Understanding change: a Lancashire perspective

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ABSTRACT

Changes in the vascular flora of West Lancaster (v.c. 60), were analysed over 100 years and over a more recent period of 30 years through site studies of roadsides, arable fields and the Lancaster Canal. Whilst 4% of the native flora was believed extinct nearly 700 species not native to the area were recorded, at least casually, and comprised 43% of the total flora of 1617 species excluding hybrids, and the critical genera of *Hieracium, Rubus* and *Taraxacum.* An assessment of native species showing changes in frequency of occurrence (23% of native species), extinct/decreasing and new/increasing, over 100 years was correlated with habitats and, using phytogeographic relationships of British plants, climate changes. The changing flora was also analysed using Ellenberg indicator values. Using data from a selection of different sites similar analyses were carried out with species showing change over the last 30 years. These analyses demonstrated that species showing change in their frequency of occurrence in v.c. 60 correlated with habitat changes and with increasing nutrient and base status of soils whilst a possible correlation with climate warming was also noted.

KEYWORDS: Ellenberg values, phytogeography, soil nutrient and base status, climate.

INTRODUCTION

The Watsonian vice-county of West Lancaster (v.c. 60) is situated in the centre of the British Isles on the western coast of England. Historically, its vascular flora is one of the least well known in England (Watson 1883; Perring & Walters 1962), yet the vice-county encompasses a wide range of habitats with a diverse flora. Nevertheless, Wheldon & Wilson (1907) published a Flora in 1907 following many years of fieldwork. Although they searched the literature and herbaria they were unaware of the work of Samuel Simpson (1802–1881) (most of his plants are at **K** and **OXF** but his main herbarium seems to be lost) and Henry Borron Fielding (1805–1851) in the first half of the 19th Century. The acquisition by the Bodleian Library, Oxford in 2000 of an ‘English Flora’ (MS. Eng. D. 3357) comprising six volumes of paintings, many of Lancashire plants by Mrs Fielding (1804–1895) with a commentary provided by her husband, H. B. Fielding, makes a valuable contribution to an understanding of the Lancashire flora prior to 1850.

Following Wheldon & Wilson’s Flora, little further work was done in the vice-county until the late 1960s. The flora was then surveyed on a tetrad basis but detailed survey work more-or-less ceased with the publication of *The flowering plants and ferns of North Lancashire* (Livermore & Livermore 1987). The B.S.B.I. ‘Atlas 2000’ project provided an impetus to update pre-1987 records, but intensive fieldwork was not possible until 1998. As a consequence of these relatively distinct phases of study it was thought it might be possible to analyse the flora to assess change over more than 200 years and to seek possible reasons for change. In this latter respect two recent publications (Preston & Hill 1997; Hill *et al.* 1999) provide new tools to aid analysis.

CHANGING COMPOSITION OF THE FLORA

Using the status assigned to species by Stace (1997) an attempt was made to analyse the composition of the flora (hybrids, subspecies and the critical genera of *Hieracium, Rubus* and *Taraxacum* were excluded). An initial analysis was published (Greenwood 1999) and in the light of more recent fieldwork the opportunity was taken to revise these figures.

Table 1 shows that prior to 1840 over 40% of the currently known v.c. 60 flora was discovered. However, these figures rely on what recorders prior to that date considered to be species and what they thought were noteworthy. Particularly noticeable was the absence of many species found commonly today. Nevertheless, they already recognised that a number of introduced species had become part of the 'wild' flora.

TABLE 1. CHANGES IN FLORISTIC COMPOSITION

	Pre 1840	1907	1992	2001
No. of native species recorded	387	797	922	925
No. of introduced species (% of recorded flora)	24 (6)	205 (21)	657 (42)	692 (43)
No. of extinct native species (% of native flora)	19	27	37	39 (4)

By 1907 86% of the native flora was recorded, but 21% of the total number of species was introduced. In 1992 the flora comprised 1579 species of which 42% was introduced. Since then further, but mainly introduced species have been discovered.

Perhaps the most surprising figure is the low level of extinctions (species not recorded for a substantial time, say 30 years, or where the last established locality is known to have been lost) despite the growth of towns and general urbanisation, mineral extraction and intensification of agricultural practices. At 4% this compares with figures for Northumberland (v.cc. 67 & 68) of 2·4%, Durham (v.c. 66) of 9·6% and Cumbria of 10·5% (Graham 1988; Halliday 1997; Swan 1993). For south-eastern England, Preston (2000) noted that 18% of the Middlesex (v.c. 21) and 13% of the Cambridgeshire (v.c. 29) floras were extinct. Preston also defined the rate of extinction but for West Lancaster, where records were made unevenly over time, meaningful analysis is not possible.

