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The effects of turf translocation and other environmental variables on the vegetation of a large species-rich mesotrophic grassland

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ABSTRACT

This paper reports on the translocation of 5.6 ha of a 9.1 ha dry mesotrophic grassland in 1998. For 4 years before and 5 years after translocation, the vegetation was monitored annually by randomised quadrat sampling and compared with an area of the site which remained untranslocated. Associated soil and climatic variables were also monitored. The hypothesis to be tested was that changes in the vegetation ascribable to translocation were of a similar amplitude to those ascribable to other causes. Soil monitoring showed that it had been possible to reconstruct both vegetation and substrate with only minor changes in soil compaction and soil fertility. The frequencies of 28 species in the source meadow in the 4 years before translocation varied significantly. Three areas of the translocated vegetation monitored separately showed significant changes in frequency in a similar number of species, as did the untranslocated area. Species density gradually declined on the translocated turf for the first 4 years after translocation but recovered in the fifth year, although at least one species has so far failed to recover. Multivariate analysis showed that the translocated vegetation diverged from the untranslocated portion for the first 4 years but that this divergence ceased and partially reversed in the final year. The divergence involved an increase in the cover-abundances of several grasses and a parallel fall in a range of forbs. Weather records suggest that this pattern correlates with 4 years without water stress followed by a much drier growing season in the fifth year. It is concluded that there was a definite response to the 1998 translocation which appears to be comparable in severity with the pre-translocation changes in terms of the effects on species frequency. The untranslocated area also changed suggesting that the changes were not all the result of translocation, and the results for the last year of monitoring imply an element of recovery. The results support the use of turf translocation as a restoration technique where the alternative is the complete loss of the site and where the process of reconstructing the functioning of the ecosystem meets certain standards. Monitoring is continuing for 5 more years.

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1. Introduction

Community (often 'habitat') translocation, the movement of assemblages of species, usually together with their associated substrates, from their original site to a new location, is typically attempted in mitigation of development. It is expensive, the results are unpredictable and in the UK it is regarded by the statutory nature conservation agencies as never being an acceptable alternative to *in situ* conservation (McLean, 2001). On the other hand, community translocation offers opportunities to study the factors affecting the functioning of specific ecosystems on largely intact species assemblages and therefore to contribute to our understanding of the control of biodiversity in ecosystem restoration.

Assessing the success of translocation depends to some extent on defining success. There will always be a loss in naturalness and in the original context. Maintaining the translocated habitat "unaltered" (Byrne, 1991) or "intact" (Bullock et al., 1997; Bullock, 1998) is probably unattainable; vegetation may change whether translocated or *in situ*. Bullock (1998) rejected this 'preservation' aim and suggested an alternative 'mitigation' aim of preserving the more important (however defined) plant species and some of the other taxa such that the translocated community resembles the pre-translocated state. Wilson (1998) and Box (2004) suggested that objectives of maintaining (or enhancing) the nature conservation value of the habitat as measured by application of Ratcliffe's criteria (Ratcliffe, 1977), the SSSI guidelines (Nature Conservancy Council, 1989) and comparisons with the National Vegetation Classification (Rodwell, 1992). Box (2004) also suggested that evaluation should include detailed species monitoring for an appropriate period of time, such as 10 years.

Only 14 grassland turf projects overall had sufficient monitoring data to be included in three reviews of community translocation in the UK by Bullock (1998), Anderson (2003) and Box (2004). At least three of the receptor sites received little preparation and at least seven of the translocated grasslands received little or inappropriate after-management, making it difficult to assess reasons for change. Bullock (1998) reviewed 10, mostly grassland projects across England and Wales. Monitoring had taken place typically for 3–4 years after translocation. He found that all grassland communities had shown both gains and losses in species. He concluded that the receptor sites were often poorly investigated and prepared and that the initial surveys, at best, started immediately before translocation, limiting comparison. He considered that there is an inherent time-lag in response, that turf depth may be important for some species and that dry grassland translocation seemed most successful. Box (2004) followed Hodgson (1989) in considering the critical factors controlling the outcome to be the similarity in the environmental context of the donor and receptor site, the translocation technique and the habitat management of the translocated habitat.

Anderson (2003) reviewed a similar set of turf translocations in the UK and considered that in many instances there were irreconcilable differences between the donor and receptor sites which affected the communities and that responses to variation in climate or management could have been confused with responses to translocation. In particular the

disturbance resulting from translocation has an impact on soil nutrient cycling. Although there are soil quality thresholds to ecosystem recovery on degraded soils (Garten and Ashwood, 2004), in old meadows on mature soils, botanical diversity is most likely to be adversely affected by the levels of available nitrogen and phosphorus being too high (Marrs, 1993; McCrea et al., 2004), a situation which might arise from the disturbance resulting from translocation and often has to be ameliorated in successful ecosystem restoration (Gilbert et al., 2003).

There are a few examples of turf translocation which offer long-term detailed monitoring data. Most consist of relatively small areas of vegetation translocated short distances in very deep turves. Circa 0.3 ha of 400–500 mm deep turves of magnesian limestone grassland translocated at Thrislington in Durham, UK were assessed for 8 years after translocation (Cullen and Wheatear, 1993). Initial changes in both flora and invertebrates appeared to be followed by at least partial recovery although considerable fluctuation in the balance between species was recorded. 0.4 ha of montane grassland in the Harz mountains in Germany was translocated in turves 500 mm deep and monitored for 5 years, with minimal appearance of disturbance indicators, successful preservation of the flora including almost all regionally threatened species and with maintenance of four different vegetation types but with loss of the original spatial pattern (Bruehlheide and Flintrop, 2000).

The most thorough and long-term monitoring of a translocation of mesotrophic grassland seems to be at Brocks Farm, Devon, UK, where 0.5 ha of species-rich mesotrophic grassland were translocated onto a nearby site as 200 mm deep turves after soil stripping and replacement with subsoil from the donor site (Jefferson et al., 1999). The vegetation was monitored annually for 9 years alongside a similar neighbouring 'control' area of grassland maintained *in situ* and another area translocated as turf fragments. The results suggested that over the 9 years of monitoring, stress-tolerant species declined on the turf transplant and that of 31 species for which comparisons could be made, 24 behaved differently on the translocated and untranslocated sites. It was concluded that floristic changes had occurred which had taken many years to become discernable. This interpretation was supported by a multivariate analysis of the Brocks Farm data (Gibson, 1997), which gave some indication that the translocated and untranslocated areas of vegetation were becoming more dissimilar with time. However, many of the species declining on the turf did not decline on the turf fragment area suggesting that at least some of the deleterious changes on the turves were not an inevitable consequence of translocation.

Both at Brocks Farm and at Thrislington, marked fluctuations in the frequencies of individual species were noted from year to year. Other studies have shown large fluctuations in apparently stable grassland, as in the monitoring of control plots in the long-term experiment at Park Grass at Rothamsted between 1929 and 1979 reported by Dodd et al. (1995), who concluded that the data suggested that the concept of a stable plant community needed re-evaluation. In some cases these fluctuations can be ascribed to annual fluctuations in the weather. Dunnett et al. (1998) showed that the control plots of the under-managed dry mesotrophic grassland road verges near Bibury, Gloucestershire (Willis, 1972, 1988) showed many significant correlations in variation in the species with

weather variables, particularly ones recorded for spring and summer seasons.

The examples suggest that turf transplant monitoring projects should monitor associated soil and weather variables both at donor and receptor sites for possible explanations of variation in the vegetation associated with the transplant period. They also suggest that success in turf translocation might be defined in the following terms:

- (a) Changes in the vegetation should be of a comparable magnitude to those recorded in the vegetation before translocation.
- (b) Changes in the vegetation should be of a comparable magnitude to those recorded in areas of the vegetation which have not been translocated.
- (c) Translocated and untranslocated areas of the vegetation should not become more dissimilar with time.

