One species lost every year? An evaluation of plant extinctions in selected British vice-counties since 1900

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ABSTRACT

A review of extinction since 1900 has been carried out in 25 British counties. Previous rates of extinction have been revised to exclude species which went extinct before 1900 and non-native species. For British counties as a whole the average rate is c.0·5 species a year with northern and western counties having lost fewer species (0·4 species a year) than those in the south and east (0·6 species a year). These losses suggest a period of heightened extinction during the 20th Century as a result of major environmental changes. However, they should be treated with caution for a number of reasons: extinction rates may also be influenced by the size of the county under investigation, its history of botanical recording and the reliability with which certain species can be recorded as extinct.

KEYWORDS: county Floras, environmental change, conservation.

INTRODUCTION

Peter Marren's study on county extinctions provides a startling account of the loss of species in England over the last century (Marren 2000, 2001). Using lists of extinct species published in local Floras, as well as Preston's (2000) study for Middlesex (v.c. 21) and Cambridgeshire (v.c. 29), he calculated an average loss of 0·7 species per year since 1900, with figures ranging from 0·3 in Norfolk (v.cc. 28 & 27) to 1·4 in Northamptonshire (v.c. 32). His "league table of extinctions" also indicated geographical variation in rates of decline: southern and eastern counties, which occupy the top ten positions, have suffered the worst, with an annual rate of 0·76 species extinctions per year, as opposed to 0·57 in the north and west (Fig. 1).

These figures, which suggest a loss of almost "one species every year" in the worst counties (Frankland 2001), are being publicised by conservationists to highlight declines and presumably lobby government departments (Vines 2000). However, they present a number of intriguing irregularities. Most surprisingly, twice as many species appear to have gone extinct in Northamptonshire (v.c. 32), which tops the "league table", than in rural Cambridgeshire or suburban Middlesex. This is surprising given the rather unexceptional nature of v.c. 32. Due to its rather uniform geology (Sutherland 1995) the flora of the county is not unduly rich and lacks many of the more localised heathland and grassland species which are present in adjacent counties. In addition, recent environmental changes appear to have been comparatively slight. For example, the area of cultivation increased by just 25% between 1928 and the 1990s (661–1214 km^2) to around half the area of the county (McCollin *et al*. 2000). Furthermore, it is not unduly urban with only 22% of land classified as "non-agricultural".

The aim of this paper is to re-examine the rate of extinction for a selection of British counties using a standardised approach which excludes introduced species and those lost before 1900. This has allowed comparisons to be made between counties and regions, as well as providing an overall extinction rate for British counties as a whole. Additionally, due to its comparatively high rate of extinction, a detailed re-evaluation of extinction in Northamptonshire is presented which takes into account the recent rediscovery of "extinct" species. Factors likely to have influenced these figures are suggested and the implications for conservation discussed. Nomenclature for vascular plants follows Stace (1997).

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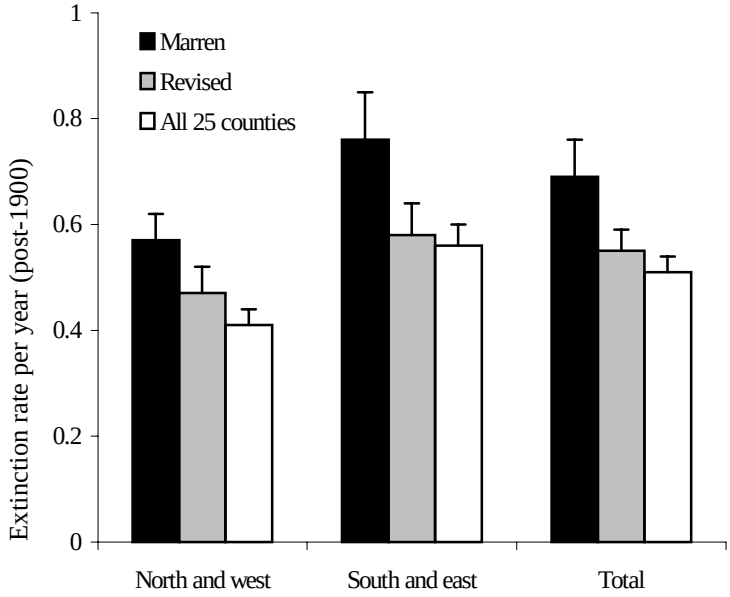

FIGURE 1. Annual extinction rates for British vice-counties since 1900. The graph displays the average rate (± 1 standard error) for Marren's original vice-counties ("Marren"; n = 15), the revised data given in Table 2 ("Revised"; n = 15), and for all 25 counties included in this study. These data are also summarised by region: "north and west" (n = 9) includes Durham, Cheshire, Westmorland, Cumberland, South Lancashire, Shropshire, Radnor, Cornwall, Northumberland; "south and east" (n = 16) includes Dorset, Surrey, Middlesex, Oxfordshire, Cambridgeshire, Bedfordshire, Northamptonshire, Leicestershire, Sussex, Kent, Essex, Suffolk, Norfolk, Gloucestershire, Lincolnshire and Bristol region. The regional differences are significant for all the vice-counties ($p < 0{\cdot}05$) but not for the "Marren" and "Revised" figures.

TABLE 1. SUMMARY OF REVISIONS TO THE GENT & WILSON (1995) LIST OF EXTINCT SPECIES IN NORTHAMPTONSHIRE (V.C. 32)

		Extinctions in v.c. 32				
	Notes	Before 1900	1900–1930	1930–1970	After 1970	Total
Number of extinctions in the 1995 Flora	a	35	16	36	9	96
Species excluded:						
– rediscovered since 1970	b	–	–	–	5	5
– subspecies (species extant)		–	1	–	–	1
– not native	*c*	1	–	–	2	3
– dubious record or error	d	4	–	–	–	4
– British natives but introduced into v.c. 32	e	3	2	4	2	11
Total number excluded in this analysis		8	3	4	9	24
Additional extinctions	f	2	6	10	13	31
Revised number		29	19	42	13	103

Notes: a. Some dates have been re-determined as a result of historical research and are therefore different from those given in Gent & Wilson (1995). b. Rediscovered as a result of fieldwork for the New Atlas. c. Native status follows Preston & Hill (1997). Two species excluded on this basis (*Centaurea cyanus* and *Prunus cerasus*) have been rediscovered in recent years. d. This figure does not include *Eriophorum gracile* which has recently been confirmed for the county. e. Not considered native in v.c. 32 given their native distribution and habitats elsewhere in the UK. f. These figures are based on recent recording data, herbarium material and correspondence with local botanists.

