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Using data from local floras to assess floristic change

K. J. WALKER*

Centre for Ecology and Hydrology, Monks Wood, Abbots Ripton, Huntingdon, Cambridgeshire PE28 2LS

ABSTRACT

Local floras provide valuable baselines which have seldom been used to measure floristic change. This is largely due to the paucity of historical data for many counties but also because of changes in recording behaviour over the past 350 years. One of the simplest ways to assess change however, is to calculate extinction rates: in English counties at least, this method has shown an average loss of around one species every two years during the last century. In contrast, quantitative assessments of increase/decline have proven more difficult because of the nature (or lack) of historical data. In order to overcome this problem regression analyses have been used to calculate *relative* changes in species distributions. This approach is particularly useful because it takes into account differences in recorder behaviour between surveys. In contrast, *absolute* floristic changes have only been recorded from sample sites ("habitat studies") in two counties (Bedfordshire and Dorset).

KEYWORDS: baseline, extinction, habitat study, recorder behaviour, vice-county.

INTRODUCTION

Although seldom acknowledged, an important role of the local flora is to provide a baseline from which to measure change (Allen 1963). This has become increasingly feasible in recent years with the publication of floras for a number of counties which possess at least one earlier work (e.g. Beckett & Bull 1999; Bowen 2000; French *et al.* 1999; Killick *et al.* 1998). Yet, with a few notable exceptions, authors have seldom attempted to use these works in order to measure floristic change. In some areas this is understandable: many counties, particularly in the remoter parts of the British Isles, lack substantial earlier works. For example, the Scottish parish of Assynt, which has long been a mecca for British botanists, was not adequately recorded until after 1990 (Evans *et al.* 2002). Compare this with the rather unremarkable county of Nottinghamshire, which by 1900 already had three major floras (Deering 1738; Howitt 1839; Ordoyno 1807).

The ways in which botanists have recorded species distributions has also restricted the number of studies which have been carried out. Over the past 350 years these have changed from simple lists of localities (e.g. Ray 1660), to entries under botanical divisions (e.g. Babington 1860) and latterly to "dot" atlases based on grid systems of different sizes (e.g. Dony 1976; Gent & Wilson 1995). In many cases this shift to a more systematic approach, and the increase in recorder effort which it demands, has made modern authors reluctant to compare their datasets with those collected for earlier works (e.g. Jermyn 1974; Killick *et al.* 1998).

The object of this paper is to assess the extent to which local floras can be used to quantify the floristic changes which have taken place in the British Isles over the last 350 years. To this end I pose the following questions: to what extent do local floras provide adequate baselines from which to measure change and, secondly, how have these been used in floristic change studies? Some of the problems associated with these various approaches are discussed, specifically in relation to extinction and the detection of broad scale changes between surveys, and possible solutions suggested. Nomenclature for vice-counties and vascular plants follows Stace (1997).

*Address for correspondence: e-mail kwal@ceh.ac.uk

METHODS

For the purposes of this study I have attempted to include all local floras (including second editions, supplements and detailed checklists) which provide complete coverage for British or Irish vice-counties or works that cover parts of different vice-counties where there is at least some tradition of botanical recording (e.g. Baker 1863; Halliday 1997; King 1891; Lavin & Wilmore 1994). As a consequence, I exclude bare lists published in general studies (e.g. Victoria County Histories), book chapters or journal papers (e.g. Druce 1922), or works dealing with smaller geographical areas, such as individual parishes (e.g. Evans *et al.* 2002), islands (e.g. Campbell 1945) and cities (e.g. Bristol, London, Liverpool, Edinburgh). These were compiled by consulting earlier lists of local floras (e.g. McCosh 1988; Perring 1971), as well as those works listed in Simpson (1960) and are summarised in the Table 1 (a complete list of works is available from the author on request).

For each local flora the following details were noted:
Is the provision of a baseline mentioned as an aim in the introductory chapters?
How do the authors record the abundance and distribution of species (e.g. sites, parishes, botanical districts, grid-squares)?
Do the authors provide a list of extinct species with the year of the last record?
Are there detailed lists of species for individual sites (e.g. "habitat studies" sensu Dony (1953))?
Have these data been utilised to quantify floristic change?

RESULTS

LOCAL FLORAS AS HISTORICAL BASELINES

The publication of local floras, 1660–2002
The first local floras differed from earlier herbals (e.g. Gerarde 1597) in attempting to provide a comprehensive list of plants for their own sake and not their potential usefulness (Marren 1999). The earliest examples, which attempted to cover entire counties, included the works of Ray (1660) and Relhan (1785) in Cambridgeshire, Deering (1738) in Nottinghamshire, Abbott (1798) in Hertfordshire, and Sibthorp (1794) in Oxfordshire. In contrast the nineteenth century saw a dramatic increase in botanical activity culminating in the publication of 43 major floras in as many years (30 of which covered English vice-counties; Fig. 1). Of these the works of Babington (1860), Druce (1886, 1897) and Trimen & Dyer (1869) were particularly influential in both style and content. This peak in botanical activity was then followed by a gradual decline during the first half of the twentieth century and culminated in only six floras being published between 1940 and 1959 (Brunker 1951; Dony 1953; Good 1948; Grose 1957; Lloyd & Rutter 1957; Riddelsdell *et al.* 1948), the lowest number since the early 1800s. However, the publication of the *Atlas of the British flora* in 1962 (Perring & Walters 1962) led to renewed activity, and an unprecedented increase in the number of floras published (66 in 42 years).

The aims of local floras
The stated aims of local floras have changed dramatically since the seventeenth century when botany was viewed as a sobering pursuit intended to distract "…men of university standing…" from "…ball-games,…drinking, gambling, money-making, popularity-hunting" (Ray 1660). Although similar sentiments are expressed in a number of eighteenth (e.g. Deering 1738), nineteenth, and even some twentieth century floras (e.g. Perring *et al.* 1964), introductory statements became increasingly scientific after 1800 as authors rushed to provide their counties with a first comprehensive flora or to fill the gaps left by previous works (Gilmour 1963). At its height, in the late nineteenth century, this Dickensian quest for "facts" led to a number of very detailed floras, including Trimen and Dyer's (1869) *Flora of Middlesex* which was intended "…to give a complete and accurate catalogue of the plants which have at any time been recorded to grow in Middlesex". As a consequence the weight of introductory material increased dramatically. For example the introductions to each of Druce's (1886, 1897, 1926, 1930) Thames series of floras ran to over 150 pages and included chapters on the physical nature and land use of the county, mini-biographies of its most famous botanists (botanologia), as well as phytogeographic comparisons with adjoining counties.