The present study concerns the translocation of a large area of species-rich grassland turf at Durnford Quarry, Long Ashton, near Bristol in SW England (national grid reference ST 538715) in winter 1998–1999. Following four seasons of vegetation monitoring before translocation, the vegetation and selected environmental variables have been monitored for 5 years at the donor and receptor sites after translocation and this exercise is still continuing. The aims of the present paper are to describe quantitatively and to attempt to evaluate year-on-year changes in the vegetation in terms of the transplant event and the background variation in the environment in order to evaluate the success of the translocation. The hypotheses to be tested is that through the monitoring period changes in the vegetation and soils ascribable to translocation are of a similar amplitude to those ascribable to other causes.

2. Methods

2.1. The translocation scheme

Top Park Field (National Grid reference ST544717) at Durnford Quarry included 9.1 ha of dry, species-rich grassland, conforming to the UK National Vegetation Classification (NVC) mesotrophic grassland community *Cynosurus cristatus*–*Centaurea nigra* (MG5), *Lathyrus pratensis* subcommunity (Rodwell, 1992), forming part of the Ashton Court Estate Site of Interest for Nature Conservation. In winter 1998–1999, 5.6 ha was translocated to Ashton Hill Field, also at Durnford Quarry, to allow the extension of limestone quarrying.

The aims of the translocation were to maintain the extant area and diversity of unimproved neutral grassland and the presence of *Orobancha minor*, *Anacamptis pyramidalis*, *Ophrys apifera* and *Ophioglossum vulgatum*. In addition, the planning agreement with North Somerset Council required the monitoring to develop performance criteria for measuring success in grassland translocation in general and at Durnford in particular, and to advance understanding and techniques of turf translocation.

The donor site lies immediately east of the quarry. Ashton Hill Field, the receptor site, lies west and north of the quarry (Fig. 1). Their soil and agricultural characteristics were

described by Reeve (1995a,b). Both overlie carboniferous limestone, with shallow soils (250–350 mm deep) of the “Crwbin” series predominating in Top Park Field (especially towards the west and the quarry) and deeper soils (circa 850 mm deep) of the “Nordrach” series predominating in Ashton Hill Field. The two types were mapped in both fields. It was necessary to translocate 3.8 ha of shallow-soil turf and 1.8 ha of deeper-soil turf.

The translocation took place between September 1998 and January 1999. Subsoils were removed and laid using an excavator and transported in dumper trucks. Turves of 2.35 m × 1.15 m were cut using a flat-tined fork with integral cutter bar, at a depth following the topsoil/subsoil interface at 150–240 mm. They were transported in a single layer on flat-bed trailers and laid using a similar implement, usually within an hour and always within 24 h. Turves were gently firmed onto the substrate using the fork. A working face not more than 5 m wide was maintained but there was no attempt to recreate the exact spatial structure of the vegetation.

The 1 ha shallow-soil area at the southern end of Ashton Hill Field was completely stripped to the bedrock and shallow-soil turf from Top Park Field laid directly to form Area 1 of the receptor site (Fig. 1). In the adjacent Area 2 (2.8 ha), 400 mm of topsoil and subsoil were removed, 200 mm of limestone brash subsoil from shallow-soil areas of the donor site were laid using an excavator and then further shallow-soil turves. In the most north-easterly Area 3 (1.8 ha), topsoil and 100 mm of subsoil were removed, and replaced by 150 mm subsoil from the deep soil part of the donor site followed by turves from the same area. Throughout the operation, subsoil compaction was monitored using a vane penetrometer and work was suspended when previously agreed adverse conditions prevailed.

In the years immediately prior to translocation the donor site had typically been flailed in late June and used as an occasional overspill car park for summer events at the Ashton Court Estate. Since translocation the receptor site has been managed as a unit, with a hay cut annually in July. In response to significant aftermath growth the sward was vigorously chain-harrowed in autumn 2000. In autumn 2001 and 2002, a forage harvester was used to make a second cut followed by scarification to simulate aftermath grazing. There was little aftermath growth in autumn 2003 and as a result there was no second cut.

2.2. Sampling design and data collection

Monthly climatic parameters from the climatological station at RAF Lyneham 48 km distant from Durnford (National Grid Reference SU0279, altitude 145 m), and daily rainfall data collected at Durnford Quarry were used to identify long-term weather trends at Durnford. After translocation, a weather station was set up in Area 2 of Ashton Hill Field, and another within the quarry, close to the remaining part of Top Park Field. The latter was approximately 5 m higher than Top Park Field, and 100 m to the west, but a closer site was not possible due to security problems. Each station had a bulk rain gauge, a humidity sensor relocated to canopy height recording at 30 min intervals, and tinytag temperature loggers at canopy height (350 mm), ground level and 60 mm below ground recording at 10 min intervals. These data have been

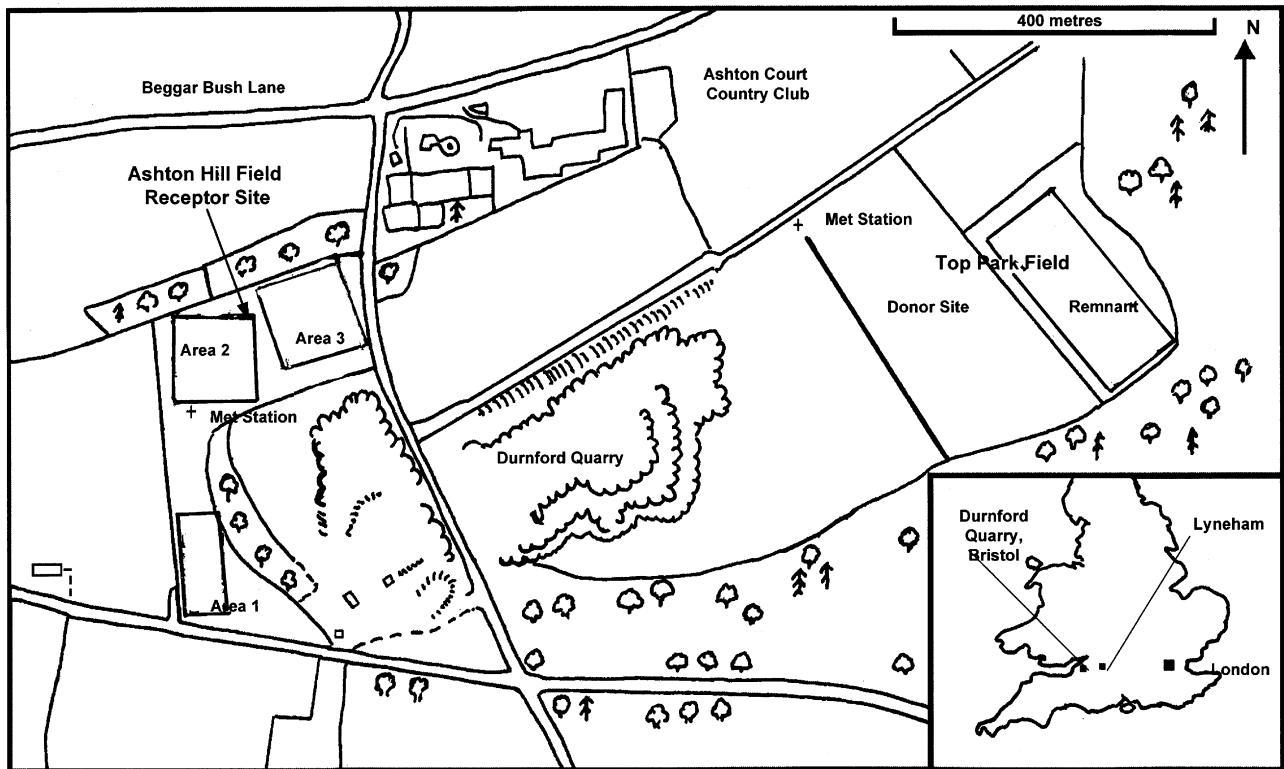


Fig. 1 – Map showing the location of the turf translocation source and receptor areas at Durnford Quarry, Bristol, and delimiting the four post-translocation sampling areas at Top Park Field and Ashton Hill Field.

supplemented by occasional simultaneous readings of ambient temperature, % relative humidity, soil temperature, wind speed and direction at two positions in Top Park Field and three within Ashton Hill Field.