METHODS

SOURCES OF DATA

Twenty-five counties are included in this study, including 15 which were originally analysed by Marren (2001) (Table 2), plus an additional ten for which there is a recent Flora and/or a list of extinctions (Table 3). Eighteen of these Floras (including Northamptonshire) provide a list of presumed extinctions with an indication of the year in which species were last recorded. For the remaining counties this information was compiled from species accounts (Cornwall, Dorset and Oxfordshire) or taken directly, without revision, from lists published in county studies of change for Bedfordshire (Boon 1998), Cambridgeshire (Preston 2000), Middlesex (Preston 2000) and South Lancashire (Greenwood 1999).

Because of its comparatively high rate of extinction Northamptonshire was treated in greater detail. Initially the list of extinctions was taken from the most recent Flora of the county (Gent & Wilson 1995; hereafter referred to as the 1995 Flora). This includes 96 species which were last recorded before the publication of George Claridge Druce's (1930) Flora of the county (hereafter referred to as the 1930 Flora), or between 1930 and 1970, but not since, despite deliberate searching at former sites (Gent & Wilson 1995). This list was subsequently revised in the light of more recent survey data collected in preparation for the New Atlas of the British and Irish flora (Preston *et al*. 2002).

ASSESSMENT OF NATIVE/ALIEN STATUS

In calculating extinction rates Marren accepted taxa as native in a county if the author of the Flora had done so, as well as non-native species so well-established in wild places that they can be categorised as permanent members of semi-natural communities (Marren 2000). The approach taken in this study differs in excluding species which are not considered native by Preston & Hill (1997), or British native species (sensu Preston & Hill) which have obviously been introduced to the county in question. As a result, for Northamptonshire it excludes many species classified in the 1930 Flora as "denizen", "colonist", "alien" or "exotic" and in the 1995 Flora as "British", "adventive" or "introduction". In addition, it also excludes a number of long-established introductions with naturalised ranges in the British Isles, such as *Centaurea cyanus*, which is considered to be native by some authorities (e.g. Stace 1997).

For all counties, where there is doubt about whether a British native species is native or not, the species is accepted as native if its habitat, history and distribution in the county are similar to those areas of Britain where it is assumed to be native. In this study a number of atlases (e.g. Perring & Walters 1962; Preston & Croft 1997; Stewart *et al.* 1994; Wigginton 1999) and monographs (e.g. Graham & Primavesi 1993; Page 1997) were particularly helpful in this respect.

ASSESSMENT OF DATES OF EXTINCTION

The year in which a species was last recorded was taken from the most recent published work for the county. Consequently, the accuracy of some of the figures presented, particularly those for counties with older Floras (e.g. Essex, Lincolnshire, Suffolk), could well be revised in the light of more up-to-date information. However, for Northamptonshire last dates were taken from data files collated for the New Atlas of the British and Irish flora (Preston *et al*. 2002). This allowed species which have been rediscovered since the 1995 Flora to be included.

For 20 species recorded in the 1930 Flora but not since, no last date is given, presumably because Druce considered the species to be extant or because no date was known to him. For these species approximate dates were derived from herbarium sheets in **OXF**, and/or plant records published by Druce in preparation for the 1930 Flora (Druce 1880–81 *et seq.*). For six species (*Eleogiton fluitans*, *Galium tricornutum*, *Mentha suaveolens*, *Oenanthe lachenalii*, *Thelypteris palustris* and *Valerianella carinata*) no last date could be traced. As a consequence these are treated as having been last seen in 1930. Similarly, for species which were known to Morton (1712) and Notcutt (1843) but no later authors the dates of extinction are given as 1712 and 1843 respectively.

TABLE 2. MARREN'S (2001) "LEAGUE TABLE" OF EXTINCTIONS. THE REVISED FIGURES EXCLUDE INTRODUCTIONS (TO THE UK OR VICE-COUNTY), HYBRIDS AND SPECIES WHICH WERE LAST RECORDED BEFORE 1900

	Number extinct		Extinction rate per year			Recording period		Source
	Marren	Revised	Marren	Revised	Change	Marren	Revised	
Northamptonshire (v.c. 32)	93	74	1·43	0·82	-0·61	1930–1995	1900–1990	This paper
Lincolnshire (v.cc. 53, 54)	77	38	0·91	0·45	-0·46	1900–1985	1900–1985	Gibbons (1975); Gibbons & Weston (1985)
Gloucestershire (v.cc. 33, 34)	78	45	0·91	0·52	-0·39	1900–1986	1900–1986	Holland *et al.* (1986)
Middlesex (v.c. 21)	76	76	0·84	0·84	0	1900–1990	1900–1990	Preston (2000)
Durham (v.c. 66)	68	55	0·77	0·63	-0·14	1900–1988	1900–1988	Graham (1988)
Cambridgeshire (v.c. 29)	66	66	0·73	0·73	0	1900–1990	1900–1990	Preston (2000)
Leicestershire (v.c. 55)	59	60	0·67	0·68	0·01	1900–1988	1900–1988	Primavesi & Evans (1988)
Surrey (v.c. 17)	51	29	0·67	0·34	-0·33	1900–1976	1900–1986	Lousley (1976); Leslie (1987)
Essex (v.cc. 18, 19)	68	68	0·61	0·61	0	1862–1974	1862–1974	Jermyn (1974)
Suffolk (v.cc. 25, 26)	50	46	0·61	0·56	-0·05	1900–1982	1900–1982	Simpson (1982)
Cheshire (v.c. 58)	49	41	0·54	0·46	-0·08	1900–1990	1900–1990	Newton (1971, 1990)
Westmorland (v.c. 69)	56	37	0·58	0·38	-0·20	1900–1997	1900–1997	Halliday (1997)
Cumberland (v.c. 70)	48	36	0·49	0·37	-0·12	1900–1997	1900–1997	Halliday (1997)
South Lancashire (v.c. 59)	50	48	0·49	0·50	0·01	1860–1963	1900–1996	Greenwood (1999)
Norfolk (v.cc. 27, 28)	33	37	0·33	0·37	0·04	1900–1999	1900–1999	Beckett & Bull (1999)

TABLE 3. EXTINCTION IN A SELECTION OF BRITISH VICE-COUNTIES. FIGURES EXCLUDE INTRODUCTIONS (TO THE UK OR VICE-COUNTY), HYBRIDS AND SPECIES