TABLE 1. THE NUMBER OF LOCAL FLORAS (INCLUDING SECOND EDITIONS, SUPPLEMENTS AND CHECKLISTS) PUBLISHED FOR BRITISH AND IRISH VICE-COUNTIES SINCE 1660

	Local flora				2nd edition/supplement			
	England	Wales	Scotland	Ireland	England	Wales	Scotland	Ireland
1660–1800	5	–	–	–	–	–	–	–
1800–1860	14	–	3	–	–	–	–	–
1860–1900	30	3	7	3	3	–	–	–
1900–1960	21	3	10	3	8	1	3	1
1960–2002	42	7	11	6	13	–	–	4
Total	112	13	31	12	24	1	3	5

	Checklist				Total		
	England	Wales	Scotland	Ireland	Local flora	2nd eddn./suppl.	Check-list
1660–1800	–	–	–	–	5	–	–
1800–1860	–	–	–	–	17	–	–
1860–1900	–	–	–	–	43	3	–
1900–1960		1	1		37	13	2
1960–2002	6	3	16	2	66	17	27
Total	6	4	17	2	168	33	29

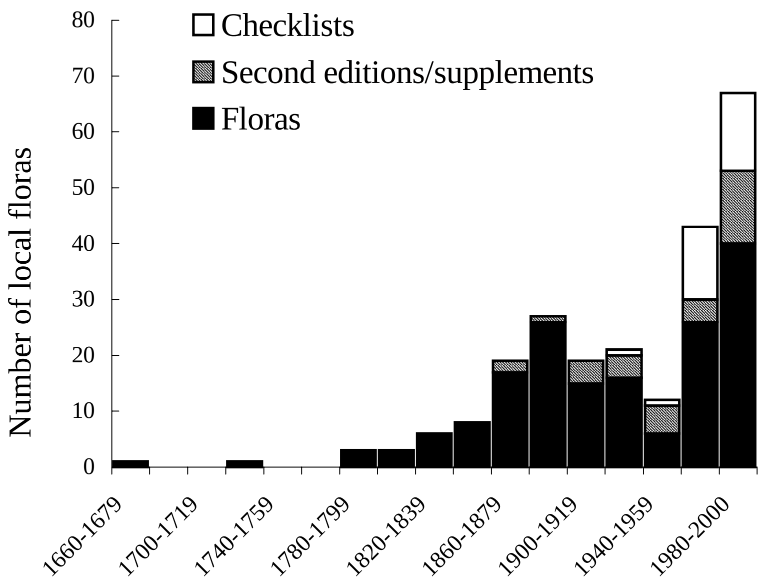


FIGURE 1. The number of local floras (including second editions, supplements and checklists) published for British and Irish vice-counties since 1660.

The potential use of the local flora to measure floristic change only became apparent after the publication of the 1962 *Atlas*. Edward Salisbury was probably the first to acknowledge this fact, suggesting that the maps produced in Dony's (1967) *Flora of Hertfordshire* "…should be regarded, not merely as a summary of past records, but as a basis for further observations on distribution and the process of never-ceasing change that the plant population evinces". Perring (1979) said as much in the Foreword to Trist's (1979) *Ecological Flora of Breckland*, whereas in Cornwall, Margetts & David (1981) acknowledged that their work would not only take stock of the work of the generation that succeeded them but also "…provide a baseline for the further investigations that are now likely to proceed vigorously". Almost without exception similar sentiments have been expressed in all subsequent local floras (e.g. Bellamy 2000; Killick *et al.* 1998; Mabey 1999; Stace 1990; Swan 1993).

Historical baselines

Our ability to measure floristic change depends primarily on the availability of historical data to which we can compare modern records. As Fig. 2 shows, this is unlikely to be a limiting factor for the majority of English vice-counties as all have at least one local flora or checklist, and 85% have two or more. Indeed, the most well recorded British county, Cambridgeshire, has five major floras as well as a recent checklist (Crompton & Whitehouse 1983). However, this is not the case for the majority of Scottish, Welsh and Irish vice-counties. Of these 14%, 20% and 61% respectively lack even a single flora or checklist and only 47%, 46% and 16% have more than one. In comparison to England no single Scottish, Welsh or Irish vice-county has more than three local floras.

The length of time since the first published flora for a vice-county will also influence our ability to measure change as counties with the longest tradition of recording will tend to be better studied. Once again English vice-counties are favoured in this respect as the majority of local floras were published between 1850 and 1899 (46%; Table 2). In contrast only 28%, 23% and 10% were published before 1900 in Scotland, Wales and Ireland respectively.

The methods used to record species distributions have changed dramatically over the past 350 years (Fig. 3). For example, the majority of early floras contain nothing more than bare lists of species for sites within easy reach of an urban centre (e.g. Ray 1660). With the development of road and rail links during the nineteenth century, however, botanists were able to visit the remoter corners of their counties. This led to the division of counties into "botanical districts" in order to ensure a more even coverage of recording effort. This approach, pioneered by Webb and Coleman (1849) in *Flora Hertfordiensis*, was adopted by many Victorian botanists and remained the preferred method until the advent of grid-based recording schemes during the 1960s (e.g. 10 × 10 km, Perring *et al.* (1964); 5 × 5 km, Bowen (1968); and 2 × 2 km, Dony (1967)). Subsequently over 60 grid-based floras have been published, over 40 of which have been for English vice-counties (Table 3).

ASSESSING FLORISTIC CHANGE

Perceptions of change

By far the simplest way to assess floristic change is to see how change has been recorded in the text of floras (e.g. Preston 2003). For example, Edward Salisbury provides a particularly revealing account of changes which took place in the flora of Hertfordshire during his lifetime (Dony 1967), in particular the "…decline or disappearance of many marsh plants such as Grass of Parnassus, *Triglochin palustris* and *Pulicaria vulgaris*…" due to "…the neglect of many ponds, upon which the watering of stock once depended…", and how on commons the abrasive effects of footwear "…have depressed or eliminated many of the smaller open habitat species" (Salisbury 1967). In some modern floras these personal accounts have been replaced by whole chapters dealing specifically with the effects of land use change (e.g. Best 1995; Bowen 1968, 2000; Killick *et al.* 1998; Lousley 1976) or accounts of the species which have increased or declined (e.g. Dony 1976; French *et al.* 1999; Primavesi & Evans 1988; Hall 1980; Halliday 1997; Kent 1975; Newton 1971). Despite their historical value, such statements are often highly selective and reliant on the author's perceptions of change. As a consequence I address the extent to which we can measure, in a more or less quantified way, the changes which have taken place.