Prior to the translocation, topsoil and subsoil (200–300 mm depth) at Top Park Field and Ashton Hill Field were sampled in January 1995 on a 100 m grid and analysed for pH and available bases and nutrients (Reeve, 1995a). Each November following translocation, five soil samples were taken beneath the turf (30–100 mm depth) and in the subsoil (150–250 mm depth) across each of the three areas of Ashton Hill Field and across two halves of the remaining Top Park Field. Each set of five samples was bulked immediately and sent for standard Direct Laboratories analysis for pH and available bases and nutrients using methods directly comparable with those used by Reeve (1995a) although levels of available ammonium and nitrate ions were measured rather than total nitrogen. In each of the five sampling areas, a Bush Penetrometer was used at 30 representative positions to measure penetrometer force in kg cm^{-2} at the surface and at 30 mm depth intervals until the penetrometer overloaded at 41.3 kg cm^{-2} .

The botanical sampling follows Byrne (1991) in using large numbers of small randomly located quadrats to characterise identified areas. An NVC survey would have required much larger quadrats. Prior to translocation, each year from 1995 to 1998 the entire 9 ha area of species-rich grassland was sampled at 100 random positions in June using 0.1 m^2 quadrats to obtain a frequency for all vascular plant species. At alternating sample positions cover-abundance of each vascular plant was

assessed as a basis for vegetation analysis using a DOMIN scale ($1 \leq 4\%$ cover, 1–2 plants; $2 \leq 4\%$ cover, several plants limited to one part of quadrat; $3 \leq 4\%$ cover, many plants throughout the quadrat; $4 = 4\text{--}10\%$ cover; $5 = 11\text{--}25\%$ cover; $6 = 26\text{--}33\%$ cover; $7 = 34\text{--}50\%$ cover; $8 = 51\text{--}75\%$ cover; $9 = 76\text{--}90\%$ cover; $10 = 91\text{--}100\%$ cover). After translocation, four permanent sampling areas were delimited, one within the remaining Top Park Field ($100 \text{ m} \times 200 \text{ m}$), one in Ashton Hill Field Area 1 ($50 \text{ m} \times 50 \text{ m}$), one in Ashton Hill Field Area 2 ($100 \text{ m} \times 100 \text{ m}$) and one in Ashton Hill Field Area 3 ($100 \text{ m} \times 100 \text{ m}$). Every June since translocation, each sampling area has been sampled at 100 random positions—as above.

2.3. Data analysis

Frequencies of individual species were compared using chi-squared statistics as advocated by Byrne (1991) with modifications by Ross (1993). Multivariate analysis was carried out using CANOCO version 4.5 (ter Braak and Smilauer, 2002) to analyse cover-abundance quadrat data.

3. Results

3.1. Environmental comparison between the donor site, Top Park Field and the receptor site, Ashton Hill Field

Although varying in magnitude, measurable differences in temperature were recorded between the two sites each year

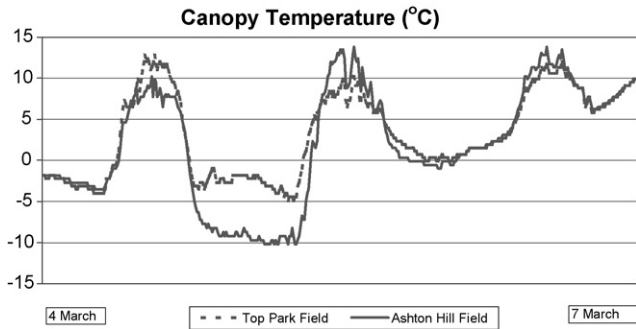


Fig. 2 – Comparison of canopy temperatures in Top Park Field and Ashton Hill Field micro-meteorological stations, 4–7 March 2001.

(1999–2003), especially in spring. Ashton Hill Field is not a topographic frost hollow, but the woods and hedges can trap katabatic air, while Top Park Field allows much freer movement of cold air. Often ground frosts continue into June in Ashton Hill Field, while ceasing in April in Top Park Field. These conditions may slow plant growth, resulting in plant damage if severe frosts occur in late spring. These effects can be illustrated by the comparison between the two sites for 4–7 March 2001 shown in Fig. 2. Although the mean canopy temperature was similar, the minimum of -10.2°C at Ashton Hill Field must have had some impact on the vegetation during March. In summer the converse occurs with higher maximum temperatures occurring in Ashton Hill Field.

Although less obvious, differences were recorded in the percentage relative humidity between the two sites, especially before cutting. Ashton Hill Field tends to be more humid compared with Top Park Field due to the occurrence of less drying winds and a denser sward. These effects can be illustrated by the comparison between the two sites for 12–14 June 2000 shown in Fig. 3. Cyclonic conditions had brought light rain and overcast conditions. Ashton Hill Field was more humid than Top Park Field with the reduction in percentage relative humidity lagging behind (Fig. 3).

The Crwbin series soils which characterise the two sites are inherently low in available nutrients (Ragg et al., 1984). Soil analyses across Top Park Field in January and March 1995 (Reeve, 1995a) gave a mean topsoil total nitrogen value of

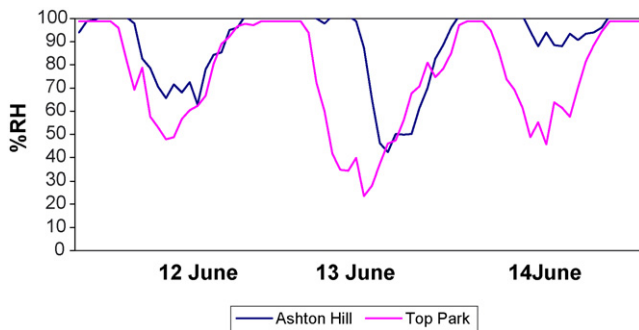


Fig. 3 – Comparison of percentage relative humidity at Top Park Field and Ashton Hill Field micro-meteorological stations, 12–14 June 2000.