However, by comparing the work of Wheldon & Wilson (1907) with the current status of the flora it is possible to define those species that have been added to the known flora but, perhaps more importantly, it is possible to identify species that appear to have decreased or increased in abundance. Although Wheldon & Wilson did not systematically survey the vice-county on a grid square basis, fieldwork over the last 30 years suggests that they covered the area well.

Table 2 summarises the changes estimated in 1996 (Greenwood 1999) and as revised in the light of fieldwork in the period 1998–2000. The main effects of this revision are to reduce the number of taxa that appeared to be increasing in abundance and increase the number of decreasing species. However, out of 925 native species recorded in v.c. 60 only 215 or 23% seemed to have changed their status since 1907. Of these the discovery of new species (4·9%) more than matches those lost (4·2%), but only a very small number of the newly discovered species are likely to be real immigrants. Perhaps more surprising is the slightly larger number of species (12·7%) that seem to be increasing in frequency as compared with those that are decreasing (6·5%). Nevertheless, those that are decreasing include some species that 100 years ago were too common for localities to be recorded, but may now be on the verge of extinction. Examples include *Platanthera chlorantha*, reduced to two nearby colonies with a total of under ten plants or *Pinguicula vulgare*, which declined from numerous sites to 17 recorded between 1965–1987 and to six sites in 2000.

TABLE 2. DECREASING / INCREASING SPECIES 1907–2001

	1996	2001	1996	2001
	Original (Nos.)	Revised (Nos.)	Original (% of native species)	Revised (% of native species)
New taxa	43	45	4.7	4.9
Increasing taxa	114	71	12.4	7.7
Total	157	116	17.1	12.7
Decreasing taxa	48	60	5.2	6.5
Extinct taxa	37	39	4.0	4.2
Total	85	99	9.2	10.7

Total number of species: original 922; revised 925. Changes include switches between categories and an additional three species.

HABITAT CHANGES

There have been major changes to the Lancashire landscape since 1800. The agricultural changes prior to 1850 were as significant as the later 19th Century industrial changes and urbanisation and later 20th Century agricultural intensification (Simmons 2001). Apart from ancient woodlands, where a net loss of perhaps 10% for Lancashire as a whole was recorded between 1945 and 1986, (Morries 1986) there are no quantitative measurements for habitat change over 100 or 200 years. However, Table 3 attempts to summarise the main changes qualitatively.

TABLE 3. HABITAT CHANGES

Loss/ Reduction	Gain/Increase
Lowland raised bog / heath	Fens
Sand dunes	Salt marshes
Mesotrophic grassland	Gravel pits & reservoirs
Ponds	Planted broad-leaved & coniferous woods
Hedges	Marshes & scrub
Ancient broad-leaved woods	Townscape
Nutrient-poor wetlands	Nutrient-rich wetlands
	Eutrophic grasslands

Lowland wet heaths, commonly called ‘moor’, were mostly common grazing and were enclosed with agricultural improvement during the late 18th and early 19th centuries. Fragments survived until the early 20th Century as at Ribbleton, Preston but none has survived to the present day. Similarly, lowland raised bogs or ‘mosses’ were drained from the 18th Century onwards, a process that continues today in the Bowland fringe. Two much modified fragments of lowland bog survive at Heysham and Cockerham but even in the Bowland fringe only a few surviving remnants remain.

Sand dunes were mostly converted into golf courses or built on to form the Fylde coast towns extending from Lytham and through Blackpool to Fleetwood.

Many ponds or marl pits, dug mostly in the 18th Century (Day *et al.* 1982), have been filled in during recent years (Boothby & Hill 1999), whilst it is believed some hedges were also removed as part of agricultural improvements. However, in Lancashire west of the M6, many hedges, along with broad-leaved copses, were planted as part of agricultural improvements and as cover for game during the early 19th Century.

Overall, these changes increased both the base (liming) and nutrient (fertilizers) status of the land and freshwaters of the area from the 18th Century onwards. To balance the losses, at least to some extent, there was an increase in some habitats. Until the later years of the 20th Century there was an increase in the extent of salt marshes over the previous 100 years despite the enclosure of some of the highest parts of the marshes. In Morecambe Bay the accretion/erosion sequence of salt marshes seems to be cyclical (Marshall 1967; Gray 1972). This has allowed the development of some *Phragmites*-dominated fen to develop. More significantly, the reclaimed Leighton Moss (formerly Warton and Storrs Moss) flooded when the steam pump required to keep the Moss drained failed due a fuel shortage in 1917 (Peter 1994). Leighton Moss then reverted to a large *Phragmites*-dominated fen, as did the nearby Hawes Water Moss where, however, drainage was never entirely successful. In addition to these newly created wetlands a number of reservoirs were built in the late 19th Century, creating new open waters but often destroying ancient broad-leaved woodlands, heaths or bogs. The building of motorways from the 1960s created a demand for gravel that was met by digging gravel pits along the M6 corridor through the vice-county. These subsequently flooded forming several new wetlands. New pits are still being created so that overall open water areas have significantly increased.

