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Approaches to reinstatement of damaged footpaths in the Three Peaks area of the Yorkshire Dales National Park

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1 *Introduction*

The Yorkshire Dales National Park includes some of the most varied and interesting countryside in upland Britain, which attracts an increasing number of visitors, and is particularly popular with walkers. In recent years, footpaths linking the Three Peaks (Ingleborough, Pen-y-ghent and Whernside) have become seriously eroded because of heavy use. More than 120 000 visitors reach the summit of Ingleborough each year (Smith 1987). The area is used both by individual groups of walkers and for organized walks and races. By 1985, the extent of wear was causing serious concern, and the Yorkshire Dales National Park Committee initiated a programme to survey the damage, test reinstatement techniques, and undertake remedial work (Plate 2).

This paper outlines (i) the results of a survey of the footpaths to pinpoint the type and extent of damage, and (ii) the first summer's trials of reinstatement techniques undertaken by the Institute of Terrestrial Ecology for the National Park Committee during 1986.

The principal problem was to find a means of reinstating native vegetation on heavily disturbed sites. The methods tested included seeding, transplanting, soil amendment, and site works to improve drainage and canalize use. The results of the trials are based on less than a full season's growth, so are necessarily tentative, and the main purpose of this account is to outline the adopted approaches to reinstatement.

2 *The footpath survey*

The aims of the survey were to assess the condition of each path and to identify relationships between path condition and site factors, such as wetness, soil type, vegetation and slope. The results were to provide a baseline analysis for future monitoring and to guide the selection of revegetation techniques and of sites for reinstatement trials.

These objectives required an assessment of path widths and site characteristics along each path. The survey was completed by the end of May 1986, and preliminary analysis by the middle of June, prior to laying out the first trials in early July.

2.1 Survey methods

Recording was based on the technique described by Bayfield *et al.* (1973). Path widths (the total width of obviously trampled ground) and bare widths (the width of ground with no surviving vegetation) were measured