	Number extinct	Extinction rate per year	Recording period	Source
Dorset (v.c. 9)	32	0·32	1900–2000	Bowen (2000)
Oxfordshire (v.c. 23)	39	0·40	1900–1998	Killick *et al.* (1998)
Bedfordshire (v.c. 30)	55	0·61	1900–1990	Boon (1998) with amendments (C. Boon, pers. comm., 2001)
Shropshire (v.c. 40)	33	0·37	1900–1990	Sinker *et al.* (1985) with amendments (A. Lockton, pers. comm., 2001)
Radnor (v.c. 43)	38	0·41	1900–1993	Woods (1993)
Cornwall (v.cc. 1 & 2)	36	0·36	1900–1999	French *et al.* (1999)
Sussex (v.cc. 13 & 14)	69	0·78	1900–1988	Hall (1980); Briggs (1990)
Kent (v.cc. 15 & 16)	28	0·34	1900–1982	Philp (1982)
Northumberland (v.cc. 67 & 68)	23	0·25	1900–1993	Swan (1993)
Bristol Region (v.cc. 6 & pt 34)	64	0·64	1900–2000	Green *et al.* (2000)

TABLE 4. REVISIONS TO THE FIGURES FOR COUNTY EXTINCTION GIVEN IN TABLE 2

	Reason for exclusion from revised list									
	Critical/ hybrids	Extinct before 1900	GB non-native	GB native-introduced	Never confirmed	Re-found	Total number excluded	Species added (extinct after 1900)	Number listed as extinct in flora	Number extinct (revised)
Lincolnshire		31	2	1		6	40	4	74	38
Gloucestershire		14	3		17		34		79[a]	45
Durham	6		5	1	1		13		68	55
Surrey		14	3		1	4	22		51	29
Suffolk			3				3		49[b]	46
Cheshire			2			6	8		49	41
Westmorland	17						17		54[c]	37
Cumberland	10						10		46[d]	36
Norfolk							0	4	33	37

Notes: [a-d] For these counties Marren quotes the following figures: [a] 78, [b] 50, [c] 56, [d] 48.

SELECTION OF SPECIES

In this paper the lists of extinctions used to calculate rates for British counties exclude the following species: those species last recorded before 1900, critical species and hybrids, species not considered to be British natives by Preston & Hill (1997), British native species which had obviously been introduced, species of dubious county status and those which had subsequently been refound since the publication of the Flora.

RESULTS

EXTINCT SPECIES IN NORTHAMPTONSHIRE

For Northamptonshire the changes to the list of "presumed extinctions" given in the 1995 Flora are summarised in Table 1. Of the original 96 species included in the 1995 Flora, 24 have been excluded from the current analysis because they are either obvious errors, introductions to Britain or v.c. 32, or have subsequently been rediscovered. Conversely, 32 species have been added to this list as a result of subsequent fieldwork and historical research. Overall this shows that 103 species have apparently become extinct in Northamptonshire since records began, representing 13% of the 810 species recorded in the county. The revised list of extinctions is given in Appendix 1 with the date of the last known record. The full list of changes to the Gent & Wilson list is given in Appendix 2.

Changes to the Gent & Wilson (1995) list of "presumed extinctions"

Five native species have been refound since the publication of the 1995 Flora and so are excluded from the revised list. In addition, *Polygala vulgaris* subsp. *collina* is excluded because subsp. *vulgaris* is still extant in the county and *Filago gallica*, which was last recorded near King's Cliffe in 1838, *Centaurea cyanus* and *Prunus cerasus* (both of which have been refound since the 1995 Flora) are all excluded as they are not considered native by Preston & Hill (1997).

Four species recorded as extinct in the 1995 Flora are likely to have been recorded in error. These include *Scleranthus perennis* subsp. *perennis* which was recorded by Morton sometime before 1712 (Druce 1930), and possibly on a wall near Wellingborough in 1974 (Gent & Wilson 1995). These records seem very doubtful given the rarity of *S. perennis* in Britain: subsp. *perennis* has only ever been confirmed from Doloritic rocks at one site in Radnorshire (Slater 1999) and subsp. *prostratus* is confined to a handful of sandy heaths in East Anglia (Leonard 1999). The Northamptonshire plants are more likely to be referable to over-wintering or biennial forms of *S. annuus* which occurs on sandy ground in the county or possibly subsp. *polycarpos* which appears to be more widespread than previously thought (Preston *et al.* 2002). Similarly, Morton's record for *Crepis foetida*, which is now a very rare native plant in the British Isles, is more likely to have been an early record for *Crepis vesicaria* subsp. *taraxacifolia*, which was first recorded in Britain in 1713 (Clapham *et al.* 1987). Other doubtful species include *Galium sterneri*, which has its most southerly English station in the Peak District (Lusby & Slack 1994), and *Sagina subulata*, which has a predominantly northern and western distribution in England (Perring & Walters 1962). Given the absence of herbarium material for these species it would seem unwise to accept them for the county. In contrast, *Eriophorum gracile*, which was collected by Druce from Hornstocks Wood near Wittering in 1878, has recently been confirmed from herbarium specimens (**OXF**) (Walker in press.).

Eleven British native species are considered to have been introduced into Northamptonshire. All these species occur outside their native range in the county (e.g. *Impatiens noli-tangere*, *Gymnocarpium robertianum*) or were recorded from artificial or disturbed habitats which suggest accidental introduction. In addition, both *Eryngium campestre* (grassland adjacent to garden) and *Daphne mezereum* (copse) were recorded in semi-natural habitats where they were presumably planted.

Thirty-one native species which were not included in the list of "presumed extinctions" in the 1995 Flora are considered extinct in this paper. Twenty-three of these have not been recorded since 1989, despite fieldwork for the New Atlas, and so are assumed to be extinct. However, a number of these are likely to have been overlooked and may well re-appear in future years (e.g. *Anagallis minima*, *Aphanes australis*, *Rosa* spp.). Of the remaining eight species six were classified as extinct in the main text of the 1995 Flora but not in the main list, and two are critical segregates (*Erophila majuscula* and *Euphrasia arctica*).

Extinction rate

Marren's extinction rate for Northamptonshire is based on the list of "presumed extinct" species given in the 1995 Flora, and is calculated by dividing the number of extinctions (96, excluding doubtfully present species) by 65, the number of years between the 1930 and 1995 Floras. This gives an average loss of 1·4 species per year, or 14 species a decade, since 1900. However, this is a significant overestimate because it assumes that all the species on this list were last recorded *after* 1930. As a result Marren includes 52 species, italicised in the Gent & Wilson list, which were last recorded *before* 1930, and in many cases before 1900. When these pre-1900 extinctions are removed from the analysis then this gives a loss of 74 species since 1900, or 0·82 species a year (Table 2).

EXTINCTION IN OTHER BRITISH VICE-COUNTIES

The revisions presented in this study show that Marren over-estimates the rate of extinction for at least nine other vice-counties (Table 4). The figure of 0·91 species a year for Lincolnshire (v.cc. 53 & 54), in particular, appears to be significantly higher than the revised rate because he includes 31 which were last recorded before 1900 within his 20th Century calculations. If non-native and rediscovered species listed in the supplement to the county Flora (Gibbons & Weston 1985) are excluded from the list given in the 1975 Flora (Gibbons 1975) then 64 native species have presumably become extinct in Lincolnshire, 38 of which were last recorded after 1900. This gives a probable rate of extinction of around 0·45 species per year since 1900, which, interestingly, is comparable to counties of similar size, such as Norfolk (v.cc. 27 & 28) and Cornwall (v.cc. 1 & 2).

