A comparison of pitfall trapping and vacuum sampling for assessing spider faunas on heathland at Ashdown Forest, south-east England

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Summary

Twelve areas of heathland at Ashdown Forest (Sussex) were selected for showing considerable differences in height of vegetation, altitude, proximity to trees and amount of soil moisture. The habitats are described. Spiders were sampled by using eight pitfall traps in each area continuously for one year, and by taking two 1 m² samples in each area with a D-vac suction sampler on seven occasions between April and November. A total of 156 species was recorded, 133 in the pitfall traps and 96 in the D-vac. The total numbers of adult individuals captured by the two methods are compared, and a site classification based on the two sets of results is presented. Some of the more interesting similarities and differences are noted and discussed. A small amount of timed hand-collecting was done at five of the sites in July; although insufficient for a full comparison with the other methods, this showed some interesting trends. The seasonal changes in numbers of individuals and species taken in the D-vac are briefly discussed.

Introduction

Ashdown Forest, in East Sussex, covers an area of about 25 km², approximately 70% being open heathland while the rest is mixed woodland. The altitude of the heathland areas ranges from about 100 m to just over 220 m. Most of the higher parts are dry heath dominated by *Calluna vulgaris* (L.), with *Ulex minor* Roth common in some areas, but lower down the heath is wetter with abundant *Erica tetralix* L. and *Molinia caerulea* (L.). In some places there is encroachment by trees, mainly *Betula* and *Pinus*, and by scattered clumps of *Ulex europaeus* L. In the valleys around the edge there are boggy areas with species of *Sphagnum*, *Juncus*, *Scirpus* and *Narthecium*.

As part of a general survey of spiders in a wide range of heathlands across southern England, done as a contribution toward the Nature Conservation Review (Ratcliffe, 1977), spiders were collected by pitfall trapping continuously throughout a year in each of twelve sites scattered in different parts of the heathland areas on Ashdown Forest. In view of the well-known disadvantages of pitfall traps, e.g. that the catch is strongly biased in favour of ground-living spiders, that some species are caught much more frequently than others regardless of their actual abundance, and that some species are caught more readily in some habitats than in others, it was decided later to compare the trap results with the results obtained by sampling the same twelve sites with a D-vac suction sampler. Ashdown Forest was selected for this because the results from the pitfall trap survey showed considerable differences between the various sites, and it was obvious that there was considerable variation in the height and age of vegetation, altitude or degree of exposure, proximity to trees, and amount of soil moisture, which might account for these differences in the spider fauna.

No large-scale comparisons of the results of pitfall trapping and suction sampling have previously been made, but Duffey (1980) compared the efficiency of the D-vac in different types of grassland by extracting the residual fauna from the sampled areas using Tullgren funnels. Besides providing information on the differences in the results obtained by the two collecting methods, it was also hoped to arrive at a classification of the sites based on indices of similarity, and that the comparison of collecting techniques might be useful in assessing their relative value for survey work on spiders.

Study Areas and Methods

The twelve sites, listed for ease of comparison in the same order as they appear in Figs. 1, 4-6 and Tables 1, 3-6, were as follows:

1. Isle of Thorns Wet (Grid ref. TQ 422306). Alt. 170 m. Wet heath. *Calluna*, *E. tetralix*, *U. minor*, *Molinia*, *Sphagnum*, *Juncus*, *Scirpus*, scattered *Pinus*.
2. Duddleswell Wet (Grid ref. TQ 457283). Alt. 120 m. Mainly wet heath. Some tall *Calluna*, *E. tetralix*, *Molinia*, patches of *Sphagnum*, young *Betula*.

3. Legsheath Wet (Grid ref. TQ 402328). Alt. 160 m. Wet heath. *Calluna, E. tetralix, Sphagnum, Molinia,* little *Scirpus, Juncus, Pteridium,* small *Pinus* and *Betula.*
4. Ridge Lower (Grid ref. TQ 441327). Alt. 130 m. Continuation of site 6, lower down slope. Mainly wet heath. Some tall *Calluna, E. tetralix, U. minor,* scattered *U. europaeus, Pteridium, Molinia, Betula, Sphagnum, Scirpus, Juncus.*
5. Twyford (Grid ref. TQ 405319). Alt. 160 m. Tall *Calluna, E. tetralix, Molinia, U. minor,* scattered *Betula, Pteridium, U. europaeus, Pinus, Sphagnum.* Wettish in places.
6. Ridge Upper (Grid ref. TQ 441326). Alt. 145 m. Dry heath, on slope. Some short and tall *Calluna, E. tetralix, U. minor,* scattered *U. europaeus, Pteridium, Molinia, Betula, Vaccinium.*
7. Legsheath Dry (Grid ref. TQ 404332). Alt. 150 m. Dry heath. Very tall *Calluna, Pteridium, Betula, Vaccinium,* little *E. tetralix, U. minor, Molinia,* small *Pinus.* On slope.
8. Isle of Thorns Tall (Grid ref. TQ 426310). Alt. 190 m. Dry heath, 20% bare ground. Very tall *Calluna, U. europaeus, E. cinerea, U. minor, Pinus.*
9. Gills Lap (Grid ref. TQ 471307). Alt. 210 m. Dry heath. Very tall *Calluna,* some *U. europaeus* and *Molinia,* small *Pinus.* Thick carpet of moss and lichen.
10. *King's Standing* (Grid ref. TQ 475301). Alt. 200 m. Wettish heath. *Calluna* and *E. tetralix* of moderate uniform height, with *Molinia,* moss and scattered *U. europaeus.*
11. Duddleswell Dry (Grid ref. TQ 462283). Alt. 150 m. Fairly young *Calluna,* with *E. tetralix* and *Molinia.* Few *U. europaeus* clumps, little *Scirpus.* Mainly dry heath but wet at southern end.