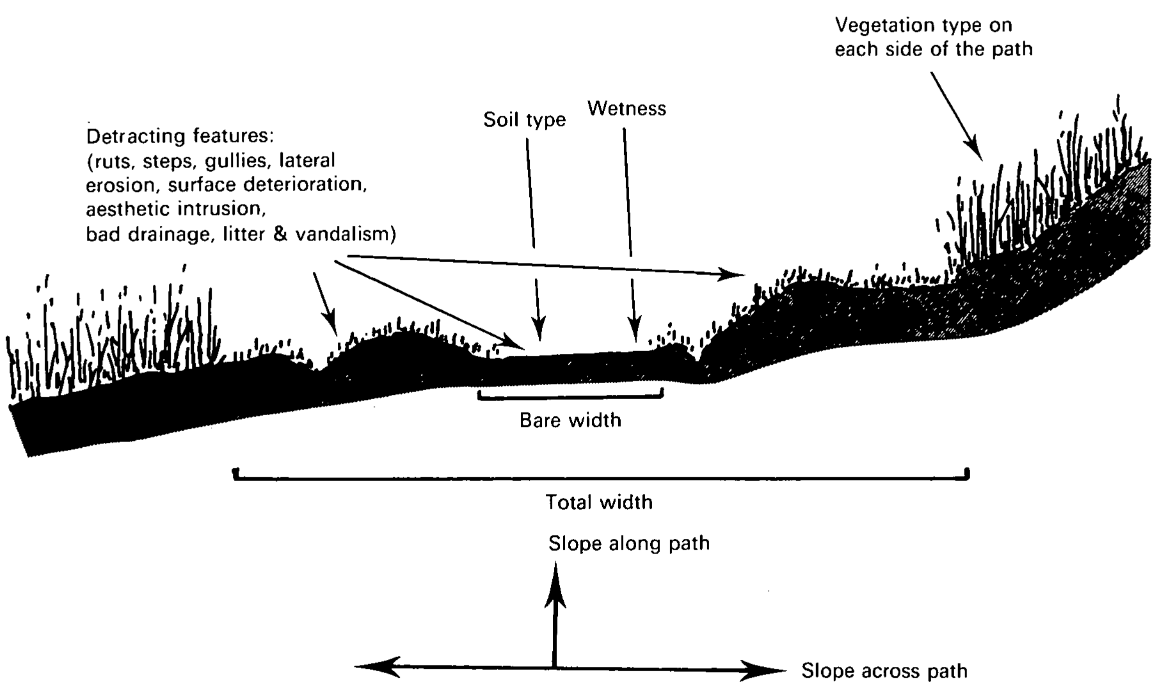


Figure 1. Path characteristics recorded at each sample point

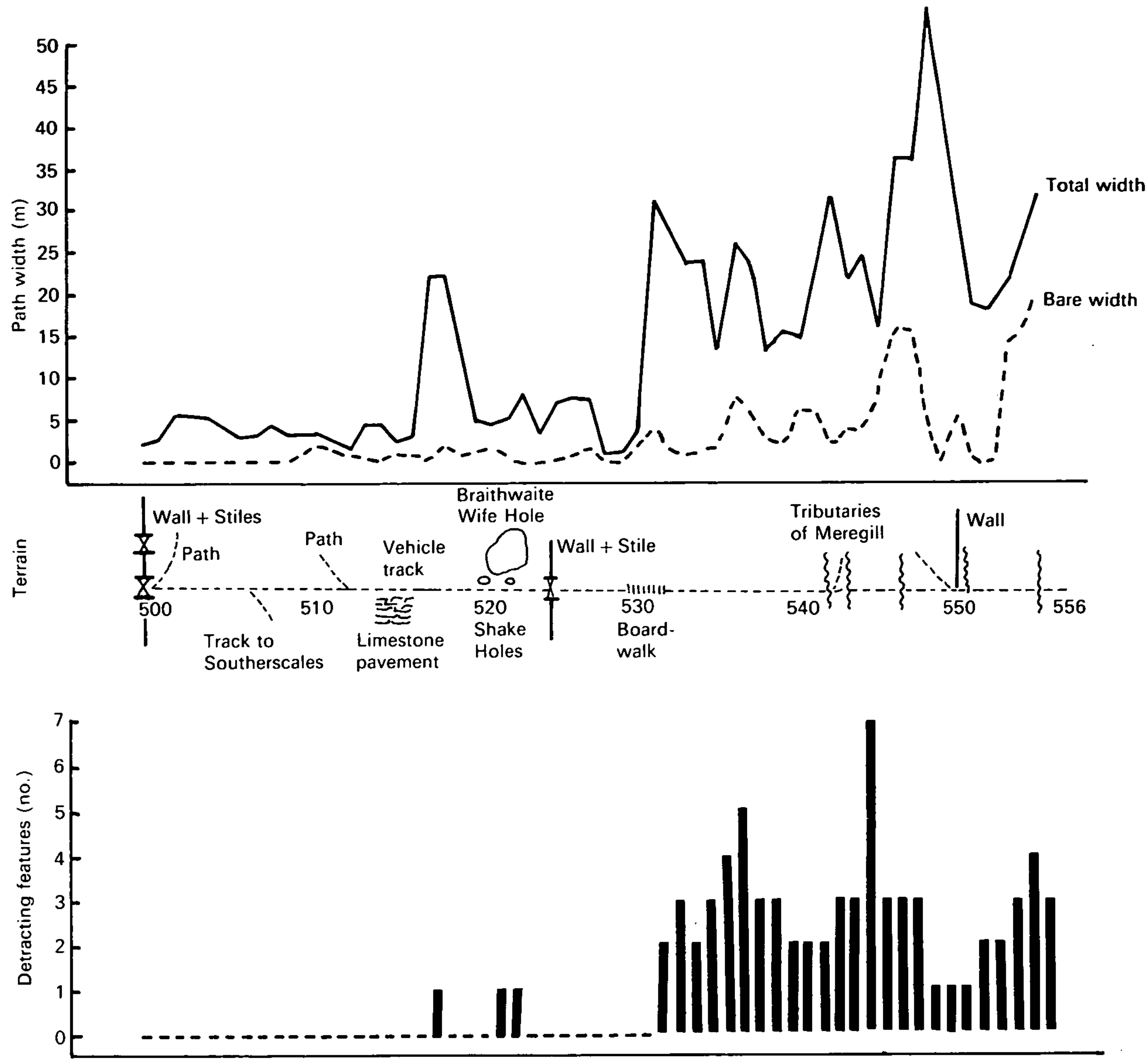


Figure 2. An example of path width data for the Southerscales–Ingleborough path. The numbered points on the terrain sketch are permanent transects

at stratified random sample points in each 50-pace (approximately 50 m) length of path. At each sample point, surface soil type, slope, wetness, adjacent vegetation, and various detracting features (features that reduced path quality) were also recorded (Figure 1). A full account of methods and definition of categories are given in Bayfield and McGowan (1986). Widths and slopes were measured using a 2 m 'A' frame, similar to a pair of large, fixed-dimension dividers with a built-in spirit level and protractor for measuring angle of slope (Bayfield 1987).

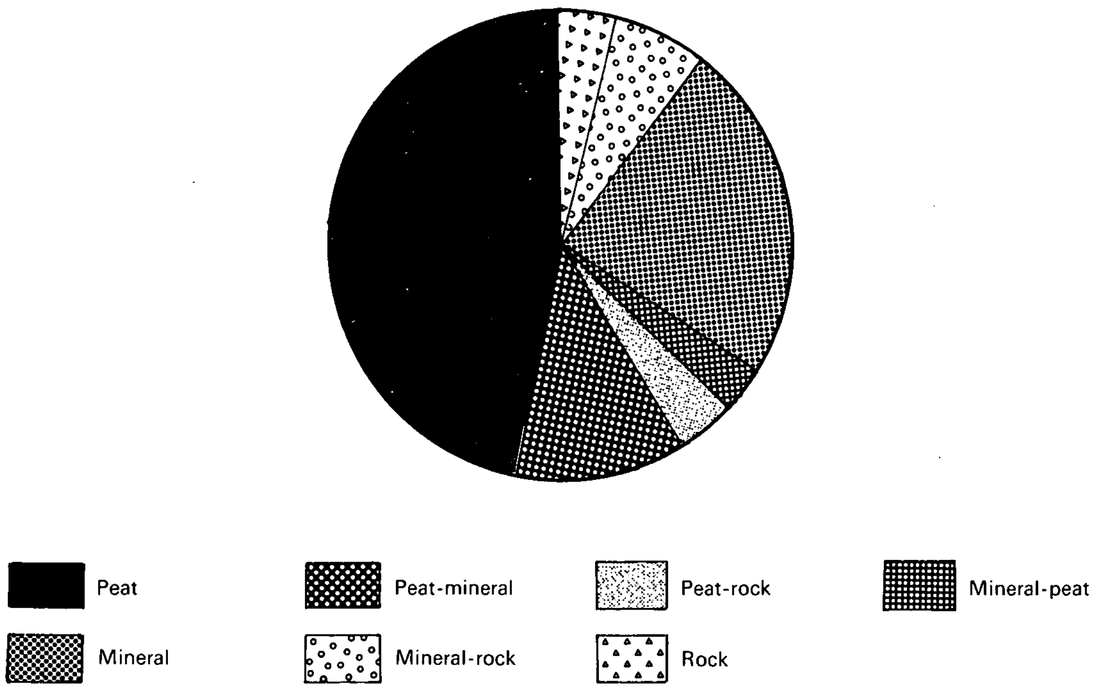
2.2 Path widths

The total length of paths surveyed was 65 km, including about 10 km where paths followed farm tracks or road, and where detailed measurements were not recorded. For each path, a listing of width and other data was drawn up to permit the rapid identification of problem sections, and corresponding soil, vegetation and other site attributes. Figure 2 is an example of such width data for the Southerscales to Ingleborough path.

The average trampled width (all paths) was 11.4 m, and bare width 2.7 m. Some sections were, of course, much more worn than others, but at over half the sample points (60%) the trampled width exceeded 5 m, and at more than a third (38%) it exceeded 10 m. Similarly, a majority (61%) of sample points had more than 2 m of bare ground, and about one in 6 (17%) had more than 5 m. These figures indicate the equivalent of about 23 km of paths that are 10 m or more wide, and 10 km with 5 m or more of bare ground.

