subsp. *littoralis*, recently described from beaches in northern Shetland, is treated as a native colonizer likely to have originated from seed dispersed naturally by sea from Norway where it is a native taxon (Stroh & Scott, 2017).

Table 3.2. Taxa that are questionably native in Britain and Ireland and are therefore categorized as 'native or alien'. An asterisk denotes taxa that have been mapped without status in this *Atlas* due to the difficulties in differentiating hectads where they are apparently native from those where they have been introduced.

Aethusa cynapium	*Maianthemum bifolium*
Ajuga chamaepitys	*Matthiola sinuata*
Allium sphaerocephalon	*Myosurus minimus*
Asplenium fontanum	*Onobrychis viciifolia*
*Berberis vulgaris**	*Phyteuma spicatum*
*Bolboschoenus laticarpus**	*Pinguicula alpina*
*Brassica nigra**	*Polycarpon tetraphyllum*
Brassica oleracea	*Pyrus cordata*
Crassula aquatica	*Ranunculus sardous*
Daphne mezereum	*Reseda lutea*
Dipsacus fullonum	*Ribes rubrum**
Festuca lemanii	*Salvia pratensis*
Filago lutescens	*Schoenoplectus pungens*
Galium parisiense	*Scorzonera humilis*
Gastridium ventricosum	*Serapias lingua*
Gaudinia fragilis	*Serapias parviflora*
Gentianopsis ciliata	*Solanum nigrum*
Helleborus viridis	*Stachys alpina*
Homogyne alpina	*Stratiotes aloides*
Lapsana communis	*Teucrium chamaedrys*
Lathyrus aphaca	*Valerianella eriocarpa*
Lathyrus hirsutus	*Verbascum pulverulentum*
Limosella australis	*Zannichellia obtusifolia*

Table 3.3. Species whose status has changed since the publication of the *New Atlas* (Preston *et al.,* 2002a).

Species	*New Atlas*	This *Atlas*	Source
Aconitum napellus agg.	Native or alien	Neophyte	Pearman (2007)
Angelica archangelica	Neophyte	Native	Stroh & Scott (2017)
Cynodon dactylon	Native or alien	Neophyte	This *Atlas*
Erica erigena	Native	Archaeophyte	Foss & Doyle (1990)
Erica mackaiana	Native	Archaeophyte	Skeffington & Van Doorslaer (2015)
Euphorbia stricta	Native or alien	Neophyte	Pearman (2007)
Fritillaria meleagris	Native or alien	Neophyte	Pearman (2007)
Laphangium luteoalbum	Native or alien	Neophyte	Pearman (2007)
Lathyrus hirsutus	Neophyte	Native or alien	Rumsey (2019)
Leucojum aestivum	Native	Neophyte	Pearman (2013)
Limosella australis	Native	Native or alien	Pearman (2007)
Muscari neglectum	Native or alien	Neophyte	Pearman (2007, 2013)
Stachys alpina	Neophyte	Native or alien	Rich (2022)
Symphytum tuberosum	Native	Neophyte	Pearman (2007)
Teucrium chamaedrys	Neophyte	Native or alien	Rumsey (2018)
Valerianella eriocarpa	Neophyte	Native or alien	Pearman (2007)

In assigning national status, a species that is native in just one part of Britain and Ireland is categorized as native throughout our area even if it has been introduced in other areas. For example, native populations of *Spergula arvensis* and *Arbutus unedo* are restricted to the Channel Islands and south-west Ireland respectively, but both are classed as native in our area. As well as these overall status assignments, we have assigned status to the component parts, namely Britain (including the Isle of Man), Ireland, and the Channel Islands. In doing this we have included the Williamson *et al.* (2008) list of archaeophytes for Ireland, noting which of the original list of archaeophytes of Preston *et al.* (2004) are absent from Ireland, or best treated as neophytes there. These additional assignments are available on the online site.

Archaeophytes, neophytes and casuals

We follow the *New Atlas* in dividing introductions with naturalized populations (*i.e.* spreading vegetatively or reproducing effectively by seed) into archaeophytes and neophytes. An archaeophyte is defined as a plant which was brought to our area by humans, intentionally or unintentionally, and became naturalized there between the start of the Neolithic period (*c.* 4000BC) and AD1500. A neophyte is a plant that was first introduced after AD1500, intentionally or unintentionally, or if present before AD1500, that occurred only as a casual and is naturalized now only because it was reintroduced subsequently. The year AD1500 was chosen as it marks the beginnings of radical change in patterns of human demography, agriculture, trade and industry and is close to the European rediscovery of North America in 1492. A detailed discussion of the concept of archaeophytes and the criteria used to categorize them can be found in Preston *et al.* (2004).

Of the original list of 157 archaeophytes (Preston *et al*., 2004), *Malus domestica* and *Salix ×rubens* are now subsumed within broader species concepts (*Malus sylvestris s.l., Salix fragilis s.l.*), whereas *Erica erigena* and *E. mackiana* are added for the reasons given above. Also added are the arable weeds *Aethusa cynapium* subsp. *agrestis* that was categorized as a 'neophyte or archaeophyte' in the *New Atlas,* and *Papaver lecoqii* following its elevation to a full species by Stace (2010).

One of the difficulties in applying the concept of archaeophytes is how to deal with plants known to have been grown for human consumption in our area prior to AD1500 as crops or for culinary purposes. Preston *et al.* (2004) listed around 30 such species, which were categorized as casuals in the *New Atlas* because there was no evidence that they had ever been established in the wild, depending instead on constant reintroduction (Table 3.4). Stace & Crawley (2015) treat all these species, as well as 15 fruit trees that were certainly in cultivation before AD1500, as archaeophytes, but for this *Atlas* we have chosen to treat all these species as neophytes.

When validating archaeophyte maps it has proven impossible to differentiate reliably long-established populations from more recent introductions, and so all records are mapped using the same colour and symbol. For example, a number of former arable archaeophytes have been virtually eradicated by modern farming methods but have been sown on a vast scale in recent decades in 'pictorial' and 'wild-flower' seed mixtures (*e.g. Agrostemma githago*, *Centaurea cyanus*).

Preston *et al.* (2002a) categorized introduced species as 'casuals' where they failed to persist for more than five years and, therefore, relied on repeated introduction to maintain their presence in the wild (Macpherson *et al*., 1996). For example, many of the crops listed in Table 3.4 that only occur as 'relics' or 'volunteers' or species of warmer climates that fail to survive in severe winters were treated as such. We have not included this category here, as it relates more to persistence rather than to status and is almost impossible to apply consistently. For example, most species categorized as 'casuals' in the *New Atlas* are short-lived grasses or herbs,

Table 3.4. Species which are known from archaeological or documentary evidence to have been present in Britain before AD1500, but which are only likely to have occurred as crop relics or casuals and were therefore not categorized as archaeophytes by Preston *et al.* (2002a, 2004). All are treated as neophytes in this *Atlas*.

Species	Vernacular name	New Atlas status
Alcea rosea	Hollyhock	neophyte
Allium cepa	Onion	casual
Allium porrum	Leek	casual
Allium sativum	Garlic	neophyte
Anethum graveolens	Dill	casual
Anthriscus cerefolium	Garden Chervil	neophyte
Atriplex hortensis	Garden Orache	neophyte
Avena sativa	Oat	casual
Avena strigosa	Bristle Oat	casual
Borago officinalis	Borage	neophyte
Calendula officinalis	Pot Marigold	neophyte
Cannabis sativa	Hemp	casual
Cicer arietinum	Chick Pea	casual
Coriandrum sativum	Coriander	neophyte
Cuminum cyminum	Cumin	casual
Eruca vesicaria	Garden Rocket	casual
Hordeum distichon s.l.	Two-rowed Barley	casual
Hordeum vulgare	Six-rowed Barley	casual
Lactuca sativa	Garden Lettuce	casual
Lathyrus oleraceus	Garden Pea	casual
Lepidium sativum	Garden Cress	casual
Linum usitatissimum	Flax	neophyte
Portulaca oleracea	Common Purslane	neophyte
Raphanus sativus	Garden Radish	casual
Secale cereale	Rye	casual
Spinacia oleracea	Spinach	casual
Trigonella foenum-graecum	Fenugreek	casual
Triticum aestivum	Bread Wheat	casual
Vicia faba	Broad Bean	neophyte
Vicia lens	Lentil	casual

whereas trees and shrubs that fail to regenerate and persist over longer timescales are not differentiated in the same way (these are often termed 'survivors'). We have, however, occasionally used the term 'casual' in the text to describe the short-lived behaviour of introduced plant populations.

Assigning native or introduced status at the 10 km square level

As in the *New Atlas*, one of the aims of this project was to map the native and alien ranges of native species at the 10 km square level, displaying native occurrences as 'blue dots' and introductions as 'red dots'; for example, in hectads where it was known that a native species had been planted and was otherwise absent as a native, it was clearly introduced and mapped as a red dot. Where a species had been introduced in a hectad but also occurred as a native, native status was given priority as a blue dot on the map, although in reality the hectad has mixed status. We have managed to assign status at the 10 km level for all but 39 of the native taxa mapped here (Table 3.5).

With very few exceptions we have used the species-hectad status assignments in the *New Atlas*. Since its publication, however, there have been tens of thousands of new species-hectad occurrences submitted with no status assigned, and significant work was therefore required to attribute status to each of these. For such cases we drew heavily on the knowledge of VCRs and species accounts in county Floras. However, for many there was an almost complete lack of empirical evidence on which to base these decisions and so, inevitably, some assessments had to be based on the editors' knowledge of the species.

As stated above, it proved impossible to separate the native and introduced ranges of 39 taxa that have been widely planted, often over many centuries (Table 3.5). These included a number of trees and shrubs that have been planted for forestry, landscaping and amenity (*e.g. Fagus sylvatica*, *Quercus robur*) and forage grasses and herbs used in agriculture (*e.g. Cynosurus cristatus*, *Lolium perenne*, *Trifolium repens*) as well as ornamentals whose native ranges are now completely obscured by garden escapes (*e.g. Carex pendula*, *Hedera helix s.l.*, *Myosotis sylvatica*). All these species are mapped without status in Chapter 7.

It proved difficult to assign status to new species-hectad occurrences for some native species that have expanded their ranges in recent decades, especially those that have been unintentionally assisted by human activities such as in the slipstreams of cars and trains, in raw materials used for construction and landscaping (*e.g.* soil, turf, sand, gravel, rubble) or attached to shoes, clothing, vehicles, pets or livestock. In our area the most successful native 'hitchhikers' have been coastal halophytes that have spread inland along roads treated with rock salt since the 1970s (Badmin, 1979; Scott & Davison, 1980). The dramatic spread of *Atriplex littoralis*, *Cochlearia danica*, *Puccinellia distans* and S*pergularia marina* was one of the main findings of the *New Atlas*, and more recently other halophytes have been reported as spreading inland along salt-treated roads, most notably *Carex maritima* (Smith, 2017), *Elytrigia atherica* (Leslie, 2019), *Hordeum marinum* (Green, 1998; Stroh, 2015e), *Juncus balticus* (Amphlett, 2019a), *Parapholis strigosa* and *Sagina maritima*. These inland occurrences were mapped as introductions in the *New Atlas*, but we have chosen to map them as extensions to native ranges because they have occurred without direct human intervention and from locations within our area where they are undoubtedly native.

When assigning status, some of the most problematic species were native taxa that are primarily dispersed by attachment to humans or their vehicles or livestock. A notable example is *Crassula tillaea*. Since the 1980s this species has spread from sandy heathlands in Breckland and the New Forest, initially to Cornwall but subsequently to west Wales and north-east Scotland where it has colonized disturbed, sandy ground on tracks and in car parks, presumably by attachment to shoes and vehicles. Views differ as to the status of these new populations; we would argue that it is spreading, and persisting, in much the same way as it does in its original strongholds. Species likely to spreading in a similar way, at least in part due to attachment to fur, include *Dipsacus fullonum* and *Medicago arabica*, and, in top-soil, *Erigeron acris*, *Geranium lucidum, G. rotundifolium*, *Lactuca virosa*, and *Orobanche hederae*. We have mapped these extensions in range as native.

Table 3.5. Native taxa whose native ranges have been completely obscured by introductions in Britain and Ireland and are therefore mapped without status (excluding aggregates for *Hieracium* and *Taraxacum*). An asterisk denotes species categorized as 'native or alien'.

Aquilegia vulgaris	*Nymphaea alba*
*Berberis vulgaris**	*Poa pratensis*
Bistorta officinalis	*Populus nigra* subsp. *betulifolia*
*Bolboschoenus laticarpus**	*Prunus avium*
*Brassica nigra**	*Quercus robur*
Carex pendula	*Ribes rubrum**
Carpinus betulus	*Salix purpurea*
Chamaenerion angustifolium	*Sorbus aucuparia*
Cynosurus cristatus	*Spartina anglica*
Echium vulgare	*Symphytum officinale*
Fagus sylvatica	*Tanacetum vulgare*
Festuca rubra subsp. *commutata*	*Taxus baccata*
Hedera helix s.l.	*Tilia cordata*
Helleborus foetidus	*Trifolium repens*
Hylotelephium telephium	*Typha angustifolia*
Ilex aquifolium	*Viola odorata*
Lolium perenne	*Viscum album*
Malus sylvestris s.l.	*Wolffia arrhiza*
Myosotis sylvatica	*Rosa canina* agg.
Narcissus	

Many national rarities have been the subject of conservation programmes aimed at restoring self-sustaining populations on sites where they formerly occurred. One analysis estimated that the majority of British rarities have been the subject of at least one reintroduction attempt, although precise figures were impossible to obtain as few initiatives document when and where introductions have taken place or monitor their long-term success (Pearman & Walker, 2004a). Where possible we have mapped such introductions as alien, even in hectads where a species formerly occurred as a native. For example, *Cypripedium calceolus* and *Bromus interruptus* have been reintroduced into many hectads where they were formerly native; all have been mapped as alien in this *Atlas*.

In the future, we hope that a more consistent approach to recording status as set out by Walker *et al.* (2019) will be adopted, with botanists providing more objective decisions about the likely origin and regeneration of plant populations (*e.g.* native, deliberately introduced, accidentally introduced, unknown) rather than subjective assessments of persistence (*e.g.* casual, surviving) which are almost impossible to decide upon with any certainty during single visits.

Chapter 4: Preparation of maps and text

Selection of taxa to be mapped

The number of taxa recorded for this *Atlas* far exceeded the number that could realistically be included in a published book. We have therefore only included here taxa in the following categories.

All native species treated *in full* (*i.e.* are included in the main keys and provided with a numbered entry) by Stace (2010), or subsequently added to the British or Irish flora (Table 3.1), have been mapped, including the sixteen native taxa considered to be extinct in Britain and Ireland (Table 4.1). Native microspecies in the large apomictic genera of *Hieracium*, *Rubus*, and *Taraxacum* have not been mapped but their combined distributions have been included under the aggregates *Hieracium*, *Rubus fruticosus* agg., and *Taraxacum*. Maps for genus-level aggregates including native taxa have also been included for *Euphrasia*, *Narcissus* and *Salicornia* alongside their component species.

Native subspecies have been mapped if they are treated in full by Stace (2010) and if the available records provide a reasonably informative map, even if coverage is less comprehensive than that of many species. For some taxa we have mapped all subspecies as well as the species (*e.g. Asplenium trichomanes*, *Dactylorhiza incarnata*, *Gentianella amarella*, *Hypericum maculatum*, *Juniperus communis*, *Limonium binervosum*, *Montia fontana*, *Rhinanthus minor*, *Salix cinerea*). For around 40 taxa with both rare and common subspecies, only the rarer taxon has been mapped alongside the species, as recorders only very infrequently recorded the more widespread subspecies systematically (*e.g. Anthyllis vulneraria*, *Cerastium fontanum*, *Pedicularis sylvatica*). In comparison, we have mapped only the subspecies of 15 taxa where their distributions do not overlap due to marked differences in ecological preferences (*e.g. Alchemilla filicaulis*, *Arenaria norvegica*, *Carex divulsa*, *Pyrola rotundifolia*, *Scleranthus perennis*, *Tephroseris integrifolia*).

All archaeophytes have been mapped, including six taxa considered to be extinct as archaeophytes, but in some cases still present as more recent introductions in Britain and Ireland (Table 4.1).

All neophytes treated in full by Stace (2010), or subsequently added to the British or Irish flora, have been mapped if they have been recorded in at least 50 10 km squares in our area, regardless of the year they were recorded (see also Chapter 7). The very few exceptions to this rule include rare neophytes once considered to be possibly native in our area (*e.g. Simethis mattiazzii*, *Equisetum ramosissimum*), neophytes that have established recently and are considered to be invasive (*e.g. Sarracenia purpurea*), or neophytes that are new to the area this century (*e.g. Lemna turionifera*, *Urtica membranacea*). To merit inclusion in Stace (2010), an alien must be naturalized (*i.e.* permanent and competing with other vegetation, or self-perpetuating) or, if short-lived (casual), frequently recurrent so that it can be found in most years. Introduced subspecies have been considered and mapped in the same way as native subspecies.

All hybrids included in Stace *et al.* (2015) have been mapped if they have been recorded in 50 or more 10 km squares, regardless of the year of the record.

For a few species the distribution data were found to be unreliable due to widespread and intractable data entry issues (*e.g. Rosa canina s.s.*, *Hedera helix s.s.*), and so the taxon was mapped within a broader species concept (aggregate or *sensu lato*). Similarly, some taxa had been recorded inconsistently due to changes in taxonomy (*e.g.*, the separation of *A. nemorosum*, *A. minus* subsp. *minus* and *A. minus* subsp. *pubens*), or difficulties in differentiating closely related taxa (*e.g.*, *Brachypodium pinnatum* and *B. rupestre*), or uneven recording and aggregation of segregates over time (*e.g.*, *Centaurea nigra* s.s. and *C. debeauxii*, formerly inconsistently recorded as *C. nigra* subsp. *nigra* and *C. nigra* subsp. *nemoralis* respectively). Many of these issues have been overcome by aggregating and mapping these taxa in the broad sense (*e.g.*, *Arctium minus s.l.*, *Brachypodium pinnatum s.l.*, *Centaurea nigra s.l.*) or at genus level (*e.g. Lycium*, *Spiraea*, *Symphyotrichum*). Aggregates mapped in this *Atlas* are listed in Table 4.2.

There remain 631 introduced taxa, present in fewer than 50 10 km squares and so not included here, which are mapped in the online version of this *Atlas*. These taxa are listed in the index, annotated as "online".

Preparation and editing of maps

Three years prior to the deadline for submission of records for this project, VCRs were asked to begin the process of checking the records held in the BSBI database for their respective vice-counties. Summary reports contained within the database were provided for each vice-county to help with the interrogation of records, and to prioritize validation tasks. At the same time, the editors started checking the data at a country level for all nationally rare, scarce and threatened taxa.

Table 4.1. Native and archaeophyte taxa that formerly occurred in Britain and Ireland, as well as the Channel Islands and the Isle of Man, with the year they were last recorded. All are regionally extinct, except *Bromus interruptus* and *Senecio eboracensis* which have not been recorded outside of Britain and so are globally extinct. Archaeophytes are indicated with an asterisk.

Taxon	Year of last record	Details
*Agrostemma githago**	?	Extinct as an arable archaeophyte; widely sown in seed mixtures
*Arnoseris minima**	1971	Formerly scattered in south and south-east England
Asplenium fontanum	1923	Possibly only a chance colonist
Bromus interruptus	1972	An English endemic, now re-established (Rumsey & Stroh, 2020)
*Bupleurum rotundifolium**	1960s	Extinct as an arable archaeophyte; widely sown in seed mixtures
Carex davalliana	1831	Formerly at a single site in Somerset
Carex trinervis	1869	Formerly at a single site in Norfolk
*Caucalis platycarpos**	1968	Formerly widely scattered, mainly in England
*Centaurea cyanus**	?	Extinct as an arable archaeophyte; widely sown in seed mixtures
*Crepis foetida**	1980	Formerly scattered, mainly in south-east England; extant populations originate from deliberate introductions (Kitchener, 2021)
Cystopteris alpina	1911	Formerly at single sites in Teesdale and Essex (Tennant, 2010)
Diphasiastrum tristachyum	1876	Formerly at a single site in North Hampshire (Rumsey, 2012)
Dryopteris remota	1894	Formerly at a single site in Scotland; introduced in Somerset
Euphorbia peplus	1976	Former colonist of coastlines in Ireland, Channel Islands and England
*Galeopsis segetum**	1975	Formerly at a single site in North Wales (Rich & Pryor, 2003)
Pinguicula alpina	1912	Formerly at a single site in Easter Ross
Rubus arcticus	1841	Formerly at scattered sites across the Scottish Highlands
Schoenoplectus pungens	1972	Formerly in Jersey; introduced in Lancashire
Senecio eboracensis	2003	An English endemic confined to York (Lowe & Abbott, 2003)
Serapias parviflora	2008	Possibly a chance colonist at a single site in Cornwall
Spiranthes aestivalis	1959	Formerly scattered in the New Forest and in the Channel Islands
Tephroseris palustris	1899	Formerly scattered in fens in East Anglia and Sussex
Trichophorum alpinum	1888	Formerly at a single bog in Angus

Once all records had been received (May 2020), the hectad maps and underlying records were checked by the editors, with the assistance of numerous experts covering a broad range of taxonomic groups. All records considered to be in error or doubtful were excluded from the *Atlas* dataset at this stage. In addition, country experts checked the mapped distributions for a selected suite of taxa whose distributions in our area mainly encompassed either Ireland, Wales or Scotland. Status for accepted individual species-hectad occurrences was assigned based on the rules described in Chapter 3.

