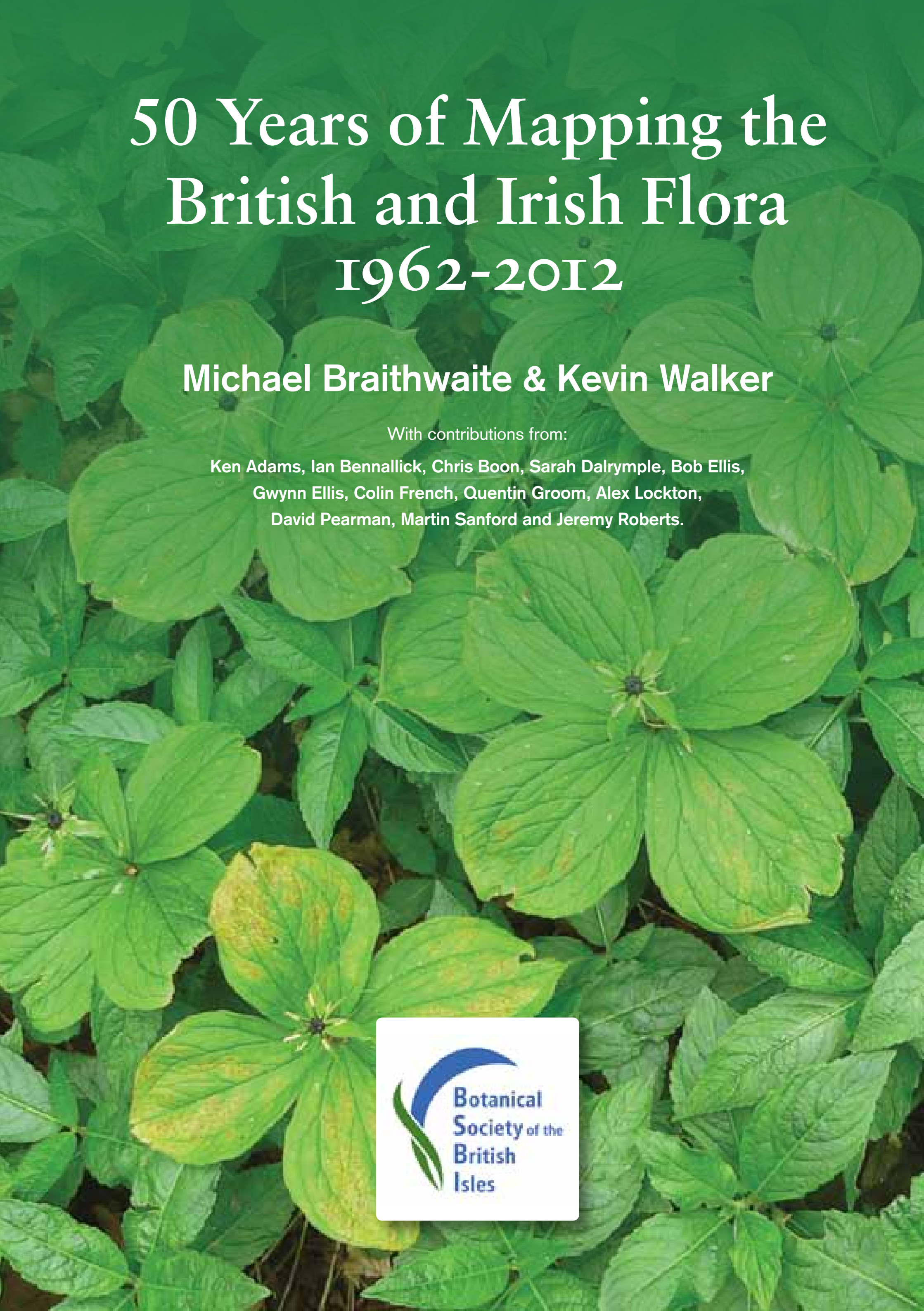

50 Years of Mapping the British and Irish Flora 1962-2012

Michael Braithwaite & Kevin Walker

With contributions from:

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The BSBI is the leading charitable voluntary organisation promoting the study and enjoyment of British and Irish plants and stoneworts (vascular plants and charophytes).
From its inception in 1836 it has welcomed both professional and amateur members. It aims to improve the understanding of British and Irish plants and to support and encourage research and conservation. The BSBI welcomes all interested botanists.

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50 Years of Mapping the British and Irish Flora 1962-2012

Introduction

This booklet has been prepared for delegates to the September 2012 conference ‘A Great leap forward – Biological Recording since the 1962 *Atlas of the British Flora*’ but we hope it is of interest to a much wider audience of biologists, conservation practitioners, policy makers and amateurs who either collect or utilise biological recording data.

It is hoped that by presenting a selection of maps prepared over the last 80 years delegates will be reminded of the setting in which the project for the 1962 *Atlas* (Perring & Walters, 1962) was conceived, the successes and limitations of the *Atlas* itself and of the numerous initiatives that it has spawned over the decades that followed, including the publication of its successor, the *New Atlas of the British and Irish flora* in 2002 (Preston, Pearman & Dines, 2002).

While this booklet does not dwell on technicalities, it is impossible to ignore the effect that technology has had on the achievements since its publication. In 1962, it was ground-breaking to prepare maps with a computer at all and all the imputing was carried out centrally at the fledgling Biological Records Centre (BRC) at Monks Wood. Now almost all recorders have a laptop computer with software and internet access that enables them to share data, prepare maps and carry out analysis at will. Furthermore the advent of handheld GPS units has enabled plant populations to be recorded with ease at fine resolution in a way unthinkable to previous generations of botanists.

We hope this booklet will, in a small way, inspire recorders as they plan their future work. There are many opportunities for yet-more-structured field recording and for further analysis with scientific and conservation objectives in mind. The key task, as ever, is to seek to use the improved communication tools to engage new generations of botanists and general public alike.

MEB & KJW August 2012

Contents

Abbreviations for key publications used in the text:

Atlas or *1962 Atlas*	*Atlas of the British Flora* (Perring & Walters, 1962)
Supplement	*Critical Supplement to the Atlas of the British flora* (Perring & Sell, 1968)
Monitoring Scheme	*The BSBI Monitoring Scheme 1987-1988* (Rich & Woodruffe, 1990)
New Atlas	*New Atlas of the British and Irish flora* (Preston, Pearman & Dines, 2002)
Local Change	*Change in the British flora 1987-2004* (Braithwaite, Ellis & Preston, 2006)

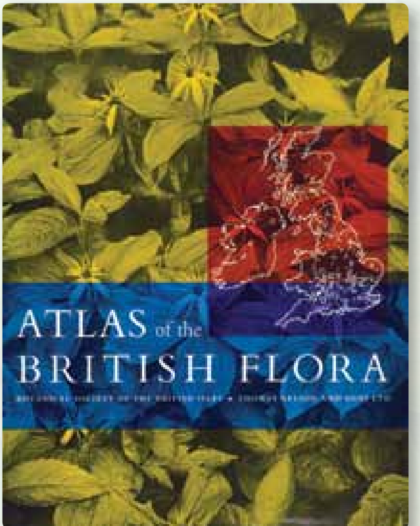
Nomenclature for vascular plants follows Stace (2010).

Mapping the national distribution of plant species

This section gives but a very brief résumé of the maps available before the *Atlas* project, those of the 1962 *Atlas* itself, their successors in the *New Atlas* and of subsequent developments.

A recurrent theme is the effect of improved recording coverage in successive surveys. Even if the effort expended in successive surveys was standardised, which it very rarely is, improved knowledge of the flora and the wider availability of fine scale Ordnance Survey maps leads to more comprehensive coverage. While it is satisfying that the survey coverage is gradually becoming more complete, it is frustrating that this leads to an understatement of losses and overstatement of gains when surveys are compared that are difficult to compensate for mathematically.

Putting these issues aside, there is much to celebrate. Our knowledge of the national distribution of the British and Irish flora is now formidable. But there is no reason to be complacent. At the site scale there are still massive shortcomings in the data desirable to inform conservation and the study of the dynamics of plant populations.



Pre *Atlas* maps outlining the range of a species: three Hiberno-Lusitanican plants, Praeger 1934

Robert Lloyd Praeger (1934) included several figures in his *The Botanist in Ireland* portraying the distribution of a species by shaded areas on a map. This was a method that was used quite widely and is still a popular one. It is particularly helpful where coverage is very incomplete, with some parts of the distribution having being much more intensively surveyed than others.

FIG. 20.—Distribution of *Dabeocia polifolia* (horizontal lines), *Erica mediterranea* (vertical lines), and *E. Mackaii* (dots).

Note.—L. Beltra in W Mayo, half way between Clew Bay and L. Conn, has now to be added to the range of *E. mediterranea*.

This figure is effective in contrasting the relatively wide but very distinct ranges of *Dabeocia cantabrica* (*D. polifolia*) and *Erica erigena* (*E. mediterranea*) with the much more localised *Erica mackayana* (*E. Mackaii*).

Maps at locality scale compared to maps at vice-county scale, *Astragalus danicus*, Walters 1950

An iconic BSBI conference on *The Study of the Distribution of British plants* was held in 1950 (Lousley, 1951) that culminated in a resolution to launch what was to become the *Atlas* project, if the necessary funds could be secured. There were papers collectively presenting a very wide review of plant distribution mapping. Stuart Max Walters (1951) presented this portrayal of the distribution of *Astragalus danicus* in his introductory talk. Although the locality map is calibrated by latitude and longitude rather than by the National Grid and although the 'dot' size of the localities is not standardised, the overall effect is very much that of the hectad maps of the *Atlas*. Its effectiveness was persuasive as to the general direction to be pursued.

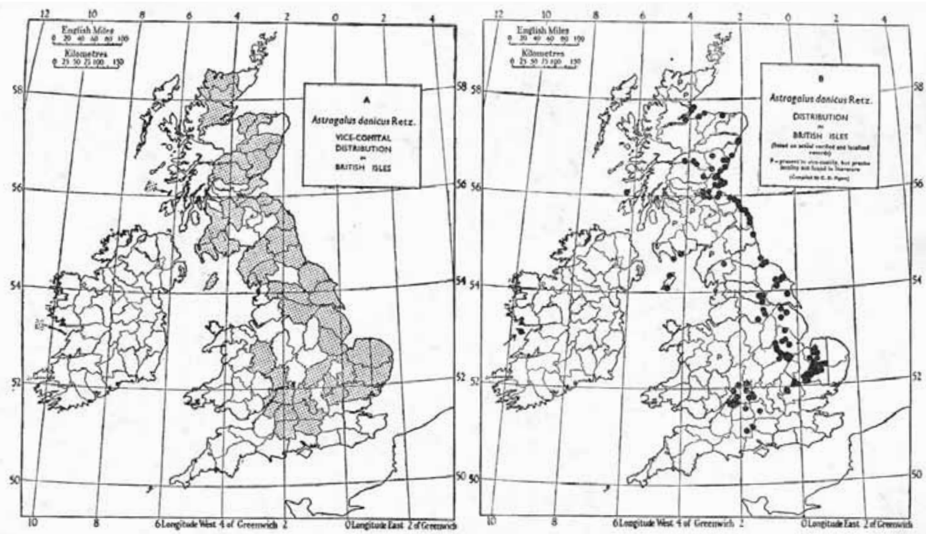


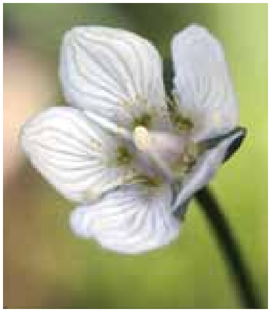
Fig. 2 Fig. 3

Astragalus danicus Retz. Comparison of the two maps shows that the very largely coastal distribution in the north is obscured by plotting by vice-counties as in Fig. 3.

