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7. MONITORING IN WOODLANDS

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The aims of monitoring include the detection, measurement and assessment of changes which may be occurring in the abiotic (physical and chemical) and biotic components of ecosystems. In practice, because of limited resources, human, financial, or both, the monitoring of woodlands will usually be confined to a small number of soil characteristics, possibly a few faunal samples and principally to floral studies often limited to vascular plants but sometimes including bryophytes and lichens. Answers are sought to a number of questions which basically are the same for all types of ecological surveys:

a. What is there?

b. How many of them are there?

c. How big are they?

d. Where precisely are they?

Whether or not change will be detected, depends on the precision with which attributes and variables are measured and their rates of change in relation to the time span between measurements. Clearly it will be impossible, because of the size of most woodlands, and in most instances unnecessary, to answer these questions for the entire ecosystem and therefore a system of sampling is used. Nonetheless, in some intensively-managed woodlands it is desirable and feasible to make a total enumeration of trees.

In common with other types of survey, monitoring requires that samples should be representative, and, additionally, relocatable so as to minimize the confounding effects of spatial and temporal variations. These considerations have led to the use of systematically arranged samples, a procedure giving good overall coverage, enabling relocation and providing a suitable framework for the selection of additional samples if required. At present a number of woodland sites are being monitored among which are Kirkconnell Flow NNR, Kirkcudbrightshire, and Stone Chest, Cumbria. At the former, baseline survey data have been collected in a systematic fashion and provide reasonably detailed information on within-site variation at a single time; at Stone Chest, Cumbria, the element of temporal variation has been added by making repeated surveys.

1. Kirkconnell Flow NNR, Kirkcudbrightshire

This site occupies a rectangular area of 155 ha. It is a partly-wooded, estuarine raised bog, lying 9 m above sea level, with 100 cm annual rainfall. The survey attempted to describe and map existing vegetation and record changes in mire vegetation and stands of pine and birch. A systematic grid with intersections at 100 m was used to locate samples. Nested quadrats from 4 m^2 to 200 m^2 were placed at each intersection for the listing of species and estimation of their cover or site occupancy. In total, there are 159 sample locations which were examined by a 2-man team completing 12 samples per day. When classified, the floral data resulted in 8 recognizable groups of quadrats identified by indicator species which are not necessarily dominants. Lists of species which are constant in each of the 8 groups are shown in Table 9 where it can be seen that *Calluna vulgaris* is the only ubiquitous species. Other plants tend to be characteristic of Groups 1-4 or of Groups 5-8. These 2 major groupings represent, on the one hand, the vegetation of the central wet bog or that associated with peat cutting activities immediately surrounding the central area, and, on the other hand, that of the peripheral and drier area, parts of which have a developing woodland flora. Using these groups, it was possible first to estimate the proportion of the NNR occupied by each of the 8 vegetation groups by equating it with the proportion of sample plots falling into each of the groups, and second to produce an estimated reconstruction of the pattern of vegetation as reflected in the spatial distribution of the vegetation groups. This reconstruction can be achieved by (i) the interpolation of freehand lines to approximate boundaries or (ii) the use of an explicit rule, often a nearest-point rule, requiring that a point should be assigned to the same group as its nearest-neighbour sample point.

Where an area is divided into a number of squares and the vegetation sampled at the centre of each square, it may be assumed that the vegetation at the centre is typical of its entire square (Figure 16). Intuitively it would be expected that the real pattern of vegetation would be more faithfully reconstructed if the sample points were closer together and the squares therefore smaller, particularly if the mosaic were on a small scale. Using the vegetation classification it was possible to construct a dichotomous key based on the presence of numbers of contrasting species at each dichotomy (Table 10). Next, by visiting a new series of sample locations at the centre of a square formed by each 4 of the previous samples, the number of samples was doubled. On this occasion, however, there was no need to compile lists of species; instead the vegetation was classified by the presence or absence of indicator species in the dichotomous key. In this way it was possible to complete approximately 40 samples per day, as compared with the original 12, with the cost effective production of a map giving the spatial distribution of the 8 vegetation groups (Figure 17).

