# ECOTONES AND COMMUNITY BOUNDARIES: ANALYSIS BY PITFALL TRAPPING

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#### Abstract

A field-based experiment for the examination of community edges or ecotones is described. Based on data collected by pitfall trapping, a series of analyses is carried out, firstly to determine species diversity and to demonstrate the effect on crossing an ecotone, and secondly to examine similarities between the different communities. Similarity matrices are calculated, and the method of illustrating data by means of nearest-neighbour clustering in dendrograms is described.

It is found that separate communities can be demonstrated in woodland and field, although theoretical considerations of the methods used, including the accuracy of pitfall trapping as a means of obtaining data, suggest that interpretation of the results is more complex than at first sight. It is also demonstrated that the allegiance of animal communities in the ecotone is not necessarily to the higher vegetation formation.

#### INTRODUCTION

An ecotone is a transitional phase between two or more different types of ecological community, which typically has considerable linear extent, but which is narrower than the adjoining community areas themselves (Odum, 1971).

Ecotones are best observed and examined where two adjoining communities show strong differences, such as at the interface between grassland and woodland, although they may also be illustrated by looking at sand dune or heathland systems where vegetation is in different developmental or successional stages. The ecotonal flora and fauna contain many organisms typical of the two adjacent communities, plus specialised organisms restricted to the ecotone itself. For this reason, it is often observed that the number of species, and the population densities of some species are greater here than in the two neighbouring communities (Elton, 1966). This tendency for increased variety and diversity at community junctions is known as the edge effect.

One of the most important general types of ecotone, so far as man is concerned, is the forest edge. Wherever man settles, he tends to produce forest edge communities in the vicinity of his settlement by woodland clearance, finally reducing such forests to scattered small areas of ancient woodland, separated by grassland, crops, and other open habitats. These patches may be connected by shelter belts and hedgerows, which are analogous to the forest edge, and thus increase diversity in the agricultural landscape (Pollard *et al.*, 1974).

Man thus consistently increases the length of forest edge, and with it the frequency of those species of plants and animals which are commonly associated with the ecotone. At the same time, the remaining forest area may be reduced in species diversity, as contact between neighbouring blocks of woodland is lost. Eventually, the forest may disappear completely, taking with it not only the specialist forest species, but many of the edge species as well. In addition, as hedgerows are removed, a potential reservoir of animals beneficial to agriculture is also lost.

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#### METHODS OF STUDY

Ecotones, by definition, occupy relatively narrow tracts of ground, and may be examined by means of linear sampling techniques, carried out at right angles to the observed direction of the community boundaries. Since they are best marked in regions of abrupt change from one community type to another, and since some visual cue is required, a suitable region for study is a woodland edge, preferably bordering on permanent grassland. It is easier to interpret the results if each community lies on the same soil type and bedrock.

On the basis of several seasons' work at a woodland edge at Butser Hill, near Petersfield, on the South Downs (grid ref: SU719211, elevation 152 m), the following investigation is suggested.

The sampling method chosen was a line transect, along which samples or habitat data are taken at regular intervals, starting in one community and ending in the other.

The transect consists of a series of pitfall traps (plastic vending cups) set in the ground with their rim level with the soil surface, and with an area of about 30 cm diameter cleared of long vegetation around each. The way in which pitfall traps are set has an effect on the catch, and a review of the various pitfall trapping methods, with their advantages and disadvantages is given in Appendix I.

Traps have normally been set 1 metre apart, over a distance of 50 metres. It is suggested that 25 metres of the transect lie in the grassland, and the remainder in the woodland. If the woodland has a discrete edge, such a transect length should produce viable results, although broad regions of scrub may necessitate a longer line. In the work described, two parallel lines of cups, 2 metres apart, were used—making a total of 102 traps.

Setting several lines of traps increases the reliability of the results, since this permits more replication at each distance, and produces statistically more viable results. This however has the disadvantage that identification and counting of animals becomes much more lengthy, and there is always the problem that lateral variations in the woodland and grassland communities may be encountered if the transect becomes too wide. From a conservation point of view, if preservative is to be used there is a real possibility of affecting the frequency and relative abundance of the animals caught, especially since the exercise may be repeated in the same place by different groups.

An alternative method of providing groups of traps for data analysis is to divide the transect into regions, each of which must contain a minimal number of traps for a representative result. Theoretical studies (Orbretal, 1968; Jansen and Metz, 1977) indicate a minimum number of 10–12 traps per site and provide a model for pitfall trap operation respectively, whereas Greenslade (1964) emphasised the importance of where traps were set: on soil surface or in vegetation, in relation to capture efficiency. There is also a disturbance or "digging in" effect (Greenslade, 1973) which produces elevated captures when traps are first set.