Preparation, editing and writing of species accounts

In total 3,495 taxa, encompassing 1,599 native taxa, 1,648 introduced taxa and 248 hybrid taxa were selected to be mapped (inclusive of the book and website) based on the criteria outlined above (Table 1.1). A panel of expert authors was recruited to update the existing text for taxa that were included in the *New Atlas*, and to write new accounts for species not previously included. Authors were able to edit text and write new accounts online within the BSBI database (database.bsbi.org). This site also contained information useful to the author, for example a map of a species'

Table 4.2. Aggregates or broad species concepts mapped in this *Atlas*. These mainly comprise closely related taxa that have been recorded inconsistently in the past.

		Erophila verna	*Nasturtium officinale*	*Rubus fruticosus*
		Festuca ovina	*Nitella flexilis*	*Sagina apetala*
		Festuca rubra	*Ornithogalum umbellatum*	*Salicornia*
Aconitum napellus	*Chenopodium album*	*Galeopsis tetrahit*	*Papaver dubium*	*Salix fragilis*
Aphanes arvensis	*Cochlearia officinalis*	*Gymnadenia conopsea*	*Phleum pratense*	*Trichophorum cespitosum*
Arctium minus	*Cotoneaster horizontalis*	*Hedera helix*	*Poa pratensis*	*Ulmus glabra × minor*
Arenaria serpyllifolia	*Cotoneaster microphyllus*	*Hordeum distichon*	*Polygonum aviculare*	*Ulmus minor*
Brachypodium pinnatum	*Crocus vernus*	*Hyacinthoides hispanica*	*Polypodium vulgare*	*Utricularia intermedia*
Bromus racemosus	*Dryopteris affinis*	*Juncus bufonius*	*Potentilla × mixta*	*Utricularia vulgaris*
Callitriche stagnalis	*Dryopteris × complexa*	*Limonium binervosum*	*Pyrus communis*	
Centaurea nigra	*Erodium cicutarium*	*Malus sylvestris*	*Rosa canina*	

distribution for all the date-classes, and a map showing changes since the 1987–99 date-class. Records for a particular taxon of interest could also be interrogated using simple searches within the database.

Following the completion of the draft accounts by the caption authors, the text was edited and checked for consistency by the editors. Updated information was also included for altitudinal limits (supplied by David Pearman), the date of the first record for introduced plants in cultivation and in the wild (supplied by Chris Preston and David Pearman from ongoing research), and taxonomic revisions published in Stace (2019).

Britain
1. West Cornwall
2. East Cornwall
3. South Devon
4. North Devon
5. South Somerset
6. North Somerset
7. North Wiltshire
8. South Wiltshire
9. Dorset
10. Isle of Wight
11. South Hampshire
12. North Hampshire
13. West Sussex
14. East Sussex
15. East Kent
16. West Kent
17. Surrey
18. South Essex
19. North Essex
20. Hertfordshire
21. Middlesex
22. Berkshire
23. Oxfordshire
24. Buckinghamshire
25. East Suffolk
26. West Suffolk
27. East Norfolk
28. West Norfolk
29. Cambridgeshire
30. Bedfordshire
31. Huntingdonshire
32. Northamptonshire
33. East Gloucestershire
34. West Gloucestershire
35. Monmouthshire
36. Herefordshire
37. Worcestershire
38. Warwickshire
39. Staffordshire
40. Shropshire
41. Glamorganshire
42. Breconshire
43. Radnorshire
44. Carmarthenshire
45. Pembrokeshire
46. Cardiganshire
47. Montgomeryshire
48. Merionethshire
49. Caernarvonshire
50. Denbighshire
51. Flintshire
52. Anglesey
53. South Lincolnshire
54. North Lincolnshire
55. Leicestershire
56. Nottinghamshire
57. Derbyshire
58. Cheshire
59. South Lancashire
60. West Lancashire
61. South-east Yorkshire
62. North-east Yorkshire
63. South-west Yorkshire
64. Mid-west Yorkshire
65. North-west Yorkshire
66. County Durham
67. South Northumberland
68. North Northumberland
69. Westmorland
70. Cumberland
71. Isle of Man
72. Dumfriesshire
73. Kirkcudbrightshire
74. Wigtownshire
75. Ayrshire
76. Renfrewshire
77. Lanarkshire
78. Peeblesshire
79. Selkirkshire
80. Roxburghshire
81. Berwickshire
82. East Lothian
83. Midlothian
84. West Lothian
85. Fife & Kinross
86. Stirlingshire
87. West Perthshire
88. Mid Perthshire
89. East Perthshire
90. Angus
91. Kincardineshire
92. South Aberdeenshire
93. North Aberdeenshire
94. Banffshire
95. Moray
96. East Inverness-shire
97. West Inverness-shire
98. Main Argyll
99. Dunbartonshire
100. Clyde Isles
101. Kintyre
102. South Ebudes
103. Mid Ebudes
104. North Ebudes
105. West Ross & Cromarty
106. East Ross & Cromarty
107. East Sutherland
108. West Sutherland
109. Caithness
110. Outer Hebrides
111. Orkney
112. Shetland
113. Channel Islands

Ireland
- H1. South Kerry
- H2. North Kerry
- H3. West Cork
- H4. Mid Cork
- H5. East Cork
- H6. Co. Waterford
- H7. South Tipperary
- H8. Co. Limerick
- H9. Co. Clare
- H10. North Tipperary
- H11. Co. Kilkenny
- H12. Co. Wexford
- H13. Co. Carlow
- H14. Co. Laois
- H15. South-east Galway
- H16. West Galway
- H17. North-east Galway
- H18. Offaly
- H19. Co. Kildare
- H20. Co. Wicklow
- H21. Co. Dublin
- H22. Meath
- H23. Westmeath
- H24. Co. Longford
- H25. Co. Roscommon
- H26. East Mayo
- H27. West Mayo
- H28. Co. Sligo
- H29. Co. Leitrim
- H30. Co. Cavan
- H31. Co. Louth
- H32. Co. Monaghan
- H33. Fermanagh
- H34. East Donegal
- H35. West Donegal
- H36. Tyrone
- H37. Co. Armagh
- H38. Co. Down
- H39. Co. Antrim
- H40. Co. Londonderry

Figure 5.1. Map of vice-counties in Britain and Ireland.

Chapter 5: Coverage achieved by the project

For the purposes of botanical recording, Britain and Ireland are divided geographically into 153 Watsonian vice-county boundaries (59 covering England, the Isle of Man and the Channel Islands, 41 in Scotland, 13 in Wales, and 40 in Ireland). These were first defined by Hewett Cottrell Watson in 1852 for Britain, and by 1901 Robert Lloyd Praeger had introduced a similar system for Ireland. Whilst administrative boundaries may change over time, the vice-county boundaries provide a permanent geographic recording unit, allowing an accurate comparison of recent and historical biological data over time.

For the *Plant Atlas* survey period, one or more expert volunteer VCRs had overall responsibility for recording in their vice-county. These recorders targeted areas for survey, arranged and led field meetings, digitized records that were made in the field (primarily using the computer recording package MapMate), and uploaded these records to the central BSBI database. Targeting of areas considered to be under-recorded relative to past survey date-classes was aided by a dedicated section in the BSBI database which summarized coverage based on pre- and post-2000 re-recording rates and the number of visits to a tetrad. This summary was updated daily to take account of data flow.

Recording some of the more rugged and remote regions in our area has always been challenging, as there are few resident botanists and much uneven, isolated terrain to cover. BSBI field meetings arranged by VCRs and BSBI Country Officers targeted such localities, particularly in the final five years of recording, resulting in much better coverage than would otherwise have been achieved. Accessing some of the more remote Scottish islands was aided by funding from The Finnis Scott Foundation, and in the final four years of surveying, the Wild Flower Society funded recording in remote and under-recorded locations across Ireland, and also in parts of north-eastern Scotland, leading to much fuller coverage of these areas. Numerous workshops for the more difficult taxonomic groups were run by experts at national BSBI Recorder Conferences and at field meetings throughout the duration of the project.

During the course of the project 28·5 million records were submitted by BSBI recorders. This represents 60% of the BSBI's entire data-holding and dwarfs the number of records submitted for previous *Atlas* projects. This is illustrated clearly in Fig. 5.2 which displays the number of species-hectad combinations submitted on an annual basis since 1950. With the exception of major peaks in 1987 (due to submission of records for the *BSBI Monitoring Scheme*) and towards the end of the *New Atlas* recording period, there was a steady increase in records for all groups. This reflects an increase in recording effort during 2000–19 as well as an increase in data capture enabled by a switch to electronic submission of all records from 2002 onwards.

The following maps provide a brief overview of the coverage achieved by BSBI recorders over the course of this project (2000–19) in terms of the total taxa recorded, including taxa not mapped in this book or on the website. Comparisons are also made with numbers of taxa recorded from 1970 to 1999 in order to show how recording for this *Atlas* compares to that of previous date-classes. Readers should refer to Chapter 5 of the *New Atlas* (Preston *et al.*, 2002a) for a more detailed discussion of the coverage achieved for the period 1987–99. Pescott *et al.* (2019b) also provide a useful summary of spatial bias in recording effort inherent in semi-structured botanical recording datasets in Britain and Ireland.

Figure 5.3 provides an overall summary of the 'recording effort' expressed as the number of 'tetrad surveys' undertaken within each hectad between 2000 and 2019. Here a tetrad survey is defined as one when more than 40 species were recorded in a tetrad on a single day. This approach is preferred to plotting the total number of records collected per hectad as it provides a more accurate measure of recording activity by removing issues of duplication and variation in plant species diversity across our area. What is immediately apparent from Figure 5.3 is the marked spatial variation in effort, with major peaks of recording activity (>200 survey days) in and around major cities and large towns, most notably London but also Aberdeen, Birmingham, Cambridge, Edinburgh, Glasgow, Newcastle and Swansea. Counties that have been surveyed intensively at tetrad (or finer) scale since 2000 also stand out clearly (*e.g.* Banffshire, Cornwall, Derbyshire, Hampshire, Lancashire, Somerset, Waterford) as do the 'home squares' of particularly active VCRs (*e.g.* NS06 on the Isle of Bute) and botanical 'hot-spots' such as Arnside Knott (SD47) in Westmorland. Overall, the southern half of Britain was the most intensively recorded region whereas the recording effort was less exhaustive elsewhere, especially in upland regions of northern England, Wales, Scotland and across much of Ireland. The median number of survey days per hectad across our area from 2000–19 was 31.

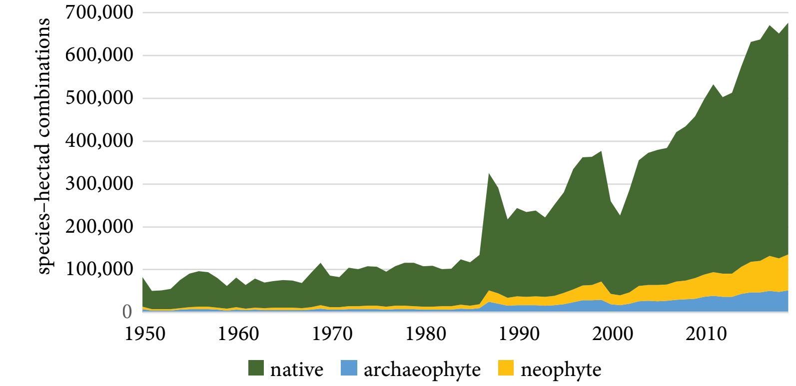


Figure 5.2. The number of hectad-species combinations submitted for all species in Britain and Ireland 1950–2019. Combinations assigned to date ranges have been attributed evenly across the years they span.

Figure 5.4 displays the total number of species recorded in each hectad between 2000 and 2019. The most obvious feature of this map is how diversity declines with increasing altitude and latitude, with the highest diversity (>1,000 species) in south-eastern England and the lowest diversity (<250 species) in upland regions of northern Scotland and western Ireland. Obvious peaks in diversity also correlate closely with urban areas, due to the close association of neophytes with human population centres, and counties where intensive botanical surveys have been undertaken since 2000 (*e.g.* Cornwall, Lancashire, Waterford). Overall, Irish hectads are less diverse than those in Britain although the obvious peak in diversity in Waterford, which has been intensively surveyed by Paul Green, suggests that Irish diversity at the hectad scale is currently underestimated.

Figure 5.5 shows a similar pattern to Figure 5.4, with a high diversity of native species (>400 species) throughout much of lowland Britain and relatively lower diversity across much of Scotland and Ireland. Exceptions include obvious 'gaps' in diversity in upland regions in south-western England, Wales and northern England as well as intensively farmed areas with little semi-natural habitat, such as Fenland and parts of the English

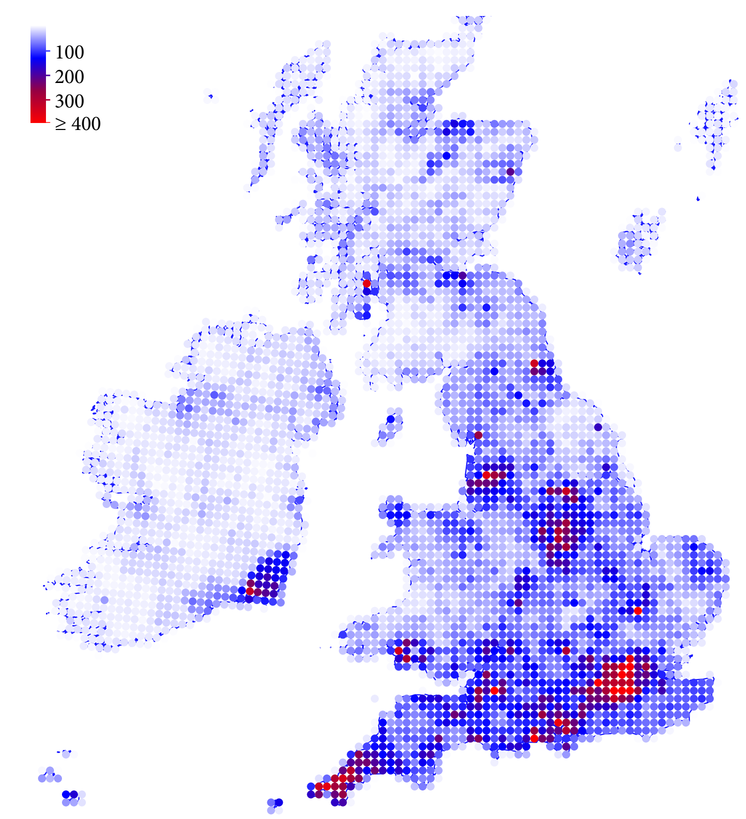


Figure 5.3. Number of tetrad (2 × 2 km square) surveys per hectad (10 × 10 km square) between 2000 and 2019. A single survey is defined as a set of at least 40 taxa recorded on the same day from a tetrad.

Midlands and eastern England. Likewise, there are peaks in diversity in Scotland and Ireland that correlate closely with base-rich rocks (*e.g.* Bredalbanes, the Burren, Morecambe Bay), or areas with high habitat and geological diversity (*e.g.* Inner Hebrides), as well as for regions that have been recorded intensively in recent times. As in the *New Atlas*, the hectad with the highest native diversity is in Dorset (SY98, 709 taxa). This square, which contains Corfe Castle and Wareham, has an exceptional range of habitats including heathland, lowland mire, chalk grassland, saltmarsh, meadows and grazing marsh. SZ39 in Hampshire, on the southern edge of the New Forest, has a similar number of species (668 taxa) and habitats. The third richest hectad is centred on Arnside Knott on the edge of Morecambe Bay (SD47, 662 taxa), where the landscape is dominated by grassland, scrub and woodland on Carboniferous limestone. The richest hectads in Ireland were O23 (468 taxa), which includes Bull Island to the east of Dublin, R39 (465 taxa) in the Burren, County Clare, and T12 (463 taxa), a coastal square to the east of Wexford.

In Figure 5.6, the highest diversity of archaeophytes occurs approximately to the south and east of a line running between the Humber and Severn estuaries. This distribution largely correlates with the greatest concentrations of arable cultivation and human population. Outliers

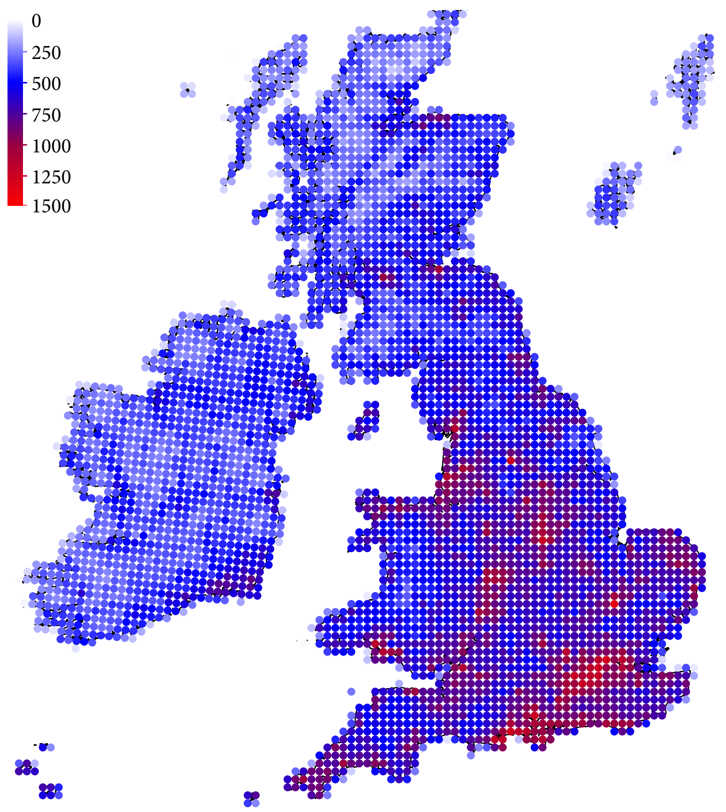


Figure 5.4. Total number of species recorded in each hectad from 2000 to 2019.

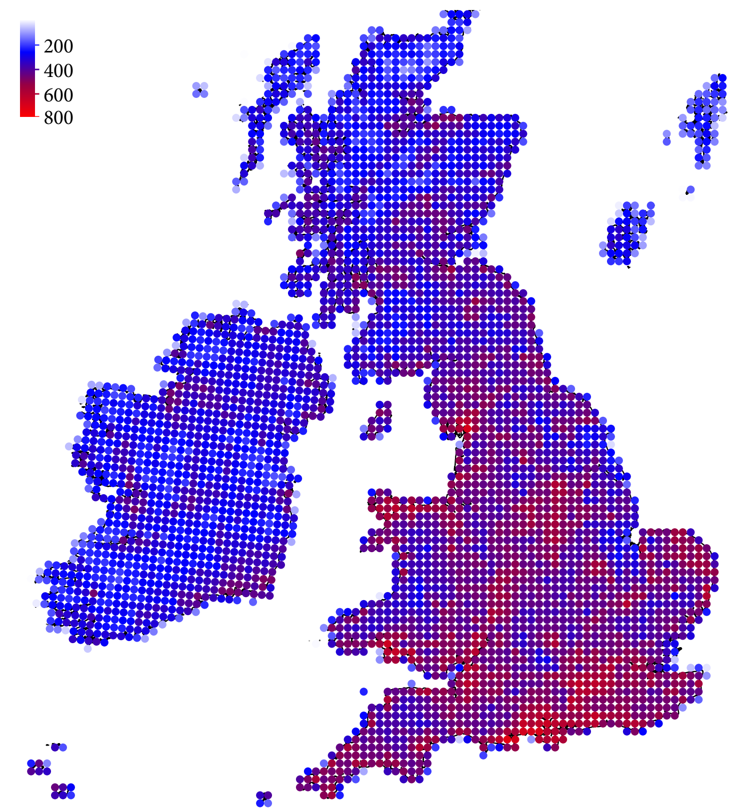


Figure 5.5. Number of native species recorded in each hectad from 2000 to 2019.