TABLE 2. PUBLICATION DATES OF THE FIRST LOCAL FLORAS FOR BRITISH AND IRISH VICE-COUNTIES

Date of first flora	Number of vice-counties									
	England (v.cc. = 46[a])		Scotland (v.cc. = 36)		Wales (v.cc. = 13)		Ireland (v. cc. = 31)		Total (v.cc. = 126)	
	no.	%	no.	%	no.	%	no.	%	no.	%
1650–1699	1	2	–		–		–		1	0.8
1700–1749	1	2	–		–		–		1	0.8
1750–1799	2	4	–		–		–		2	1.6
1800–1849	6	13	3	8	–		–		9	7.1
1850–1899	21	46	7	19	3	23	3	10	34	27.0
1900–1949	9	19	8	22	2	15	2	6	21	16.7
1950–2002	6	13	13	36	6	46	7	23	32	24.4
Total v.cc.	46	100	31	86	11	85	12	39	100	79.4
Total pre-1900	31	67	10	28	3	23	3	10	47	37.3

[a]The total number of vice-counties for England, Scotland, Wales and Ireland are 58, 41, 13 and 40 respectively. The figures quoted here differ because a number of vice-counties have traditionally been combined within floras. These include vice-counties 1 & 2, 3 & 4, 5 & 6, 7 & 8, 11 & 12, 13 & 14, 15 & 16, 18 & 19, 25 & 26, 27 & 28, 33 & 34, 53 & 54, 62 & 65, 63 & 64, 67 & 68 and 69 & 70 in England, 79 & 80, 82–84, 87–89, 91 & 92 and 107 & 108 in Scotland, and H1 & H2, H3–5, H7 & H10, H15 & H17, H26 & H27, H34 & H35, H38–40 in Ireland. Four additional areas have also been included within the English figures: Scillies (1b), Jersey (S), Guernsey (S), Breckland (part 26 & 28).

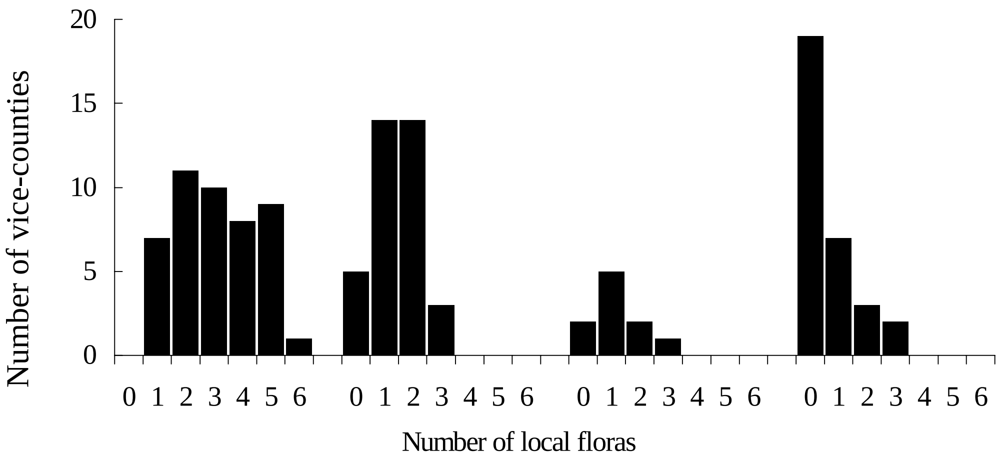


FIGURE 2. The number of local floras (including second editions, supplements and checklists) published for individual English, Scottish, Welsh and Irish vice-counties since 1660.

TABLE 3. THE WAYS IN WHICH SPECIES DISTRIBUTIONS HAVE BEEN RECORDED IN LOCAL FLORAS (INCLUDING SECOND EDITIONS, SUPPLEMENTS AND CHECKLISTS) SINCE 1780

	England		Scotland		Wales		Ireland		Total	
	no.	%	no.	%	no.	%	no.	%	no.	%
Sites	37	26	25	49	9	50	8	42	79	34
Districts	61	43	13	25	4	22	9	47	87	38
10 × 10 km	12	8	9	18	1	6	1	5	23	10
5 × 5 km	5	4	2	4	2	11	–	–	9	4
2 × 2 km	25	18	2	4	2	11	1	5	30	13
1 × 1 km	2	1	–	–	–	–	–	–	2	1
Total	142	–	51	–	18	–	19	–	230	–

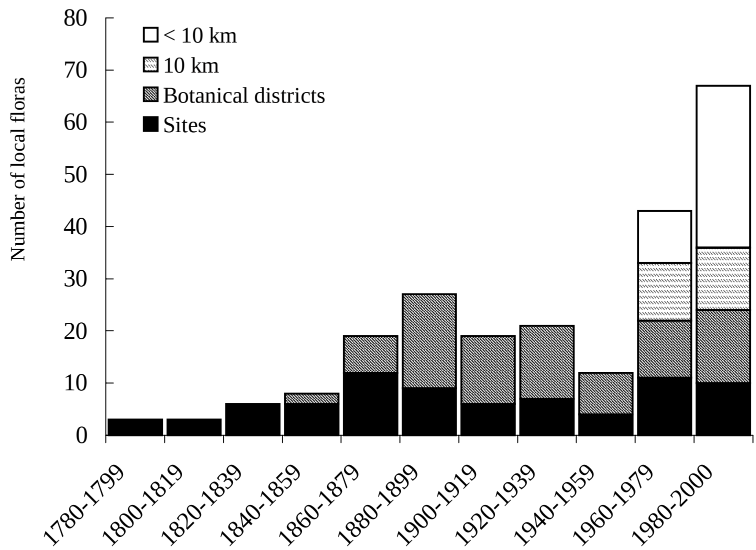


FIGURE 3. The ways in which distributions have been recorded in local floras since 1780.

County extinction

Over the last 40 years the number of floras which include lists of extinct species has risen markedly (Fig. 4). As a result there have been a number of attempts to use these data to calculate extinction rates for individual counties (e.g. Marren 2000, 2001; Preston 2000; Walker 2003). These suggest that British vice-counties have lost one species every two years since 1900, with, on average, southern and eastern counties having lost more (0.6 species a year) than those in the north and west (0·4 species a year; Walker 2003). In addition, these data have also been used to identify periods of heightened extinction. For example, in Cambridgeshire Preston (2000) showed that the peak periods of extinction coincided with the first main wave of parliamentary enclosure during the early part of the nineteenth century whereas in Middlesex they occurred soon after 1870 as a result of the spread of the London conurbation.