The conference came to recognise how important it was to map at as fine a scale as possible given the practicalities of obtaining comprehensive coverage in a country-wide survey. The 10 × 10 km squares (hectads) of the National Grid were soon seen as an obvious choice and it was Arthur Roy Clapham who brought the various threads of the conference together and formally proposed it as the way forward.

Maps at hectad scale showing decline, *Parnassia palustris 1962 Atlas*

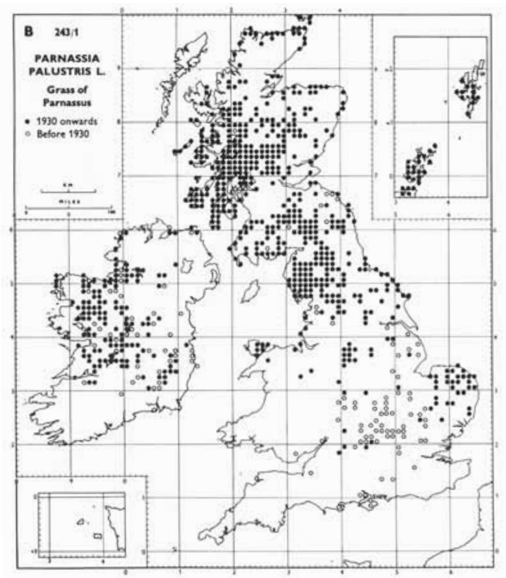
One of the successes of the *Atlas* was to demonstrate visually the sad decline in many native species. Information on the losses of *Parnassia palustris* over large parts of England had been available in county Floras for many years, but it was not until the comprehensive *Atlas* survey was complete that these could be demonstrated. These losses are shown as open circles in the map below. In many Scottish and Irish vice-counties, *P. palustris* was too common for a representative list of localities to have been drawn up so here the frequency was quantified for the first time in the *Atlas* survey.



Peter Stroh

Experience has shown that there is a strong correlation between fine scale frequency and clustering at hectad scale. Thus the scattered distribution in eastern Britain is now known to correlate with low frequency at monad or tetrad scale, while the clustered distribution in Argyll, for example, correlates with much higher frequency at monad or tetrad scale. Nevertheless, the first impression from a hectad-scale map such as this is of a frequency much in excess of the reality. It takes much experience in the field to enable the underlying frequency at the scale of individual populations to be visualised from hectad data.

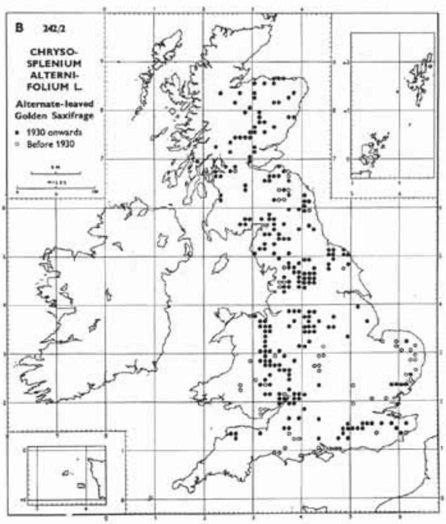
The extent of the decline shown by this map is certainly an underestimate. The survey coverage before 1930 was very much less comprehensive than the survey coverage after that date. However, in central England, where the greatest decline is apparent, *P. palustris* will have been becoming a prized local rarity at an early date and its localities will have been sought out accordingly, so the bias between dateclasses is not as great as might be supposed from the overall level of recording activity.

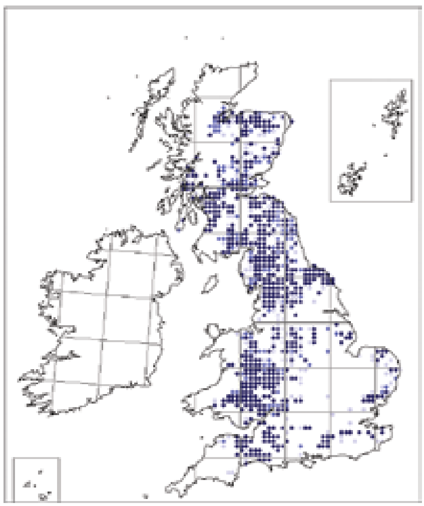


Coverage of the two *Atlas* surveys compared, *Chrysosplenium alternifolium*

Chrysosplenium alternifolium is a relatively inconspicuous herb of flushes and wet woods best surveyed in winter or early spring when its distinctive leaves are at their most obvious. It is no surprise that the *New Atlas* showed the species to be more frequent within its range than previously recorded with a *Change Index* of +0.62. This index was calculated from the hectad totals in both *Atlas* surveys and indicates the change in distribution relative to the average species. Nevertheless, the degree of under-recording in the first *Atlas* survey is striking.

There is reason to suppose that the underlying distribution of the species changed little in the period between the two surveys, with only a modest decline probable due to habitat losses. There is no evidence for the apparent spread shown by the maps. For *C. alternifolium* it is thus reasonable to attribute all the apparent spread to better survey coverage in the second survey. With such wide differences between the coverage of the two surveys, and with further wide variation species by species, it is inevitable that many frustrations should have been encountered in seeking to use the data from the two surveys to demonstrate real changes in distribution over time.





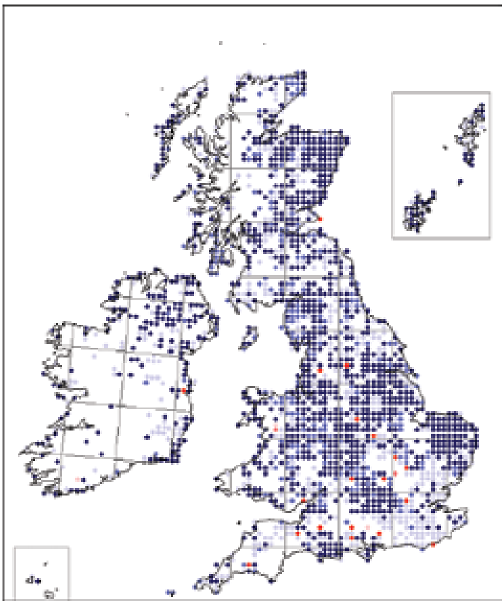
This is not a criticism of the two projects as they were not designed to be repeatable in any statistically valid way. The surveys were designed to obtain the best possible coverage for all species and inevitably this was much better for some species in the second survey. They were remarkably successful in meeting this objective.

Hectad map showing apparent decline, *Viola tricolor*, *New Atlas* 2002

Viola tricolor is a species which can occur as an annual as well as a perennial. The annual forms are most typical of arable fields and some sandy habitats, the perennial forms are more frequent in permanent grassland. The annual populations fluctuate from year-to-year in response to climate and to cropping and they may be observable only for a short window in the recording season. The species is relatively scarce in many areas. This combination of characters means that recording can be a hit-and-miss affair: it is to be expected that there would be an above average number of hectads where it was overlooked in one or other of the two *Atlas* surveys, compared to more predictable species. The overall patchiness of the map may well reflect this situation with true decline being largely obscured.

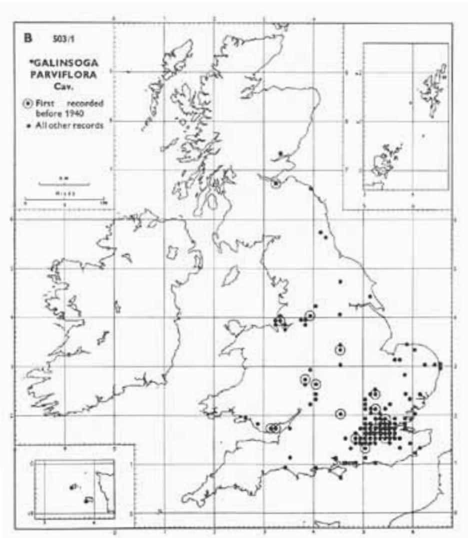
The scale of losses in southeast England is so severe that real decline is evident (e.g. Essex, Sussex). Elsewhere the position is not so clear-cut from this map alone. Statistics derived from the underlying data do suggest a real decline (*Change Index*, -1.52) but the confidence limits for this species may be wider than average due to the recording difficulties.

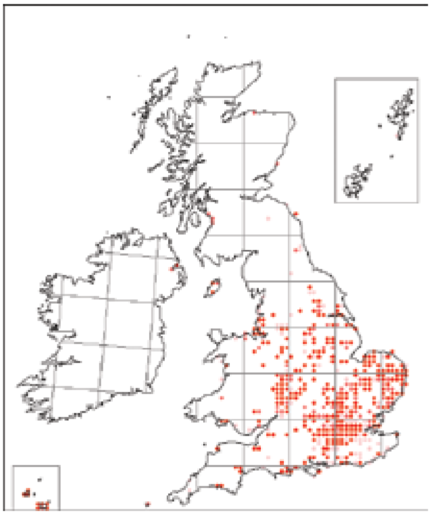
Kevin Walker



Hectad maps showing spread, *Galinsoga parviflora*, 1962 and 2002 *Atlases*

The *New Atlas* map for the Peruvian herb *Galinsoga parviflora* does not show spread, indeed it shows apparent modest decline. This is because the most recent records are placed 'on top' of older records. Therefore, it is only by comparing the two maps that spread becomes obvious, with a clear pattern of the new distribution radiating outwards from its previous limits in and around London (it was first introduced to Kew Gardens in 1796). No amount of extra recording effort in the second survey can explain this pattern.