Since many of the invertebrates caught are predatory, it is advisable either to examine the traps daily, or to include a small quantity of preservative in each trap. In the work described, a mixture of  $50^{\circ}_{0}$  ethylene glycol,  $5^{\circ}_{0}$  formalin, and  $1^{\circ}_{0}$  detergent in water was used, and found to maintain the specimens in good condition. This preservative penetrates well, and will fix any soft-bodied invertebrates such as earthworms. It is less suitable for molluscs, since it reacts with the body mucus, forming a gel. If a collection is to be kept for further examination, the "catch" should be transferred to  $70^{\circ}_{0}$  alcohol,  $5^{\circ_0}$  glycerol, although worms are best stored in  $2^{\circ_0}$  formalin. If animals are desired alive, a small quantity of moss or leaf-mould in the bottom of each trap can reduce in-trap predation.

Traps are normally covered with a lid, which keeps out rain, leaf-litter, and those small mammals, especially shrews, which are prone to pitfall trapping. Lids have been constructed from a square of plywood, slightly larger than the trap diameter, which is supported about 1 cm from the ground by a nail driven through each corner and pushed into the soil. The most accurate way of digging holes for trap insertion is to use a commercially available bulb planter, especially if it has a mechanism for pushing out the resultant soil core. Such cores can be replaced after the exercise, thus leaving little trace of the sampling operation.

During the present study, traps have been left *in situ* for 3 or 4 nights, at the end of which all the animals from each pair of traps are collected into labelled bottles. If two lines of traps have been set, and the above transect dimensions used, this results in fifty-one bottles which can then be returned to the laboratory for identification and counting of contents. If desired, the animals from each trap can be kept separate, and if several lines of traps have been set the lines can be treated as replicates and data analysed further than is described here.

In the laboratory, each student is given one or two bottles the contents of which are tipped into a petri dish and sorted into species. Many keys and other publications are available for the identification of the insects and other arthropods which constitute the bulk of the catch, and several useful works are listed in the Bibliography of Key Works, after the references. Unfortunately, many of these works require either specialised know-ledge, or a helpful expert to hand. Fortunately, an investigation of species number and diversity can be carried out without fully identifying everything, providing types can be repetitively recognised and assigned to the same group. The main problem lies in coordinating the identification. This can be overcome by sorting out a reference collection beforehand, and by the supervisor checking each collection before results are entered. This can be time consuming, but produces the best results. As an alternative, a decision can be made to concentrate on one or two major groups, such as the Coleoptera (beetles) or the Aranaea (spiders). In the present work, groups not recorded as ground running, such as Diptera (flies), Hemiptera (bugs), Annelida (worms), and Mollusca (slugs and snails), have been excluded from the analysis.

Counting and species-separation are facilitated by dividing the taxa into separate compartments of a sorting tray, and much use has been made of the plastic wax block moulds, used in histology to embed materials. They are light and stackable, each providing 8 or 10 compartments, into which species can be sorted.

#### RESULTS

The results should be set out as in Table 1, which is part of a much larger table. As explained, the results from a single trap pair are not very representative if just two lines of traps have been set: a minimum of ten traps per site is required, so the transect is divided into regions, each containing ten traps for the purpose of analysis. Distribution patterns shown in the original data should not be ignored, however.

Reducing the number of regions has practical as well as theoretical significance—it vastly reduces the number of paired comparisons to be made when calculating similarity values later.

					7	Frap pai	r numbe	er			
	Species	1	2	3	4	5	6	7	8	949	50
	Harvestmen										
1	Nemastoma bimaculatum									1	
2	Homalenotus 4-dentatus			1							
3	Leiobunum rotundum										
4	L. blackwalli										
5	Oligolophus palpinalis										
6	O. agrestis										
8	Mitopus morio										
9	Platybunus triangularis									1	
	Mites										
10	Parasitus										1
11	Oribatidae										1
12	Thrombidium	7	1	12	2	5					
	Ants										
93	Myrmica scabrinodis	3	8	1	1	1	1	17	3	1	
94	Lasius flavus	4			3	1	1	1	4		

Table 1. Arrangement of raw data prior to region grouping. Numbers are the combined count for the paired pitfalls

Note: A 0-50 metre transect produces 51 pairs of traps. A decision was taken to exclude pair 51 from the analysis to give each region an equal sample size.

Table 2. A comparison	of species'	published	habitat	specificity
with the regions in	which they	were actu	ally traj	oped

	Total numbe	er of species found ir	n each habitat
Expected habitat	In field	In scrub	In wood
Field	32	20	11
Scrub	16	16	12
Wood	9	15	21
Ubiquitous species	11	9	12

The list in Appendix II contains 37 species normally found in grassland areas, 22 scrub/ light cover species, and 32 species with woodland affinities, although several of these have a ubiquitous distribution in lowland Britain. The remaining species were not identified far enough for habitat specificities to be determined.

Data obtained from the Butser Hill transect are presented in Appendix II. A total of 94 species of surface active arthropods was collected in 4 nights in 1980, from 26–30 September. Table 2 shows the published habitat preferences of these species compared with the regions within which they were actually found.