TABLE 9 Constant species in 8 vegetation groups at Kirkconnell Flow NNR

Species	Group 1	2	3	4	5	6	7	8
Calluna vulgaris	✓	✓	✓	✓	✓	✓	✓	✓
Erica tetralix	✓	✓	–	✓	✓	–	–	–
Eriophorum angustifolium	✓	✓	✓	✓	–	–	–	–
Eriophorum vaginatum	✓	✓	–	✓	–	–	–	–
Oxycoccus palustris	–	✓	–	–	–	–	–	–
Pinus sylvestris	✓	✓	–	✓	✓	–	–	–
Andromeda polifolia	✓	✓	–	–	–	–	–	–
Odontoschisma sphagni	✓	–	–	✓	–	–	–	–
Pleurozium schreberi	✓	✓	✓	✓	✓	–	–	–
Sphagnum palustre	–	✓	–	–	–	–	–	–
Dryopteris dilatata	–	–	–	–	✓	✓	✓	–
Galium saxatile	–	–	–	–	–	–	–	✓
Holcus lanatus	–	–	–	–	–	–	–	✓
Molinia caerulea	–	–	–	–	–	✓	–	✓
Oxalis acetosella	–	–	–	–	–	–	✓	–
Rumex acetosella	–	–	–	–	–	–	–	✓
Sorbus aucuparia	–	–	–	–	–	–	✓	–
Betula pubescens	–	✓	✓	✓	✓	✓	✓	✓
Leucobryum glaucum	–	–	–	–	✓	–	–	–
Dicranum scoparium	–	–	✓	✓	–	✓	–	–
Polytrichum formosum	–	–	–	–	–	✓	–	–
Vaccinium myrtillus	–	✓	–	–	✓	✓	–	–

By doubling the numbers of samples, some areas which appeared previously to be homogeneous were found not to be; this change of status could be important if some, but not all, vegetation groups were to be managed in a particular way (Table 11). Because the stands of pine and birch and their development in time are of particular interest at Kirkconnell Flow, it was necessary to collect additional information on the structure of these stands in different regions of the site, the locations to be sampled being selected using the 8 vegetation groups as strata. The diameter, height, and crown size, and position of individual trees were recorded, as were the numbers of saplings and seedlings (Figure 18).

TABLE 11 Area estimates, as percentages of the total area, of the 8 vegetation groups at Kirkconnell Flow using different grid size/sample size

No. of plots		159	312
Distance between plots (m)		100	70.7
Sampling fraction		0.2	0.4
	1	17.6	19.2
	2	13.8	13.5
	3	12.6	13.8
Vegetation groups	4	11.9	12.2
	5	9.4	7.7
	6	10.7	13.1
	7	15.7	12.8
	8	8.2	7.7

The distinctions between the vegetation groups are clearly seen: first, at a coarse level, the contrast between the relative importance of Scots pine and birch in Groups 6-8 both in numbers and in basal area, and secondly, at a finer level, between the numbers of Scots pine trees, saplings and seedlings in Groups 1 and 2. The vegetation in Group 2 is taken to be a successional development of that in Group 1.

2. Stone Chest, Cumbria

In the north of Cumbria the use of the Stone Chest site of 200 ha changed in 1971/72, with its ownership, from poor sheep grazing to plantation forestry. The site is unusual in some respects: although managed as a commercial enterprise by Economic Forestry (Scotland) Ltd, some concessions to normal planting practice have been made in order, it is hoped, to increase the sporting interest of the property. Thus, although 70% of the area has been planted with Sitka spruce, there are lesser plantings of other species with numbers of indigenous and exotic shrubs planted alongside extra-wide rides and metalled roads. Additionally a series of small ponds has been

TABLE 10 Dichotomous key to 8 vegetation groups at Kirkconnell Flow, based on indicator species analysis*

TYPES OF INDICATOR SPECIES		
POSITIVE		NEGATIVE
1. Seedlings of *Sorbus aucuparia* *Dryopteris dilatata*		*Eriophorum angustifolium* *Eriophorum vaginatum* *Andromeda polifolia*
	If aggregate score is: -1 or less --- (2) 0 or more --- (5)	
2. *Molinia caerulea* Saplings of *Betula* spp		*Oxycoccus palustris* *Andromeda polifolia* *Sphagnum magellanicum*
	If aggregate score is: -1 or less --- (3) 0 or more --- (4)	
3. *Oxycoccus palustris* *Vaccinium myrtillus* Seedlings of *Betula* spp		*Drosera rotundifolia* *Trichophorum cespitosum*
	If aggregate score is: 1 or less, assemblage belongs to GROUP 1 2 or more, assemblage belongs to GROUP 2	
4. *Eriophorum vaginatum* *Odontoschisma sphagni* *Sphagnum palustre* *Sphagnum plumulosum* *Aulacomnium palustre*		
	If aggregate score is 0 or less, assemblage belongs to GROUP 3 1 or more, assemblage belongs to GROUP 4	
5. *Corydalis claviculata* *Holcus lanatus* *Pteridium aquilinum*		*Calluna vulgaris* *Erica tetralix*
	If aggregate score is: 0 or less --- (6) 1 or more --- (7)	
6. Trees of *Betula* spp Seedlings of *Pinus sylvestris* *Polytrichum formosum*		Trees of *Pinus sylvestris* *Stellaria media*
	If aggregate score is: 0 or less, assemblage belongs to GROUP 5 1 or more, assemblage belongs to GROUP 6	
7. *Molinia caerulea* *Potentilla erecta* *Rumex acetosella*		*Oxalis acetosella* *Vaccinium myrtillus*
	If aggregate score is: 0 or less, assemblage belongs to GROUP 7 1 or more, assemblage belongs to GROUP 8	

* Each indicator species present in the sample has either a unit positive or unit negative score. The aggregate score for the sample is calculated and progress through the key depends upon its value.