The 11.4 m trampled width in the Three Peaks compares unfavourably with upland footpaths elsewhere. The Pennine Way, for example, although badly worn in places, averaged only 3.5 m in 1983 (Bayfield 1985). It is clear that the Three Peaks footpaths are very badly worn.

i.



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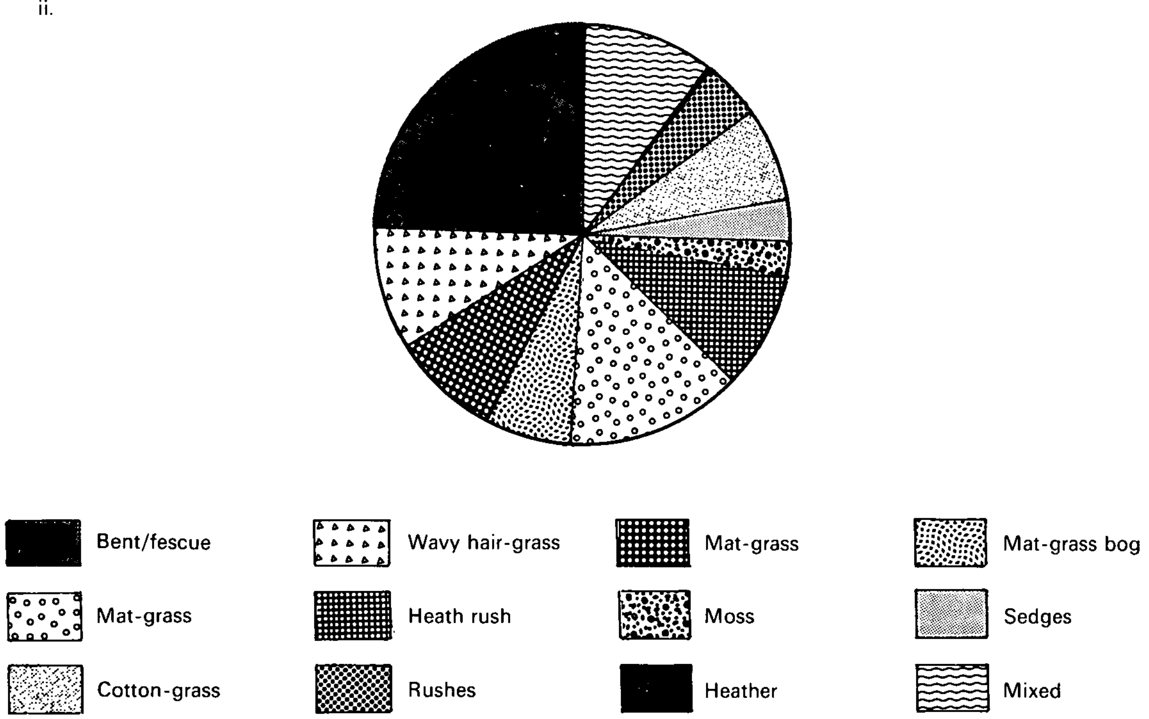

Figure 3. The percentage frequencies of (i) soil surface categories, and (ii) vegetation categories along paths in the Three Peaks area (n=1157)

2.3 Soils and vegetation

During the course of the survey, it was noticeable that badly worn sections of path were predominantly on peaty ground. The soil category with the greatest average width (> 15 m) was 'peaty mineral', mainly found at sites where the peat had been worn away from part of the path to expose mineral subsoil. 'Peat' and 'peat-rock' (peat with exposed rocks) also had high average width (>10 m), whereas predominantly 'mineral' surfaces had widths less than 8 m.

Peat was also the most frequent type of surface, comprising 63% of path samples (Figure 3). The survey indicated that about 77% of badly worn sections occurred on peaty soils. The vegetation of the Three Peaks area is a mixture of heather (*Calluna vulgaris*) and

Plate 2i. Severe erosion on the path from Simon Fell to Ingleborough (Photograph N G Bayfield)

grass heaths, with the latter predominant. Twelve broad vegetation categories were recorded during the footpath survey, based on the predominant species. The single most frequent type was bent/fescue (*Agrostis/Festuca*) grassland, the characteristic vegetation of mineral soils overlying limestone (Figure 3). On peaty soils, the