The rate for Gloucestershire (v.cc. 33 & 34) is also different because he includes all 79 (Marren actually cites 78) species listed as probably extinct in the supplement to the Flora of the county (Holland *et al.* 1986). However, this figure includes 17 species which have never been satisfactorily confirmed for the county (all recorded before 1948), three ancient introductions not considered as native by Preston & Hill (1997) and 14 species which were last recorded before 1900. When these figures are taken into account the overall rate declines from 0·91 to 0·52 species per year since 1900.

Similarly, for Surrey Marren includes all 51 species listed as extinct in Lousley's Flora of the county (Lousley 1976) despite the fact that 14 of these species were last recorded before 1900. In addition, he includes three species which are not considered native by Preston & Hill (1997), four species which subsequently have been rediscovered and one species (*Carex diandra*) which has never been satisfactorily confirmed (Leslie 1987). When these figures are taken into account 43 native species are considered to have disappeared, of which 29 were last recorded after 1900. As a result the rate of extinction declines from 0·67 to 0·34 species a year (Table 2).

For a further six vice-counties, the revised figures presented in this paper are different to those given by Marren due to the exclusion of 13 non-native, critical and doubtful species in Durham (Graham 1988), 17 and ten hybrids in Westmorland and Cumberland respectively (Halliday 1997), six recently discovered species and two aliens in Cheshire (Newton 1971, 1990) and three non-native species in Suffolk (Simpson 1982). Norfolk is the only county for which the Marren estimate is lower than the one presented in this paper due to his exclusion of four species which were last recorded between 1900 and 1914 (*Epipactis purpurata*, *Herminium monorchis*, *Huperzia selago* and *Hypochaeris maculata*) (Beckett & Bull 1999). As a consequence Marren's figure of 0·33 species per year increases to 0·37 when these species are included.

ONE SPECIES LOST EVERY YEAR?

Marren's study was admittedly based on a small and geographically biased sample of counties. However, the revisions presented in this paper suggest that vice-counties in Britain have lost just over half a species a year during the last century (0·55), and not "one species a year" as the Marren "league table" suggests (Fig. 1). Not surprisingly, this figure is further reduced, to 0·51 species per year, when the sample size is increased to include more vice-counties (Fig. 1).

Figure 1 also shows the uneven geographical distribution of extinction. Counties to the north and west of the Tees-Exe line have, on average, lost fewer species and thus have a lower rate of extinction (0·41 species per year) than those in the south and east, which have lost 0·56. Although there is a great deal of variation within this dataset the overall regional differences are statistically significant when all the counties shown in Fig. 1 are included ($p<0·05$).

Although these data suggest a much lower level of extinction than was first thought, they do support Marren's original assertion that Northamptonshire has suffered more than most other counties during the 20th Century (0·82 species per year) (Marren 2000, 2001). Indeed, even when the revisions presented in this paper are taken into account the overall loss of species in v.c. 32 is comparable to suburban Middlesex (0·84), and is higher than Cambridgeshire (0·73) and Sussex (0·78). The reason for this may be related to the timing of peak periods of extinction in Northamptonshire, which appears to have occurred much later than in some other counties (Fig. 2). For example, in Cambridgeshire the first wave of extinction coincided with habitat destruction caused as a result of parliamentary enclosure during the early part of the 19th Century (Preston 2000). However, in Northamptonshire 20th Century losses were much higher than in the preceding century, presumably because the majority of semi-natural grasslands were ploughed up after 1920.

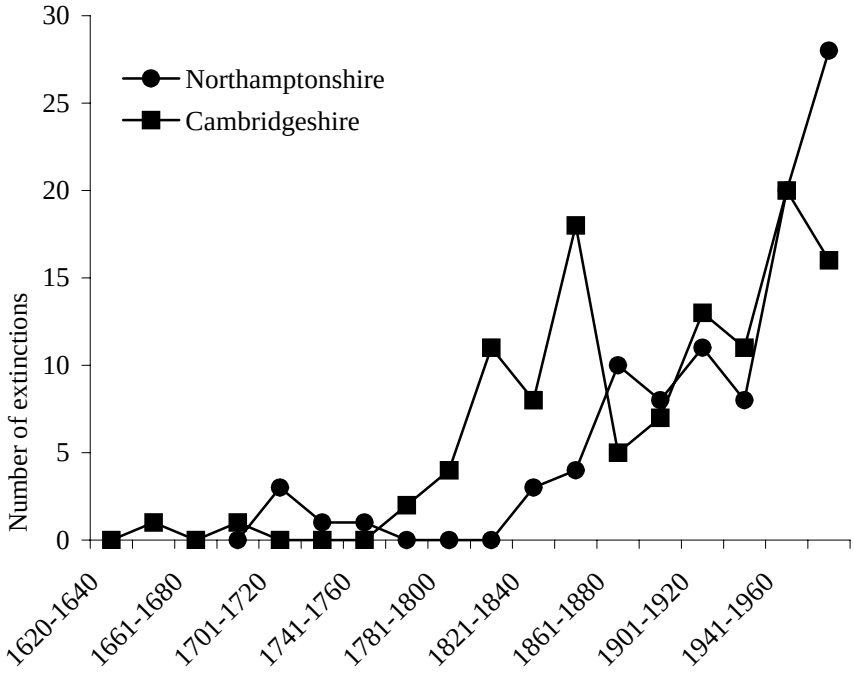

FIGURE 2. The number of extinct species in Cambridgeshire (v.c. 29) and Northamptonshire (v.c. 32) since 1620. The number of extinctions are plotted for 20 year intervals, using the assumption that a species became extinct in the period in which it was last recorded.

DISCUSSION

FACTORS INFLUENCING EXTINCTION RATE

The figures for plant extinction presented in this paper reflect the pace and scale of major environmental changes which have occurred within individual counties during the 20th Century. However, they may have also been influenced by a number of other factors (e.g. recording bias, county area, etc.) which may have led to the *actual* rate of extinction being over- or under-estimated. Such problems are rarely acknowledged in studies of floristic change, despite the effects they are likely to have on the overall findings and conclusions.