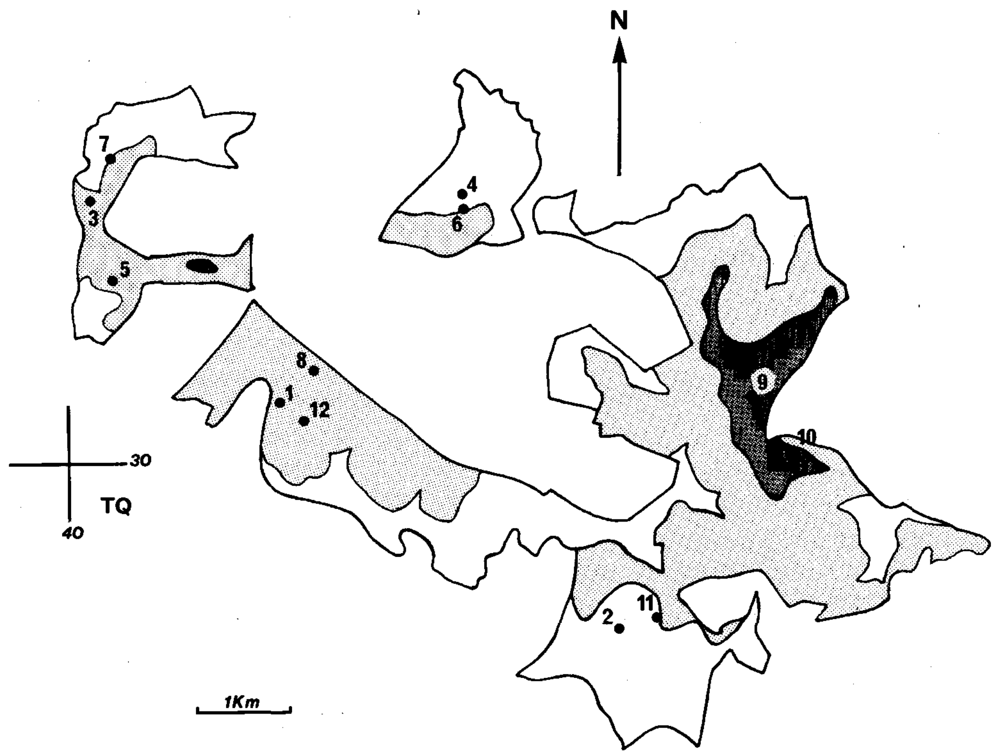

Fig. 1: Map of heathland areas of Ashdown Forest to show position of sampling sites. Ground over 200 m shown black, over 150 m grey, below 150 m unshaded. Most of the central area outside the boundary of the heathland area is mixed woodland. Main co-ordinate of National Grid shown at bottom left. Sites 1-12 are named and described in text.

12. Isle of Thorns Sparse (Grid ref. TQ 425304). Alt. 180 m. Dry heath, 40% bare ground. Partly fairly young vegetation, patches of tall *Calluna* and *E. cinerea, Molinia, U. europaeus, U. minor.*

The distribution of the sites is shown in Fig. 1, and their main features are shown in Table 1. At each site eight pitfall traps were placed in a line 10 m apart. The traps used were plastic pots 7.5 cm in diameter, with a depth of 10.5 cm and holes drilled in the side 3 cm from the top to allow drainage. Phenyl-mercury acetate was used as a preservative, with detergent added to prevent the spiders escaping. The traps were used continuously between May 1968 and June 1969. Also at each site two 1 m^2 samples were taken with the D-vac on each of seven occasions between 9 April and 20 November 1973 (approximately monthly but omitting August), each sample being composed of eleven sub-samples. The suction head was placed down firmly over the vegetation, so as to sample from both the vegetation and litter layers as far as possible, but collections from the litter layer are obviously likely to be less complete from under areas of tall vegetation than from under short vegetation. Since it has been found that wet vegetation seriously affects the catch obtained in the D-vac on heathland, all suction sampling was done in dry weather. All spiders caught were preserved in 70% ethyl alcohol, but only adults were used in the detailed analysis of results. Although four years had elapsed between the pitfall trapping and D-vac sampling, the vegetation appeared to have changed little, and it was thought unlikely that the spider fauna would have changed much during this period. In July two man-hours hand-collecting (one hour by each of us) was done at each of five sites, namely Legsheath Wet, Ridge Upper, Legsheath Dry, Gills Lap and King's Standing. All spiders seen were collected.

Results

Relative effectiveness of pitfalls and D-vac

Before attempting any detailed comparison of the results from the two methods, it is necessary to emphasise that they operate on different ranges of microhabitats in addition to differing in their effectiveness according to the size and activity of the spiders. Pitfall traps are relatively most effective at catching large, active, ground-living species, whereas the D-vac catches mainly small species living higher among the vegetation.

A total of 156 species was recorded, 133 in the

	Soil moisture	Vegetation height	Altitude (m)	% bare ground	*Calluna vulgaris*	*Erica cinerea*	*Ulex minor*	*Ulex europaeus*	*Pteridium*	*Betula*	*Pinus*	*Vaccinium*	*Erica tetralix*	*Molinia*	*Sphagnum*	*Scirpus*	*Juncus*	*Narthecium*
1. Isle of Thorns Wet	++++	++	170	0	+		+				+		++	++	++	+	+	+
2. Duddleswell Wet	++++	++	120	10	+		+			+			++	++	++	+	+	+
3. Legsheath Wet	++++	+++	160	0	+				+	+	+		++	++	++	+	+	+
4. Ridge Lower	++++	+++	130	0	+		+	+	+	++			++	++	++	+	+	+
5. Twyford	+++	+++	160	0	++		++	+	++	+	+		++	++	+			
6. Ridge Upper	++	+++	145	0	++		++	+	+	+		+	+	+				
7. Legsheath Dry	++	++++	150	0	+++		+		+++	+++	+	+	+	+				
8. Isle of Thorns Tall	+	++++	190	20	+++	+	+	++			+							
9. Gills Lap	+	++++	210	0	++			++			+			+				
10. King's Standing	++	++	200	0	++			+					+	+				
11. Duddleswell Dry	++	++	150	0	++			+					+	+		+		
12. Isle of Thorns Sparse	+	+	180	40	++	+	++	++						+				