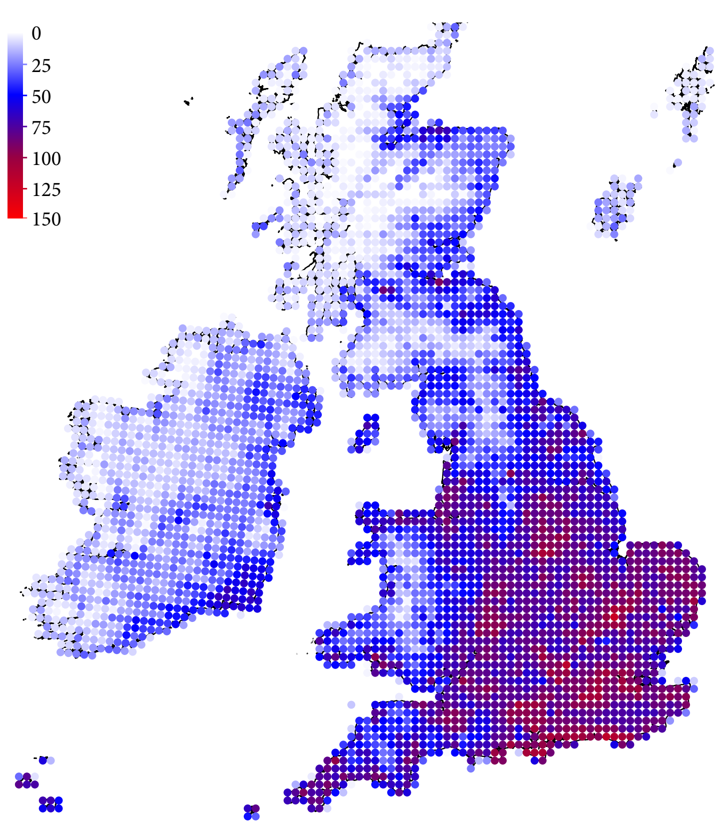


Figure 5.6. Number of archaeophytes recorded in each hectad from 2000 to 2019.

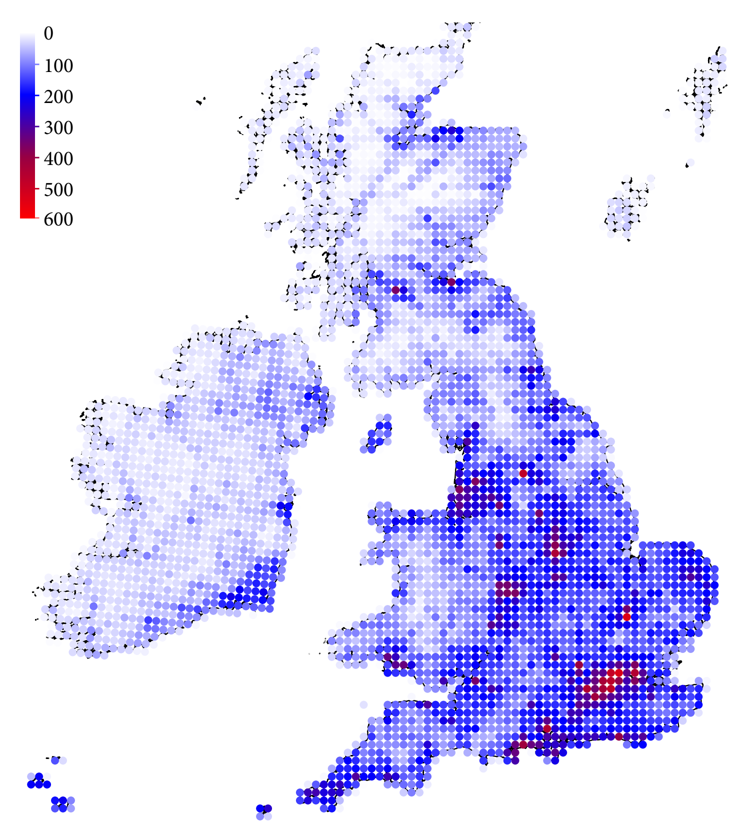


Figure 5.7. Number of neophytes recorded in each hectad from 2000 to 2019.

include lower intensively farmed regions in south-western England and Wales, the coastal plain of Cheshire and Lancashire and major cities such as Edinburgh, Glasgow and Newcastle. In Ireland the greatest diversity is concentrated along the southern and eastern seaboards, with distinct peaks in Wexford and around Dublin. The relative paucity or absence of archaeophytes throughout much of upland Britain and western Ireland is striking.

The pattern of diversity of neophytes (Fig. 5.7) differs markedly from those for native and archaeophyte species, with the greatest diversity (>400 species) restricted largely to urban areas where these species are often first introduced as ornamentals and then escape into ruderal habitats, often benefitting from the raised temperatures of urban 'heat islands'. Foremost amongst these is London, which accounts for five of the ten most diverse hectads for neophytes. Elsewhere, high numbers of neophytes occur in major cities and towns including Birmingham, Brighton, Bristol, Edinburgh, Glasgow, Liverpool and Nottingham. Other notably rich hectads include the 'home squares' of botanists who specialize in recording aliens, most notably Cambridge, Bradford, and Southampton. To a lesser extent, high diversity of neophytes is correlated with recording intensity, with greater numbers in counties that have been subject to intensive surveys since 2000 (*e.g.* Cornwall, Hampshire, Lancashire, Nottinghamshire, Somerset, Sussex, Waterford). As with archaeophytes, there is a striking dearth of neophytes from upland regions in Britain and across much of Ireland, although the higher figures for Waterford and in north-eastern Scotland suggests that their numbers are possibly underestimated in some of these regions.

Chapter 6: The changing floras of Britain and Ireland

Here we provide an overview of some of the main time trends in plant distributions revealed by the *Plant Atlas 2020* project. This chapter should be seen as an introduction to the qualitative trend descriptions and modelled trend metrics presented within each species account; species-level trend metrics are also displayed in more detail, and further broken down by country, on the accompanying website (plantatlas2020.org). For earlier accounts of national-level change in our floras, largely based on BSBI recording activity, see Braithwaite *et al.* (2006), McCollin & Geraghty (2015), Preston *et al.* (2002a, 2002b, 2003), and earlier papers based on the 1987–88 BSBI Monitoring Scheme (*e.g.* Rich & Woodruff, 1990; Rich, Beesley & Goodwillie, 2001). Numerous insights into the floristic change undergone by our islands over the past few decades can also be found, at various different scales, in many excellent local Floras, long-term structured monitoring scheme results (*e.g.* the UKCEH Countryside Survey), and in assessments conducted for the purpose of national Red Listing (*e.g.* Stroh *et al.*, 2014; Wyse Jackson *et al.*, 2016).

Methods overview[1]

Time trends for all taxa were created using the "FREquency SCAling LOcal" (Frescalo) model of Hill (2012). This approach estimates an adjustment for variable recording effort over time and space based on the observed frequencies of locally common 'benchmark' species. The resulting relative frequency estimates (the "time factors" of Hill, 2012) are those of a taxon relative to these benchmark species within its occupied areas. Readers should consult Hill (2012) for more detail on the method, and Pescott *et al.* (2019b) for the justification for its specific application to 10 km/broad date-class distribution data here.[2]

Scale of the analysis

We should perhaps also justify the scale of the analysis separately to the use of any particular model. The focus on relatively broad units of space and time is partly to do with the availability of more historic data at these scales, reducing (but by no means eliminating) the risk of bias in our analyses. The assumption that making inferences at ever finer grains is necessarily and always superior does not hold much water when sampling is non-random. Meng (2018) demonstrated theoretically that even small sampling biases scale extremely unfavourably with increasing overall population size (*e.g.* as with smaller spatio-temporal grains), and this should give pause for thought for those assuming that small is always beautiful. This is not to say that *recording* at small scales is not useful; the value of precise locational

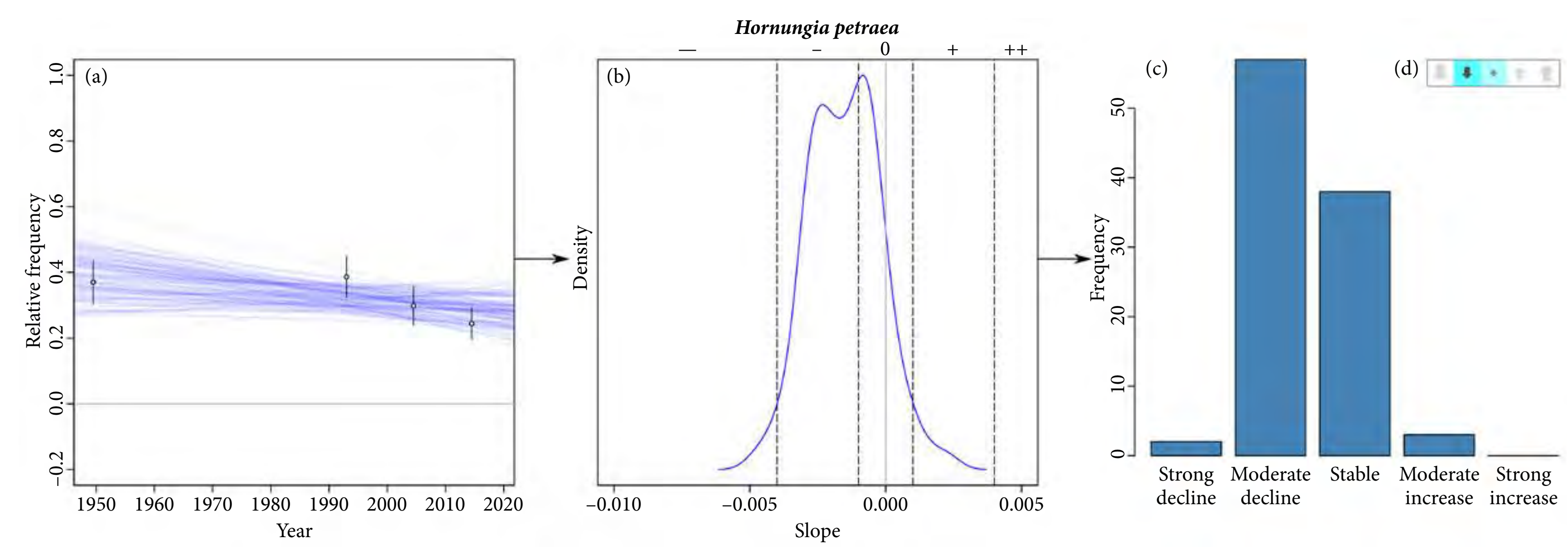


Figure 6.1. An example of the flow of information and uncertainty through our analyses, for *Hornungia petraea* in Britain (adapted from Pescott *et al.*, 2022). The graphs (a), (b) and (c) are available for every modelled taxon/country/time period combination on the *Plant Atlas 2020* website, but are not presented in these volumes. The summary strip (d) is used both on the website and in the species' accounts (Chapter 7). For (a) the filled white circles and black bars are the Frescalo means and standard deviations for each time period, plotted at the median of each date-class; the transparent blue lines represent a random selection of 100 trends that are compatible with these estimates (the line 'ensemble'). For (b) the blue smoothed line is the distribution of the 100 slope estimates from (a). The vertical broken lines in (b) represent the discretization scheme used to create the summary in (c), a simple count of how many of the 100 trend line slopes fall into each size category. Summary (d) is just an alternative, space-saving, visualization of (c). The "model-based certainty" estimate used in this chapter is the mean of the density distribution in (b), divided by its standard deviation; it can be seen that the lower the uncertainty this distribution has (*i.e.* the 'sharper' it is, giving a small denominator), and the larger the distance of its mean from zero (large numerator), the larger the absolute value of this metric.

[1] All the data and results supporting this chapter will be lodged with the Natural Environment Research Council's Environmental Information Data Centre (eidc.ac.uk/) in 2023.

[2] The original Fortran computer code for the Frescalo model is available at brc.ac.uk/biblio/frescalo-computer-program-analyse-your-biological-records, whilst an *R* translation by OLP (editor) can be found at github.com/sacrevert/fRescalo. Bijlsma (2013) also provides a useful VBA translation of the model. For the results presented here, Frescalo was run through the sparta *R* package (github.com/BiologicalRecordsCentre/sparta), with all subsequent processing and analysis performed using custom scripts in *R* 4.1.2.

Table 6.1. Numbers of available trends, or trend comparisons, across regional statuses and analyses. Different status sub-categories of hybrid have been amalgamated. The category "alien" applies to Ireland only, and indicates that a specific designation as archaeophyte or neophyte is not available. See Chapter 3 for more information about status categories.

Status	Britain: long term	Britain: short term	Ireland: long term	Ireland: short term	Britain: slope comparison	Ireland: slope comparison
Native	1,136	1,165	819	847	1,244	859
Alien	-	-	2	3	-	2
Archaeophyte	144	149	95	93	148	101
Neophyte	226	836	254	460	227	334
Native or alien	28	26	4	4	32	5
Hybrid	11	52	10	35	9	8
Totals	**1,545**	**2,228**	**1,184**	**1,442**	**1,660**	**1,309**

information and thorough local recording at fine scales is unquestionable: the resulting records have more than one potential use, after all. The stumbling block is the assumption that this means that national-level inference should automatically be based on such data, which are typically highly non-random when brought together across vice-counties and time periods. If we desire unbiased inference from non-random data across large areas, such as Britain or Ireland, then working at relatively coarser scales[3] is far more likely to produce accurate statistics (Meng, 2018). Other projects exist for asking and answering questions about change at finer scales for plants in Britain and Ireland (*e.g.* Braithwaite *et al.*, 2006; Pescott *et al.*, 2019a), and future monitoring at these scales will hopefully build on many of the interesting changes presented here.

The relevant date-classes used for our analyses are as follows: "long term" refers to trends across the 1930–69, 1987–99, 2000–09, and 2010–19 classes; whereas "short term" refers to trends across the 1987–99, 2000–09, and 2010–19 classes only. Information on the taxa used for each analysis is outlined in Chapter 7, "Modelled trend summaries"; it suffices to say here that separate lists of taxa were used for the two different temporal analyses, in an attempt to minimize the effects of changing taxonomic circumscriptions and recorder focus over time (Preston *et al.*, 2002a; Pescott *et al.*, 2018). Note that whilst we often use the word "species" in this chapter for convenience, the analyses were actually applied across lists that included some species aggregates and infraspecific taxa.

Metrics of change

For each separate analysis (British long term, Irish short term, *etc.*), the Frescalo model outputs a relative frequency estimate for a species per time period, along with its standard deviation (a measure of uncertainty; Fig. 6.1a). All statistics and plots presented in this chapter are derived from these outputs in various ways, as overviewed in Figure 6.1. In order to fully propagate the model-based uncertainty associated with the Frescalo estimates to downstream trend summaries, a type of random sampling – Monte Carlo resampling – was used. For changes at the species level (*e.g.* Table 6.2), an estimate was drawn from each relative frequency distribution for each time period (defined by its Frescalo mean and standard deviation), and a linear model fitted to these numbers (Fig. 6.1a). This process was repeated 100 times for each species within an analysis, in order to capture the range of potential trends associated with the relative frequency estimates over time (Fig. 6.1a; Pescott *et al.*, 2022). The resulting distribution of slope estimates (Fig. 6.1b) was used to rank the information content of species' estimated time trends by dividing the absolute value of the mean of the slope distribution by its standard deviation; this approach gives more weight to larger mean slopes (whether positive or negative) with smaller uncertainty. This is the "model-based certainty" estimate used in this chapter (*e.g.* Fig. 6.2, Table 6.2, *etc.*).[4] The sets, or 'ensemble', of 100 linear trends for each species (Fig. 6.1a) are also the basis of the modelled trend summaries given within the species' accounts (Figs 6.1c, 6.1d, also see Chapter 7).

The distributions of slope estimates were also used to compare changes in the magnitude and direction of a species' trend between our long- and short-term analyses, for taxa included in both (Tables 6.6, 6.7). In this case, the difference in the two mean slope estimates was divided by the standard error for the difference (Paternoster *et al.*, 1998). Species have larger values of the resulting *z*-statistic where the change in slope is large and the uncertainty associated with this change is low.

Grouped trends

The plots showing smoothed change calculated over collections of species (*e.g.* Fig. 6.4) were estimated in a similar way to the individual species' trends, but by using generalized additive models (GAMs)[5] to smooth between date-class medians. Each species' GAM was based on random draws from its estimated Frescalo relative frequency distributions as for the linear trends;[6] however, a different approach was taken to propagate the uncertainty from these ensembles of smoothed species' trends to the grouped multi-species lines. The general method is based on calculating a single grouped trend by averaging across the smoothed species' trends for each set of relevant taxa (Soldaat *et al.*, 2017). This process can then be repeated based on different draws from the estimated Frescalo distributions. Here it was repeated 100 times, providing a distribution of grouped trends for any given set of species (*e.g.* all taxa with an Ellenberg N value between 1 and 3); the final grouped trend that we display here is the median of this resampled distribution of grouped trends, along with its 90% uncertainty interval band (representing variability among the 100 realizations of the process). All grouping variables used were derived from Hill *et al.* (2004), with a small amount of gap-filling by the editors where required. Apart from status, all grouped summaries are limited to the long-term trend analysis, largely because a large proportion of the neophytes included in the short-term analysis currently lack values for the variables used. Note that the grouped summaries include all taxa, rather than filtering out rarities (see below and Chapter 7); in all cases investigated filtering reduced uncertainty, but did not alter trend trajectories. For all smoothed group trends in this chapter, the x-axis for the long-term trend begins at 1950, rather than 1930. This is because the trend shown is smoothed between date-class mid-points, and the mid-point of the 1930–69 period is the middle of 1949; for the same reason, the short-term trend is shown starting in 1993 (the 1987–99 mid-point). Across all smoothed plots, broken vertical grey lines indicate the modern date-class recording boundaries.

Residual bias

By the methods described in this section, all of the model-based uncertainty from Frescalo is propagated to the final statistics presented, whether numeric or visual. Readers should keep in mind, however, that Frescalo only adjusts for variable overall recording effort between times and places, and not for systematic biases in the relative attention paid to species (Hill, 2012). We attempt to highlight such issues in this chapter, as indeed do many of the expert trend assessments throughout the species' accounts. There is a strong argument for creating formal 'risk-of-bias' assessments for every modelled trend presented here (Boyd *et al.*, 2022; Pescott *et al.*, 2022); unfortunately we have not had the resources to achieve this fully to date, although it remains a longer-term aim.

Change in the floras: results of the analyses

After applying the hectad frequency filters noted in Chapter 7 (≤15 unique hectads across the relevant date-classes for Britain, ≤6 for Ireland), trends were obtained for the following numbers of taxa: Britain long term: 1,545; Britain short term: 2,228; Ireland long term: 1,184; Ireland short term: 1,442. Comparisons between long- and short-term trends were possible for 1,660 taxa in Britain and 1,309 taxa in Ireland; rare species that were filtered out for the single time-period analyses were retained for the comparison, so as not to exclude taxa that had declines crossing the hectad filter levels over the long term. A breakdown of trends across status categories[7] is given in Table 6.1.

[3] Although it is worth noting that the production of believable trends at the 10 × 10 km scale, covering a period of almost 100 years, across areas the size of Britain and Ireland, can hardly be considered coarse compared to what is possible in other areas of our planet.

[4] Readers with a statistical background may question why we do not use the *t*-statistic to then test the resulting sample of linear trends in relative frequency for a difference from zero (the *t*-statistic being the mean divided by its standard error). The reason is that the standard error requires the sample size, which here is an arbitrary number of Monte Carlo-generated slope values that is constant across taxa. The *t*-statistic would therefore just be a monotonic transformation of the value that we use, as would any derived *p*-values (and the latter could be made arbitrarily small by taking more Monte Carlo samples). Given that we are interested here in the relative ordering of the trends in terms of their model-based certainty, we use the simplest approach providing that ordering.

[5] Generalized additive models (GAMs) are nonlinear models that, roughly speaking, allow the analyst to control the amount of smoothing expected in the relationship between an outcome and a predictor variable (Wood, 2017, provides an overview of the theory, and we use his *R* package, *mgcv*, to implement these models here). The number of 'knots' in a GAM controls the amount of smoothing, and the general advice is that this "should be chosen to be large enough that you are reasonably sure of having enough degrees of freedom to represent the underlying 'truth' reasonably well, but small enough to maintain reasonable computational efficiency" (Wood, 2022). Here we fixed the number of knots at 3 across species and model fits, allowing fits to be nonlinear (*e.g.* humped or 'U'-shaped) if the data supported it, and approximately linear if not.

[6] These smoothed model fits can also be viewed on the *Plant Atlas 2020* website.

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Overall patterns

The mean trend slopes for these taxa are plotted against their model-based certainties in Figure 6.2. These plots suggest two main patterns: higher average certainty in the long-term analyses, and in the British trends compared to the Irish trends. Neither of these is particularly surprising. The short-term analyses contain more species, largely additional neophytes which are likely to be more variably recorded across time and space; Britain has more available data with which to estimate the Frescalo relative frequencies. The estimated density contours also make it clear that, in the long term, Britain has a larger proportion of species estimated to be declining (*i.e.* negative mean time trend slopes), whereas Ireland has a larger proportion estimated to have increased. In the short term this pattern is not quite so evident; here Ireland has larger slope estimates coupled with higher average uncertainty (*i.e.* larger absolute mean slope values at lower values of model-based certainty) relative to Britain. However, there is still evidence for a greater number of increasers with large slope values relative to the decreasers in Ireland in the short term.