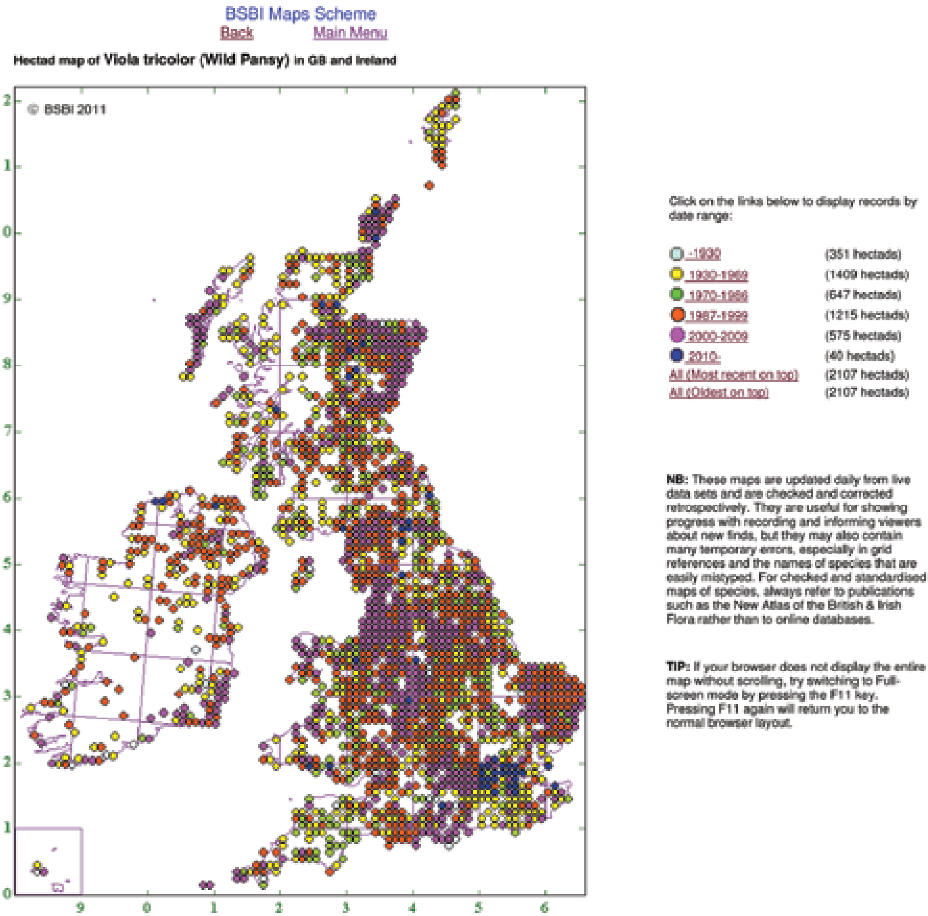




On the face of it, it is surprising that the *New Atlas* did not seize the opportunity to present 'oldest on top' maps for species that were spreading. It seems that the reason for this was the absence of adequate historical data for the great majority of aliens mapped in the *New Atlas*. Either the species had not been mapped before, or the data for the earlier map were inadequate. So uniformity of presentation was opted for and, where applicable, demonstration of spread was left to the statistics (*Change Index*, +0.63). This is a shame, as the data are compelling when adequately displayed.

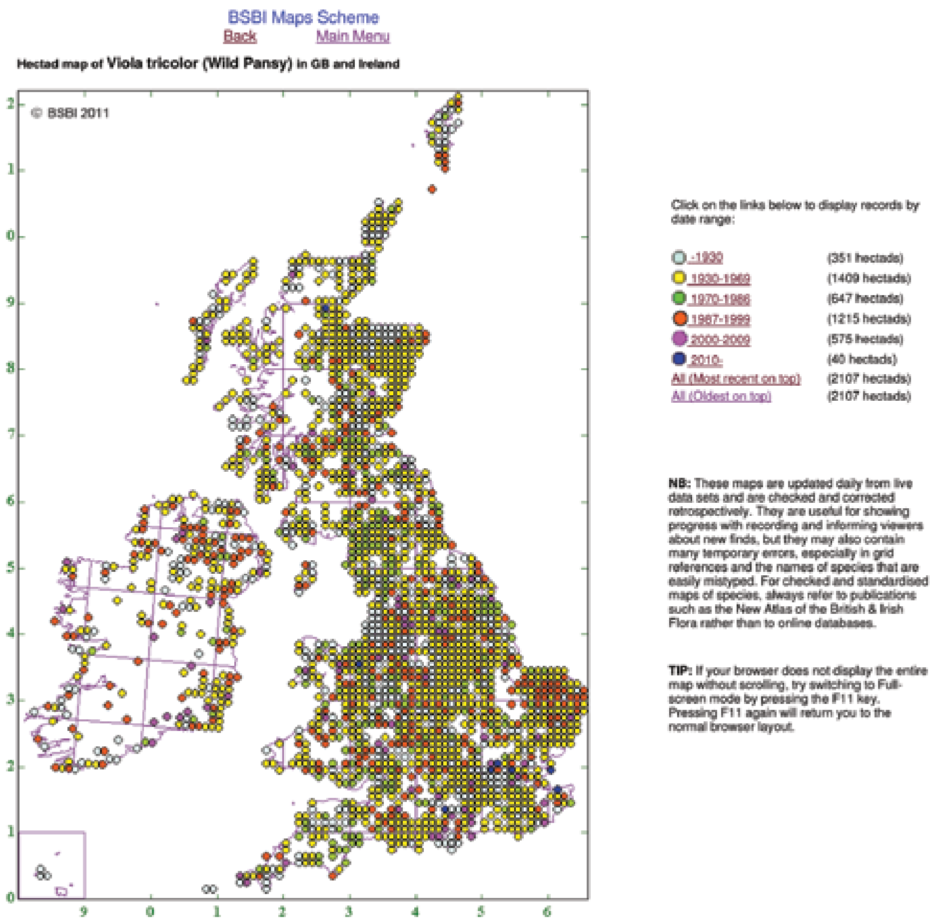
BSBI Maps Scheme website

The BSBI website now boasts a very popular hectad mapping facility which provides an up date to the maps in the *New Atlas* presenting records within six dateclasses (before 1930, 1930-1969, 1970-1986, 1987-1999, 2000-2009, 2010 onwards). These data are updated several times a year from records sent in by vice-county recorders. Only very limited checks are made centrally, so there are some anomalies. A recent innovation has been the ability to choose whether the data in the hectad maps are displayed in the familiar 'most recent on top' format with the potential to demonstrate decline or in the 'oldest on top' format with the potential to demonstrate spread.



The traditional 'most recent on top' map for *Viola tricolor* is shown left. Even allowing for the absence of recent survey in many areas, there is only modest evidence of decline. *V. tricolor* is still remarkably widespread in the areas most recently surveyed, a finding that challenges the conclusions in the *New Atlas* (see page 8).

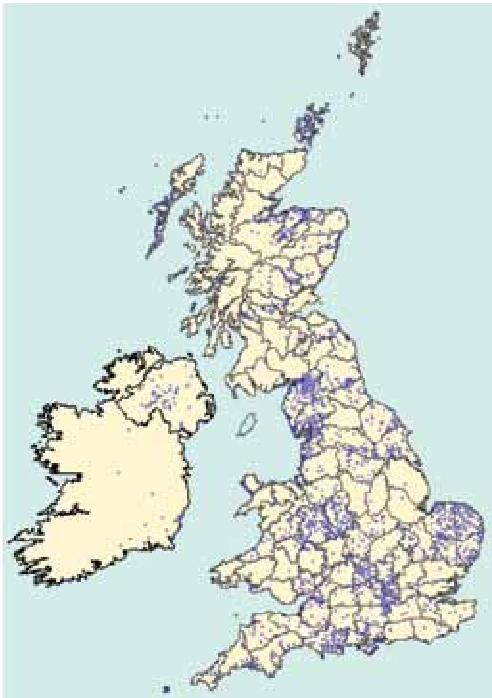
In comparison, the 'oldest on top' map (below) shows that *V. tricolor* has always been notably widespread throughout lowland Britain and that many of the gaps in the pre-1970 coverage have been 'filled' by more recent survey, for example with better survey coverage of arable areas in East Anglia between 1987 and 1999.



Tetrad scale map, *Viola tricolor*

The BSBI Maps Scheme also allows the mapping of records at the 2 × 2 km (tetrad) scale. Unlike the hectad maps, these are presented as 'all records' and are based on tetrad flora projects that have been published or are in progress. The downside of this approach is that coverage is inevitably patchy. BSBI aspires to full tetrad coverage of England and possibly Wales by 2019 but only sample tetrad coverage of Scotland and Ireland where obstacles to complete coverage at this scale are formidable.

Data from completed tetrad projects have been received from a number of English vice-counties and these clearly stand out on the map (e.g. Cumbria, Norfolk, Staffordshire). The data suggest that *V. tricolor* remains very widespread in lowland Britain, but this remains speculation on the basis of this map alone as the absence of dateclasses precludes any impression of change.



Studying the flora at finer scales

It was inevitable that, as soon as hectad maps became available, there was a demand for maps at finer scales. The outcome has been strongly influenced by the realities of County Flora projects. In England and Wales, it has been found that tetrad coverage is an achievable goal for such a project, but that finer scales (monad scale in particular) are not achievable. Many fine County Floras with tetrad maps have been published in recent years (e.g. James, 2009; Chater, 2010; Sanford & Fisk, 2010; Boon & Outen, 2011; Hawksford & Hopkins, 2011; Greenwood, 2012).

When BSBI realised that a national project was desirable to demonstrate the changes in the flora, tetrad scale was chosen as that would tie in with the County Flora projects. A sample of tetrads was surveyed in 1987-88 and again in 2003-04 and the results were published in *Change in the British Flora 1987-2004* (Braithwaite, Ellis & Preston, 2006). Much interesting change in the flora was revealed. Nevertheless, the project was not an unqualified success. It became apparent that tetrad data could never be very satisfactory as the basis for studying decline as many of the apparent losses related to populations being overlooked. More important still, habitat data were not available to help interpret the losses. Tetrad data proved more satisfactory in demonstrating spread as the survey area must be large in order to have a chance of recording scarce species.

These limitations of tetrad mapping have led to work at still finer scales. Much of the work has involved rare and scarce species leading to County Rare Plant Registers and site data. The need has largely been for data management rather than fine scale mapping, but site maps and maps of abundance are playing a part.

Tetrad maps showing change over time, *Campanula rotundifolia*, *Change in the British Flora 1987-2004*

The *Local Change* report presented statistics, a map and commentary for a selection of the species surveyed at tetrad scale in the BSBI *Monitoring Scheme* and the repeat survey, BSBI *Local Change*.

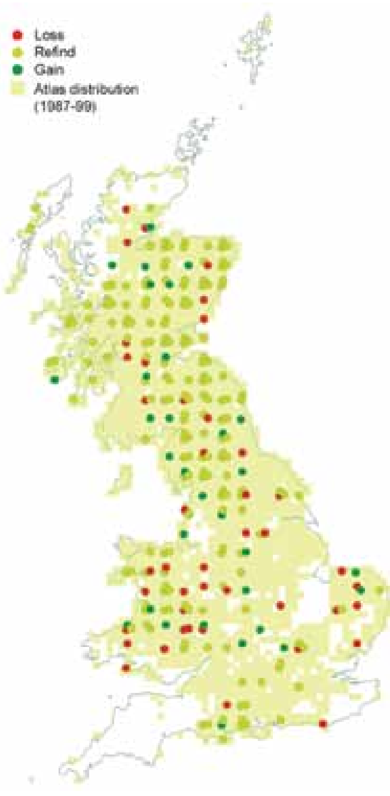
This map demonstrates the advances made and their limitations. The comparison between hectad and tetrad scale identifies areas where the species is infrequent, though allowance has to be made for areas where *Local Change* data are lacking, as in southwest Scotland and the eastern part of Yorkshire. As to the demonstration of change, what is most noticeable is that there is a mix of apparent gains and apparent losses. The probability of a species being recorded in a tetrad in which it is highly localised is relatively low, so chance comes into play.

The portrayal of change in the map is misleading unless it is appreciated that the second survey was more intensive than the first, so, in any tetrad in which it is present, a species is more likely to have been recorded in the second survey than the first. Thus, for a species with no real change more blue dots than red dots are to be expected. For *C. rotundifolia* there are more red dots than blue dots (*Mapped Change*, -5%), so the reality is of greater decline than that portrayed in the map (*Relative Change*, -11%).

Before the measures of change can be compared for groups of species it is necessary to apply a range-related weighting to allow for the fact for a very widespread species change is only likely at the fringes of its distribution and any such change observed is all the more significant. A 'Change Factor' (CF) was calculated in this way.