Table 1: Main physical and vegetational features of sites 1-12. Soil moisture and vegetation height expressed on arbitrary scale of + (driest and shortest) to ++++ (wettest and tallest). Approximate relative abundance of 14 commonest plants represented as + to +++. Six plants characteristic of wet habitats shown at right-hand end of table.

pitfalls and 96 in the D-vac; thus 60 species were exclusive to the pitfalls and 23 were exclusive to the D-vac. The total numbers of adult individuals were 6715 in the pitfalls and 5292 in the D-vac. Since the numbers taken in pitfall traps cannot be related to population density, the efficiency of the pitfalls and D-vac cannot be compared directly within a species, but it is of interest to compare the results obtained for related species and different families by the two methods. This not only provides information about the collecting methods, but also indicates differences in the ecology or behaviour of species which render them more susceptible to capture by one method or the other. The proportion of the total catch (*n*) of each family (or subfamily) taken in the pitfalls and in the D-vac is shown in Fig. 2, and the proportion taken by the two methods for each of the 50 commonest species (i.e. those of which a total of over 25 individuals was caught) is shown in Fig. 3. The numbers of individuals taken by the two methods for a further 46 rarer species (those of which between 5 and 25 individuals were caught) are given in Table 2; these results based on small numbers could be misleading if shown as proportions as in Fig. 3, and some of the smallest differences are not statistically significant, but the presence of a species at least shows that it is taken by one method although its absence may not be significant. When considered in conjunction with similar results obtained on heathland in Dorset (Merrett, 1983), some of these results based on small numbers also strongly suggest that a species is more likely to be caught by one method than by the other.

Since the D-vac was not used between December and March, it might be expected that some winter-maturing species (mainly small litter-living linyphiids) would be under-represented in the D-vac totals for the year in comparison with the pitfalls which were used throughout the year. However, when the results obtained here are compared with those from the study in Dorset (Merrett, 1983) where both methods were used throughout the year, it appears that any distortion caused by this factor is relatively slight. Since the dates when the pitfall traps were emptied do not coincide with the D-vac sampling dates, it is not practicable to separate the winter pitfall results and compare only the months when both methods were used.

It is clear from Fig. 2 that some of the families of larger ground-living spiders were taken almost exclusively in the pitfalls, e.g. Gnaphosidae, Liocranidae (*Agroeca* and *Scotina*), Lycosidae and Agelenidae. These species are not picked up by the D-vac probably because of a combination of their relatively large size and weight, inaccessibility and in some cases low population densities. It is interesting that *Pardosa nigriceps* (Thorell), which is the most arboreal of all British lycosids, was the only species of lycosid to be represented in the D-vac samples to the extent of more than 1% of the total catch (Fig. 3). This was also reflected in the catch of juveniles (not shown in Fig. 3) of which large numbers of *P. nigriceps* were taken in the D-vac but relatively few of any other lycosid. Similarly, although related to the ground-living gnaphosids and liocranids, the much more arboreal clubionids were taken to a large extent in the D-vac.

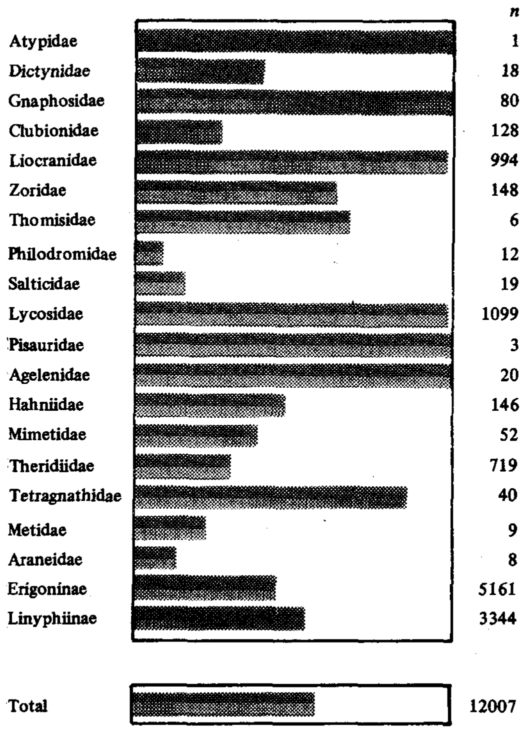

Fig. 2: Proportion of the total catch (*n*) of each family (or subfamily) taken in the pitfalls (shaded bars) and in the D-vac (open bars). Families designated as in Brignoli (1983).

Among other families the distinctions are not so clear cut, some species being caught mainly in the pitfalls while others, in some cases closely related, were caught mainly in the D-vac. In the Hahniidae, for example, about three-quarters of the specimens of *Hahnia montana* (Bl.) were in the D-vac while *H. nava* (Bl.) was exclusively in the pitfalls, the latter probably being more litter-living (or ground-living) than the former. In the Theridiidae, although most species spin webs high among the vegetation and consequently were caught mainly in the D-vac, the litter-living species *Euryopis flavomaculata* (C. L. Koch) and *Robertus lividus* (Bl.) were taken exclusively in the pitfalls. Since it is frequently found among litter it is perhaps surprising that the tiny *Pholcomma gibbum* (Westr.) was taken predominantly in the D-vac, suggesting that it leads a more arboreal existence than is generally supposed. Although only five individuals were caught of each of the two salticids listed in Table 2, the fact that they were all in the D-vac is of some interest in view of the well-known tendency to capture few salticids in pitfall traps. Altogether 6 species of salticids were recorded, from 3 individuals in the pitfalls and 16 in the D-vac.

As might be expected on account of their small size and, in many cases, web-spinning habits, a considerable proportion of the total catch of linyphiids was taken in the D-vac, but there were some interesting differences between species. Only about a quarter of the catch of *Ceratinella brevipes* (Westr.) was in the pitfalls, in contrast to over three-quarters of that of *C. brevis* (Wider). Most *Walckenaera* species were caught mainly or entirely in the pitfalls (Fig. 3 and Table 2), and it is noteworthy that *W. unicornis* O. P.-C., which is sometimes found on *Ulex europaeus* bushes, was the only species of the genus to be taken in large numbers in the D-vac.

