The floristics of contrasting grazed-down Scottish moorland sites initially dominated by heather (*Calluna vulgaris*)

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Vegetation and herbivore usage at three moorland sites have been monitored since 1969/1970. Heavy grazing soon caused *Calluna* to be replaced by graminoid species, and this paper is concerned mostly with the floristics of the new grasslands observed over the last 20–23 years of the study. Compositional changes in this period were minor, with no change in the best-fit allegiances to NVC vegetation types. At one site where the livestock were restricted to a relatively small range within which some reseeding occurred, the vegetation belonged to NVC *Lolium-Cynosurus* grassland MG6b despite not having been ploughed. At a second site the vegetation was NVC *Agrostis-Festuca-Galium* grassland U4d with much *Luzula multiflora*. At the third site the vegetation was NVC U4a but fairly rich in species including some of NVC *Festuca-Agrostis-Thymus* grassland CG10. This last site has conservation value due to both the rarity of the grassland type in NE Scotland and the occurrence of rare angiosperms. The driver of change at the three sites was thought to be the grazing exerted, and no evidence was found of species composition reacting to climate change or nitrogen deposition.

Keywords: grasslands, grazing, heather moorland, NVC plant communities, vegetation change

Introduction

That grasslands develop from heather moorland when heavily grazed by large herbivores is now well known (Welch, 1984a), but the factors controlling the types of grassland produced are less certain. This paper reports observations over 40–43 years at three sites with dry soils at which different grassland communities developed after initial heavy grazing; at all three sites heather (*Calluna vulgaris*) had at first > 45% cover, but its cover declined to < 15% within 5–14 years of the start of observations. So the newly-created grassland communities have been monitored for upwards of 25 years, allowing evaluation of the fluctuations and trends in the cover of their component species. The new grasslands have been relatively stable in composition, so their affinity within the British National Vegetation Classification (NVC) and also their conservation value can be assessed.

This long-running study on the impact of grazing on heather moorland in north-east Scotland began in 1969/1970. Some 32 sites were set up on a range of soil types at a range of altitudes subjected to grazing by cattle, red deer or sheep (Welch, 1984b); at 16 sites the monitoring continued for 20 years and the findings were reported by Welch & Scott (1995).

The present three sites are still monitored and are the only ones of these 16 that lay on dry soils and also became grasslands.

Unploughed semi-natural grasslands have become a quite rare vegetation type in Britain, many having been reclaimed for intensive agriculture or afforested (Fuller, 1987; Hopkins & Wainwright, 1989; Rodwell et al., 1992; Tudor & Mackey, 1995).

However, to some extent these losses have been counterbalanced by the development of new grasslands from heather moorland due to heavy grazing pressures. Semi-natural grasslands vary greatly in their species richness (King & Nicholson, 1964; Rodwell et al., 1992), and it needs to be established that the grasslands newly developed from moorland do provide, at least when management and soils are favourable, species-rich swards that are considered of conservation value.

Study sites

The three sites are situated in the Grampian foothills, with altitudes ranging between 124 and 290 m (Table 1). They lie 20 to 60 km from the coast, so have a hemi-oceanic climate; for Aboyne, their closest meteorological station, 1980–2010 averages are: January mean temperature 2.5°C, July mean temperature 14.4°C, annual days air frost 86, annual rainfall 780 mm.

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Table 1   Site information.

	Site E3	Site F2	Site G2
Location	Midtown, Kincardineshire	Garrol Hill, Kincardineshire	Deskry, Aberdeenshire
Grid reference	NO704909	NO718912	NJ404129
Altitude (m)	124	198	290
Topography	flat	5° W slope	8° N slope
Soil type	podsol	weak podsol	brown earth
pH	4.4	5.0*	4.9
Extractable K^	20	14	13
Extractable Ca^	20	70*	17
Grazing regime/situation	unrestricted, improved grsld usually available	restricted to 6–15 ha; mostly reseeded ryegrass	restricted to 50 ha; some improved grsld available
Main herbivore	cattle	sheep	cattle
Subsidiary herbivores	sheep, rabbits	cattle, rabbits	sheep, rabbits
Initial % cover			
Calluna	85	46	47
Agrostis+*Festuca*	39	36	79
Initial height *Calluna* (cm)	13	8	20

*Limed several years before start of observations
^Expressed as mg dry weight 100 ml^{-1}

The soils are well drained, derived from drift, and initially ranged in pH from 4.4 to 5.0 (Table 1). At site F2 (codes follow Welch 1984b), liming had taken place in the 1960s before monitoring began, and some ground in the range available to the livestock that grazed F2 had been ploughed and reseeded then. Another tract there, very close to the monitored plots, was rotovated, reseeded and fertilised in 1984.

