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DEVELOPMENT OF POST-FIRE VEGETATION IN THE CALEDONIAN PINEWOOD OF COILLE CREAG-LOCH, SHIELDAIG, WESTER ROSS

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Development of Post-fire vegetation in the Caledonian pinewood of Coille Creag-loch, Shieldaig, Wester Ross.

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Summary

Following a wildfire in the Caledonian pinewood at Shieldaig, Wester Ross in late March 1974, the recovery of vegetation, and particularly Scots pine seedlings, was monitored in a series of sample plots located in parts of the wood affected by the fire. Almost all trees less than 5cm d.b.h. were directly killed by the fire, and approximately 45% of larger Scots pine and 60% of larger birch trees had died by 1980. Post-fire regeneration of Scots pine occurred to the extent of approximately 2 500 per ha. Field layer species were affected differently by the fire. Whereas *Molinia caerulea* and *Pteridium aquilinum*, with buried rootstocks and rhizomes recovered quickly, the redevelopment of *Calluna vulgaris* and many bryophytes has continued slowly.

Introduction

Coille Creag-loch, the most westerly of the native pinewoods identified and described by Steven and Carlisle (1959), lies south of Shieldaig village (NG 820 524) and occupies approximately 70 hectares between sea level and 300m. The upper part of the wood is on thin-soiled, rocky terrain and appears to be of a relatively even-aged structure, probably having originated in the period 1870-1900, following fencing.

At lower altitudes the tree cover is more irregular, both in size and spatial distribution, being rather sparse on the flat, and often badly-drained areas and with relatively dense thicket- or pole-stage groups on some of the boulder-strewn, steeper slopes.

Fire has been recorded as having occurred in the wood during the early 1930's (Steven and Carlisle, 1959) and it seems likely that it has been, and still is, an important factor in determining the composition and age-structure of vegetation. A fire entered the wood from the south on 30th March 1974 and burned until late the following day. It moved through most of the wood as a ground fire, with the exception of an area of about 8 ha at the northern end, being less intense in the southern sector and most intense in the central sector, where some crown fires occurred.

Following the fire, the opportunity was taken in late June 1974, of establishing a number of sample plots for observing the effects of fire on existing Scots pine and the development of vegetation, including Scots pine seedlings, in the years immediately after the fire.

Site description and methods

Nineteen sample plot locations were chosen non-randomly, but objectively, by measurement at right angles to the transmission poles which carry the telephone lines along a route roughtly parallel with the road beside Loch Dughaill (Figure 1); a twentieth plot was located on one of the more elevated terraces. The plots are believed to have provided an acceptably representative sample of the vegetation through which the fire passed, though it may under-represent the denser pinewood of the upper terraces. Much of the vegetation in the plots consists of a community dominated by