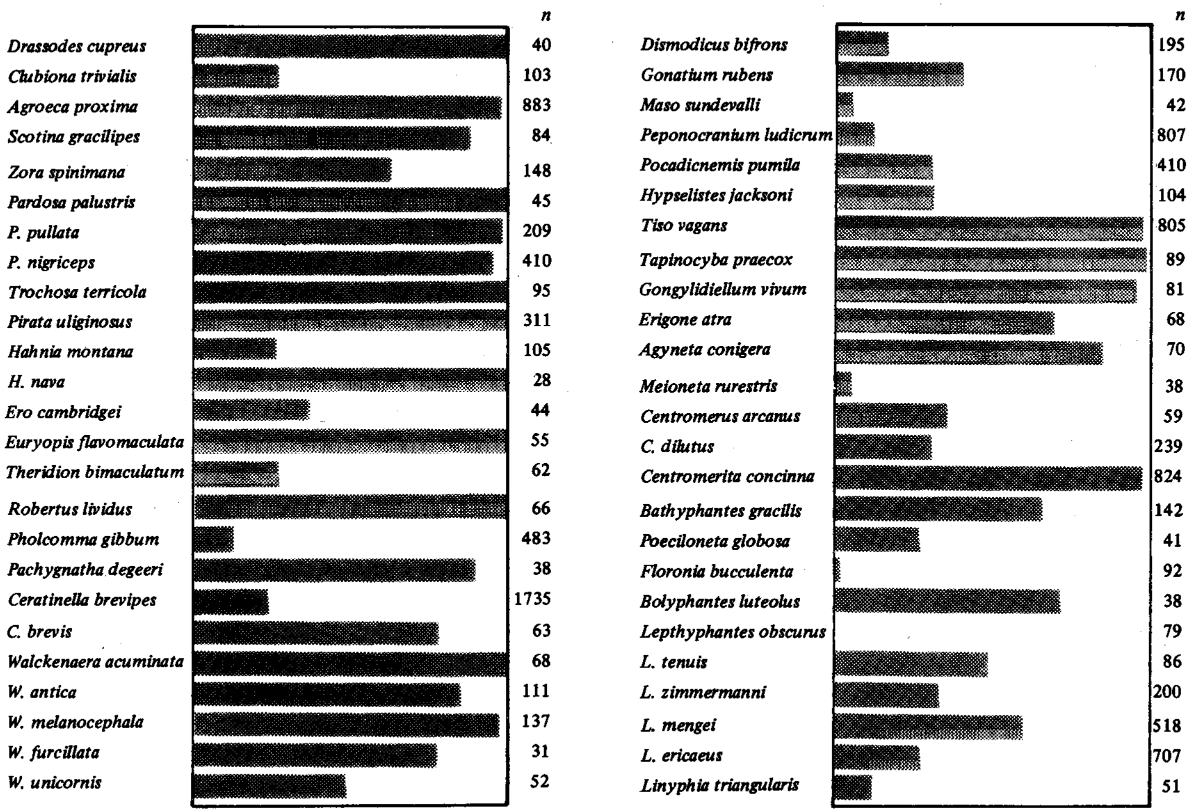

Fig. 3: Proportion of the total catch (*n*) of each of the 50 commonest species taken in the pitfalls (shaded bars) and in the D-vac (open bars). Nomenclature as in Locket, Millidge & Merrett (1974).

Nearly all these species should have been present during the period when the D-vac was used. Other examples of erigonine species which frequently occur up among the vegetation and which were taken mainly in the D-vac are *Dismodicus bifrons* (Bl.), *Maso sundevalli* (Westr.), *Peponocranium ludicrum* (O. P.-C.) and *Pocadicnemis pumila* (Bl.). On the other hand, *Trichopterna thorelli* (Westr.), *Tiso vagans* (Bl.), *Tapinocyba praecox* (O. P.-C.), *Monocephalus fuscipes* (Bl.), *Gongylidiellum vivum* (O. P.-C.) and *Erigonella hiemalis* (Bl.) were all caught almost entirely in the pitfalls. As these six species are all very small, it cannot be their size which causes them to be caught rarely in the D-vac, but they are all litter-living and presumably rarely occur within range of the suction of the D-vac. With the possible exception of *T. praecox,* all should have been present in some numbers during the period when the D-vac was used.

Among the linyphiines, all the *Lepthyphantes* and *Linyphia* species, which spin webs among the heather and other vegetation, were taken frequently or mainly in the D-vac, and exclusively so in the case of *Lepthyphantes obscurus* (Bl.) which is a regular component of the fauna of *Ulex europaeus* bushes. Two further comparisons are worth noting among the linyphiines; *Agyneta conigera* (O. P.-C.) occurred predominantly in the pitfalls while the related *Meioneta rurestris* (C. L. Koch) was almost exclusively in the D-vac, and the two *Centromerus* species were both mainly in the D-vac while the related *Centromerita concinna* (Thorell) was almost entirely in the pitfalls. It is particularly surprising that nearly three-quarters of the specimens of *Centromerus dilutus* (O. P.-C.), a tiny species which is often abundant in litter, should have been taken in the D-vac.