Information on county extinctions can also be used to identify which species have declined the most and thus the habitats which have suffered the greatest changes in recent decades. For example, Table 4 lists those species which have been lost from more than half the best recorded counties in south east England. Five of these species have a predominantly northern distribution in the British Isles but have undergone severe declines as a result of drainage and habitat loss (*Antennaria dioica*, *Carex dioica*, *Lycopodium clavatum*, *Parnassia palustris*, *Utricularia minor*),

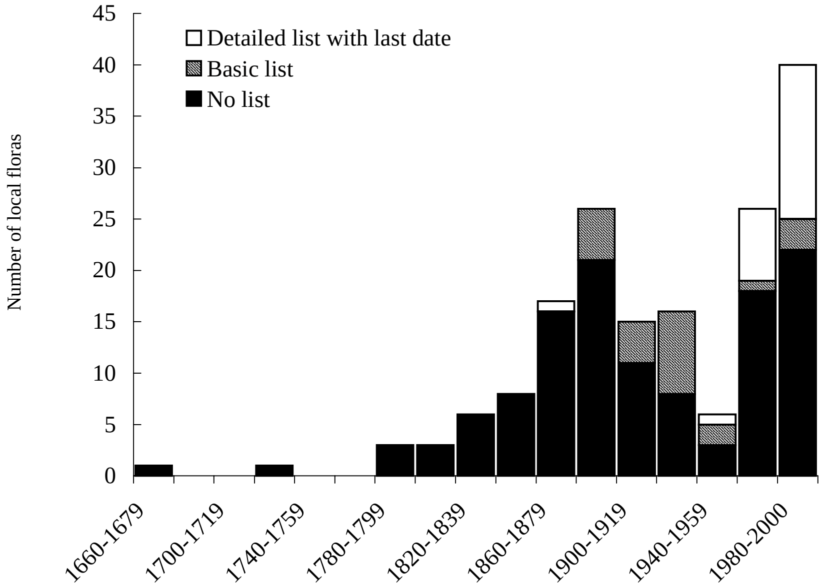


FIGURE 4. The number of British and Irish local floras which include lists of extinct species.

TABLE 4. EXTINCT SPECIES IN LOWLAND COUNTIES[a]

Species	Status	Broad habitat	Number formerly present	Number extinct	% extinct
Arnoseris minima	Extinct[b]	Arable	9	9	100
Pulicaria vulgaris	Red Data	Acid grassland	9	8	89
Antennaria dioica	Not scarce	Calcareous grassland	8	7	88
Lycopodiella inundata	Scarce	Bog/heath	9	7	78
Melampyrum arvense	Red Data	Arable	9	7	78
Hammarbya paludosa	Scarce	Fen, marsh, swamp	8	6	75
Valerianella rimosa	Red Data	Arable	11	8	73
Carex dioica	Not scarce	Fen, marsh, swamp	10	7	70
Lythrum hyssopifolium	Red Data	Arable	9	6	67
Parnassia palustris	Not scarce	Fen, marsh, swamp	9	6	67
Anagallis minima	Not scarce	Acid grassland	11	7	64
Mentha pulegium	Red Data	Standing water	11	7	64
Utricularia minor	Not scarce	Fen, marsh, swamp	10	6	60
Hypochaeris glabra	Scarce	Acid grassland	11	6	55
Lycopodium clavatum	Not scarce	Bog/heath	11	6	55

[a]The species listed are those which have been lost from over half of the following counties: Bedfordshire (v.c. 30), Cambridgeshire (v.c. 29), Dorset (v.c. 9), Kent (v.cc. 15 & 16), Lincolnshire (v.cc. 53 & 54), Middlesex (v.c. 21), Norfolk (v.cc. 27 & 28), Northamptonshire (v.c. 32), Oxfordshire (v.c. 23), Suffolk (v.c. 25 & 26) and Surrey (v.c. 17).

[b] Last recorded in the British Isles in 1971.

four were formerly rare plants of cultivated land (*Arnoseris minima*, *Lythrum hyssopifolium*, *Melampyrum arvense*, *Valerianella rimosa*), and six were localised species of acid grasslands and bogs (*Anagallis minima*, *Hammarbya paludosa*, *Hypochaeris glabra*, *Lycopodiella inundata*, *Mentha pulegium*, *Pulicaria vulgaris*).

Comparisons between time-periods

Rather surprisingly there have only been a handful of attempts to quantify floristic changes using data collected for earlier floras. For most counties this is simply due to a lack of adequate historical data to which modern records can be compared. However, even where these data do exist, differences in the ways in which the data were originally collected has made comparisons with modern datasets difficult to interpret (Primavesi & Evans 1988). For example, even extremely thorough recorders, such as Druce and Gibson, did not always cover the various parts of the county with equal intensity (Killick *et al.* 1988; Jermyn 1974). As a consequence their qualitative statements of abundance are likely to be biased (Perring 1963; Rich & Smith 1996).

Given these caveats, however, there is no reason why qualitative datasets should not be used to provide some indication of the overall floristic changes which have taken place. To illustrate this I have plotted Druce's (1930) personal assessments of abundance for the Orchidaceae and Cyperaceae in Northamptonshire against those given in a recent flora of the county (Fig. 5; Gent & Wilson 1995). Although rather crude this approach shows that, despite the increase in recording activity since the turn of the century, 49 species (61%) appear to have become less common (e.g. *Orchis morio* and *Luzula pilosa* decreased by 5 and 4 categories respectively), whereas only eight species (10%) appear to have increased (e.g. *Carex remota*, *C. ovalis* and *Juncus compressus* increased by 3, 3 and 2 categories respectively).

Given the subjectivity involved in assigning species to abundance categories a more statistically rigorous approach is to compare quantitative measures between time periods. However, despite the fact that many counties have grid-based floras (Table 3), no repeat surveys have been published. An alternative approach is to compare earlier qualitative measures with modern grid-based data. For example, in a recent study of changes in the flora of Northamptonshire Druce's (1930) qualitative assessments (eight abundance categories) were plotted against modern pentad (5 × 5 km) distributions (Fig. 6; McCollin *et al.* 2000). Changes during the intervening period were then calculated as standardised residuals from the linear regression line for the whole dataset (R^2 = 64·4%, F_{680} = 1233, p <0·0001). Thus differences between the observed and predicted values (standardised residuals) provided an indication of the *relative change* in distribution since 1930: those species which deviated most from the predicted distribution were assumed to have changed the most and vice versa. Using this method species which had apparently declined the most (i.e. those with an observed value greater than two standard deviations below the regression line) included seven arable plant species (*Agrostemma githago, Anthemis cotula, Legousia hybrida, Ranunculus arvensis*, *Sison amomum*, *Torilis arvensis* and *Veronica polita*), five species associated with semi-natural grassland (*Astragalus danicus, Helianthemum nummularium, Orchis morio, Rhinanthus minor* and *Thymus polytrichus*) and three aquatics (*Hottonia palustris, Oenanthe fluviatilis* and *Spirodela polyrhiza*).

Recently, a similar approach has been developed in order to measure change in the distributions of species included in the *New Atlas of the British and Irish flora* (Telfer *et al.* 2002). As in the McCollin *et al*. (2000) study the measure of change for each species (the Change Index) was based on its standard deviation from the regression line for the entire dataset, i.e. the extent to which a species 10 × 10 km distribution has changed *relative* to the overall change in the British flora between 1930–1969 and 1987–1999. This is a particularly powerful technique because it takes into account recorder biases caused by differences in the geographical coverage and the greater intensity of recorder effort in the latter survey period.