Grazing management differed between sites (Table 1). For all three the moorland studied was just part of a range that also included some improved grassland. At site E3 the livestock could move freely on to a very large block of heather moorland but rarely went far into this hill ground; instead they spent some time each day in fields of improved grassland, and were only debarred from these when reseeding took place at roughly twelve-year intervals. At site F2 the livestock were confined by fences to 6–15 ha of ground that was mostly improved grassland, and some internal fences became derelict during the study. Site G2 was intermediate in the extent of range available to its livestock, and whilst initially there was a considerable tract of heather moor and stands of broom (*Cytisus scoparius*) these features became almost eliminated by the half-way stage of the monitoring.

The sites differed also in the initial state of their *Calluna* stands (Table 1): at E3 the sward was quite low but continuous, whereas bushes were distinct at F2 and G2. They had already been grazed down at F2 when the study began, but at G2 some bushes reached 30 cm height initially. There was no evidence of recent muirburn at any of the three sites.

Methods

The sites studied were initially in tracts of relatively homogenous vegetation, and were 0.5–1.5 ha in extent. Within each site eight permanent monitoring plots were set up, 15 × 1 m long; measurements on

dung deposition were made within the plots and measurements on vegetation alongside the plots. Monitoring began at F2 and G2 in 1969 and at E3 in 1970.

Detailed information about the dung measurements is given by Welch & Scott (1995). Dung of cattle, sheep, red deer, hares + rabbits, and red grouse was assessed separately, by volume measurements at 3-week intervals in the first seven years of the study, thereafter on a six-point index scale for each type from the standing crop of dung present in April and September each year. To produce the yearly totals of herbivore occupancy (Fig. 1), totals for the five types were added, the volume for cattle being first divided by 1.8 to allow for its low dry-matter content (Welch, 1982).

Plant cover was estimated by point-quadrat analysis every second or third year. A 10-pin frame 1 m long was placed in 10 positions alternately parallel and normal to the long axes of the monitoring plots and 1 m apart, giving 800 points per site. The pins were held vertically, and for each pin every species contacted was recorded. Analyses took place in late June and July, the timing at each site differing within this period by at most 14 days over the whole study. *Calluna* height and shoot utilisation were recorded in 16 1 m square permanent positions, two per plot. Height was measured each September by 10 spot measures at each position, and utilisation was recorded both then and in April, when it was at its maximum before new growth started. For utilisation the fraction of main shoots that had been browsed was assessed in each 1 m^2 position on a 4-point index scale.

For a basic assessment of trends in vegetation composition (Fig. 2), the species were grouped according to type: bryophytes, lichens, ericoids (*Calluna, Erica, Vaccinium*), unpalatable graminoids (*Juncus,*

a) herbivore occupancy

Site E3   Site F2   Site G2
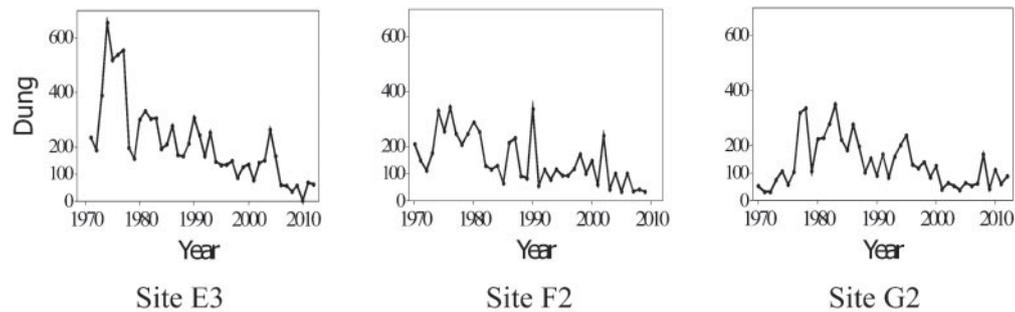
b) heather utilisation

Site E3   Site F2   Site G2
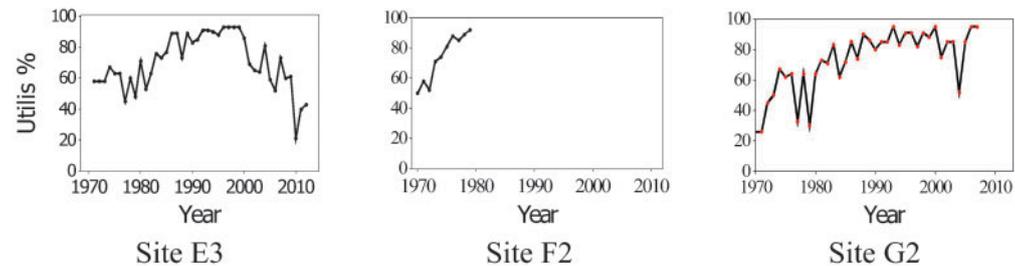
Figure 1 Herbivore occupancy (ml m^{-2} yr^{-1}) for April-April periods and mean % heather utilisation recorded in April at the end of these years for the three sites. At site F2 no heather remained in the observation plots after 1979.