Site classification

The Bray & Curtis (1957) index of similarity, $C = 2w/(a + b)$ (where a = the total number of adult individuals of all species from one site, b = the total number of adult individuals from the other site, and w = the sum of the lesser abundances of those species present at both sites) was used to assess the similarity of species composition among all twelve sites. This index was calculated for all pairs of sites for the pitfall results alone, D-vac alone, and for pitfall traps +

	Pitfalls	D-vac
Dictyna arundinacea (Linn.)	6	10
Haplodrassus signifer (C. L. Koch)	14	0
Zelotes pusillus (C. L. Koch)	9	0
Z. latreillei (Simon)	12	0
Clubiona diversa O. P.-Cambridge	5	4
C. subtilis L. Koch	0	14
Agroeca brunnea (Blackwall)	24	0
Tibellus oblongus (Walckenaer)	1	8
Neon reticulatus (Blackwall)	0	5
Euophrys frontalis (Walckenaer)	0	5
Pardosa lugubris (Walckenaer)	10	0
Pirata hygrophilus Thorell	14	0
Coelotes terrestris (Wider)	17	0
Antistea elegans (Blackwall)	7	0
Hahnia helveola Simon	5	1
Ero furcata (Villers)	4	4
Episinus angulatus (Blackwall)	6	6
Crustulina guttata (Wider)	0	6
Theridion simile C. L. Koch	0	11
T. pallens Blackwall	0	12
Meta segmentata (Clerck)	2	7
Mangora acalypha (Walckenaer)	0	5
Walckenaera cucullata (C. L. Koch)	10	0
W. nodosa O. P.-Cambridge	6	1
W. nudipalpis (Westring)	21	0
W. vigilax (Blackwall)	9	0
Gonatium corallipes (O. P.-C.)	3	6
Oedothorax retusus (Westring)	4	1
Trichopterna thorelli (Westring)	17	0
Cnephalocotes obscurus (Bl.)	2	5
Monocephalus fuscipes (Bl.)	13	0
Micrargus herbigradus (Bl.)	19	5
Notioscopus sarcinatus (O. P.-C.)	3	2
Erigonella hiemalis (Bl.)	23	1
Phaulothrix hardyi (Blackwall)	20	0
Aphileta misera (O. P.-C.)	2	11
Agyneta subtilis (O. P.-C.)	7	1
Meioneta mollis (O. P.-C.)	1	10
M. saxatilis (Blackwall)	7	2
Sintula cornigera (Blackwall)	2	20
Oreonetides abnormis (Bl.)	9	0
Bathyphantes parvulus (Westr.)	6	0
Stemonyphantes lineatus (Linn.)	10	0
Lepthyphantes cristatus (Menge)	1	7
L. flavipes (Blackwall)	0	5
Linyphia clathrata Sundevall	4	10

Table 2: Total numbers taken in the pitfalls and D-vac of those species of which between 5 and 25 individuals were caught.

	1	2	3	4	5	6	7	8	9	10	11	12
1. Isle of Thorns Wet		+++	++	++					+			+
2. Duddleswell Wet	0.59		+++	++	+							
3. Legsheath Wet	0.54	0.56		++++								
4. Ridge Lower	0.54	0.54	0.68		+	+						
5. Twyford	0.44	0.49	0.40	0.46		+++	++	++				
6. Ridge Upper	0.34	0.38	0.34	0.45	0.55		++	+++		+		
7. Legsheath Dry	0.33	0.35	0.38	0.43	0.54	0.51		++++				
8. Isle of Thorns Tall	0.38	0.37	0.34	0.41	0.52	0.56	0.61		+++	+++		
9. Gills Lap	0.49	0.40	0.39	0.44	0.39	0.42	0.37	0.57		++++	+	++
10. King's Standing	0.41	0.30	0.30	0.38	0.33	0.47	0.39	0.55	0.63		++++	
11. Duddleswell Dry	0.44	0.30	0.26	0.29	0.30	0.30	0.21	0.35	0.49	0.62		+++
12. Isle of Thorns Sparse	0.46	0.32	0.25	0.29	0.31	0.30	0.23	0.43	0.53	0.44	0.59	

Table 3: Bray & Curtis similarity indices for all sites based on D-vac and pitfall trap results combined. + = 0.45-0.49, ++ = 0.50-0.54, +++ = 0.55-0.59, ++++ = over 0.60.

D-vac combined. Making the assumption that the pitfall trap and D-vac results combined should give the most complete picture of the spider fauna, the indices based on these combined results were arranged in a trellis diagram, the sites being arranged by trial and error so that the highest values come nearest to the diagonal (Table 3). This suggests that the sites fall into three groups (see also Table 1, in which the order of sites was derived from that shown in Table 3). First there is a group of 4 wet heath sites, all with abundant *E. tetralix*, *Molinia* and *Sphagnum.* Secondly there are 4 sites (sites 5-8) which all had old tall vegetation; the first three (5-7) were also at relatively low altitude, had rather diverse vegetation, and were wettish in places, with some *E. tetralix* and *Molinia,* and scattered *Sphagnum* in the case of Twyford (site 5). Isle of Thorns Tall (site 8) was at higher altitude, but sheltered by trees, and drier than sites 5-7, and appears therefore to be transitional between this group and the last group of sites, which were all either at higher altitudes or more exposed to wind, and had fewer plant species than sites 5-7. Sites 9-11 were all on the eastern side of Ashdown Forest, and notably lacked *Ulex minor.* Isle of Thorns Sparse (12) was rather anomalous in that it contained a considerable amount of bare ground, and part of the area

	1	2	3	4	5	6	7	8	9	10	11	12
1. Isle of Thorns Wet		++++	++++	++								
2. Duddleswell Wet	0.60		++	++	+						+	
3. Legsheath Wet	0.61	0.54		++++							+	
4. Ridge Lower	0.54	0.51	0.64				+					
5. Twyford	0.44	0.49	0.35	0.39		+	+++	+				
6. Ridge Upper	0.25	0.36	0.28	0.34	0.48		+++	+		++		
7. Legsheath Dry	0.40	0.39	0.36	0.46	0.58	0.56		++++		++		
8. Isle of Thorns Tall	0.35	0.33	0.37	0.39	0.47	0.48	0.62		+++	++++	+	
9. Gills Lap	0.39	0.32	0.42	0.41	0.34	0.36	0.39	0.57		++++	++++	++
10. King's Standing	0.26	0.31	0.36	0.41	0.32	0.53	0.54	0.64	0.63		++	
11. Duddleswell Dry	0.39	0.48	0.49	0.43	0.39	0.35	0.32	0.47	0.61	0.51		+++
12. Isle of Thorns Sparse	0.36	0.35	0.44	0.44	0.28	0.23	0.26	0.41	0.51	0.38	0.59	

Table 4: Bray & Curtis similarity indices for all sites based on D-vac results alone. + = 0.45-0.49, ++ = 0.50-0.54, +++ = 0.55-0.59, ++++ = over 0.60.