Campanula rotundifolia

Harebell



Mapped Change	- 5%	
Relative Change	-11%	± 7%
Weighted CF	-21%	±12%
Tetrad Frequency	67%	

Tetrad maps showing decline of an archaeophyte, *Myrrhis odorata*, *Change in the British Flora 1987-2004*

It was something of a surprise to find that the introduced species *Myrrhis odorata* is in decline. While some of its populations are well-naturalised along rivers and roadsides, others are relatively modest patches near farmsteads where it was once cultivated. It is perhaps understandable that some of these latter habitats should have been disturbed to the detriment of the species. However, the distribution is well-defined geographically and climatic factors may be at play.

Presence or absence tetrad surveys cannot in themselves give reasons for the gains and losses observed. But they provide a framework against which hypotheses can be tested and point the way for more detailed studies.

Myrrhis odorata
Sweet Cicely

Mapped Change	-14%	
Relative Change	-22%	±11%
Weighted CF	-25%	±12%
Tetrad Frequency	44%	

Tetrad maps showing increase of a native, *Vulpia bromoides*, *Change in the British Flora 1987-2004*

Although the hectad distribution of *Vulpia bromoides* did not change significantly between the two *Atlas* surveys this map shows that it has been increasing its frequency at the tetrad scale. Its natural habitat is dry nutrient-poor grassland but it is also a frequent colonist of anthropogenic habitats such as quarries, development sites and other patches of disturbed or cultivated nutrient-poor ground in rural and urban areas.

The mix of gains, losses and refinds indicates that the habitat patches occupied by this species are often small and easily overlooked unless quite an intensive survey of a range of different habitats is made. The wide confidence limits in the statistical table reflect this underlying difficulty.

Jenny Seawright

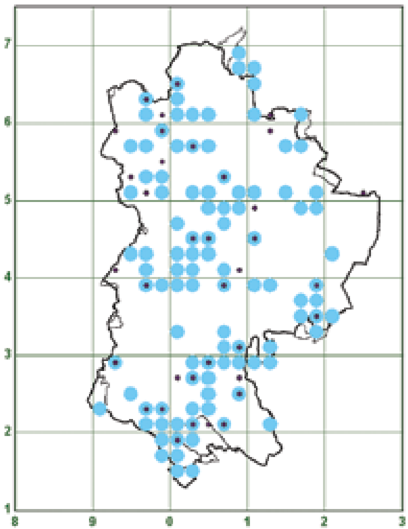
Vulpia bromoides
Squirrel-tail Fescue

Mapped Change	+33%	
Relative Change	+25%	±18%
Weighted CF	+32%	±20%
Tetrad Frequency	42%	

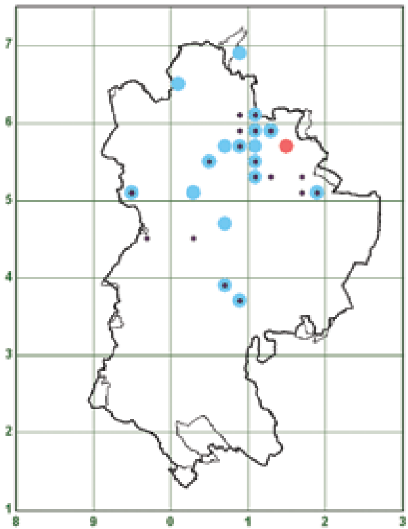
Repeating earlier surveys: tetrad scale mapping in Bedfordshire

A re-survey of Bedfordshire tetrads was completed in 2005 providing an assessment of change over the past four decades (Dony, 1976; Boon & Outen, 2011). The maps below combine Dony's 1970-76 records and the modern day distributions thereby allowing a visual assessment of the differences to be made. Four examples are provided which illustrate clear range expansions and contractions over the last 40 years that would probably not be discernible or only partially discernible at the hectad scale.

Ophrys apifera



Trifolium ochroleucon



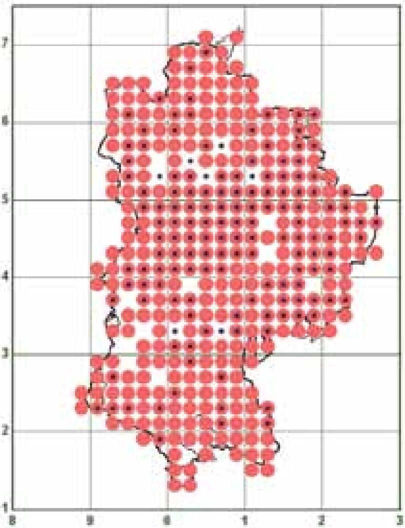
Blue disks: native 1987-2006; red disks: archaeophyte, neophyte or introduced 1987-2006; purple dots: recorded 1970-1976.

There has been a striking increase in *Ophrys apifera* (left), in line with its range expansion over all lowland England at the present time. In contrast, the picture for *Trifolium ochroleucon* (right) is more complex: its distribution has remained stable in terms of the number of tetrads (18 in both surveys) but in reality it has been lost from seven but found in seven others, including one introduction. It is a poor colonist and was therefore probably always present in these 'new' sites. Therefore it has probably been lost from around a third of its Bedfordshire sites since 1976 which mirrors declines elsewhere in eastern England (Ellis, 2004; Adams, 2007; Walker & Pinches, 2009; Cadbury, 2012).

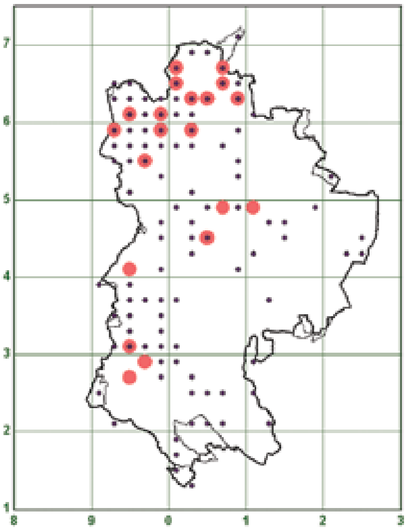
Richard Pryce

Kevin Walker

Lactuca serriola



Anthemis cotula



Red disks: archaeophyte, neophyte or introduced 1987-2006; purple dots: recorded 1970-1976

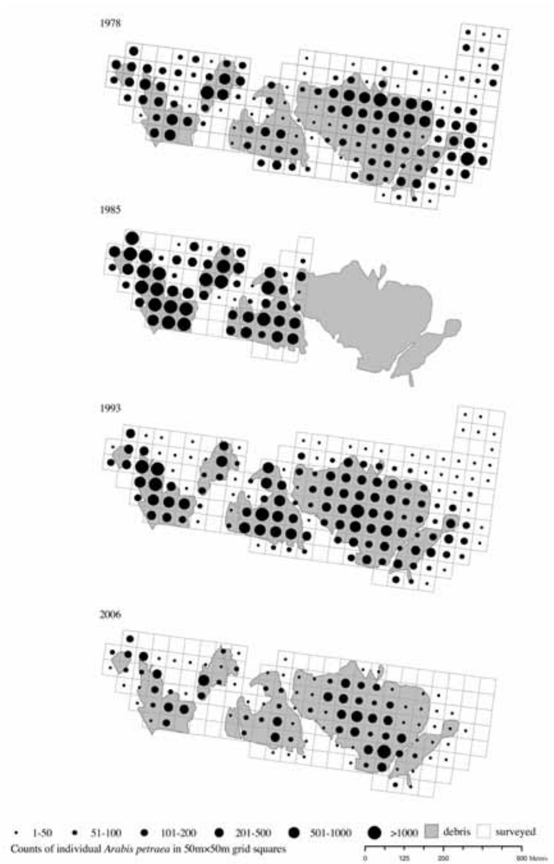
Lactuca serriola is a neophyte whose spread into ruderal habitats, like that of *O. apifera,* is a country-wide phenomenon. In contrast, *Anthemis cotula* has declined dramatically as a weed of cultivated land on the Oxford clays as elsewhere in lowland England. These results provide convincing evidence for a change in distribution for both species and supports the broader findings of the *New Atlas*.

Fine-scale mapping of serpentine specialists on the Keen of Hamar

The Keen of Hamar National Nature Reserve, Unst, Shetland has been the subject of detailed surveys to describe the distribution and abundance of rare plants and ecotypes since the late 1970s (Slingsby *et al.*, 2010). This monitoring has been undertaken in a number of small fixed plots as well as within a 50 × 50 m grid laid across the site as a whole.

Kevin Walker

The maps opposite, which show the distribution and abundance of *Cerastium nigrescens* subsp. *nigrescens* across the whole site in 1978, 1985, 1993 and 2006, demonstrate that this endemic has the potential to shift its centres of abundance within a single site within the space of a few decades. Consequently it would be difficult to conclude anything about its status from larger units or indeed in a few small, fixed quadrats alone, despite the high frequency of surveys through time. Such studies are invaluable in helping to explain the main factors controlling population dynamics such as management or in this case climate change.

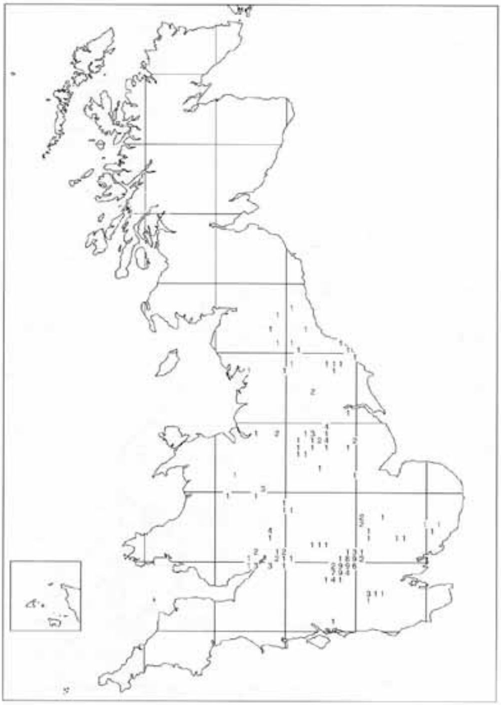


Tetrad frequency, *Scarce Plants* 1994, *Hordelymus europaeus*

In the BSBI *Scarce Plants* project (Stewart, Pearman & Preston, 1994), detailed locality information was collated for a selection of species less rare than those covered by the *Red Data Book* (Wigginton, 1999), those believed to be present in more than 15 hectads and less than 100 hectads nationally. For some of these species, data were presented by mapping the tetrad frequency as a numeral in the hectads where the species was present.

Kevin Walker

The map for *Hordelymus europaeus* the woodland grass shows that the species is frequent in the Chilterns where its hectad distribution is clustered in an unbroken oval shape. There are a few other regions where the distribution is clustered, but not as an unbroken group. The species is notably less frequent in these. This map is helpful in illustrating that texture visible in coarse-scale distributions is often a good pointer to the distribution at finer scales. To put it another way, if one investigates the fine-scale distribution of a species in one area, that knowledge may give a good indication as to how to interpret its distribution over a much wider area for which only coarse-scale data are available.