Habitat studies

A small number of floras include detailed "habitat studies" which provide lists of species for individual sites as well as, in some cases, additional information on soil type, pH, aspect, topography etc. (Table 5). The pioneer of this approach was Ronald Good (1948) who, during the 1930s, recorded the vegetation and flora of 7500 sample sites in the Poole Basin in Dorset. Fortunately he marked the precise location of his study areas on Ordnance Survey maps, thus

TABLE 5. "HABITAT STUDIES" INCLUDED IN LOCAL FLORAS

County	Number	Sample area	Number re-surveyed	Source(s)
Dorset	7500	Various	390	Good (1948); Byfield & Pearman (1994)
Bedfordshire	86	5 yd radius	86	Dony (1953, 1977)
Wiltshire	5000	c.250–350 yd^2	0	Grose (1957)
Hertfordshire	109	5 yd radius	0	Dony (1967)
Derbyshire	84	Various	0	Clapham (1969)
Breckland	26	Various	0	Trist (1979)
Leicestershire	107	Whole site	0	Primavesi & Evans (1988)
Flintshire	49	2–20 m^2	0	Wynne (1993)

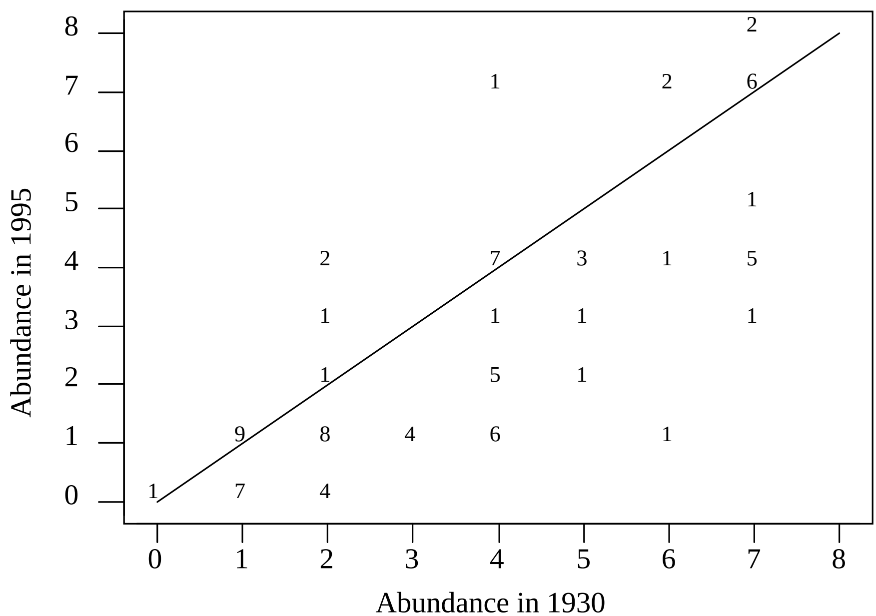


FIGURE 5. The relationship between the abundance of Cyperaceae (n = 59) and Orchidaceae (n = 22) in Northamptonshire in 1930 and 1995 (R^2 = 63 %, F_{79} = 135, $p < 0.001$). The number of species within each abundance category are shown in relation to a 1:1 line. Categories are as follows: 0 – 'extinct', 1 – 'very rare', 2 – 'rare', 3 – 'very local', 4 – 'local', 5 – 'locally common', 6 – 'locally abundant', 7 – 'frequent/common', 8 – 'very common' (see McCollin *et al.* 2000 for details). Abundance scores taken from Druce (1930) and Gent & Wilson (1995).

allowing modern workers to determine changes over the intervening years (Byfield & Pearman 1994). Over a decade later John Dony (1953) carried out a similar, albeit much more limited study in Bedfordshire and latterly Hertfordshire (Dony 1967). However, these were a marked improvement on the Good Survey surveys because the samples were of equal area (a circle of 5 yards radius) and were placed in representative stands of vegetation, and not just those of conservation interest. As a result all subsequent habitat studies have attempted to emulate Dony in some way (e.g. Clapham 1969, Primavesi & Evans 1988; Trist 1979, Wynne 1993), although surprisingly few have used his standardised sample area (Table 5).

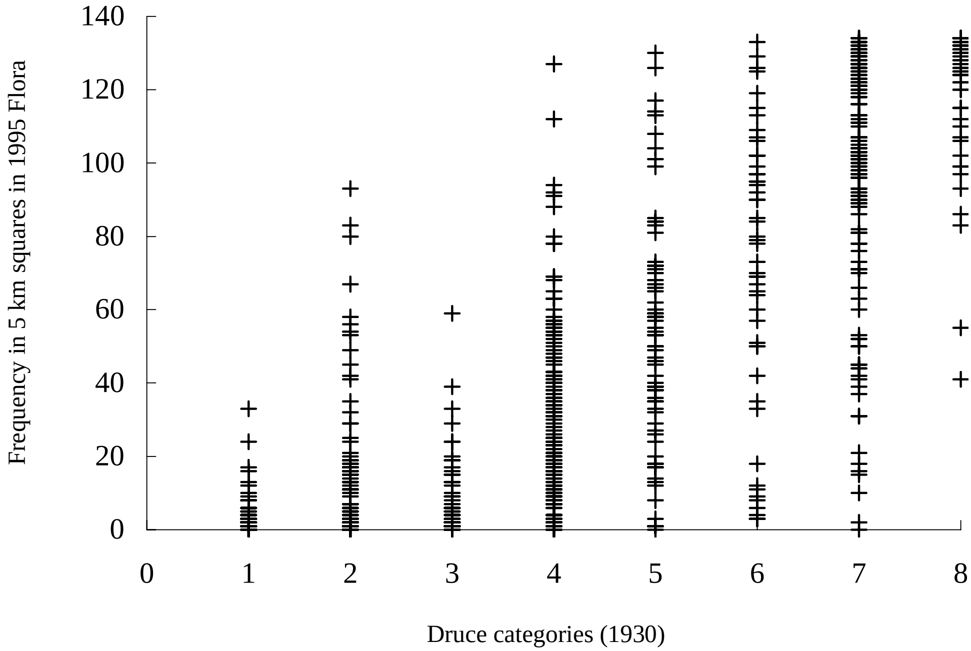


FIGURE 6. The relationship between the abundance of species in Northamptonshire in 1995 and 1930 (R^2 = 64.4%, F_{680} = 1233, $p < 0.0001$; abundance categories are the same as for Fig. 4). Data for 1995 are pentads (5 × 5 km) and for 1930 abundance scores assigned to species by Druce (1930) in his flora of the county. Graph taken from McCollin *et al.* (2000) and reproduced by kind permission of the authors and Elsevier Press.