	1	2	3	4	5	6	7	8	9	10	11	12
1. Isle of Thorns Wet		+	+	+					+			+
2. Duddleswell Wet	0.48		+	++								
3. Legsheath Wet	0.46	0.45		++++								
4. Ridge Lower	0.49	0.50	0.68		++	+++						
5. Twyford	0.42	0.38	0.40	0.50		+++		++	+			
6. Ridge Upper	0.39	0.36	0.42	0.56	0.59			+++	+			
7. Legsheath Dry	0.19	0.22	0.38	0.32	0.36	0.31						
8. Isle of Thorns Tall	0.32	0.26	0.25	0.30	0.50	0.58	0.26		+			
9. Gills Lap	0.49	0.35	0.31	0.40	0.45	0.46	0.21	0.49		++++		+
10. King's Standing	0.44	0.23	0.23	0.32	0.34	0.39	0.13	0.37	0.60		++++	
11. Duddleswell Dry	0.43	0.16	0.15	0.21	0.23	0.24	0.08	0.26	0.44	0.64		+++
12. Isle of Thorns Sparse	0.47	0.25	0.16	0.21	0.29	0.35	0.10	0.39	0.47	0.39	0.55	

Table 5: Bray & Curtis similarity indices for all sites based on pitfall trap results alone. + = 0.45-0.49, ++ = 0.50-0.54, +++ = 0.55-0.59, ++++ = over 0.60.

had been burnt a few years previously. It was basically similar to site 8 but partly with less mature vegetation. It is worth noting the presence of *E. cinerea* at these two sites, and the absence of *E. tetralix* here and at Gills Lap (9). In general the grouping of sites based on indices of similarity in Table 3 agrees well with the grouping based on physical and vegetational features suggested by Table 1. Twyford, which was the only site in the second group where *Sphagnum* occurred, shows some affinity to the wet sites 1-4 in Table 3, and Isle of Thorns Tall shows its transitional position by its affinity to members of both the second and third groups of sites. Also, in Table 3 Ridge Lower shows some affinity to the second group of sites. This is probably because it was rather less wet than sites 1-3, and was in the same geographical area as sites 5 and 6, with which it also shared the presence of *U. europaeus*.

The indices based on the D-vac results alone (Table 4) show a similar grouping of sites but a little less convincingly, as might be expected. The four wet sites form a compact group as before, but the generally lower similarities in the middle group and the, rather surprising, fairly high similarity of King's Standing to Ridge Upper and Legsheath Dry makes the grouping of the drier sites a little less clear. Isle of Thorns Tall again shows similarities to both the second and third groups, and Legsheath Dry shows high similarities to Twyford and Ridge Upper (cf. Table 5).

The pitfall trapping results alone produce even less clear groupings of sites (Table 5). The overall level of similarity is lower, there being only 10 pairs of sites with similarity indices over 0.50, whereas there are 18 for the D-vac alone and for the pitfalls + D-vac combined. This might be expected since the efficiency of pitfall traps is likely to vary more than that of the D-vac, particularly in relation to the height of the vegetation and the amount of bare ground. The following features of the trapping indices

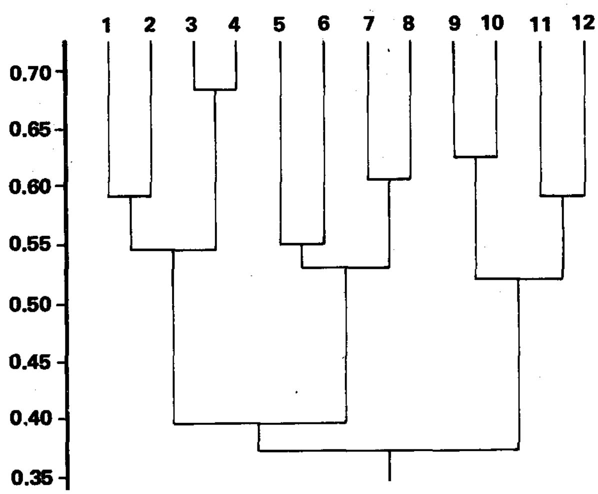

Fig. 4: Dendrogram based on Bray & Curtis similarity indices for D-vac and pitfall trap results combined. Site numbers as in Table 3.

are worth noting in comparison with the D-vac indices: (1) The similarities of most of the wet sites are lower; (2) Ridge Lower shows a much higher similarity to Twyford and Ridge Upper (there is no obvious reason why this should be so); (3) Legsheath Dry, which had the tallest and oldest vegetation with small trees, shows no particular similarity to any other site; (4) Isle of Thorns Tall, the other site with very tall heather, shows an affinity to the middle group of sites with tall vegetation, but not to the third group with mainly shorter heather. With reference to (3) and (4) above, it would be expected that the results from pitfalls and D-vac would be most dissimilar at the sites with tall heather.

In addition to using the trellis diagrams, the weighted group average hierarchical clustering method was applied to the Bray & Curtis similarity indices in each of Tables 3-5 to produce dendrograms (Figs. 4-6). These provide an objective method of classification, but the divisions produced can in some cases be rather artificial, and similarities which are revealed in the trellis diagrams may thereby be lost in the dendrograms.

The dendrogram based on the D-vac and pitfall results combined (Fig. 4) agrees well with the grouping suggested in the trellis diagram (Table 3), except that the similarity of Isle of Thorns Tall (site 8) to Gills Lap and King's Standing (9 and 10) is not shown because its slightly greater similarity to Legsheath Dry (7) causes it to be split off into the middle group of sites.