Status

Some additional insight into these patterns is provided by Figure 6.3, which replaces the overall contours with status-specific estimates for the main three categories of native, archaeophyte and neophyte. It is clear from this that neophytes are much more likely to be increasing than not across all analyses, although these estimates are often relatively uncertain, particularly in the short term. An interesting feature of Figure 6.3 is the indication that, compared to Britain, Irish archaeophytes are more balanced between species with average increases and decreases (inspecting the actual data gives 49 average increasers versus 46 decreasers, totalling 95 as in Table 6.1). In addition, in the long term, Irish natives show a general preponderance of increasers, a clear difference from the British long-term trends. Table 6.2 supports the latter pattern at least, with ten Irish natives in the top 25 most certain increasers over this period (readers should continually recall throughout this discussion that the use of the word "certain" actually means certain, conditional on the data and the model used to describe them).

The smoothed multi-species indicator status plot (Fig. 6.4) provides an interesting contrast to Figure 6.3, as this shows a fairly confident strong average decline in Irish archaeophytes over the long term. How can this be reconciled with the relative balance of increasers and decreasers indicated by the mean slopes and contour in Figure 6.3? Ordering the species by the absolute value of the mean slope (data not shown), rather than model-based certainty (as in Table 6.2), indicates that most of the largest absolute mean slope values were for decreasers. Indeed, of the ten Irish archaeophytes with the largest absolute slopes, nine were decreasing in the long term: *Roemeria argemone*, *Fumaria densiflora*, *Artemisia absinthium*, *Scandix pecten-veneris*, *Lolium temulentum*, *Valerianella rimosa*, *Capsella bursa-pastoris*, *Anthemis cotula* and *Blitum bonus-henricus* (listed in decreasing order of slope magnitude; *cf.* Table 6.3). However, these species had lower mean certainty (3·6) for their trends compared to the corresponding top nine Irish archaeophyte increasers (mean certainty = 10·1): *Helminthotheca echioides*, *Allium ampeloprasum*, *Melilotus altissimus*, *Valerianella carinata*, *Euphorbia lathyris*, *Avena fatua*, *Kickxia elatine*, *Veronica hederifolia* and *Vinca minor* (compared to the decreasers, these were spread out between ranks 6 and 27 in terms of their absolute mean slope). Readers should be able to get a feel for this distinction by looking through the Irish long-term trends for these species on the *Plant Atlas 2020* website. This illustrates the different conclusions that can be reached depending on whether one only emphasizes patterns with the highest certainty (*e.g.* Table 6.2, and as would also happen if one only reported 'significant' trends), or whether one averages over all trends and estimable uncertainty, as in Figure 6.4. To summarize, whilst similar numbers of Irish archaeophytes had average increasing or decreasing trends over the long term, the decreasers tended to have steeper slopes, even if they were more uncertain on average, and it is this pattern that dominates in the grouped trend (Fig. 6.4).

The smoothed status plots in Figure 6.4 generally support the impressions received from the overall distribution of species' trends in

Table 6.2. Top twenty-five **long-term increasers** in Britain and Ireland. Status in this, and the other tables in this chapter, refers specifically to that within Britain or Ireland as appropriate.

Britain			Ireland		
Taxon	**Model-based certainty**	**Status**	**Taxon**	**Model-based certainty**	**Status**
Picea sitchensis	56·5	neophyte	*Picea sitchensis*	31·2	neophyte
Lamiastrum galeobdolon subsp. *argentatum*	50·9	neophyte	*Epilobium ciliatum*	30·2	neophyte
Hyacinthoides × *massartiana*	44·9	neophyte	*Potamogeton natans*	30·0	native
Ligustrum ovalifolium	44·5	neophyte	*Veronica montana*	25·1	native
Crassula helmsii	43·9	neophyte	*Tripleurospermum maritimum s.l.*	25·1	native
Picea abies	41·4	neophyte	*Potamogeton polygonifolius*	24·2	native
Triticum aestivum	40·4	neophyte	*Prunus laurocerasus*	24·1	neophyte
Tsuga heterophylla	40·4	neophyte	*Buddleja davidii*	23·9	neophyte
Prunus laurocerasus	40·2	neophyte	*Hypericum perforatum*	23·4	native
Acer platanoides	39·0	neophyte	*Chamaenerion angustifolium*	22·7	native
Cupressus lawsoniana	38·5	neophyte	*Ligustrum ovalifolium*	22·5	neophyte
Crocosmia × *crocosmiiflora*	38·4	cultivated hybrid (alien × alien)	*Carex pendula*	21·3	native
Pseudotsuga menziesii	38·3	neophyte	*Ribes uva-crispa*	21·1	neophyte
Alnus incana	38·1	neophyte	*Arabidopsis thaliana*	21·0	native
Cotoneaster horizontalis	37·3	neophyte	*Pseudotsuga menziesii*	20·0	neophyte
Larix kaempferi	35·8	neophyte	*Pinus contorta*	19·7	neophyte
Thuja plicata	35·8	neophyte	*Lamiastrum galeobdolon* subsp. *argentatum*	19·4	neophyte
Rosa rugosa	35·7	neophyte	*Ribes rubrum*	19·2	neophyte
Pinus contorta	35·5	neophyte	*Leycesteria formosa*	19·2	neophyte
Lysimachia punctata	35·3	neophyte	*Cotoneaster horizontalis*	19·2	neophyte
Buddleja davidii	35·0	neophyte	*Taxus baccata*	18·5	native
Tripleurospermum maritimum s.l.	34·6	native	*Juncus tenuis*	18·5	neophyte
Epilobium ciliatum	33·7	neophyte	*Hyacinthoides* × *massartiana*	18·4	neophyte
Leycesteria formosa	33·2	neophyte	*Hypericum maculatum*	18·2	native
Pilosella aurantiaca	33·2	neophyte	*Rhododendron ponticum*	17·6	neophyte

[7] Statuses in this chapter are specifically those within the relevant region for a given analysis, not those for Britain and Ireland as a whole.

Figure 6.3, although, as just discussed, additional insights are provided. The much shallower average decline in native species over the short term in Britain, compared to the long term, is notable (this also applies to British archaeophytes). The steeper trends, ending at higher average relative frequency values, for neophytes in the short term in both areas are also clear. The points about relative uncertainty made above in relation to Figure 6.2 are also generally evident here (*i.e.* higher uncertainty in the short term, and in Ireland relative to Britain).

Increasing species

Tables 6.2 and 6.4 list the top 25 species with the most 'certain' increases for both areas, for the long and short term respectively. For Britain, with the exception of a small number of native species (8% overall), both lists are dominated by neophytes. The Irish top 25s contain a greater proportion of natives (40% in the long term; 28% in the short term; 34% overall). Of the natives, the long-term increases for *Tripleurospermum maritimum s.l.* are largely due to inconsistencies in the way that statuses were applied to 10 km squares historically, which was unfortunately detected too late to be amended. Several other large apparent changes can be attributed with certainty to recording bias caused by taxonomic issues: the short-term increase for *Trichophorum germanicum* is clearly determined by the clarification of the characters used to distinguish the taxa (Hollingsworth & Swan, 1999) and the subsequent change in taxonomic rank. (The aggregate species *T. cespitosum s.l.*, more appropriately used for the long-term trend, showed a moderate decline in Britain, and was assessed to be approximately stable in Ireland.) The increases in *Hedera helix*, *Poa humilis* and *Rumex crispus* subsp. *littoreus* in Ireland are all similar cases in the sense that either increases in knowledge and/or recorder awareness are likely to be the primary agents of estimated change. Taxonomic shifts are also likely to be behind the short-term increases for *Sagina apetala* and *S. filicaulis* in Ireland; however, there may also be an element of real change here, as, in Ireland in the long term, the aggregate *S. apetala s.l.* also shows a small increase (but approximately stable in Britain). The expert trend assessment suggests that increases in urban land cover, and spread along roads and railways, may be driving this change.

Some of the remaining native increasers in these tables are clearly due to the admixture of native populations with garden escapes. *Arum italicum*, *Carex pendula* and *Hypericum androsaemum* probably all belong in this category (although some of the increase for the last of these is likely due to confusion with *H.* × *inodorum*). It is tempting to speculate that the success of such garden-origin populations may be due to the presence of non-native genotypes or the horticultural selection of robust lineages. The remaining native taxa are those that show evidence for long-term increases in Ireland. The two *Potamogeton* taxa here (*natans* and *polygonifolius*) seem both to be explainable by recording biases: a result of the reluctance of data curators to accept the non-expert determined records from the 1930–69 period (see the maps of Perring & Walters, 1962, which make this distinction, and Preston, 1995b, pp. 136–137). The short-term Irish trends seem a far surer guide here: these suggest that *P. polygonifolius* is stable, whereas a moderate to strong decline for *P. natans* is suggested (although see the "Decreasing species" section *opposite*). The extreme increase in *Veronica montana* also suggests a serious recording bias against the species in Ireland historically (*cf.* Perring & Walters, 1962); indeed, even the erratic jumps in the short-term trend (see website) strongly suggest a pattern of shifting spatio-temporal recording focus. The plant is not really a species from which one would expect such natural dynamism (Grime *et al.*, 2007). The two *Hypericum* species listed (*perforatum* and *maculatum*) are a similar case, except here the culprit appears to be historic data loss rather than recording bias *per se*: the maps in Perring & Walters (1962) are far closer to the *New Atlas* 1987–99 distributions than to the holdings now available for the 1930–69 date-class.[8] Of the remaining three species under discussion (*Arabidopsis thaliana*, *Chamaenerion angustifolium* and *Taxus baccata*), *C. angustifolium* is the species with the most believable increase over the long term for Ireland (widely speculated to be due to the introduction of a non-native genotype to our islands). The other two are most likely because of greater attention paid to anthropogenic habitats in recent times, both in terms of weeds of such surfaces and the recording of planted trees.

The remaining increasers listed in Tables 6.2 and 6.4 are, except for three archaeophytes, all neophyte aliens of various types. Of the archaeophytes, the short-term Irish increase listed for *Vicia sativa* subsp. *segetalis* is likely to be a result of recorders identifying this common subspecies with more confidence. *Valerianella carinata* in Ireland and *Bromus secalinus* in Britain, however, both seem likely to be the result of true increases in 10 km square

[8] Dr Chris Preston (*in litt.*) has confirmed this, at least for *H. perforatum* (see also Preston *et al.*, 2002a, p. 36).

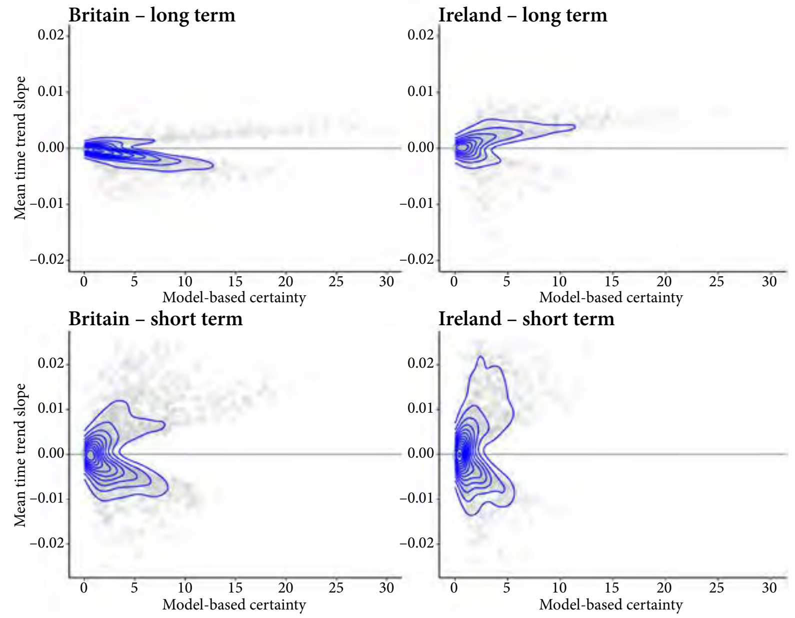

Figure 6.2. Relationships between species' average time trends and their model-based certainties across analyses, with density contours. Small numbers of outliers along both axes are omitted to better enable comparisons between analyses.

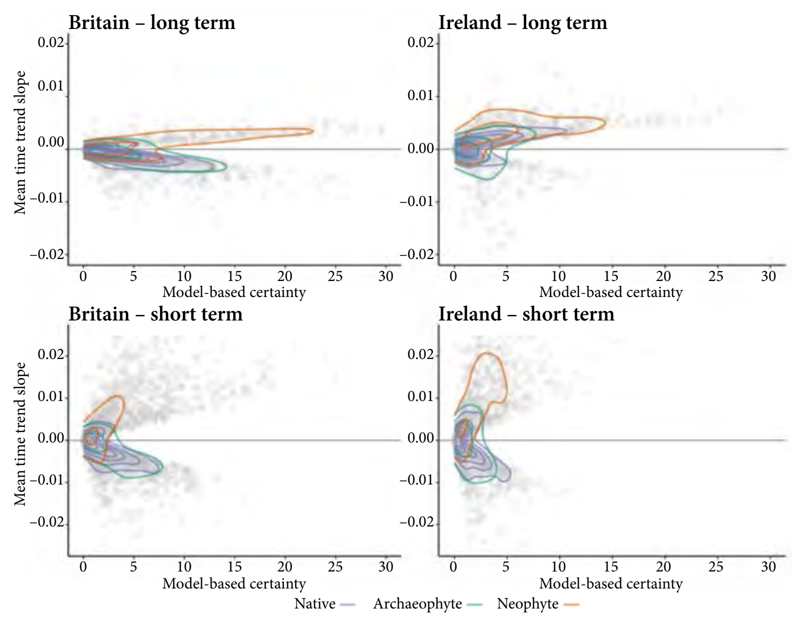

Figure 6.3. Relationships between species' average time trends and their model-based certainties across analyses, with density contours coloured by regional status. As for Figure 6.2, small numbers of outliers are omitted along both axes.

occupancy. *Valerianella carinata* also shows a strong increase in Britain over the long term; the rate of change has increased even since it was reported as one of the top 100 increasers by Preston *et al.* (2002a); the reason it does not appear in the top 25 for Britain (Table 6.4) is the slightly higher uncertainty associated with this short-term increase. Milder winters, and spread in soil by horticulture, are both suggested as mechanisms for this. *Bromus secalinus* in Britain is another interesting case: between 1930 and 1999 the modelled trend suggests stability, followed by large increases over the last 20 years. Herbicide resistance, and perhaps the end of stubble-burning in arable farming, appear to be the main drivers for the increase of this grass, especially in areas cultivated for winter wheat.

Across the long- and short-term increasers, the neophytes can be grouped loosely into several categories: woody species; herbaceous garden escapes; ruderal, non-ornamental species; and two agricultural species that do not fit into any of these neatly (*Phacelia tanacetifolia, Triticum aestivum*). The long-term lists have the largest proportion of woody species, which can be roughly subdivided into commercial forestry trees and ornamental trees and shrubs of gardens. Strikingly, the North American conifer Sitka Spruce *Picea sitchensis* comes out on top in both Britain and Ireland in the long term, and makes it into the top five of the Irish short-term list as well. In this context it is no doubt notable that Johnson (2015) claims that this conifer is "more perfectly adapted to Argyllshire or Snowdonia than any tree growing wild in Europe today"; the trend caption authors also point to Moore's (2011) statistic that it is now the most widely planted commercial conifer tree, and accounts for around 50% of the total area of conifer forest in Britain. It is also a prolific self-seeder in the colder and wetter parts of our islands (Dehnen-Schmutz *et al.*, in press), even regenerating naturally at high altitudes, and it would be surprising if many of the 10 km occurrences in these climate zones lacked both planted and self-sown occurrences within them. Ultimately the increases calculated for both this and the other trees in Tables 6.2 and 6.4 (*Acer platanoides*, *Alnus incana*,

Table 6.3. Top twenty-five **long-term decreasers** in Britain and Ireland.

Britain			Ireland		
Taxon	**Model-based certainty**	**Status**	**Taxon**	**Model-based certainty**	**Status**
Spergula arvensis	25·2	archaeophyte	*Agrimonia eupatoria*	12·5	native
Raphanus raphanistrum subsp. *raphanistrum*	24·8	archaeophyte	*Glebionis segetum*	11·9	archaeophyte
Blitum bonus-henricus	24·3	archaeophyte	*Sinapis arvensis*	11·5	archaeophyte
Ranunculus arvensis	23·9	archaeophyte	*Atriplex patula*	10·9	native
Sinapis arvensis	23·5	archaeophyte	*Mentha arvensis*	10·5	native
Scleranthus annuus	23·1	native	*Callitriche stagnalis s.l.*	10·1	native
Scandix pecten-veneris	21·0	archaeophyte	*Danthonia decumbens*	10·0	native
Viola tricolor	20·4	native	*Artemisia vulgaris*	9·9	archaeophyte
Pedicularis sylvatica	19·5	native	*Spergula arvensis*	9·8	archaeophyte
Stachys arvensis	18·5	archaeophyte	*Aira caryophyllea*	9·8	native
Arenaria serpyllifolia s.s.	18·5	native	*Fallopia convolvulus*	9·4	archaeophyte
Glebionis segetum	18·4	archaeophyte	*Torilis japonica*	9·3	native
Omalotheca sylvatica	18·3	native	*Sisymbrium officinale*	9·1	archaeophyte
Galeopsis speciosa	18·2	archaeophyte	*Asplenium ruta-muraria*	9·0	native
Fallopia convolvulus	18·1	archaeophyte	*Rhinanthus minor*	9·0	native
Galeopsis angustifolia	17·9	archaeophyte	*Leucanthemum vulgare*	8·7	native
Polygala vulgaris	17·7	native	*Euphrasia officinalis* subsp. *pratensis*	8·5	native
Lolium multiflorum	17·7	neophyte	*Capsella bursa-pastoris*	8·5	archaeophyte
Anthemis cotula	17·2	archaeophyte	*Galeopsis tetrahit s.s.*	8·5	native
Solidago virgaurea	16·9	native	*Euphrasia arctica*	8·2	native
Mentha arvensis	16·7	native	*Schedonorus pratensis*	8·0	native
Buglossoides arvensis	16·4	archaeophyte	*Ligustrum vulgare*	8·0	neophyte
Sisymbrium altissimum	16·3	neophyte	*Ulmus minor* agg.	7·7	native
Poterium sanguisorba subsp. *sanguisorba*	16·3	native	*Rumex acetosella*	7·6	native
Silene vulgaris	16·1	native	*Asplenium ceterach*	7·6	native

Table 6.4. Top twenty-five **short-term increasers** in Britain and Ireland.

Britain			Ireland		
Taxon	**Model-based certainty**	**Status**	**Taxon**	**Model-based certainty**	**Status**
Alchemilla mollis	24·8	neophyte	*Trichophorum germanicum*	18·0	native
Trichophorum germanicum	23·9	native	*Hedera hibernica*	16·1	native
Senecio inaequidens	22·8	neophyte	*Alchemilla mollis*	15·4	neophyte
Geranium × *oxonianum*	22·3	cultivated hybrid (alien × alien)	*Lamiastrum galeobdolon* subsp. *argentatum*	13·3	neophyte
Cupressus × *leylandii*	22·1	cultivated hybrid (alien × alien)	*Picea sitchensis*	12·8	neophyte
Polypogon viridis	22·0	neophyte	*Erigeron floribundus*	12·7	neophyte
Verbena bonariensis	21·4	neophyte	*Geranium* × *oxonianum*	12·4	cultivated hybrid (alien × alien)
Lonicera pileata	21·0	neophyte	*Buddleja davidii*	12·3	neophyte
Erigeron floribundus	20·9	neophyte	*Lemna minuta*	12·2	neophyte
Lamiastrum galeobdolon subsp. *argentatum*	18·9	neophyte	*Cotoneaster horizontalis*	11·4	neophyte
Cyclamen hederifolium	18·6	neophyte	*Carex pendula*	11·0	native
Hyacinthoides hispanica agg.	18·6	neophyte	*Epilobium ciliatum*	10·8	neophyte
Lonicera nitida	18·5	neophyte	*Prunus laurocerasus*	10·6	neophyte
Erigeron karvinskianus	18·5	neophyte	*Pinus contorta*	10·0	neophyte
Bromus secalinus	18·2	archaeophyte	*Cupressus lawsoniana*	9·7	neophyte
Anisantha diandra	18·0	neophyte	*Sagina apetala*	9·7	native
Erigeron sumatrensis	17·9	neophyte	*Poa humilis*	9·5	native
Phacelia tanacetifolia	17·9	neophyte	*Cotoneaster sternianus*	9·2	neophyte
Leycesteria formosa	17·9	neophyte	*Hyacinthoides hispanica* agg.	9·2	neophyte
Echinochloa crus-galli	17·8	neophyte	*Vicia sativa* subsp. *segetalis*	9·2	archaeophyte
Arum italicum	17·7	native	*Rumex crispus* subsp. *littoreus*	9·1	native
Campanula poscharskyana	17·3	neophyte	*Leycesteria formosa*	8·9	neophyte
Tellima grandiflora	17·3	neophyte	*Polypogon viridis*	8·7	neophyte
Hypericum androsaemum	17·0	native	*Valerianella carinata*	8·7	archaeophyte
Allium triquetrum	16·9	neophyte	*Sagina filicaulis*	8·6	native

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Cupressus lawsoniana, *C.* × *leylandii*, *Larix kaempferi*, *Picea abies*, *Pinus contorta*, *Pseudotsuga menziesii*, *Thuja plicata* and *Tsuga heterophylla*) are a confounded mix of shifting recording bias and true increases in frequency. Whilst these taxa were known to field botanists in the early and middle parts of the 20th century – most were listed as additional taxa in at least the later editions of Bentham & Hooker, as well as being fully described in the main Flora (Clapham, Tutin & Warburg, 1952) used by recorders for the 1962 *Atlas* (Perring & Walters, 1962, p. xi), not to mention popular tree books of the time – clearly they were not recorded with any consistency (and, indeed, they were not mapped in the 1962 *Atlas*). However, in regions where the increases in plantation forestry after the First World War have been clearly documented by botanists (*e.g.* Chater, 2010b), the reality of landscapes being gradually transformed by large-scale non-native tree planting across these years is apparent. Whether or not numerous young trees or plantations were ignored by the field botanists of the 1950s, the trends seem very likely to at least reflect the reality of the massive increases in these taxa, even if the rates of change are slightly exaggerated in relation to their true frequencies in the period 1930–69.