Definition of native taxa

The revised figures for extinction presented in this paper are lower than in the Marren study, partly because of the exclusion of non-native British species (sensu Preston & Hill 1997) or British native species which have obviously been introduced outside their native range. For a sizeable proportion of these species there may be good grounds for exclusion. For Northamptonshire obvious examples include casuals imported into the county in rubble and sand (e.g. *Medicago minima, Potentilla argentea, Trifolium scabrum*) and colonists introduced by other means (e.g. *Impatiens noli-tangere, Gymnocarpium robertianum*). However, the exclusion of a number of long-established alien species, such as *Centaurea cyanus*, which were probably introduced by early farmers after the Neolithic, is more problematic. Many of these species, which were fully naturalised by the 15th Century, are important indicators of environmental change because they have undergone dramatic declines in recent years as a result of modern farming practices (Sutcliffe & Kay 2000). Conversely, many more recent introductions are becoming increasingly widespread on highly fertile, disturbed soils associated with human activities (Thompson *et al*. 1995).

Reliability of last date

In the absence of more detailed information the extent to which the date of last record actually reflects the timing of extinction can vary from species to species. For example, Druce provides precise dates for the loss of only two species in Northamptonshire; *Diplotaxis tenuifolia* which was "formerly on the south-west bastion of Northampton Castle, where it was plentiful until the castle was destroyed in 1879" (Druce 1930, p. 22) and *Daphne mezereum* which was "destroyed in 1909 by someone digging up the large shrub" (Druce 1930, p. 202). For most species, however, the date of the loss is not known. Two notable examples are given in the 1930 Flora; the loss of *Stachys germanica*, from "some old quarries between Fineshade and Wakerley" which "have since been filled up, and the plant destroyed" (Druce 1930, p. 184), and *Ophrys sphegodes* for which "the large planting of larch appears to have been responsible for its destruction" (Druce 1930, p. 225). As is more frequently the case, extinction usually follows a long period of decline during which successional or man-made changes render a site increasingly unsuitable for a particular species. In Northamptonshire, this presumably accounts for the loss of a number of heathland species (e.g. *Lycopodium clavatum, Juncus squarrosus* and *Moenchia erecta*) which declined as a result of piecemeal drainage, afforestation with conifers and housing development. Similar losses must have gone unnoticed during major periods of agricultural innovation. Indeed, Druce gives the example of *Ajuga chamaepitys*, which disappeared well before his day, presumably as a result of the "extensive enclosures" which took place in the early part of the 19th Century (Druce 1930).

These discrepancies between the date of the last record and the actual "extinction" are compounded by the nature of the recorders themselves. Botanists tend to be reluctant to classify a species as extinct, even if has not been seen for many years, and prefer to use terms such as "presumably extinct" or "almost certainly extirpated", rather than to write it off completely (Marren 2001). Given the arbitrary nature of this decision then it would seem sensible to accept Preston's (2000) cut-off: a species should not be considered extinct if it has been seen in the preceding decade unless there is good evidence to the contrary.

Is extinction forever?

As Preston (2000) quite rightly stated "at the vice-county level the slogan of 'extinction is forever' is manifestly false" as, occasionally, apparently extinct species reappear. This is often the case for species which form persistent seed banks. For example, in Northamptonshire *Genista anglica* was refound "springing up in newly cleared ground" at Harlestone Heath (Druce 1930, p. 50) following the removal of a plantation and more recently *Agrostemma githago* flowered following ground disturbance associated with the planting of a new hedge (Gent & Wilson 1995).

However, it is more common for species to reappear because they have been overlooked, either in places where they have not been previously sought or in old sites where they were formerly recorded. For most species this is because their ecology or taxonomy makes them difficult to record. For example, of the five species which have been rediscovered in Northamptonshire, two are very closely related to more common taxa (*Ulex minor* and *Pedicularis sylvatica*), one is an inconspicuous aquatic (*Potamogeton alpinus*) and one is a cornfield weed with a tendency to appear sporadically (*Papaver hybridum*).

Some species tend to be overlooked because they are inconspicuous, difficult to identify or occur in habitats which are poorly recorded. As a result there may be an argument for excluding such taxa from lists of extinct species because they are unlikely to have been recorded consistently in the past. For example, the historical distributions of *Erophila* taxa have only recently been understood through the use of herbarium material (Rich & Lewis 1999). Furthermore, the distribution of critical segregates of *Rosa*, *Rubus*, *Hieracium* and *Euphrasia* often reflect the areas where taxonomists have worked rather than the actual distribution of the individual species. As a result, for these species "rediscovery" or "extinction" may well represent nothing more than a change in the intensity of recording.

Aquatic species, in particular, pose a number of problems for the study of extinction. Traditionally they have been poorly recorded, largely because they occur in habitats which are difficult to examine and the major genera are taxonomically difficult (Preston & Croft 1997). Furthermore, the life histories of some species make them hard to study: most species are highly mobile, being adapted to the highly unstable conditions of water bodies. Some species are also susceptible to competition with alien waterweeds, such as *Elodea* spp. and *Azolla filiculoides*, which spread rapidly throughout Britain in the 20th Century. All these factors have meant a "kaleidoscopic pattern of change" in the distribution of some species (Preston & Croft 1998) making an assessment of their apparent extinction and colonisation difficult to interpret. The most obvious example in Northamptonshire is *Luronium natans*, which was last recorded in the county in 1986. In Britain the extent of its distribution has only recently been fully appreciated, following the discovery that the majority of its populations occur as inconspicuous, submerged plants, with rosettes of unremarkable grass-like leaves (Ferguson *et al*. 1998). The variability in growth-forms of other aquatic species, such as pondweeds and water-starworts, pose similar problems for the study of extinction.

Thus for Northamptonshire the rate of extinction presented in this paper may well be an over-estimate, as some species may be rediscovered, especially amongst the 23 species not recorded since 1989. For example are *Anagallis minima*, *Aphanes australis*, *Rosa obtusifolia* and *R. rubiginosa* really extinct in v.c. 32 or have they just been overlooked?

County area

As with species richness the number of extinctions recorded in an area will be scale-dependent, with smaller areas tending to lose more species (Fig. 3). For example, twice as many species have gone extinct in the tiny suburban county of Middlesex (724 km^2) than in rural Lincolnshire which is almost ten times as big (7200 km^2). The underlying cause of this relationship is habitat availability: in smaller areas a species is more likely to become extinct because the extent of its habitat is more restricted. However, this relationship is likely to be strongly influenced by a number of other factors, not least regional differences in the scale of habitat destruction, climate, species-pool and habitat diversity. For example, since 1900 the Shetland Islands, which are comparable in area to Bedfordshire, have only lost two species (Scott & Palmer 1987). As a consequence, the overall relationship between extinction and area is relatively weak (R^2 = 14·6%; p = 0·059).