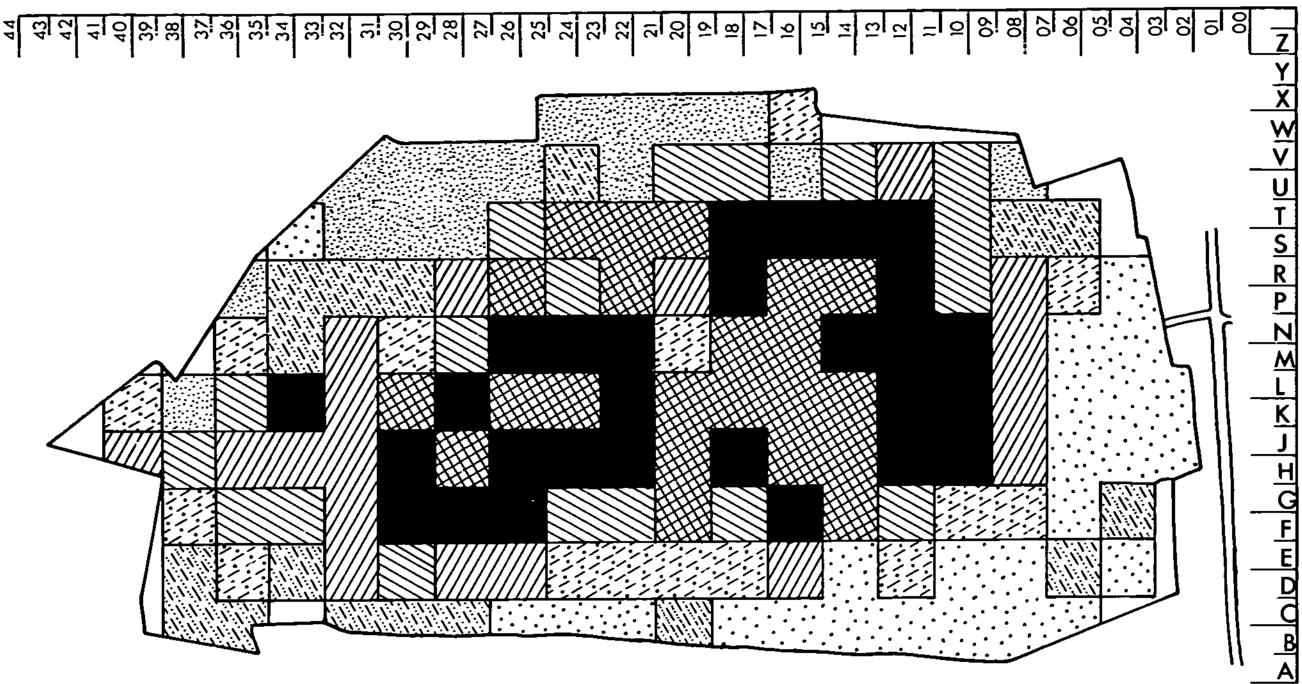

Fig. 16 *Map showing the distribution of 8 vegetation groups at Kirkconnell Flow NNR, based on samples taken 100 m apart (compare with Figure 17 where samples were taken 71 m apart). See Table 9 for Group component species.*