If species regarded as ubiquitous are removed from the list, it is clear that invertebrates can be collected from habitats wherein they are not normally regarded as resident, a result compounded from the small distances involved, the high mobility of some species, and the far from complete understanding of distribution of many species. It is noticeable, however, that far fewer species regarded as having a field habitat preference penetrated the wood than *vice-versa*, and that fewer species than expected are found in the preferred habitat. Spread of scrub into the field is predictable in terms of woodland succession, and since woodland invertebrates tend to expand their distributions with the scrub habitat, the former observation at least can be explained.

## **Results: Data analysis**

### (a) Species diversity

Several methods exist for calculating species diversity, which simply stated is the relationship between the number of species present in each transect region and the total number of individuals in that region.\* One of the simpler indices is calculated using a formula devised by Fisher, Corbet and Williams (1943), which was simplified by Margalef (1951) to:

Diversity 
$$(\alpha) = \frac{S-1}{\log e N}$$

Where S = number of species in a region, N = total number of individuals in that region, and e is the base of natural logarithms (2.3026), e.g.: in the species list (Appendix II), region A has 24 species and 99 individuals,

hence:

$$\alpha = \frac{24 - 1}{\log e \, 99} = 5.01$$

It follows that  $\alpha$  will be small if almost all individuals collected belong to one or two species. If all individuals belong to the same species, diversity will be zero. Conversely, if each individual collected is of a different species, a maximum value of  $\alpha$  will be recorded.

If the diversity of each region is calculated, and plotted against distance, a peak in diversity can be demonstrated, which should match with the community boundary (Fig. 1).



Butser Hill transect: elevation in species diversity as an indicator of the ecotone (scrub region).

\*Species Diversity Indices. See Chalmers and Parker for a general review; Yapp (1979), Usher (1983) and Giavelli *et al.* (1986) for critical appraisals of different indices. Ed.

It is likely that the two communities investigated will have different diversities: the reasons for this can be one basis for group discussion, but one effect is an experimental one. The habitat in grassland is more two dimensional, since vegetation is shorter, and a greater proportion of animals is likely to be pitfall trapped than in woodland, with a more three dimensional structure. Here, many of the inhabitants are not ground active, and may be missed by this technique.

## (b) Similarity between regions

Further analysis can be carried out by calculating how similar the different transect regions are in terms of species presence and absence. Again, several methods exist for comparing species lists from different communities. Many of these are derived from analysis of plant communities (Williams and Lambert, 1959); some are gleaned from methods employed by numerical taxonomists, who use quantitative methods to assess similarity between species (Sokal and Sneath, 1963). Several indices of association are described by Southwood (1978), although those used in the present analysis are largely derived from Cook *et al.* (1972) and Nield (1974).

The analysis is performed in two steps. Firstly, a series of similarity coefficients between each of the possible pairs of regions along the transect is calculated by one of several methods. Secondly, these can be expressed graphically by means of dendrograms, wherein similar values are clustered, i.e. cluster analysis. The application of such analysis to numerical taxonomy is described by Goto (1982), and the techniques outlined below for community analysis follow the same general lines as in Russell (1972) and Cook *et al.* (1972).

### (i) Constructing a similarity matrix

The method consists of comparing each region of the transect with each other region in turn, i.e. region A is compared with B, then with C, then D and so on. The outcome of this process is illustrated in Table 3, which shows all possible combinations for the Quotient of Similarity.

It soon becomes obvious that such comparisons can be a lengthy process, and are much facilitated by a combined class operation, a programable calculator, or a computer. The number of possible comparisons which produce different combinations of regions is given by:

$$\frac{(\mathbf{r}^2\!-\!\mathbf{r})}{2}$$

where r = the total number of regions into which the transect was divided.

It is easy to calculate that with a transect divided into 10 regions, there are 45 possible combinations.

Described below are three methods for calculating a similarity matrix from the data in Appendix II. The first is based on the presence of species only, the second on the presence and absence of species, and the third on the numbers of individuals in each different species represented.

In comparing two regions, there are 4 possibilities for a species. It can be: (a) present in both regions; (b) present in one region, but absent from the other; (c) the reverse of (b); or (d) absent from both regions, but present somewhere else along the transect.

This can be represented as:



Region B

Taking the first site pair (A–B), count up the numbers of species which fall into each of these 4 categories, and thus obtain values for a, b, c and d:

Species	Region A	Region B	Code
1	absent	absent	d
2	present	absent	с
3	absent	absent	d
4	absent	absent	d
5	absent	absent	d
•	•	•	•
•	•	•	•
•	•	•	•
91	absent	absent	d
92	present	present	а
93	present	present	а
94	present	present	а

These are put into the above calculation as:





After which one of several similarity coefficients can be calculated.

Quotient of similarity (Sørensen, 1948)

Sørensen's formula was:

$$I = \frac{2j}{a+b}$$

Where a was the total number of species present at region A and b the total number of species present at B. The value of j was the number of joint occurrences. In the table above this is the number of species present at both sites, i.e., the value of a, so the formula can be re-written as:

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$$I = \frac{2a}{2a+b+c} \times \frac{100}{1} = \frac{2(15)}{2(15)+13+9}$$

This produces a similarity of 0.577 or 57.7% between regions A and B.