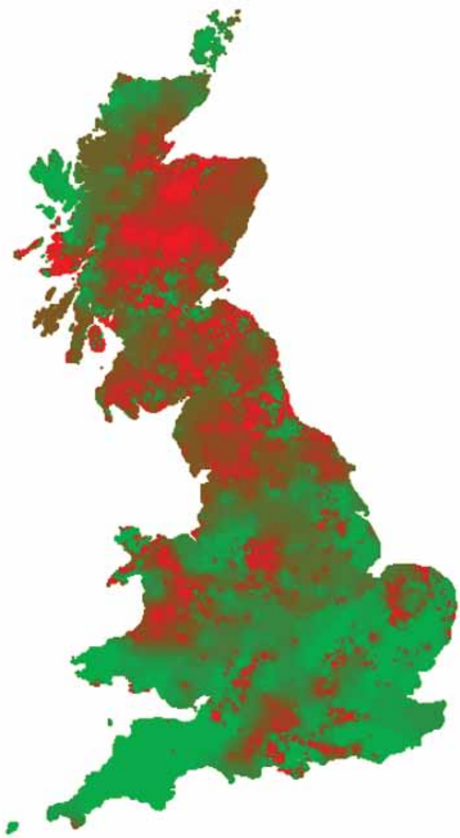


The number of tetrads in each 10 km square in which *Hordelymus europaeus* has been recorded as a native species from 1970 onwards. Squares in which the species is recorded in 9 or more tetrads are plotted as 9: *H. europaeus* is actually recorded in 9 tetrads in SP90,12 in SU78, 21 in SU89 and 22 in SU79. The species has been found in a total of 209 tetrads from 1970 onwards. The tetrad data are inadequate in Gloucestershire, where the species is still plentiful (Holland 1986).

Filling the gaps: interpolating abundance across unsurveyed areas

Kevin Walker

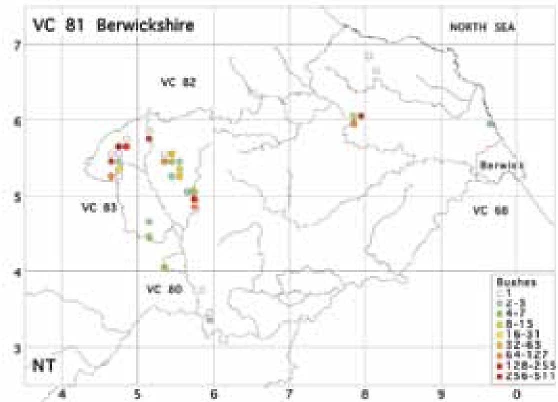
One might think that the gathering of tetrad records over the past ten years has been too patchy and inconsistent to create national maps (see page 12). However, there is an interpolation technique known as kriging which is able to make an informed guess at the presence or absence of a species based on the presence or absence in nearby squares. The map below shows the actual presence (shown in red) and absence of *Campanula rotundifolia* since 2000 with predictions of the distributions in the place of the gaps.



Kriging is possible on BSBI data, not only due to the counties which have been conducting county-wide tetrad surveys, but also because of the *Local Change* project. This national sample survey of tetrads gave us enough information in otherwise unsurveyed areas to 'fill the gaps'. It is encouraging to see that this method has picked out the restriction of *C. rotundifolia* to calcareous soils in the southern half of England, whilst the species is almost ubiquitous in the uplands. Interestingly, it is virtually absent from the southwest except on the Lizard Peninsula where it is relatively common. One advantage of these maps is that you can see much finer detail in species distributions. If you compare these maps with the hectad map for *C. rotundifolia* (page 14), the latter looks very crude.

Abundance map at monad scale, *Juniperus communis*, Berwickshire

Michael Braithwaite carried out an almost complete survey of *Juniperus communis* in Berwickshire over the two winters between 2001 and 2003. Each population was divided into 10 × 10 m cells within which individual bushes were counted. A total of 2,286 bushes were found. Only three further native bushes have come to light since, though many have been planted. For this example 1 × 1 km data has been exported from MapMate to DMap.



This map shows that in Berwickshire *J. communis* is only abundant in a quarter of the monads in which it was recorded mainly in the west of the county but with a few notable outliers to the east. More recently, digital versions of the Ordnance Survey 1:25,000 maps have become widely available on Memory-Map and as air photographss on Google Earth. These provide opportunities to prepare detailed population maps at site scale.

Kevin Walker

Abundance map at the site scale, *Dryas octopetala*

The illustration below shows a remarkably detailed map of the distribution of *Dryas octopetala* at one of its few English localities. This was produced by Jeremy Roberts using a handheld GPS with repeated 'waypointing' over the patches. Records were imported into Google Earth and overlaid onto the aerial photo using the 'MacGPS Pro' application. Each dot therefore represents presence within a 10 × 10 m grid cell. Even allowing for distortions caused by aligning the photo to the OS grid and GPS accuracy the map gives a remarkably clear impression of the distribution of *D. octopetala*, and should provide a valuable baseline for future monitoring.

Kevin Walker

Aids to interpretation of the maps

Once species distribution maps became available the need for aids to further interpretation became obvious. Transparent overlays were provided for this purpose with the 1962 *Atlas* as well as in a few older Floras. Recent County Floras have used a variety of computer generated under-lays for the same purpose to show a wide range of environmental parameters, such as soils, rivers, transport networks and urban areas.

Computers facilitate the preparation of coincidence maps and multi-species maps and these are now familiar formats for presenting often complex information and to show interesting patterns that are not obvious from single species maps. The widespread use of GIS in recent years has also increased the ease with which fine-scale distributions can be overlaid onto various mapped polygons such as the boundaries of protected sites. A few examples are provided in this section.

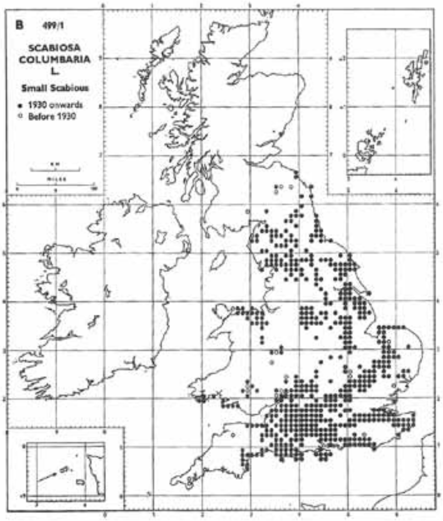
Sometimes it is most helpful to map other parameters as background to the realities of survey work. These are often vital in helping to interpret apparent changes and explain gaps in coverage. Examples are presented on survey coverage and the distribution of recorders.

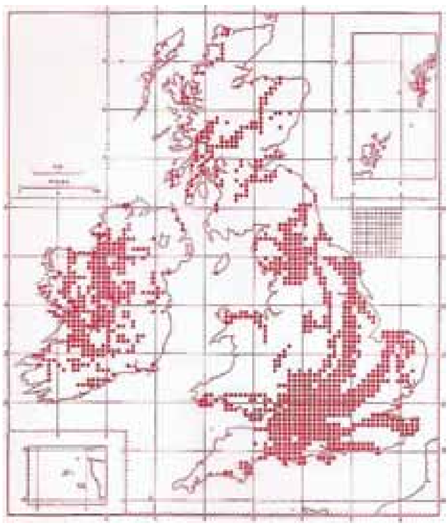
Hectad maps interpreted by overlays, *Scabiosa columbaria*, 1962 *Atlas*

Kevin Walker

Transparent overlays mapping environmental factors were a feature of the *Atlas* and have been used quite widely elsewhere. Nowadays the desired effect is often achieved by superimposing the data electronically. Interpretation is often left to the reader. It is no surprise that the distribution of calcareous grassland species match the underlying geology as the relationship has been recognised for centuries. While it can be amusing to try to match other distributions with temperature and rainfall overlays, it is rather seldom that anything very definite is learned. Plant distributions are very species specific, no two being the same, and it would require elaborate computer modelling to achieve anything like a perfect prediction of a species distribution from its observed traits, such as biogeographic affinities, January and July temperatures, precipitation, or Ellenberg indicator values for light, soil moisture, fertility and reaction. This remains an elusive goal to this day.

The distribution of *Scabiosa columbaria* almost exactly matches chalk and limestone formations in England and Wales, but the species only just reaches Scotland and is absent from Ireland. It has been reasoned that poor seed dispersal is the key to its absence from calcareous soils in these areas.

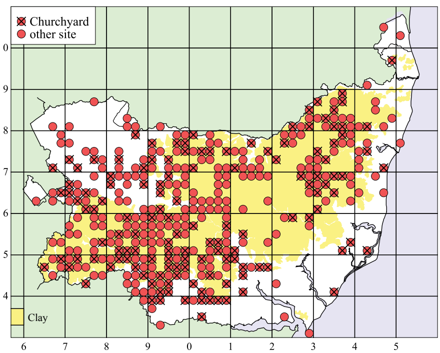


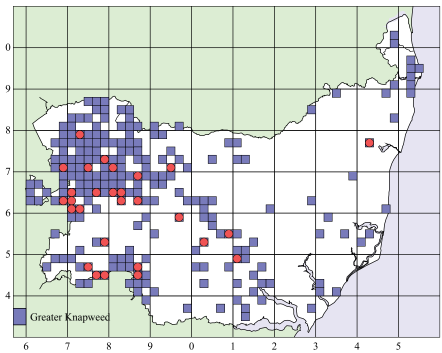


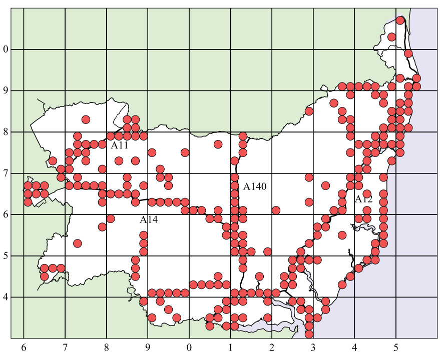
Interpreting tetrad maps by environmental underlays, Suffolk

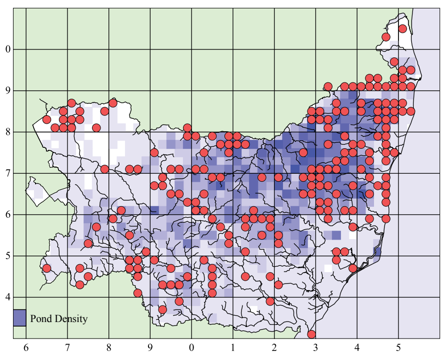
Environmental information, such as soil type, solid geology, conurbations, etc., are increasingly being used on maps in county Floras to help interpret distribution patterns. These can be extremely informative especially where a species has a very narrowly defined niche. The example maps below are taken form the recently published *Flora of Suffolk* (Sanford & Fisk, 2010) which has gone further than any other Flora in including this sort of information.

For example, they show how the distribution of *Pimpinella saxifraga* (top left) is almost entirely coincident with chalky boulder clay and often in unimproved grasslands within churchyards. Understandably the distribution of *Orobanche elatior* (top right) is nested within the broader distribution of *Centaurea scabiosa* whereas the map for *Cochlearia danica* (bottom left) clearly illustrates its spread along and away from major roads. The final map for *Potamogeton natans* (bottom right) shows the strong relationship between its distribution and the density of ponds within the county.