Table 4 demonstrates that species showing change correlate well with the known habitat changes. Interestingly, the loss of sand dunes has not caused a significant loss of species and, overall, there is an increase of coastal species. However, the large increase of open habitats provided by the greatly enlarged towns is reflected by greater numbers of increasing and new species in these habitats.

TABLE 4. HABITAT CHANGES
(HABITAT CATEGORIES BASED ON RODWELL 1991–2000)

	Decreasing & Extinct (No.)	Increasing & New (No.)	-Loss +Gain (No.)
Woodland & scrub	13	9	-4
Grassland & montane screes	18	19	+1
Mires & heaths	34	7	-27
Aquatic (Ellenberg values 9–12)	15	18	+3
Maritime (Sand dunes & salt marshes)	8	24	+16
Open habitats	11	38	+27

CLIMATE

At the present time the consequences of climate change are constantly in the news. Yet ever since the substantial warming following the last ice age there were many relatively minor climatic fluctuations. However, the present debate is given added impetus because it is believed that the present warming is due, in part, to human activity.

Table 5 illustrates the observed warming that has taken place in Central England (Hulme & Barrow 1997). This shows a significant warming in autumn and winter and, more recently, in summer as well. Precipitation is variable, but it is possibly getting wetter, at least in winter.

TABLE 5. TEMPERATURE CHANGES IN CENTRAL ENGLAND
(FROM HULME & BARROW 1997)

	1753–1995 (Change in degrees C)	1901–1995 (Change in degrees C)
Winter (DJF)	1·10*	-0·11
Spring (MAM)	0·39	0·42
Summer (JJA)	0·02	0·63*
Autumn (SON)	0·96*	0·93*
Annual	0·62*	0·47*

*Significant at 95% level

Note warmest decade was at the end of the 20th Century.

Central England Temperature Record = average daily max. & min. temperature. Northern station in Lancashire & one in west and one in east of south midlands, latterly Rothamsted, Malvern & average of Blackpool and Manchester.

Preston & Hill (1997) provided tools for analysing change. They assigned each British and Irish vascular plant to a floristic element based on their climatic preferences in the Northern Hemisphere. Their classification allocated species to major biomes (Arctic, Boreal, Temperate and Southern) and their longitudinal distribution (Oceanic, Suboceanic, European, Eurosiberian, Eurasian and Circumpolar).

Table 6 indicates the number of species showing change in each biome and for each biome whether or not there is a net loss or gain in the decreasing/extinct or increasing/new categories. The results show that species favouring a northern European distribution and therefore generally cooler climate are tending to decrease, whilst species favouring a more southern European distribution and therefore warmer climate are increasing.

TABLE 6. ANALYSIS OF CHANGE IN FLORISTIC ELEMENTS: MAJOR BIOMES (ELEMENTS BASED ON PRESTON & HILL 1997)

Major biome	Decreasing & Extinct (Nos.)	Increasing & New (Nos.)	-Loss +Gain (Nos.)
Arctic-montane	1	1	0
Boreo-arctic montane	4	1	-3
Wide-boreal	1	0	-1
Boreal-montane	18	5	-13
Boreo-temperate	24	14	-10
Wide-temperate	1	2	+1
Temperate	33	49	+16
Southern-temperate	14	35	+21
Mediterranean	3	8	+5

Berry (2000) pointed out that the whole of the British Isles has a very oceanic climate. On a world scale of 0 for maximum oceanicity to 100 for maximum continentality the range within the British Isles is from less than 4 to 12·5 with Lancashire at 8. It is therefore not surprising that most species showing a net gain in Lancashire fall within Preston & Hill's middle or European group, although the circumpolar group, reflecting species characteristic of a colder climate, showed a net decrease. (Table 7).

TABLE 7. ANALYSIS OF CHANGE IN FLORISTIC ELEMENTS: LONGITUDINAL DISTRIBUTION (ELEMENTS BASED ON PRESTON & HILL 1997)

Eastern limit	Decreasing + Extinct (Nos.)	Increasing + New (Nos.)	-Loss +Gain (Nos.)
Oceanic	13	11	-2
Sub-oceanic	8	15	+7
European	32	45	+13
Euro-siberian	14	20	+6
Eurasian	7	11	+4
Circumpolar	25	13	-12

Overall the analysis of Lancashire species showing change correlates well with a slightly warmer climate but it is inconclusive in respect of continentality/oceanicity gradients.

ELLENBERG VALUES

Hill *et al.* (1999) re-worked Ellenberg's indicator values for vascular plants of Central Europe for plants found in Britain. The basis of indicator values is the realised ecological niche. Plants have a certain ecological tolerance and Ellenberg defined seven major scales. Temperature and continentality are considered above under Preston & Hill's classification of floristic elements. The other scales were for light (L) where 1 is for plants in deep shade and 9 for plants in full light; moisture (F) where 1 indicates extreme dryness and 12 a permanently submerged plant; reaction (R) where 1 indicates extreme acidity and 9 indicates basic reaction (although the scale reflects soil and water pH it is not a pH scale) nitrogen (N) a general indicator of soil fertility where 1 indicates extremely infertile sites and 9 indicates extremely rich situations and salt (S) where 0 represents plants absent from saline situations and 9 indicates species of very saline places.