Table 3 shows the form of the similarity matrix which is produced by this method. In the case of a transect line which passes from one vegetation community to another, a change in animal species similarity pattern is shown by decreasing values of I with increasing separation of regions.

For communities to be clearly delineated, the "cross similarity" between sites in one community type and another should be low. For example, the average value of similarity between field and wood in Table 4 is 21.6%. In contrast, the intra-site similarity for field regions is much higher. The fact that the average scrub/field similarity is 24% higher than the woodland/scrub similarity is one pointer to the allegiance of the scrub community.

Note that if only the Quotient of Similarity is to be calculated, the original Sørensen formula can be used, since 2j = 2a, and the total number of species at each region, A and B, have already been calculated for the diversity index.

# Corrected Chi<sup>2</sup>

The corrected chi-squared  $(\chi^2)$  makes few assumptions about the distribution of the data, since it is a non-parametric analysis, and has the advantage that a probability value can be attached to each pair of comparisons. Unlike the above method, it uses data coded (d).

Region										
А	*									
в	57.7	*								
С	51.9	58.6	*							
D	53.3	62.5	57.6	*						
E	62.2	57.1	66.6	56.1	*					
F	35.8	36.6	46.6	50.6	40.6	*				
G	33.3	19.3	25.9	33.3	31.1	38.8	*			
н	15.0	22.7	30.4	26.9	21.6	38.9	35.0	*		
Ι	14.3	13.0	25.0	25.9	15.4	36.1	23.8	52.9	*	
J	9.3	17.0	20.4	14.6	10.0	16.1	18.6	51.4	43.2	*
Region	Α	в	С	D	Е	F	G	Н	I	J

Table 3. Values of the Quotient of Similarity (1) for the Butser Hill transect regions (as %)

 Table 4. Average value of similarity (%I) between communities

			Community	
		Field	Scrub	Wood
	Field	56.9	50.5	21.6
Community	Scrub		40.6*	26.0
	Wood			37.5

\*Only one value, as only one comparison was possible.

This has been criticised in that rare species may artificially inflate (d), and produce a larger than expected similarity (Macan, 1954).

For each pair of sites the data are arranged as below, and the marginal totals calculated:

$$\begin{array}{ccc} b & d & b+d \\ a & c & a+c \end{array} \\ a+b & c+d & n \end{array}$$

where n = (a+c)+(b+d)

The formula for chi-squared, with Yate's correction is then:

$$\chi^{2} = \frac{n(|ad - bc| - 0.5n)^{2}}{(a + c)(b + d)(a + b)(c + d)}$$

where the vertical lines in |ad-bc| mean that the absolute (i.e., positive) value of the difference between ad and bc must be taken. Note that if ad is greater than bc then the association is positive (affinity between regions), but if bc is greater than ad then there is a negative association (repulsion).

With a  $2 \times 2$  chi-squared table, there is only one degree of freedom, so if the calculated value equals or exceeds 3.84, the two regions are significantly associated at a probability of 0.05 (in only 5° of cases could such a result be expected to occur by chance).

Table 5 shows the similarity matrix of chi-squared values which is produced by this method. A value of 16.16 for the comparison between regions A and B indicates significant association, and as ad is greater than bc then this is positive. The pattern of significant chi-squared values in this table indicates no cross-community similarities, although the scrub site F is significantly associated with field site D, and the scrub site E, nearer to the grassland is significantly associated with all grassland sites.

### Correlation coefficients and Z-scores

In the above methods, only the presence or absence of species is considered, the actual

Region										
Α	*									
В	16.2+	*								
С	12.6†	14.9†	*							
D	11.7†	18.1†	11.4+	*						
E	23.7†	17.3†	27.1†	16.1†	*					
F	0.8	0.0	2.7	$4.8^{+}$	2.7	*				
G	1.0	0.7	0.1	0.3	0.8	0.9	*			
н	0.5	0.0	1.2	0.2	0.1	2.4	3.3	*		
I	0.9	1.8	0.1	0.0	0.4	3.3	0.1	16.9†	*	
J	2.9	0.5	0.2	2.4	1.9	3.6	0.1	15.3†	7.9†	*
Region	Α	В	С	D	E	F	G	н	Ι	J

Table 5. Values of chi-squared for the Butser Hill transect region

\*Chi-squared significant at a probability of 0.05 (1 deg of freedom).

numbers of individuals being ignored, so rare and common species receive equal weighting. Numerical representation can be introduced into the analysis by means of correlation coefficients, although this does make assumptions about the distribution of the data which is unlikely to satisfy the requirements of a parametric r-test. This devalues any probabilities calculated. An alternative is to use the non-parametric Wilcoxon matchedpairs signed-ranks test (Siegel, 1956) to calculate Z-scores.

Whichever method is used, sites are compared in pairs, but now the number of individuals represented by each species is entered, and a correlation coefficient (r value) or Z-score calculated using each pair of sites as a pair of x,y variables. In the case of the Wilcoxon test, values are ranked before calculations are carried out, and any species present at one site but absent from the other of the two sites being compared are excluded from the comparison. This means that although a matrix of z scores similar to the matrix of r values can be calculated, there is no overall level of significance for the data, unlike with r values.