Molinia, Nardus, Trichophorum) and graminoids-herbs (all other angiosperms). A group was recorded for a pin if any member species was hit, the number of contacts not mattering. For analysis of the floristics of the new grasslands, mean composition was calculated from all recordings after year 19 of their monitoring; by this time *Calluna* was already extinct at site F2, had less than 1% cover at site G2, and though having 17% cover at site E3 in year 20 the vegetation there was essentially a grassland. The affinity of the new grass-lands to NVC types in the British National Classification (Rodwell *et al.*, 1992) was assessed using TABLEFIT (Hill, 1996). This was done both for the mean composition of the sites after year 19 of their monitoring and for their final composition at year 40/43. The estimation of mean composition after year 19 created a long tail of species only intermittently recorded and having negligible cover, and made the vegetation appear more species-rich than it actually was. So only species with mean cover greater than 1% were included in diagnosing post-year-19 affinity.

Nomenclature follows Stace (2010) for vascular plants, Smith (1978) for bryophytes, and Duncan & James (1970) for lichens.

Results

The grazing received

At all three sites herbivore occupancy peaked in the first ten years of the study and then declined (Fig. 1). At sites E3 and F2 yearly dung deposition was quite high initially and had fallen much below this level by the last ten years, whereas at G2 deposition was low

in the first five years but nearly double the initial mean in the final five years. Shoot utilisation of *Calluna* increased sharply early in the observations, soon surpassing 70% at site F2. This severe impact depleted the *Calluna*, and led to its extinction there by 1980 even though herbivore occupancy declined after a peak in 1976. At site G2 there was also severe utilisation of *Calluna* with about 80% of shoots browsed over a fifteen-year period starting in 1988, and eventually it became extinct. At site E3 utilisation showed an opposite trend to dung deposition in the middle years of the study, reflecting the grazing being concentrated on a small and steadily decreasing number of *Calluna* bushes and patches. Finally the much reduced herbivore occupancy here did lead to a relaxation in the utilisation of the remnant *Calluna*.

Cattle were the main grazers at sites E3 and G2, with sheep important in some years (Table 1). In contrast sheep were the more regular main grazers at site F2. There was also substantial presence of rabbits, particularly at sites E3 and F2, and some hare grazing, both of which contributed to the deposition totals at E3 and F2 being greater than at G2 up to about 1980 (Fig. 1). The prevalence of myxomatosis reduced rabbit usage after the 1980s, and shooting became more intensive after 1985 at F2 and after 1999 at E3, both adding to the downward trend of the overall dung total at these sites; at E3 the fall in *Calluna* utilisation after 1999 may also have resulted from rabbit numbers being much reduced. Herbivore occupancy at all three sites was year-round,
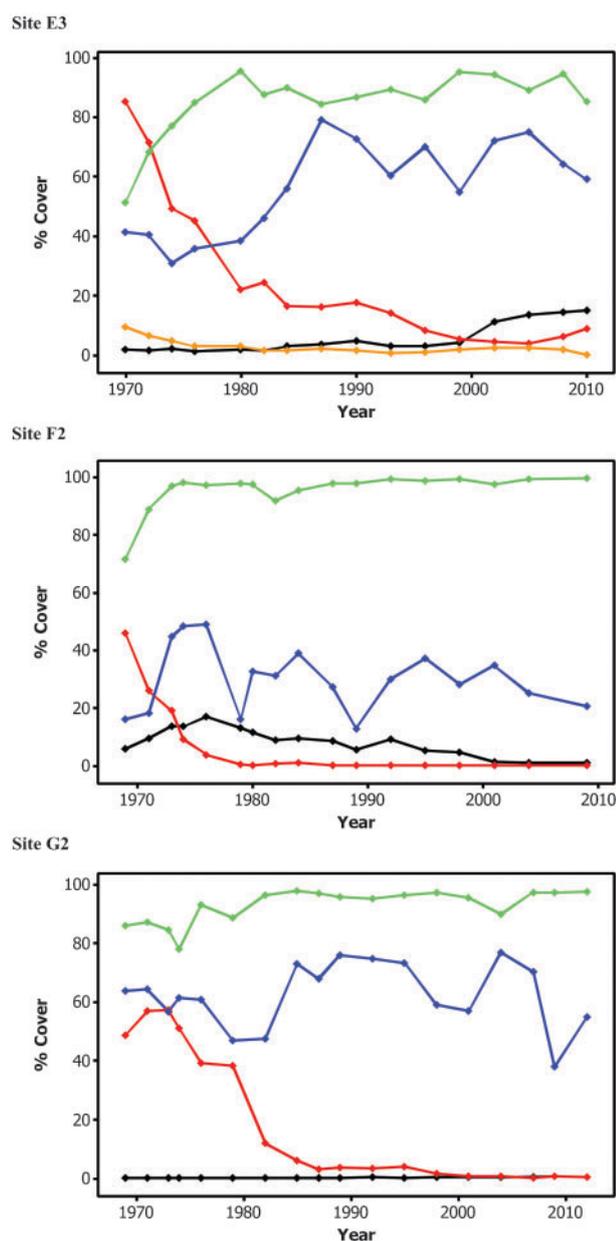
Figure 2 Cover trends for main species groups at the three sites. Key: green = graminoids-herbs, red = ericoids, blue = bryophytes, black = unpalatable graminoids, ochre = lichens).