In 1976 Dony (1977) re-recorded the original Bedfordshire "habitat studies" in order to assess the changes which had taken place during the intervening 26 years. The results of this survey were extremely revealing (Table 6): overall c.13% of the sites had been converted to other land uses, whereas a further 28% had deteriorated to a greater or lesser extent. Some habitats had fared much worse than others: in particular, wet grasslands, heathlands and calcareous grasslands had seen the greatest losses whereas woodlands had remained largely unaffected. In addition, Dony was able to show that the percentage of recorded extinctions within his "habitat studies" were comparable to the losses for the county as a whole (Table 6).

TABLE 6. CHANGES IN THE FLORA OF BEDFORDSHIRE BETWEEN 1949/50 AND 1976 AS RECORDED BY DONY'S (1953, 1977) "HABITAT STUDIES"

Broad habitat	Number of "habitat studies"						Extinct species	
	"Lost"		Deteriorated		Unchanged		% lost	% lost since 1978
	no.	%	no.	%	no.	%		
Woodland	2	8	2	8	20	83	4·6	5·3
Calcareous grassland	1	13	3	38	4	50	4·3	6·1
Acid pasture and heath	1	9	4	36	6	55	16·2	19·0
Marshes and meadows	4	22	8	44	6	33	22·8	35·3
Total	8	13	17	28	36	59	–	–

For Dorset a more restricted re-survey of Good's plots was undertaken in order to assess the changes in the distribution of 41 rarer heathland species (Byfield & Pearman 1994). In this study 390 of the original stands were relocated, using Good's original OS maps, and the presence of target species noted. Of these 35% had been converted to agriculture (22%) or forestry (7%) (miscellaneous (6%)). More importantly, there had been a 75% decline in the number of populations of target species. For example, eleven species which were fairly widespread in Good's day (present in more than 20 sites) had declined by more than 50% (*Anagallis minima, Chamaemelum nobile, Filago vulgaris, Genista anglica, Lycopodiella inundata, Potentilla palustris, Pinguicula lusitanica, Radiola linoides, Rhynchospora fusca* and *Veronica scutellata*).

DISCUSSION

ASSESSING CHANGE USING DATA ON EXTINCTION

Although figures for extinction give an indication of the nature and scale of environmental changes over recent decades there are a number of problems associated with their use (Walker 2003). In many cases extinction at the local (county) scale is rarely forever: some species will be overlooked because they are taxonomically difficult, cryptic, or occur in habitats which are difficult to study (e.g. water bodies) or have been traditionally ignored by botanists (e.g. agricultural land). On the other hand some species may well reappear because they have unpredictable or transient life-histories (e.g. arable weeds). For example, in Hertfordshire over 20 "extinct" species which have reappeared since Salisbury's (1924) surveys in the 1920s (Dony 1974; James 1997). A similar rate of rediscovery has been found in Cheshire (14%; Newton 1971, 1990), Norfolk (12%; Beckett & Bull 1999; Petch & Swan 1968), Lincolnshire (8%; Gibbons 1975; Gibbons & Weston 1985) and Northamptonshire (5%; Walker 2003). Alternatively the ultimate demise of a species may take many years to be acknowledged, whereas some species believed extinct may well have survived unnoticed. As a consequence, the perceived number of extinctions may well be very different from the *actual* number within a given area.

Secondly, smaller areas tend to have higher extinction rates because the area of habitat available for a species is reduced (relative to larger areas), thus increasing the threat of localised extinction. As a consequence, smaller counties, such as Middlesex, have very high extinction rates, whereas for very large counties such as Cornwall or Norfolk rates are much lower (Walker 2003). A similar argument applies to the latitudinal position of a county: southern and eastern counties tend to have more species, and so are likely to lose more species regardless of the environmental changes which have taken place.

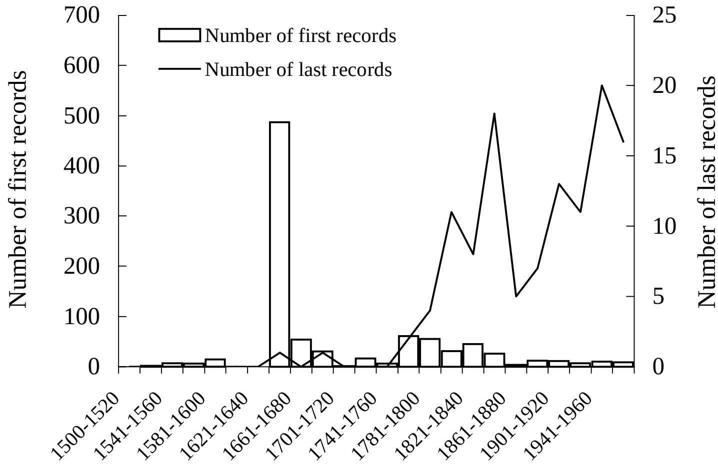
Finally, the rate of extinction may well be influenced by the history of plant recording in the county, with concentrations in periods of intensive recording (Preston 2000). For example, in both Northamptonshire (Walker 2003) and Bedfordshire (Fig. 7b) earlier peaks in extinction appear to coincide with the publication of major works (e.g. Abbott 1798; Morton 1712). Prior to this few extinctions had been recorded, not necessarily because environmental changes had been slight, but because so few species were known to sixteenth, seventeenth and eighteenth century botanists. In contrast, the peak periods of extinction in Cambridgeshire (Fig. 7a) appear unrelated to recording activity in the county, presumably because the majority of its species were first recorded well before the major agricultural changes of the eighteenth and nineteenth centuries (Preston 2000).

ASSESSING CHANGE USING HISTORICAL DATA

Despite the publication of over 200 local floras over the past 350 years very few attempts have been made to assess floristic changes. As the results of this study have shown this is primarily due to a lack of adequate historical data for many areas (Fig. 2). Whilst the majority of English counties possess at least one modern flora, much of Wales and Scotland has to make do with checklists, while most of Ireland has not even got that (Marren 1999). As Figure 3 shows this problem is compounded by the nature of historical data (Perring 1963; Rich & Smith 1996): due to changes in recording methods and behaviour, particularly the increased effort in later surveys, few counties are likely to possess historical datasets which are directly comparable to modern data. Furthermore, increasing knowledge of the taxonomy and biogeography of difficult, critical or cryptic taxa may mean that apparent changes in the distributions of some species are likely to be relative rather than absolute (Rich 1998; Rich & Smith 1996; Rich & Woodruff 1992).