The history of botanical recording

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). This was certainly the case in Northamptonshire, where the first major period of botanical activity in the county, between 1800–1900, was immediately followed by a pronounced peak in plant extinction (Fig. 4). Prior to this few extinctions had been recorded, not necessarily because the environmental changes had been slight, but because so few species were known to 16th, 17th and 18th Century botanists. For example, only around 200 species were known to Morton in 1700, whereas, by 1900, Druce had recorded over 700 species in the county. As a result the number of extinctions increased markedly towards the end of the 19th Century. Given that most species had been discovered by the time of the 1930 Flora, the second peak in extinction after 1920 is presumably a more realistic reflection of the environmental changes which were taking place in the county around that time.

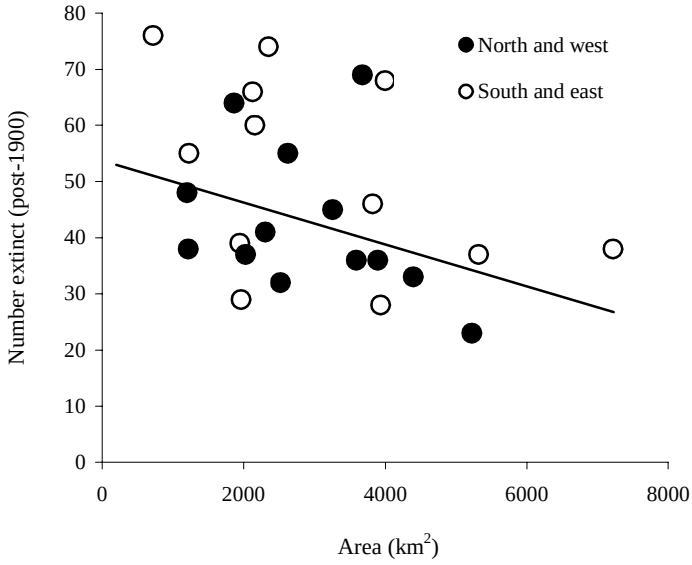

FIGURE 3. The relationship between county extinction since 1900 and area (R^2 = 14%, p = 0·059).

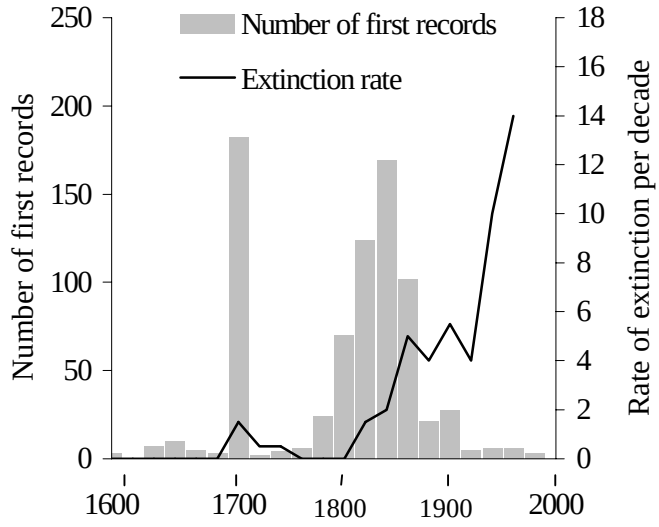

FIGURE 4. The discovery of new species in Northamptonshire (v.c. 32) (within 20 year categories) in relation to extinction rate (calculated for 20 year categories up to 1980). First dates are taken from the Gent & Wilson (1995) Flora (for 35 species no first date is given). Notable botanical works, which included new plant records for the county, are: Gerarde (1597), How (1650), Morton (1712), Notcutt (1843), Druce's early published plant records (1880–81 *et seq*.), and Druce (1930).

EXTINCTION AND CONSERVATION

Given the inherent problems in the study of extinction at the county scale, the figures presented in this paper should not be regarded as very precise: some species listed as extinct may well reappear, whereas others will be missing because insufficient time has elapsed for their loss to be noted or a judgement to be made as to their status. Moreover, not everyone will agree with the exclusion of non-native species, or indeed Preston & Hill's conclusions as to the native status of some species. Although this treatment is certainly the most credible for most species, it could well be refined, particularly with regard to some long-established introductions. Furthermore, the accuracy of some of the revised figures presented in this paper could be revised in light of more up to date information, particularly with respect to the rediscoveries since the publication of the last Flora.

Despite these caveats the overall figures suggest a period of heightened extinction at the county scale in Britain during the 20th Century, of which Northamptonshire appears to be a particularly illustrative example. Although the pace and scale of change may not be as bad as first thought, in lowland counties at least, we still appear to be "losing what is natural, particular and special" (Marren 2000). However, if these figures are to be used to highlight changes which have taken place in our native flora then we must ensure the correct use of the available data and acknowledge the inherent problems that the study of extinction inevitably presents.

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REFERENCES

BECKETT, G. & BULL, A. (1999). *A Flora of Norfolk*. Privately published, Norwich.

BOON, C. (1998). British and Irish floristic elements applied to the flora of Bedfordshire. *Bedfordshire Naturalist* **52**: 78–91.

BOWEN, H. (2000). *The flora of Dorset*. Pisces Publications, Newbury.

BRIGGS, M. (1990). *Sussex plant Atlas: selected supplement*. Booth Museum of Natural History, Brighton.

CLAPHAM, A. R., TUTIN, T. G. & MOORE, D. M. (1987). *Flora of the British Isles*, 3rd ed. Cambridge University Press, Cambridge.

DRUCE, G. C. (1880–1). Contributions to a Flora of Northamptonshire. *Journal of the Northampton Natural History Society* **1**: 48, 92, 152, 179, 215, 271, 334.

DRUCE, G. C. (1882–3). Contributions to a Flora of Northamptonshire. *Journal of the Northampton Natural History Society* **2**: 25, 50, 142, 227, 279, 315.

DRUCE, G. C. (1884–5). Contributions to a Flora of Northamptonshire. *Journal of the Northampton Natural History Society* **3**: 26, 79, 104, 143, 179, 219, 276.

DRUCE, G. C. (1886–7). Contributions to a Flora of Northamptonshire. *Journal of the Northampton Natural History Society* **4**: 5, 37, 116, 173, 235, 324.

DRUCE, G. C. (1888–9). Contributions to a Flora of Northamptonshire. *Journal of the Northampton Natural History Society* **5**: 29, 117, 149, 235, 249, 309.

DRUCE, G. C. (1890–1). Contributions to a Flora of Northamptonshire. *Journal of the Northampton Natural History Society* **6**: 7, 56, 65, 100, 172, 249.

DRUCE, G. C. (1892–3). Contributions to a Flora of Northamptonshire. *Journal of the Northampton Natural History Society* **7**: 64, 136, 161, 250, 292.

DRUCE, G. C. (1894–5). Contributions to a Flora of Northamptonshire. *Journal of the Northampton Natural History Society* **8**: 5.