but was somewhat greater in the summer than the winter six months, as could be expected when swards are predominantly grass and have more dead herbage in winter.

Trends in species groups

The cover of the graminoids-herb group exceeded 90% by the tenth year of monitoring at all three sites and remained at this high level (Fig. 2). At site E3 this group had only 51% cover initially in the dense *Calluna* sward, and its increase was paralleled by a major decline of ericoids, from 85% in 1970 to 22% in 1980; almost all the ericoid cover here came from *Calluna*, with *Erica cinerea* and *E. tetralix* together having just 3% cover in 1970 and 0.5% in 1980. At the other two sites graminoids-herbs had higher initial

cover, fitting with lower initial cover for ericoids, and again when the ericoids declined the graminoids-herbs increased. This major change in composition took place about six years later at site G2 than site F2, reflecting the later onset of heavy herbivore occupancy at G2 (Fig. 1).

Bryophytes averaged about 50% cover at the three sites, but showed considerable variation between years depending partly on the weather prior to the analyses, dry springs leading to lower cover. Bryophytes also suffered when grass growth was dense due to light grazing, and their lower and falling cover at site F2 was very probably related to the dense growth there of 'agricultural' grasses (*Cynosurus cristatus, Dactylis glomerata, Lolium perenne*) in most years later in the study.

Unpalatable graminoids had little cover, not being favoured by the dry soils. They increased in the early years at site F2 and in the final 10 years at site E3. Most of this cover was contributed by *Nardus stricta*, and its decline after 7 years at F2 reflected not only it being grazed quite intensively in some summers but also it being overtopped by tall grasses in other years with relatively light summer grazing. At site E3 the late increase of unpalatable graminoids was probably related to the diminished grazing pressure then. Lichens had insufficient cover for plotting in Fig. 2 except at site E3, where the main species, *Cladonia impexa* and *Parmelia physodes*, were intimately associated with the *Calluna* bushes.

Site differences in composition

Initially, *Calluna* was the dominant individual species at all three sites, and *Agrostis capillaris* and *Festuca ovina* were the leading grasses having 16–42% and 17–36% cover respectively, both with most cover at site G2. Other graminoids exceeding 10% cover were *Carex panicea* at F2 and *Deschampsia flexuosa* at E3 and G2. The other main initial difference in composition was in the bryophyte layer, with *Hypnum cupressiforme* having 27% cover at E3, the site with lowest pH, and *Hylocomium splendens* having 32% cover at site G2; both these mosses had < 10% cover at their other sites. The many significant trends in individual species as grasslands developed are reported by Welch & Scott (1995).

Differences between sites were greater in the new grasslands based on all analyses made after year 19 (Tables 2 and 3). *Luzula multiflora* became prominent at site E3, being the most abundant graminoid in five analyses from 1990 to 2002, and *Galium saxatile* exceeded 20% cover in all eight analyses on which the mean composition after year 19 was based for this site. *Agrostis capillaris* and *Festuca ovina* maintained their high cover there, but *Pleurozium schreberi* and *Rhytidiadelphus squarrosus* increased greatly, virtually

Table 2 Vegetation attributes, a) main species and b) species number, in the newly created grasslands at the three sites, based on all point-quadrat analyses made after year 19 of the study. To qualify as main species, % mean cover was > 20%

a) main species

Site E3	Site F2	Site G2
Agrostis capillaris	*Agrostis capillaris*	*Agrostis capillaris*
Festuca ovina	*Cynosurus cristatus*	*Anthoxanthum odoratum*
Galium saxatile	*Holcus lanatus*	*Festuca ovina*
Luzula multiflora	*Rhytidiadelphus squarrosus*	*Galium saxatile*
Pleurozium schreberi		*Hylocomium splendens*
Rhytidiadelphus squarrosus		*Rhytidiadelphus squarrosus*

b) species number

	Mean/total number of species recorded				
	Dicots	Monocots	Bryoph	Lichens	All species
Site E3	7/11	14/17	7/9	1/4	29/41
Site F2	11/20	13/17	5/10	1/3	30/50
Site G2	21/32	14/16	9/10	4/8	47/66