Studies which focus on the nature, rate and scale of extinction avoid many of these problems because they are less influenced by problems of recording behaviour. However, such studies

a) Cambridgeshire



a) Bedfordshire

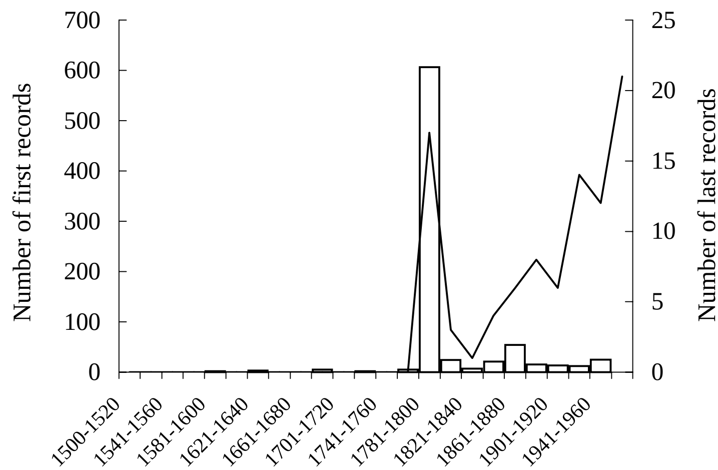


FIGURE 7. First and last records for species in a) Cambridgeshire and b) Bedfordshire (within 20 year intervals). For Cambridgeshire last dates were taken from Preston (2000) and first dates from Perring *et al.* (1964) and Crompton (2001). For Bedfordshire first dates were taken from Dony (1953, 1976) and figures for last records supplied by the vice-county recorder (C. Boon, pers. comm., 2001).

provide very *conservative* estimates of change for a small sample of rare or localised species. In comparison, quantitative assessments of change, which utilise earlier distribution data, allow us to take stock of *all* the species in an area and gauge the relative magnitude of the changes which have taken place during the intervening time period. As a consequence they often highlight changes in the distribution of formerly "common" species which may have become increasingly localised or threatened during the intervening period. Regression analyses, which provide a measure of *relative change* between surveys, are particularly useful in this respect because they take into account the differences in recorder effort between surveys. Similarly, the effects of recorder bias can be minimised in repeat habitat studies if there is precise information on how and where the original survey was carried out.

CONCLUSION

As the results of this brief study have shown, many counties in the British Isles lack adequate baselines from which to measure floristic change. As a consequence, a priority for botanists over the coming decade might be to "fill these gaps" with baseline floras, as well as repeat grid-based surveys for counties where detailed baselines already exist (in particular earlier tetrad surveys). With this in mind, recorders should attempt to collect their data in ways which will be of use to future botanists, who will inevitably look back at our floras, as we have done with Ray, Babington, Druce, and Dony, in order to assess the floristic changes which have taken place. Anyone currently embarking on a local flora project would do well to bear this in mind before they begin.

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REFERENCES

ABBOTT, C. (1798). *Flora Bedfordiensis*. W. Smith, Bedford.
ALLEN, D. E. (1963). Why and what?, in WANSTALL, P. J., ed. *Local floras*, pp.14–20. Botanical Society of the British Isles, London.
BABINGTON, C. C. (1860). *Flora of Cambridgeshire*. John van Voorst, London.
BAKER, J. G. (1863). *North Yorkshire*. Longman, Green, Longman, Roberts, & Green, London.
BECKETT, G. & BULL, A. (1999). *A Flora of Norfolk*. Privately published, Norwich.
BELLAMY, D. (2000). Foreword, in GREEN, I. P., HIGGINS, R. J., KITCHEN, C. & KITCHEN, M. A. R., eds. (2000). *The flora of the Britsol Region*, p.v. Pisces Publications, Newbury.
BEST, J. (1995). 'What time hath stole away', in GENT, G. & WILSON, R., eds. *The flora of Northamptonshire and the Soke of Peterborough*, pp.60–70. Robert Wilson Designs, Rothwell.
BOWEN, H. J. M. (1968). *The flora of Berkshire*. Privately published.
BOWEN, H. (2000). *The flora of Dorset*. Pisces Publications, Newbury.
BRUNKER, J. P. (1951). *Flora of County Wicklow*. Dundalgan Press, Dundalk.
BYFIELD, A. & PEARMAN, D. A. (1994). *Dorset's disappearing heathland flora. Changes in the distribution of Dorset's rarer heathland species 1931 to 1993*. Plantlife and RSPB, London.
CAMPBELL, M. S. (1945). *The Flora of Uig (Lewis).* T. Buncle & Co., Arbroath.
CLAPHAM, A. R., ed. (1969). *Flora of Derbyshire*. County Borough of Derby Museum & Art Gallery, Derby.
CROMPTON, G. (2001). *Cambridgeshire flora records since 1538*. Private website (http://mnlg.com/gc).
CROMPTON, G. & WHITEHOUSE, H. L. K. (1983). *A checklist of the flora of Cambridgeshire*. Privately published, Cambridge.
DEERING, C. (1738). *Catalogus Stirpium, etc., or a catalogue of plants naturally growing and commonly cultivated in divers parts of England, more especially about Nottingham*. Nottingham.
DONY, J. G. (1953). *Flora of Bedfordshire*. Corporation of Luton Museum and Art Gallery, Luton.
DONY, J. G. (1967). *Flora of Hertfordshire*. Hitchin Urban District Council, Luton.
DONY, J. G. (1974). Changes in the flora of Hertfordshire. *Transactions of the Hertfordshire Natural History Society* **27**: 255–264.
DONY, J. G. (1976). *Bedfordshire plant atlas*. Borough of Luton Museum and Art Gallery, Luton.
DONY, J. G. (1977). Change in the flora of Bedfordshire, England, from 1798 to 1976. *Biological conservation* **11**: 307–320.
DRUCE, G. C. (1886). *The flora of Oxfordshire*. Parker & Co., Oxford & London.
DRUCE, G. C. (1897). *The flora of Berkshire*. Clarendon Press, Oxford.
DRUCE, G. C. (1922). Flora Zetlandica. *Report of Botanical Society and Exchange Club (supplement to part 3)* **6**: 457–546.
DRUCE, G. C. (1926). *The flora of Buckinghamshire*. T. Buncle & Co., Arbroath.
DRUCE, G. C. (1930). *The flora of Northamptonshire*. T. Buncle & Co., Arbroath.
EVANS, P. A., EVANS, I. M. & ROTHERO, G. P. (2002). *Flora of Assynt*. Privately published.
FRENCH, C. N., MURPHY, R. J. & ATKINSON, M. G. C. (1999). *Flora of Cornwall*. Wheal Seton Press, Camborne.