The following analysis is limited to a treatment of correlation coefficients. A Wilcoxon test of the type described produces very similar results.

Unless work is delegated to several people, the amount of calculation involved in hand working a correlation matrix quickly becomes unmanageable. In the present study, correlation coefficients were calculated using the statistical package "Statpack" (Western Michigan University) on a DEC 20 mainframe computer, although a microcomputer with array capability and at least 48K RAM should be able to analyse a 10-region transect. For "Statpack", data are entered row by row, one row for each species, each column containing one variable for each region, in this case 10 columns, by 94 lines. Species absence is indicated by a zero in the data, species presence by the number of organisms of that species found at each site along the transect. Table 6 is an example of the output produced from the Butser Hill transect data.

The values of correlation coefficient (r) range from +1, which means  $100^{\circ}{}_{\circ}$  positive correlation between regions to -1,  $100^{\circ}{}_{\circ}$  negative correlation, through 0, which means no correlation. Normally, values of r will be intermediate, although large negative values are unlikely here because of similarity between regions of the same community, and since many species present in one community are simply absent from the other. As in any correlation test, significance of values can be checked by reference to a table of the correlation coefficient, to be found at the back of most statistics books.

Calculating the number of degrees of freedom at which to enter the table presents something of a problem. Normally this is (n-1), where n is the number of pairs of comparisons made (here 94). In this instance, though, because of the inevitable large number of zeros in the calculations, the degrees of freedom have been reduced to the number of matrix entries -1, here 44. Thus, for a probability of 0.05, calculated values of r show significant correlation between regions if they are 0.29 or greater.

If the Wilcoxon test has been used, each individual Z-score probability has to be looked up. Siegel (1956) provides a suitable table of probabilities. If the tabulated value shows a probability of 0.05 or less, then the site pair shows significant association in terms of species and number of each species.

The correlation matrix (Table 6) shows similar significant site pairings to the chisquared analysis, but there are some striking differences with regard to regions F and G, which show similarities not previously demonstrated. The basic reason is, that although these regions only have a small number of species in common with field and other scrub regions, those species which were found are present in roughly equal numbers.

Region										
Α	*									
В	0.51+	*								
С	0.50†	0.38†	*							
D	0.63†	$0.84^{+}$	0.18	*						
Е	0.39+	0.33†	0.75†	0.10	*					
F	0.15	0.04	0.14	0.07	$0.45^{+}$	*				
G	0.44*	0.10	0.12	0.29	0.18	0.28	*			
Н	0.02	0.10	-0.05	0.14	-0.00	0.03	0.28	*		
I	-0.09	-0.09	-0.07	-0.06	- 0.09	0.04	$0.40^{+}$	0.59†	*	
J	-0.11	-0.08	-0.09	-0.07	-0.03	-0.05	0.19	0.66†	0.63†	*
Region	А	В	С	D	E	F	G	Н	I	J

Table 6. Values of the correlation coefficient  $(\mathbf{r})$  for the Butser Hill transect regions

+Correlation significant at a probability of 0.05 or greater (44 degrees of freedom)

# (ii) Representation of site similarities by means of dendrograms

The information in the similarity matrices (Tables 3, 5 and 6) can be represented graphically by means of another technique "borrowed" from numerical taxonomy, which aims to construct a tree which reflects the division of the transect into larger areas or clusters of sites on the basis of similarity.

This technique has been used in numerical taxonomy to cluster species on the basis of shared character states. Sokal and Sneath (1963) discuss the methods, and one example is provided by Holloway (1973). Goto (1982) gives a complete account of matrix construction and dendrogram preparation. With regard to community analysis, the technique was applied to vegetation types by Pritchard and Anderson (1971), to seashore zonation by Russell (1972), and to animal communities by Cook *et al.* (1972) and Nield (1974). Claridge and Wilson (1981) used the method, amongst others, to demonstrate tree specificity in leaf hoppers.

Various methods exist for reducing matrices to dendrograms. The one described below clusters sites on the nearest-neighbour principle, one of the simplest methods requiring no further calculations. It is not the most efficient, but it is the easiest to understand and produces reliable results. For more complex methods, reference should be made to Southwood (1966).

Southwood (1978) gives a concise account of dendrogram construction as used to produce Figs 2, 3 and 4 in this account. Basically, the pair of sites with the highest level of similarity, however obtained in a matrix, is joined by a horizontal line at that level on the graph. The matrix is then re-examined for the next highest similarity value. If this is between another site and one of the pair already plotted, it is joined to both members of the existing site pair at that level. If the next highest value is between a new pair of sites, these are joined together as a second cluster. The process continues until all sites are joined together into one cluster. It is important to remember that some sites will be "redundant", e.g., if A and B are joined, then C joins the A/B cluster because of its similarity to A, the similarity to B is assumed at the same level. If, later on, a B/C similarity occurs, this value is not used. Consequently, sites are linked only once, and each site appears only once on the dendrogram. If similarity values "tie" in the matrices, and the sites involved have not already been included at a higher similarity level, they are joined at the same level, providing they lie within the same cluster.