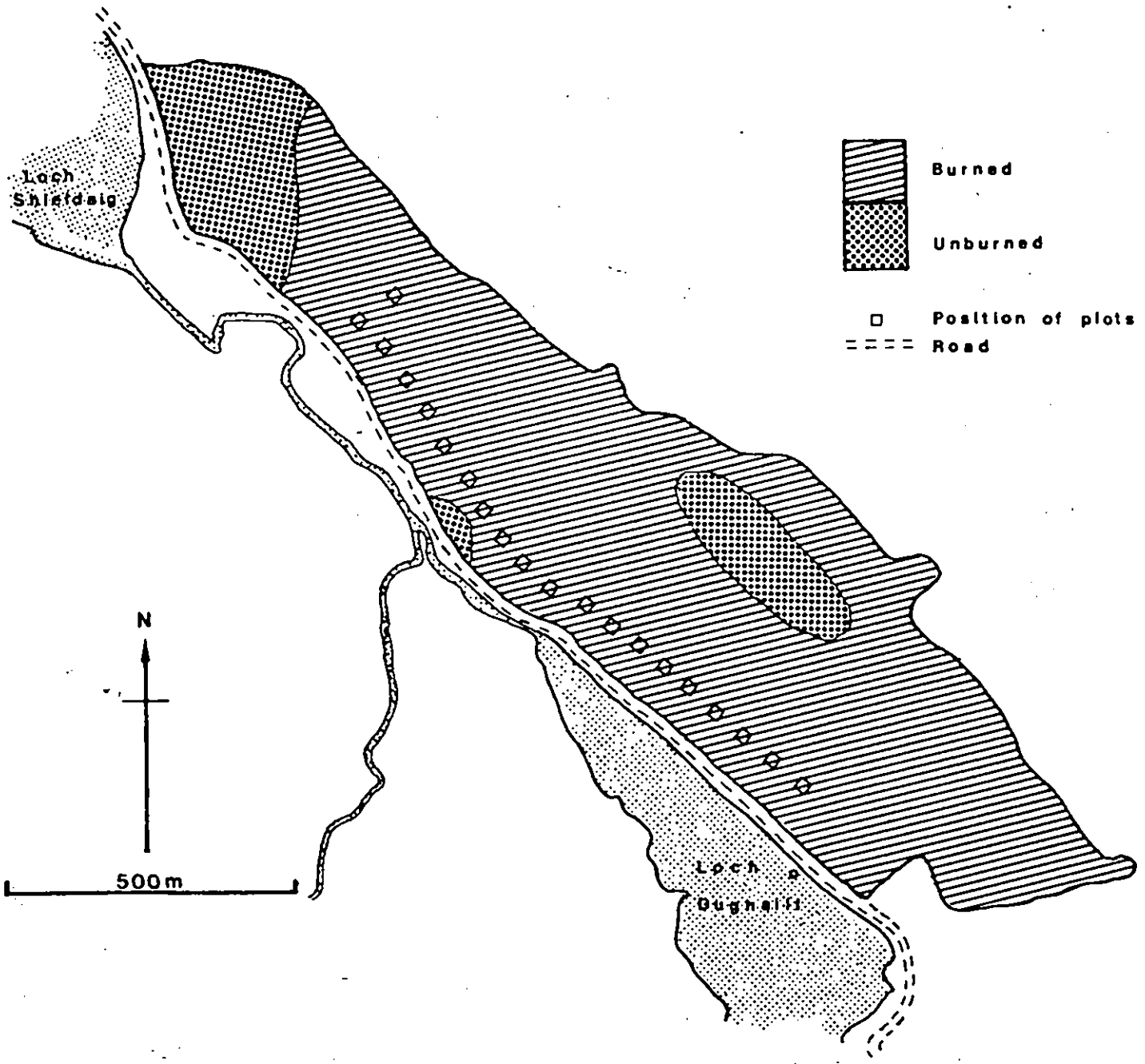

Figure 1

Approximate extent of the 1974 fire and location of 20 sample plots at Coille Creag-loch, Shieldaig, Wester Ross.

Molinia caerulea[4] and *Calluna vulgaris*, similar to Community no. 9 of Steven and Carlisle (1959), and commonly found in the high rainfall districts of the west. A local variant of this community is found on the steeper, better-drained slopes where *Pteridium aquilinum* often dominates the canopy of the field layer; *Calluna* is still present to the same extent, but *Molinia* decreases in cover and is replaced by *Vaccinium myrtillus*. The slopes containing these communities are often cut by small streams, adjacent to which are characteristic flush communities. These are still dominated by *Molinia*, but also contain a considerable number of herbs such as *Prunella vulgaris*, *Primula vulgaris*, *Viola* spp. *Cirsium palustre* and, in a few instances, *Cirsium heterophyllum*. These communities correspond to the *Molinia* flush, Community No. 16, of Steven and Carlisle, but at Shieldaig they tend to be somewhat more species-rich than these authors have implied. A few plots on flat and badly-drained terrain support vegetation with depauperate *Molinia* tussocks, scattered *Calluna* and with species such as *Narthecium ossifragum*, *Trichophorum cespitosum* and *Campylopus atrovirens* occurring with great frequency. Allocation of the 20 plots to the types derived from a classification of similar plots in a series of 26 Caledonian pinewoods (Bunce, 1977) resulted in five being placed in types with a distinctly western distribution, whilst the remainder were allocated to types represented throughout the series.

At each sample location, a central quadrat of $25m^2$ was searched for Scots pine seedlings in June 1974 and at the beginning of July in each succeeding year until 1980. Records of vascular plants and bryophytes, together with a visual estimate of their cover, were collected from a $200m^2$ quadrat, which was concentric with the $25m^2$ quadrat, annually from 1974 to 1976 and then biennially until 1980; the size and condition of trees was also recorded in these quadrats.