DRUCE, G. C. (1898–9). Botany notes. *Journal of the Northampton Natural History Society* **10**: 135, 208, 265.

DRUCE, G. C. (1900–1). Notes on the flora. *Journal of the Northampton Natural History Society* **11**: 13.

DRUCE, G. C. (1904–5). Northampton plants. *Journal of the Northampton Natural History Society* **13**: 290.

DRUCE, G. C. (1909–10). Botany of Fenland. *Journal of the Northampton Natural History Society* **15**: 100.

DRUCE, G. C. (1909–10). Additions to the Flora of Fenland. *Journal of the Northampton Natural History Society* **15**: 221.
DRUCE, G. C. (1909–10). Plant notes. *Journal of the Northampton Natural History Society* **15**: 281–296.
DRUCE, G. C. (1910–11). Plant notes. *Journal of the Northampton Natural History Society* **16**: 291–295.
DRUCE, G. C. (1930). *The flora of Northamptonshire*. T. Buncle & Co., Arbroath.
FERGUSON, C., BRIGGS, J. & WILLBY, N. (1998). Floating water-plantain in Britain – under-recorded and overlooked? *British Wildlife* **9**: 298–303.
FRANKLAND, L. (2001). Gone – one wild flower a year. *B.S.B.I. News* **86**: 44–45.
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.
GRAHAM, G. G. (1988). *The flora and vegetation of County Durham*. Durham Flora Committee and the Durham County Conservation Trust, Durham.
GRAHAM, G. G. & PRIMAVESI, A. L. (1993). *Roses of Great Britain and Ireland*. Botanical Society of the British Isles Handbook No. 7. B.S.B.I., London.
GREEN, I. P., HIGGINS, R. J., KITCHEN, C. & KITCHEN, M. A. R. (2000). *The flora of the Britsol Region*. Pisces Publications, Newbury.
GREENWOOD, E. F. (1999). Vascular plants: a game of chance?, in GREENWOOD, E. F., ed. *Ecology and landscape development: a history of the Mersey basin*, pp. 195–211. Liverpool University Press and National Museums and Galleries on Merseyside, Liverpoool.
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.
HOLLAND, S. C., CADDICK, H. M. & DUDLEY-SMITH, D. S. (1986). *Supplement to the Flora of Gloucestershire*. Grenfell Publications, Bristol.
HOW, W. (1650). *Phytologia Britannica*. London.
JERMYN, S. T. (1974). *Flora of Essex*. Essex Naturalists' Trust Limited, Fingringhoe.
KILLICK, J., PERRY, R. & WOODELL, S. (1998). *The flora of Oxfordshire*. Pisces Publications, Newbury.
LEONARD, Y. (1999). *Scleranthus perennis* ssp. *prostratus* Sell (Caryophyllaceae), in WIGGINTON, M. J., comp. & ed. *British Red Data Books 1 Vascular plants*, 3rd ed., p. 337. Joint Nature Committee Council, Peterborough.
LESLIE, A. C. (1987). *Flora of Surrey supplement and checklist*. Privately published, Guildford.
LOUSLEY, J. E. (1976). *Flora of Surrey*. David & Charles, Newton Abott.
LUSBY, P. J. & SLACK, A. (1994). *Galium sterneri* Ehrend., in STEWART, A., PEARMAN, D. & PRESTON, C. D., comps & eds. *Scarce plants in Britain*, p. 189. Joint Nature Conservation Committee, Peterborough.
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.
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.
NOTCUTT, W. L. (1843). A catalogue of plants observed in the neighbourhood of Daventry, Northamptonshire. *The phytologist* **1**: 500–508.
PAGE, C. N. (1997). *The ferns of Great Britain and Ireland*, 2nd ed. Cambridge University Press, Cambridge.
PERRING, F. H. & WALTERS, S. M., comps & eds. (1962). *Atlas of the British flora*. Thomas Nelson & Sons, London.
PHILP, E. G. (1982). *Atlas of the Kent flora*. Kent Field Club, Maidstone.
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. & CROFT, J. M. (1997). *Aquatic plants in Britain and Ireland*. Harley Books, Colchester.
PRESTON, C. D. & CROFT, J. M. (1998). Britain's changing aquatic flora. *British Wildlife* **10**: 18–28.
PRESTON, C. D. & HILL, M. O. (1997). The geographical relationships of British and Irish plants. *Botanical Journal of the Linnean Society* **124**: 1–120.
PRESTON, C. D., PEARMAN, D. & DINES, T., comps & eds. (2002). *New Atlas of the British and Irish flora*. Oxford University Press, Oxford.

PRIMAVESI, A. L. & EVANS, P. A., eds. (1988). *Flora of Leicestershire*. Leicestershire Museums, Art Galleries and Record Services, Leicester.

RICH, T. C. G. & LEWIS, J. (1999). Use of herbarium material for mapping the distribution of *Erophila* (Brassicaceae) taxa sensu Filfilan & Elkington in Britain and Ireland. *Watsonia* **22**: 397–403.

SCOTT, W. & PALMER, R. (1987). *The flowering plants and ferns of the Shetland Islands*. Shetland Times, Lerwick.

SIMPSON, F. W. (1982). *Simpson's Flora of Suffolk*. Suffolk Naturalists' Society, Ipswich.

SINKER, C. A., PACKHAM, J. R., TRUEMAN, I. C., OSWALD, P. H., *et al*. (1985). *Ecological flora of the Shropshire region*. Shropshire Trust for Nature Conservation, Shrewsbury.

SLATER, F. M. (1999). *Scleranthus perennis* ssp. *perennis* P. D. Sell (Caryophyllaceae), in WIGGINTON, M. J., comp. & ed. *British Red Data Books 1 Vascular plants*, 3rd ed., p. 336. Joint Nature Conservation Committee, Peterborough.

STACE, C. A. (1997). *New Flora of the British Isles*, 2nd ed. Cambridge University Press, Cambridge.

STEWART, A., PEARMAN, D. & PRESTON, C. D., comps & eds. (1994). *Scarce plants in Britain*. Joint Nature Conservation Committee, Peterborough.

SUTCLIFFE, O. L. & KAY, Q. O. N. (2000). Changes in the arable flora of central southern England since the 1960s. *Biological Conservation* **93**: 1–8.

SUTHERLAND, D. S. (1995). Geology and soils, in GENT, G. & WILSON, R., eds. *The flora of Northamptonshire and the Soke of Peterborough*, pp. 23–30. Robert Wilson Designs, Rothwell.

SWAN, G. A. (1993). *Flora of Northumberland*. Natural History Society of Northumbria, Newcastle upon Tyne.

THOMPSON, K., HODGSON, J. G. & RICH, T. C. G. (1995). Native and alien invasive plants: more of the same? *Ecography* **18**: 390–402.

