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CHANGES IN FLORA AND FAUNA ASSOCIATED WITH THE AFFORESTATION OF A SCOTTISH MOOR - AN EVALUATION

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Introduction

In general, the commercial afforestation of areas previously used for extensive sheep grazing, grouse shooting, or deer stalking results in a number of changes in the fauna and flora of the area:-

i. A change in bird species and numbers (see Fig. 1) usually involving an increase in the overall diversity of species and in the total number of breeding pairs, but possibly involving a decrease in readily-observed or easily-identifiable species.

ii. A decrease, or elimination, of the previous vegetative cover within the planted areas, and a change in the species content of the areas left as rides or open glades, followed by an influx of a number of more shade-tolerant species.

iii. A decrease in some species of mammals and reptiles (e.g. lizards, adders and mountain hares), and an increase in other species (e.g. roe deer, and red squirrels).

iv. A reduction in invertebrate species dependent upon a moorland vegetation (e.g. northern eggar moth) and an increase in species dependent on woodland conditions (e.g. wood wasps).

The overall result is, therefore, complex, and an assessment of its implications for wildlife conservation depends as much on a definition of the objects of conservation as on a knowledge of the exact effect on each species involved.

The rationale behind the conservation of wildlife has been discussed elsewhere (Helliwell 1971), and a number of general principles have been evolved which may be of use here.

An attempt is made in this paper to use these principles to arrive at an objective assessment of the effects of afforestation on the wildlife of an area in South Scotland.

1) Choice of study area and scope of the study

The impetus for this study arose from the purchase by the Forestry Commission of several thousand acres of land in an area of particular interest to the Nature Conservancy.

Survey resources were limited, but an examination of the area was thought to be desirable.

The area of particular concern was about 5,000 hectares of land around the Cairnsmore of Fleet, adjoining the Forestry Commission forests known as Kirroughtree Forest, and Bennan Forest, which form part of the area which the Commission have designated as the Glen Trool Forest Park.

This area forms part of an outcrop of granite (Map. 2), and is surrounded by the sedimentary/metamorphic rocks which form most of Scotland south of a line from Girvan to Dunbar.

The remaining part of this outcrop has, to a large extent, been afforested already; mostly in the last 25 years. It was logical, therefore, to study an area roughly corresponding to this outcrop in order to examine the probable effects of further afforestation around the Cairnsmore.

The interest of the Cairnsmore is, to a large extent, a direct result of its geological composition, which makes it more craggy and more acidic than the surrounding areas. A similar (though generally higher) area of granite occurs a few miles to the north in the centre of the Forest Park, and there is another outcrop to the south-west of Dumfries, around Criffell.

The vegetation of the study area is, in general, distinctly different from most sites at similar altitudes elsewhere in south Scotland. A number of sample sites were visited (see Map 1 and Appendix 1) in order to obtain a comparison (Fig. 3-6) with other areas.

Within the main study area, the forestry Commission kindly supplied estimates of the numbers of deer, goats, foxes, hares and squirrels. The Scottish Naturalists Trust and Mr. E. L. Roberts and Dr. D. A. Ratcliffe of the Nature Conservancy provided information on the numbers and territories of the larger and rarer bird species, and 10 minute counts were made of all birds species seen or heard at each of the 49 sample points in the area (Fig. 2).

These bird counts are not significant individually, but, taken overall, conform closely to the pattern found by previous workers.

It was not possible, with the time and resources available, to survey invertebrates, reptiles, or small mammals, and the floristic survey was restricted to flowering plants and a limited number of ferns and mosses.

2) Sampling in the study area

The study area contains the centre points of 186 1 km grid squares of the National Grid. A method of sampling these was required.

Details of the slope, aspect, altitude, distance from the sea, the nearest stream, and the nearest public road were recorded for each of the 186 points. These data were then subjected to principle components analysis, and the values for the first 5 components were analysed to assess the similarity between pairs of points, giving "nearest neighbours", or points which are most similar to each other in respect of the factors recorded. These were then grouped into a number of "clusters" or groups of points, giving 12 such groups (Map 3).

From 10 of these groups, two pairs of sites were selected from each, such that one of each pair was on land which had been afforested for more than 5 years and the other was not. Where there were more than two such pairs in a group, the two which were closest in the "nearest neighbour" analysis were selected.

In the remaining 2 groups only 1 such pair could be obtained for each group, owing to the fact that these groups of sites were mostly above the elevational commercial planting limit. A single unpaired, unplanted, site was also taken, in each of these two groups, at random.

This gave a total of 46 sample sites.

Two additional sites were also samples to increase the range of age of plantations sampled; and one site to include broadleaved trees; giving a total of 49 sites in all.

The vegetation was recorded in 10 quadrats of 1 sq. m. each, placed, by reference to a table of random numbers, within a square area of 70 x 70 m. (approx. $\frac{1}{2}$ hectare) at each site. Species were recorded as being present or absent in each quadrat. Species present within

the area and not recorded in any quadrat were also listed.

3) Results

Fig. 3 shows the relative positions of all 63 sites (including those outside the Cairnsmore area), using the first two axes of an ordination of the floristic data, using the perpendicular axes method described by Orloci (1966), with interstand distance as the coefficient of similarity.

Fig. 4 shows that the sites outside the Cairnsmore study area tend to occur towards the top left corner of the ordination. They appear to represent the more "lowland" types of vegetation with a greater diversity of species.

Fig. 5 shows that sites with forest cover tend to occur towards the top right hand corner of the ordination, representing a tendency towards fewer species and a tendency for "upland" species to be replaced by "lowland" species.

Fig. 6 shows that the distribution of sites of low conservation importance conforms (with one easily-explained exception) to very similar axes to the distribution of afforested sites.

The method used for assessing "conservation importance" in this instance was based on the method described later in this paper, whereby each species is allotted a "basic score". In this case, the scores for all species occurring in at least one quadrat were added to a quarter of the total score of any other species recorded outside the quadrats, to give an estimate of the conservation importance of the flora. This assumes that the species occurring outside the quadrat are about one fortieth as abundant as those recorded in the quadrats, and is, therefore, only an approximation.

There was considerable variation between individual quadrats at a site, due to the existence of a pattern of drier and wetter areas in the upland sites and to the presence of rides or gaps in the plantations. The scale of this variation was fairly constant, however, as could be seen from aerial photographs of part of the Cairnsmore, and was less than the 70 x 70 m sample size in all the unplanted areas. Most of the planted areas had a gap or ride within the sample.

The change in numbers of plant species per square metre and per 70 x 70 m plot can be tested statistically using the 44 paired plots in the main study area:

1 m x 1 m quadrats

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F values
Blocks	10	31.75	3.175	4.446 *
Error (a)	11	7.78	0.7142	
Afforestation	1	68.40	68.40	37.782 ***
Error (b)	21	38.02	1.8104	
Total	43	145.95		

	Mean no. of plant species	Standard error
Afforested quadrats (mean of 10)	3.45	± 0.2294
Non-afforested quadrats	5.92	± 0.2378

70 m x 70 m plots

Source variation	Degrees of freedom	Sum of squares	Mean squares	F values
Blocks	10	792	79.2	1.332 (N.S.)
Error (a)	11	654	59.46	
Afforestation	1	427	427	13.167 **
Error (b)	21	681	32.43	
Total	43	2,554		

	Mean no. of plant species	Standard error
Afforested plots	13.5	± 0.8795
Non-afforested plots	19.8	± 1.901

This analysis suggests that, in the area examined, afforestation is associated with a highly significant decrease in the number of species per square metre, and a somewhat lesser decrease in species per 70 x 70 m plot.

Figs. 7 and 8 show these trends in graphical form, with the results from two additional, older stands added, which indicate that there may be a likelihood of some increase in the number of species as the trees mature.

The same results are also represented in Figs. 9 and 10 showing the somewhat greater disparity between the numbers of species in afforested and unafforested sites at the quadrat level than in the whole plot samples. This effect is due to the few individual plants which survive in rides and clearings, which are more likely to be recorded in the larger-sized samples.

4) Discussion

The main tree species being planted in S.W. Scotland is Sitka spruce, with the intention of growing it for about 50 years and then clear-felling before planting the next crop. Some Lodgepole pine is also planted, usually in mixture with the Spruce.

The vegetation within any planted area is completely, if temporarily, eliminated, except where there is a gap in the canopy, during the thicket stage; and if this stage is reached once every 50 years there will not be very much opportunity for a complex woodland flora to develop. Similarly, rides and trackways will be disturbed by timber extraction and are unlikely to be very useful for the conservation of flora unless they were to be wider than those currently in existence, thus admitting more light and giving a greater area of land between the plantation edge and the roadway itself.

The only site bearing a second crop of Spruce (site 19) does not have a flora significantly different from first rotation crops in the area, and gives no indication that future crops will be of much more conservation value than those examined in this study.

It is evident, however, that, in general terms, some afforestation is beneficial for wild-life conservation, as it brings in bird species such as coal tit, chaffinch, and goldcrest, which are not present on the open hill. Most of the species of birds which are found on the open hillside are, however, eliminated from the afforested area, along with most of the vegetation and its associated moths, bees, and other insects.

In general terms, therefore, some mixture of forested and open land will conserve the greatest variety of wild life.

The actual proportion of each which would give optimal results may vary according to:-

a) the species of trees planted
b) planting distance and thinning regime
c) length of crop rotation
d) method of regeneration
e) the number and nature of open spaces within the forested area
f) the management of the open land not afforested
g) the existence of critical limits to territorial areas of certain species
h) the proportion of forested land in adjacent areas

Assuming, however, that the vegetation and fauna recorded in the present study is indicative of the future situation, an attempt can be made to compile a "balance sheet" for an area of land (e.g. 1 square kilometre), as open hill or as a conifer plantation with a normal distribution of age classes and a few open rides and gaps.

The method used for giving scores to each species is based on the principles outlined by Helliwell (1971). In the case of the animal species, the overall length of the animal has been multiplied by a figure relating to its estimated rarity in the British Isles to give a "basic score" for the species. For example, using the lower curve in Fig. 13 (which is reproduced from the above mentioned paper) it is evident that a bird such as the black-grouse, which has a relatively restricted distribution, should receive considerably greater weight than a very common species of equal size, such as the crow, in those areas where it does occur. The question of size is introduced as the presence of one individual of a large species such as red deer is likely to be more significant than the presence of one individual of a smaller species, such as red squirrel. The larger the animal the fewer individuals would one expect to find in a given area. Thus, a healthy and flourishing population of red deer may have an average area of 50 hectares per animal, whilst a healthy and flourishing population of red squirrels may be expected to be more numerous than that. Also, the existence of a population of the larger animals often indicates the existence of conditions which are suitable for a range of smaller animals, whereas the reverse is not necessarily the case.

The "total score" given in Table 1 is obtained by multiplying the "basic score" by a factor related to the numbers of individuals

estimated to be present in the area being considered. This factor is obtained by reference to the upper curve in Fig. 13, which relates to the relative values of different amounts of a resource.

The "relative numbers" listed in Table 1 are derived from the survey data and information mentioned above. To a certain extent, however, these figures are not completely objective. For example, the number of records of cuckoos made during the survey would considerably over-estimate their abundance relative to, for example pied wagtails, which are less easily seen or heard. Some adjustment was necessary, therefore. Whether or not this has been done correctly is, perhaps debateable; but to have carried out a completely objective survey would have required a full census of each species, which would have taken skilled observers several months to complete. However, it is thought that the order of magnitude of the numbers is correct, and slight alteration would not greatly affect the total result; particularly as the numbers have not been used as they stand, but through the medium of the curve in Fig. 13. If, therefore, an estimated number of 8 birds has been given and the true figure is only 6, the "total score" for that species would only be over-estimated by 12%; not 33% , as may be supposed at first sight. Also, reasonably accurate estimates are possible for the species with the highest "basic scores", as the numbers of these are known.