Of these values analysis of the Lancashire flora for salt tolerance, with a few exceptions, was of little value, but the other values, i.e. light, moisture, reaction and nitrogen, were used to assess those species that showed change. The analysis of species for light and moisture was inconclusive but significant (where p = 0·001) differences were revealed for reaction and nitrogen. Table 8 shows these changes together with the average height of the species in each category. It shows that extinct species have the lowest reaction and nitrogen values, followed by decreasing and increasing species, and that increasing species are generally taller than extinct and decreasing species.

TABLE 8. ELLENBERG VALUES: ANALYSIS OF CHANGE 1700–2001

	Nos. of species	R Average	N Average	Height (Average in cm)
Extinct	39	4·9	3·1	58·1
Decreasing	60	5·8	3·7	56·3
Increasing	71	6·8	5·9	101·7
New	45	6·2	4·7	*140
New (natural spread)	9	6·9	4·7	48·6

*76 if *S. torminalis* is excluded

The figures for new species are apparently anomalous. The height of new species is skewed by the presence of a tree, *Sorbus torminalis*, which is an example of a species that although only discovered since 1900 at Silverdale in v.c. 60, is undoubtedly native. It was known from Cumbria much earlier (Wilson 1938), but it was also not discovered until the 20th Century in similar habitats to those in Lancashire at nearby Arnside. Of the new species, only nine could claim to have spread naturally into the vice-county. Whilst these species generally favour base rich sites they have often colonised open habitats of relatively low nutrient status and are usually low growing.

This analysis of species showing change over the last 100–200 years suggests that species preferring a warmer climate and richer soils with a higher base status were favoured. This is in accordance with the climate records and with agricultural improvements since at least 1800 that have increased soil fertility and base status.

CHANGES SINCE 1970

In the early years of the present survey of the flora of v.c. 60, a number of habitats were examined with the aim of describing their floristic composition. These included arable fields and roadside verges (including the hedge or wall separating the road from the adjacent field). Later, Livermore & Livermore (1989) carried out a systematic survey of the Lancaster Canal in Lancaster District. The existence of these data provided the opportunity for the same sites to be re-surveyed in the period 1998–2000 and any observed changes assessed.

ARABLE FIELDS

In 1971/2, 50 fields in the west of the vice-county were surveyed. They were on a variety of soils ranging from ones derived from boulder clay to ones derived from reclaimed mosses (raised bogs). Although only 21 fields were sampled in 1998 a species/area curve showed that their flora was a representative sample. However as crops vary from year to year and often include grassland in the rotation the fields surveyed in 1971/2 were not necessarily re-surveyed in 1998 although they were all located within the same general area. In both surveys, species lists were compiled for each field and the process of recording ceased when no further species could be added to the list. Recording took place within the ploughed area and not in any verge left between the ploughed area and the field boundary. In practice, most weeds were found within a few metres of the ploughed edge in cereal crops with few if any weeds in the main crop area. With root crops, especially potatoes, some fields became full of weeds after the main growth of the crop ceased and before harvesting.

Cereal crops included wheat, barley, oats (in 1972 only) and maize (in 1998 only). Other crops were potatoes, beans and swede (in 1998 only). In neither year was oil seed rape grown. Also no distinction was noted between winter and spring sown crops. In both years surveys took place in late July or August. This meant that wheat, barley and oat crops were surveyed just before or immediately after harvesting.

Table 9 shows that both the total number of species recorded and the number of weeds per field appear to have decreased. However, the species composition also changed with 42 species recorded in 1971/2 not being seen in 1998 yet 15 species were newly recorded in 1998. The species that were not recorded in 1998 along with the newly recorded ones were analysed according to their Ellenberg values. Little or no change was discernable in respect of light and moisture preferences and whilst new species showed some preference for more base rich soils there was a much greater preference for more nutrient rich soils.