The dendrogram based on D-vac results alone (Fig. 5) differs from the trellis diagram (Table 4) and from Fig. 4 in that King's Standing (10) becomes part of the "middle" group of sites because its similarity to Isle of Thorns Tall (8) is very slightly greater than is its similarity to Gills Lap (9), and because the fairly high similarity of King's Standing to sites 6 and 7 (as shown in Table 4) outweighs the similarity of Isle of Thorns Tall to the third group which is suggested in Table 4. Also the rest of the third group of sites (9, 11 and 12) show slightly more affinity to the first group of wet sites (1-4) than do sites 5-8 and 10.

The dendrogram of the pitfall trap results (Fig. 6) shows a greater range of similarity values, as was also indicated by the trellis diagram (Table 5). The most important difference between Fig. 6 and Fig. 4 is that site 7 (Legsheath Dry) is shown as being separated from all other sites in Fig. 6, as also noted

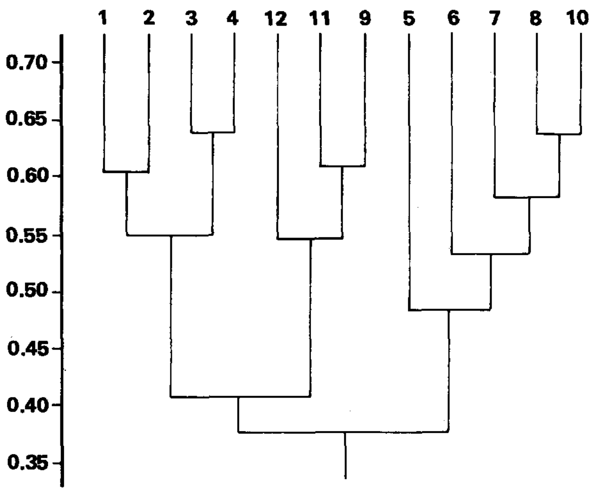

Fig. 5: Dendrogram based on Bray & Curtis similarity indices for D-vac results alone. Site numbers as in Table 4.

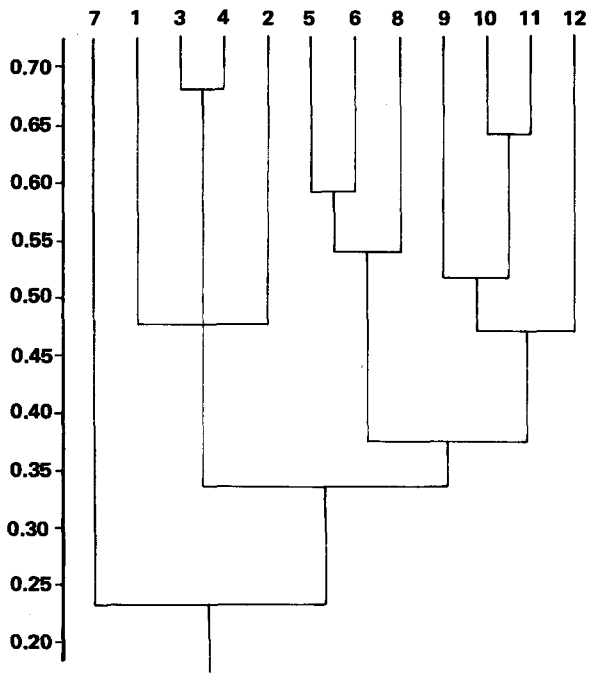

Fig. 6: Dendrogram based on Bray & Curtis similarity indices for pitfall trap results alone. Site numbers as in Table 5.

in the trellis diagram. Figure 6 differs from Table 5 in that the fairly high similarity of Ridge Lower (4) to Twyford and Ridge Upper (5 and 6) shown in Table 5 is masked in Fig. 6 by its higher similarity to site 3 (Legsheath Wet). Also the two groups of "dry" sites are revealed as being slightly closer to each other than either of them is to the group of wet sites. The differences in the indices between the three main groups of sites are, however, small in all three dendrograms.

Distribution of spider species

Most of the species did not show any clear patterns of distribution, but the results from the pitfalls and D-vac are given in Table 6 for eight species which are of interest. The distribution of *Scotina gracilipes* (Bl.) appears to be influenced by geographical factors, in that it was taken on the four eastern sites and the three Isle of Thorns sites (both wet and dry), but not at Legsheath, Twyford or Ridge. This is remarkable in view of the considerable differences in vegetation between sites within these two groups. The only vegetational feature shared by Isle of Thorns and the eastern sites is the absence of *Pteridium* (Table 1), but since this was not abundant on some of the other sites it seems unlikely that its presence could account for the absence of *S. gracilipes.* Some of the sites where *S. gracilipes* occurred also contained some bare ground, which appears to favour the species, but this was not true in all cases. *Pirata uliginosus* (Thorell) shows a clear tendency to be most abundant in the sites at the wetter end of the range, especially in the four wettest sites with abundant *Sphagnum.* The two *Ceratinella* species show some interesting differences. *C. brevipes* was scarce or absent at the wettest sites and most abundant at the dry sites with tall vegetation. While the numbers of *C. brevis* were much smaller, its distribution appears to be shifted more towards the wet end of the range of sites and away from the dry end, in comparison with *C. brevipes.* As mentioned earlier, *C. brevipes* was also relatively much more numerous in the D-vac samples than *C. brevis,* and this also suggests that *C. brevis* occurs more in litter and is less tolerant of drier conditions. A similar difference may exist between *Walckenaera furcillata* (Menge) and *W. unicornis.* Although the numbers are small, the results suggest that *unicornis* occurs more towards the drier end of the range of sites, this again being supported by the fact that it was relatively more numerous in the D-vac than *furcillata. Hypselistes jacksoni* (O. P.-C.) is well-known to be a species of wet habitats, which is reflected here in its occurrence in the four wet sites and the moderately wet Twyford. It was, however, also taken in the three eastern "dry" sites, Gills Lap, King's Standing and