Nearest-neighbour clustering of transect regions based on the quotient of similarity. (F=field regions, Sc=scrub, W=woodland)



Nearest-neighbour clustering of transect regions derived from chi-squared values.



Nearest-neighbour clustering of transect regions based on correlation coefficient values.

Figures 2, 3 and 4 illustrate the similarity dendrograms produced by the above method for the Quotient of Similarity (Table 3), Chi-squared (Table 5), and Correlation Coefficient (Table 6) respectively.

In the dendrograms, regions can be ordered subjectively, providing no cluster lines cross. In Fig. 2 the sequence CEABDFHIJG could be drawn AECDBFIHJG, since sections of the dendrogram can be rotated without changing the overall meaning. A degree of symmetry, with highest clustered sites towards the outside, where possible, is perhaps more aesthetically pleasing, but it is the contents of the clusters that really matter.

The similarity values in Fig. 2 divide the transect into a field/scrub cluster, and a woodland cluster, although woodland region G has a low similarity with all sites. The scrub site E nearer to the field has a higher affinity with the field sites than the scrub/ woodland boundary region F, although this is still within the field cluster. From the similarity matrix (Table 3) it can be seen that this is due to its higher similarity with site D.

The chi-squared similarity dendrogram (Fig. 3) produces the same field/scrub and woodland clusters, although the two main groups link below a value of 3.84, which means that they are not significantly similar at p=0.05. Region G is not significantly similar to any other region.

The correlation dendrogram (Fig. 4) shows the same division into field/scrub and woodland clusters, but region G is now included within the field cluster, and there are some changes in region-pairings within the individual community clusters. The significance levels indicate that all sites can be joined at a level greater than 0.290 or a



Butser Hill transect: contour graph of the quotient of similarity matrix (1 values), (cross-hatched area represents similarity of scrub with other regions).

probability of 0.05 for 44 degrees of freedom. This suggests that the transect regions cannot be regarded as being members of different communities, which is perhaps rather surprising.

Higher than expected levels of similarity between dissimilar communities is one result of the method of clustering used. Southwood (1978) points out that the nearest-neighbour technique uses only the highest values in the matrix, and thus much data are lost.

There are methods of re-calculating the matrix as the dendrogram is drawn which can overcome this. Mountford (1962) describes one such technique, and his method is discussed by Southwood (1966). Alternatively, coefficients of similarity can be plotted on ordination diagrams (Goldsmith and Harrison, 1976) or three dimensional models made (Davis, 1963) or illustrated (Cook *et al.*, 1972). One of the easier methods is demonstrated in Fig. 5, which is a contour graph of the Quotient of Similarity matrix (Table 3) plotted in 3-dimensions. As well as using all of the data, these look attractive and are simple to interpret, since they demonstrate highlands of similarity, which form plateaux if all sites in a community are relatively similar, and ridges if regions are less homogeneous.

#### DISCUSSION

The Butser Hill transect has been worked for several years as a one-day practical exercise for B.Sc.(Hons) Ecology students, and was developed as part of a trapping





Fig. 6.

The Butser Hill site in 1982 showing the chalk downland and hawthorn fringe to the wood, looking to the NE. In the Centre of foreground is one of the marker canes for the transect.



Fig. 7.

A view along the Butser Hill transect, looking west from just inside the wood. The closer marker cane is at 25 m whilst the one in the distance marks the field end of the transect.

programme to survey the Downs and Petersfield area. It produces consistent results, in which the community boundary can be demonstrated by a raised value of diversity. The individual values determined are for alpha diversity, although Odum *et al.* (1960) point out that if diversity is measured along a transect, the slope of the line will measure beta diversity (inter-, as opposed to intra-community diversity), and sudden changes will reflect community boundaries. This effect is evident from the survey described. Cluster analysis carried out indicates that different grassland and woodland communities can be demonstrated, although the relationships within community clusters can vary according to the method of analysis used. The results are predictable, but the allegiance of the scrub interface is not.

Elton (1966) comments that the woodland/scrub edge, as a transitional zone between lower and higher vegetation types is a community which is always allocated to the higher formation type, the woodland. However, both the similarity matrices and the dendrograms include the scrub regions with the adjacent field community, although the region furthest away from the field invariably has the lowest similarity to the field. Bearing in mind normal patterns of succession, woodland would be expected to expand, which does not predict this result.

The pattern at Butser has, however, been influenced by scrub clearance in preparation for fencing and grazing, and also by visitors trampling the woodland edge, which is one reason for the dip in diversity along the field side of the boundary. Such a dip has been observed in other locations where this exercise has been carried out (for example at Preston Montford Field Centre, Shrewsbury), where cattle trampling along a field boundary has produced the same effect.