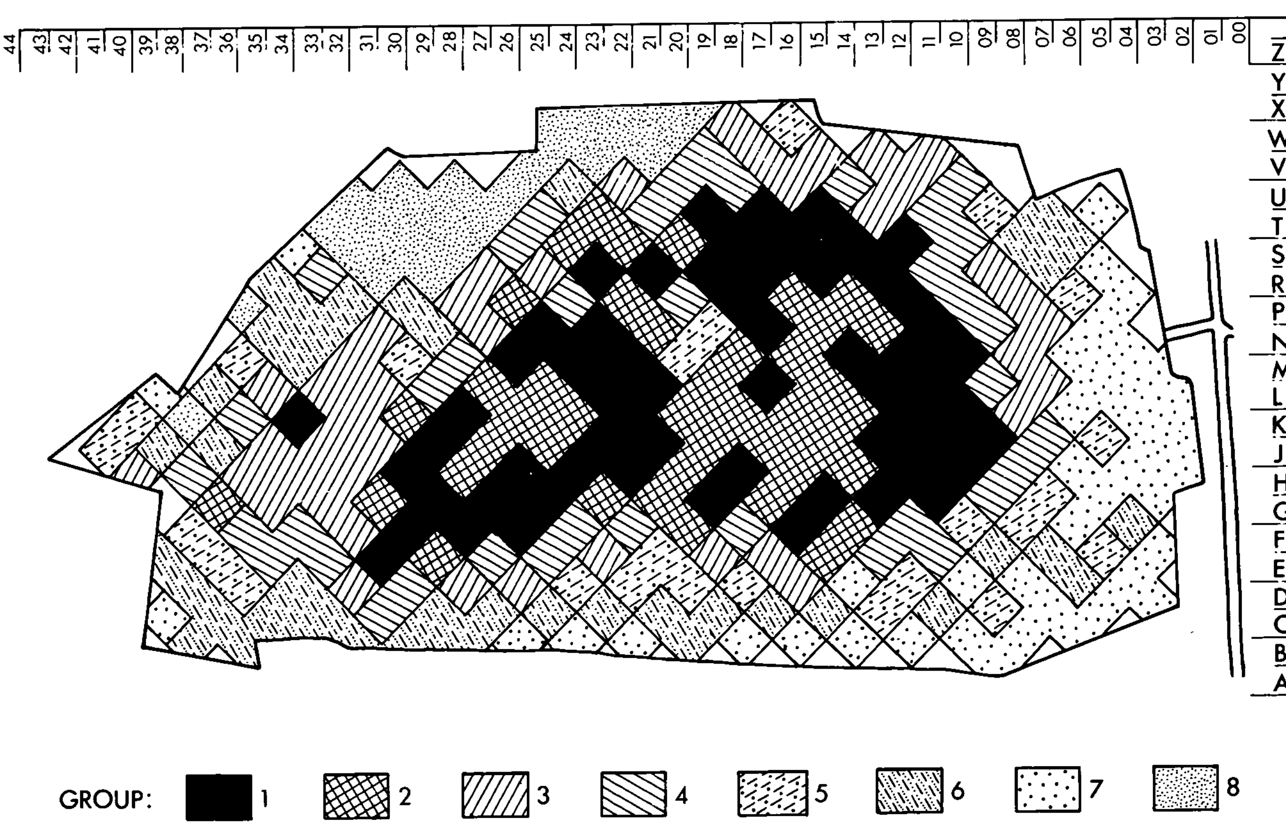

Fig. 17 *Map showing the distribution of 8 vegetation groups at Kirkconnell Flow NNR, based on samples taken 71 m apart (compare with Figure 16 where samples were taken 100 m apart). See Table 9 for Group component species.*

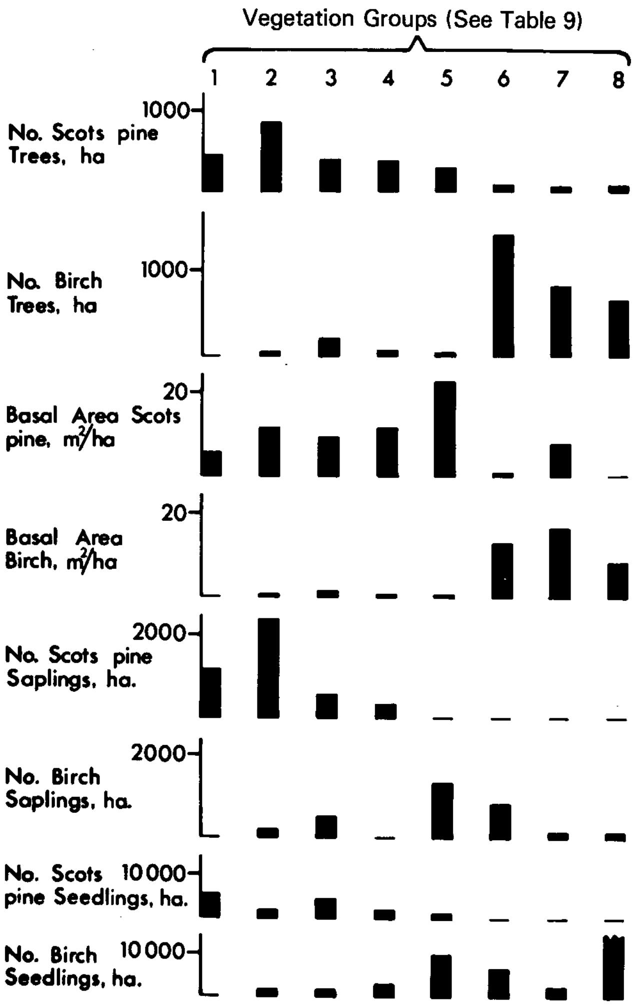

Fig. 18 *Association, at Kirkconnell Flow NNR, between the distribution of sapling and mature specimens of* Betula *spp and* Pinus sylvestris, *and the occurrence of 8 different groupings of other plants.*

created to attract wildfowl, while an arable area of 1.5 ha is left fallow or planted with barley or kale. Because the 'concessions' were expected to increase habitat diversity, attempts are being made to assess the effects of this modified afforestation on the pre-existing vegetation.