[4] Plant species names follow Clapham *et al* (1962) and Watson (1968)

Attempts to re-locate the positions of quadrat samples used by Bunce in 1972 were unsuccessful and it was therefore impossible to make any direct comparisons of vegetation before and after the fire.

Results

a) Tree species

Fifteen of the sample plots contained pine trees (>5cm d.b.h.), five contained both pine and birch, three contained only birch and two contained no trees. The representation of different size classes in the sample is shown in Table 1. There were 96 Scots pine in the plots before the fire and more than one third of this number died as an immediate result of the fire. The dead trees ranged in size from 5cm to 38cm d.b.h., though there was a preponderance of smaller trees. Scorching of stems was almost universal among surviving trees in the sample, generally blackening a zone between 1m and 3m above ground level, but reaching 9m in extreme cases. Crowns were also scorched to different degrees in surviving trees, often by convected heat but sometimes by crown fires. Smaller trees were more susceptible because of their thinner bark, lower crowns, proximity to neighbouring trees and the greater amounts of easily combustible fuel on the ground beneath them. Bracken was commonly prevalent on the steep slopes beneath thicket or pole stage pine, and it is probable that very intense fires developed in these conditions. Mortality in the years following the fire was spasmodic, most occurring in 1974-75 and a further 11 trees dying between 1975-80; the cumulative total of trees which had died by 1980 represented 45% of trees in the sample. Some of the remaining trees barely survive, with only few needles, and may be expected to die within the next few years. In addition to the

Table 1. Effects of fire, March 1974, on the subsequent fate of trees of different size classes at Shieldaig.

	Trees <1.3m before the fire	Trees >1.3m before the fire Diameter at 1.3m (d.b.h.) in cm											
		<5	5-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50	51-55	>55
a) Scots pine													
Pre-fire 1974	165	64	23	24	9	4	5	11	10	3	2	3	2
Died during fire 1974	138	64	14	10	4	2	1	1	1				
Died 1974-76			1	1	1			1					
Died 1976-78			1	3					1			1	
Died 1978-80											1		
Alive 1980	27	0	7	10	4	2	4	9	8	3	1	2	2
b) Birch													
Pre-fire 1974	25	44	13	8	3	2		1					
Died during fire 1974	25	44	7	4	1								
Died 1974-76			1										
Died 1976-78			3	1									
Died 1978-80													
Alive 1980	0	0	2	3	2	2		1					

primary effect of the fire on tree health, secondary effects have resulted from the activity of the pine shoot beetle (*Myelophilus piniperda* L.) which has attacked debilitated and dead trees and caused the shedding of shoots from otherwise apparently healthy trees.

Almost half of the 27 birch trees present in the sample plots died immediately following the fire (see Table 1b) and five others died subsequently, bringing the 1980 total to over 60%. A few of these trees have produced weak shoots from stem bases, but the frequency of such trees has declined markedly since 1975. Two small oak stems were killed by the fire and failed to produce re-growth, whilst three rowan stems, growing in a plot which was only slightly burned, were apparently unaffected.

All pine saplings, defined here as being <5cm d.b.h. and taller than 1.3m, were killed by the fire, as were those of birch. Birch regeneration,consisting of individuals smaller than 1.3m, was also completely eliminated but some pine regeneration survived in five of the 15 sample plots in which it existed before the fire; unfortunately most of the survivors are growing in boggy areas where the fire was light and where the opportunities for vigorous growth, or even survival, are rather poor.

During the period of approximately 2 months between the fire and the first survey reported here, germination of pine seed, presumed to have been released from cones after the fire, had taken place in 11 of the 20 sample plots (Table 2). The mean number of seedlings per plot was equivalent to approximately 950 per ha, and this had more than doubled to 2 000 per ha by 1975, though the majority of the recruits developed from germination of seed in later summer and autumn 1974 rather than

Table 2. Number of $25m^2$ plots containing different numbers of Scots pine seedlings in the years following a fire in 1974 at Shieldaig.