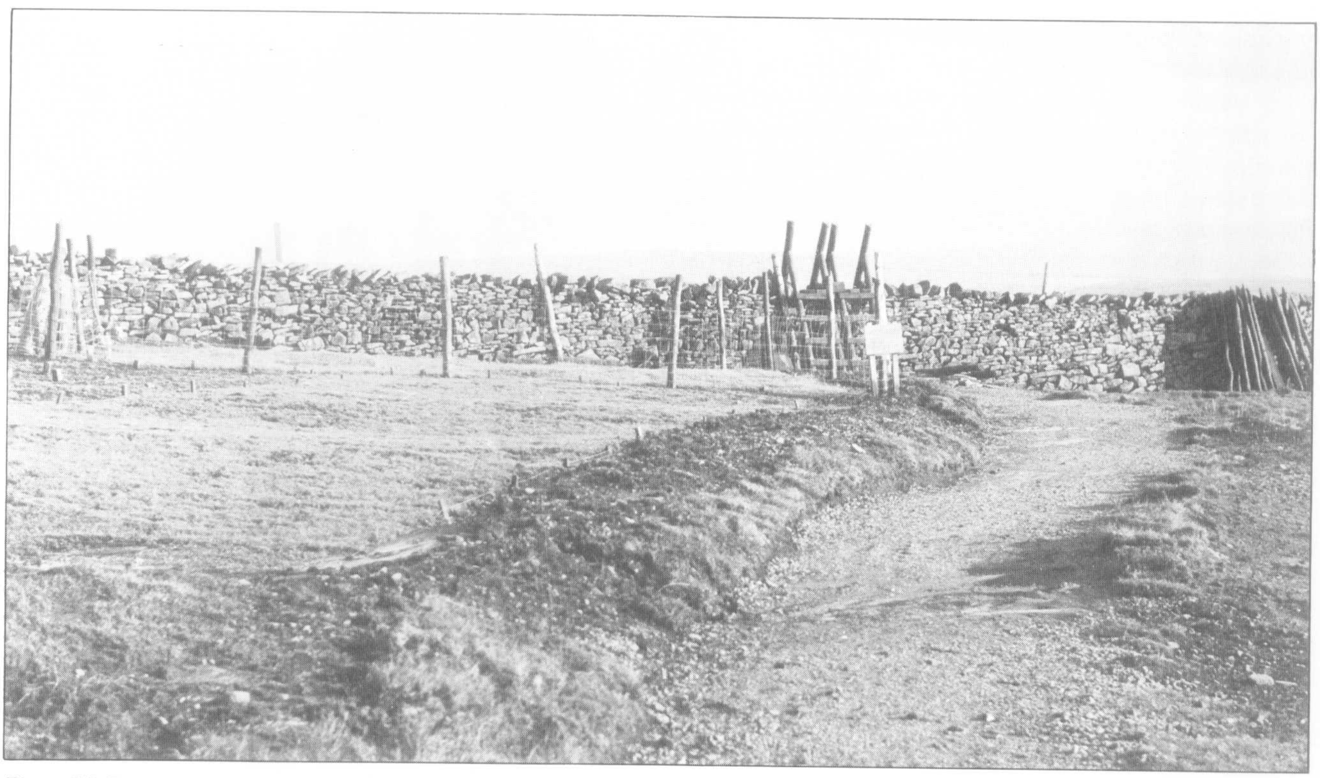

Plate 2ii. Part of a trial site on Simon Fell, with a constructed gravel surface and fenced and unfenced plots of various seed mixtures (Photograph N G Bayfield) vegetation comprised principally graminoids, notably mat-grass (*Nardus stricta*), wavy hair-grass (*Deschampsia flexuosa*), sheep's fescue (*Festuca ovina*), common bent-grass (*Agrostis capillaris*), heath rush (*Juncus squarrosus*), cotton-grass (*Eriophorum* spp.), soft rush (*Juncus effusus*), sedges (*Carex* spp.) and mosses. Heather was predominant at only 0.3% of the path sample points.

3 The approach to reinstatement

The principal considerations in designing the first season's reinstatement trials were:

i. to relate trial design to the main types of deterioration identified during the footpath survey;
ii. to seek, where practicable, solutions that would withstand grazing and disturbance by sheep;
iii. to use locally native species wherever possible;
iv. to conserve any surviving vegetation, and to explore means of increasing its resistance to further disturbance;
v. to explore the possibilities of transplanting established plants in order to create rapid cover, texture or pattern;
vi. to use any other readily available sources of plant material, including moss fragments, seed-rich plant litter and seeds;
vii. to treat not only symptoms but also causes, by landscaping surfaces and canalizing use to minimize further disturbance.

The initial trial sites were located at peat sites because of their apparent vulnerability. The species planted or sown were principally the graminoids and mosses predominant in the path survey. Constraints of time and resources meant that only a limited range of comparisons could be attempted in the first season, so those chosen were deliberately contrasting. The intention was that promising lines of investigation would be examined in more detail in subsequent studies. However, all trials were replicated (usually 4 replicates) to permit statistical analysis of the data. There were 3 main types of trials: seed mixtures, transplants, and the use of fertilizers to improve the resistance of vegetation to disturbance (Bayfield & Miller 1986).

The seeds and transplanting trials were laid out at 2 gently sloping peat sites on Simon Fell (about 500 m above sea level), where there was extensive exposure of bare ground (Plate 3; Figure 4). To prevent heavy disturbance of the plots, use was canalized by providing a new gravel path at one site and a boardwalk at another. To protect from the possible impact of sheep grazing, some of the trials (principally seeds trials) were fenced, but the majority of trials had no protection from sheep. No serious interference with initial plant establishment by sheep was noted, although most plots were closely grazed.

The fertilizer trials were laid out on sections of existing path with continuing use, and marked inconspicuously to avoid altering the pattern of use.

3.1 Seed mixtures trials

Replacement of vegetation by seeding bare ground is a widely used reinstatement technique, and one that has proved successful even in such harsh conditions as the Trans-Alaska pipeline system (Hubbard 1980), subalpine camp-grounds (Hingston 1982) and Scottish ski-grounds (Bayfield 1980). In most cases, however, agronomic species have been used, and there have been few attempts in Britain to sow mixtures of upland native species (Environmental Unit 1981). In the Three Peaks trials, the aim was to use mainly native species, but with some agricultural mixtures for comparative purposes and as an insurance against possible failure of the native species.

Not all the principal species identified in the path survey could be obtained commercially as seed. Some mixtures were supplemented with either chopped moss fragments or plant litter, to try and increase species diversity. There were 2 mixtures based on the agricultural grass mixtures used for reinstatement work at ski sites in Scotland (Bayfield 1980). The composition of the various mixtures is shown in Table 1.

Table 1. Seed mixtures used in the 1986 trials

		% by weight	Seeds m-2	Sowing rate (g m-2)
'I'	(Sheep's/fescue/bent/wavy hair-grass mixture			
	Wavy hair-grass (*Deschampsia flexuosa*)	27	8000	
	Sheep's fescue (*Festuca ovina*)	27	1500	
	Bent-grass (*Agrostis capillaris*)	10	9000	6
	Sweet vernal grass (*Anthoxanthum odoratum*)	34	500	
	Tormentil (*Potentilla erecta*)	1	600	
	Harebell (*Campanula rotundifolia*)	1	1200	
'N'	(Mat-grass mixture)			
	Wavy hair-grass	70	11000	
	Mat-grass (*Nardus stricta*)	14	1300	
	Bent-grass	14	11000	4.5
	Tormentil	1	400	
	Harebell	1	800	
'G'	(Agricultural mixture)			
	Red fescue (*Festuca rubra*)	48	2500	
	Meadow grass (*Poa pratensis*)	18	2400	5.3
	Bent-grass	15	12000	
	Crested dog's-tail (*Cynosurus cristatus*)	18	1900	
'GH'	(Agricultural mixture with Yorkshire fog)			
	As 'G' (80%) plus:			
	Tormentil	1	400	
	Harebell	1	800	
	Clover (*Trifolium repens*)	3	200	5.3
	Yarrow (*Achillea millefolium*)	1	500	
	Yorkshire fog (*Holcus lanatus*)	15	2000	
'IM'	('I' plus moss)			
	'I' above plus 2 g m^{-2} chopped moss fragments (bog moss (*Sphagnum* spp.), bog hair moss (*Polytrichum commune*), fork moss (*Dicranum* and *Campylopus* spp.), feather moss (*Hylocomium splendens* and *Brachythecium* spp.)			
'IF'	('I' plus litter)			
	'I' plus 0.5 l m^{-2} local plant litter			