In the case of the plant species, the figures obtained during survey work can be used as they stand; only making allowance for the fact that the older age-classes of plantations are under-represented at the present time.

The scoring for the plant species is on the basis that, if a common species scores 1, a less common species will score about 3, an uncommon species 10, a rare species 30, and a very rare species 100 (see Fig. 13). Scores were given on this basis, using the Atlas of the British Flora (Perring and Walters, 1962), at a South Scotland level and at a British Isles level; the mean of the two scores being used.

No rare species of plant are known to occur in this study area, except one species of moss (in a single locality, where it can be fairly easily conserved).

Table 1. Evaluation of species on open hill and in forest

A. Open hill land				B. Afforested land		
Relative numbers	Basic score	Total score		Relative numbers	Basic score	Total score
			Blackbird	10	10	50
			Blackcap	6	9	38
1	108	238	Black Grouse	3	108	346
			Blue tit	10	5	25
			Bullfinch	6	6	25
0.25	126	164	Buzzard	0.1	126	101
			Chaffinch	50	6	51
			Chiff-chaff	6	6	25
			Coal tit	60	5	105
1	19	42	Crow	0.5	19	32
0.25	13	17	Cuckoo	0.2	13	14
1	33	73	Curlew	0.1	33	26
			Dunnock	8	6	28
			Garden warbler	4	9	32
			Goldcrest	30	4	29
0.1	660	528	Golden eagle			
			Greenfinch	6	6	25
0.25	216	281	Hen harrier	0.5	216	367
2	12	33	Lapwing			
1	23	51	Mallard	1	23	51
65	6	60	Meadow pipit	16	6	36
0.25	170	221	Peregrine	0.1	170	136
			Pheasant	2	32	88
0.25	150	195	Raven	0.1	150	120
4	60	216	Red grouse			
1	40	88	Ring ouzel			
			Robin	10	6	30
			Siskin	4	15	54
10	7	32	Skylark	2	7	12
			Song thrush	6	9	38
			Sparrow hawk	1	20	44
2	12	33	Stonechat	4	10	36
			Tree pipit	8	12	56
			Willow warbler	40	4	33
4	10	36	Whinchat	10	10	50
			Whitethroat	4	6	22
			Wood pigeon	4	16	58
93.5		2308		312.6		2183
1	80	176	Blue hare	0.2	80	88
0.3	33	49	Brown hare	0.2	33	36
0.5	52	88	Fox	0.2	52	57
2	300	825	Goat (feral)			
2	400	1100	Red deer	0.5	400	680
			Red squirrel	5	20	78
			Roe deer	0.5	215	366
5.8		2238		6.9		1305
2	16	44	Adder	0.5	16	27
2	8	22	Lizard	0.5	8	14
2	15	42	Slow worm	0.5	15	25
6		108		1.5		66
		4654				3554

Table 1. continued

Relative numbers	Basic score	Total score		Relative numbers	Basic score	Total score
150	1	13	Agrostis spp.	100	1	12
20	1.5	9	Anemone nemarosa	2	1.5	4
50	1	9	Anthoxanthum odoratum	100	1	12
			Betula spp.	10	1	5
30	1.5	11	Blechnum spicant	3	1.5	5
1000	1	26	Calluna vulgaris	10	1	5
150	1	13	Carex spp.	50	1	9
3	15	48	Carum verticillatum			
20	1	6	Cerastium spp.	3	1	3
5	1	4	Cirsium spp.	50	1	4
			Conopodium majus	2	1	3
1	6	14	Dactylorchis maculata			
50	1.5	14	Deschampsia flexuosa	200	1.5	22
10	6	30	Drosera rotundifolia	0.2	6	7
5	1.5	6	Endymion non-scripta	10	1.5	8
			Epilobium angustifolium	1	1	2
100	2	23	Erica cinerea	2	2	6
800	1.5	36	Erica tetralix	16	1.5	9
400	5	95	Eriophorum angustifolium	8	5	24
300	7	119	Eriophorum vaginatum	6	7	29
100	1	12	Festuca ovina	10	1	5
20	1	6	Galium saxatile	30	1	7
1	15	33	Genista anglica			
20	1	6	Holcus lanatus	50	1	9
50	1	9	Juncus articulatus	3	1	3
10	1	5	Juncus effusus	30	1	7
20	4	24	Juncus squarrosus	2	4	11
30	1	7	Luzula spp.	30	1	7
1000	1.5	39	Molinia caerulea	100	1.5	17
100	8	92	Myrica gale	2	8	22
50	2	18	Nardus stricta	1	2	4
300	7	119	Narthecium ossifragum	6	7	30
30	1	7	Oxalis acetosella	300	1	17
10	1.5	8	Pedicularis spp.	0.1	1.5	1
5	6	23	Pinguicula vulgaris	0.1	6	5
10	1	5	Poa spp.	10	1	5
50	1.5	14	Polygala spp.	1	1.5	3
50	1.5	14	Polytrichum commune	100	1.5	17
400	1	19	Potentilla erecta	40	1	8
50	1	9	Pteridium aquilinum	100	1	12
3	1	3	Rumex spp.	3	1	3
1	1	2	Salix spp.	5	1	4
400	7	113	Scirpus caespitosus	8	7	33
1	1	2	Sorbus aucuparia	10	1	5
100	1.5	17	Sphagnum spp.	100	1.5	17
50	1	9	Trifolium repens	2	1	3
100	2	23	Vaccinium myrtillus	100	2	23
20	3	19	Viola palustris	50	3	27
2	1	3	Viola riviniana	20	1	6
6077		1156		1641.4		480

Some species of relatively limited distribution were recorded, but the flora is not, in itself, very remarkable, except as an example of an upland type of vegetation which is more commonly found further north and west.

The main interest of the area lies in its fauna; in particular the larger birds, deer, goats, and mountain hares. Thus, on the basis of the scoring system used here, 10 species of animal (black grouse, buzzard, golden eagle, hen harrier, peregrine, raven, red grouse, blue hare, goat, and red deer) account for approximately 85% of the value of the fauna of the open land, whilst the 14 commoner species account for the remaining 15%.

As the assessment of the fauna is necessarily based on different units of measurement to those used for the flora, some means must be found of placing these assessments on a comparable footing. The method described in Appendix 3 of the paper mentioned above (Helliwell 1971) is designed for the valuation of species which are under some form of major threat and is not designed for the accurate evaluation of populations representing only a very small fraction of the species. Nevertheless, when used for a large number of species, such as is involved here, it should give a reasonably sound basis for assessing the relative importance of one large group of species (i.e. animals) against another large group (plants).

Using this method, the animals are valued at approximately 2.2 times the value of the plants, on the open hill.

It is necessary therefore, to adjust the relative values of the flora and fauna accordingly, giving:

	Open hillside	Forest
Fauna	4,654	3,554
Flora	2,115	878
Total	6,769	4,432

On this basis it is evident that an area of open hillside is worth about 53% more than a comparable area of plantations, for wildlife conservation.

Referring again to the upper curve in fig. 13, it is possible to estimate the proportion of afforestation which would be of greatest value to wildlife conservation. In spite of the fact that the open hillside scores more than the afforested areas it is evident that the planting of, say, 10% of the area would introduce an added range of wildlife without greatly reducing the existing range. Table 2 gives the relative values obtained by different proportions of forest.

Table 2. Relative values of different proportions of forest land

% area afforested	Relative value of forest	Relative value of open land	Total relative value
0	-	153	153
10%	43	153	196
20%	55	144	199
30%	64	137	201
40%	72	128	200
50%	78	119	197
60%	84	110	194
70%	90	98	188
80%	94	84	178
90%	98	66	164
100%	100	-	100

This is shown graphically in Fig. 14.

The optimum amount of afforestation would, therefore, be about one third of the total area.

This amount has already been exceeded; but the value of the area will not start to fall sharply until more than 50% has been planted; which is, approximately, the current state of affairs (see Map. 4).

However, as additional areas in South-west Scotland are afforested, the value of the remaining unplanted areas will tend to increase, rather than decrease, altering the equation in favour of less afforestation in any one particular area.

If the 10 species of animal mentioned previously were not present, the above evaluation would change to:

	Open hillside	Forest
Fauna	710	1,716
Flora	2,115	878
Total	2,825	2,594

In such a case (as may commonly occur elsewhere) the optimal extent of afforestation would be about 50% of the total area.

In order to increase this to, say, 70% of the total, appreciable modifications would be needed, to improve the conservation value of the plantations. For example, Jenkyn (1968) found 25 species of butterflies in an unplanted strip, three times the width of a normal forest road, which had been left beneath an electricity line running through a plantation. Similarly, using the general principle evolved by MacArthur (1964) and figures from Lack and Lack (1951)• it is evident that a greater degree of structural diversity in the forest would be likely to give a greater number and variety of birds (Figs. 11 and 12).

In only very exceptional circumstances could the afforestation of the whole of an area of this size (about 20,000 hectares) be justified in terms of wildlife conservation. Such a situation may arise where there is a large area (200 square miles, or more) of a uniform type of habitat, when afforestation, of say, 50% of the habitat may invclve a block of 25,000 hectares of forest; but in this case the total area of the granite outcrop is only about 60 square miles, requiring a smaller scale of afforestation if wildlife conservation is a major consideration.

As a final point it must be emphasised that the assessments in this paper are based entirely on the value of the area as a habitat for wild plants and animals.

If the area were considered from the point of view of its suitability as a nature reserve, the emphasis would be changed somewhat, according to the objects of management of the reserve. The value of the site as a representative of a certain habitat type, which could be used for

research work and educational purposes, may differ from the values mentioned here. The case for the establishment of a nature reserve is, therefore, outside the scope of this particular study.

5) Summary

i) An ordination of floristic data from the Cairnsmore of Fleet area and a number of other sample sites in South Scotland shows that the sites in the study area represent a more "upland" type of vegetation and have fewer species at the 70 x 70 m plot level than the other sample sites.

ii) Sites with forest cover have fewer species of plant than otherwise similar sites without forest cover; the difference being greater at the 1 x 1 m quadrat level than at the 70 x 70 m plot level.

iii) An evaluation of the flora reflects this reduction in species numbers, being lower in the afforested areas.

iv) Because of the elimination of vegetation during the "thicket" stage of a plantation, there is no reason to expect any significant difference in the flora of 1st and 2nd rotation crops. The only 2nd rotation crop sampled in the study area supports this view in being similar to 1st rotation crops.

v) The information collected on bird populations does not enable precise estimates to be made, but supports the view that afforestation gives an increase in the diversity of bird species.

vi) Available evidence, based on records over a number of years, indicates that certain species of birds and mammals are reduced in numbers by extensive afforestation. Of particular concern are:
golden eagle, peregrine, raven, buzzard, red grouse, blue hare, feral goat, and red deer.

vii) Some other species of birds and mammals are likely to increase in numbers after extensive afforestation; in particular:-
hen harrier, black grouse, and roe deer.

viii) An evaluation of such changes in flora and fauna indicates the optimal level of afforestation to be about 30% of the study area, as far as wildlife conservation is concerned.

ix) If the 10 species of birds and mammals of greatest "conservation value" were not present in this area, the optimal extent of afforestation would be about 50% of the total area.

x) It is possible that measures taken to enhance the value of the plantations for wildlife could increase the optimal amount of afforestation to some degree.

xi) Further large-scale afforestation in South Scotland is likely to increase the conservation value of any non-afforested areas which remain, which could reduce the optimal amount of afforestation in this particular area.

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Appendix 1

Choice of sample sites

The choice of sample sites within the main study area has been described on page 3 and is shown on Maps 3 and 5.