Table 1 – Available nutrients in soil samples from Top Park Field and Ashton Hill Field 1999–2003

	Top Park Field		Ashton Hill Field	
	TS	SS	TS	SS
NH₄ (mg kg⁻¹)				
1999	12.5 ± 2.1	3.6 ± 1.8	18.7 ± 3.2	2.4 ± 2.3
2000	3.0 ± 0.4	2.6 ± 0.1	3.5 ± 0.9	2.8 ± 0.5
2001	1.3 ± 0.0	1.0 ± 0.1	1.3 ± 0.2	0.8 ± 0.3
2002	2.0 ± 0.1	1.3 ± 0.2	2.3 ± 0.8	1.7 ± 1.1
2003	2.7 ± 0.0	2.7 ± 0.1	2.7 ± 0.1	2.7 ± 0.0
NO₃ (mg kg⁻¹)				
1999	5.2 ± 2.4	2.6 ± 1.6	6.6 ± 5.2	4.4 ± 3.4
2000	0.9 ± 0.0	1.0 ± 0.1	1.1 ± 0.2	1.1 ± 0.3
2001	2.1 ± 0.1	1.9 ± 0.0	2.1 ± 0.1	1.9 ± 0.1
2002	3.5 ± 0.1	3.4 ± 0.1	3.8 ± 0.1	3.5 ± 0.2
2003	2.1 ± 0.3	1.7 ± 0.6	1.9 ± 0.2	1.4 ± 0.5
P (mg l⁻¹)				
1999	3.0 ± 0.0	2.5 ± 0.7	2.7 ± 1.2	3.3 ± 0.6
2000	3.5 ± 0.7	3.0 ± 1.4	4.3 ± 0.6	4.0 ± 1.0
2001	8.0 ± 2.8	5.5 ± 0.7	8.3 ± 3.1	6.7 ± 3.2
2002	6.5 ± 2.1	4.0 ± 0.0	4.7 ± 2.1	4.7 ± 0.6
2003	5.5 ± 2.1	4.0 ± 1.4	5.3 ± 0.6	4.7 ± 0.6
K (mg l⁻¹)				
1999	74.0 ± 0.0	64.5 ± 6.4	79.0 ± 18.4	70.7 ± 8.0
2000	58.0 ± 2.8	60.0 ± 1.4	68.7 ± 11.9	64.3 ± 16.2
2001	59.0 ± 1.4	54.5 ± 2.1	64.3 ± 10.3	62.3 ± 6.1
2002	67.5 ± 9.2	62.0 ± 1.4	66.0 ± 10.4	84.7 ± 4.0
2003	69.0 ± 4.2	62.0 ± 4.2	74.3 ± 6.4	67.0 ± 3.6
Mg (mg l⁻¹)				
1999	70.5 ± 6.4	42.0 ± 4.2	78.3 ± 17.0	61.0 ± 4.6
2000	61.0 ± 11.3	44.5 ± 2.1	66.3 ± 3.2	56.3 ± 9.9
2001	57.0 ± 4.2	33.0 ± 5.7	60.3 ± 4.0	45.3 ± 11.8
2002	62.5 ± 7.8	37.0 ± 0.0	65.3 ± 17.6	45.7 ± 11.6
2003	78.0 ± 0.0	49.0 ± 8.5	84.3 ± 4.2	62.3 ± 6.0

TS = topsoil (30–100 mm), SS = subsoil (150–250 mm). Means are shown ± standard deviation.

0.3% (S.D. = 0.50), available phosphorus 5.0 mg l^{-1} (S.D. = 1.00), available potassium 74.0 mg l^{-1} (S.D. = 15.9) and available magnesium 64.3 mg l^{-1} (S.D. = 11.4). Similar low values have been recorded since translocation on both sites. Nevertheless, some measurable differences in available nutrients between the two sites have been recorded since translocation (Table 1).

In 1999, immediately after the translocation event, nitrogen in the form of NH₄ and NO₃ was at raised levels at both sites, but particularly at Ashton Hill Field, especially in the topsoil, presumably due to increased microbial activity as a result of disturbance. Since 1999, overall levels, the differences in available nitrogen content between the soils of the two sites and levels of variability as measured by standard deviations have all diminished. Table 1 gives little evidence for increases in available phosphorus as a result of translocation, but levels of other available nutrients, especially K and Mg, have been noticeably higher in both topsoil and subsoil of Ashton Hill Field compared with Top Park Field although the differences are generally small compared with the variance.

Penetrometer readings were taken to measure soil compaction at the two sites (Table 2). Following translocation in 1999, the turf layer in Ashton Hill Field was more com-

Table 2 – Mean penetrometer readings in kg cm⁻² using a Bush Penetrometer

Year	Top Park Field			Ashton Hill Field		
	Turf	TS	SS	Turf	TS	SS
1999	6.2 ± 0.49	18.7 ± 0.07	29.3 ± 1.84	9.7 ± 0.47	17.6 ± 2.37	21.6 ± 2.89
2000	6.5 ± 0.28	13.9 ± 2.33	19.2 ± 3.75	5.7 ± 0.06	10.1 ± 0.30	17.8 ± 2.87
2001	11.5 ± 0.57	19.5 ± 0.99	26.3 ± 2.62	7.2 ± 1.79	15.7 ± 2.50	25.1 ± 0.98
2002	14.5 ± 0.21	22.1 ± 1.41	24.3 ± 1.34	12.1 ± 0.55	17.2 ± 0.76	22.0 ± 2.12
2003	21.4 ± 2.33	41.2 ± 2.69	NV	30.9 ± 3.97	43.0 ± 0.93	NV

Turf = 0–30 mm; TS = topsoil (60–150 mm); SS = subsoil (180+ mm); NV = no value.
Means are shown ± standard deviation.

pacted than the donor site. This was assumed to be due to the translocation process. Results for the three subsequent years (2000–2002) showed that penetrometer readings were higher in Top Park Field than Ashton Hill Field at all depths. This was probably due to the distribution of stones in the undisturbed soil while the translocated soils were moister and deeper with fewer stones. Following the exceptionally dry summer of 2003, penetrometer measurements were noticeably greater in Ashton Hill Field. The undisturbed structure of the soil in Top Park Field appeared to resist the impact of the hot dry conditions more than the translocated soils. Boundaries of the translocated turf were particularly visible during the 2003 drought.

3.2. Weather records

Records for mean maximum monthly temperature and total monthly rainfall recorded at RAF Lyneham for the pre-translocation years 1994–1998 are shown in Table 3. These data clearly indicate that after a dry spring there was an exceptionally dry and warm summer in 1995, taking effect principally after the site had been surveyed for that year. This summer drought was not repeated in any of the three following years.

Table 4 records the sunshine hours and rainfall recorded at Lyneham Climatological Station for the different seasons from 1999 to 2003. These data suggest that years 1999–2002 were without any extended periods of dry sunny weather. In 2003 however, there is clearly a long dry sunny period in late

summer and a less marked one in spring. The data indicate that after translocation there was a 4-year period of relatively equable weather, and that only in 2003 was there much likelihood of water stress operating on the two fields under study.

3.3. Botanical monitoring before translocation (1994–1998)

Seventy species were recorded in the pre-translocation period, of which 43 were recorded in all years. Twenty-eight of the 43 three species recorded consistently in the sample varied significantly in frequency from year to year before translocation took place. Variation in the frequency of 14 species had chi-squared > 16.27 ($p = 0.001$, 3d.f.), a further seven > 11.35 ($p = 0.01$, 3d.f) and a further seven > 7.82 ($p = 0.05$, 3d.f).