The top long-term increasers in the other neophyte categories mentioned (herbaceous garden escapes, ruderal non-ornamentals and agricultural species) contain little that will surprise the active field botanist in Britain or Ireland, although it is of note that some species have continued to expand and consolidate their distributions over the past 20 years. For example, *Buddleja davidii*, *Crocosmia* × *crocosmiiflora*, *Epilobium ciliatum*, *Lysimachia punctata* and *Prunus laurocerasus* were all among the top 100 increasers listed by Preston *et al.* (2002a), and they have all continued on the same trajectory. Other taxa, as with the trees discussed above, did not previously receive change estimates by Preston *et al.* (2002a) due to their not being among the "necessarily arbitrary" selection of "most well-established introductions" mapped by Perring & Walters (1962), and a similar conclusion of an unknown mixture of bias and true increase pertains for most. The list here contains familiar garden escapes, plantings and accidental introductions. For example, *Cotoneaster horizontalis*, *Crassula helmsii*, *Hyacinthoides* × *massartiana*,[9] *Lamiastrum galeobdolon* subsp. *argentatum*,[10] *Leycesteria formosa*, *Ligustrum ovalifolium*, *Pilosella aurantiaca* and *Rosa rugosa*. Of these, perhaps the most accurate estimate of long-term change is likely to be for the highly invasive aquatic *Crassula helmsii*, with its first record in 1956 and much attention paid to its continual spread since then due to its severe negative impacts on aquatic ecosystems (Smith & Buckley, 2020). *Ribes rubrum*, *R. uva-crispa* and *Rhododendron ponticum* in Ireland are perhaps in an intermediate category, with some combination of under-recording in the 1930–69 period coupled with real, and ongoing, spread. The presence of *Triticum aestivum* in Table 6.2 is most likely the result of changes in recording culture, with casual plants by roads and in towns reported more frequently than previously.

The short-term increasers deserve additional comment, as, on average, these are likely to be estimated with less bias across the territories. For Britain this includes garden escapes or plantings such as *Alchemilla mollis**, *Allium triquetrum*, *Campanula poscharskyana*, *Cyclamen hederifolium*, *Erigeron karvinskianus*, *Geranium* × *oxonianum**, *Hyacinthoides hispanica* agg.*, *Lamiastrum galeobdolon* subsp. *argentatum**, *Lonicera nitida*, *L. pileata* and *Tellima grandiflora*. The starred taxa also appear in the top 25 increasers for Ireland. Of these the *Allium*, *Cyclamen* and *Erigeron* received change estimates in the *New Atlas*, all appearing in the top 100 for Britain at that time; their onward marches continue. *Geranium endressii* also appeared in that top 100 list, and the fact that *G.* × *oxonianum* has a much larger predicted increase in our analysis may result from an increasingly critical approach to recording this cultivated hybrid and its parents. Perhaps the most eye-catching result among the garden plants in Table 6.4 is the presence of *Cotoneaster sternianus* in the Irish list. This garden shrub has been very well recorded by two botanists in County Waterford since the year 2000, and many, if not the majority, of these records appear to refer to self-sown plants (Green, 2008). Given that Waterford is also the best-recorded county in Ireland in recent years (see Chapter 5), this means that our estimate of change for this species is very high, even though there is also clear uncertainty (see the relevant line ensemble plot on the Trends page of the *Plant Atlas 2020* website for this taxon).[11]

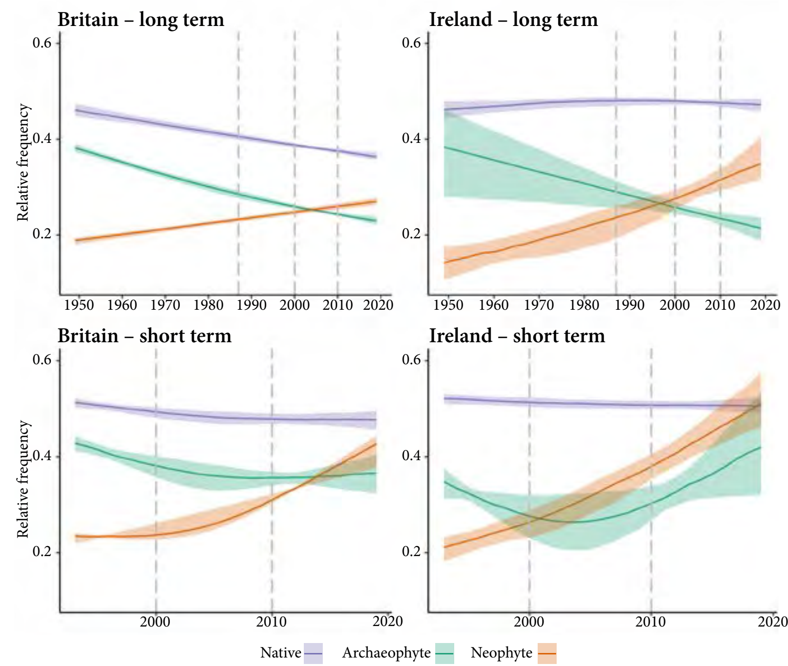

Figure 6.4. Smoothed status trends by region and analysis, medians with 90% uncertainty intervals. Numbers of taxa averaged: Britain long term: Native = 1,274; Archaeophyte = 148; Neophyte = 248. Ireland long term: Native = 882; Archaeophyte = 106; Neophyte = 353. Britain short term: Native = 1,359; Archaeophyte = 154; Neophyte = 850. Ireland short term: Native = 921; Archaeophyte = 105; Neophyte = 801.

In the loose category of non-ornamental ruderals, we have only *Epilobium ciliatum* and *Juncus tenuis* for the long term (Table 6.2). *Epilobium ciliatum* was fourth in the top 100 list for Britain in the *New Atlas*, and has consolidated its range in the north of England and Scotland since then, although the rate of change has clearly slowed. In Ireland, where the first record was 1958, the expansion still seems to be in its exponential phase, with similar rates of change in both the short and long terms. The range infilling that was noted for *J. tenuis* in the *New Atlas* seems to have now turned into a range expansion, and, even though the species is not in the top 25 for Britain, there have clearly been considerable increases there as well as in Ireland. In the short term, the remaining top increasing ruderals are a selection of increasingly well-known grasses and composites: *Anisantha diandra*, *Echinochloa crus-galli*, *Erigeron floribundus*, *E. sumatrensis*, *Polypogon viridis* and *Senecio inaequidens*. With the exception perhaps of *A. diandra*, which prefers arable or open semi-natural habitats, these plants have become increasingly frequent in lowland urban and other anthropogenic sites throughout Britain and Ireland; milder winters are speculated to play a part in this, although with human-aided movement (in soil or along transport corridors) no doubt also a major factor. Finally, *Phacelia tanacetifolia* is much more frequently grown in the wider landscape than it was previously, variously as a constituent or contaminant of gamebird food crops, as a part of agri-environment scheme sowings (*e.g.* for pollinators), or as green manure; allotments and gardens also often feature it for some of these reasons, or just simply for ornament.

It is also worth noting that certain sets of species have fallen entirely outside the top 25 increasers selection reviewed here, despite ongoing expansions. These include the coastal halophytes spreading along roadsides inland, for example *Cochlearia danica* and *Puccinellia distans*, whose increases have been much discussed before (*e.g.* Coombe, 1994). In contrast, some species notable for their large positive change indices in the *New Atlas* are no longer near the top of the lists. This appears to be for a variety of reasons: for example, woody species that were probably under-recorded in the period 1930–69, but which are now well-recorded but fairly stable in their distributions, probably due to low rates of self-sowing and associated human-independent spread (*e.g. Laburnum anagyroides*, *Prunus cerasifera* and *Syringa vulgaris*). Some other very common taxa with high change indices in the *New Atlas*, such as the grasses *Agrostis stolonifera* and *Festuca rubra* agg., do not appear here due to the high model-based uncertainty associated with their mean time trend slopes downweighting their scores.[12]

[9] This trend is probably exaggerated a little as, although the first wild record was made in 1923, the Flora (Clapham, Tutin & Warburg, 1952) used by recorders for the 1962 *Atlas* did not separate this hybrid from *H. hispanica*.

[10] This taxon was not described until 1975; if this year was used as the baseline for the long-term trend, then it would actually be steeper than estimated.

[11] There is a technical point here relating to the fact that the Frescalo algorithm downweights neighbourhood/time period combinations with little evidence of systematic sampling (those where the proportion of local benchmark species recorded is <0·1). This means that national estimates of change will be somewhat biased towards better-sampled areas if there is a large amount of spatial variation in effort within a time period (*e.g.* see the date-class-specific "recording day" effort maps in Pescott *et al.* 2019b). Species with very clumped distributions within time periods, such as occurs when species are well-recorded only within particular vice-counties, as here for *C. sternianus*, will also have higher uncertainty (estimated standard deviation) in the Frescalo algorithm: because of the high boundary-to-area ratio of these cases, there will be a greater proportion of neighbourhoods where the species is estimated to be at an intermediate frequency (as opposed to being very common or very rare); all other things being equal, this results in higher variance because relative occupancy is modelled as a binomial variate.

Table 6.5. Top twenty-five **short-term decreasers** in Britain and Ireland.

Britain		
Taxon	**Model-based certainty**	**Status**
Blitum bonus-henricus	15·7	archaeophyte
Sisymbrium altissimum	13·3	neophyte
Viola tricolor	13·3	native
Elodea canadensis	13·1	neophyte
Triglochin palustris	11·7	native
Potamogeton perfoliatus	11·4	native
Artemisia absinthium	11·3	archaeophyte
Zannichellia palustris	11·3	native
Nasturtium microphyllum	11·2	native
Azolla filiculoides	11·1	neophyte
Polygala vulgaris	11·0	native
Ranunculus peltatus	10·9	native
Vicia sativa subsp. *nigra*	10·9	native
Silaum silaus	10·8	native
Ranunculus aquatilis s.s.	10·8	native
Koeleria macrantha	10·7	native
Senecio squalidus	10·7	neophyte
Isoetes lacustris	10·7	native
Ophioglossum vulgatum	10·7	native
Callitriche platycarpa	10·5	native
Populus nigra subsp. *betulifolia*	10·3	native
Callitriche brutia	10·3	native
Anthemis cotula	10·3	archaeophyte
Potamogeton berchtoldii	10·3	native
Poterium sanguisorba subsp. *sanguisorba*	10·3	native

Ireland		
Taxon	**Model-based certainty**	**Status**
Callitriche stagnalis s.l.	10·4	native
Arctium minus s.l.	9·4	native
Triglochin palustris	8·6	native
Chenopodium album agg.	8·1	native
Atriplex patula	7·8	native
Sisymbrium officinale	7·3	archaeophyte
Zannichellia palustris	7·3	native
Danthonia decumbens	7·0	native
Pedicularis palustris	6·9	native
Galeopsis tetrahit agg.	6·8	native
Artemisia vulgaris	6·6	archaeophyte
Glebionis segetum	6·5	archaeophyte
Carex pulicaris	6·5	native
Amaranthus retroflexus	6·5	neophyte
Crataegus × *media*	6·5	spontaneous hybrid (native × native)
Trisetum flavescens	6·5	native
Fallopia convolvulus	6·5	archaeophyte
Callitriche brutia	6·3	native
Carex caryophyllea	6·1	native
Hydrocotyle vulgaris	6·0	native
Helosciadium nodiflorum	6·0	native
Hippuris vulgaris	5·9	native
Ranunculus bulbosus	5·8	native
Helosciadium inundatum	5·7	native
Potamogeton crispus	5·7	native

Decreasing species

Tables 6.3 and 6.5 list the top 25 species with the most 'certain' decreases for both areas, for the long and short terms respectively. The British long-term list has the highest proportion of archaeophytes, largely arable weeds,[13] closely in line with the results of the *New Atlas*. These trends are largely driven by high relative frequency estimates in the 1930–69 date-class when these species were still relatively abundant in arable habitats, and would have required recent substantial recoveries to reverse this long-term decline. That being said, however, almost all of these species show much shallower trends in the short term, although in several cases a short-term linear decline of the same magnitude would have been impossible due to a paucity of recent 10 km sites (*e.g. Ranunculus arvensis*, *Scandix pecten-veneris*). One arable exception for Britain is *Anthemis cotula*, which appears to have continued to decline at the same rate since the *New Atlas*, and also appears as a top 25 decreaser for the short term in Table 6.5; another is *Blitum bonus-henricus*, although this is typically a species of disturbed fertile ground and linear features in farmed landscapes, rather than a weed of arable systems. Similar cases of ongoing declines within the decreasers include *Galeopsis speciosa*, and the native species *Mentha arvensis*, *Scleranthus annuus* and *Viola tricolor*. In general, Braithwaite *et al.* (2006) provide an excellent overview of longer-term changes in arable weeds, and we do not repeat that material here. Since then, however, McClean *et al.* (2011) demonstrated widespread declines in the mean Ellenberg fertility scores of many upland hectads, linking this to declines in the area of arable in these regions. Several of the arable plants in Tables 6.3 and 6.5 have distribution maps that are very suggestive of this pattern of marginal distributional losses due to the loss of small-scale (often subsistence) arable cultivation in these regions (*e.g. Fallopia convolvulus* and *Sinapis arvensis*). For Ireland, Morrow & Forbes (2012) provide an excellent account of agricultural change in County Fermanagh that contextualizes the decline in arable and its associated flora for that area. For the current discussion, it perhaps suffices to quote the authors' statement that, "[a]t the present time, there is very little arable land left anywhere in Fermanagh" (*ibid.*, p. 47). Pearman & Preston (2000) also discuss a Hebridean example of long-term arable decline.

Artemisia absinthium is the remaining British archaeophyte with a top 25 decreasing trend in the short term. The reason for this is unclear, although, perusing Floras for the areas outside of the persistent core of its range, one suspects that this may be to do with its apparently poor colonizing ability (Burton, 1983), coupled with too high a turnover in the types of disturbed site that it favours: a type of 'meta-population' persistence failure perhaps. This could also explain declines in areas where favoured historic (pre-anthropogenic?) habitats centred on relatively unstable substrates, such as river gravels and gravelly banks (James, 2009; Coldea, 2012).

The native decreasers in these tables cover a range of habitats, both within and across countries. With the exception of the aquatic plants, which are likely to have exaggerated declines due to the focused recording effort that they received in the late 20th century (*e.g.* the Scottish Loch Survey, the Northern Ireland Lakes Survey *etc.*; Preston, 1995b; Preston & Croft, 1997), the majority of the remaining declines appear very plausible. The British long term top 25 (Table 6.3) includes a spread of plants of various infertile semi-natural habitats, including dry calcareous grassland (*Arenaria serpyllifolia s.s.*, *Polygala vulgaris*, *Poterium sanguisorba* subsp. *sanguisorba*), and drier (*Omalotheca sylvatica*, *Solidago virgaurea*) and wetter (*Pedicularis sylvatica*) acidic habitats. The majority of these declines seem to have slowed in recent times, with only *Polygala vulgaris* and *Poterium sanguisorba* subsp. *sanguisorba* also appearing in the top 25 short-term decreasers (Table 6.5). Excluding aquatics, the remainder of the native short-term British decreasers are mainly plants of relatively nutrient-poor grassland habitats of various types (*Koeleria macrantha*, *Ophioglossum vulgatum*, *Silaum silaus*, *Triglochin palustris* and *Vicia sativa* subsp. *nigra*). *Populus nigra* subsp. *betulifolia* is the only native tree in the top 25 decreaser lists for Britain, a species that is now typically denied what would have been one of its primary regeneration opportunities in unstable floodplain woodland (Rackham, 1986).

Turning to Ireland, and again disregarding the aquatic species for which we suspect too big an impact of recording bias for their trends to be particularly meaningful, we are left with a preponderance of grassland and wayside species. The 'improvement' (*i.e.* degradation or destruction) of lowland limestone grassland no doubt accounts for the presence in this list of

[12] Very common species will tend to have large variance estimates in Frescalo, as the variance across local neighbourhoods is additive.

[13] Although notably not those species now frequently included in wild-flower mixes. See the section on "Shifting change".

Table 6.6. Top fifty **positive long- to short-term slope magnitude changes** in Britain and Ireland. These changes can either be positive shifts in direction (*i.e.* negative to positive), or shifts in magnitude in one direction (*i.e.* negative to less negative, or positive to more positive). Note that "0·000" in this table, and in Table 6.7, is the result of rounding for presentation, and does not indicate that the slope was exactly zero. The full distributions of the slopes estimated for any trend can be viewed on the *Atlas* website.

Britain				Ireland			
Taxon	***z***	**Status**	**Slope change**	**Taxon**	***z***	**Status**	**Slope change**
Bromus secalinus	147·2	archaeophyte	0·003 → 0·017	*Lamiastrum galeobdolon* subsp. *argentatum*	85·8	neophyte	0·007 → 0·020
Echinochloa crus-galli	133·4	neophyte	0·004 → 0·019	*Cotoneaster horizontalis*	75·2	neophyte	0·005 → 0·016
Erigeron karvinskianus	129·3	neophyte	0·006 → 0·020	*Buddleja davidii*	73·3	neophyte	0·006 → 0·015
Anisantha diandra	127·3	neophyte	0·004 → 0·015	*Rosa rugosa*	63·1	neophyte	0·005 → 0·019
Arum italicum	125·3	native	0·005 → 0·016	*Vulpia myuros*	59·5	archaeophyte	0·002 → 0·015
Leycesteria formosa	122·1	neophyte	0·004 → 0·014	*Carex pendula*	59·4	native	0·006 → 0·013
Hypericum androsaemum	121·0	native	0·003 → 0·011	*Valerianella carinata*	56·4	archaeophyte	0·006 → 0·017
Euphrasia arctica	118·3	native	-0·003 → 0·005	*Oenothera glazioviana*	56·0	neophyte	0·006 → 0·022
Helleborus foetidus	117·1	native	0·003 → 0·012	*Solanum nigrum*	55·7	neophyte	0·006 → 0·018
Allium triquetrum	115·5	neophyte	0·006 → 0·019	*Cupressus lawsoniana*	55·2	neophyte	0·006 → 0·014
Cichorium intybus	103·9	archaeophyte	-0·002 → 0·006	*Pinus contorta*	54·8	neophyte	0·005 → 0·013
Melissa officinalis	100·7	neophyte	0·003 → 0·011	*Tilia × europaea*	52·0	cultivated hybrid (native × native)	0·003 → 0·011
Lamiastrum galeobdolon subsp. *argentatum*	100·1	neophyte	0·006 → 0·013	*Allium triquetrum*	50·6	neophyte	0·006 → 0·017
Rosa rugosa	97·0	neophyte	0·004 → 0·011	*Leycesteria formosa*	50·4	neophyte	0·006 → 0·014
Carex pendula	92·6	native	0·004 → 0·013	*Geranium endressii*	48·6	neophyte	0·005 → 0·016
Polypogon monspeliensis	91·6	native	0·005 → 0·021	*Picea sitchensis*	48·1	neophyte	0·007 → 0·011
Pulmonaria officinalis	89·7	neophyte	0·003 → 0·009	*Phalaris minor*	47·9	neophyte	0·007 → 0·029
Erodium moschatum	89·5	archaeophyte	0·004 → 0·019	*Anisantha diandra*	47·3	neophyte	0·007 → 0·026
Origanum vulgare	88·9	native	0·001 → 0·007	*Epilobium obscurum*	47·0	native	0·005 → 0·012
Crocosmia × crocosmiiflora	88·7	cultivated hybrid (alien × alien)	0·005 → 0·012	*Aphanes australis*	46·7	native	0·001 → 0·009
Triticum aestivum	87·1	neophyte	0·005 → 0·011	*Euphorbia peplus*	46·4	archaeophyte	0·002 → 0·009
Spergularia marina	86·6	native	0·004 → 0·010	*Pilosella aurantiaca*	46·1	neophyte	0·005 → 0·015
Helianthus annuus	85·9	neophyte	0·003 → 0·011	*Malva moschata*	45·8	neophyte	0·003 → 0·013
Aquilegia vulgaris	82·7	native	0·003 → 0·007	*Epilobium ciliatum*	45·4	neophyte	0·006 → 0·011
Buddleja davidii	79·4	neophyte	0·006 → 0·012	*Veronica agrestis*	44·5	archaeophyte	-0·001 → 0·006
Oxalis corniculata	78·7	neophyte	0·002 → 0·008	*Cichorium intybus*	44·1	archaeophyte	0·003 → 0·017
Pilosella aurantiaca	78·1	neophyte	0·004 → 0·010	*Galanthus nivalis*	44·0	neophyte	0·006 → 0·014
Cornus sericea	73·4	neophyte	0·003 → 0·010	*Helminthotheca echioides*	43·7	archaeophyte	0·008 → 0·028
Geranium lucidum	73·0	native	0·003 → 0·008	*Geranium lucidum*	43·3	native	0·004 → 0·010
Polycarpon tetraphyllum	72·9	native or alien	0·004 → 0·029	*Vulpia bromoides*	43·2	native	0·000 → 0·005
Epilobium obscurum	72·0	native	0·001 → 0·007	*Arum italicum*	43·2	neophyte	0·006 → 0·019
Iris foetidissima	70·1	native	0·004 → 0·012	*Veronica polita*	40·8	neophyte	0·001 → 0·012
Juncus tenuis	69·8	neophyte	0·002 → 0·007	*Scrophularia auriculata*	40·2	native	0·003 → 0·007
Poa infirma	69·6	native	0·008 → 0·028	*Myosotis sylvatica*	39·8	native	0·005 → 0·016
Valerianella carinata	69·6	archaeophyte	0·005 → 0·012	*Atriplex glabriuscula*	39·6	native	0·000 → 0·011
Plantago coronopus	69·2	native	0·002 → 0·010	*Fuchsia magellanica*	39·2	neophyte	0·003 → 0·010
Cupressus lawsoniana	68·2	neophyte	0·004 → 0·008	*Buxus sempervirens*	38·8	neophyte	0·005 → 0·011
Torilis nodosa	68·2	native	0·000 → 0·008	*Lactuca serriola*	38·5	neophyte	0·009 → 0·028
Euphorbia amygdaloides	67·8	native	0·001 → 0·008	*Prunus laurocerasus*	38·3	neophyte	0·007 → 0·011
Galium parisiense	66·2	native or alien	0·003 → 0·021	*Calendula officinalis*	38·2	neophyte	0·005 → 0·016
Centaurea cyanus	66·1	archaeophyte	0·001 → 0·006	*Melissa officinalis*	37·9	neophyte	0·002 → 0·015
Fuchsia magellanica	65·7	neophyte	0·003 → 0·009	*Erigeron canadensis*	37·6	neophyte	0·008 → 0·024
Euphrasia micrantha	65·3	native	-0·003 → 0·003	*Allium ampeloprasum*	37·4	archaeophyte	0·006 → 0·018
Filago germanica	64·5	native	-0·001 → 0·006	*Echium vulgare*	37·3	native	0·003 → 0·017
Crassula tillaea	61·1	native	0·004 → 0·015	*Oxalis articulata*	37·1	neophyte	0·007 → 0·016
Papaver cambricum	61·0	native	0·004 → 0·007	*Tussilago farfara*	36·6	native	-0·007 → 0·002
Laphangium luteoalbum	59·7	neophyte	0·005 → 0·030	*Datura stramonium*	36·5	neophyte	0·002 → 0·025
Trifolium incarnatum subsp. *incarnatum*	59·6	neophyte	-0·001 → 0·011	*Veronica persica*	36·4	neophyte	0·002 → 0·007
Prunus laurocerasus	59·2	neophyte	0·005 → 0·010	*Dipsacus fullonum*	36·3	native or alien	0·006 → 0·012
Agrostemma githago	58·9	archaeophyte	0·000 → 0·006	*Fumaria purpurea*	36·1	native	0·003 → 0·016