	Nos. seedlings per plot							
	0	1-5	6-10	11-15	16-20	>20	Total no. seedlings	Mean no. seedlings per $25m^2$ plot
1974 (post fire)	9	7	3	1	0	0	47	2.3
1975	5	10	1	2	1	1	99	4.9
1976	3	12	2	2	0	1	177	5.8
1977	3	12	1	2	1	1	125	6.2
1978	1	11	5	2	0	1	118	5,9
1979	2	12	3	2	0	1	130	6.5
1980	3	8	6	2	0	1	123	6.2

in spring 1975. Additional seedlings have been recruited into the sample, through new germination, in every year with the exception of 1980, but this increase in numbers has been offset by seedling deaths, with the result that the mean seedling density has apparently reached an equilibrium since 1977, equivalent to approximately 2 500 seedlings per ha. The frequency distribution of 5cm height classes in 1980 (Fig. 2) shows that approximately half the seedling sample was in the smallest class and suggests that the proportion of seedlings surviving to move into higher classes is small. Whilst some seedlings are vigorous, many are not, and almost 40% were subjectively classed as "unhealthy" in 1980 in terms of lack of extension growth, poor colour and few leaves; these unhealthy seedlings were usually growing either in shade, on pine litter, or on shallow peat which was either very wet or very dry.

Large numbers of birch seedlings were found in one quarter of the sample plots in 1974, having resulted from germination of seed which fell immediately after the fire or from seed buried in the soil, but few survived. Whilst there was no repetition of this prolific local germination in succeeding years, 95% of the plots contained birch seedlings by 1980. Rowan seedling frequency paralleled that of birch, but oak seedlings developed and survived in only 10% of the plots.

b) Field layer species

Post-fire changes in the field layer vegetation are shown in Appendix I where frequencies are shown for those species which, at some time, occurred in at least one quarter of the 20 sample plots; a list of species which occurred less frequently is shown in

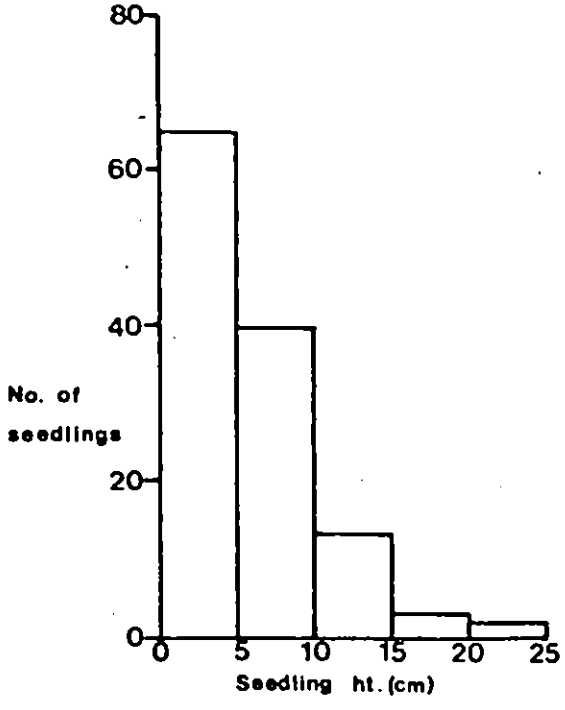

Figure 2

Frequency distribution of Scots pine seedling height in 1980, following a fire in 1974 at Shieldaig.

Appendix II. Changes in frequency are shown for 49 flowering plants and ferns and for 22 bryophytes, the total list comprising 111 and 59 species respectively for these groups. Accepting a modest smoothing to allow for inefficiencies in recording, the plants fall into two main categories which show either a steadily rising or a constant frequency. In addition there are a few species which do not fit conveniently into either category; many species can be confidently allocated to a category on the basis of their habitat preference or growth form.

Those species with constant frequency are, for the most part, the residual flora which were not destroyed by the fire and which fall into two groups. In the first, the species tend to occur in the wetter habitats and survived either because the fire was less intense as a result of the discontinuous nature of the low fuel load, or the roots or rhizomes could survive a fire in wet peat or soil; examples of this type are *Narthecium ossifragum, Pedicularis sylvatica* and *Carex echinata*. The second group of species with constant frequency contains those with robust rhizomes or rootstocks. These species are not confined to wetter habitats and some are almost ubiquitous in the sample plots, eg *Blechnum spicant, Pteridium aquilinum* and *Molinia caerulea,* whilst others occur only in drier habitats, eg *Teucrium scorodonia*. The sensibly constant time trend of the average frequency of species in these groups is shown in Figure 3. Two species, which survived as rootstocks and rhizomes respectively, *viz Pteridium aquilinum* and *Molinia caerulea,* were also important contributors to vegetative cover, as can be seen from Figure 4 which shows the mean cover of these species in the years following the fire. Although no evidence is available to suggest the cover attained by these, or other species before the fire, it is clear that cover values increased

during the two growing seasons following the fire and subsequently declined. The early, increasing values could be the result of gradual recovery from damage caused by the fire but the subsequent decline suggests that the cause was more likely to be a short-lived stimulation of growth by fire-induced nutrient release or physical stimulation.