TABLE 9. ARABLE FIELD FLORAS: ELLENBERG VALUES

	Species present 1971/2, absent 1998 (average for 42 species)	Species present 1998, absent 1971/2 (average for 15 species)
Reaction (R)	5·9	6·3
Light (L)	7·0	7·0
Nitrogen (N)	4·9	6·0
Moisture (F)	5·2	5·7

NUMBER OF SPECIES RECORDED

	1971/2(50 fields)	1998(21 fields)
Total number of species	113	75
Average/field	20·5	15·7

ROADSIDE VERGE FLORAS

In 1977 a number of 100 km-long roadside verges were surveyed to reflect their floristic composition in different parts of the vice-county. Some were selected because they were known to be floristically rich. In general, the richer verges were found in areas typical of ancient countryside (Rackham 1999) situated in the Bowland fringe in the east of the vice-county The verge was defined as the area between the made-up road surface to the field side of the boundary fence or hedge. Besides the hedge the verge often comprised a ditch and a strip of grassland, of which a metre width adjacent to the road was mown several times during the growing season, whilst the remainder was mown once, usually in July. Hedge clipping and ditch cleaning (if done at all) took place in the winter months. In places, however, the grassland was replaced by scrubby woodland. It is believed that management remained unchanged through the years although it was noted that one hedge had been re-laid.

In 2000/1 ten of the richest verges identified in 1977 were re-surveyed but one was found to be essentially a semi-natural woodland and, as such, highly atypical of verges as a whole. As a consequence the analysis shown in Table 10 is for nine verges only.

Verges were surveyed by recording species present in the survey lengths once at the end of May or early June. In 2000 and 2001 a second visit was made at the end of June or early July before the whole verge was cut for maintenance purposes.

Table 10 shows that whilst verges might have become less species rich this is not significant. On the other hand the species composition had often changed markedly. Whereas 42 species recorded in 1977 were not seen in 2000/1, 24 species were newly recorded in 2000/1. Analysis of these species in terms of their Ellenberg values showed clear preferences. Notably there was a significant change for species preferring more nutrient rich soils and this corresponded with an increase in the average height of species. The values for reaction, light and moisture were not or little changed although there was a tendency for species to favour less light and soils with higher base status.

TABLE 10. ROADSIDE VERGE FLORAS: ELLENBERG VALUES

	Species present 1977, absent 2000/1 (average for 42 species)	Species present 2000/1, absent 1977 (average for 24 species)
Reaction (R)	5·8	6·2
Light (L)	6·6	6·3
Nitrogen (N)	4·6	5·9
Moisture (F)	5·9	5·9
Height (average in cm)	71·3	99·1

NUMBER OF SPECIES RECORDED

	1977	2000/1
Total number of species	156	146
Average/verge	65·3	61·8

The verges selected for re-survey in 2000/2001 also contained species with a more localised distribution in v.c. 60 when they were surveyed in 1977. Each species occurred in one or more of the surveyed verges in 1977 and were *Dactylorhiza fuchsii, Helictotrichon pubescens, Listera ovata, Ophioglossum vulgatum, Ranunculus bulbosus, Salix pentandra, Oreopteris limbosperma, Triglochin palustris* and *Valeriana dioica.* However, in 2000/2001 none were re-found in any of the verges. Whilst their average Ellenberg Reaction value was 6·3, slightly above the average for species as a whole not seen in 2000/2001, the Ellenberg Nitrogen value was only 3·3. Furthermore, two other localised species, *Baldellia ranunculoides* and *Hottonia palustris,* were found formerly in roadside ditches in the west of the vice-county and although these verges were not re-surveyed in 2000/2001, the ditches were searched in 1998 but neither species was re-found. They had Ellenberg N values of 2 and 5 respectively.

Overall, there is compelling evidence that eutrophication is a major reason for the changing species composition of roadside verges.

THE LANCASTER CANAL

The Lancaster Canal is entirely man-made and, like other 18th Century canals, was a major feat of civil engineering when first built. Today it is an attractive waterway and it is difficult to envisage the scar on the landscape that it created when being built. The canal from Preston to Tewitfield (on the Cumbrian border north of Lancaster) was opened in 1797 and, unusually, has no locks. The cut was lined with puddled clay, with a towpath on the western side that is separated from adjacent fields by a hedge. Until the 1970s, when an iron plate was fitted, there was no hard boundary between the towpath and the canal. There is usually no boundary fence on the other side of the canal but both banks are often lined with a marsh or reed bed zone. This initial stretch of the canal was watered by a number of intakes from nearby streams. Later the canal, with a flight of locks at Tewitfield, was extended to Kendal (currently abandoned but with plans for re-instatement). A branch from Galgate, via a flight of locks to the sea at Glasson Dock, was also built. To maintain water levels in the extended system, a reservoir at Killington in the Howgill Fells near Tebay was constructed. The original plans included an aqueduct across the R. Ribble to connect the canal to the rest of the canal system but this was never built (Hadfield & Biddle 1970). However, a link involving a short sea passage across the estuary of the R. Ribble was built in 2002. Thus from 1795 until 2002, the canal was isolated from the rest of the canal system and so far as is known any deliberate planting was limited. Accordingly, it is believed plants have colonised the waterway by natural processes and accidentally through human activities. However, as there are several non-native species characteristic of the waterway, e.g. *Acorus calamus*, it is believed that accidental introductions were unusually significant.