The sites outside the main study area were selected so as to be at the same altitude as the mean altitude of the sites within the study area (i.e. 715 ft. above sea-level). All 10 km squares of the National Grid lying between the English border and a line from Girvan to Dunbar which contained land at 715 ft. elevation were listed, and a number of these selected at random. Within each square thus selected each 1 km square containing a 715 ft. contour was listed and one selected at random. The sample site was located at the point on the 715 ft. contour closest to the centre of this square.

Where possible an afforested site was also selected, at 715 ft., as near to the unafforested site as possible. (One of these "afforested" sites turned out to be a semi-natural woodland of oak, birch, etc., in a steep-sided ravine, (Site No. 5), and is not directly comparable to the other sites visited, though it made an interesting comparison).

23 sites were selected in this way, and survey work commenced on the Eastern side of the country, working Westwards. 10 sites were surveyed before the weather changed to steady rain. A further 4 sites were examined, although quadrat data were not recorded, owing to the impossibility of recording in the pouring rain. A simple list of species only was recorded for these 4 sites. It was then decided to omit the remaining 9 sites.

Appendix 2

Faunistic Data

Bird Counts

During the 10 minute counts at sample sites, the following numbers of birds were seen or heard.

Meadow pipit	126		Oystercatcher	3
Black-headed gull	32	(mostly in one flock)	Starling	3
Wood pigeon	24		Pheasant	3
Sky lark	19		Tree pipit	3
Chaffinch	19		Wheatear	2
Willow warbler	18			
Grouse spp.	16		Song thrush	2
Curlew	15		Garden warbler	2
Coal tit	14		Whitethroat	2
Cuckoo	10		Black cap	2
Blue tit	6		Raven	2
Robin	6		Buzzard	1
Whinchat	5		Peregrine	1
Crow	5		Goldcrest	1
Blackbird	4		Tawny owl	1
Lapwing	4		Dunnock	1
Herring gull	4		Pied wagtail	1
Greenfinch	3		Bullfinch	1
Chiff-chaff	3			

The number of different species recorded at each site is shown, in relation to the height of the trees, in Fig. 2.

A number of other species were also seen occasionally, but were not recorded in any of the 10 minute counts.

Estimated number of mammals

(list suppied by the Forestry Commission)

Red deer	Stags	27
	hinds	45
	calves	21
Roe deer	bucks	76
	does	77
	kids	49
Goats		213
Fox		35
Blue hare		97
Brown hare		32
Red squirrel		25

Fig.1. CHANGES IN BIRD SPECIES AFTER AFFORESTATION (from other sources)