The second main category comprises species with less persistent underground organs which did not survive the fire to the same extent as those above, and whose regrowth had to develop from burned, viable propagules remaining at the site, augmented by a smaller element of vegetative growth. The tendency for species in this category to show an increasing frequency is seen in Figure 3. *Calluna vulgaris* survived to regenerate from stem bases only in areas where it occurred sparsely on wet ground; in other situations the often tall and straggly *Calluna* plants did not survive, as is common with over-mature plants (Gimingham, 1960), particularly where there were large amounts of fuel and the fire was intense. Regeneration of *Calluna* from seed was common in these areas and the approximately linear increase in mean cover (Fig 4) continued to 1980. *Erica cinerea* reached only small cover values, never exceeding 5%, but its frequency had more than doubled by 1978 as a result of the germination of imported or, more probably, buried seed which is known to show a higher germination following a brief period of heat treatment (Bannister, 1965).

Bryophytes were very markedly affected by the fire and an estimate of charred moss cover, mainly thick mats of pleurocarpous species, suggested a previous mean cover of at least 30%, as compared with a post-fire

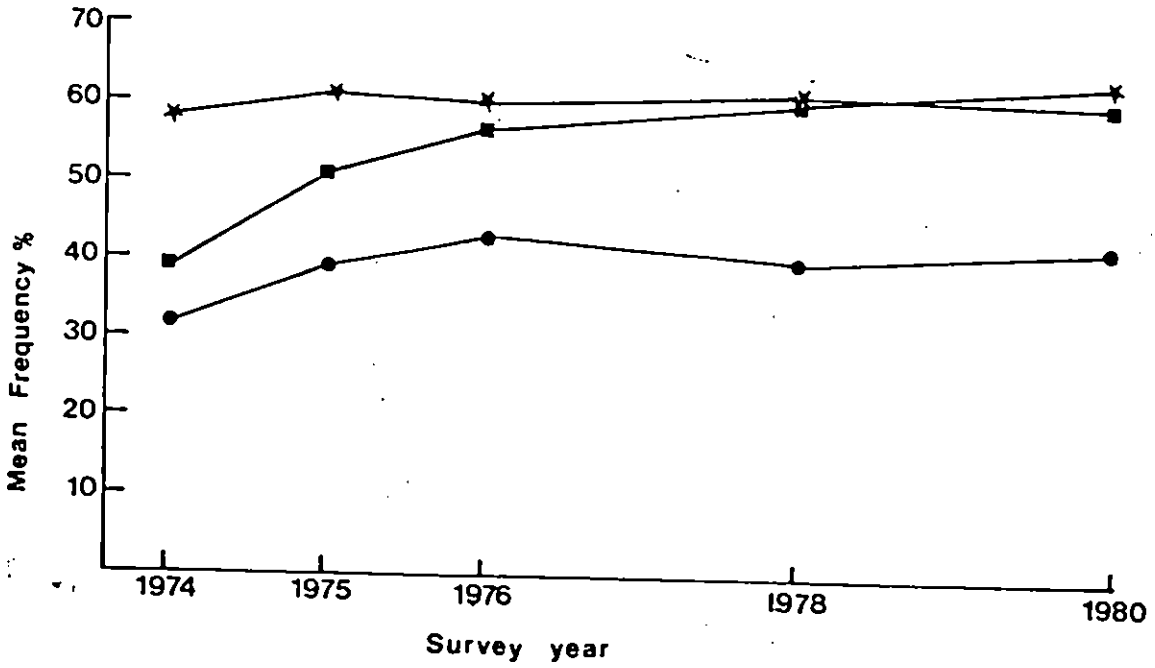

Figure 3

Overall trends in frequency of three groups of species

i) plants of bogs and flushes (●)

ii) plants of drier habitats, or with wider distribution, with persistent perennating organs (★)

iii) plants of drier habitats, or with wider distribution, without persistent perennating organs (■), at Shieldaig following a fire in 1974.