Plate 3. A view of the 'boardwalk' site on Simon Fell Breast (Photograph N G Bayfield)

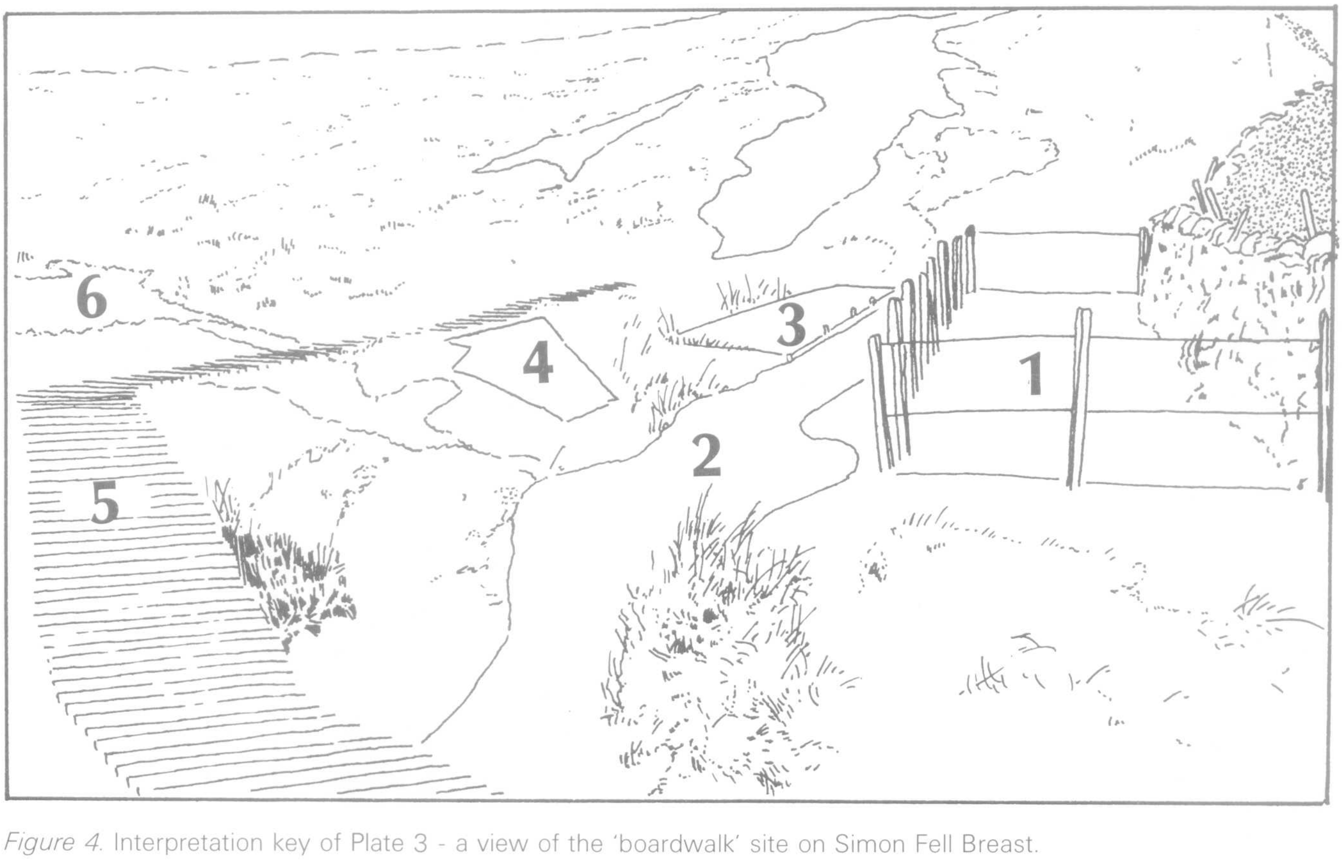

Figure 4. Interpretation key of Plate 3 - a view of the 'boardwalk' site on Simon Fell Breast.
1, fenced seed mixtures trial; 2, ditch; 3, unfenced seed mixtures trial; 4, soft rush transplants; 5, boardwalk; 6, soft rush, mat-grass and heath rush transplants

The sites were prepared by digging and raking the ground to a fine tilth, then applying 35 g m^{-2} Vitax Q4 low-nitrogen fertilizer (5.3:7.5:10 NPK) prior to seeding plots 2 m x 1 m. All the seed mixtures produced a satisfactory cover after 2½ months (mean range 58–85%), and the native species mixtures compared favourably with the agricultural mixtures. Table 2 gives an example of data for the 4 mixtures compared at the 'boardwalk' site. Of the sown grasses, bent-grass was a major contributor to cover in all 4 mixtures. The other native species, sheep's fescue and sweet vernal-grass (*Anthoxanthum odoratum*), provided much less cover, and wavy hair-grass was a very minor component. Sown herbs (broadleaved species, common tormentil (*Potentilla erecta*) and harebell (*Campanula rotundifolia*)) were only present in traces, but self-sown species (mainly soft rush) were present to some extent on all plots, and especially on the control plots (more than 20% cover).