Fig. 4 is a biplot of the two strongest axes of a direct gradient analysis (RDA) of the 1995–1998 data for which species cover-abundance was recorded. It shows the species and those environmental variables, year of data collection and position of the sample in the field (eastern or western half) which had proved to be significant in Monte Carlo permutation tests. The diagram shows an association of a disparate group of forbs with 1995, some of which are associated with moist or fertile soils (*Prunella vulgaris*, *Ranunculus acris*, *Ranunculus repens*, *Trifolium pratense*), others with shallow soils (*Daucus carota*, *Pilosella officinarum*, *Senecio squalidus*) and also the parasitic plant *O. minor* which is uncommon in the UK. A much more

Table 3 – Mean maximum monthly temperature and total monthly rainfall recorded at RAF Lyneham 1995–1998 (data taken from the Royal Meteorological Society's weather log)

	1995		1996		1997		1998	
	Temperature (°C)	Rain (mm)	Temperature (°C)	Rain (mm)	Temperature (°C)	Rain (mm)	Temperature (°C)	Rain (mm)
January	7.7	206	5.9	40	4.5	6	7.5	90
February	9.3	66	5.3	55	9.3	80	10.3	11
March	9.2	41	7.5	40	12.0	19	10.7	65
April	12.8	16	12.6	44	13.8	21	11.0	109
May	16.4	48	13.2	38	16.4	57	17.8	31
June	19.0	12	19.9	16	17.9	65	17.6	119
July	23.8	12	22.2	28	21.5	30	19.2	32
August	25.7	2	21.2	57	22.9	110	20.6	27
September	17.4	104	17.6	21	18.5	9	18.5	100
October	16.3	54	14.6	54	14.3	74	13.4	128
November	10.6	89	8.9	87	11.3	86	8.9	55
December	3.9	95	4.7	26	8.1	93	8.6	72

Months	Climatic parameter	1999	2000	2001	2002	2003
Winter						
January and February	Sunshine hours	138	178	174	122	168
	Rainfall (mm)	135	107	138	222	109
Spring						
March, April and May	Sunshine hours	417	474	450	621	560
	Rainfall (mm)	143	276	198	179	126
Early summer						
June and July	Sunshine hours	469	362	477	356	416
	Rainfall (mm)	67	65	60	161	126
Late summer						
August and September	Sunshine hours	348	343	327	385	400
	Rainfall (mm)	239	159	114	102	14
Autumn						
October and November	Sunshine hours	244	165	236	184	216
	Rainfall (mm)	97	261	135	264	132
Total	Sunshine hours	1616	1522	1664	1668	1760
	Rainfall (mm)	681	868	645	928	507

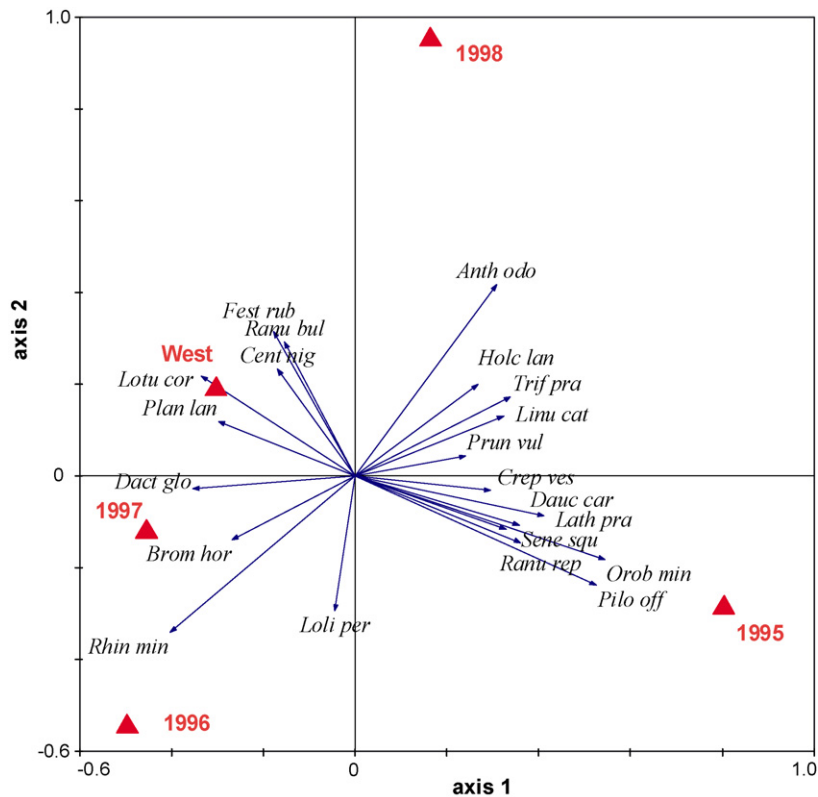


Fig. 4 – Biplot of the first two axes of an RDA analysis of the cover-abundance quadrat data and associated significant constraining environmental variables for Top Park Field prior to translocation. The constraining explanatory nominal variables are the year of the survey (1995–1998) and the position of each sample in the western or eastern half of the field, “west” being scored as positive. The eigenvalues for axes 1 and 2 were 0.062 and 0.034, respectively. The two axes account for 78.4 of the species-environment relation, but explain only 9.6% of the variance of the species data. All variables except 1997 are significant at higher than the 1% level in Monte Carlo permutation tests. 1997 is necessarily collinear with the other years, therefore cannot be ascribed a separate significance, but has been included in the diagram for completeness. Species showing at least 5% fit with the ordination space are shown in an abbreviated form for which Table 7 is a key.

Table 5 – Number of vascular plant species per quadrat in the frequency samples

Sample area	Year	No. of species
Top Park Field	1995	12.0 ± 3.19
	1996	12.0 ± 2.38
	1997	10.7 ± 2.61
	1998	12.8 ± 3.04
Untranslocated part of Top Park Field	1999	No data
	2000	14.8 ± 3.01
	2001	13.2 ± 2.71
	2002	13.4 ± 2.73
	2003	13.9 ± 3.05
Ashton Hill Field Area 1	1999	15.0 ± 2.75
	2000	15.3 ± 3.18
	2001	13.5 ± 3.00
	2002	12.6 ± 2.56
	2003	14.5 ± 2.88
Ashton Hill Field Area 2	1999	13.5 ± 2.84
	2000	13.9 ± 3.12
	2001	12.0 ± 3.05
	2002	12.4 ± 2.65
	2003	13.1 ± 2.61
Ashton Hill Field Area 3	1999	12.2 ± 2.73
	2000	11.6 ± 2.79
	2001	11.0 ± 2.42
	2002	11.2 ± 2.20
	2003	12.5 ± 2.52

Means are shown ± standard deviation.

limited range of ruderal (*Bromus hordeaceus*, *Rhinanthus minor*) and competitive (*Dactylis glomerata*, *Lolium perenne*) species is associated with 1996 and 1997, and the diagram suggests a possible partial return towards the 1995 position in 1998. The clustering of a range of species with “West” in the RDA suggests that variation in conditions across Top Park Field are interacting with the between-years response of the vegetation. The species associated with 1995 were less common in the western half of the field even in 1995. As described in the methods section, there is a concentration of shallower soils in the western part of the field.

3.4. Botanical monitoring after translocation (1999–2004)

The following analysis refers to 5 years of data for the three sampling areas of translocated vegetation on Ashton Hill Field and 4 years for the remaining Top Park Field sample area. The untranslocated part of Top Park Field was cut extremely early in June 1999 so there is no data available for that year.

As a simple measure of the species richness of the vegetation the number of vascular plant species per quadrat was calculated for each sampling area for all years (Table 5). Over the first 4 years after translocation there was a gradual decline in species number per quadrat on all three of the translocated field samples, a fall which was present but rather less marked on the untranslocated area of Top Park Field. In the fifth year however there was a marked increase in species number at all sites but especially on the translocated vegetation.

There have been no major changes in the species lists for the sites. No species consistently recorded on Top Park Field before translocation has disappeared subsequent to translocation. Seven species, all recorded at frequencies of 0–3% before translocation, were not recorded on one or other site after translocation but only *Achillea millefolium* has not been recorded only from the translocated site. Twenty-two species appeared in the samples for the first time after translocation, 13 of these only in the translocated samples, but all of these 13 were of low and intermittent occurrence (0–2% frequency).