The distribution of sampling sites at Stone Chest is, like that at Kirkconnell Flow, based on a regular grid with intersections at 100 m intervals. On the first occasion, in 1972, quadrats were located at 139 sites (Figure 19). The second set of samples, in 1975, was confined to 80 locations whereas in 1978, the third occasion, 87 quadrats were recorded, some having been sampled in 1972 but not in 1975 whereas others had been sampled both in 1972 and 1975. With this sampling method, akin to a partial replacement system, 63 quadrats have been sampled on all 3 occasions.

Ordination has been used as a method for the preliminary examination of changes in the vegetation. Each individual stand is represented as a point in space whose co-ordinates are determined by the species contained in the stand. The first or principal axis along which stands are arranged represents the direction of maximal variation between stands and this is supplemented by other axes which represent other small variations between stands. The arrangement of stands along these axes, which may be expected to reflect environmental gradients, was calculated in this case by using the ordination technique of 'reciprocal averaging' (Hill, 1973). Figure 20 shows the arrangement of stands on the first and second axes of the ordination; each of the re-sampled stands is represented 3 times, one for each sampling occasion, and lines have been drawn between them to show the temporal movement of each stand through the species space of the ordination. In general there is a tendency for stands to have lower scores on the second axis in 1975 and 1978 than in 1972, causing a movement trend down the second axis; on the first axis there is a suggestion of movement from both ends towards the centre. These tendencies are seen more clearly when axes are separated as in Figure 21

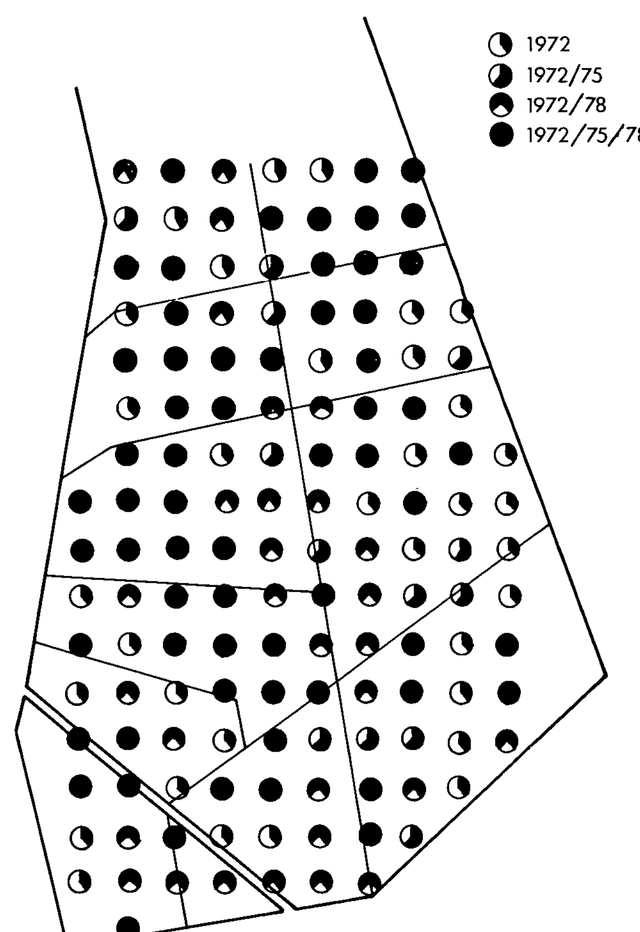

Fig. 19 *Location of sample quadrats, arranged on a 100 m grid at Stone Chest, in 1972, 1975 and 1978.*