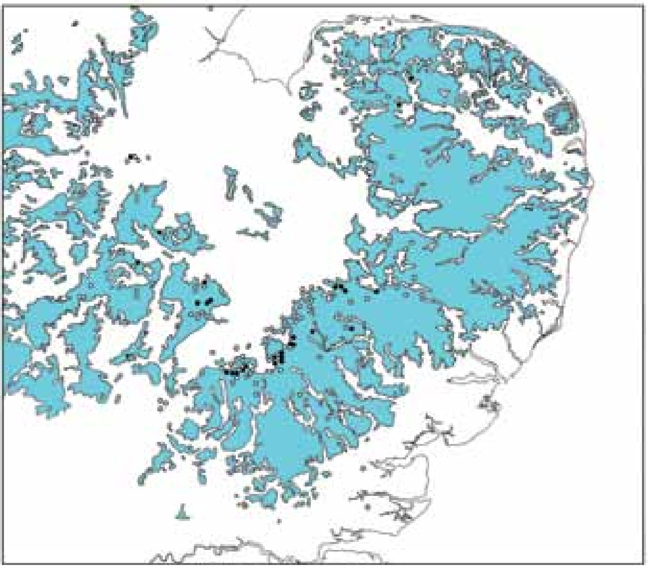




Interpreting tetrad maps by environmental underlays, East Anglia

Peter Stroh

A more detailed example is given below. This map shows the close association between the distribution of the hemi-parasite annual plant *Melampyrum cristatum* and the chalky boulder clay 'uplands' of East Anglia (open circles indicate former sites; closed circles where it is still present). The majority of sites are located on road verges and field margins on the northwestern edge of these uplands, mainly in Cambridgeshire, Essex, and Suffolk, with notable clusters in similar habitats in Huntingdonshire, Norfolk and Northamptonshire. The bulk of sites are on the gentle slopes that dip to the southeast and are therefore protected from the cold winds from the north, and being inclined to the sun will receive a greater level of insolation (Adams, 2008). This species has undergone a catastrophic decline throughout this range in the last few decades, mainly due to the flailing of road verges during the flowering period, thus preventing seed production (Adams, 2008).



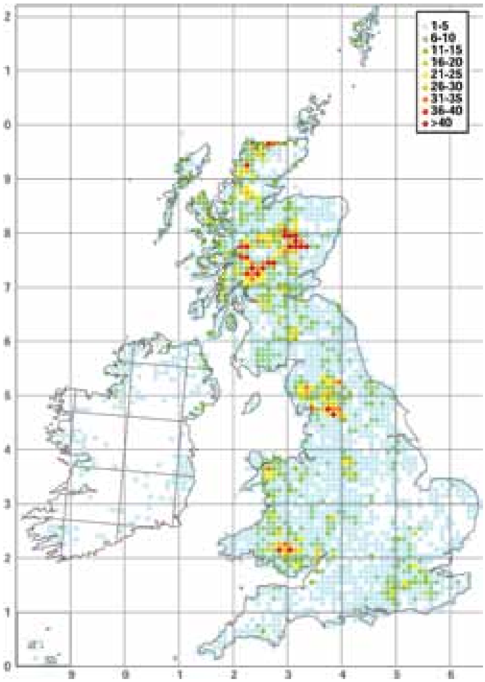
Map reproduced by kind permission of Ken Adams

Coincidence mapping: British and Irish hawkweeds

Hawkweeds (*Hieracium* ssp.) are the largest and most taxonomically difficult plant group in Britain and Ireland with over 400 microspecies. Although far from complete our understanding of their distributions has improved significantly with the publication of a critical taxonomic account (Sell & Murrell, 2006) and accompanying atlas (McCosh & Rich, 2011). The map shows the number of these species that have ever been recorded in each hectad. What is most striking is the paucity of species over much of lowland Britain in contrast to 'hot-spots' of diversity in the uplands of South Wales, northern England, and Scotland. Undoubtedly many areas remain poorly recorded, especially in Ireland, whereas others have higher than expected diversity due to the presence of active recorders (e.g. London, North Norfolk, North York Moors).

Tim Rich

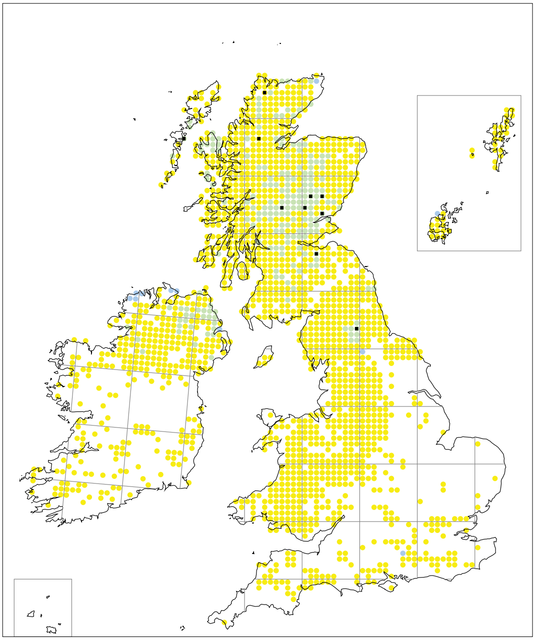
Hieracium angustatiforme, a very rare species restricted to the Brecon Beacons



Mapping the distributions of hybrids and their parents

In the forthcoming *Hybrid flora of the British Isles* hectad maps will display the distribution of hybrids in relation to parent taxa. The example given below is for *Equisetum* × *mildeanum* (*E. pratense* × *E. sylvaticum*), a rare hybrid horsetail confined to scattered sites within the restricted upland range of *E. pratense*, plus a few sites in the absence of it. The symbols show hectads with *E. sylvaticum* only (yellow), *E. pratense* only (blue), both parents (grey) and the hybrid (black). With two exceptions hybrids occur in squares where both parents are present.

Mike Foley

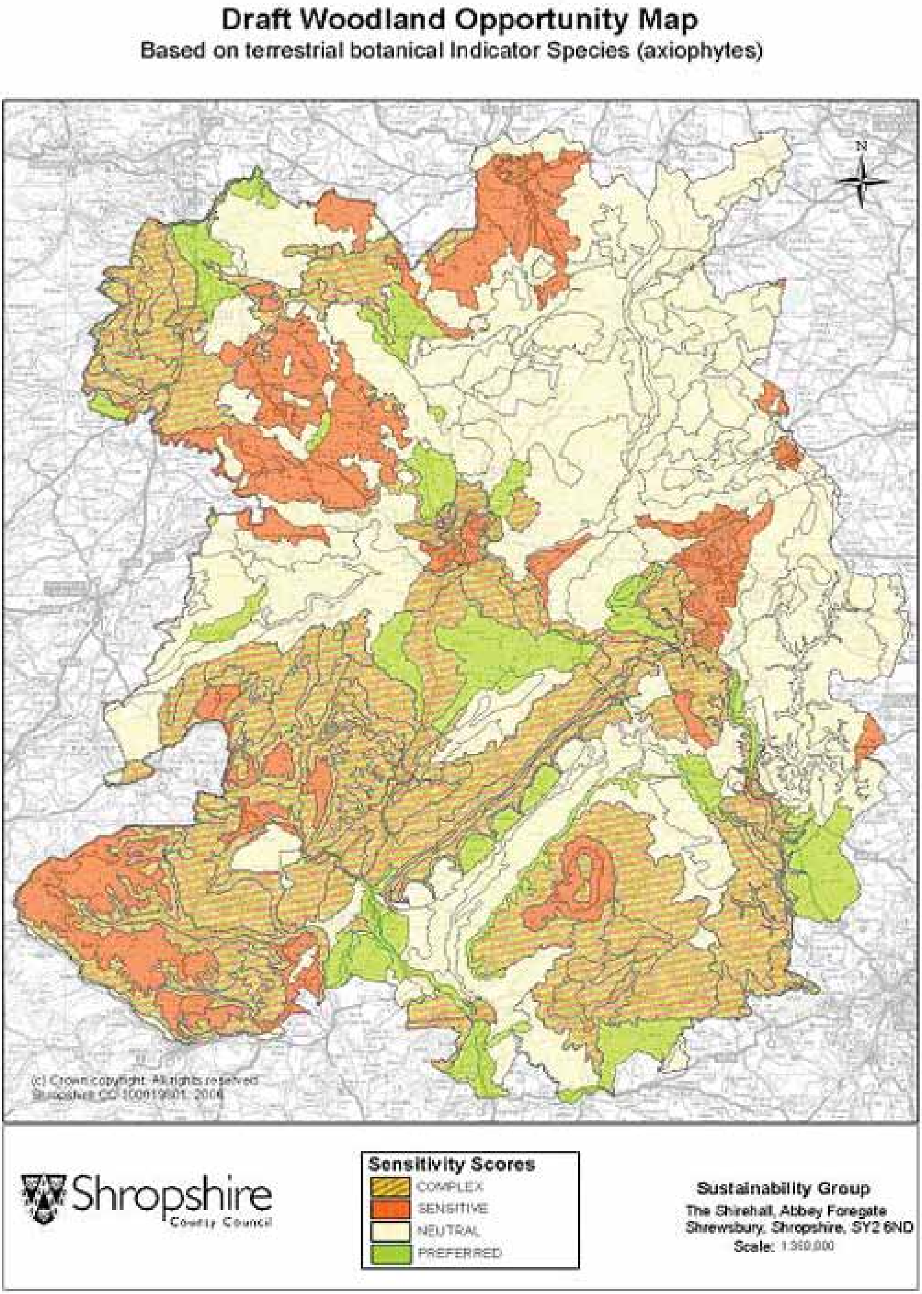


Axiophyte richness in Shropshire

Species richness is the essence of biodiversity, but it cannot be applied at all scales. If a patch of urban weeds occurs where garden waste has been deposited in a hay meadow, the total species richness of the meadow has gone up, while its biodiversity value has decreased – especially if any rare plants have been destroyed. Thus, the concept of axiophytes was introduced (Lockton, 2005) to enable us to distinguish the 'good' biodiversity (habitat specific native species) from the bad and the indifferent. Vice-county Recorders were asked to use their experience to draw up lists of axiophytes for each county, which typically number about 300 species, or 20% of the total flora.

Concentrating on the axiophytes can reveal a lot more than simply looking at all species distributions. Important sites such as Sites of Special Scientific Interest contain many axiophytes, and changes in the number of species over time reveals how the site is faring. A study of Attingham Park in Shropshire (Whild & Lockton, 2005) showed how the woodland had matured through the acquisition of 'ancient' woodland indicators and how much of the wetland had dried out over a 30-year period.

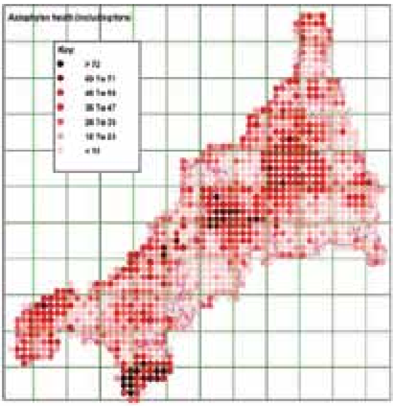
A more sophisticated analysis showed how areas could be targeted for new woodlands by mapping the existing ancient woods and looking for adjacent areas which were not good for other habitats – thus identifying places where woods could be planted without destroying something else of value. Tetrad scale data were transposed onto Landscape Areas by using a simple algorithm to divide the species listed in each grid square into the overlapping geographical boundaries. The map shows preferred areas for woodland planting in green, while areas to leave alone are in shown in red.