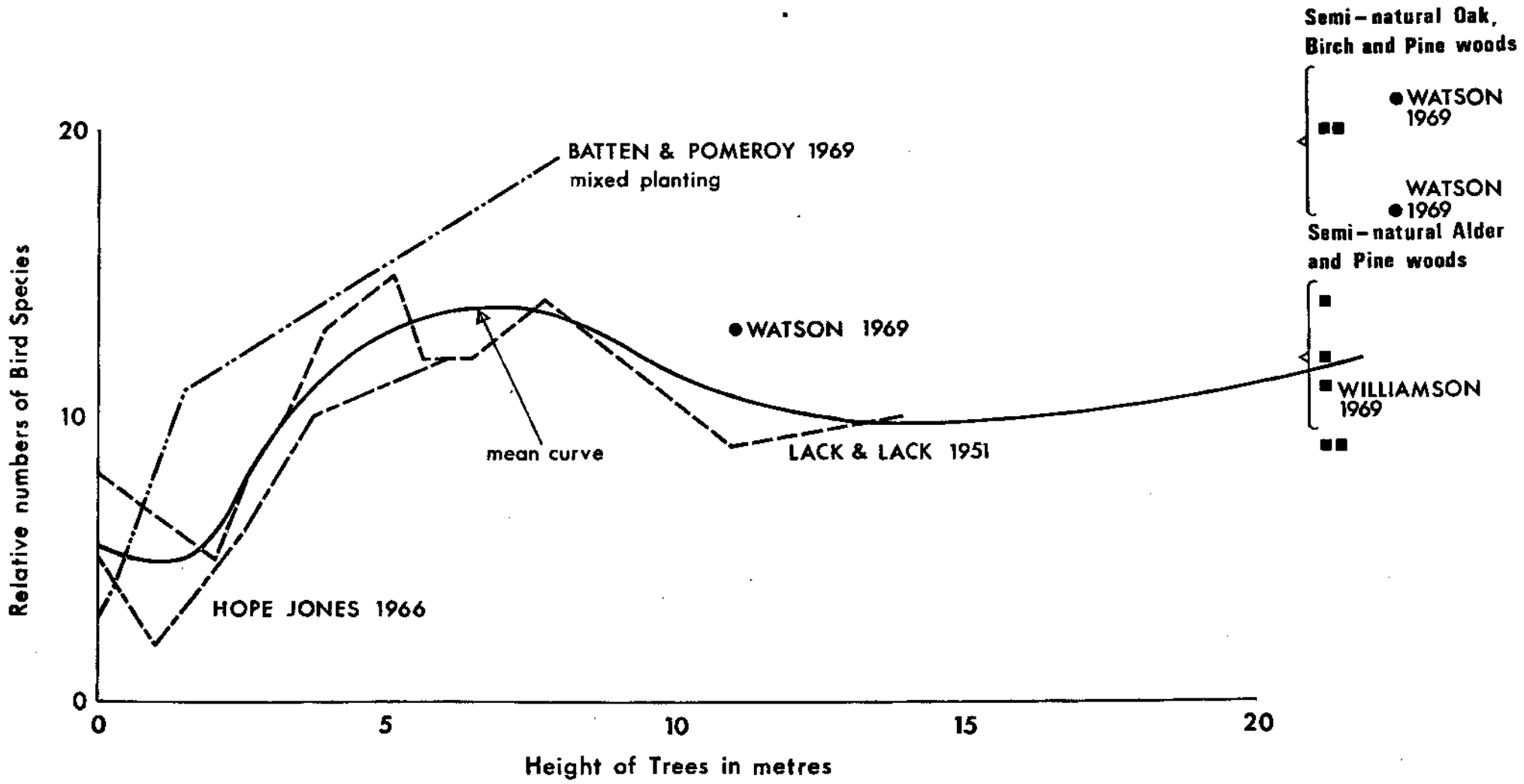


Fig.2. BIRD COUNTS AT FORTY-NINE SITES IN THE STUDY AREA

Fig. 3. ORDINATION OF FLORISTIC DATA FROM SIXTY THREE SITES IN SOUTH SCOTLAND

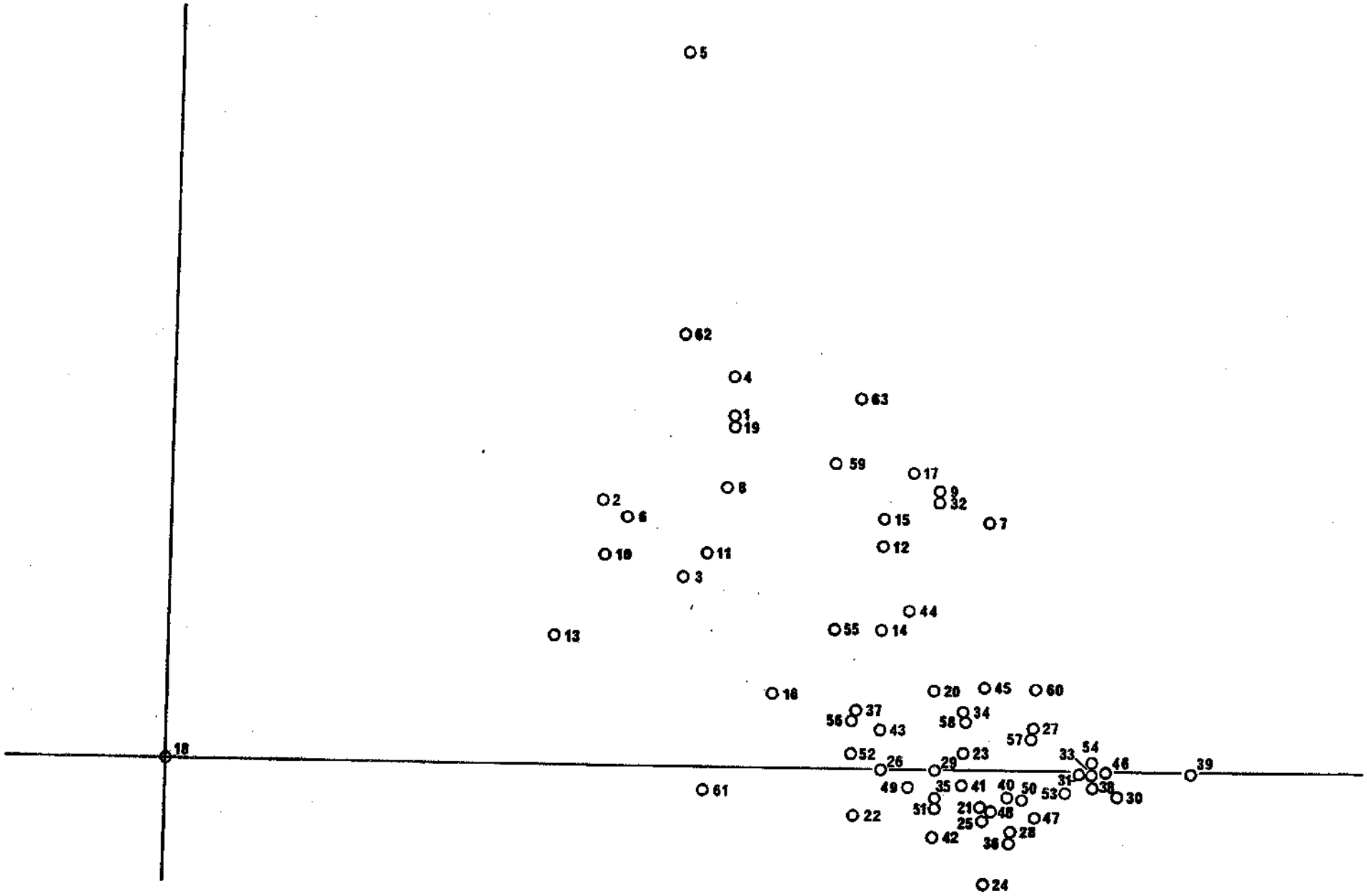


Fig. 4. ORDINATION OF FLORISTIC DATA FROM SIXTY THREE SITES SHOWING LOCATION

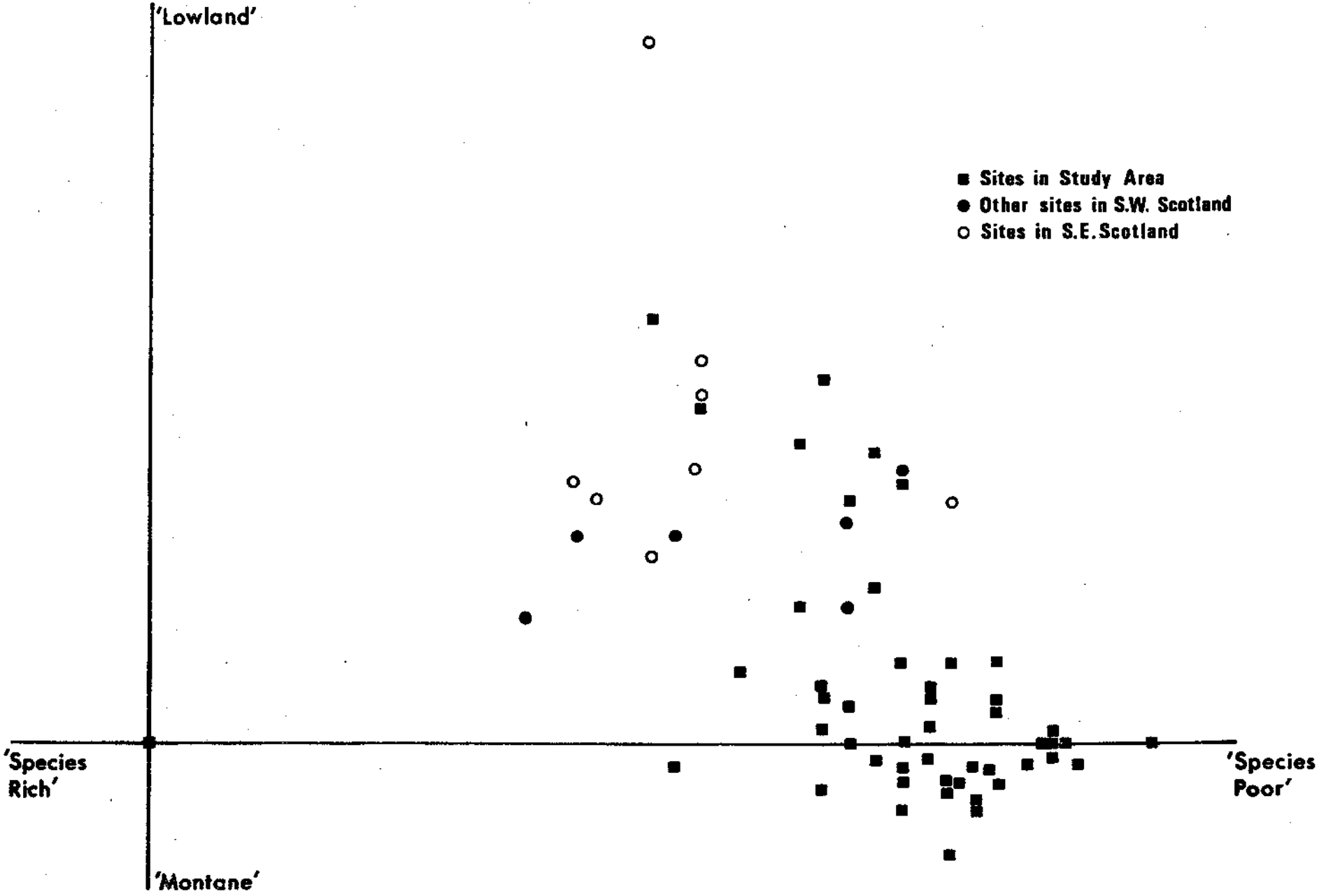


Fig.5. ORDINATION OF FLORISTIC DATA FROM SIXTY THREE SITES SHOWING MAIN TRENDS

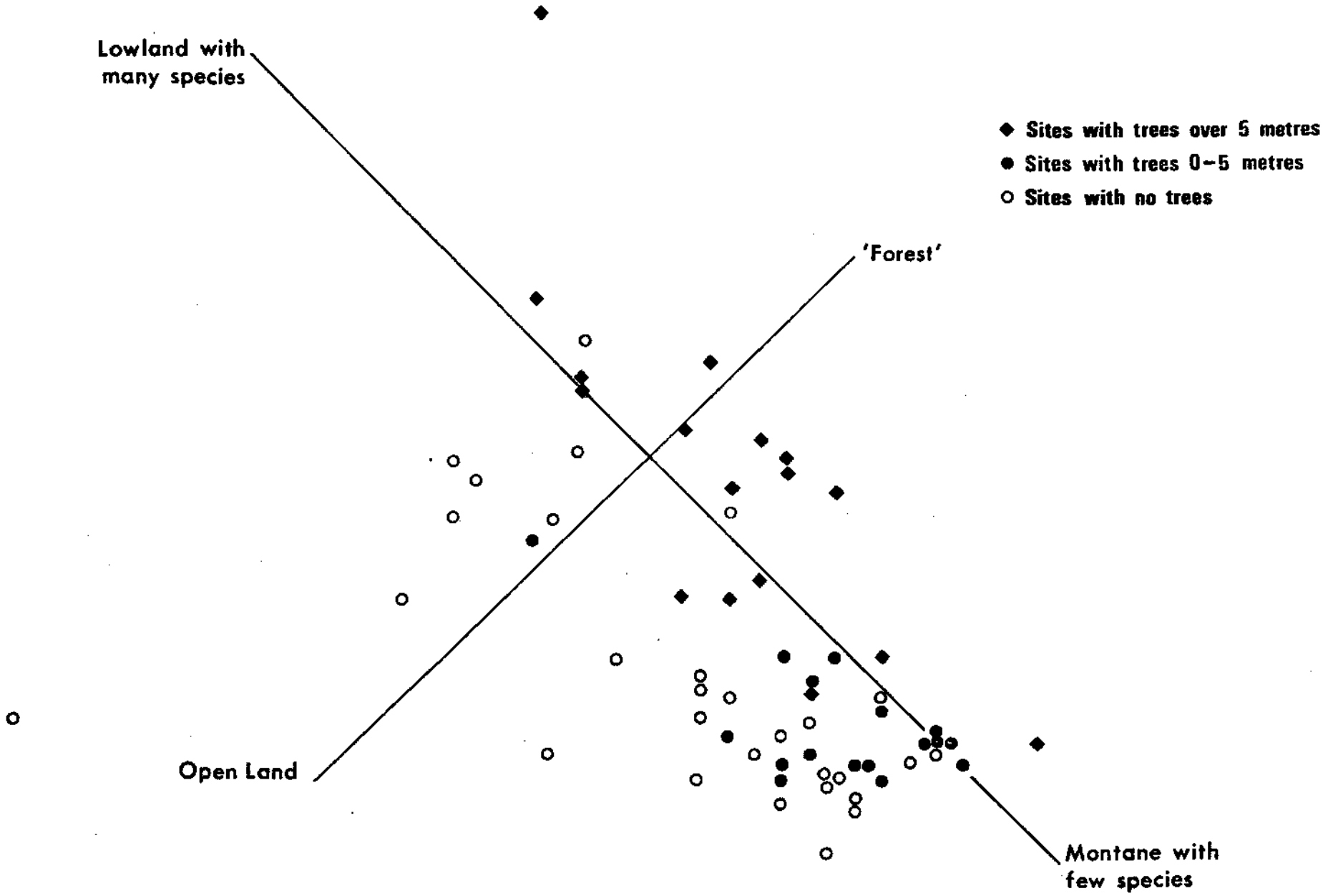