All of the species regularly recorded on Top Park Field before translocation continued to be regularly recorded on the translocated vegetation but some showed significant variation in frequency. In comparison with the 28 species showing significant variation in frequency on Top Park Field prior to translocation, Ashton Hill Field Area 1 had 27 species, Area 2 had 28 species and Area 3 had 31 species with frequencies varying significantly (chi-squared > 9.49 with 4d.f.) and the untranslocated area of Top Park Field had 24 species varying significantly in frequency (chi-squared > 7.82 with 3d.f.) in the period subsequent to translocation. Furthermore, the analysis does not demonstrate unequivocally that the differences are increasing each year. In Table 6 all the significant changes in frequency in the most species-rich area of Ashton Hill Field, sampling Area 1, are examined from year to year over the post-translocation period and compared with the frequency range in Top Park Field before translocation and the frequency range in the remaining Top Park Field since translocation. All of these 27 species except *B. hordeaceus* and *L. perenne* showed frequencies beyond the range seen before translocation but this was also true for 19 of the species on the untranslocated area of Top Park Field.

D. carota, *Leontodon saxatilis*, *Leucanthemum vulgare* and *Medicago lupulina* all showed increases in frequency following translocation which later subsided (Table 6). These species did not increase on the untranslocated area of Top Park Field, implying that the changes were a response to translocation. However in a much larger number of species the frequencies varied significantly on both Ashton Hill Field Area 1 and the untranslocated area of Top Park Field and also showed the same pattern of initial increase followed by decrease on both sites: *Agrostis stolonifera*, *C. nigra*, *Cerastium fontanum*, *Crepis capillaris*, *Crepis vesicaria*, *Hypochaeris radicata*, *L. saxatilis*, *L. perenne*, *Lotus corniculatus*, *R. minor* and *Trifolium dubium*. Some of these are ruderals and might be expected to respond positively to turf damage. Although not translocated, the remnant of Top Park Field is disturbed by public use; also our surveyors have occasionally reported evidence of extensive disturbance by badgers there.

Increases in frequency in *Arrhenatherum elatius*, *Bromopsis erecta* and *L. pratensis* seem still to be occurring on both sites and in *Convolvulus arvensis*, *D. glomerata*, *Holcus lanatus* and *Ranunculus bulbosus* on the translocated vegetation. Most of these species might be expected to respond positively to undermanagement and the vegetation becoming more closed.

After an initial increase, *C. nigra* and *D. carota* dwindled to very low frequencies on both sites, lower than those recorded before translocation. *C. capillaris* and *C. vesicaria* are less extreme examples of the same phenomenon, and *H. radicata* and *T. dubium* are also at an historically low frequency,

Table 6 – Frequencies of species on Top Park Field (TPF) and Ashton Hill Field sampling Area 1 (AHF1)

Species	% frequency									
	TPF pre-trans-location	AHF1 post-translocation					TPF post-translocation			
	1995–1998	1999	2000	2001	2002	2003	2000	2001	2002	2003
<i>Agrostis stolonifera</i>	1–15 ^{***}	21	4	10	5	2 ^{***}	12	3	5	2 ^{**}
<i>Arrhenatherum elatius</i>	13–17	5	8	13	23	20 ^{***}	12	32	16	13 ^{***}
<i>Bromopsis erecta</i>	5–25 ^{***}	12	34	27	21	29 ^{**}	18	15	27	52 ^{***}
<i>Bromus hordeaceus</i>	20–51 ^{***}	26	48	29	43	31 ^{**}	30	32	35	7 ^{***}
<i>Centaurea nigra</i>	0–9 ^{***}	9	14	4	0	1 ^{***}	5	6	0	0 ^{**}
<i>Cerastium fontanum</i>	16–37 ^{***}	37	27	31	20	17 ^{**}	36	19	28	9 ^{***}
<i>Convolvulus arvensis</i>	11–24 [*]	35	70	65	54	56 ^{***}	14	16	7	8
<i>Crepis capillaris</i>	4–19 ^{***}	13	2	2	3	1 ^{***}	16	4	7	2 ^{***}
<i>Crepis vesicaria</i>	3–17 ^{***}	10	18	7	2	2 ^{***}	7	11	7	5
<i>Cynosurus cristatus</i>	25–49 ^{***}	60	41	60	62	42 ^{**}	57	44	35	42 [*]
<i>Dactylis glomerata</i>	54–74 ^{**}	67	77	44	55	65 ^{***}	60	55	55	51
<i>Daucus carota</i>	8–19	46	17	4	0	0 ^{***}	1	2	1	2
<i>Holcus lanatus</i>	15–69 ^{***}	53	67	92	91	82 ^{***}	69	72	58	48 ^{**}
<i>Hypochoeris radicata</i>	47–60	51	52	25	19	21 ^{***}	68	34	56	26 ^{***}
<i>Knautia arvensis</i>	18–35 ^{***}	12	10	1	1	1 ^{***}	25	27	32	24
<i>Lathyrus pratensis</i>	0–5	2	6	2	5	13 ^{***}	17	14	19	17
<i>Leontodon saxatilis</i>	5–9	13	3	5	0	4 ^{***}	2	4	3	9
<i>Leucanthemum vulgare</i>	3–12	32	31	11	4	8 ^{***}	13	9	8	14
<i>Linum catharticum</i>	12–48 ^{***}	43	29	11	1	20 ^{***}	49	21	41	40 ^{***}
<i>Lolium perenne</i>	22–73 ^{***}	66	47	44	39	29 ^{***}	73	67	60	40 ^{***}
<i>Lotus corniculatus</i>	41–60 ^{***}	90	98	95	89	82 ^{**}	72	66	63	72
<i>Medicago lupulina</i>	0–2	15	28	14	1	0 ^{***}	3	1	1	0
<i>Ophioglossum vulgatum</i>	0–1	0	1	0	0	1	1	0	1	0
<i>Orobanche minor</i>	1–12 ^{**}	1	1	4	0	1	2	2	14	4 ^{***}
<i>Plantago lanceolata</i>	82–90	92	98	99	94	87 ^{***}	91	78	73	72 ^{**}
<i>Ranunculus acris</i>	17–32	37	10	13	13	31 ^{***}	42	38	43	34
<i>Ranunculus bulbosus</i>	33–66 ^{***}	9	45	37	29	53 ^{***}	18	15	26	22
<i>Rhinanthus minor</i>	22–84 ^{***}	64	81	44	13	59 ^{***}	8	9	11	25 ^{***}
<i>Trifolium dubium</i>	15–54 ^{***}	21	14	3	6	4 ^{***}	22	23	22	13

The species selected are all those showing significant changes in frequency on Ashton Hill Field Area 1 plus *O. vulgatum* and *O. minor*.

* Variation in frequency array significant at at least 5% level in chi-squared test. Chi-squared ≥ 7.82 with 3d.f. for Top Park Field before and after translocation. Chi-squared > 9.49 with 4d.f. for Ashton Hill field Area 1.

** Variation in frequency array significant at at least 1% level in chi-squared test. Chi-squared ≥ 11.35 with 3d.f. for Top Park Field before and after translocation. Chi-squared > 13.28 with 4d.f. for Ashton Hill field Area 1.

*** Variation in frequency array significant at at least 0.1% level in chi-squared test: chi-squared ≥ 16.27 with 3d.f. for Top Park Field before and after translocation. Chi-squared > 18.47 with 4d.f. for Ashton Hill field Area 1.