Following changes in the flora since it was built are difficult. Although Mr and Mrs Fielding lived within a few hundred metres of the canal none of the wetland species illustrated in their 'English Flora', compiled in the 1830s, were from the canal, yet they illustrated a few ruderal species from its banks. Perhaps at that time there were few aquatic and marsh plants present, although in **OXF** there is a specimen of *Groenlandia densa* collected from the canal at Lancaster in 1816 but the collector is unknown. Any significant records of plants found in and by the canal was not noted until the 1850s (Ashfield 1858, 1860, 1862, 1864). These were consolidated by Wheldon & Wilson (1907) in their Flora, which together with a few other records made subsequently, provide the basis of an account of the more noteworthy aquatic species (plants with an Ellenberg M value of 10 or more) recorded before 1940. Subsequently there were few observations made until the 1960s.

If the pre- and post-1940 aquatic floras are compared (Table 11), eleven species were seen prior to 1940 but not later and five new species were recorded after 1940. If the Ellenberg values for N and R are compared for these two groups there is an apparently significant change for species favouring waters of both higher nutrient and base status.

TABLE 11. LANCASTER CANAL: ELLENBERG VALUES FOR AQUATIC SPECIES WHOLE CANAL

	Present pre-1940 Absent 2000	Species present 2000 Absent pre-1940
Number of species	11	5
Mean Ellenberg N value	4·8	6·6
Mean Ellenberg R value	6·3	7·2

Livermore & Livermore (1989) carried out a detailed survey of the canal in Lancaster District by noting species present within the curtilage of the canal along defined lengths of the canal (a length was the distance between two bridges and was therefore a variable distance). They carried out their survey by walking up and down the towpath in each length three times between May and September noting the species observed. In 2000 five of the richest lengths surveyed by the Livermores were re-surveyed using their methodology. It was found that 25 species recorded in the five survey lengths by the Livermores were not seen in 2000. On the other hand 34 new species were recorded in 2000. Analysis of their Ellenberg N an R values showed some eutrophication but little change in base status (Table 12).

TABLE 12. LANCASTER CANAL: ELLENBERG VALUES FOR ALL SPECIES (FIVE SURVEY LENGTHS)

	Present 1987 Absent 2000	Present 2000 Absent 1987
Number of species	25	34
Mean Ellenberg N value	4·6	5·1
Mean Ellenberg R value	6·0	6·1

Note run-off from fields to towpath negligible? But run-off from fields into canal considerable with several minor feeders in addition to main feeder from Killington.

However, if the analysis is confined to aquatic species (Ellenberg M values of 10 and above) there appears to be a marked eutrophication of the waters and some increase in base status (Table 13). Another factor known to adversely affect macrophytic plant growth is boat traffic intensity (Murphy & Eaton 1983). It is also believed that boat traffic affects species diversity (Willby *et al.* 2001) but the significance of these issues for the Lancaster Canal is not considered here.

TABLE 13. LANCASTER CANAL: ELLENBERG VALUES FOR AQUATIC SPECIES (FIVE SURVEY LENGTHS)

	Species showing net loss 1987–2000	Species showing net gain 1987–2000
Number of species	13	12
Mean Ellenberg N value	5·4	6·3
Mean Ellenberg R value	6·3	6·8

DISCUSSION

It was pointed out previously that farming practices in the first half of the 19th Century were highly significant in causing a general increase in the base and nutrient status of agricultural land. However, agricultural depression followed and whilst continued progress was made in the development of new farming methods changes were not so dramatic as earlier. Nevertheless, from the middle of the 19th Century new manures and fertilizers became available and it is believed that some in particular may have significantly raised phosphate levels. These fertilizers were possibly significant in reducing the floristic diversity of many meadows and pastures.

The individual habitat studies over the last 30 years suggest that further increases in base and nutrient status have occurred and it is generally acknowledged that this coincides with a considerable intensification of agricultural practices (Simmons 2001).

Figure 1 suggests that farmers considerably increased their fertilizer applications in the period 1973–1991 and that the direct affects of this would be noted in arable fields and indirectly through run-off from fields into the Lancaster Canal. In addition to feeder inlets many fields slope down to the canal on its eastern side, and the odd open drain from farm buildings has also been seen although they may not now be active. It is less easy to see how run-off could affect roadsides except, perhaps, where a ditch receives drainage from the adjacent field. Generally, however, the ditch is designed to drain the verge and not the field. On the other hand, verges might receive significant nutrient enrichment from motor vehicles. NEGTAP 2001 (2001) demonstrated that significant nitrogen pollution is associated with motorways although in this study all the verges were on minor roads where it is presumed nutrient enrichment from motor vehicles was minimal.