Fig. 6. ORDINATION OF FLORISTIC DATA FROM SIXTY THREE SITES SHOWING CONSERVATION IMPORTANCE

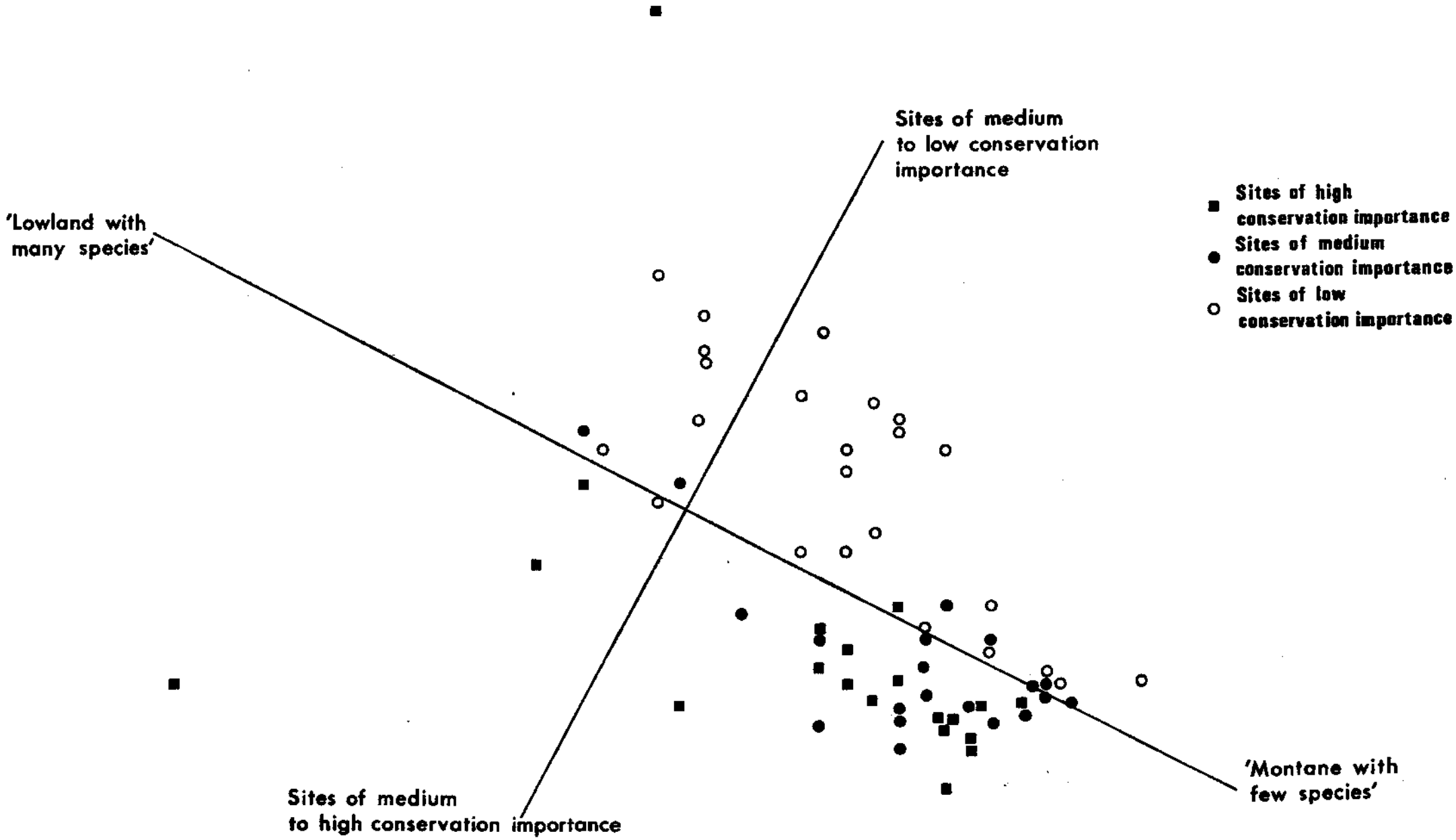


Fig.7. EFFECT OF AFFORESTATION ON FLORA
— square metre quadrats

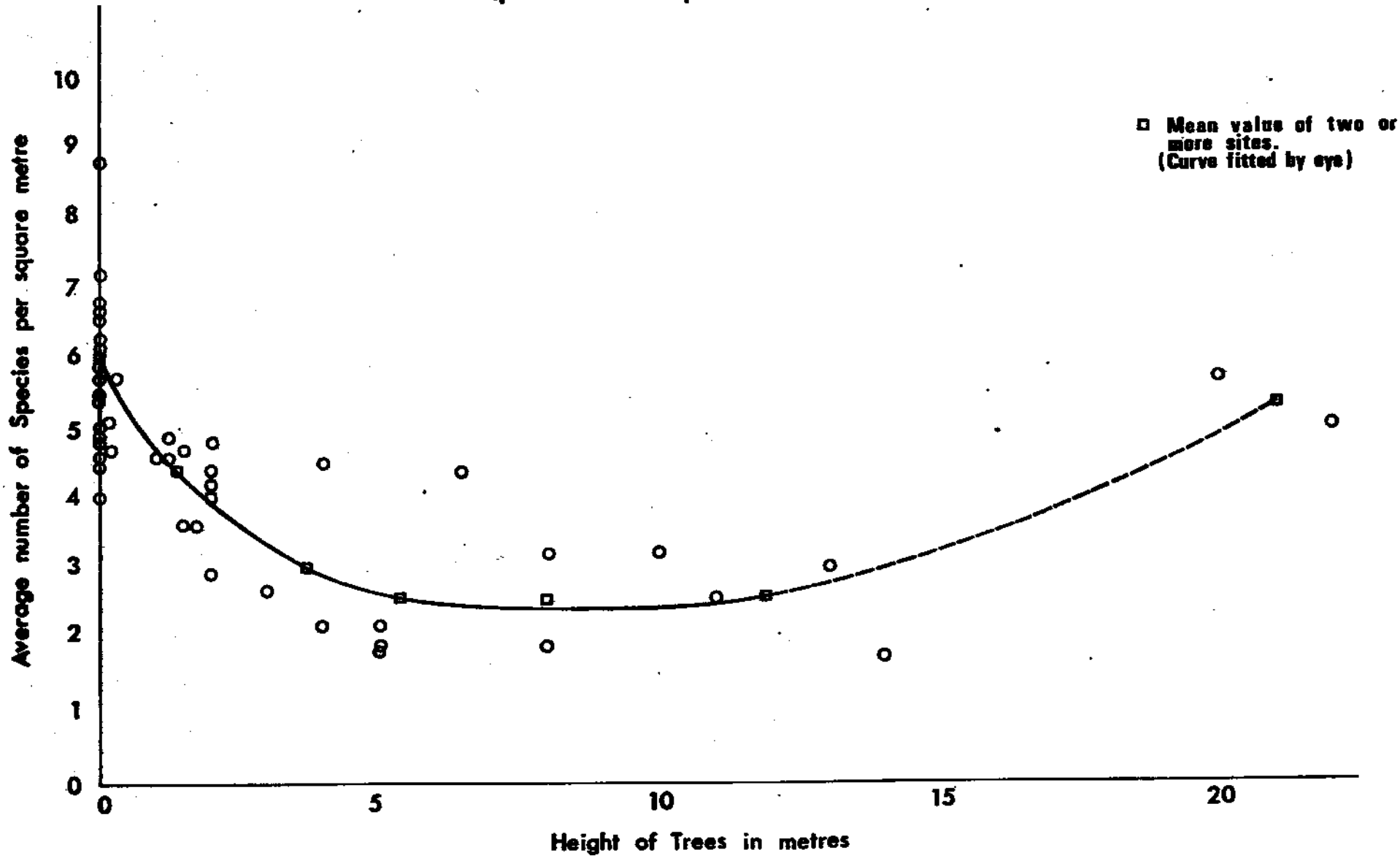


Fig. 8. EFFECT OF AFFORESTATION ON FLORA
— 70m. x 70m. plots

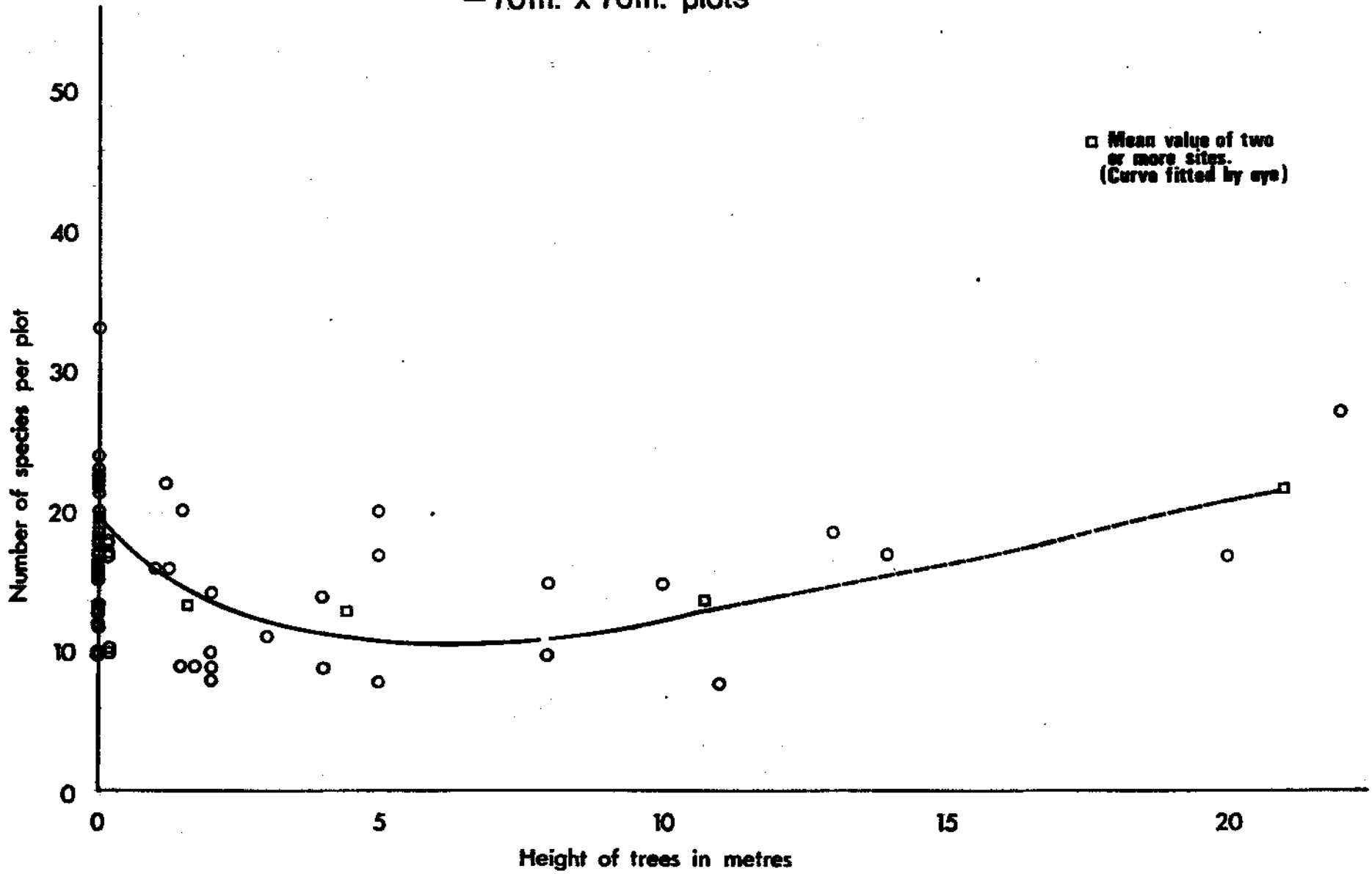


Fig. 9. EFFECT OF AFFORESTATION ON NUMBERS OF SPECIES
— per one square metre quadrat