Such observations form the basis for a discussion on the results obtained. It is important at this stage not to neglect the raw data, since individual species' distributions are responsible for the observed patterns. Some species of arthropods, such as wolf spiders of the family Lycosidae and rove beetles of the Staphylinidae (sub-family Staphylininae) are clearly adapted to open habitats, and are found almost exclusively in the field. Species of ants (Formicidae) are mostly field or scrub orientated, although they do tend to penetrate woodland fringes. Other species, such as some members of the Carabidae (ground beetles) are specifically described as occurring in open habitats, or in light cover, and tend to be trapped in these places.

The distribution of many herbivores is limited by food plant availability, and as many carnivores are oligophagous (i.e., have a relatively specialised diet), community species complexes are developed. In contrast, the survey recorded many species regarded as ubiquitous, many of them polyphagous predators which could be expected at any point along the transect, a factor which tends to blur the community boundaries. Many species are of course limited by their tolerance of climatic variability, such as differing ranges of temperature and humidity in woodland and grassland. Chalk grassland in particular has a characteristically shallow soil, which dries out quickly, and open downland has a considerable diurnal temperature variation. There are also variations in the physical structure of the environment, which produces differing micro-habitats for the animals. The woodland at Butser is predominantly ash (*Fraxinus excelsior*), with a considerable ground cover of dog's mercury (*Mercurialis perennis*), and a soil surface rich in mosses. There is also much fallen timber, which can provide both cover and food.

All of these variations can, and should be, measured as the basis for a more extensive analysis of community boundaries and differences, although the experiment and analysis as described can be completed in a few hours if traps have already been set.

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#### Appendix I

# A note on Pitfall Trapping

Pitfall traps have been used extensively in studies of surface-active animals such as spiders, centipedes, ants and beetles, especially the ground-dwelling Carabidae. Their origin has been variously attributed, although the development of deliberate traps can be traced to Barber (1931), hence they are sometimes called "Barber traps". Such traps have many advantages, being cheap and easy to operate. The current study has employed double-walled plastic drinking cups (Mono Containers 7DW Monogloss). These consist of a ribbed outer container within which is fixed a very smooth-sided inner cup. The double-walled construction makes the traps much stronger than ordinary single walled cups, and the smooth inner surface reduces escapes.

Many studies have shown that the number of animals caught by pitfall traps is influenced by a wide range of factors in addition to population size (Greenslade, 1964; Luff, 1975). One of the most important variables is the degree of surface activity of animals. Pitfalls will always catch some animals, such as earthworms, diptera, and even fleas, which are not regarded as surface runners, but the numbers caught will not be representative of the true population density. In contrast, pitfalling can over-estimate a species which has a high surface activity, but a lower population density (Evans, 1969).

Factors affecting capture have been summarised by Jansen and Metz (1977). They consider that the number of animals trapped depends upon:

- (a) population density
- (b) movement (Brownian)
- (c) pitfall boundary (absorptiveness)
- (d) outer area boundary, and the extent of its penetration by animals (probability of adsorption).

Since movement of running arthropods is affected by climatic factors, these must be corrected for, and this makes comparison of population densities in different habitats, where temperature may differ, more complex.

Since the "active" part of the trap is its edge, then larger traps would be expected to catch more animals than smaller ones. In a comparison of different-sized traps, Nield (1974) found that traps with a longer perimeter did indeed catch more animals, but if the catch per unit length was compared, then no significant difference could be demonstrated. Luff (1975) pointed out that catch size is proportional to perimeter in a circular trap, but that if the approach to the trap is linear, then a rectangular or polygonal trap will also catch in relation to its diameter. He also pointed out that the capture efficiency varied with the size of animals he was trapping: smaller diameter traps were more efficient for small beetles, larger ones caught a greater proportion of those large beetles which encountered the trap edge.

Another factor to consider is the ease with which animals can escape, once trapped. The reason that the double walled plastic cups were used for this survey (and for others by the same author) is that they had previously been found to be very retentive. In an experiment described by Nield (1974), individual beetles were placed in different trap types, and the rate of disappearance over several days recorded. It was found that  $83^{\circ}_{0}$  of animals disappeared from rough-walled plastic pots,  $50^{\circ}_{0}$  from jamjars, but only  $40^{\circ}_{0}$  from double walled cups. Lids were not used in this experiment, so some losses must have been due to predation by birds, but the three trap types were of similar size and depth.

The use of preservative renders the above something of an academic argument, except that the use of formaldehyde has been shown to influence captures (M. L. Luff—pers. comm.).

In the present study, some of the above criticisms are diminished by the fact that the relative abundance of a species is being measured, and not its absolute population density. The major assumption is that a species behaves in the same way in different parts of the transect, and so its probability of capture is the same. This is one reason why methods of analysis using just presence or absence of species have been included. The correlation analysis imposes more constraints on the method, although a drastic reduction in the degrees of freedom, or use of a non-parametric method are seen as possible solutions.