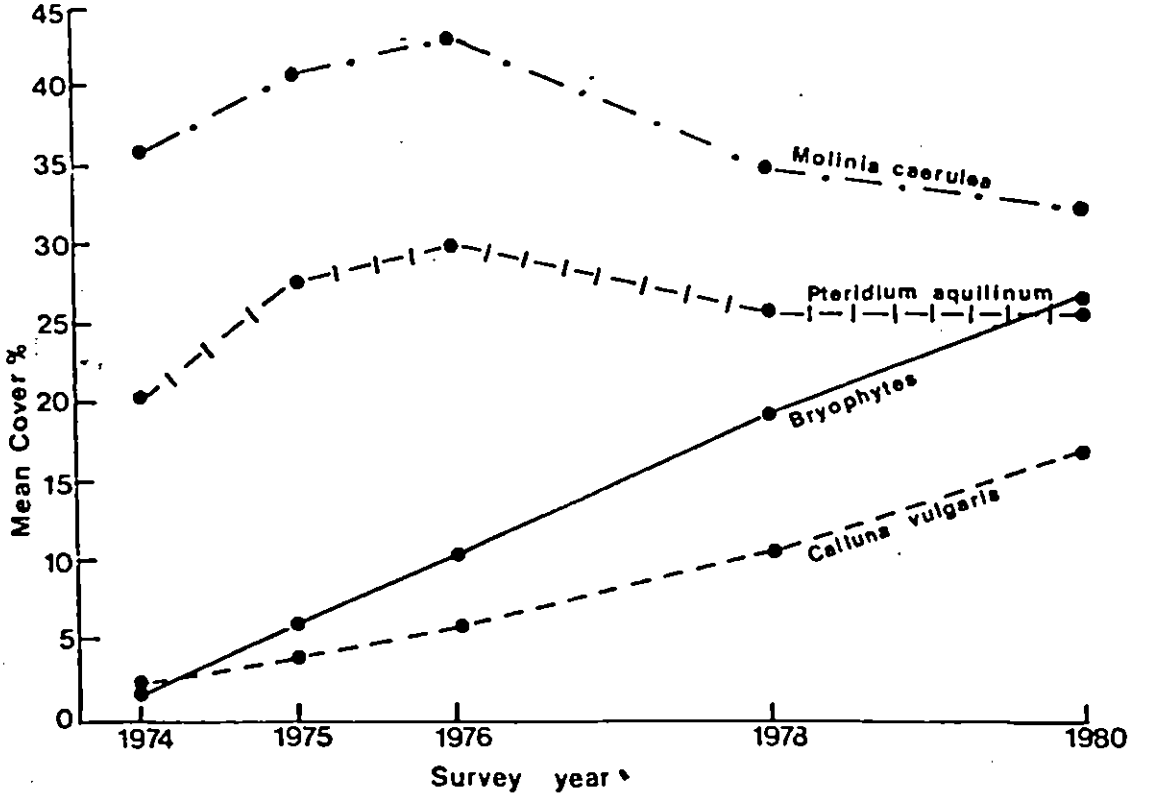

Figure 4

Mean cover of some vegetation components in 20 sample plots at Shieldaig, following a fire in 1974.

estimate of less than 5%. Bryophyte recovery followed the same course as that of *Calluna*, with regeneration from both spores and relatively small vegetative propagules. Re-establishment of many of the pleurocarpous mosses such as *Hylocomium splendens* and *Pleurozium schreberi*, which have infrequently-produced fruiting bodies, was largely from small remnants which survived in crevices and beneath rocks, though often badly scorched. It appears that bryophytes are unlikely to reach their optimum cover value for several years, particularly on the surfaces of rocks where shallow layers of humus, built up over many years, have often been completely removed by the fire and subsequent heavy erosion.