Table 3 Mean % cover of angiosperm and bryophyte species in the newly created grasslands, based on all analyses after year 19 of the study. Species are grouped by their site preference. Only species attaining at least 2% cover in an analysis after year 19 are included; means in parentheses at non-preference sites show the species never attained 2% cover there. Bold shows species that had 5% or more cover in an analysis at the site.

	Site E3	Site F2	Site G2
Calluna vulgaris	**8.3**		(0.3)
Carex nigra	2.7	(0.0)	
Carex panicea	3.4		1.9
Deschampsia flexuosa	**18.6**		**7.0**
Galium saxatile	**32.2**	(0.0)	**23.3**
Luzula multiflora	**36.4**	7.9	12.4
Nardus stricta	**8.2**	3.9	(0.3)
Pleurozium schreberi	**31.7**		8.7
Rhytidiadelphus squarrosus	**29.9**	20.5	27.0
Bellis perennis		1.1	
Brachythecium rutabulum		5.8	
Cerastium fontanum	(0.8)	6.9	(0.7)
Cirsium vulgare		0.6	
Cynosurus cristatus		47.2	
Dactylis glomerata		1.2	
Festuca rubra		**2.8**	(0.5)
Holcus lanatus	(0.4)	**27.7**	**2.0**
Lolium perenne		9.1	(0.0)
Poa annua	(0.1)	0.4	(0.2)
Poa pratensis	2.4	**18.9**	7.1
Trifolium repens	(0.1)	**19.3**	1.0
Agrostis capillaris	**23.8**	**49.9**	**54.4**
Anthoxanthum odoratum	**2.3**	**5.4**	**20.8**
Carex pilulifera	**5.3**	(0.1)	**7.1**
Cytisus scoparius			1.9
Festuca ovina	**31.1**	**2.5**	**34.7**
Hylocomium splendens	**8.9**	(0.0)	**30.6**
Hypnum cupressiforme	1.0		1.6
Lathyrus linifolius			2.0
Potentilla erecta	2.4	(0.8)	**9.5**
Pseudoscleropodium purum	(0.1)		**4.0**
Rumex acetosella	(0.1)		0.9
Senecio jacobea			0.8
Vaccinium myrtillus	(0.2)		1.0
Veronica chamaedrys		(0.4)	**3.2**
Veronica officinalis		(0.0)	2.5
Viola lutea			1.0

replacing *Hypnum cupressiforme* which had only 0.5% cover in the final analysis. In contrast at site F2 *Cynosurus cristatus* was the most prominent species and *Holcus lanatus* and *Trifolium repens* abundant. *Agrostis capillaris* gained cover compared to its initial extent at F2, whereas *Festuca ovina* was much reduced, being unable to compete with the taller grasses. At site G2 *Agrostis capillaris* and *Festuca ovina* remained the main graminoids, *Agrostis* having gained cover compared to the early years of the study, and there was a notable presence of herbs with obvious flowers: *Galium saxatile, Lathyrus linifolius, Potentilla erecta, Veronica chamaedrys, V. officinalis* and *Viola lutea. Hylocomium splendens* kept its initial high cover, while *Rhytidiadelphus squarrosus* increased markedly.

Species richness was much greater at site G2 than the other sites, this mostly resulting from the presence of more dicotyledonous species (Table 2). Site F2 had more species recorded than site E3, but some of these were 'agricultural casuals', such as *Cirsium vulgare* and *Urtica dioica,* which were only intermittently present, and the mean number of species present in an analysis hardly differed between these two sites.

The difference between sites in species number widened during the study (Fig. 3). The three sites had quite similar species numbers at their first analysis, and only after 15 years did the greater richness of G2 emerge. This resulted more from declines in number at sites E3 and F2 than gain at site G2; in *t* tests the average number of species at E3 and F2 was significantly fewer (P <0.001) after year 19 than up to that year, and also compared to site G2 after year 19. At the former two sites the early rise in species number was caused by grassland species entering the swards while heathland species remained, and then after 10 years or so species such as *Erica tetralix,*
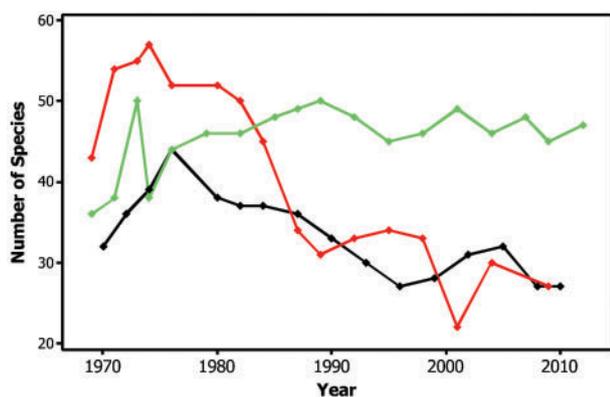
Figure 3   Trends in species number recorded at the three sites. Key: black = E3, red = F2, green = G2.