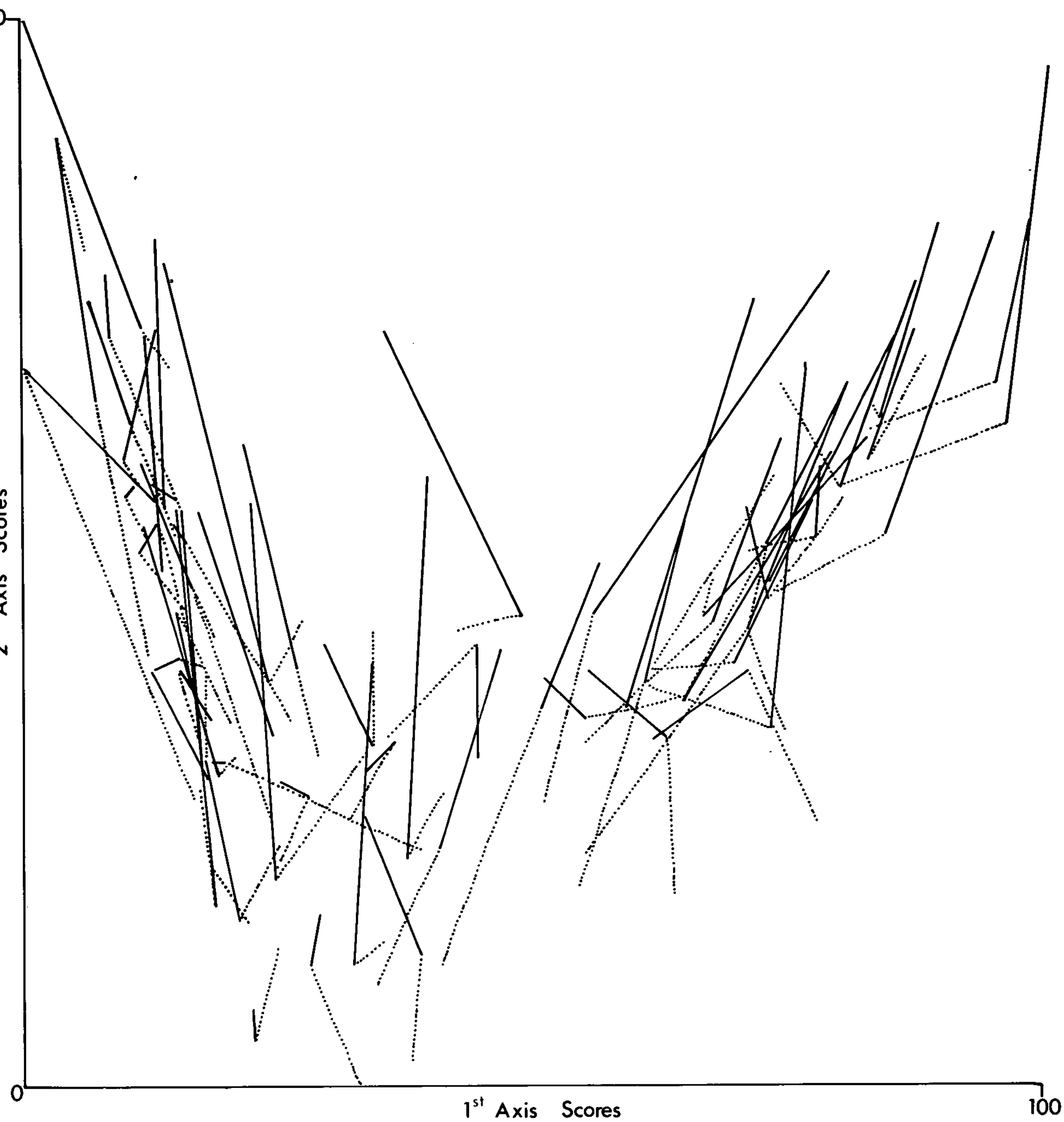

Fig. 20 *Changes in vegetation at Stone Chest, represented by 'movements' on the first and second axes of a reciprocal averaging ordination during 2 periods (1972-5, —, 1975-8, ·····).*

where each line shows the way in which a single stand moved along each of 3 axes during the 2 3-year periods. Stands which had high scores on the first axis in 1972 tended to have lower scores by 1978 and the converse was true of stands with low scores in 1972; those with moderate scores changed relatively little but tended to oscillate. A quite different pattern emerges on the second and third axes, where the overall trend is the same in all stands but is exaggerated in the period 1972-75.

To understand the meaning of these trends requires an interpretation of the meaning of the axes of variation. A step towards explaining their meaning is taken by plotting first axis stand scores against the pH of the 0-5 cm soil horizon (Figure 22). There is seen to be a strong overall relationship between the scores and pH which, when taken together with the time trajectories of the stands on the first axis, suggests that highly acidic soils have decreased in acidity, less acidic soils have become more acidic and those in the middle of the range have been little affected. Classification of the stands into 4 groups based on their first axis scores allows a clearer sight of these different trends (Figure 23). Whilst the mean score of all stands remains constant in time on the first axis, the behaviour of Group 3, which is the most acidic and has vegetation made up of such species as *Calluna vulgaris, Trichophorum cespitosum, Eriophorum angustifolium* and *Vaccinium myrtillus,* is different from Groups 1 and 2, the least acidic which contain species such as *Ranunculus acris, Prunella*