GENT, G. & WILSON, R., eds. (1995). *The flora of Northamptonshire and the Soke of Peterborough*. Robert Wilson Designs, Rothwell.
GERARDE, J. (1597). *The herball or generall historie of plantes*. London.
GIBBONS, E. J. (1975). *The flora of Lincolnshire*. Lincolnshire Naturalists' Union, Lincoln.
GIBBONS, E. J. & WESTON, I. (1985). *Supplement to The flora of Lincolnshire*. Lincolnshire Naturalists' Union, Lincoln.
GILMOUR, J. S. L. (1963). The changing pattern, in WANSTALL, P. J., ed. *Local floras*, pp.9–13. Botanical Society of the British Isles, London.
GOOD, R. (1948). *A geographical handbook of the Dorset flora*. Dorset Natural History and Archaeological Society, Dorchester.
GROSE, D. (1957). *The flora of Wiltshire*. The Natural History Section, Wiltshire Archaeological and Natural History Society, Devizes.
HALL, P. C. (1980). *Sussex plant atlas*. Booth Museum of Natural History, Brighton.
HALLIDAY, G. (1997). *A Flora of Cumbria*. Centre for North West Regional Studies, Lancaster.
HOWITT, G. (1839). *The Nottinghamshire flora*. Hamilton, Adams, & Co., London.
JAMES, T. (1997). The changing flora of Hertfordshire. *Transactions of the Hertfordshire Natural History Society* **33**: 62–84.
JERMYN, S. T. (1974). *Flora of Essex*. Essex Naturalists' Trust, Colchester.
KENT, D. H. (1975). *The historical Flora of Middlesex*. Ray Society, London.
KILLICK, J., PERRY, R. & WOODELL, S. (1998). *The flora of Oxfordshire*. Pisces Publications, Newbury.
KING, T. (1891). *The Clydesdale flora*. Fifth edition. Hugh Hopkins, Glasgow.
LAVIN, J. C. & WILMORE, G. T. D., eds. (1994). *The West Yorkshire plant atlas*. City of Bradford Metropolitan Council, York.
LLOYD, L. C. & RUTTER, E. M. (1957). *Handlist of the Shropshire flora*. Caradoc & Severn Valley Field Club, Shrewsbury.
LOUSLEY, J. E. (1976). *Flora of Surrey*. David & Charles, Newton Abott.
MABEY, R. (1999). Preface, in BECKETT, G. & BULL, A. (1999). *A Flora of Norfolk*, pp.4–5. Privately published, Norwich.
MARGETTS, L. J. & DAVID, R. W. (1981). *Review of the Cornish flora 1980*. Institute of Cornish Studies, Redruth.
MARREN, P. (1999). County floras. *British wildlife* **10**: 373–380.
MARREN, P. (2000). *Where have all the flowers gone? A study of local extinctions as recorded in the county floras*. Plantlife, London.
MARREN, P. (2001). "What time hath stole away": local extinctions in our native flora. *British wildlife* **12**: 305–310.
MCCOLLIN, D., MOORE, L. & SPARKS, T. H. (2000). The flora of a cultural landscape: environmental determinants of change revealed using archival sources. *Biological conservation* **92**: 249–263.
MCCOSH, D. J. (1988). Local Floras – a progress report. *Watsonia* **17**: 81–89.
MORTON, J. (1712). *The natural history of Northamptonshire*. Knaplock & Wilkin, London.
NEWTON, A. (1971). *Flora of Cheshire*. Cheshire Community Council, Chester.
NEWTON, A. (1990). *Supplement to Flora of Cheshire*. Privately published, Leamington Spa.
ORDOYNO, T. (1807). *Flora Nottinghamiensis*. Newark.
PERRING, F. H. (1963). Dividing the area, in WANSTALL, P. J., ed. *Local floras*, pp.28–36. Botanical Society of the British Isles, London.
PERRING, F. H. (1971). The vice-county guide. *Watsonia* **8**: 435–447.
PERRING, F. H. (1979). Foreword, in TRIST, P. J. O., ed. (1979). *An ecological flora of Breckland*, p.vii. EP Publishing Limited, Norwich.
PERRING, F. H. & WALTERS, S. M., eds. (1962). *Atlas of the British flora*. Thomas Nelson & Sons, London.
PERRING, F. H., SELL, P. D., WALTERS, S. M. & WHITEHOUSE, H. L. K. (1964). *A Flora of Cambridgeshire*. Cambridge University Press, Cambridge.
PETCH, C. P. & SWANN, E. L. (1968). *Flora of Norfolk*. Jarrold & Sons, Norwich.
PRESTON, C. D. (2000). Engulfed by suburbia or destroyed by the plough: the ecology of extinction in Middlesex and Cambridgeshire. *Watsonia* **23**: 59–81.
PRESTON, C. D. (2003). Perceptions of change in English county floras, 1660–1960. *Watsonia* **24**: 287–304.
PRIMAVESI, A. L. & EVANS, P. A., eds. (1988). *Flora of Leicestershire*. Leicestershire Museums, Art Galleries and Record Services, Leicester.
RAY, J. (1660). *Catalogus plantarum circa Cantabrigiam nascentium*. Cambridge and London.
RELHAN, R. (1785). *Flora Cantabrigiensis*. Cambridge.
RICH, T. C. G. (1998). Squaring the circles – bias in distribution maps. *British wildlife* **9**: 213–219.
RICH, T. C. G. & SMITH, P. A. (1996). Botanical recording, distribution maps and species frequency. *Watsonia* **21**: 155–167.
RICH, T. C. G. & WOODRUFF, E. R. (1992). Recording bias in botanical surveys. *Watsonia* **19**: 73–95.
RIDDELSDELL, H. J., HEDLEY, E. W. & PRICE, W. R., eds. (1948). *Flora of Gloucestershire*. Cotteswold Naturalists' Field Club, Cheltenham.

SALISBURY, E. J. (1924). Changes in the Hertfordshire flora: a consideration of the influence of man. *Transactions of the Hertfordshire Natural History Society* **18**: 51–68.
SALISBURY, E. J. (1967). Foreword, in DONY, J. G. *Flora of Hertfordshire*. Hitchin Urban District Council, Luton.
SIBTHORP, J. (1794). *Flora Oxoniensis*. Oxford.
SIMPSON, N. D. (1960). *Bibliographical index of the British flora*. Brighton.
STACE, C. A. (1990). Foreword, in CRACKLES, E. (ARNETT, R. R. ed.) *Flora of the East Riding of Yorkshire*. Hull University Press and Humberside County Council, Hull.
STACE, C. A. (1997). *New Flora of the British Isles*. Second edition. Cambridge University Press, Cambridge.
SWAN, G. A. (1993). *Flora of Northumberland*. Natural History Society of Northumbria, Newcastle upon Tyne.
TELFER, M. G., PRESTON, C. D. & ROTHERY, P. (2002). A general method for measuring relative change in range size from biological atlas data. *Biological conservation* **107**: 99–109.
TRIMEN, H. & DYER, W. T. T. (1869). *Flora of Middlesex*. Robert Hardwicke, London.
TRIST, P. J. O., ed. (1979). *An ecological flora of Breckland*. EP Publishing Limited, Norwich.
WALKER, K. J. (2003). One species lost every year? An evaluation of plant extinctions in selected British vice-counties since 1900. *Watsonia* **24**: 359–374.
WEBB, R. H. & COLEMAN, W. H. (1849). *Flora Hertfordiensis*. W. Pamplin, London.
WYNNE, G. (1993). *Flora of Flintshire*. Gee & Son, Denbigh.

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