Genista anglica, Vaccinium myrtillus, Ceratodon purpureus and *Pohlia nutans* were lost. At site F2 these losses reflected not only the shift from ericoid dominance but also the shading effect on low-growing species of the dense tall grass sward; at this site the difference between the mean and total number of species was especially large for bryophytes (Table 2).

Another attribute used to assess sward floristics, mean number of species hit per point, was quite variable over time (Fig. 4). Again site G2 was on average the richer in species at this micro level, though with significance only $P < 0.01$ in t tests. But during the study site E3 showed a gradual increase in species hit per point and eventually sometimes had greater means than the other sites. However, this attribute is much dependent on sward depth, and its fluctuations result partly from variation in grazing pressure producing tall swards in some years and short ones in others, the latter giving fewer hits per point.

Entry of new species
Site E3 had especially few entrant species, and site G2 a considerable number, ten of which qualified for inclusion in Table 4. The average time of entrance was somewhat later at G2 than the other sites, and at
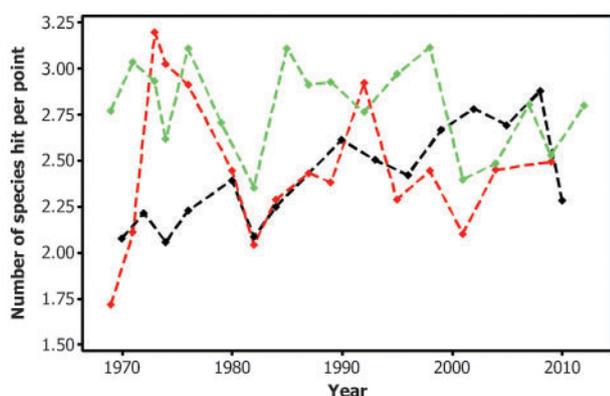

Figure 4   Trends in mean number of species hit per point in analyses at the three sites. Key: black = E3, red = F2, green = G2.

F2 all but one of the qualifying entrants had appeared before year 20, the mid-point of the recording; this reflected the difficult conditions for new colonisation caused by the dense herbage there. Many of the entrants were herbs, including rosette species e.g. *Bellis perennis, Pilosella officinarum, Prunella vulgaris* and *Scorzoneroides autumnalis*, which were unfitted to exist in *Calluna* moorland. Most entrants had final % cover (mean of last two analyses) little increased on their mean cover observed since their entry. But some species appearing early in the study did increase substantially, notably *Anthoxanthum odoratum* at site F2 and *Rhytidiadelphus squarrosus* at site E3 which averaged 36% cover in the last two analyses there.

Affinities of the grasslands
The top goodness-of-fit values obtained for both mean and final compositions all rated good (70–79%) or very good (80% plus) in TABLEFIT (Table 5). Including all species in the diagnoses gave somewhat less good fit than when species with less than 1% cover were omitted. But the suggested affinities of the new grasslands to NVC types were not always definite, with little difference between first- and second-best fit, and not always satisfactory, e.g. NVC H18 is a community of steep slopes mostly above 400 m in northern Britain (Rodwell *et al.,* 1991). For site F2, the new grassland clearly belongs to NVC MG6, *Lolium perenne-Cynosurus cristatus* grassland, and the second-best relationship to U4b, the more mesophytic *Holcus lanatus-Trifolium repens* sub-community of *Festuca ovina-Agrostis capillaris-Galium saxatile* grassland shows that species of U4 occur, especially some with little cover that were included in the all-species diagnoses.

For sites E3 and G2 affinity to four sub-communities of NVC U4 and 5 grasslands is suggested, and the apparent difference between E3 and G2 in greater species number and more basiphilous species at the latter is echoed only in the second- or third-best fits. These are for E3 to the wetter U5 *Nardus stricta-Galium saxatile* grasslands, and for G2 to the CG10 *Festuca ovina-Agrostis capillaris-Thymus drucei* calcicolous grasslands. That the final composition at G2 has better fit to CG10a than does the mean composition suggests that CG10 species were being gained.