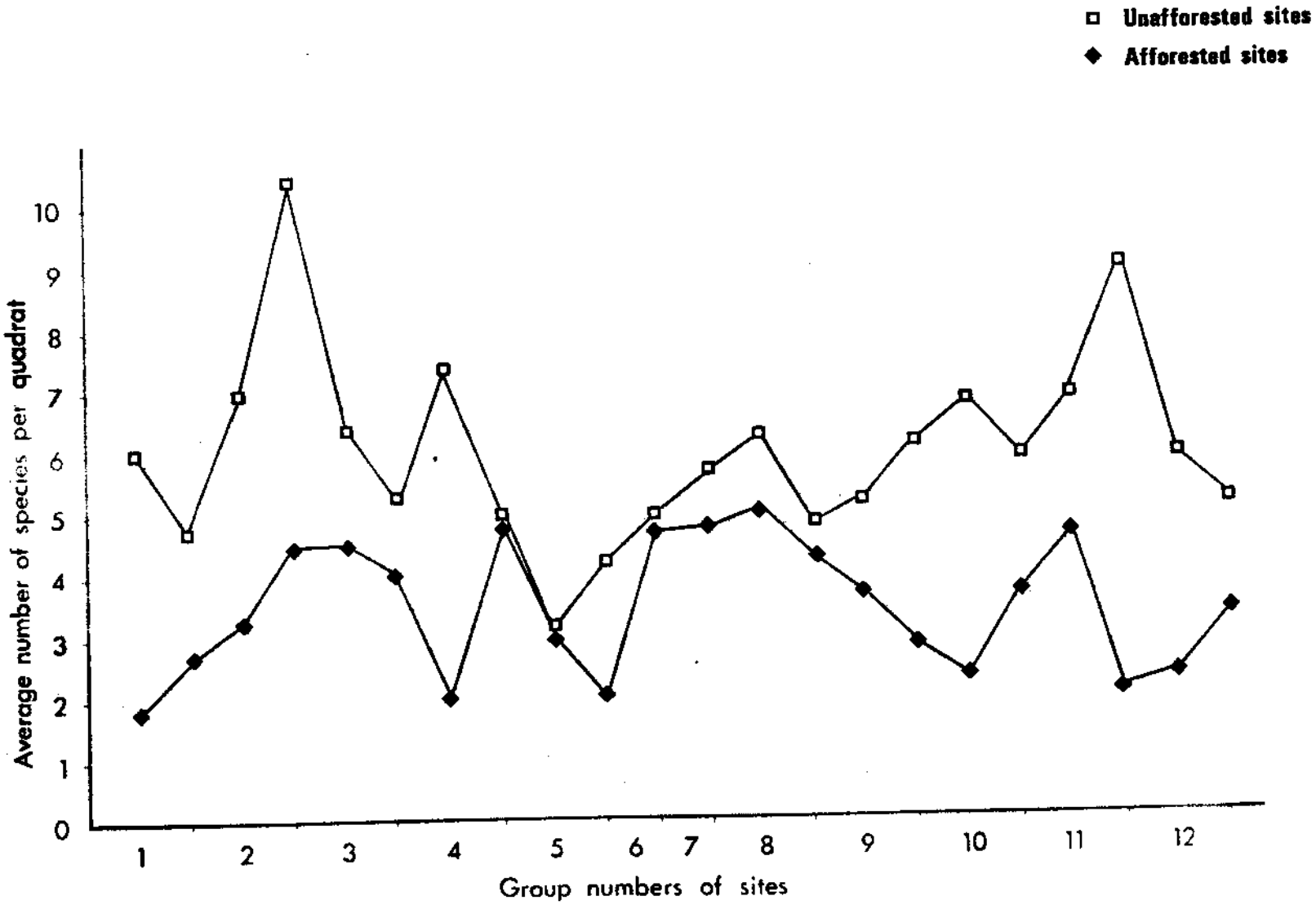


Fig.10 EFFECT OF AFFORESTATION ON NUMBERS OF SPECIES
— per 70m. x 70m. plot

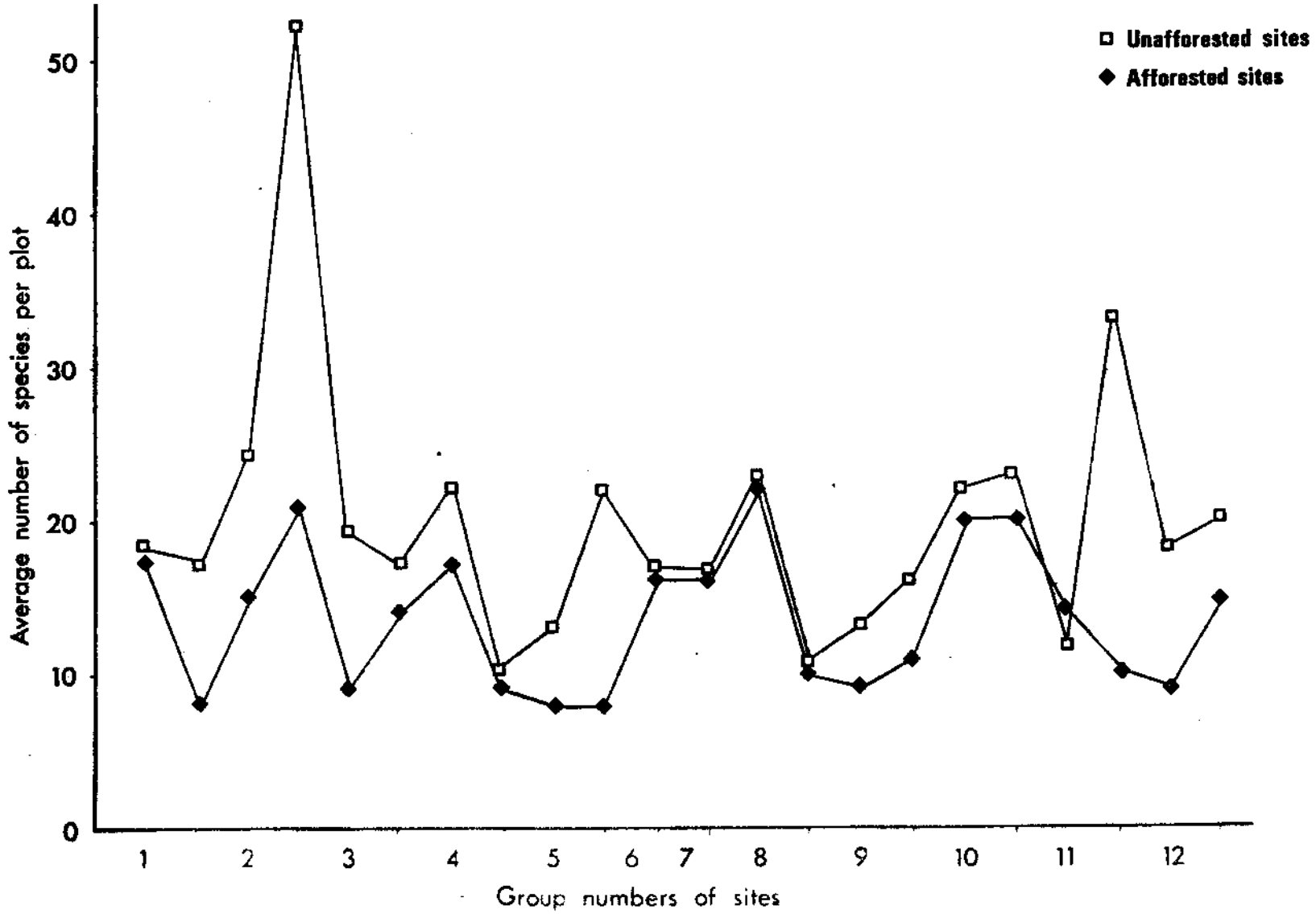


Fig. 11. ACTUAL AND THEORETICAL CHANGES IN DIVERSITY OF BIRD SPECIES IN SPRUCE / PINE PLANTATIONS

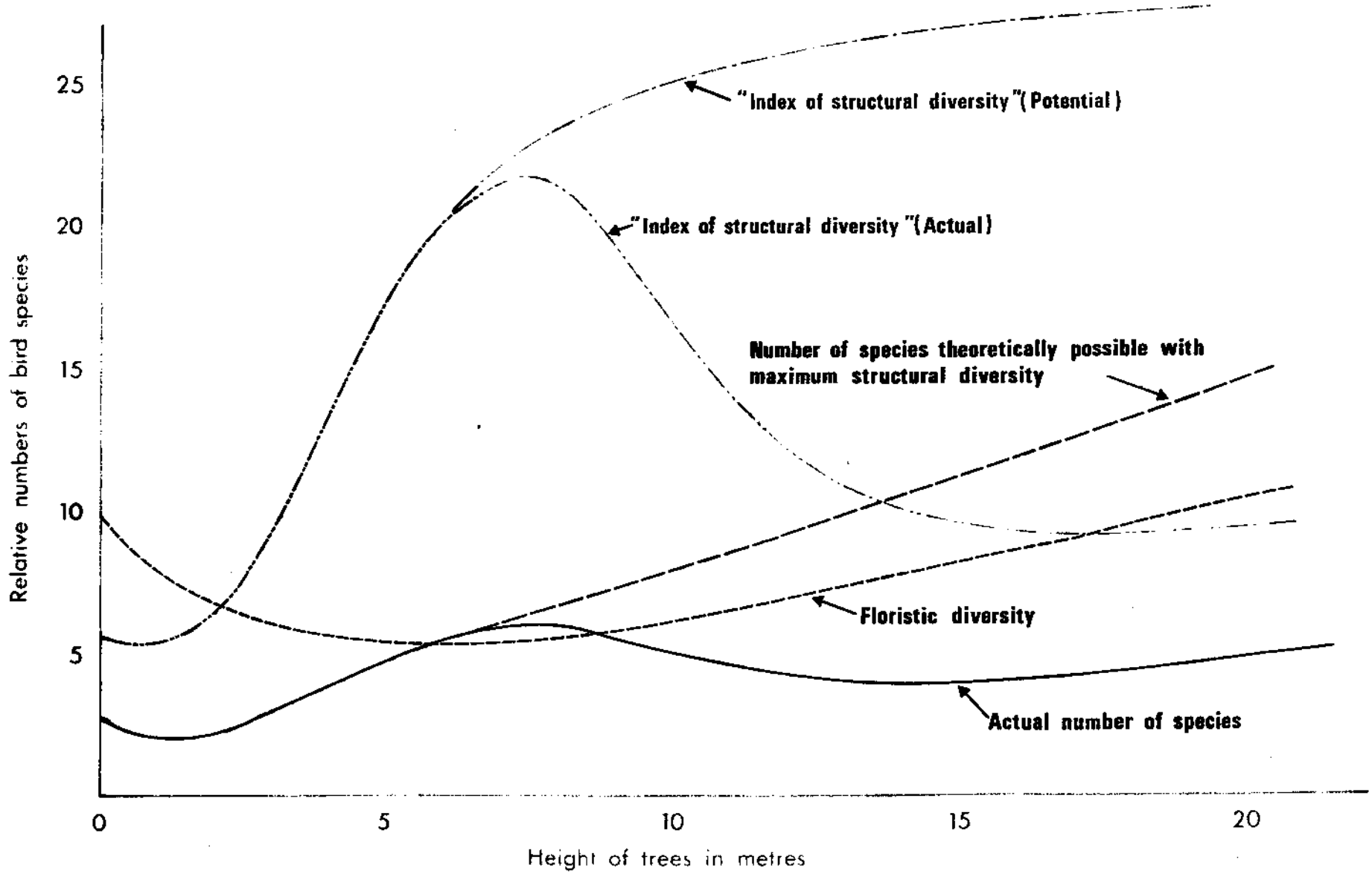


Fig.12. CHANGES IN BIRD SPECIES DURING AFFORESTATION
(AFTER LACK & LACK 1951)

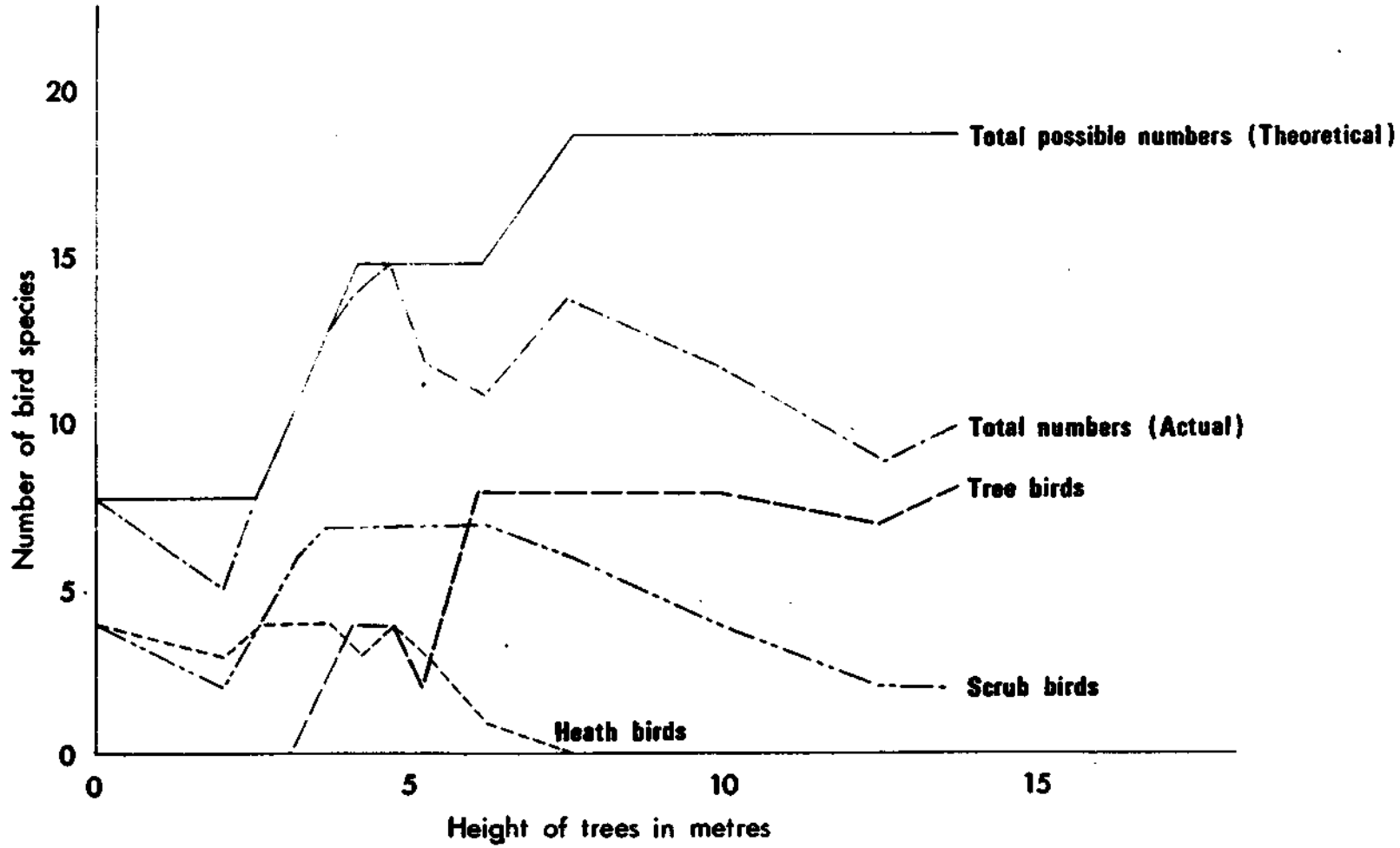


Fig.13.