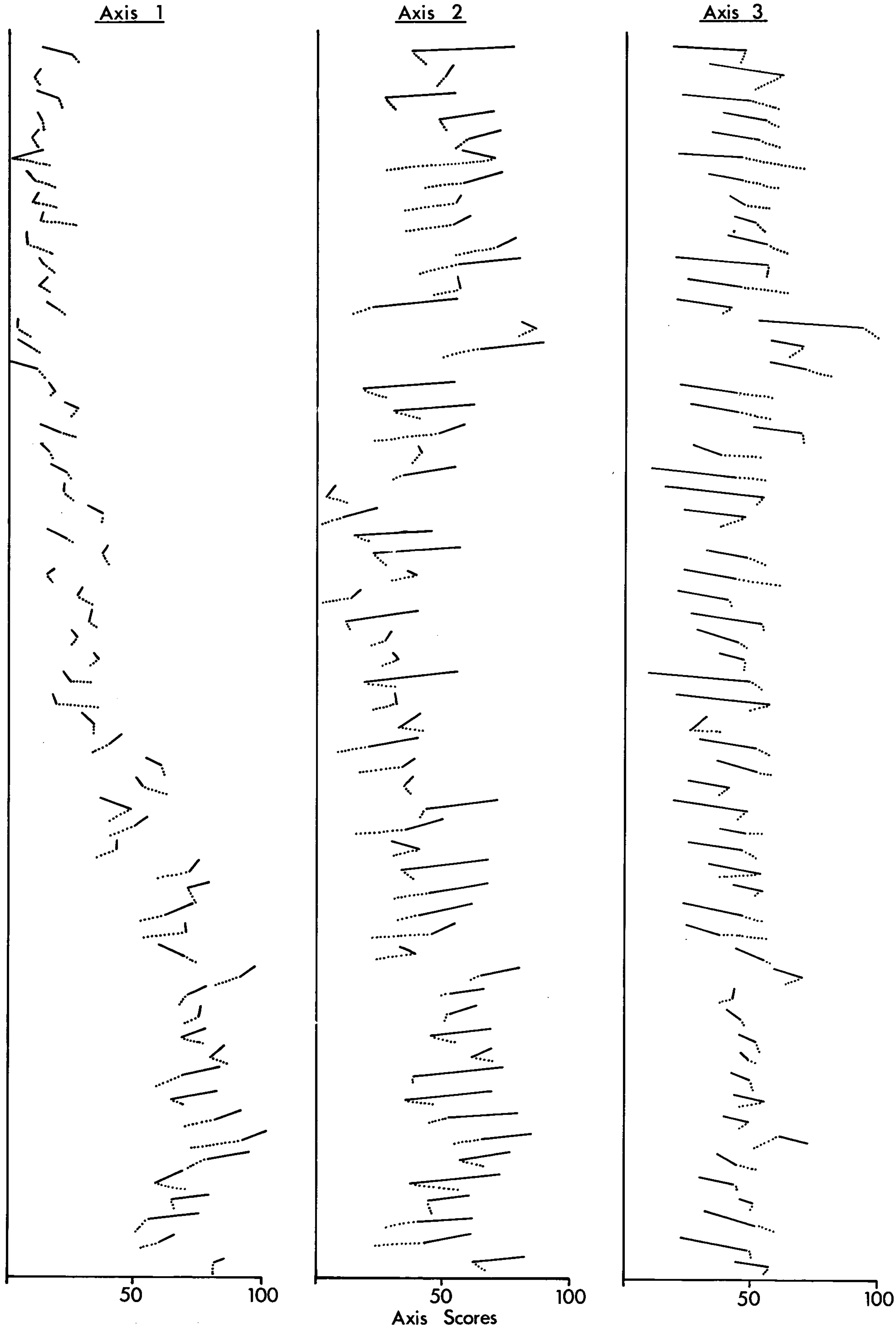

Fig. 21 *The extent of change during 1972-5 (—) and 1975-8 (·····) in vegetation assemblages at Stone Chest, when plotted on each of 3 axes of a reciprocal averaging ordination.*

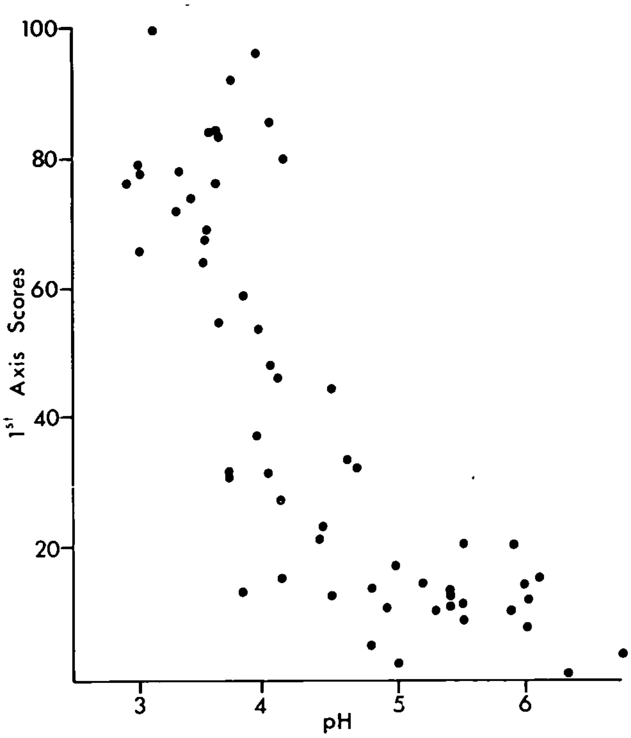

Fig. 22 *Relation between first axis scores from a reciprocal averaging ordination and soil pH in the 0.5 cm soil horizons at Stone Chest.*

vulgaris and *Trifolium repens.* The hypothesis of changing acidity can obviously be tested in the field.