VINES, G. (2000). *Where have all the flowers gone? Loss and decline of species at the local level*. Plantlife, London.

WALKER, K. J. (In press). *Eriophorum gracile* W. D. J. Koch ex Roth formerly present in Northamptonshire (v.c. 32). *BSBI News*.

WIGGINTON, M. J., comp. & ed. (1999). *British Red Data Book 1 Vascular plants*, 3rd ed. Joint Nature Conservation Committee, Peterborough.

WOODS, R.G. (1993). *Flora of Radnorshire*. National Museum of Wales in association with the Bentham-Moxon Trust, Cardiff.

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APPENDIX 1. EXTINCT NATIVE SPECIES IN NORTHAMPTONSHIRE (V.C. 32) WITH DATE OF LAST RECORD

Ajuga chamaepitys, 1712; *Allium oleraceum*, 1873; *Anagallis minima*, 1956; *Aphanes australis*, 1950; *Arabis glabra*, 1960; *Arnoseris minima*, 1879; *Botrychium lunaria*, 1954; *Bromus interruptus*, 1907; *Bupleurum tenuissimum*, 1965; *Callitriche hamulata*, 1987; *Carduus tenuiflorus*, 1950; *Carex binervis*, 1979; *Carex dioica*, 1974; *Carex echinata*, 1950; *Carex laevigata*, 1905; *Carex muricata*, 1980; *Cerastium pumilum*, 1965; *Ceratophyllum submersum*, 1878; *Cirsium dissectum*, 1950; *Cladium mariscus*, 1950; *Clinopodium calamintha*, 1957; *Cochlearia officinalis*, 1950; *Colchicum autumnale*, 1980; *Cynoglossum germanicum*, 1883; *Drosera rotundifolia*, 1822; *Eleocharis multicaulis*, 1915; *Eleocharis quinqueflora*, 1971; *Eleocharis uniglumis*, 1956; *Eleogiton fluitans*, 1930; *Epipactis palustris*, 1956; *Erica tetralix*, 1980; *Eriophorum gracile*, 1878; *Eriophorum latifolium*, 1965; *Erophila majuscula*, 1905; *Euphrasia arctica*, 1935; *Euphrasia pseudokerneri*, 1969; *Festuca filiformis*, 1878; *Filago minima*, 1953; *Fritillaria meleagris*, 1822; *Galeopsis angustifolia*, 1969; *Galium parisiense*, 1926; *Galium pumilum*, 1914; *Galium tricornutum*, 1930; *Gentianella anglica*, 1965; *Gentianella campestris*, 1882; *Gymnocarpium dryopteris*, 1973; *Hypericum montanum*, 1980; *Hypochaeris glabra*, 1878; *Jasione montana*, 1965; *Juncus squarrosus*, 1880; *Juniperus communis*, 1712; *Linum perenne*, 1978; *Luronium natans*, 1986; *Lycopodium clavatum*, 1885; *Lythrum hyssopifolium*, 1912; *Lythrum portula*, 1880; *Marrubium vulgare*, 1975; *Mentha suaveolens*, 1930; *Misopates orontium*, 1951; *Moenchia erecta*, 1877; *Montia fontana*, 1965; *Myosurus minimus*, 1979; *Myriophyllum alterniflorum*, 1987; *Nardus stricta*, 1950; *Oenanthe crocata*, 1976; *Oenanthe lachenalii*, 1930; *Ophrys sphegodes*, 1852; *Orchis ustulata*, 1956; *Oreopteris limbosperma*, 1889; *Osmunda regalis*, 1822; *Parnassia palustris*, 1970; *Persicaria minor*, 1851; *Persicaria mitis*, 1965; *Pilularia globulifera*, 1746; *Platanthera bifolia*, 1960; *Polygonatum multiflorum*, 1907; *Potamogeton acutifolius*, 1910; *Potamogeton friesii*, 1948; *Potamogeton gramineus*, 1910; *Potamogeton obtusifolius*, 1984; *Potamogeton trichoides*, 1900; *Potentilla palustris*, 1950; *Rosa obtusifolia*, 1970; *Rosa rubiginosa*, 1987; *Rosa stylosa*, 1911; *Salvia pratensis*, 1884; *Silene gallica*, 1843; *Solidago virgaurea*, 1960; *Sparganium natans*, 1910; *Spiranthes spiralis*, 1847; *Stachys germanica*, 1870; *Stellaria neglecta*, 1972; *Teesdalia nudicaulis*, 1712; *Tephroseris integrifolia*, 1726; *Teucrium scordium*, 1884; *Thelypteris palustris*, 1930; *Thymus pulegioides*, 1975; *Torilis arvensis*, 1974; *Utricularia minor*, 1965; *Utricularia vulgaris*, 1989; *Valerianella carinata*, 1930; *Valerianella dentata*, 1975; *Valerianella rimosa*, 1882.

APPENDIX 2. REVISIONS TO THE GENT & WILSON (1995) LIST OF EXTINCTIONS FOR NORTHAMPTONSHIRE

Species excluded	Additional extinctions
Rediscovered since 1970:	Not recorded since 1989
Papaver hybridum	*Anagallis minima*
Pedicularis sylvatica	*Aphanes australis*
Potamogeton alpinus	*Arabis glabra*
Stratiotes aloides	*Callitriche hamulata*
Ulex minor	*Carex binervis*
	Carex muricata
Subspecies (taxa still extant):	*Cerastium pumilum*
Polygala vulgaris subsp. *collina*	*Cochlearia officinalis*
	Erica tetralix
Not native:	*Euphrasia psuedokerneri*
Centaurea cyanus	*Galium parisiense*
Filago gallica	*Luronium natans*
Prunus cerasus	*Myosurus minimus*
	Myriophyllum alterniflorum
	Potamogeton obtusifolius
Never confirmed, probably recorded in error:	*Rosa obtusifolia*
Crepis foetida	*Rosa rubiginosa*
Galium sterneri	*Rosa stylosa*
Sagina subulata	*Spiranthes spiralis*
Scleranthus perennis	*Stellaria neglecta*
	Thymus pulegioides
	Torilis arvensis
British natives but probably introduced in Northamptonshire:	*Valerianella dentata*
Cardamine impatiens	
Chamaemelum nobile	Not included in the Gent & Wilson list
Chenopodium vulvaria	*Bromus interruptus*
Cystopteris fragilis	*Cladium mariscus*
Daphne mezereum	*Eleocharis uniglumis*
Erodium moschatum	*Galium tricornutum*
Eryngium campestre	*Lythrum hyssopifolium*
Gymnocarpium robertianum	*Silene gallica*
Impatiens noli-tangere	
Plantago coronopus	Critical segregates
Trifolium scabrum	*Erophila majuscula*
	Euphrasia arctica