Discussion

The obvious manifestations of fire, ash from burned litter and vegetation, charred *Calluna* and tree stems, and orange-red needles on many Scots pine, had largely disappeared by 1980. Apart from a few dead, but as yet upright, pine saplings and some uncolonized rock surfaces, there was little to suggest that a fire had passed through the wood, six years earlier. The data presented here show that more subtle changes in species composition and quantity were still occurring. Although it was not possible to make direct comparisons with vegetation present before the fire, there is no evidence to suggest that the composition of the vegetation which has developed since the fire will be very markedly different from that which pre-dated the fire, though it may be different in structure where pine saplings and mature *Calluna* plants have been killed. Such differences in composition and structure as may have occurred seem more likely to have affected drier sites where the balance between *Calluna* and *Pteridium* may be critically affected

by fire. Although fire commonly induces regeneration of *Calluna*, either from old stem bases or from seed, *Pteridium* has an early competitive advantage resulting from its rhizomatous stems and can spread into areas previously dominated by *Calluna*. A changing balance between these species may have an important influence on pine regeneration, which has the best opportunities for success on the drier sites where *Calluna* is itself regenerating following fire. Those areas of the wood which had dense stands of pine saplings before the 1974 fire have an almost entire cover of *Pteridium* which must have existed before the fire; yet it is inconceivable that pine regeneration of the density necessary for the development of such a sapling stand could have been initiated beneath a *Pteridium* canopy. The likelihood is that, following an earlier fire which was sufficiently intense to kill most of the *Calluna*, dense pine regeneration developed and was subsequently invaded by *Pteridium*. Having been occupied by *Pteridium*, these otherwise favourable pine sites have a greatly reduced potential for pine regeneration, reduced even further by the greater fire hazard caused by a highly inflammable fuel load in autumn and spring. The spread of *Pteridium* must therefore be regarded as an important factor influencing the survival prospects of the wood.

The effect of browsing on pine regeneration at Shieldaig is unknown but populations of deer and sheep are assumed to have been low at the times when regeneration was most successful, approximately 30 and 100 years ago. Cattle and sheep have certainly used the wood since 1974 but were not in evidence after 1976. If the use of the wood by domestic stock remains low, there will be improved prospects for survival and vigorous growth of pine seedlings now established on suitable sites.

Acknowledgements

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A (i) Plants of bogs and flushes showing constant overall frequency.

Species	Frequency % 1974	1975	1976	1978	1980
Carex binervis	0	40	35	45	50
Carex demissa	40	35	40	30	45
Carex echinata	40	60	55	50	50
Carex nigra	15	30	35	15	20
Carex panicea	60	75	80	65	75
Carex pulicaris	20	50	65	50	65
Cirsium heterophyllum	25	20	25	20	20
Drosera rotundifolia	45	45	55	40	35
Erica tetralix	50	60	60	75	65
Eriophorum angustifolium	0	20	25	20	20
Juncus bufonius	10	35	30	20	45
Juncus conglomeratus	5	15	15	15	30
Myrica gale	15	15	15	20	25
Narthecium ossifragum	60	50	65	55	55
Orchis ericetorum	35	35	55	25	30
Pedicularis sylvatica	30	40	45	40	35
Pinguicula vulgaris	40	30	30	40	35
Plantago lanceolata	15	40	40	35	35
Primula vulgaris	40	45	30	40	40
Prunella vulgaris	10	15	25	35	30
Selaginella selaginoides	20	15	20	25	25
Succisa pratensis	70	70	70	70	70
Thelypteris oreopteris	40	35	35	40	40
Trichophorum cespitosum	55	55	70	55	60
Viola riviniana	50	50	55	70	65

A (ii) Plants of drier habitats, or with wider distribution, showing constant overall frequency as a result of persistent perennating organs.

Species	Frequency % 1974	1975	1976	1978	1980
Blechnum spicant	95	95	95	85	95
Hieracium spp.	15	25	15	5	0
Molinia caerulea	100	100	100	100	100
Potentilla erecta	95	95	95	100	95
Pteridium aquilinum	90	90	90	90	90
Rubus fruticosus agg.	10	20	20	30	10
Taraxacum officinale	15	25	25	30	20
Teucrium scorodonia	45	40	40	55	40

B Plants of drier habitats, or with wider distribution, showing increasing overall frequency as a result of regeneration from seed, supplemented by some vegetative re-growth.