Discussion
The new grasslands developed in 15- to 20-year periods of heavy grazing and could perhaps have still been evolving in composition in the 20- to 23-year periods with which this paper is chiefly concerned. But few new species entered after year 19 of the recording at sites E3 and F2 (Table 4), and for all three sites there was no difference between final composition and mean

Table 4   Average (Av) and Final (Fin) % cover of entrant species* and timing of their entry (yr = years from start of study) (qualification: 3 or more occurrences at a site and present in both the last 2 analyses there). For these species, presence at other sites at which they do not qualify, is shown by giving either average % cover in parentheses (for non-entrant species present initially) or year of entry in parentheses (for entrants with insufficient occurrences to qualify).

	Site E3			Site F2			Site G2		
	%	%		%	%		%	%	
	Av	Fin	yr	Av	Fin	yr	Av	Fin	yr
Site E3 qualifying entrants									
Carex binervis	1	1	10	(+)					(18)
Carex leporina	+	+	35						
Polygala serpyllifolia	+	+	20			(4)	(1)		
Rhytidiadelphus squarrosus	20	36	6	(16)			(19)		
Site F2 qualifying entrants									
Anthoxanthum odoratum	(2)			4	12	2	(15)		
Bellis perennis				1	+	2			
Brachythecium rutabulum			(14)	6	5	2			(16)
Campanula rotundifolia				+	+	15	(1)		
Cirsium vulgare				1	+	15			
Festuca rubra				1	6	2	(+)		
Plagiomnium undulatum				+	1	18			
Prunella vulgaris				+	+	13			
Veronica chamaedrys				+	+	21	(2)		
Site G2 qualifying entrants									
Nardus stricta	(5)			(6)			+	1	23
Pilosella officinarum							+	1	38
Ranunculus repens				(1)			+	1	13
Rumex acetosella	(+)			(+)			1	3	16
Scorzoneroides autumnalis							+	1	32
Senecio jacobea							1	2	20
Succisa pratensis							+	+	32
Taraxacum officinale						(26)	+	+	20
Trientalis europaea							+	+	10
Trifolium repens			(6)	(17)			1	2	10

*Species not present in first analysis (1969) at site F2 or first two analyses at sites E3 and G2.
+Cover >0<0.5%.

composition after year 19 in best-fit affinity (Table 5). Moreover all the angiosperms listed in Table 2 as being main species with mean cover > 20% had occurrences with cover > 20% both in the first two analyses and also the final two analyses of the post-19-year period. Some changes did occur in bryophyte composition, notably the replacement of *Pleurozium schreberi* by *Rhytidiadelphus squarrosus* at site E3; the latter species only appeared after 6 years at this site (Table 4) and

gained cover in every one of the next ten analyses spread over 30 years.

At site E3 the abundance of *Luzula multiflora* was very striking, with cover > 40% in 1993, 1996 and 1999. This might have affected the TABLEFIT diagnoses since in no NVC community including those of U4, U5 and H18, has the species so much cover. Averis *et al.*, (2004), in an appraisal of NVC upland communities, observed that other forms of

Table 5   Affinities to NVC types in *British Plant Communities* of the grasslands at the three sites, for a) mean composition based on all analyses after year 19, and b) final analyses at year 40/43 of the study. The three most-closely related NVC types are given together with goodness-of-fit X^2 values obtained in TABLEFIT diagnoses; for a) the diagnoses used only species with cover > 1%, but for b) extra diagnoses used all species present.

Site	Mean composition after year 19		Final composition			
	Spp <1% excluded		Spp <1% excluded		All spp included	
	NVC type	X^2	NVC type	X^2	NVC type	X^2
E3	U4d	81	U4d	81	H18b	76
	U5d	75	U5c	79	U5c	73
	U5c	74	H18b	76	U4d	72
F2	MG6b	88	MG6b	88	U4b	77
	U4b	84	U4b	82	MG6b	75
	MG6a	78	MG6a	74	MG6a	63
G2	U4a	83	U4a	80	U4d	70
	U4d	82	U4d	79	U4a	69
	CG10a	64	CG10a	66	CG10a	66

U4 not included in Rodwell *et al.,* (1992) occur, but did not mention a *Luzula multiflora* sub-community. Another problem for the TABLEFIT diagnoses was my lumping cover of *Agrostis* into the one species *Agrostis capillaris*, since separation from *A. canina* was very difficult or tedious in grazed-down swards. *Agrostis canina* was certainly present at site E3, so I checked the effect of dividing the *Agrostis* cover between the two species and assigning each half this cover. Changes to the X^2 values in Table 5 were negligible and both best fits to NVC U4d remained, but U5b appeared as the community with second-best fit when species with cover < 1% were excluded from the diagnoses, and for the all-species diagnosis H18b was relegated to second-best fit by U4d.