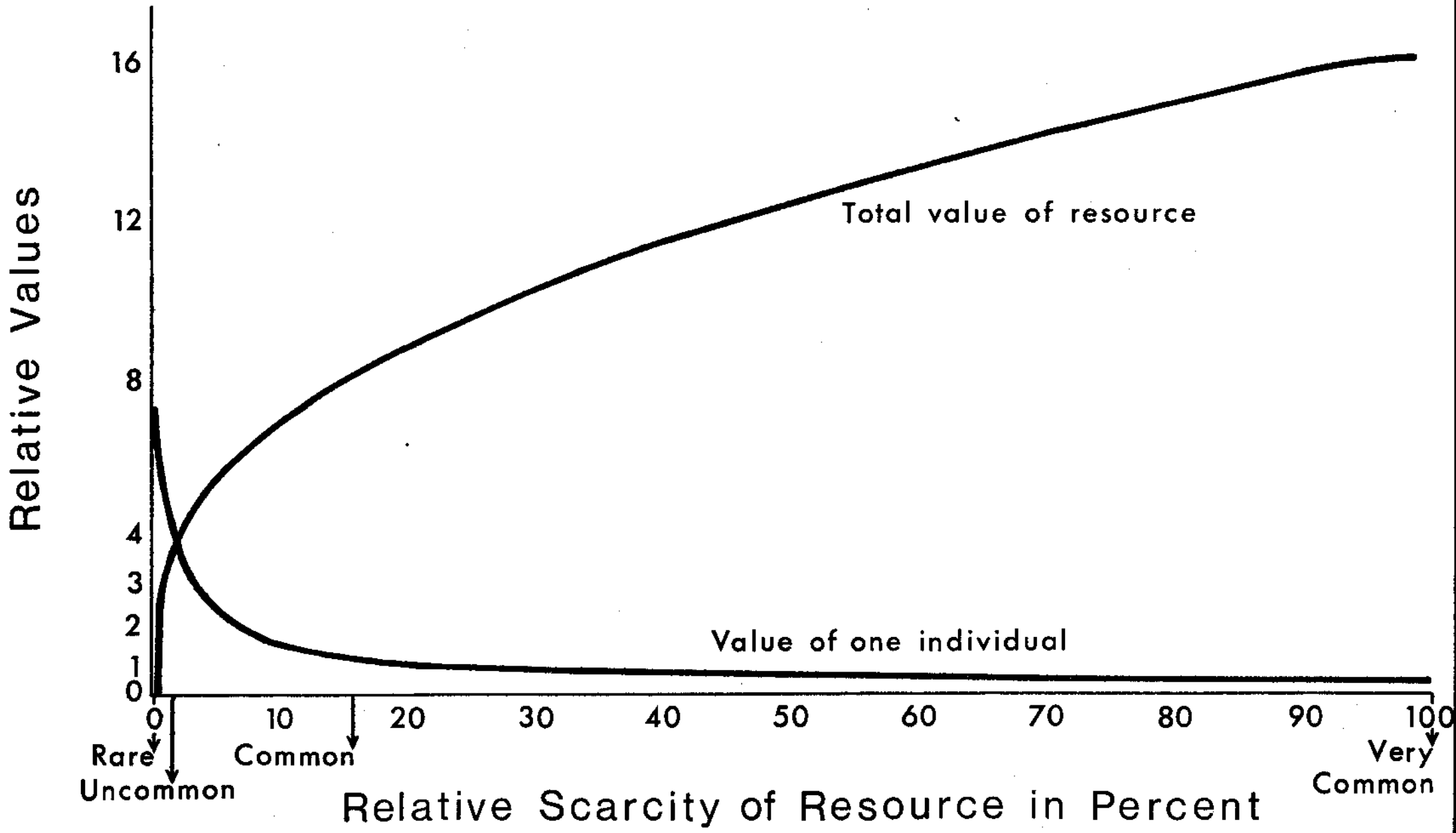
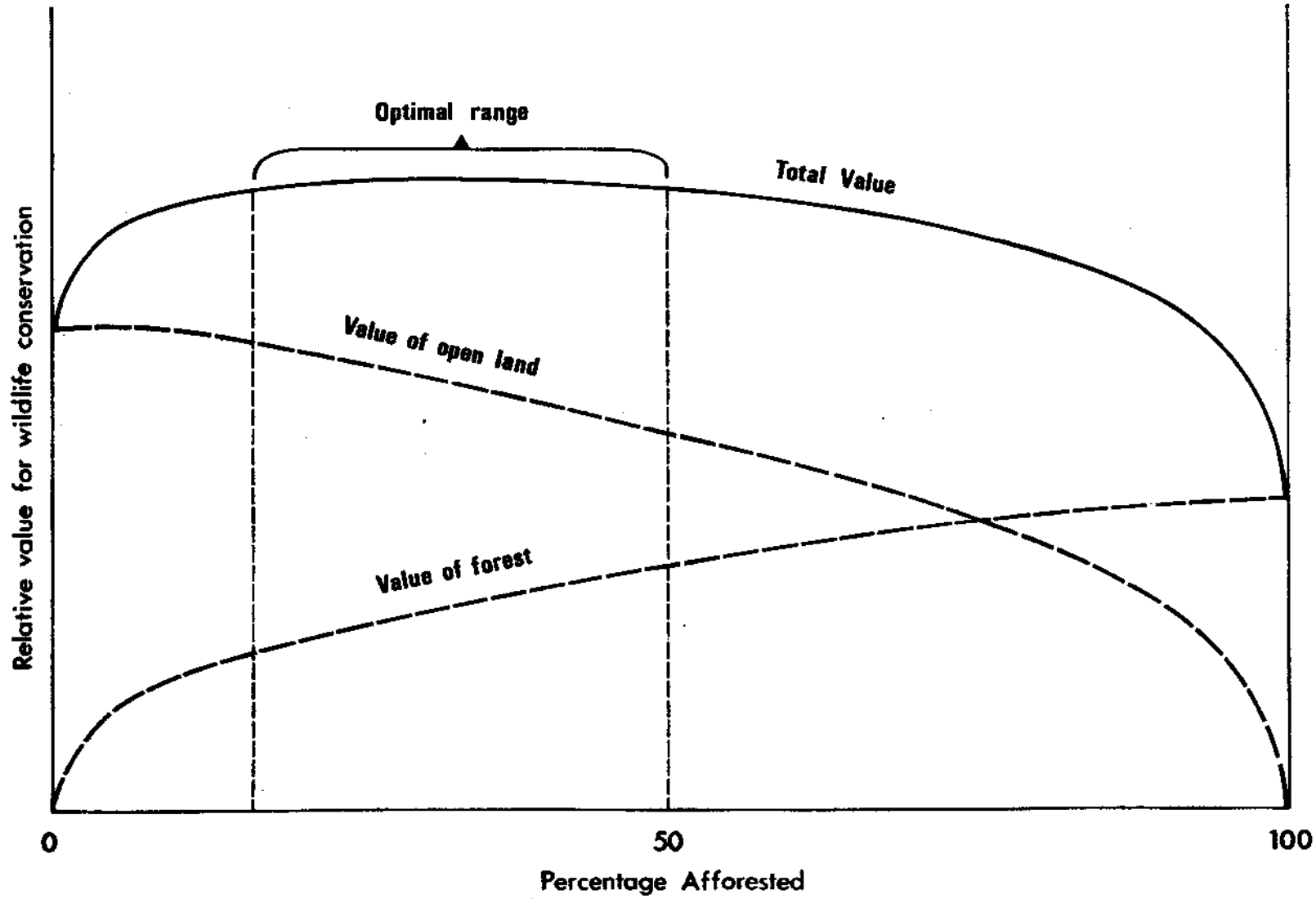
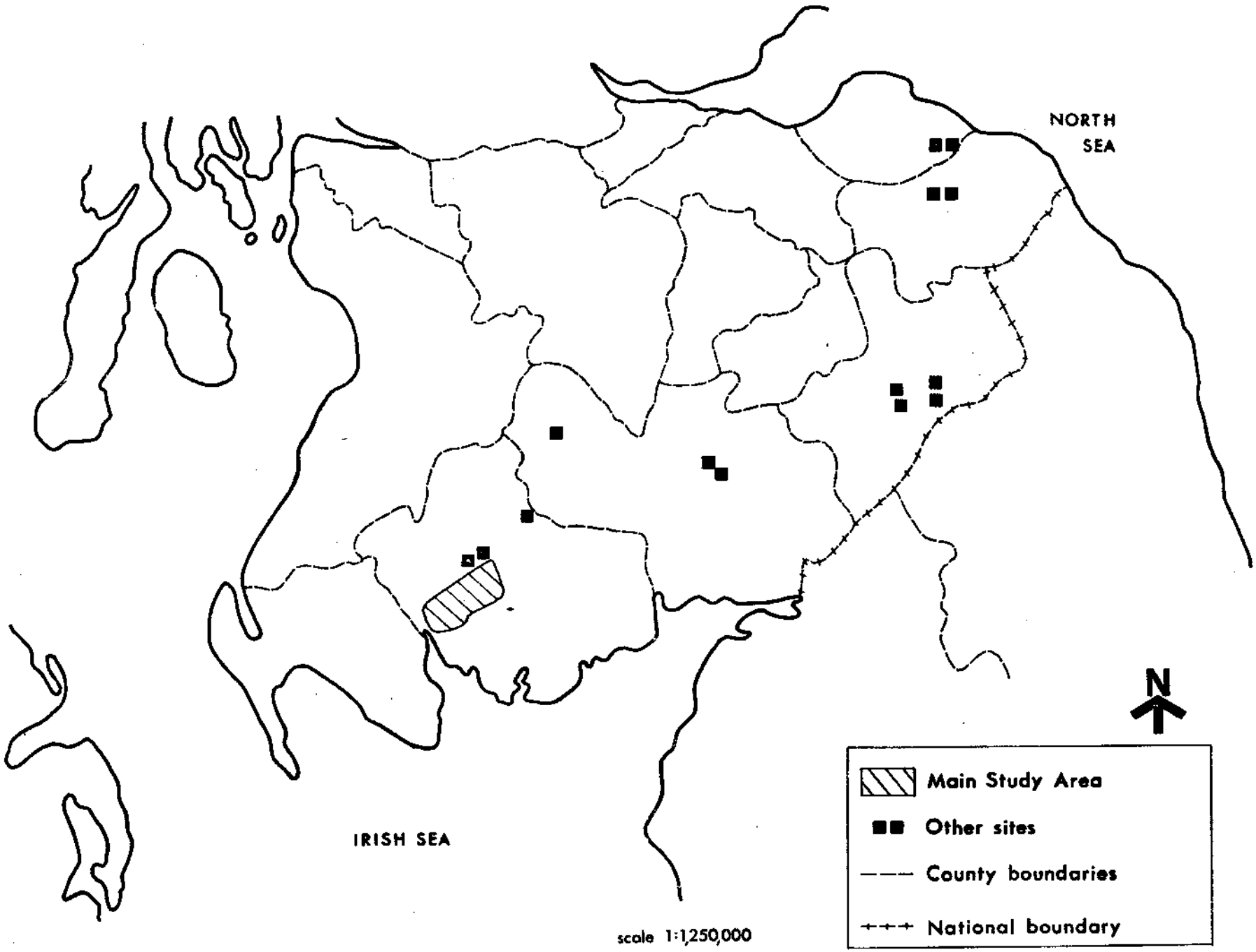
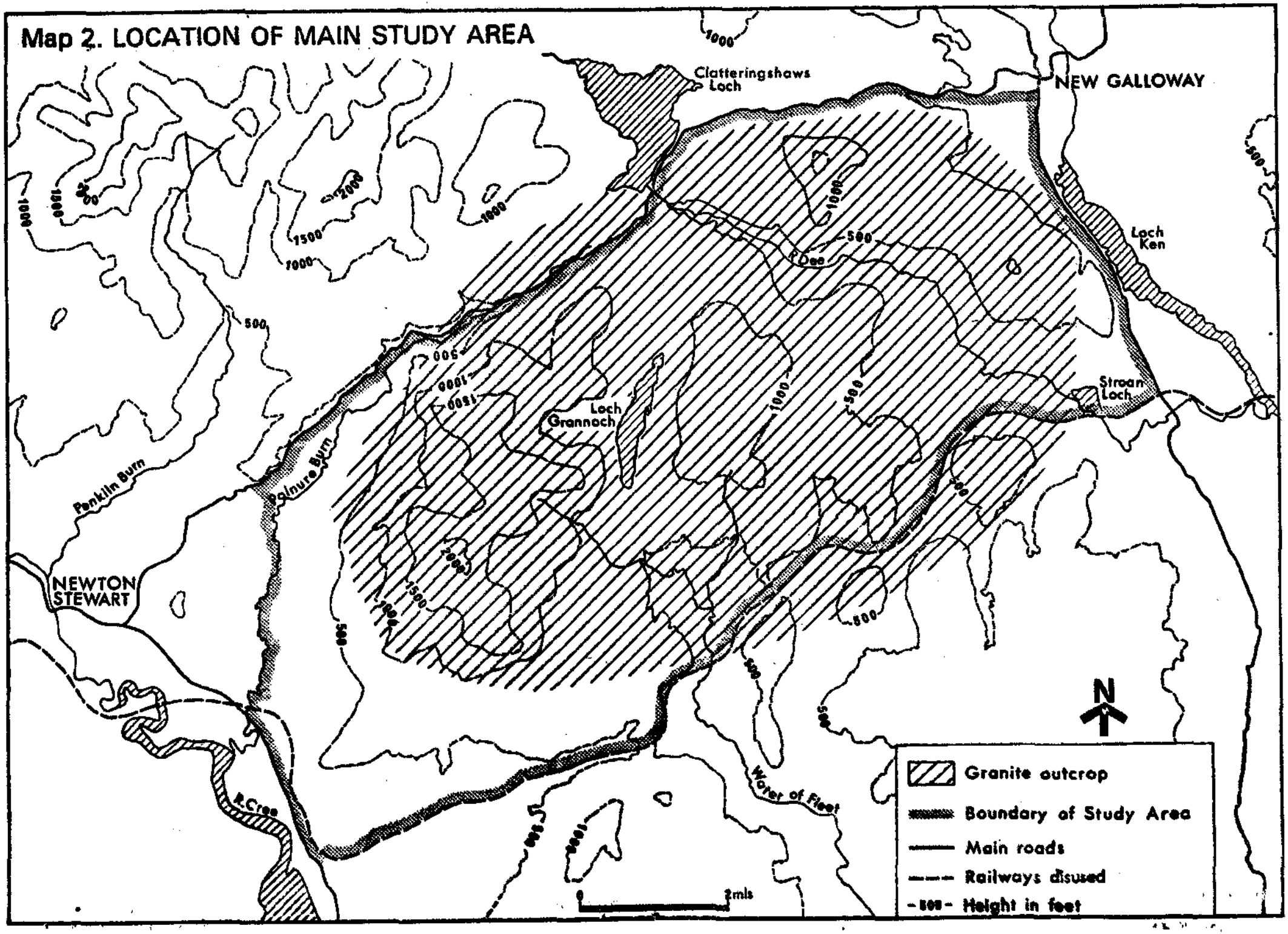