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# Appendix II

Species list and working data for Butser Hill transect, catches summed by region, with an indication of preferred habitat (F: field; Sc: scrub; W: woodland; U: ubiquitous)

				Transect region									
Group/species	Habitat	Α	В	С	D	E	F	G	Η	Ι	J		
Harvestmen													
Nemastoma bimaculatum	Sc			1			4	3	1	6	1		
Homalenotus 4-dentatus	Sc/W	1		1	2	1	1						
Leiobunum rotundum	U				1								
L. blackwalli	W							1					
Oligolophus palpinalis	W									1			
O. agrestis	W						6	1					
O. tridens	W						6	1	1				
Mitopus morio	F/Sc				1		2			2			
Platybunus triangularis	W										1		
Mites													
Parasitus sp.	U			1							1		
Oribatidae	W		1							1	1		
Thrombidium sp.	$\mathbf{F}/\mathbf{Sc}$	27	16	2	63	1	2	5	1				
Pseudoscorpions													
Neobisium sp.	W										1		
Spiders													
Uloborus walckenaerius	F	2	1			1							
Clubiona terrestris	W/Sc	2		4	4		1			1			
Agroeca inopina	Sc	2		1	2	6	13	4					
Zora spinimana	U						2						
Segestria senoculata	U	1				1		1					
Hahnia montana	W						1						
Ero furcata	F/Sc							1					
Xysticus cristatus	F/Sc	2	1		1								
Pachygnatha degeeri	F				2	1	1						
Xerolycosa nemoralis	Sc						1						
Trochosa terricola	F		2	2	1	3							
Pardosa pullata	U			3									
P. tarsalis	F		9		3		1						
P. monticola	F						1						
Alopecosa pulverulenta	F/Sc	3	6	7	1	6		3					
Bathyphantes concolor	Sc				3								
Lepthyphantes tenuis	U		1	1	1		1		3	2	2		
Ergione dentipalpis	U								1	1			
Centromerita concinna	U							1			1		
Typhocrestus digitatus	Sc/W							1					
Woodlice	·												
Trichoniscus pusillus	U								2	2			
Philoscia muscorum	F/Sc	11	1	6	2	1	4	1					

					Tra	nsee	ct reg	gion			
Group/species	Habitat	Α	В	С	D	E	F	G	н	Ι	J
Oniscus asellus	U		2						3		1
Porcellio scaber	F/Sc		1		1		1				
Armadillidium vulgare	F	3	3	9	11	4	3	1			
Centipedes											
Lithobius dubosqui	F	1	1	3	2	3	1		1	1	1
L. variegatus	U										1
Millipedes											
Polydesmus angustus	U		1	1	1	1					
Tachypodoiulus niger	F/Sc			1							
Cylindroiulus punctatus	W				1		1				
Ophyiulus pilosus	W								1		1
Glomeris marginata	Sc				1		1	2		3	
Earwigs											
Apterygida albipennis	W							1	1		1
Forficula auricularia	U			1		3	2		2	1	
Cockroaches											
Ectobius laponnicus	W						1	2		1	
Beetles											
Carabus problematicus	F/Sc	7			4			2			
C. violaceus (larva)	U		2	1		1					
Nebria brevicollis	U							1	1	3	2
Leistus spinibarbis	W/Sc						1				
L. rufomarginatus	W						1				
L. ferrugineus	F						1				
Notiophilus biguttatus	Sc						1				
Loricera pilicornis	Sc				2		1	3	1		
Pterostichus madidus	U			1	1	3	2		2	1	4
P. versicolor	F	2		1							
Abax parallelopipedus	Sc		1		1						
Trechus quadristriatus	F				1		1	4	4	8	5
Calathus fuscipes	F		1		1						
Nargus velox	W						1			1	
Silpha tristis	W							1			
Choleva agilis	W						1			1	
Micropeplus fulvus	W										1
Drusilla canaliculata	U	1								2	2
Oxypoda lividipennis	W				1						
Tachyporus hypnorum	W/Sc						1				
Quedius rufipes	F	3	2	4	3	4	1				
Quedius fuliginosus	F	2	1	2	4	2					
Philonthus fuscipennis	F		1	3	1						
P. politis	F				1						
Staphylinus olens	U	2	1	1	3	5	17				
S. globulifer	F	1									
S. aenocephalus	F		1								

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				Tra	nsec	t reg	ion				
Group/species	Habitat	Α	В	С	D	Ε	F	G	н	I	J
Oxytelus sculpturalis	U						1	1			
Phaedon tumidulus	F		1	1			1				
Phyllotreta sp.	F			1							
Longitarsus sp.	F	1	1								
Sphaeridium scarabaeoides	F					1					
Cercyon minutus	U			1							
Liodes dubia	W						1				
Cantharis sp. (larva)	SC										1
Lampyris noctiluva (female)	F			1							
Anthicus floralis	U						1				
Crepidodera ferruginea	F	1									
Aridius nodifer	W										1
Sitona lineata	F				1						
Barynotus moerens	W							1			
Sawflies											
Symphyta (larva)	F	1	1								
Ants											
Formica rufa	W						1				
Myrmica ruginodis	Sc	14	23	11	9	10	2				
M. scabrinodis	F	3	40	1	71		1		1		
Lasius flavus	F	5	4	4	3	3	1	1			