The grassland at site G2 appears to be approaching the calcicolous CG10 community (Table 5), but lacks *Thymus polytrichus,* considered by Rodwell *et al.,* (1992) to be the commonest dicotyledenous associate of CG10. However *Thymus polytrichus* did occur with 2% mean cover at the neighbouring G1 site (Welch, 1984b). Sites G1 and G2 had similar situation and soils, being separated by just a stock fence; G1 was an *Agrosto-Festucetum* with grazed-down *Calluna*, whereas G2 was initially a *Callunetum*, the heather having a mean height of 20 cm in 1969. G1 was ploughed up late in 1973 by which time the increased grazing on G2 was starting to make that sward more suitable for low-growing species such as *Thymus polytrichus.* Several other G1 species have not been recorded at G2, e.g. *Achilllea millefolium, Hypericum pulchrum, Ranunculus acris, Salix repens* and *Trifolium pratense*, and possibly a lack of nearby seed sources after the ploughing-up of G1 hindered their entry to the G2 grassland. CG10 species occurring at site G2 but not mentioned earlier in this text due to their little cover include *Antennaria dioica, Deschampsia cespitosa, Lotus corniculatus* and *Rhytidiadelphus triquetrus*.

Scottish vegetation descriptions do not provide an exact counterpart for the G2 grassland. Of King & Nicholson's (1964) units, their Type 5, *Festuca-Agrostis*, is the most similar, and has been assigned to NVC U4a by Rodwell *et al.,* (1992), the community found by TABLEFIT to most resemble the G2 grassland (Table 5); the main G2 absentee compared to the Type 5 list is *Danthonia decumbens*. The *Viola-Festuca-Agrostis* nodum of Huntley (1979) is quite similar, containing about 80% of the angiosperms present at G2, but is much richer in species and belongs to NVC CG10a. Several G2 species not reported in King & Nicholson's list for Type 5 are found in Huntley's Caenlochan grassland, e.g *Antennaria dioica, Rhinanthus minor, Veronica chamaedrys* and *Viola lutea*.

Although site F2 has not been ploughed, its new grassland closely resembles NVC MG6b (Table 5), the *Lolio-Cynosuretum* grassland of reseeded ploughed farmland said by Rodwell *et al.*, (1992) to be 'virtually ubiquitous' in lowland Britain. However, *Lolium perenne* has notably less cover than in typical *Lolio-Cynosuretum*, and stands with much *Cynosurus cristatus* are considered by Rodwell *et al.*, (1992) to have been longer established after reseeding. Such *Cynosurus*-rich stands may have become less frequent due to rotation length shortening since the fieldwork of which Rodwell's account was based, and moreover the map given by these workers shows quite few occurrences of MG6 in northern Scotland. So the F2 grassland may have some conservation value in being a much less-common vegetation type than the normal *Lolium* pasture.

Species of conservation concern occurred only at site G2. Just *Genista anglica* is classed higher than the 'Least Concern' category of Cheffings & Farrell (2005), being 'Near Threatened' (NT), but *Viola lutea* has become a rare species in lowland Britain, and is at the eastern extreme of its Scottish range at G2. Another NT species, *Pseudorchis albida*, was found in similar grassland at the H1 site (Welch, 1984b) two kilometres south of G2, and could colonise G2. But more important than the rarity of individual constituent species is the rarity of the vegetation type, and for the Grampian region of NE Scotland semi-natural rough grassland occupied only 3.2% of the land area in 1988 (MLURI, 1993). This compares to an estimate of 4% for the extent of unimproved grasslands in England and Wales in 1984 (Fuller, 1987). For northern Scotland, the NVC U4a grasslands on more fertile soils are doubtless rarer than the U4d grasslands, and these richer sites have been the more likely to be ploughed and reseeded, as happened to sites G1 and H1 in the 1970s.

Several factors besides grazing are considered to be driving compositional changes in British grasslands at present, including climate change and atmospheric deposition, this causing soil acidification and/or eutrophication (McGovern *et al.*, 2011). With 25 years of close monitoring of the present three grasslands, one or more of these drivers could possibly have been demonstrated as having an impact. However, the entrants (Table 4) did not include any thermophilous Southern plants, and the only strongly nitrophilous species to appear, *Urtica dioica*, was only recorded in 1995 and 1998 at site F2 and had only 0.1% cover then. From studies on acidic grasslands across the UK, Stevens *et al.*, (2004) considered that greater N deposition caused an increase in *Hypnum cupressiforme* and a decrease in *Hylocomium splendens*, yet the opposite trends were recorded in the present study. My conclusion is that the main factors affecting the present sites have been heavy grazing and the consequent replacement of *Calluna* by graminoids, changing the humus type from mor to mull.

Acknowledgements

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