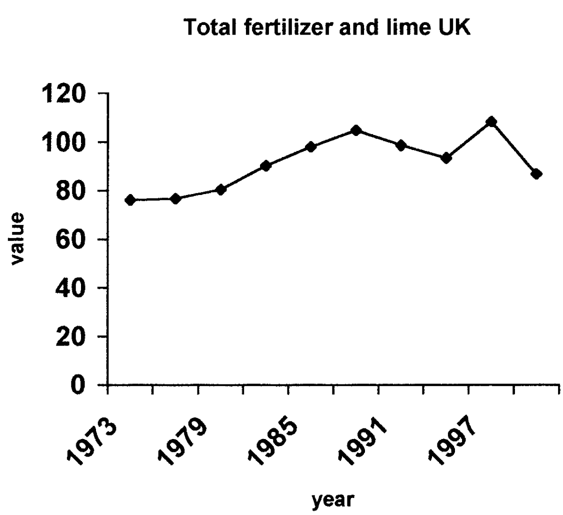

FIGURE 1. Relative values for the volume of lime and fertilizers consumed in the UK where the value for 1995 = 100. Figures taken from *Agriculture in the United Kingdom* on the DEFRA website.

TABLE 14. DEPOSITION OF ATMOSPHERIC NITROGEN FROM KIRKHAM (2001)

Area	Amount deposited in Kg N/ha/pa
N. Pennines	18·6
Wales	24·8
N. Yorks Moors	25·4
Exmoor	25·8
Cumbria	26·1
Dartmoor	30·9
S. Pennines	31·0
Bowland	33·2
Upland England	26
England	19

The effects on plants of sulphur dioxide and solid carbon born through atmospheric pollution are well known but much less is known about other atmospheric pollutants. Nevertheless in recent years there has been considerable research into the affects of atmospheric nitrogen pollution. Unfortunately measurements of the amount of atmospheric nitrogen deposition have only been made relatively recently. Table 14 shows that Bowland has possibly the highest deposition rate in the country and well above levels that will change lowland heaths to grasslands. According to Kirkham (2001) at least two thirds of the nitrogen deposited may be in the form of reduced nitrogen (as NH_3 and NH_4^+) whilst the remainder is derived from nitrogen oxides. NEGTAP 2001 (2001) confirmed these findings and suggested that reduced nitrogen was largely derived from farm animals and slurry. The early springtime application of slurry in pastoral Lancashire is a feature of the farming calendar. The present high levels of atmospheric deposition are probably recent, but work cited by NEGTAP 2001 suggests atmospheric nitrogen pollution has been an increasing problem for over 100 years.

Lowland heaths change to grasslands where deposition rates are >15–20 Kg/ha/pa (NETGAP 2001). The changes noted here in the composition of the Lancashire flora are mostly in line with the wider Countryside Surveys (Firbank *et al.* 2000, Haines-Young *et al.* 2000). These show that acidification was not a problem as Wigginton (1995) has pointed out despite wet deposited acidity being amongst the highest in the country. The Countryside Surveys also suggested that there was general eutrophication making long-term conservation of low nutrient status sites difficult to maintain in some upland areas. However, the somewhat less diverse weed flora of Lancashire arable fields is contrary to their findings.

This analysis of the changing flora of West Lancaster, v.c. 60, indicates that, whether change to the whole flora over 100 years or the flora of selected habitats over a more recent timescale of less than 30 years are analysed, a similar picture emerges. These changes are consistent with climatic warming and of increasing base and nutrient status of soils and water systems.

It is important to appreciate that whilst correlations have been drawn with farming methods and atmospheric pollution it is unsafe to draw conclusions as to cause and effect. Clearly there are direct affects of habitat destruction, but often the building of towns, motorways etc. create new habitats. If there is a continuing source of seeds and propegules and the new habitats are suitable, plants readily colonise them. Whilst the new habitats are initially open and, perhaps, nutrient poor, they are often base rich. In time a closed and less diverse community develops and no doubt the nutrient status increases.

Many processes lead to nutrient enrichment, few lead in the opposite direction and then possibly for only a short period.

The difficulty of assigning cause and effect is illustrated by the extinction of *Antennaria dioica*. Formerly it occurred in several localities in three different areas of v.c. 60. Whilst the habitats were all probably open they varied from sea-level on the sand dunes at St Annes, on limestone rocks at Silverdale and to higher levels inland on neutral or possibly slightly acidic rocks at Leck. The last record was in 1909 on coastal limestone rocks at Silverdale but more interesting was the loss from a nearby limestone hill. One hundred years ago the top of the limestone hill was largely free of trees and shrubs, presumably through grazing animals, but gradually scrub encroached over almost the whole hill until recently when the National Trust introduced a programme of scrub clearance. Was extinction caused by a lack of grazing and consequent woodland development? Insufficient is known about the other Silverdale sites to discuss possible causes of extinction. However, at St Annes the site was simply eradicated through building development.