16
12
8
4
3
2
1
0
Relative Values
Total value of resource
Value of one individual
0
10
20
30
40
50
60
70
80
90
100
Rare
Uncommon
Common
Very
Common
Relative Scarcity of Resource in Percent

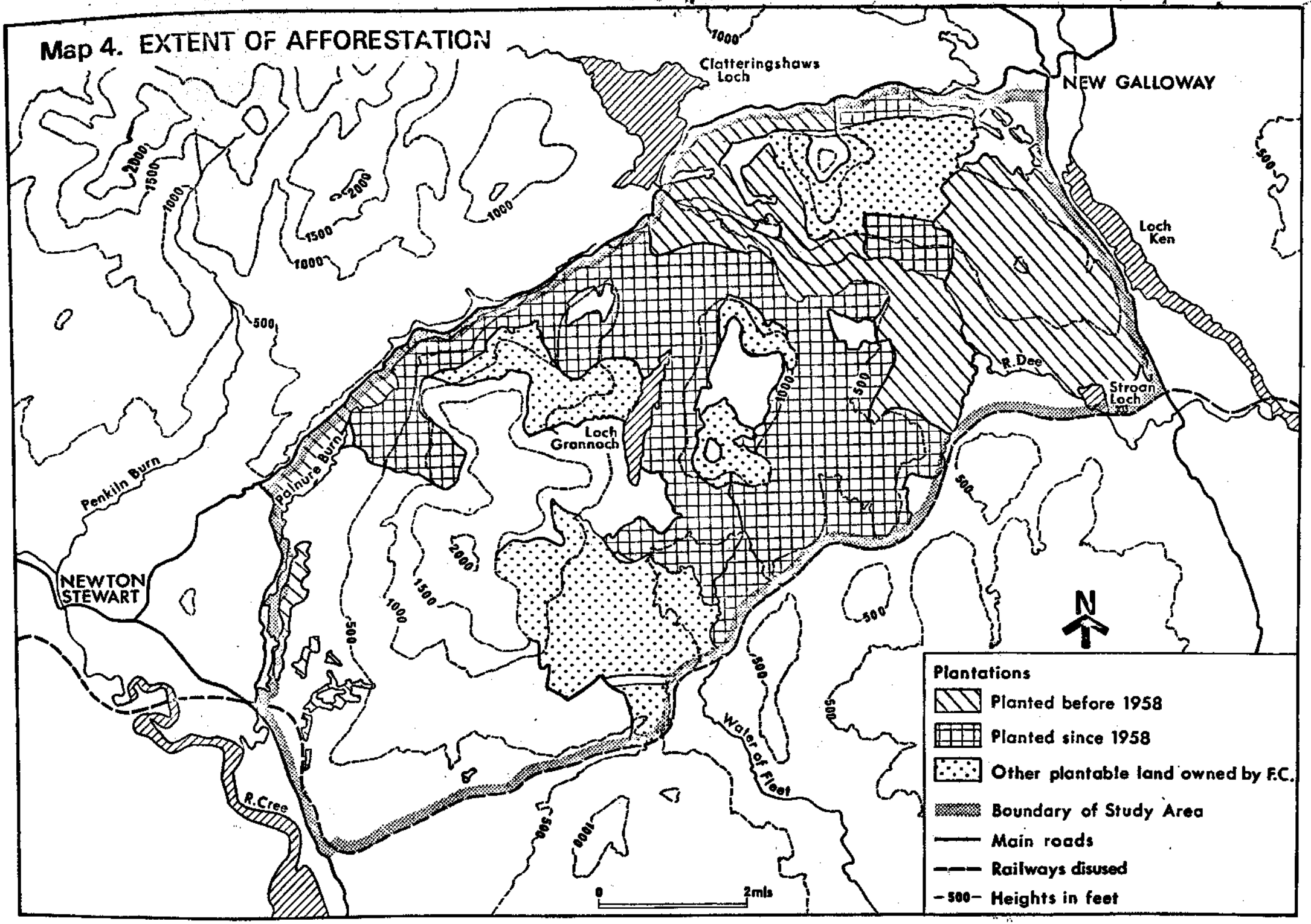
Fig.14. RELATIVE VALUES OF DIFFERENT PROPORTIONS OF FOREST

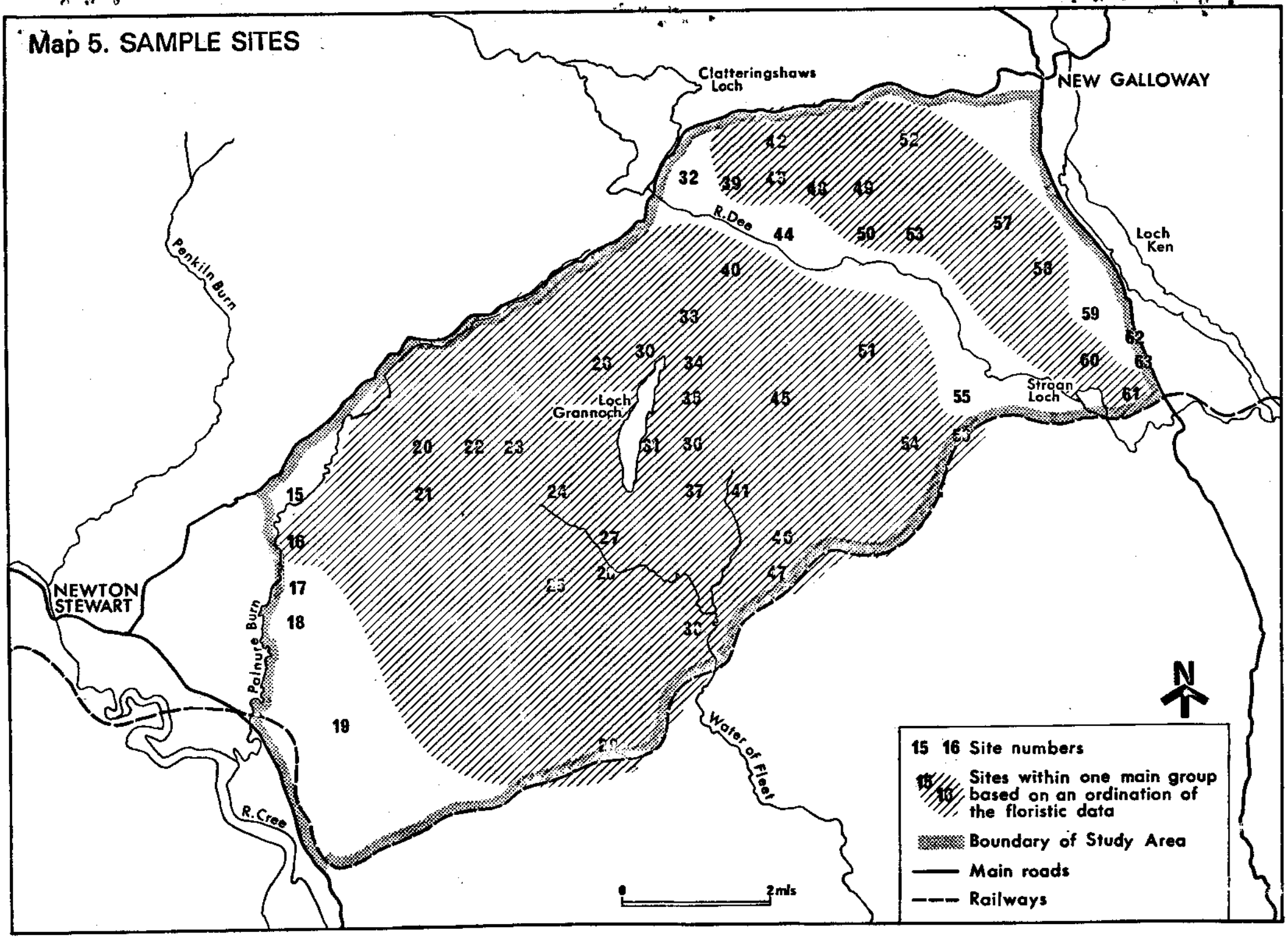


Map 1. LOCATION OF SAMPLE SITES




Map 2. LOCATION OF MAIN STUDY AREA
Clatteringshaws Loch
NEW GALLOWAY
Loch Ken
R. Dee
Stroan Loch
Loch Grannoch
Penkiln Burn
Polnure Burn
NEWTON STEWART
R. Cree
Water of Fleet
2mls
N
Granite outcrop
Boundary of Study Area
Main roads
Railways disused
Height in feet


Map 4. EXTENT OF AFFORESTATION
Clatteringshaws Loch
NEW GALLOWAY
Loch Ken
R. Dee
Stroan Loch
Loch Grannoch
Palnure Burn
Penkiln Burn
NEWTON STEWART
R. Cree
Water of Fleet
1000
2000
1500
500
N
0
2mls
Plantations
Planted before 1958
Planted since 1958
Other plantable land owned by F.C.
Boundary of Study Area
Main roads
Railways disused
-500- Heights in feet


Map 5. SAMPLE SITES
Clatteringshaws Loch
NEW GALLOWAY
Penkiln Burn
R. Dee
Loch Ken
Loch Grannoch
Stroan Loch
NEWTON STEWART
Palnure Burn
R. Cree
Water of Fleet
2mls
15 16 Site numbers
Sites within one main group based on an ordination of the floristic data
Boundary of Study Area
Main roads
Railways