Although the trends of movement by stands along the second and third axes during the 2 time periods are more distinct than those along the first axis, they have not, at this early stage, been fully interpreted because there is no readily measured environmental variable with which they can be correlated. They are likely to be related to a complex of the following factors which have resulted from change in land use at Stone Chest:

(i) Changes in drainage patterns and moisture content of the soil.

(ii) Removal of grazing, enabling some plant species to become dominant at the expense of others which decline or disappear.

(iii) The initial but temporary presentation of new surfaces for colonization resulting from ploughing.

A complete interpretation of the time trends shown by these techniques will depend on an understanding of the species and communities concerned. With only 3 sets of time sequence data available, it is too early to assess the usefulness of this approach in understanding the processes of change, but it appears to be a useful means of summarizing large amounts of data.

Reference

Hill, M.O. 1973. Reciprocal averaging: an eigenvector method of ordination. *J. Ecol.*, **61**, 237-249.

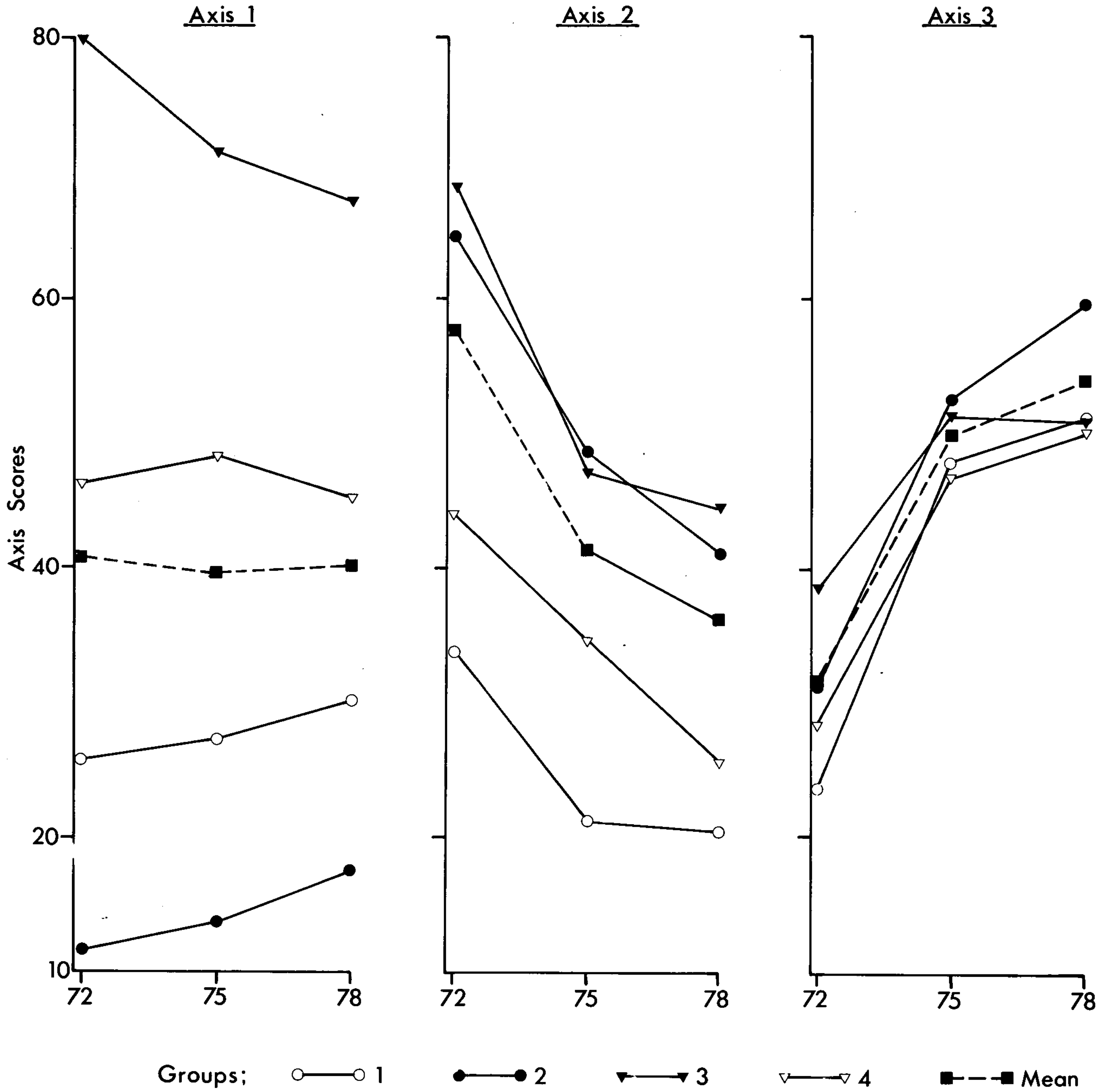

Fig. 23 *Changes in time at Stone Chest in the mean axis scores of 4 vegetation groups.*