Species	Frequency % 1974	1975	1976	1978	1980
Agrostis canina	10	55	60	60	60
Anthoxanthum odoratum	0	15	25	20	25
Betula spp. sdg.	25	55	70	70	85
Calluna vulgaris	85	95	100	100	100
Campanula rotundifolia	25	15	15	0	15
Deschampsia flexuosa	75	65	70	80	90
Erica cinerea	40	75	85	100	100
Festuca ovina	35	40	50	75	65
Galium saxatile	5	35	40	40	50
Hypericum pulchrum	40	55	50	60	60
Luzula multiflora	5	5	10	20	25
Pinus sylvestris sdg.	85	95	100	95	90
Polygala serpyllifolia	30	85	85	45	45
Sieglingia decumbens	20	0	5	40	30
Sorbus aucuparia sdg.	55	45	65	70	90
Vaccinium myrtillus	85	80	85	90	90

Bryophytes

Species	Frequency % 1974	1975	1976	1978	1980
Breutelia chrysocoma	45	40	50	45	35
Calypogeia fissa	5	20	25	5	0
Campylopus atrovirens	5	10	15	30	25
Campylopus flexuosus	0	0	0	10	75
Ceratodon purpureus	0	0	45	40	0
Dicranodontium denudatum	5	55	60	55	35
Dicranum majus	15	30	35	50	40
Dicranum scoparium	15	35	70	80	75
Diplophylum albicans	10	25	10	5	20
Hylocomium splendens	40	85	85	80	70
Hypnum cupressiforme	40	80	75	80	85
Isopterygium elegans	0	5	10	35	20
Leucobryum glaucum	25	45	50	45	15
Pellia fabbroniana	40	25	20	40	30
Plagiothecium undulatum	0	15	25	10	10
Pleurozium schreberi	35	50	70	45	55
Polytrichum formosum	0	30	30	15	30
Polytrichum juniperinum	0	15	25	5	10
Rhacomitrium lanuginosum	5	5	35	20	25
Rhytidiadelphus loreus	0	25	5	20	20
Sphagnum spp.	50	65	70	70	75
Thuidium tamariscinum	35	60	45	20	15

Additional species with low frequencies

Agrostic stolonifera
Agrostis tenuis
Andromeda polifolia
Angelica sylvestris
Asplenium adiantum-nigrum
Brachypodium sylvaticum
Cardamine flexuosa
Carex lepidocarpa
Carex ovalis
Carex pallescens
Cerastium holosteoides
Cerastium **spp.**
Cirsium palustre
Crepis mollis
Crepis paludosa
Deschampsia caespitosa
Drosera intermedia
Dryopteris dilatata
Dryopteris filix-mas
Eleocharis acicularis
Endymion non-scriptus
Eriophorum vaginatum
Festuca vivipara
Fragaria vesca
Hedera helix
Hieracium pilosella
Holcus lanatus
Holcus mollis
Hypericum humifusum
Hypericum **spp.**
Ilex aquifolium **sdg.**
Juncus articulatus
Juncus effusus
Juncus squarrosus
Leontodon hispidus
Linum catharticum
Listera cordata
Lonicera periclymenum
Lotus corniculatus
Lotus uliginosus
Luzula campestris
Luzula pilosa
Lycopodium annotinum
Lycopodium selago
Melampyrum pratense
Nardus stricta
Oxalis acetosella
Platanthera bifolia
Platanthera chlorantha
Polypodium vulgare
Potamogeton polygonifolius
Quercus **spp. sdg.**
Ranunculus flammula
Rhododendron ponticum
Rhynchospora alba
Rosa **spp.**
Salix repens
Schoenus nigricans
Senecio jacobaea
Solidago virgaurea
Thymus drucei
Tragopogon pratensis
Vaccinium vitis-idaea
Veronica officinalis
Viola palustris

Bryophytes

Acrocladium cuspidatum
Atrichum undulatum
Aulacomnium palustre
Bryum capillare
Campylium stellatum
Campylopus introflexus
Cephalozia bicuspidata
Cratoneuron comutatum
Dicranella heteromalla
Drepanocladus revolvens
Fissidens adianthoides
Fissidens taxifolius
Frullania dilatata
Funaria obtusa
Hookeria lucens
Hygrophypnum ochraceum
Isothecium myosuroides
Lepidozia reptans
Lophocolea bidentata
Lophozia ventricosa
Mnium hornum
Nardia scalaris
Odontoschisma sphagni
Plagiochila punctata
Pleurozium purpurea
Polytrichum commune
Polytrichum urnigerum
Pseudoscleropodium purum
Rhacomitricum aquaticum
Rhacomitricum heterostichum
Rhytidiadelphus squarrosus
Scapania gracilis
Scapania undulata
Scorpidium scorpioides
Sphagnum recurvum
Splachnum ampullaceum
Tetraphis pellucida