Carex caryophyllea, *Ranunculus bulbosus* and *Trisetum flavescens*, and perhaps *Danthonia decumbens* to a smaller degree, although this more soil reaction-catholic species is presumably also affected by agricultural changes in upland acid pasture (Forbes & Northridge, 2012). The shift away from hay to silage in meadows may be the main driver for the declines of *Leucanthemum vulgare*, *Rhinanthus minor* and *Schedonorus pratensis* in Ireland (*ibid.*). Even with the added taxonomic uncertainty, it seems likely that the meadow eyebrights *Euphrasia arctica* and *E. officinalis* subsp. *pratensis* have also been negatively affected by such changes. The drivers of declines in the two plants of drier grassland, and other types of droughted substrates, *Aira caryophyllea* and *Rumex acetosella*, are less clear, although general environmental eutrophication may play a part in the declines of these very poor competitors (Braithwaite *et al.*, 2006). Three plants of damper, base-rich, open habitats also show strong short-term declines in Ireland: *Carex pulicaris*, *Pedicularis palustris* and *Triglochin palustris*. Direct habitat loss and drainage seem the most likely broad-scale drivers of change for these.

With the exception of the long-term decline of the elm *Ulmus minor* agg., the remaining taxa in our lists showing declines in Ireland are perhaps the most mysterious in terms of understanding change. For *Asplenium ruta-muraria*, for example, one would have assumed that reductions in acidic air pollution would have favoured fern growth in general (Lawrence & Ashenden, 1993). The species may well simply have been over-recorded in relation to the general effort expended in Ireland for the 1962 *Atlas*. The species of rough grassland and wayside are also interesting cases; for example, declines in *Artemisia vulgaris* have previously been reported for Ireland and Scotland (Rich & Woodruff, 1990), although, to our knowledge, no particularly good explanation for this has been found. Perhaps it is linked to wetter winters in already wet areas, coupled with the fact that germination in this plant is enhanced by a period of drying (Grime *et al.*, 2007)? Declines in *Agrimonia eupatoria* and *Torilis japonica* over the long term are perhaps easier to explain as the result of local eutrophication (*T. japonica* admittedly has a relatively high Ellenberg N value of 7, but competition can affect its growth, perhaps influencing its detectability; Forbes & Northridge, 2012). The estimated short-term decline in *Arctium minus s.l.* is baffling, particularly as the use of the aggregate should have avoided the taxonomic confusion in this small group.

We end with the decreasing neophytes. In the long term top 25s we have *Lolium multiflorum* and *Sisymbrium altissimum* for Britain, and *Ligustrum vulgare* for Ireland. The spatial pattern of decline for *L. multiflorum* in Britain appears reminiscent of those discussed above under the topic of declines in marginal arable land, and may be linked to the loss of ley-arable rotations in these areas. Reasons for the decline of *S. altissimum* are unclear, but are perhaps due to cleaner seed imports. The long-term losses of *L. vulgare* in Ireland appear to be in that island's wettest parts, but whether this is significant or not is unclear; at least it seems unlikely that any recording confusion with *L. ovalifolium* should have been confined to these areas alone. In the short term, the British decline in *S. altissimum* has continued, whilst the two aquatics *Azolla filiculoides* and *Elodea canadensis*, and the ruderal *Senecio squalidus*, are all new entries. Estimated declines for these taxa in Britain have been noted elsewhere (Braithwaite *et al.*, 2006; Stace & Crawley, 2015), and may reflect an increase in pests and pathogens reducing the vigour of these non-natives over the long term. Interestingly, although not listed here in our top decreasers, several other well-known invasives also show short-term declines of various sizes for Britain, including *Heracleum mantegazzianum*, *Lagarosiphon major*, *Reynoutria japonica* and *R. sachalinensis*. For some of these this may be the result of targeted eradication programmes. The only Irish short-term decreasing neophyte in our top 25 list is *Amaranthus retroflexus*. This plant appears quite stable in Britain over the same period, and it is not clear why it has undergone such a large decline in Ireland. Given that a large majority of the Irish records for 1987–99 are by a single recorder, it may be a case of spatio-temporal shifts in expertise unrelated to changes in the species' true local frequency.

Shifting change

Tables 6.6 and 6.7 list the top 50 species, for both areas, with the largest positive and negative shifts in time trend slope between the long and short term, scaled by the certainty of the shift. Many of the species appearing in these lists have already been covered above. However, many new species are also highlighted, and the relative positions of taxa already discussed provide additional information. For example, the neophyte aquatic fern *Azolla filiculoides* tops the list of negative slope changes for Britain (Table 6.7), despite not having the most certain decline in Table 6.5. We do not propose to discuss all of the entries in these tables here for reasons of space, but some of the patterns are worth remarking on. The vast majority of the positive shifts in Table 6.6 are for taxa that were already increasing in the long term, but for which this trend has recently increased further (*i.e.* already positive slopes becoming steeper). The only taxa here with long-term negative trends that have recently changed direction are *Euphrasia arctica*, *E. micrantha* and *Cichorium intybus* in Britain, and *Veronica agrestis* in Ireland (Table 6.6). The shift in fortunes for the eyebrights is likely to be due to improved recording in recent decades. This may also be the case for *V. agrestis* in Ireland, possibly due to more attention being paid to ruderal habitats, but perhaps also because of recorders having to relearn its characters after its earlier decline (*e.g.* Forbes & Northridge, 2012).

There are many more taxa for the opposite case, *i.e.* long-term positive trends with recent negative downturns, in Table 6.7, particularly for Ireland.[14] Many of these cases are aquatics, where the already discussed drop-off in recording since the late 20th century is likely to be the main culprit; of course, there may also be real change admixed with the recent potentially biased recording for some of these taxa. The British list includes another neophyte, *Veronica filiformis*, that seems to have previously only possessed "anecdotal evidence" of a decline (Stace & Crawley, 2015); although James (2009) suggests that it may also sometimes be overlooked in drought years. The decline in *Symphytum officinale* is probably largely due to historic over-recording for *S.* × *uplandicum*, something that was also conjectured by Braithwaite *et al.* (2006). The Irish species showing the same pattern of an overall positive trend shifting to more recent decline are a mixed bag; species not already discussed or fitting into categories with which we have already dealt include *Carex diandra*, *C. dioica*, *C. rostrata*, *C. viridula*, *Conopodium majus*, *Epilobium palustre*, *Erucastrum gallicum*, *Hesperis matronalis*, *Isolepis setacea*, *Sanicula europaea*, *Setaria viridis* and *Thlaspi arvense*. The species *C. majus* and *S. europaea* fit with the finding of Rich *et al.* (2001) that plants of woodland, scrub and hedgerows had tended to increase in Ireland from pre-1960 to the systematic-random *BSBI Monitoring Scheme* survey of 1987–88; those authors speculated that this might be due to these species being relatively under-recorded historically. The recent decline could be real, however, particularly for *C. majus* given its additional occurrence in grassland habitats. The long-term positive trends for these Irish woodland taxa are probably exaggerated due to the suspiciously high relative frequency estimates for the 2000–09 date-class (this also affects *V. montana*, discussed above). This date-class was included as a separate entity due to the presence of the systematic-random *Local Change* survey of 2003–04; this was only repeated in Britain however, and the Irish data for these ten years have the fingerprints of various biases of recording focus, including these high estimates for woodland taxa. The other native taxa listed for Ireland in Table 6.7 (*C. diandra*, *C. dioica*, *C. viridula*, *E. palustre*, *I. setacea*) display more believable trajectories of change, presumably linked to increased destruction of semi-natural habitat and/or changing management since the 1987–99 period.

Another pattern worth remarking on is that Table 6.6 (positive slope shifts) is dominated by non-natives (around 65%), whereas Table 6.7 (negative slope shifts) is dominated by natives (only 19% non-natives). Table 6.6 also has just over double the number of archaeophytes as in Table 6.7, which is perhaps of interest when we consider the somewhat bleak picture painted for these non-natives by Table 6.3 (the long-term decreasers). Of particular note in this context are the recent positive trends for the former arable weeds *Agrostemma githago* and *Centaurea cyanus*, plants with small negative trends in the *New Atlas*, but which are now increasing due to their inclusion in wild-flower mixes and other planting schemes. Because of this, these species are assessed here now to be approximately stable in the long term.

Grouped trends

The final sections below present brief descriptions of the average changes over the long term for groups of species with particular ecological attributes, biogeographic affinities and habitat associations (see Hill *et al.* 2004 for more detail on the levels of the variables used, and the figure legends for the numbers of taxa averaged over in each case). As explained in the methods section above, the solid trend lines in these plots represent the median trend across the taxa averaged, and the ribbon or band represents the 90% uncertainty interval for this (note also that possible alternative trends within this band do not need to be parallel to the median line to be compatible with the range of uncertainty presented).

Aggregating over taxa within groups should help to reduce bias on average, in the same way that restricting our inferences to larger spatio-temporal scales should help to reduce the effects of uneven sampling at finer grains (Pescott *et al.*, 2019b). However, it should be borne in mind that such averaging will not eliminate bias where there is a correlation between group membership and the probability of a trend being biased in a particular direction. A clear example is the strong decline in 'underwater' species (*i.e.* those with Ellenberg moisture (F) values of 11–12) indicated for Britain in Figure 6.8; this is almost certainly driven by prevailing recording biases, as discussed above.

Ellenberg N (fertility, Fig. 6.5)

In both areas, species of less fertile habitats (*i.e.* with Ellenberg N values of between 1 and 3) appear to have fared much worse than those of intermediate or high fertility. This is in line with the findings of Preston *et al.* (2002a), as well as much other research (*e.g.* Stroh *et al.*, 2014). Perhaps counterintuitively, for Britain there is an indication that the high N value species may have declined slightly more than those of intermediate fertility

[14] We assume here that slope parameters rounded to 0·000 in these tables were essentially stable within a given analysis.

Table 6.7. Top fifty **negative long- to short-term slope magnitude changes** in Britain and Ireland. These changes can either be negative shifts in direction (*i.e.* positive to negative), or shifts in magnitude in one direction (*i.e.* positive to less positive, or negative to more negative). The full distributions of the slopes estimated for any trend can be viewed on the *Atlas* website.

Britain

Taxon	z	Status	Slope change
Azolla filiculoides	126·7	neophyte	0·002 → -0·012
Potamogeton natans	106·9	native	0·003 → -0·005
Potamogeton berchtoldii	104·3	native	0·000 → -0·006
Elodea canadensis	103·2	neophyte	-0·002 → -0·010
Potamogeton perfoliatus	102·8	native	-0·001 → -0·011
Isoetes lacustris	101·2	native	0·000 → -0·011
Ophioglossum vulgatum	100·1	native	0·000 → -0·008
Potamogeton crispus	97·0	native	0·000 → -0·007
Callitriche brutia	95·3	native	0·000 → -0·007
Sisymbrium altissimum	94·0	neophyte	-0·005 → -0·020
Callitriche stagnalis s.l.	91·3	native	-0·001 → -0·010
Zannichellia palustris	89·4	native	-0·002 → -0·010
Blitum bonus-henricus	88·5	archaeophyte	-0·006 → -0·013
Senecio squalidus	88·3	neophyte	-0·002 → -0·011
Stuckenia pectinata	86·7	native	0·000 → -0·008
Agrostis gigantea	86·2	archaeophyte	0·000 → -0·005
Myriophyllum spicatum	85·3	native	-0·001 → -0·008
Subularia aquatica	83·5	native	-0·001 → -0·010
Veronica filiformis	83·2	neophyte	0·002 → -0·004
Hordeum jubatum	80·9	neophyte	0·000 → -0·013
Myriophyllum alterniflorum	80·8	native	0·001 → -0·006
Nasturtium microphyllum	80·1	native	-0·002 → -0·009
Rorippa sylvestris	79·6	native	-0·001 → -0·007
Eleocharis palustris	79·5	native	-0·001 → -0·009
Potamogeton obtusifolius	78·9	native	0·000 → -0·009
Koeleria macrantha	78·9	native	-0·002 → -0·010
Narcissus pseudonarcissus subsp. *pseudonarcissus*	78·0	native	-0·001 → -0·008
Artemisia absinthium	77·9	archaeophyte	-0·004 → -0·013
Triglochin palustris	77·7	native	-0·004 → -0·011
Glyceria declinata	77·0	native	0·001 → -0·004
Sparganium emersum	75·0	native	-0·001 → -0·006
Brassica rapa	74·8	archaeophyte	-0·001 → -0·006
Reynoutria sachalinensis	74·7	neophyte	-0·001 → -0·009
Potamogeton pusillus	72·9	native	0·000 → -0·005
× *Schedolium loliaceum*	72·3	spontaneous hybrid (native × native)	-0·001 → -0·010
Symphytum officinale	71·4	native	0·002 → -0·004
Littorella uniflora	71·0	native	-0·001 → -0·009
Rosa tomentosa	70·0	native	0·000 → -0·010
Viola tricolor	69·8	native	-0·004 → -0·009
Callitriche obtusangula	69·5	native	-0·001 → -0·010
Carex viridula	69·4	native	0·000 → -0·008
Lupinus arboreus	68·6	neophyte	0·000 → -0·013
Silaum silaus	67·3	native	-0·004 → -0·011
Sparganium angustifolium	66·7	native	0·002 → -0·006
Catabrosa aquatica	66·1	native	-0·003 → -0·009
Cerastium diffusum	65·7	native	-0·001 → -0·007
Reseda lutea	65·5	native or alien	-0·001 → -0·008
Brachypodium pinnatum s.l.	65·3	native	-0·003 → -0·013
Senecio sylvaticus	65·1	native	-0·002 → -0·006
Papaver dubium s.s.	65·0	archaeophyte	-0·003 → -0·007

Ireland

Taxon	z	Status	Slope change
Arctium minus s.l.	103·7	native	0·002 → -0·013
Potamogeton natans	82·0	native	0·005 → -0·005
Triglochin palustris	74·3	native	-0·001 → -0·012
Zannichellia palustris	72·8	native	0·000 → -0·015
Potamogeton crispus	72·7	native	0·003 → -0·008
Chenopodium album agg.	71·2	native	-0·001 → -0·010
Amaranthus retroflexus	67·8	neophyte	0·001 → -0·024
Callitriche brutia	63·7	native	0·000 → -0·012
Thlaspi arvense	62·5	archaeophyte	0·002 → -0·011
Callitriche stagnalis s.l.	61·4	native	-0·004 → -0·012
Callitriche obtusangula	61·2	native	0·002 → -0·010
Potamogeton pusillus	60·8	native	0·002 → -0·011
Carex caryophyllea	60·6	native	0·000 → -0·007
Potamogeton polygonifolius	60·2	native	0·006 → -0·002
Ranunculus bulbosus	59·0	native	0·000 → -0·008
Hesperis matronalis	55·8	neophyte	0·002 → -0·004
Helosciadium inundatum	55·3	native	0·000 → -0·011
Carex pulicaris	55·2	native	-0·001 → -0·008
Bidens cernua	55·2	native	0·000 → -0·010
Veronica scutellata	55·0	native	0·001 → -0·006
Sanicula europaea	54·8	native	0·003 → -0·004
Persicaria lapathifolia	54·2	native	0·000 → -0·007
Hippuris vulgaris	53·5	native	0·000 → -0·008
Lemna minor	53·1	native	0·001 → -0·008
Carex viridula	52·8	native	0·001 → -0·009
Sparganium angustifolium	52·6	native	0·001 → -0·013
Carex lepidocarpa	52·3	native	0·000 → -0·008
Potamogeton coloratus	51·4	native	0·002 → -0·011
Ranunculus hederaceus	50·2	native	-0·001 → -0·007
Isolepis setacea	50·0	native	0·002 → -0·002
Rosa mollis s.s.	49·9	native	0·000 → -0·026
Carex dioica	49·9	native	0·002 → -0·010
Conopodium majus	49·3	native	0·004 → -0·002
Epilobium palustre	49·3	native	0·002 → -0·006
Trisetum flavescens	49·3	native	-0·002 → -0·010
Erucastrum gallicum	48·7	neophyte	0·002 → -0·026
Veronica anagallis-aquatica	48·7	native	0·001 → -0·004
Setaria viridis	48·6	neophyte	0·002 → -0·022
Helosciadium nodiflorum	48·3	native	-0·002 → -0·010
Sparganium emersum	47·6	native	0·003 → -0·003
Symphytum officinale	46·6	native	0·003 → -0·004
Carex lasiocarpa	46·4	native	0·000 → -0·011
Carex diandra	46·4	native	0·001 → -0·006
Elodea canadensis	46·1	neophyte	0·004 → -0·003
Carex canescens	45·8	native	0·000 → -0·009
Stuckenia pectinata	45·5	native	0·003 → -0·006
Carex rostrata	45·2	native	0·001 → -0·006
Catabrosa aquatica	44·9	native	0·000 → -0·007
Pedicularis palustris	44·8	native	-0·003 → -0·010
Glyceria notata	44·5	native	0·001 → -0·005

in recent years (the short-term part of the slope being marginally steeper for the high-fertility group). Although many such species are associated with agricultural land enriched with fertilizers, other factors, such as the use of herbicides and improved seed cleaning, as well as a general 'tidying-up' of agricultural land, may have led to a loss of highly eutrophic areas supporting specialized species (*e.g.* areas poached by chickens and geese, manure heaps, *etc.*). The trends in Ireland are qualitatively similar, in that the 'low' group show a probable recent decline, and that species of intermediate fertility environments have performed better than those at the higher end of the Ellenberg N range.