It is difficult to know why the Leck colonies became extinct, although it is believed to have occurred in moorland areas grazed mainly by sheep. The last record was reported by Wheldon & Wilson (1907). The Ministry of Agriculture, Fisheries and Food carried out annual Parish surveys (Public Record Office: MAFF 68) from the second half of the 19th Century and these show that for Leck there were 1481 sheep in 1870 but by 1890 the numbers had risen to 3287 and by 1910 to 3536. Unfortunately it is not possible to accurately convert these figures to number of animals for a specific area, but a more than doubling of sheep numbers would no doubt cause problems for grazing-sensitive species. Similar increases in sheep numbers occurred at Silverdale and increased grazing at other sites in the Parish may have been responsible for the extinction of *Antennaria dioica* at these sites. As a popular area for tourists public pressure may also have been a contributing factor.

These observations suggest that changes in grazing pressure my be the limiting factor for the extinction or reduced frequency of some species. However, NEGTAP 2001 pointed out that there is a complicated relationship between grazing levels and eutrophication. Furthermore, calculations of critical loads of atmospheric nitrogen for different habitats vary and are subject to further refinement. Despite these uncertainties it is suggested that ombrotrophic bogs are most sensitive and calcareous grasslands least sensitive to atmospheric nitrogen. Nevertheless using current figures it appears that nutrient nitrogen levels are exceeded for most if not all habitats in Lancashire and are expected to remain so until at least 2010.

Whilst climatic warming is taking place and has been for 100 years it is not necessarily the cause of the extinction or decline of more northerly species. It so happens that most of the species involved prefer soils of low nutrient status.

Rubus chamaemorus is confined today to undisturbed bog surfaces near the tops of the Lancashire fells. It requires long periods of low temperature (eight months at 4–5°C) for seed to germinate (Taylor 1971). Temperatures of this kind are unlikely to occur today. However, Conolly & Dahl (1970) pointed out that the southernmost localities in England, which includes Lancashire, correlates well with 26°C average maximum isotherm. It may not be temperature that limits the reproductive capacity of *Rubus chamaemorus* as it rarely flowers or produces fruit in Lancashire. Instead, for the northern Pennines at least, Taylor (1971) showed that the level of grazing was the limiting factor.

Similarly, the species that appear to be increasing also seem to be ones that prefer more base and nutrient rich soils. In particular, Pigott & Huntley (1978, 1980,1981) showed that for *Tilia cordata* to reproduce, regular periods of high summer temperatures are required; something that must have occurred in the past 10,000 years to have allowed the species to spread to the Morecambe Bay area of Lancashire and Cumbria, its northern limit of distribution in the British Isles. These temperatures have not yet been reached regularly. Nevertheless, both *Tilia cordata* and *Rubus chamaemorus* are able to survive vegetatively for long periods.

The results reported here did not find a link between changing rainfall patterns and changing species composition. However, the discovery of gametophytes of the highly oceanic *Trichomanes speciosum* in Bowland and the western Pennines suggests that the climate was once more oceanic. The oceanic *Hymenophyllum* spp. also occurred more commonly. These observations indicate that whilst rainfall may have increased the overall evapo-transpiration rates may also have increased, at least locally. It is possible that some of the floristic changes do not reflect climate changes but were caused by increased grazing, removal of tree cover by what ever means or other environmental changes.

Therefore climatic changes or global warming may not be significant at the present time. However, if predictions prove correct (Table 15, Hulme & Jenkins 1998) it may well be an important factor in changing the composition of the flora in future. This will be limited if the warming is mostly in the winter months as whilst frost sensitive plants may survive they must also tolerate low light levels. Relative to other parts of the world with a similar climate it must be

TABLE 15. CLIMATE AND SEA LEVEL PREDICTIONS

	2020	2050	2080
Temperature (with respect to 1961–90 mean)	+0·5–1·2 C	+0·8–2·0 C	+1·0–2·8 C
Annual rainfall (% change from 1961–90 mean)	+3–6	+3–5	+3–15
Net sea level rise in cm		*c.* 15–70	

remembered Lancashire is a long way north in the Northern Hemisphere (54°N) - on the same latitude as southern parts of Hudson Bay in Canada. Without a substantial increase in summer temperatures it will not be possible for plants requiring sustained high summer temperatures to produce seed to reproduce sexually although they may survive and propagate vegetatively. These temperatures may nevertheless be reached towards the end of the 21st Century. Other predictions include increasing numbers and severity of storms and increasing incidence of hot summers. Thus unless there are substantial changes in human behaviour to alter the present environmental trends the Lancashire flora will appear lush and plants tolerating low light levels will grow throughout the winter. Plants requiring low winter temperatures and favouring low nutrient levels will continue to retreat. On the other hand, species favouring high nutrient levels will flourish, especially if they can grow in the cool but perhaps frost free and dark winter months but plants requiring sustained high summer temperatures will not spread northwards unless the prediction of substantially warmer summers is realised. Overall the flora will continue to become more diverse as yet more species escape from cultivation and humans continue to grow an ever more diverse range of plants from all over the world in their passion for gardening.

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