Table 2. Percentage cover of principal species on plots sown with various seed mixtures at the boardwalk site on Simon Fell Breast. Visual estimates of cover (means of 4 replicates) after 2½ months (September 1986). Total plant cover data are back transformed from angular transformations. Details of mixtures are given in Table 1

	Mixture				
	I	IM	IL	G	C
Sown grasses					
Bent-grass (*Agrostis capillaris*)	42	55	55	29	4*
Sheep's fescue (*Festuca ovina*)	7	3	7		t*
Red fescue (*Festuca rubra*)				31	
Wavy hair-grass (*Deschampsia flexuosa*)	2	1	1		
Meadow grass (*Poa pratensis*)				1	
Sweet vernal grass (*Anthoxanthum odoratum*)	7	5	7		
Crested dog's-tail (*Cynosurus cristatus*)				t	
Sown herbs					
Self-sown species					
Soft rush (*Juncus effusus*)	7	6	5	4	24
Other species	t	t	1		1
Mosses	1	3	4	t	6
Total plant cover	65	74	78	67	34
(95% confidence limits)	(50-78)	(60-86)	(64-89)	(52-50)	(20-49)

t, trace (less than 1% cover. * not shown in these plots, seeds presumably windblown from adjacent plots

Cores of soil from the site were found to contain a seed reservoir equivalent to about 20 000 seed m^{-2}, mainly of soft rush. Ground preparation and the addition of fertilizer appeared to have stimulated many of these seeds to germinate. The second seeds trial site had a similar seed reservoir, but produced fewer seedlings, possibly because the ground was much drier. The addition of chopped moss fragments and plant litter increased the variety and cover of mosses (Table 3), although mosses were still a minor contributor to cover. Litter was more effective than chopped moss fragments. On control plots, even higher moss cover was recorded, but this was mostly an undifferentiated filamentous mat without recognizable species.

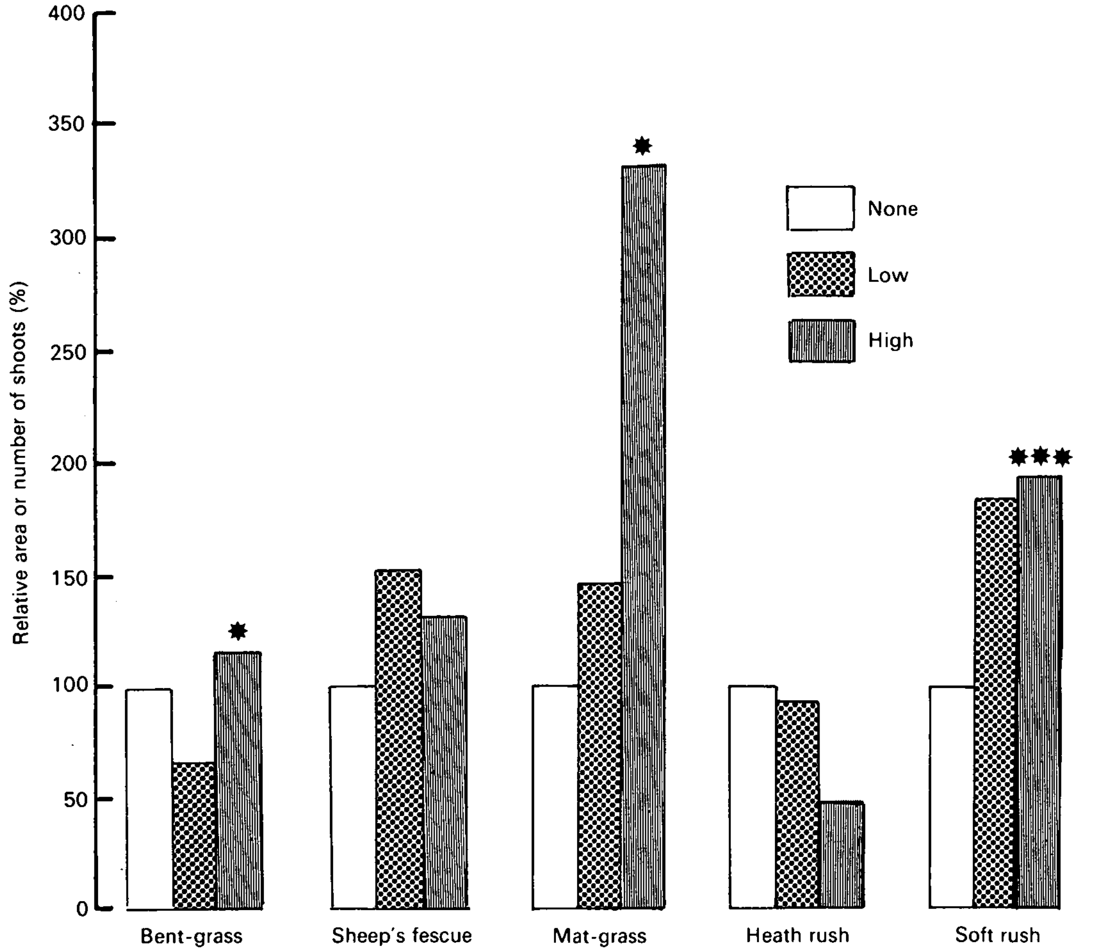

Figure 5. Effects of fertilizer (0, 70 or 140 gm m^{-2} Vitax Q4) on the areas of surviving divots. The areas on fertilized plots are expressed as a proportion of those on unfertilized plots (* $P < 0.05$; *** $P < 0.001$)

Table 3. Comparison of the numbers of quadrats in which various mosses were recorded, and the mean % cover of mosses in seeded plots at the boardwalk site on Simon Fell Breast. Eight quadrats were recorded on each seeds mixture treatment (2 quadrats on each of 4 replicates). Total moss cover untransformed. The composition of the mixtures is given in Table 1

	Mixture				
	I	IM	IL	G	C
Hair moss (*Polytrichum* spp.)	1	4	8		2
Bog moss (*Sphagnum* spp.)		1	7		
Feather moss (*Brachythecium* spp.)		2	8		
Marsh thread moss (*Aulacomnium palustre*)		1			
Fork moss (*Dicranum* or *Campylopus* spp.)		1	1		
Undifferentiated moss mat	6	8	6	5	7
Total moss cover (%)	0.9	2.6	3.6	0.6	5.7

3.2 Transplanting trials

Transplanting of alpine species has been used successfully in the United States (Brown *et al.* 1978) and spot or close turfing is widely recommended as one of the best revegetation techniques for erosion control (Schiechtl 1980). Little is known, however, of the suitability of most common British upland species for transplanting work.