Ellenberg R (reaction, Fig. 6.6)
In Britain, species adapted to more acidic or base-rich environments have steeper declines than those associated with soils (or waters) of intermediate reaction. Trends for those species associated with base-rich habitats have been on average steeper, possibly because these habitats are more restricted to southern Britain where land-use changes have been greater. In Ireland, the trends at the two ends of the spectrum are much more uncertain, although a recent downturn for species of the most acidic habitats appears likely; these two, however, are in clear contrast to the increase in species of intermediate reaction status, with its high model-based certainty.

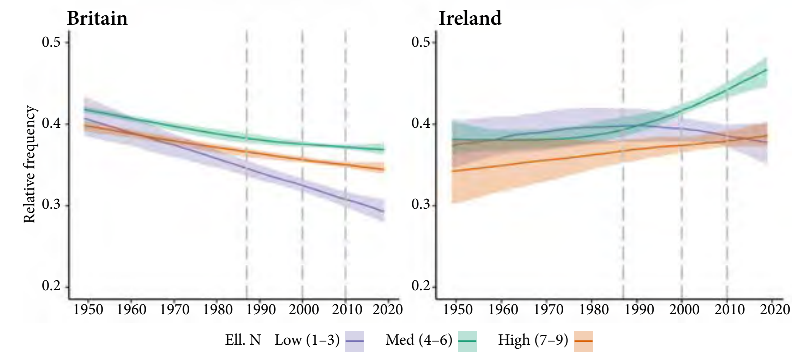

Figure 6.5. Ellenberg N smoothed long-term trends, medians with 90% uncertainty intervals. Numbers of taxa averaged: Britain: Low = 626; Medium = 820; High = 261. Ireland: Low = 402 taxa; Medium = 711; High = 240.

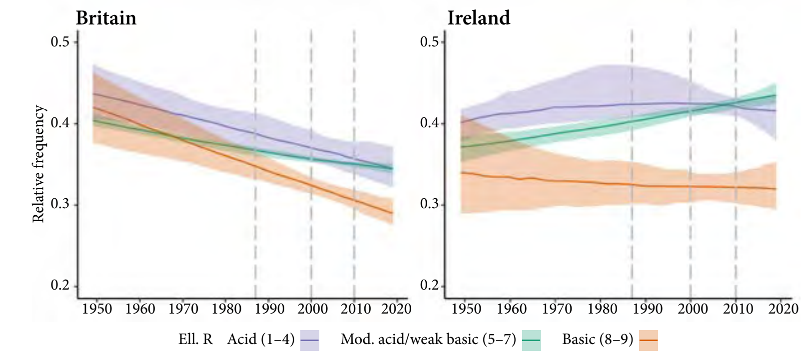

Figure 6.6. Ellenberg R smoothed long-term trends, medians with 90% uncertainty intervals. Numbers of taxa averaged: Britain: Acid = 227; Moderate acid/weak basic = 1,209; Basic = 271. Ireland: Acid = 169; Moderate acid/weak basic = 1,025; Basic = 159.

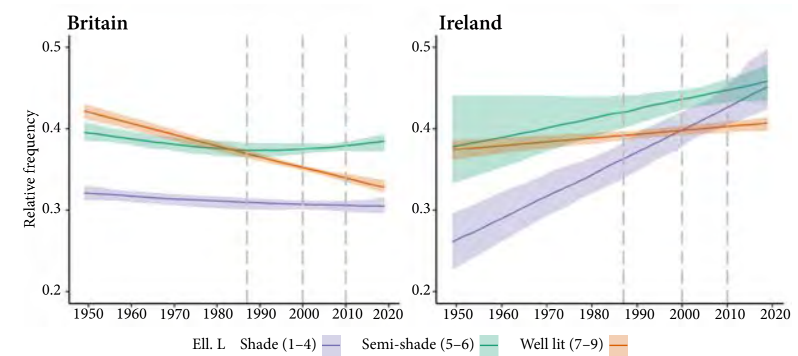

Figure 6.7. Ellenberg L smoothed long-term trends, medians with 90% uncertainty intervals. Numbers of taxa averaged: Britain: Shade = 92; Semi-shade = 307; Well lit = 1,327. Ireland: Shade = 76; Semi-shade = 263; Well lit = 1,014.

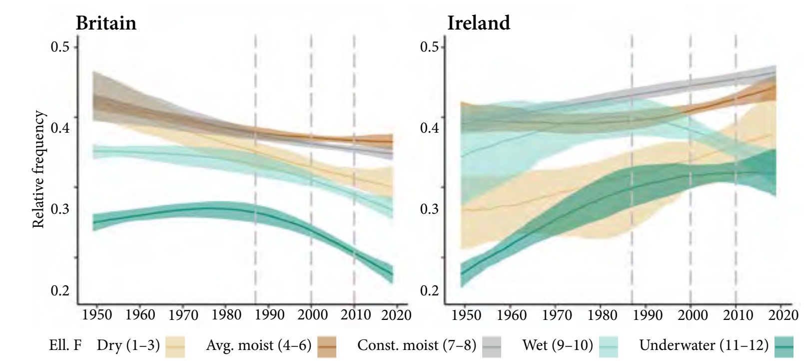

Figure 6.8. Ellenberg F smoothed long-term trends, medians with 90% uncertainty intervals. Numbers of taxa averaged: Britain: Dry = 175; Average dampness = 999; Constantly moist = 282; Wet = 176; Underwater = 75. Ireland: Dry = 101; Average dampness = 825; Constantly moist = 223; Wet = 139; Underwater = 65.

Ellenberg L (light availability, Fig. 6.7)
For Britain, only slight declines, if any, are suggested for species of lower or intermediate light environments (*i.e.* shaded habitats), whereas species of open environments have a strong decline with low model-based uncertainty. This supports the findings above, as the most infertile basic or acidic habitats are often also the most open (*e.g.* grasslands and heathlands). The Irish trends give a somewhat different picture, with strong increases in the low and intermediate light (shaded) categories, and a much weaker increase for species of well-lit habitats. Part of this is likely to be due to the probable biases in favour of woodland species in the 2000–09 date-class discussed above for Ireland. It is notable, however, that the relative performance between categories is similar to that in Britain, with the species of open environments having done comparatively worse than the shaded habitats.

Ellenberg F (moisture, Fig. 6.8)
The trends for taxa grouped by Ellenberg moisture value also show striking differences between areas. In Britain, the steepest declines are for species of the driest (Ellenberg F ≤ 3) and wettest (Ellenberg F ≥ 9) habitats, with the decline of the latter since the 1987–99 period likely dominated by recording bias. Many of the drier habitats also have infertile basic or acid soils, and so are correlated with the changes already described above. For Ireland, the 'underwater' grouping is roughly stable for this period, whilst the preceding category (F = 9–10) is the only group showing a decline. Here the other groups all show recent increases, even the trend for the highly uncertain 'dry' category is much more likely to be positive than otherwise.

Major biome (Fig. 6.9)
These trends are perhaps the most difficult to interpret, at least without delving into the identities of the individual species within the groups; however, several trends emerge across the two plots. The first, and perhaps most understandable, is the increases in the most southerly distributed species (groups 9 and 0), the Mediterranean-Atlantic and Mediterranean groups (although it is worth remembering that many neophyte species, which might have similar climate preferences to the members of these groups, are not included in the long-term trends; these increases are therefore probably quite conservative). The second is consistent declines in both areas for groups 5 and 6, the Boreo-temperate and Wide-temperate species (albeit small for group 5 in Ireland), which are often the most numerous biogeographic groups of species in many semi-natural habitats.

The declines in the (small) group of Wide-temperate species may be driven largely by the marginal upland declines of some weedy taxa in this group (*e.g. Atriplex patula*, *Capsella bursa-pastoris*, *Chenopodium album* agg., *Elymus repens*, *etc.*). A small decline for group 1, the Arctic-montane species, in Britain is also notable (see also Fig. 6.12).

Broad habitats (Figs 6.10, 6.11, 6.12, 6.13)
Most species in Hill *et al.* (2004) are attributed to more than one broad habitat, so, unlike the previous grouped plots, these trends are not completely independent, in that many species will contribute to more than one grouped trend. Many interesting trends, most of which appear to correspond to other sources of evidence, appear clear from these plots, however. Figure 6.10 shows a long-term decline in arable species for Britain, albeit one that has flattened of late, possibly because many species now survive in refugia where their populations are maintained by conservation measures (and possibly also due to introductions and seed sowing); whereas species of broadleaved, mixed and yew woodland show a slight

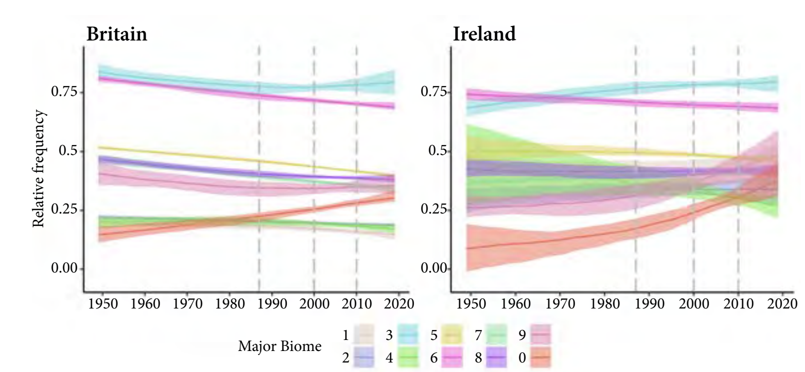

Figure 6.9. Major biome smoothed long-term trends, medians with 90% uncertainty intervals. Major biome codes: 1 = Arctic-montane; 2 = Boreo-arctic montane; 3 = Wide-boreal; 4 = Boreal-montane; 5 = Boreo-temperate; 6 = Wide-temperate; 7 = Temperate; 8 = Southern-temperate; 9 = Mediterranean-Atlantic; 0 = Mediterranean. Numbers of taxa averaged: Britain: 1 = 74; 2 = 38; 3 = 16; 4 = 108; 5 = 233; 6 = 35; 7 = 576; 8 = 297; 9 = 130; 0 = 14. Ireland: 1 = 22; 2 = 20; 3 = 14; 4 = 71; 5 = 209; 6 = 35; 7 = 464; 8 = 238; 9 = 87; 0 = 14.

Figure 6.10. Broad habitat smoothed long-term trends 1, medians with 90% uncertainty intervals. Numbers of taxa averaged: Britain: Arable = 185; Broadleaved, mixed and yew (Bld) woodland = 297; Coniferous woodland = 29; Boundary and Linear features = 487. Ireland: Arable = 159; Bld woodland = 257; Coniferous woodland = 24; Boundary and Linear features = 434.

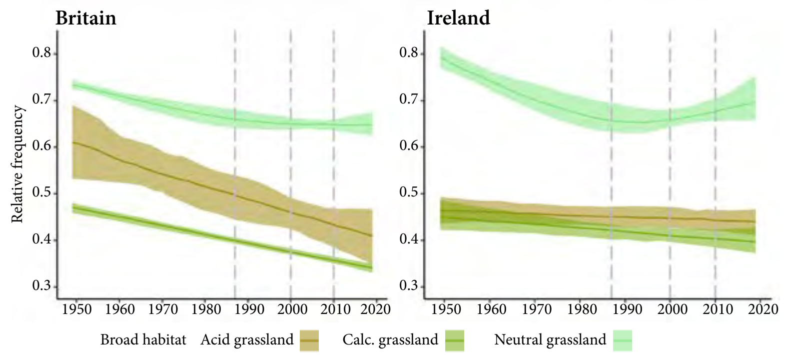

Figure 6.11. Broad habitat smoothed long-term trends 2, medians with 90% uncertainty intervals. Numbers of taxa averaged: Britain: Acid grassland = 81; Calcareous grassland = 207; Neutral grassland = 153. Ireland: Acid grassland = 54; Calcareous grassland = 146; Neutral grassland = 134.

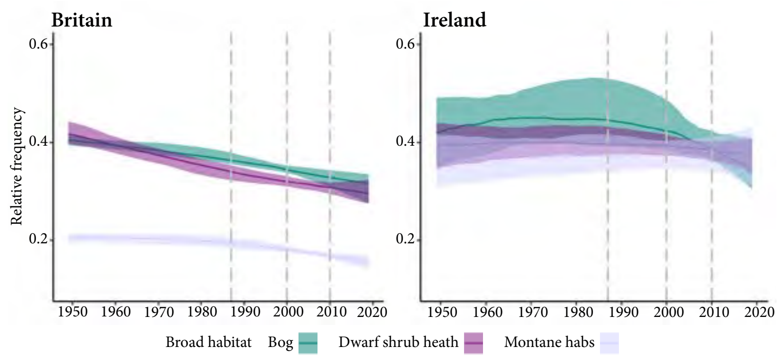

Figure 6.12. Broad habitat smoothed long-term trends 3, medians with 90% uncertainty intervals. Numbers of taxa averaged: Britain: Bog = 40; Dwarf shrub heath = 77; Montane habitats = 95. Ireland: Bog = 37; Dwarf shrub heath = 62; Montane habitats = 35.

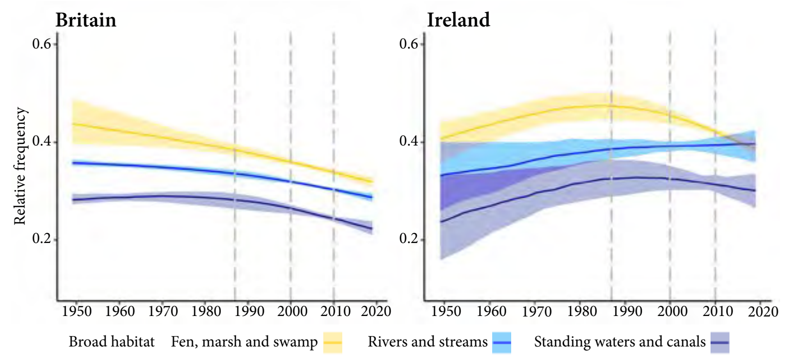

Figure 6.13. Broad habitat smoothed long-term trends 4, medians with 90% uncertainty intervals. Numbers of taxa averaged: Britain: Fen, marsh and swamp = 235; Rivers and streams = 132; Standing waters and canals = 146. Ireland: Fen, marsh and swamp = 193; Rivers and streams = 122; Standing waters and canals = 120.

increase, and those of coniferous woodland a major one due to an increase in commercial forestry and reporting of these species by recorders. Similar trends are apparent in Ireland, with the exception that the trend in arable plants is highly uncertain (perhaps due to the much more localized nature of cultivation), and could equally support a real decline or increase within its uncertainty range. Figure 6.11, the grasslands, shows average declines for species of acidic and calcareous types, whilst species of neutral grassland appear to have fared better, particularly in recent date-classes. Figure 6.12 shows a striking similarity in declines in Britain for bogs and heathlands, and to a lesser extent montane habitats. The equivalent trends for Ireland are much less clear, with the exception of species of bog habitats, which appear to have declined strongly in recent times. Given the biases repeatedly mentioned, Figure 6.13 is perhaps harder to interpret, with the trends for the rivers and streams, and standing waters and canals, groups appearing roughly parallel; this might be expected if the species therein were broadly affected by the same survey biases on average. The declines in the fen, marsh and swamp category seem more believable and are consistent with trends reported elsewhere for these species.

Conclusion

This chapter only scratches the surface of the results from the *Plant Atlas 2020* project, and it is clear from these, and from the expert accounts and maps presented in Chapter 7, that many interesting patterns remain to be investigated. No doubt the reader will spot many such trends of interest to them by browsing the species accounts in this book and online. Arbitrarily restricting the discussion to top sets of changing species is perhaps unsatisfactory, but it is hoped that the grouped trends go at least some way towards highlighting overall patterns that can be investigated in more detail in the future. In addition to the results here, the country trends available on the website also deserve inspection, albeit tempered by the acknowledgement that these are likely to be more uncertain on average, given the smaller areas dealt with.

Providing a concise overview of the changes seen in our floras over the last 20 years and beyond is challenging; however, the outline of various patterns can at least be seen amid the fog that separates the landscape of the sample from that of the truth. The fact that many of these patterns, even if bias-related, clearly build upon understanding gleaned from previous surveys should give us additional confidence that we have not strayed too far into serious error. It seems clear, for example, that many declines in species of open, infertile, semi-natural habitats have continued; tendencies towards recent stabilization have also been suggested for some groups, such as for the historical declines in arable weeds and plants of neutral grassland in Britain. These conclusions both reinforce the findings of previous studies (*e.g.* Braithwaite *et al.*, 2006). Other patterns described here, for example the recent decline in species of bogs in Ireland, do not seem to have been previously demonstrated at the national scale (*cf.* McCollin & Geraghty, 2015). Likewise, the large increase in species with southern biogeographic affinities is very much apparent, even if the included taxa only represent a small sample of such plants in our floras. The rise and rise of neophyte aliens has also been strikingly demonstrated, albeit with some falling away of invasive species, perhaps due to modern surveillance and control. The deficiencies in our understanding are also clear, and the fact that we can say little that we consider reliable about aquatic species is an unfortunate consequence of a change in relative effort between aquatics and non-aquatics between time periods, even when adjusting for changes in regional recording activity. Other slight oddities, such as some 'confident' declines in ubiquitous species over the long term (*e.g. Poa annua* or *Rumex obtusifolius* in Ireland, *Urtica dioica* in Britain),[15] seem likely to have similar origins. Here, it seems possible that over-recording relative to the overall effort for the 1930–69 period may be to blame, perhaps due to the BSBI's 'common species' initiative (Scott, 1975; Perring & Scott, 1977).[16]

[15] See these species' accounts in Chapter 7.

[16] Whilst this was initiated in 1975 (Perring & Scott, 1977), it seems unlikely that these gap-filling hectad contributions for common species would have been dated accurately, and they are now probably subsumed into the 1930–69 date-class (Dr C.D. Preston, *in litt.*).

Chapter 7: Introduction to the species accounts

The species accounts that follow contain distribution maps and accompanying text and graphics for 2,863 of the total 3,495 taxa covered by the *Plant Atlas 2020* project.

Taxonomy and nomenclature

Scientific and common names follow the fourth edition of the *New Flora of the British Isles* (Stace, 2019), save for the few exceptions listed in Chapter 3. The order in which the taxa appear follows Stace (2019). Some scientific names may be unfamiliar to readers accustomed to Stace (2010), and consequently we have provided recent synonyms in the index.

Notes on the distribution maps

The standardized base map for each taxon shows the altitude across Britain and Ireland. Areas where the maximum is <200 m have no shading. Areas where the maximum altitude is from 201 m to 400 m are shaded a pale green, 401–600 m as dark green, 601–800 m as pale brown, 801–1,000 m as dark brown, and >1,000 m as purplish-brown. The Channel Islands are included as an inset in the bottom left of the map, and Orkney and Shetland as an inset in the top right.

Due to historic data collection and compilation practices (see Chapter 1), occurrences are mapped at the 10 × 10 km (hectad) scale using multi-year date-classes. The following symbols are used to show the date of the most recent record in each hectad:

- present as a native 2000–19
- present as a native 1987–99, but not since
- present as a native 1970–86, but not since
- present as a native before 1970, but not since
- present as an introduction 2000–19
- present as an introduction 1987–99, but not since
- present as an introduction 1970–86, but not since
- present as an introduction before 1970, but not since

Note that recent reintroductions of native taxa are mapped as introductions regardless of whether the taxon was formerly native in a given hectad.

There are 45 species classified as 'native or alien'; these are mapped as native unless known to have been introduced into a given hectad. As explained in Chapter 3, the distributions of 41 native taxa are so intractably muddled by introductions that they are mapped without status using greyscale colours, with the darkest shade representing the most recent recording period, and the lightest representing the earliest. We have also used this approach for mapping *Taraxacum* and *Hieracium* at genus level. For species that are unequivocally native, hectads solely containing records of introductions are mapped as alien. All alien taxa (neophytes and archaeophytes) are mapped as introductions.

For each taxon, a key for the map includes the number of hectads in which it has been recorded in each date-class, using the combinations set out above. The key lists the total number of hectads per date-class separately for Britain, including the Isle of Man and the Channel Islands (GB), and Ireland (IR). We take the total number of hectads in these areas to be 2,852 and 1,007 respectively. Note that the key accompanying each species map presents the total number of hectads for each date-class. Consequently, the combined total for all date-classes will only rarely reflect the number of mapped dots, due to overlap, *i.e.* the most recent record for a hectad is mapped. This differs from the key in the *New Atlas*, where only the most recent date-class was stated.

Additional online map resources

The online *Atlas* (plantatlas2020.org) contains a number of additional map types not featured in these volumes for reasons of space. The basic distribution overview map on the website also contains an additional date-class (pre-1970 is broken down into 1930–69 and pre-1930), and the default presentation there is without hectad status (although this can be enabled where the information exists). The three additional summary map types on the website are: distribution-by-year range; observed change maps; and tetrad frequency maps. The distribution-by-year range maps allow the user to view the cumulative distribution of hectads by date-class: in each case the selected date-class is shown in black, along with the cumulative distribution up to that point in grey. Observed (*i.e.* unmodelled) change maps present the differences between the 1930–69 and 2000–19 date-classes, and between the 1987–99 and 2000–19 date-classes. The mapping symbols indicate observed change by categorizing hectads into gains, losses and no change between time periods. Finally, the tetrad frequency maps display the all-time observed tetrad frequency within a hectad. These map types are illustrated for *Ononis repens* in Figure 7.1.