Table 7 – Key to abbreviated names shown in Figs. 4 and 5

Agro cap	<i>Agrostis capillaris</i>	Leuc vul	<i>Leucanthemum vulgare</i>
Agro sto	<i>A. stolonifera</i>	Linu cat	<i>Linum catharticum</i>
Anth odo	<i>Anthoxanthum odoratum</i>	Loli per	<i>Lolium perenne</i>
Brom ere	<i>Bromopsis erecta</i>	Lotu cor	<i>Lotus corniculatus</i>
Brom hor	<i>Bromus hordeaceus</i>	Orob min	<i>Orobanche minor</i>
Cent nig	<i>Centaurea nigra</i>	Pilo off	<i>Pilosella officinarum</i>
Cera fon	<i>Cerastium fontanum</i>	Plan lan	<i>Plantago lanceolata</i>
Crep ves	<i>Crepis vesicaria</i>	Pote rep	<i>Potentilla reptans</i>
Cyno cri	<i>Cynosurus cristatus</i>	Prun vul	<i>Prunella vulgaris</i>
Dact glo	<i>Dactylis glomerata</i>	Ranu acr	<i>Ranunculus acris</i>
Dauc car	<i>Daucus carota</i>	Ranu bul	<i>Ranunculus bulbosus</i>
Elym rep	<i>Elymus repens</i>	Ranu rep	<i>Ranunculus repens</i>
Fest rub	<i>Festuca rubra</i>	Rhin min	<i>Rhinanthus minor</i>
Holc lan	<i>Holcus lanatus</i>	Sene squ	<i>Senecio squalidus</i>
Hypo rad	<i>Hypochoeris radicata</i>	Tara off	<i>Taraxacum sp.</i>
Lath pra	<i>Lathyrus pratensis</i>	Trif dub	<i>Trifolium dubium</i>
Leon aut	<i>Leontodon autumnalis</i>	Trif pra	<i>Trifolium pratense</i>
Leon his	<i>Leontodon hispidus</i>	Trif rep	<i>Trifolium repens</i>
Leon sax	<i>Lathyrus saxatilis</i>	Tris fla	<i>Trisetum flavescens</i>

especially in the translocated vegetation. With the possible exception of *C. nigra*, these are all species associated with open vegetation. Much of the change in this group cannot be directly attributed to translocation since it is operating at both sites.

A number of species have shown a cumulative fall in frequency on Ashton Hill Field Area 1 since translocation, in some cases after an initial increase in frequency. This includes *L. vulgare*, *Linum catharticum*, *L. saxatile*, *R. acris* and *R. minor*. All of these show some reversal of this downward trend in the 2003 data. On the other hand *Knautia arvensis* has shown no signs of reversal of falls in frequency in the translocated vegetation.

Of the species named in the objectives of the translocation as desirable, none were sufficiently frequent to allow statistical analysis. *A. pyramidalis* and *O. apifera* are too infrequent to appear in the quantitative data but both have been observed in the translocated turf. The frequency data for *O. minor* and *O. vulgatum* are shown in Table 6. *O. minor* fell to very low frequencies on the translocated turf and *O. vulgatum* may be increasing in frequency on Ashton Hill Field being recorded in all three sample areas and with a frequency of up to 5% on Ashton Hill Field Area 3.

The frequency data for Ashton Hill Field Areas 2 and 3 show similar trends to Area 1, although they were less species-rich, after translocation.

Fig. 5 is an RDA species/environmental variable biplot of all the vegetation data for which species cover-abundance was recorded, from the western half of Top Park Field, which was translocated to Ashton Hill Field in winter 1998–1999. The constraining variables are represented as the interactions between year and the four different sample areas possible: Top Park Field before translocation (TP*1995 to TP*1998) and Ashton Hill Field sampling Areas 1–3 after translocation (AH1*1999 to AH3*2003).

Axis 1 largely separates the untranslocated samples and the early translocated samples from the later translocated samples, suggesting a trend of increasing differentiation in time between the donor site samples and the receptor site samples. In 1999, Ashton Hill Field Area 1 (AH1) is very close to the positions of the Top Park Field samples, especially the one for 1998. The samples from areas associated with deeper soils and lower diversity, AH2 and AH3, have considerably lower scores on axis 1 in 1999 and these scores mostly become lower

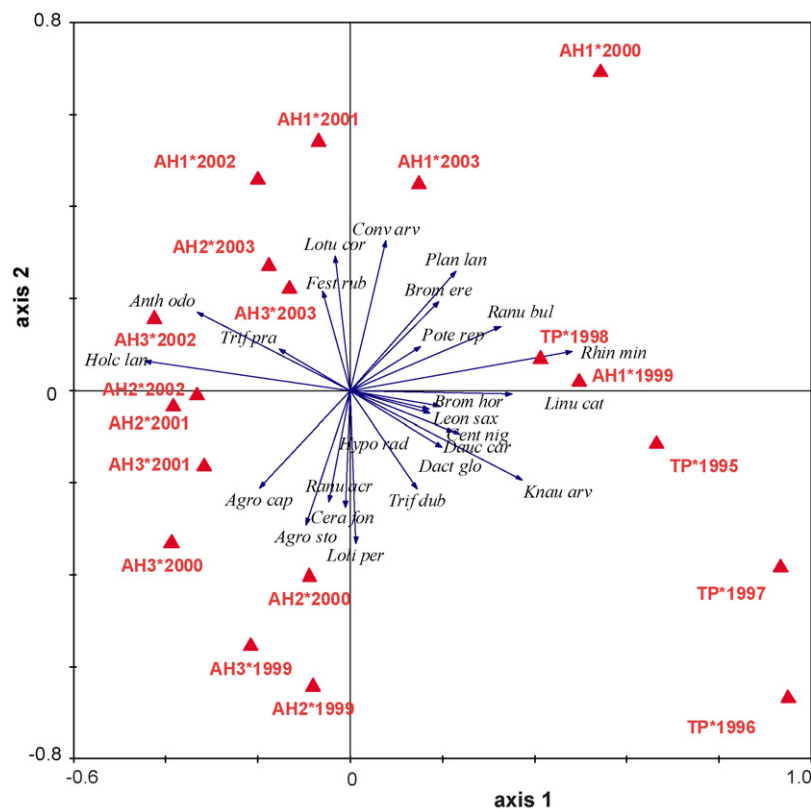


Fig. 5 – Biplot of the first two axes of an RDA analysis of the cover-abundance quadrat data and associated significant constraining environmental variables for the western half of Top Park Field before and after translocation of the western half. The constraining explanatory nominal variables are the interactions of year of survey (1995–2003) with sample: TP*1995 to TP*1998 constrain the pre-translocation samples. AH1*1999 to AH1*2003 constrain the Ashton Hill Field Area 1 samples, AH2*1999 to AH2*2003 constrain the Ashton Hill Field Area 2 samples, AH3*1999 to AH3*2003 constrain the Ashton Hill Field Area 3 samples. The eigenvalues for axes 1 and 2 are 0.040 and 0.032, respectively, and the axes represent 52.2% of the variation of the species/environment data. Relationships with all years are significant at higher than the 1% level in Monte Carlo permutation tests except AH2*2002, which was significant at the 5% level and AH3*2003, which is not testable because of collinearity, but has nevertheless been included in the diagram for completeness. Species showing at least 5% fit with the ordination space are shown in an abbreviated form for which Table 7 is a key.

still in 2000, 2001 and 2002. AH1 also scores lower in 2001 and lower still in 2002 on axis 1. There is, however, now some evidence for a reversal in this trend, since all three increase their scores on axis 1 in 2003.

The species associated with low scores on axis 1 are a small number of mostly grass species. A larger number of mostly forb species have high scores on axis 1. Many, such as *L. catharticum* and *D. carota*, are also species disadvantaged by the 1995 drought event. Others, such as *D. glomerata*, *K. arvensis* and *R. minor*, became more prominent on Top Park Field after 1995.

Axis 2 differentiates particularly between the later AH1 samples (high scores) and the Top Park samples responding to the 1995 drought (low scores). The early AH2 and AH3 samples also score low on this axis. Species associated with low scores include colonising species such as *A. stolonifera*, *T. dubium* and *C. fontanum*. The species associated with high scores on axis 2 are *Festuca rubra*, *Plantago lanceolata* and *L. corniculatus*, all species which are increasing on the untranslocated area of Top Park Field (Table 6). The competitive ruderal *C. arvensis* is also associated with high scores.