These trials aimed to discover which species could be transplanted satisfactorily, the most effective size of transplant, and the effect of fertilizer on establishment. Seven species were compared (sheep's fescue, bent-grass, soft rush, heath rush, sedge (*Carex nigra*), mat-grass and cotton-grass (*Eriophorum vaginatum*). In each case, 10 cm diameter circular turves were cut and transplanted intact, 'stretched' to about double their initial area, or divided into 9 smaller rooted 'divots'. In each case, the material was planted into 0.5 m² plots.

Fertilizer applications were 0, 70 or 140 g m^{-2} Vitax Q4. Intact turves and stretched turves only received the lower fertilizer application and transplanted well, without any losses after 2½ months. The divots received the full range of fertilizer applications and also transplanted quite well, with 65–100% survival in most cases. An exception was heath rush, which only had a survival rate of 53% on heavily fertilized plots. The area occupied by the surviving transplants was compared after 2½ months. For bent-grass, mat-grass and heath rush, the area of divots and stretched turves slightly exceeded that of intact turves (differences not, however, significant). In the case of soft rush and sheep's fescue, the area of divots was more than double that of intact turves ($P<0.05$). The growth of cotton-grass and sedge was not analysed, as these species appear to have a flush of growth in the spring, and had made no growth since transplanting. The use of fertilizer on divots increased the area substantially in the case of soft rush and mat-grass,

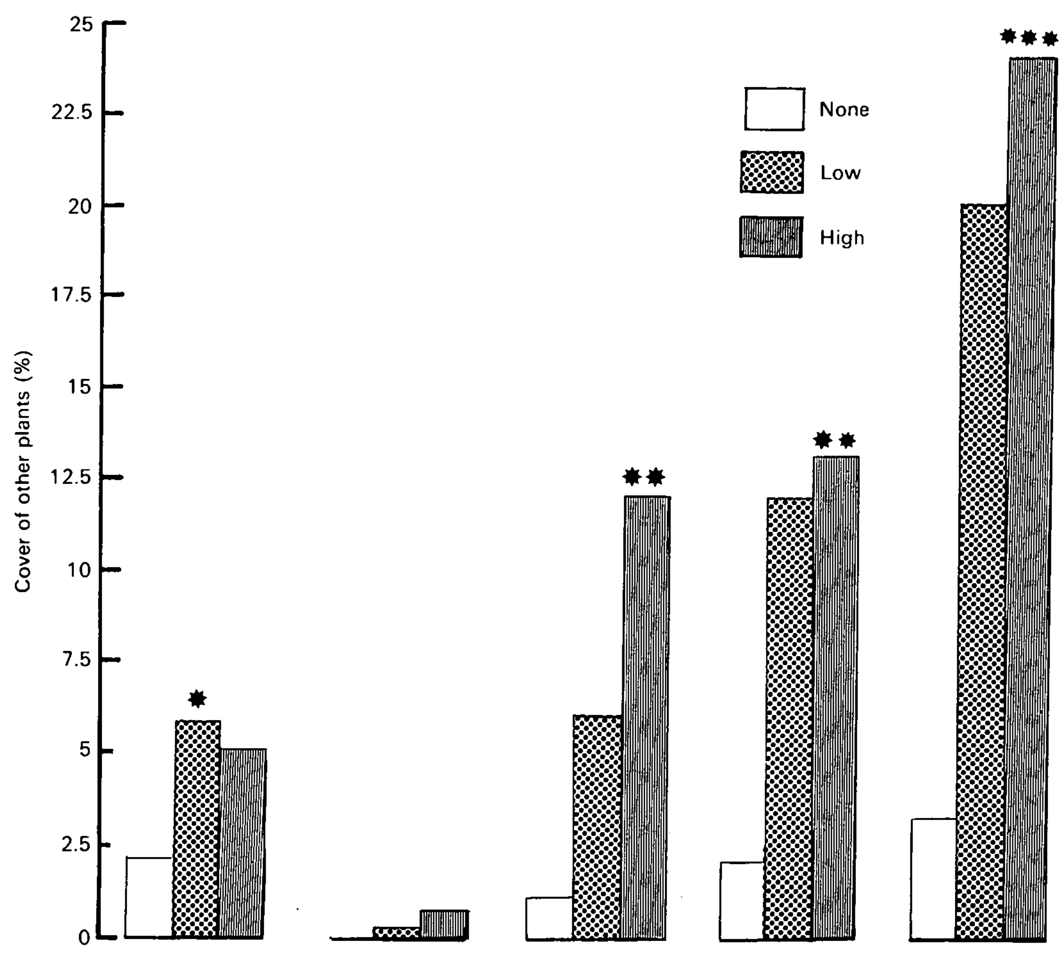

Figure 6. Effects of fertilizer on the cover (visual estimates) of other plants colonizing divot plots of bent-grass, sheep's fescue, mat-grass, heath rush and soft rush (* $P<0.05$; ** $P<0.01$; *** $P<0.001$)

affected bent-grass and sheep's fescue only slightly, and reduced the area of heath rush (Figure 5). Another important effect of fertilizer was a substantial increase in the cover of other species colonizing the transplant plots (Figure 6). The fertilizer appeared to both stimulate germination and increase growth rates of colonizing plants. The main colonizing species was soft rush, with smaller numbers of heath rush and brown bent-grass (*Agrostis canina*).

3.3 Use of fertilizers on damaged vegetation

Fertilizer is applied routinely to heavily used sports turf in order to maintain plant vigour, and has been recommended to help maintain plant cover in wilderness camp-grounds in the United States (Hendee *et al.* 1977). The aim of the present trials was to see whether the addition of fertilizer to damaged vegetation along paths could improve plant cover, and increase resistance to further disturbance. Treatments included fertilizer, lime and alginure soil improver, but some of these were not applied until late in the season, and their effects will not be analysed until 1987. At 5 sites on Simon Fell, however, the effect of fertilizer was analysed after 2½ months. Each site had 3 adjacent 2 m strips across the path dressed with 0, 35 or 105 g m^{-2} of Enmag slow-release low-nitrogen fertilizer (4.5:20:10 NPK).

The application of fertilizer increased plant cover by up to 28% (Figure 7). Detailed botanical changes were not recorded at this stage, but superficially it appeared that narrow-leaved grasses (mainly sheep's fescue) contributed the greatest improvement to cover. A similar response, although by different species, has been noted in the case of fertilized tundra vegetation (Shaver & Chapin 1986).