Notes on the species accounts

The 2002 *Atlas* included accounts alongside each map that provided a concise summary of a species' overall distribution and trends, and information about habitat, altitudinal range, and global distribution. We have updated and edited all these published captions, including those that were included in the *New Atlas* CD-ROM, in light of changes in distribution that have occurred since 2000, or new information that has been published on the status, taxonomy, ecology, genetics or wider global distribution of the species. When updating the captions for hybrid taxa, we have drawn heavily on information contained in the recent *Hybrid Flora of the British Isles* (Stace *et al.*, 2015). The structure of the caption text largely follows the 2002 *Atlas* and is summarized below.

Description

This first section details the species' life-form, habitats and altitudinal range. Information concerning habitat is based on the authors' knowledge of the species and a wide variety of published reference works, primarily county Floras, scientific papers and vegetation descriptions (*e.g.* Rodwell, 1991–2000). Where specified, "lowland" indicates that a species is not found above 300 metres, "upland" indicates a species that is mainly present from 300 to 600 metres, and "montane" is used for those species that are mainly found above 600 metres. Precise altitudinal ranges are only provided for taxa occurring above 300 metres although it should be noted that many upland and montane species descend to well below 300 metres, and often down to sea level. The overall status of a species in our area *i.e.*, native (N), native or alien (N?), archaeophyte (Ar), neophyte (Ne) is presented in a circular graphic above the description, to the left of the species' name. Note that there are a small number of native species for which no status has been assigned to their mapped distribution due to intractable problems with differentiating native from introduced occurrences (see Chapter 3). In such instances, the overall national status (*i.e.* N) is used for the icon. Hybrids are annotated as Hy, with the status of the parent species, and whether the taxon is a spontaneous or cultivated hybrid, explained at the end of the paragraph.

Trends

The text in this section provides the authors' commentary on species' trends and their likely reasons, such as environmental drivers or changes to taxonomy and/or recording behaviour. This interpretation, which occasionally includes information on more localized trends, particularly for species that are rare or scarce, is often gleaned from published papers, recent surveys, county Floras and maps available in the BSBI database, as well as the authors' knowledge of the species. For neophytes, the first date of introduction into cultivation in our area, and the date of the first record in the wild, is usually included. In a few cases, comments on taxonomy are mentioned in this section, particularly when issues may have resulted in potential misidentifications, or under- or over-recording. Occasionally, the text refers to a taxon being mapped as 'all records' in the 1962 *Atlas*. This simply means that the 1962 *Atlas* map showed all records without differentiating between pre- and post-1930 occurrences.

Note that these expert interpretations may sometimes provide a view that is at variance with the modelled trend summary graphic (see *page 30*). This is partly because the modelled trends were not available to caption authors at the time of writing. Such differences may arise in a variety of ways, but the most obvious is the fact that the modelled trends attempt to adjust for overall changes in local recording effort across date-classes, which is inevitably difficult to account for when viewing raw maps. This is not to say that where there is a difference in interpretation the modelled trend should always be preferred; statistical models, particularly when applied across thousands of taxon, country and date-class combinations as here (and on the accompanying website), are inevitably an approximation of reality that will capture 'truth' to a greater or lesser extent depending on factors such as sampling variance, systematic bias and the amount of information about posited model parameters actually contained within the data (Pescott

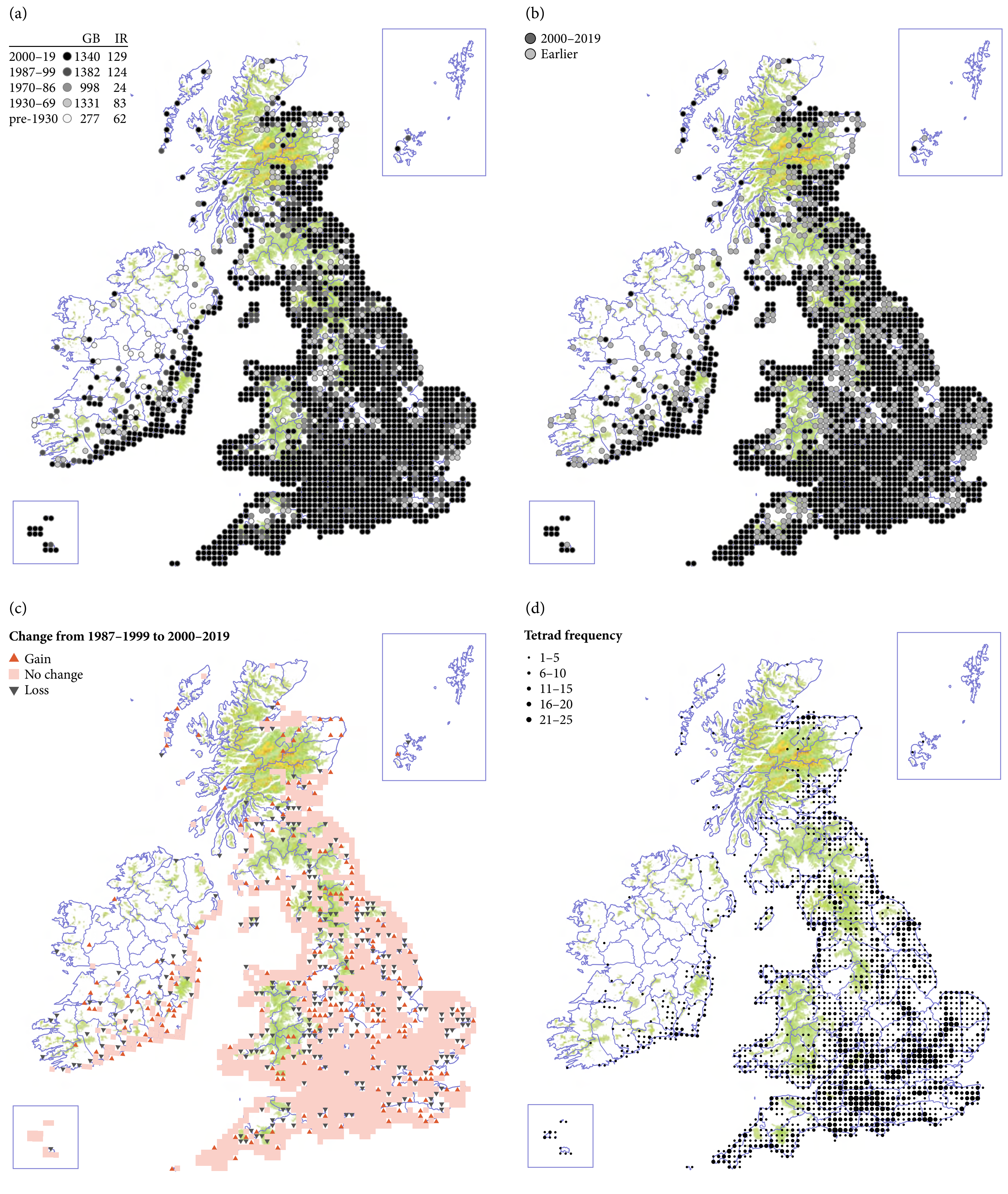

Figure 7.1. *BSBI Online Plant Atlas*-only map examples for *Ononis repens*.
(a) Distribution overview map with five date-classes, without hectad statuses; (b) distribution by year range, for 2000–19 versus all earlier periods; (c) observed change map, for 1987–99 versus 2000–19; (d) tetrad frequency map (all time).

et al., 2019b). This is particularly true for very rare and extremely common species; features of the method (and data) used mean that these are particularly likely to be biased and/or very uncertain. Ultimately, we hope that, whether in agreement or conflict, the qualitative expert assessments of change and the effort-adjusted modelled estimate (with its uncertainty) simply provide two, partially independent, views for consideration by the reader. Conflicts, or a lack of certainty, may also indicate the need to consult other analyses of change at finer scales that are likely to be more relevant for rare (Walker *et al.,* 2017) or very common (Pescott *et al.,* 2019a) species. See Chapter 6 for a more detailed explanation of these issues.

Biogeography

For native species and subspecies, the European range and phytogeographical floristic element is given according to the classification in Preston & Hill (1997). Native ranges are provided for archaeophytes and neophytes, as well as an indication as to whether they are naturalized elsewhere globally.

Key references

A list of key references is provided; these are usually only a point of entry into the literature, as to cite all relevant information available for each species is impractical for the account format. For example, we have attempted to cite all accounts published in the *Biological Flora of the British Isles* series in the *Journal of Ecology*, which themselves will contain a wealth of further references. For rare or threatened species in Britain, we have usually cited Braithwaite *et al.* (2006), Walker *et al.* (2017), or Stroh *et al.* (2019), in addition to retaining relevant references that were included in the *New Atlas*, such as Wigginton (1999), or Stewart *et al.* (1994). Biogeographic references included in *New Atlas* captions (*e.g.* Meusel *et al.*, 1965, 1978; Bolos & Vigo, 1984–95) are not cited here, but are retained in the main references section at the end of Volume 2. Four canonical references, although occasionally cited in the body of the caption text, are usually not listed in the key references to avoid unnecessary repetition: Stace (2010, 2019), Perring & Walters (1962), and Preston *et al.* (2002b). Where there are no key references for a taxon, the section is excluded.

Authorship

The text for a species caption is often based on that originally written for the 2002 *Atlas*. When such an account has been revised appreciably, the name of the author responsible for the revision is cited alongside the original author. When there has been significant revision to an account, the new author is cited first. Accounts abridged from the *Hybrid Flora* are cited as "C.A. Stace, C.D. Preston & D.A. Pearman" unless another author was specified in the original *Hybrid Flora* account.

Modelled trend summaries

Long-term (1930–2019) and short-term (1987–2019) changes in species' 10 km square relative frequencies for Britain and Ireland are presented in four summary graphics above each distribution map. Unlike for the map keys, here "Britain" is used in its strict sense, *i.e.* excluding the Isle of Man and the Channel Islands. These effort-adjusted trends were calculated and summarized using the methods outlined in Chapter 6 (see also Hill 2012, Pescott *et al.,* 2019b, and Pescott *et al.,* 2022 for more detail and justification). Note that the date-class 1970–86 was not used for any trend calculations displayed here, as the relative attention paid to taxa of varying commonness or rarity within this period was considered to be too much at variance with species' true relative frequencies for the recording effort adjustment model used to be valid (Hill, 2012). Following the 2002 *Atlas*, trend calculations used all mapped data available for a taxon, regardless of assigned native or alien 10 km square statuses.

For ease of interpretation, the trends are summarized on a five-point scale, ranging from 'strong decrease' to 'strong increase', with the relative shading intensity of each category's cell indicating the proportion of overall change associated with it. This is intended to better communicate at least part of the uncertainty associated with each trend (Pescott *et al.,* 2022); more 'certain' trends (at least as far as the model is concerned), will have a single, more intensely coloured cell; uncertain trends will show a spread of less intense colour across categories. See Chapter 6, and Figure 6.1 in particular, for more background on these summary 'strips'. Readers should also consult the online *Atlas* (plantatlas2020.org) for more information on the underlying numbers associated with these visualizations, as well as for other complementary plots, including 10 km square trends calculated separately for England, Northern Ireland, the Republic of Ireland, Scotland and Wales.

The long-term trend is only available for a subset of taxa and aggregates; these are normally taxa that were also included in the 1962 *Atlas* (Perring & Walters, 1962), although the list was also reviewed by the editors and compared to taxa listed in the main Flora available to recorders at that time (Clapham, Tutin & Warburg, 1952). In a small number of cases (and mainly for the long-term trend) an unmapped aggregate was used for a trend analysis. In these cases, the accounts for the relevant segregates will indicate the unmapped aggregate to which the given trend refers alongside the trend summary. Results for native taxa present in 15 hectads or fewer in Britain, and in 6 hectads or fewer in Ireland, within the relevant time periods covered by each trend are not given (the Irish cut-off here is based on the equivalent proportion used for Britain, where 15 or fewer hectads is the definition of the Nationally Rare designation). This is partly due to the typically very high uncertainty in the modelled results, and partly due to the fact that such very rare native species are likely to be totally censused at the hectad scale regardless of time period, potentially undermining (*i.e.* biasing) the model used here to adjust for changing recording effort across time and space (Hill, 2012). Neophytes occurring in 30 hectads or fewer post-1987 hectads across the whole of Britain and Ireland are also excluded from the short-term trends; these were totally excluded from the modelling process, rather than merely being suppressed *post hoc*. All such omitted trends are simply indicated with the text "No trend" in place of the summary.

Apparency diagram

This graphic combines the detectability and phenology of a species, together with recording intensity, and illustrates the frequency with which a species was recorded on a daily basis from 2000 to 2019, using data extracted from the BSBI database (see Fig. 7.2). These data were based on counts of unique taxon-tetrad occurrences (aggregating over finer spatial scales) on Julian days averaged across all 20 years and smoothed for presentation purposes. Days either side of New Year were excluded so that annual BSBI New Year Plant Hunt data did not unduly influence the figures on the graphs. These graphics are also available subdivided by latitude for Britain on the *Plant Atlas 2020* website.

Phenology diagram

The ranges in flowering and leafing months are displayed below the apparency graph. Flowering months are filled in as an orange bar, whilst leafing duration is shown in green (Fig. 7.2). For non-flowering plants (*e.g.* ferns, horsetails, *etc.*), the "In flower" bar is equivalent to the months when spore-bearing structures are visible. Data used for these graphics were extracted from Sell & Murrell (1996–2018) and Poland & Clement (2020) respectively. Missing months were taken from a range of other sources including, most notably for leaf phenology, the unpublished observations for over 1,000 taxa made and provided to us by John Poland. If either the leaf or flower data are missing from a species account, it is because the values were not included in the sources interrogated. The phenology of a

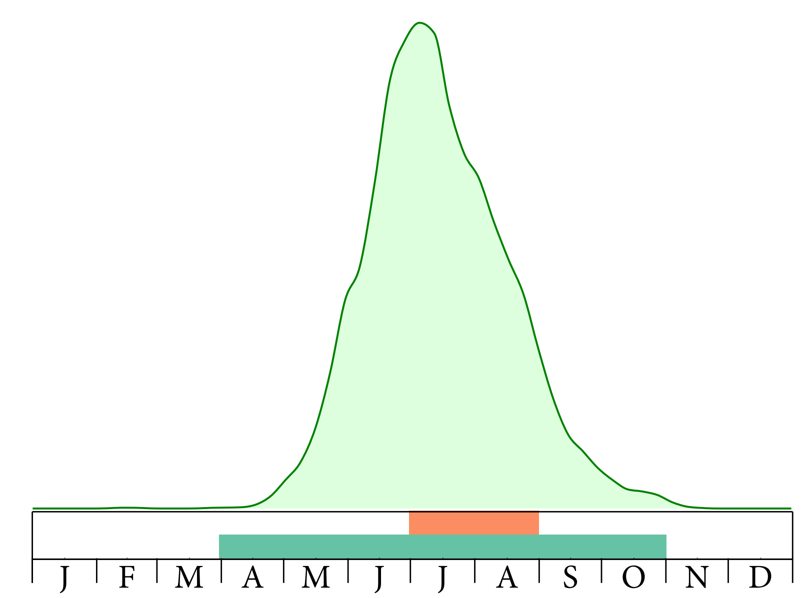

Figure 7.2. Apparency and phenology example diagrams for *Drosera anglica*, showing field records from 2000 to 2019 peaking in mid-summer. For this taxon, apparency fits well with phenology.

species will not always correspond exactly with its apparency curve due to its detectability when not in flower or leaf; see, for example, the plots of *Fraxinus excelsior* or *Phragmites australis*. In addition, published sources used for flowering and leafing may differ from the apparency diagram because the information contained in the sources used did not take into account geographic variation, especially of flowering times, throughout our area; the duration of detectability throughout the year might also now differ as a result of the effects of climate change.

Altitude diagram

Following Blockeel *et al.* (2014), this displays the distribution of a taxon within 50 km latitudinal by 100 m altitudinal bands in Britain. These plots are based on data across all date-classes, and show the proportion of all available tetrads in each latitude/altitude cell in which the taxon has been reported. Figure 7.3 shows the number of tetrads available within each such cell; cells with fewer available tetrads will often show higher occupancy when a species is present for obvious reasons. Tetrads were assigned to cells based on their means as calculated from the digital terrain dataset produced by Intermap Technologies (2009). Percentage tetrad occupancies within cells were rounded to the nearest 0·1%.

For many species there are discrepancies between the altitude diagram and the altitude range given in the accompanying text. There are several reasons for this. The most important is that the altitudinal range in the text gives the precise (*i.e.* record precision 100 m or better) altitude at which the plant has been recorded, whereas the altitude diagram gives the mean altitude of the tetrads within which it grows. The choice of the digital terrain model (DTM) used to calculate these mean altitudes (and the method of averaging) will also influence this disparity. We used a 50 × 50 m DTM with the average altitude calculated for each monad and then across the four constituent monads within each tetrad, with the monad averages weighted to take account of the area of land in each monad. Other DTMs and calculations would likely give slightly different results. Discrepancies between the text and diagram may also occur when records are plotted from tetrads in which the species actually grows outside the stated altitudinal range but for which no precise altitudinal record is available (and so the mean altitude for the tetrad is used – see example *below*). There are also some altitude records cited in the text that are not represented in the database. For some native species, the altitudinal range within the diagram falls outside the altitudinal ranges stated in the text because it includes tetrads where a species has been introduced. Where there were obvious disparities between the text and the diagram, the database was interrogated and the text corrected when a higher, precise record was found.

By way of an example, we describe the disparities between the altitudes given in the text and on the altitude diagram for *Lycopodiella inundata* (Fig. 7.4). The maximum altitude for this species is stated as 390 m in the accompanying caption text, based on a precise record in North Wales. On the altitude diagram, however, there appear to be a number of higher records, with the highest maximum altitude at 600–700 m, based on

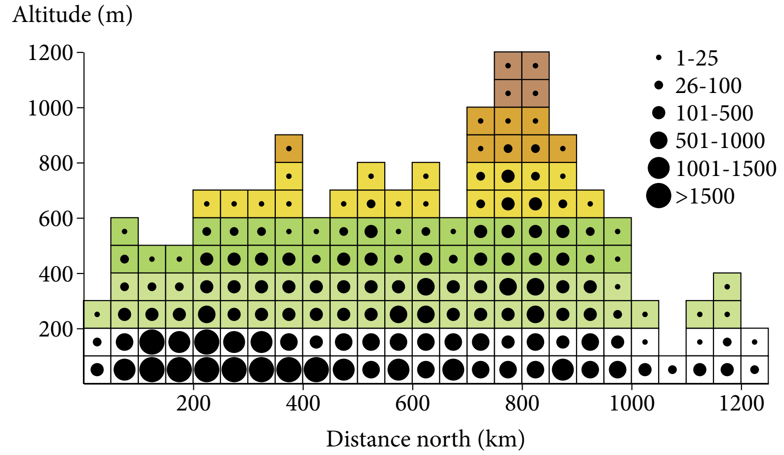

Figure 7.3. The number of tetrads within each of the latitude/altitude cells displayed in the altitude diagram, following Blockeel *et al.* (2014).

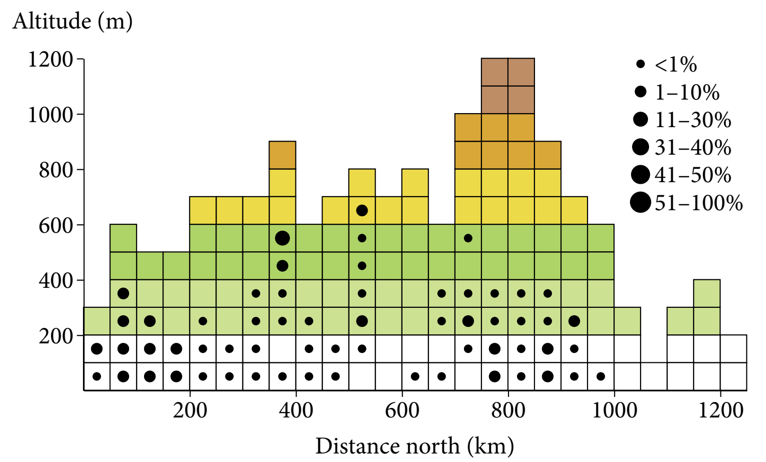

Figure 7.4. Example altitude diagram for *Lycopodiella inundata*.

a record from Red Screes in Westmorland (NY30Z). This record was submitted at tetrad (2 × 2 km) precision and so, theoretically, could occur anywhere within the tetrad. Critically, this tetrad has a wide altitudinal range (from *c.* 320 m to *c.* 760 m) and an estimated mean altitude of 638 m. The record for Red Screes was, consequently, assigned to this mean. The reader should, therefore, not assume that the diagram always shows the highest altitudinal record for a species accurately. Instead, the diagram should be used as a broad guide to the latitudinal and altitudinal distribution of a species across its entire British range.

The species accounts