4. Discussion

The climatological comparison of the source site Top Park Field and the receptor site Ashton Hill Field suggested that the latter is more sheltered, with small but measurable tendencies to higher humidity, greater frost liability and higher summer temperatures. The soil penetrometer analysis showed that following translocation there was early compaction of the surface soil on the translocated turves of Ashton Hill Field which gradually ameliorated over the next 3 years and may even have reversed in the dry summer of 2003. There were therefore some differences between the source and receiver site which might have been expected to lead to changes in the vegetation.

Soil chemical analysis did not suggest that the disturbance associated with translocation produced marked or long-term perturbations in plant nutrient availability which could alter the balance between competitive and stress-tolerant species in the vegetation. These data suggest that with attention to detail in reconstructing the substrate and handling the turves it is possible to lift and re-lay at least the low fertility soils encountered at Durnford with only a brief increase in available nitrogen and practically no increase in available phosphorus and potassium. This also appears to be true for the relocated subsoils. Under these circumstances the results of the botanical monitoring can be discussed without the need to account for large fluctuations in soil fertility.

The results of the botanical monitoring demonstrate that there was considerable variation from year to year in the vegetation of Top Park Field even before the translocation exercise took place, with significant fluctuations in the frequencies of more than half of the consistently recorded species. The multivariate analysis of the cover-abundance data showed that much of this variation was concentrated in the period between the first and second years of the monitoring, with competitive and stress-tolerant species partially replaced by ruderals and with a tendency towards reversal in the subsequent years. Also the changes appear to have been concentrated in the half of Top Park Field with shallow soils.

The changes in the vegetation between monitoring in 1995 and 1996 correlate with the summer drought of 1995 which is identifiable in the weather reports described in Section 2.3. Other grassland plant communities responded to this 1995 drought. Buckland et al. (1997) examined the effects of the 1995 drought on an area of calcareous grassland in northern England and showed that many, but not all tap-rooted forbs were less likely to desiccate and that drought sensitive species were particularly disadvantaged on shallow soils. Morecroft et al. (2002) also reported significant perturbations in plant species frequency at three UK sites being monitored through the 1995 drought period.

The variation in the vegetation continued subsequent to translocation in both translocated and untranslocated areas, and gives some evidence that some of the criteria for success in translocation listed in Section 1 have been met since many of the changes are of comparable magnitude to those seen in monitoring the untranslocated turf. Species density has been maintained without any significant appearance or disappearance of species. The number of species showing significant variation in frequency is similar to that observed on the grassland prior to translocation and on the untranslocated area of Top Park Field. A range of disturbance indicator species increased after translocation, but it appears that under the low fertility conditions prevailing they quickly subsided. This pattern is also seen to occur for many species on the untranslocated turf suggesting that the response is not entirely specifically to translocation. Bullock (1998) in his review of turf translocations also noted that where there were comparisons with untranslocated vegetation it too had changed.

There are, however, a small number of species which appear to be behaving differently on the translocated turf. There are some increases in frequency on the translocated areas which seem to be absent elsewhere and not seen on the untranslocated turf and are difficult to explain except as responses to translocation. Also, a few species had immediate or cumulative negative responses to translocation, and the case of *K. arvensis* is of particular concern since this species does not create a seedbank (Grime et al., 1988) and because there is little sign of the recovery seen in other species in 2003. Possibly the depth of the turves is a controlling factor, although it would have been physically very difficult to lift deeper turves on the limestone and extremely expensive to attempt to do so in a large scheme such as Durnford.

No list of species specifically vulnerable to translocation emerges in Bullock (1998) and the same species can increase or decrease at different sites; the simplest interpretation would be that the responses are site specific. However, there was loss of *K. arvensis* in an initial trial of deep turf translocation at Thrislington in County Durham (Park, 1989) and also in the shallow turf moved at Newhall Reservoir in Nottinghamshire (Cox et al., 1992). *K. arvensis* and possibly *O. minor* which has also not recovered at Durnford may be particularly badly affected by the physical root pruning which might occur in turf cutting.

The monitoring exercise gives some evidence for recovery in the fifth year after translocation. The multivariate analysis, which takes into account cover-abundance as well as frequency gives a particularly clear evaluation of this change

of direction. It suggests that in the first 4 years after translocation there was a trend towards increasing differentiation between the translocated samples and that part of Top Park Field from which it came, with the development of a less forb-dominated and a more grass-dominated vegetation. In the fifth year (2003), however, this trend appears to have ceased or even reversed. There is some evidence from the monitoring programme that this change coincided with a major fluctuation in weather conditions. The weather records (Results, Section 3.2) suggest a run of growing seasons from 1999 to 2002 without water stress. 2003 was the first growing season since the translocation when weather conditions could have generated water stress.

The marked response of vegetation to annual fluctuations in the weather was very clear in the long-term analysis (Dunnett et al., 1998) of the control plots of the under-managed dry mesotrophic grassland road verges near Bibury, Gloucestershire (Willis, 1972, 1988), showing many significant correlations in variation in the species with weather variables, particularly ones recorded for spring and summer seasons. Sternberg et al. (1999), manipulating the local climate in a calcareous grassland developing on an ex-arable field concluded that wetter conditions during summer caused perennial grasses to close the sward and inhibited the establishment of later successional species, a process which seems to have operated at Durnford in the first 4 years after translocation. Stampfli and Zeiter (2004), recording species change over 12 years in a species-rich grassland in the Southern Alps concluded that relative cover of graminoids decreased over a drought period with replacement by seedlings of forb species, a process perhaps beginning at Durnford after the dry spring and summer of 2003.

These results highlight the important role which annual weather patterns play in controlling the frequency of large numbers of plants in such drought-labile vegetation as the Durnford grasslands, and the necessity to consider this in interpreting trends in translocated vegetation. The negative response to years without water stress in the growing season does however seem stronger in the translocated turves. There is little evidence from Durnford that a second cut and scarification of the turf produced a positive change, but it seems clear that the dry spring and summer of 2003 had a positive effect, although it is not possible to separate these two possible causes of recovery in the monitoring data. Furthermore, axis 2 in the multivariate analysis demonstrates that the drier summer of 2003 did not produce exactly the same effect on the vegetation as the drought event of 1995, since the samples are at opposite ends of this axis. It is hypothesised that the 1995 event was more severe, causing the widespread preferential death of particular plant species.

5. Conclusions

The results of the monitoring programme, although not yet complete, give some support to the use of turf translocation as a technique of value in the mitigation for loss and in nature conservation where the alternative is the complete loss of the site. The results obtained so far support the hypothesis that changes in the vegetation ascribable to translocation are

largely of a similar amplitude to other changes taking place on the site and that the vegetation has been translocated successfully. This is despite measurable differences between the meteorology and soil compaction of the source and receptor sites, although soil monitoring has demonstrated that careful reconstruction of the soil profile at the receptor site has prevented differentiation in soil fertility between source and receptor sites. The programme has demonstrated effects of translocation on the vegetation and some recovery from these effects, but also a small number of persistent changes in the translocated vegetation. The translocated vegetation, and the part of Top Park Field which remained untranslocated are both still changing and further monitoring is necessary. This will take place for the full 10 years advocated by Box (2004). Since the monitoring methods used represent a rapid but quite intensive level of monitoring they should be taken into account in the design of future monitoring projects. Anderson (2003) has advocated an experimental approach to the evaluation of turf translocation. This would involve replicated, randomised block experiments and the measuring of responses of soil and soil microflora and microfauna, engineering site hydrology, comparing soil transfer and turving in situ and to a new situation. This work is needed. However, the present study suggests that there is still much to be learned about vegetation responses to translocation from detailed long-term monitoring of translocation projects.

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