4 *Conclusions*

All 3 approaches to reinstatement (seeding, transplanting and fertilizing) showed promising results after only a few months, but it is long-term performance that will indicate which are the most satisfactory techniques. Analysis of plots after winter should be quite instructive, but performance will need to be monitored over several seasons.

As the transplanting of native species appears to be a practical possibility, it may be feasible to consider trials which combine seeding and transplanting to create reinstated vegetation with areas of contrasting texture

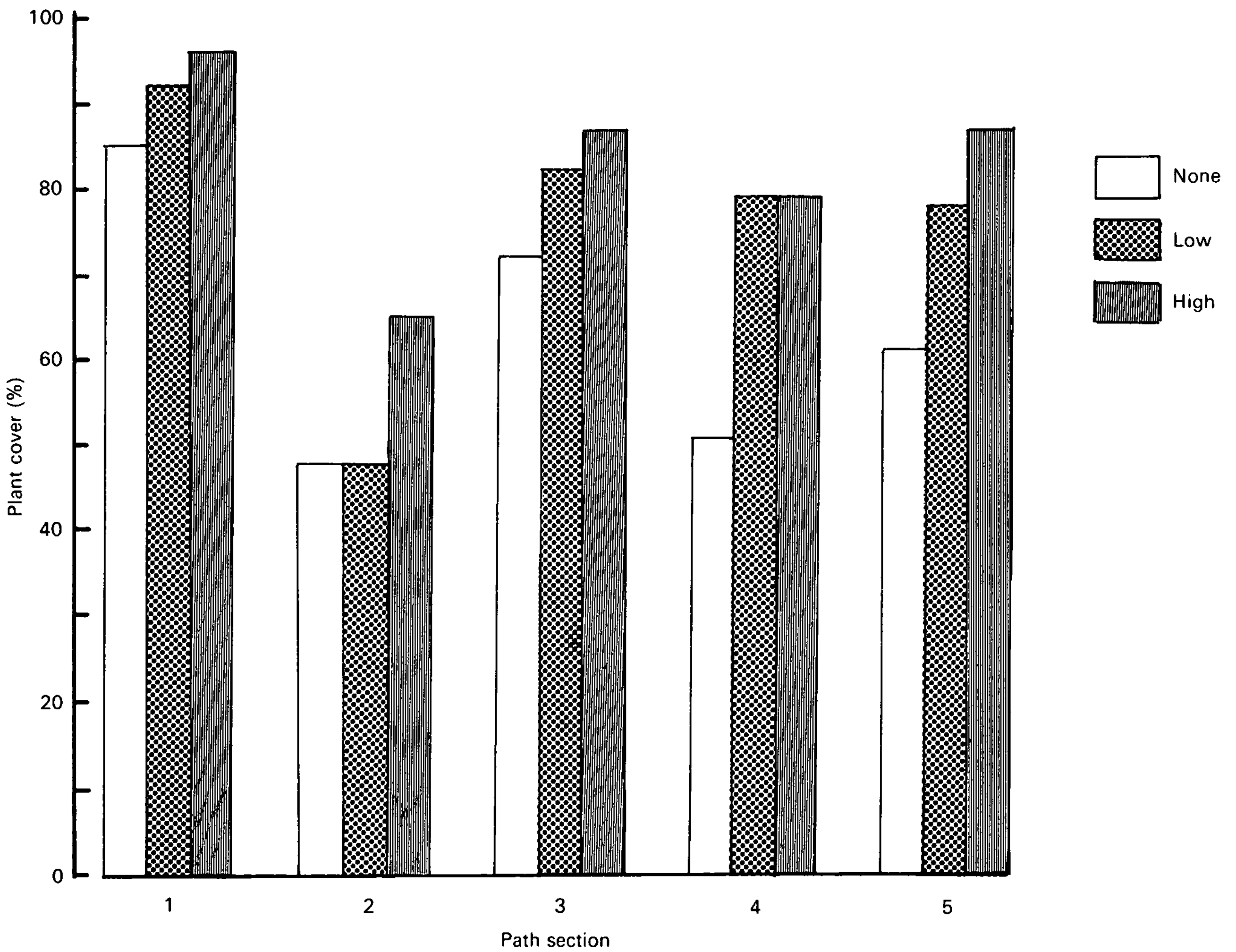

Figure 7. Effects of 2 levels of fertilizer (35 or 105 g m^{-2} Enmag) on vegetation cover at 5 damaged sections of path at Simon Fell Breast. Data are step point estimates of cover (source: Cunningham 1975)

and pattern, rather than just a uniform grassy sward. This method could be important for creating landscaped routes which blend imperceptibly with the surrounding ground. Similarly, trials with different textures, materials and colours of path surfaces need to be undertaken to establish how best to create visually acceptable path surfaces. The use of fertilizer to improve the resistance of damaged vegetation seems to be an effective and economical approach to managing paths where vegetation has been extensively damaged, but not eliminated, and could be a simple means of reducing the rate of path deterioration. Fertilizers appear to be beneficial, even where vegetation has been eliminated, in stimulating the germination of buried seed. Treatment could be easily applied to long stretches of path at comparatively low cost. Before this technique is used on a wide scale, however, it would be sensible to undertake further analysis of the trial plots to assess the persistence of the improvement, and the nature of any changes in species composition.

Some further trials on peat soils will probably be justified, but it should be possible to progress to trials on mineral and steeply sloping sites. Seed mixture trials should include, where possible, native species not tested in 1986, and transplanting should include species such as deer-grass (*Trichophorum cespitosum*), purple moor-grass (*Molinia caerulea*) and wavy hair-grass which have not so far been examined.

The contribution of buried seeds to cover at one of the trial sites indicates an important site characteristic about which we know rather little. A survey of the extent of buried seed reservoirs at different types of site could be helpful in choosing an appropriate combination of reinstatement techniques.

Finally, as reinstatment is introduced on an increasing scale, it will be important to monitor both the effectiveness and persistence of the techniques used, and the acceptability of the work to walkers and other users; we are seeking solutions which are aesthetically pleasing, and not just tidy and cost-effective.

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