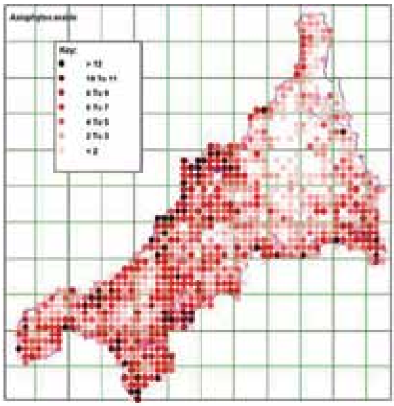

Draft Woodland Opportunity Map
Based on terrestrial botanical Indicator Species (axiophytes)
N
(c) Crown copyright. All rights reserved
Shropshire CC 100019801. 2006
Shropshire
County Council
Sensitivity Scores
COMPLEX
SENSITIVE
NEUTRAL
PREFERRED
Sustainability Group
The Shirehall, Abbey Foregate
Shrewsbury, Shropshire, SY2 6ND
Scale: 1:350,000

Axiophyte diversity of habitats in Cornwall

Mapping the diversity of axiophytes can be very useful in highlighting the most important areas for specific habitats or for predicting their occurrence based on species distribution data alone. Such maps have wide application for conservation including targeting management and habitat restoration. This approach has been carried out at the tetrad and monad scale for all semi-natural habitats in Cornwall. For some habitats the resulting coincidence maps clearly show the hotspots and thus the areas within hectads where a habitat is most likely to occur.

The map for heathlands (below left) shows that the highest concentration of axiophytes occur on the serpentine and gabbros of the Lizard Peninsula, the granite uplands of Bodmin Moor and West Penwith and the mid Cornwall Moors. The northern coastal fringe stands out to a lesser extent as important for heathland.



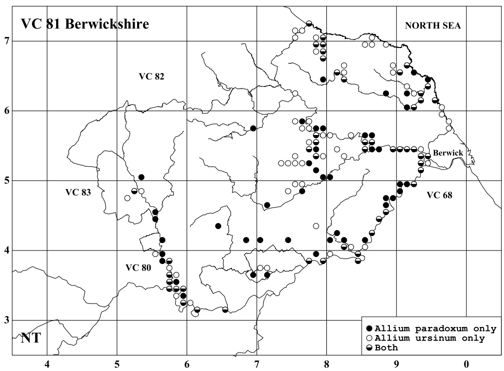


Arable and horticultural crops are widely grown throughout the county and yet the areas with a rich arable weed flora are fairly localised (above right). The north coast from Perranporth to Wadebridge is particularly important for its arable weed flora. Elsewhere the Roseland Peninsula and the southern tip of the Lizard Peninsula are hotspots for arable weeds.

Coincidence map at monad scale within vice-county, Berwickshire. *Allium paradoxum* and *A. ursinum*

Ramsons *Allium ursinum* is largely confined to ancient woodland on fertile soils. Such woodland mainly survives in Berwickshire on steep banks in deans, by rivers and at the coast. By contrast, *A. paradoxum* is a rapidly spreading neophyte that was not recorded in Berwickshire until 1947. The movement of garden material by gardeners has been the main mode of dispersal, but more recently it has been dumped, rather widely on roadsides and in waste places, from where it has been dispersed further on vehicle tyres, colonising roadside hedges, verges and secondary woodland. These mechanisms have also allowed spread between river catchments. Following such dispersal it has become almost ubiquitous along the main river, with its bulbils being spread over the floodplain during extreme flood events.

Kevin Walker

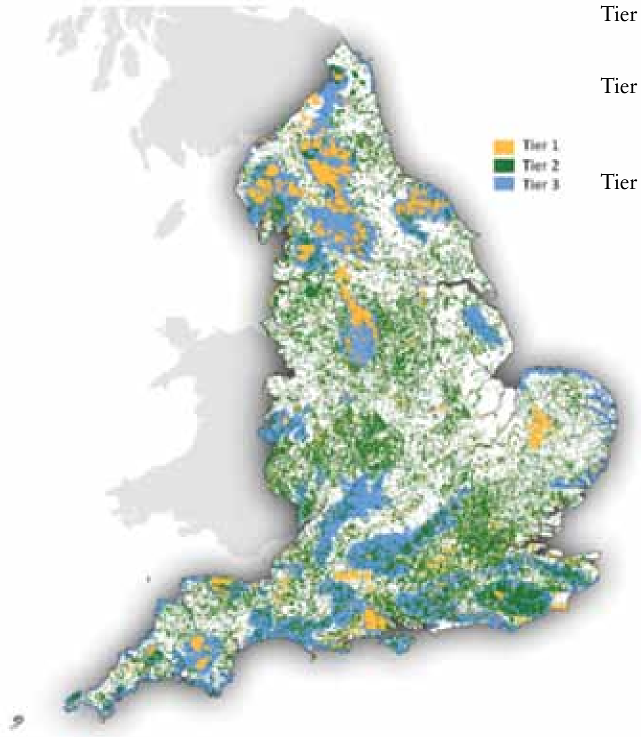


Allium paradoxum only, 46 monads
Allium ursinum only, 54 monads
Both, 49 monads

Coincidence mapping confirms a similarity in distribution, though *A. paradoxum* has a wider ecological amplitude than *A. ursinum*. *A. paradoxum* has yet to reach some of the more upland deans and parts of the coast that are haunts of *A. ursinum*. This map is much more effective than a data table in illustrating the inter-relationship of the two species, particularly as the data are based on a sample survey only.

Mapping areas of conservation priority

The map below was produced as part of the Government's review of the effectiveness of wildlife sites in protecting England's biodiversity and shows the distribution and extent of various wildlife sites in England (Lawton *et al*., 2010). It is dangerous to generalise from such a complex map, but it is clear to most of the extensive 'ecological networks' are upland or coastal areas designated as either SSSIs, National Nature Reserves (NNRs) or Areas of Outstanding Natural Beauty (AONBs). Notable exceptions include Breckland and Salisbury Plain. The upland sites show up most clearly and although extensive these are seldom species-rich areas. It is left to the innumerable small scale local or county wildlife sites (Tier 2) to pick up the pockets of high diversity in a highly fragmented lowland landscapes.



Tier 1 – protected sites (SSSIs, NNRs, etc.)

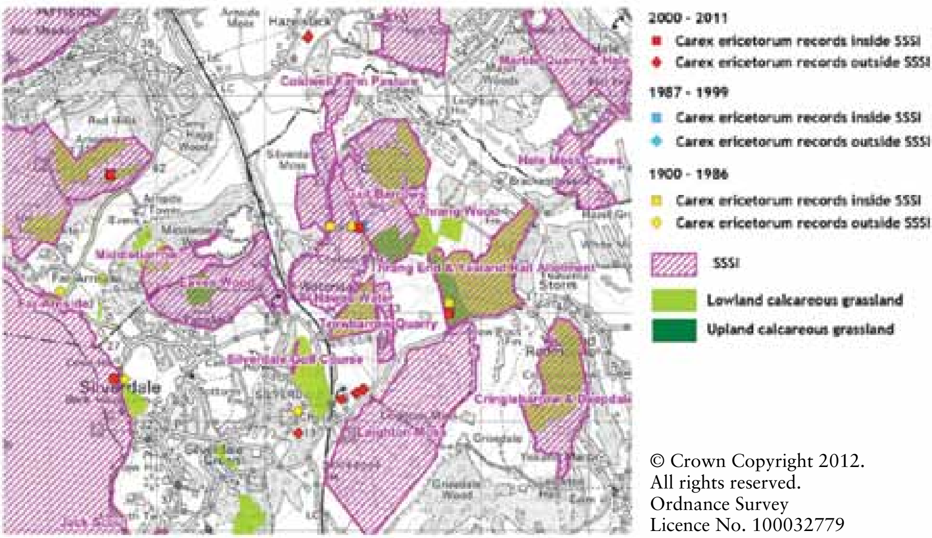
Tier 2 – designated sites (local/county wildlife sites, etc.)

Tier 3 – landscape and recreational sites (AONBs, etc.)

Mapping distributions against protected areas: *Carex ericetorum*

Land managers and conservationists increasingly rely on the provision of high resolution records for rare and threatened species in order to more effectively target management decisions on protected sites. One way to achieve this is to map species' distributions against digitized conservation site boundaries. In the example below the distribution of *Carex ericetorum* around Morecambe Bay, North Lancashire, is shown at 100 m resolution and mapped in relation to the boundaries of SSSIs (SSSI; Newman, 2012).

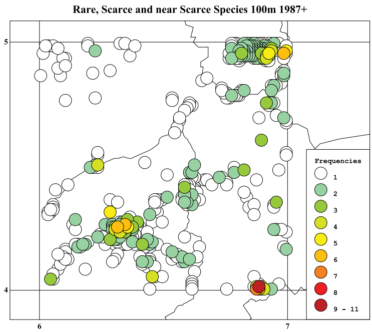
Kevin Walker

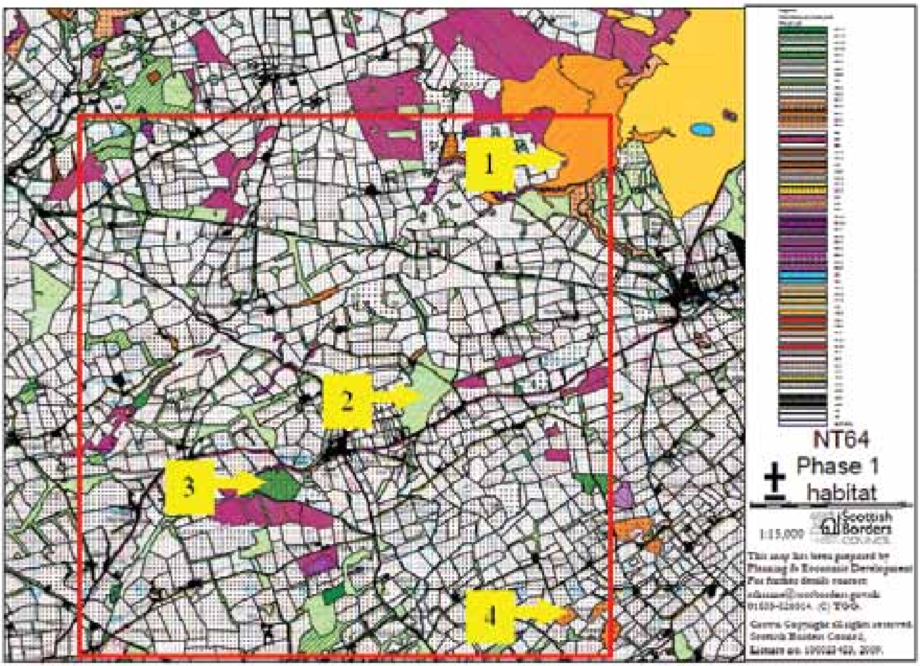


Although quite complex, this map shows that even in such a highly protected landscape, a relatively high proportion of populations fall outwith the SSSI network. The further use of these data for targeting agri-environment scheme options would be one to ensure that these sites are managed appropriately for this species.

Rare and scarce species matched to 'Phase 1' habitats

The 1 km coincidence map of the rare and scarce species in the *BSBI Berwickshire Rare Plant Register* (Braithwaite, 2004) for the hectad NT64 is shown opposite the Phase 1 Habitat map derived from air photographs. The four richest sites stand out on the map below: (1) Dogden Moss, a fine raised bog; (2) Gordon Common, now a community woodland; (3) Gordon Moss, now a wet birchwood with little-drained grassland; and (4) Hareheugh Craigs, an intrusive rock feature with species-rich grassland.

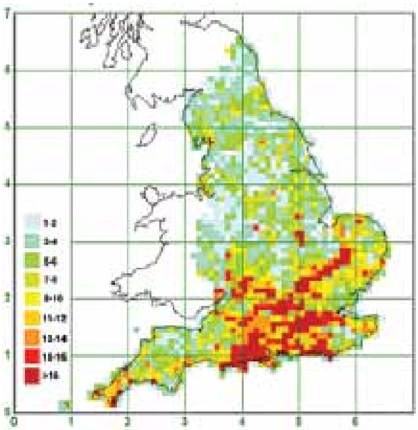


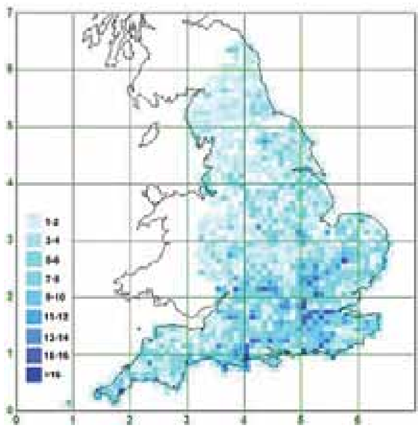


Coincidence mapping: Biodiversity Action Plan (BAP) priority species

Coincidence mapping provides a powerful tool for investigating distribution patterns as well as identifying 'hot' or 'cold' areas for plant diversity. They have frequently been used as a conservation planning tool, especially in relation to priority species, in order to more effectively target resources through delivery mechanisms such as agri-environment schemes and protected areas.

The maps below provide examples for Biodiversity Action Plan (BAP) priority species in England. This list, which includes the species considered to be the highest priority for conservation action in England, was revised in 2007 to take into account new threat status categories applied to all native taxa (Cheffings & Farrell, 2005)





Lowland farmland is home to more BAP species than any other habitat and is arguably one of the most threatened because many species are dependent on traditional forms of land use, many of which are in decline. The map on the left shows the occurrence of Farmland BAP species regardless of dateclass and illustrates a clear bias in diversity to the south and southeast of England and with hots pots on either very calcareous or acid soils.

Much more revealing however is the map on the right which shows the coincidence of 'losses', calculated as absences since 1987 when present 1930-1987, for the same group of species. Presenting the data in this way highlights the 'cold spots', the areas where we have lost the most diversity.

Mapping with Google Earth

Google Earth is now being used by a number of national and international mapping projects in order to visualize distribution data at a variety of scales. The example left shows the 50 km records currently available for *Pulsatilla vulgaris* on the Global Biodiversity Information Facility (GBIF). These records can be accessed online via the website and are then mapped directly into Google Earth.

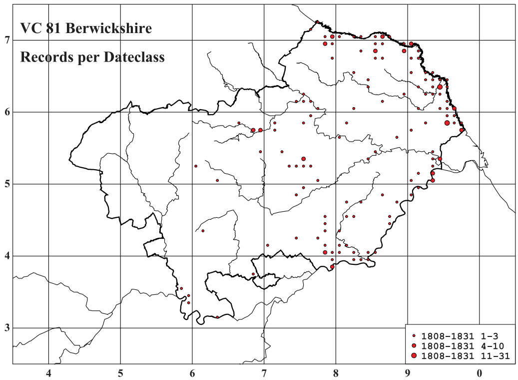
The second example shows detailed records from the *Ceredigion Rare Plants Register* (Chater, 1990) mapped as a Google Earth layer. Once loaded into Google Earth the records can be searched interactively and details be accessed by clicking the 'tag' on the screen (as shown for *Pseudorchis albida*).

Records by Dateclass, Berwickshire

It can be instructive to compare the overall coverage of an area for different time periods. This is desirable before seeking to comment even in the most general terms on the spread or decline in a species.

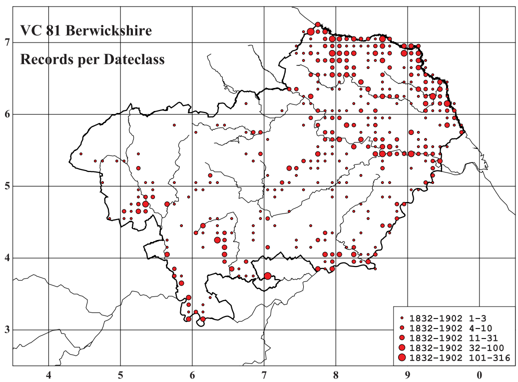
1808-1831 Dr George Johnston's Flora 1829, 1831

Johnston worked with a small group of fellow doctors and ministers. Travel opportunities were limited so while his Flora covered the species and their habitats adequately the same was not true of their localities.



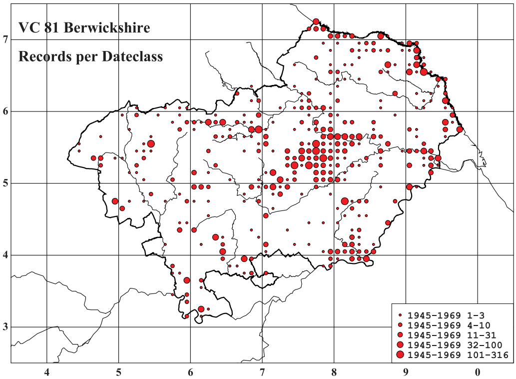
1832-1902 The heyday of the Berwickshire Naturalists' Club

The exertions of a series of capable botanists led to truly representative sample coverage of the habitats and the botanically richer localities in the vice-county.



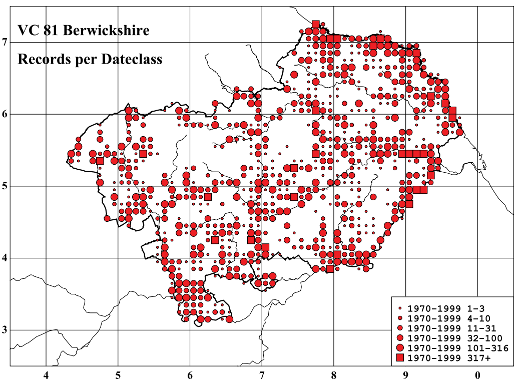
1945-1969 The Longs, WFS and the *1962 Atlas*

Albert and David Long achieved a new systematic sample survey of the vice-county. They also harvested the notebooks of three Wild Flower Society stalwarts. There is a concentration of records in hectad NT75 where the Longs lived. A BSBI party led by Franklyn Perring in 1960 extended the coverage, but many of the party's records were made at 10 km scale. However, they did complete individual record cards for notable species from many of the localities they visited, so the pattern of their recording can be largely reconstructed.



1970-1999 to the *New Atlas*

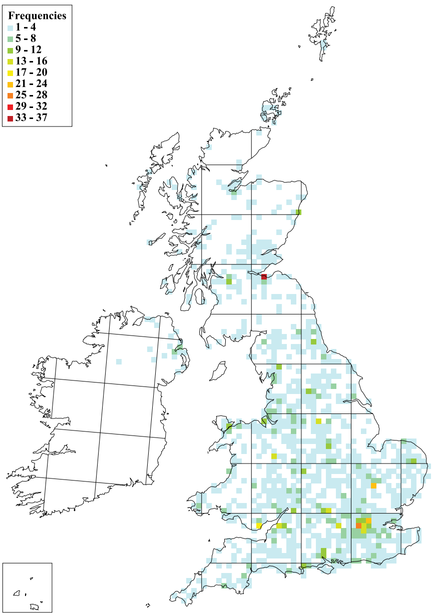
A more uniform sample coverage was achieved during this period. The vice-county recorder lived outwith the vice-county and his primary objective was to obtain as comprehensive a species list as possible for each hectad. To achieve this goal it was found necessary to sample part hectads more intensively than complete hectads.

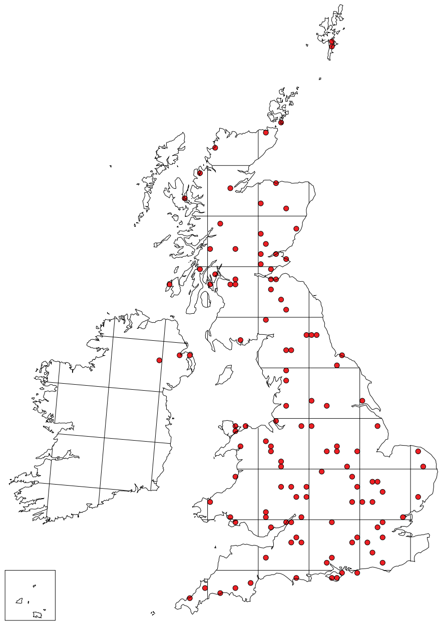


The distribution of botanical recorders

The maps showing the distribution of members (left) and vice-county recorders (right) highlights one of the most important factors affecting recording coverage. There is a spatial bias in the distribution of recorders towards lowland and urban areas. England has a greater density of recorders than Scotland, Wales or Northern Ireland (members in Eire are not mapped).

The lack of recorders or resident vice-county recorders in the remoter parts of Scotland and Northern Ireland is particularly striking and suggests that achieving anything more than sample coverage within hectads in these areas is unlikely to be achievable in a single generation.





Conclusion

The *1962 Atlas* played a vital part in transforming natural history observation into a scientific endeavour. This approach, which was devised for national purposes, has now been embraced at the international as well as the local scale, with the vast majority of biological recording programmes employing systematic grids of one form or another.

Since the late 1980s the ability to record and share biological records has been enhanced by the availability of affordable personal computing, civilian GPS and the internet. This has led to a dramatic increase in the resolution and precision of biological records (especially since the US military turned off restrictions to civilian GPS readings in 2000), as well as in the speed with which they can now be 'shared' via the internet. The volume of records available has increased ten-fold and they are now employed routinely for a variety of research, conservation and public-policy purposes.

The half-century since the publication of the *1962 Atlas* has witnessed dramatic environmental changes due to increased industrialisation and urbanisation. Plants have often been on the frontline, especially in intensively-managed landscapes, but even in remote regions the insidious effects of air pollution and more recently climate change are now being felt. The *1962 Atlas* is one of the few biological baselines from which we can measure subsequent changes and it has been instrumental in helping to document and understand the main drivers of change. Research into the processes underlying these changes is still in its infancy and there is much we have yet to learn. However, the increase in the amount and quality of data, as well as improvements in the way we analyse them, means that the results are more accurate and powerful than ever before.

Only recently have we started to understand and correct for the influence of recording behaviour on the data that we produce. This remains one of the greatest challenges to interpreting the maps that the *1962 Atlas* stimulated. Other taxonomic groups, albeit less species-rich, have developed powerful techniques to overcome this bias. Botanists are some way behind, but at least we aware of the pitfalls and can plan our recording activities accordingly or develop techniques to overcome them. This will be the challenge for the botanists who produce the next *Atlas*, which will hopefully be completed in time for the sixtieth anniversary of the *1962 Atlas* in 2022.

Acknowledgements

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