	I.o.T. Wet	Dudd. Wet	Legs. Wet	Ridge Lower	Twyfd.	Ridge Upper	Legs. Dry	I.o.T. Tall	Gills Lap	King's Stand.	Dudd. Dry	I.o.T. Sparse
Scotina gracilipes (Bl.)	18	6						4	10	5	21	11
	(4)										(5)	
Pirata uliginosus (Thorell)	83	40	85	67	7	22		1	2			4
Ceratinella brevipes (Westr.)			1	5	5	80	7	184	18	23	18	64
				(20)	(43)	(478)	(239)	(171)	(95)	(199)	(51)	(34)
C. brevis (Wider)	5	1	4	3	16	4	5	8		2		1
	(3)		(5)	(4)			(1)	(1)				
Walckenaera furcillata (Menge)		1	9	2	6	3	3					
		(1)		(1)	(2)	(3)						
W. unicornis O. P.-C.	1				1		5	17		1		
					(5)	(2)	(10)	(9)		(1)		
Hypselistes jacksoni (O. P.-C.)	6	3	2	1	6					8	6	
	(4)	(37)	(5)	(2)	(5)				(3)	(6)	(10)	
Centromerita concinna (Thorell)	74	8		5	4	7		12	35	25	278	353
	(1)				(2)			(2)	(2)	(2)	(3)	(11)

Table 6: Total numbers of adults of eight species collected at each site in pitfalls (upper line) and D-vac (lower line – in parentheses).

Duddleswell Dry. Here altitude may be important in the case of the first two sites (the two highest sampled), and Duddleswell Dry was wet at one end of the transect. The most obvious feature of the results for *Centromerita concinna* is that most were taken in the pitfalls in the two sites with fairly young vegetation or extensive bare ground, i.e. Duddleswell Dry and Isle of Thorns Sparse. This probably partly reflects a greater efficiency of the pitfalls under these conditions, but the species is also known elsewhere to be scarcer in more mature vegetation. Here none was taken at Legsheath (Wet or Dry), two sites with very old vegetation.

Hand-collecting

The results from the total of ten man-hours of hand-collecting are inadequate for any detailed comparison with the other methods, but a few observations can be made. First, the hand-collected species were much closer to the D-vac results than to the pitfall results, as might be expected. Secondly, in general the species were found at the same sites as by the other methods. Thirdly, the total of 42 species from the hand-collecting compares favourably with the total of 30 species collected from the same five sites in July with the D-vac, but the total number of adult individuals, at 175, was less than the corresponding D-vac total of 287. Two species, *Clubiona reclusa* O. P.-C. and *Araneus quadratus* Clerck, were collected by hand but were not by either of the other methods.

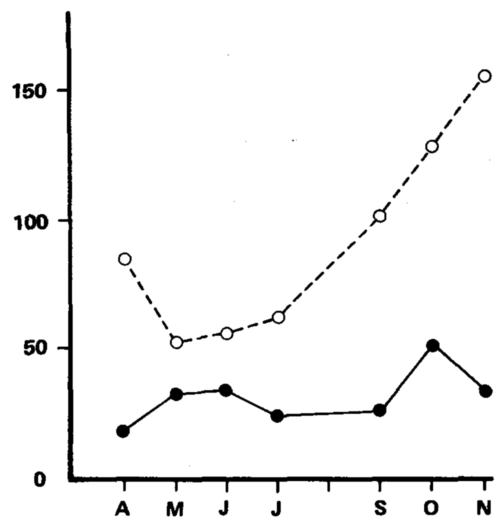

Fig. 7: Mean numbers per square metre of all spider species collected in the D-vac in the seven months between April and November 1973 (no collection in August). Solid line = adults, dashed line = juveniles.

Population densities

The mean numbers per square metre of adults and juveniles collected in the D-vac in each month are shown in Fig. 7. The peak for adults in May/June and in October is typical of most spider populations that have been investigated, as is the winter peak of juveniles. The densities of adults ranged from 5 per m^2 at Legsheath Wet in April to 113 per m^2 at Ridge Upper in October, and for adults and juveniles combined from 34 at Isle of Thorns Sparse in September to 431 at Twyford in November. These figures must, of course, be considerable underestimates of the total numbers present, in view of the inefficiency of the D-vac with regard to many groups of species.

Number of species taken each month with D-vac

An interesting aspect of the D-vac sampling is the number of species taken on each visit, and the most effective combination of visits to obtain the maximum number of species with minimum effort. This knowledge could be valuable when considering rapid survey work. Out of the total of 96 species taken in the D-vac, the best month was June with 52 (54.2%), closely followed by May and October with 51 (53.1%), then July 48 (50%), September 44, November 43 and April 36. If two months' catches are combined, the highest number of species (77, or 80.2%) was obtained in June + October, followed by May + October and May + June with 72 (75%) and May + November and June + November with 70 (72.9%). When three months' catches are combined, 89 species (92.7%) were obtained in May + June + October, 86 (89.6%) in May + June + November, 82 (85.4%) in May + June + September, and 81 (84.4%) in April + June + October. Only one species would have been lost if the July and September collections had been omitted. Thus the months when most species were collected (May, June and October) coincide with the periods of peak numbers of adult individuals shown in Fig. 7. These results agree well with the general impressions of the most productive months gained by hand-collecting. The pitfall traps at Ashdown Forest were emptied too infrequently to permit any comparison of seasonal changes in the catch with those recorded in the D-vac.

Discussion

Pitfall trapping has been widely used as a sampling method in ecological studies on spiders. The effectiveness of pitfall traps in comparison with quadrat sampling was discussed by Uetz & Unzicker (1976), who also reviewed earlier literature on pitfall trapping and indicated ways of reducing sampling errors caused by differential activity. They concluded that quadrat sampling takes a disproportionately larger fraction of the species present in more diverse communities, and that pitfall traps give a closer estimate of the total number of species present in an area, and are more useful in studies of species diversity.

Some small-scale comparisons of quadrat sampling and D-vac sampling were described by Duffey (1974), who found that the D-vac results compared favourably with those obtained by hand-collecting. Duffey (1980) also compared the efficiency of the D-vac in different types of grassland by extracting the residual fauna from the sampled areas using Tullgren funnels. These and other collecting methods were also reviewed by Turnbull (1973), and the efficiency of different types of pitfall traps has been discussed by Curtis (1980).

It is perhaps surprising that there has been no previous comparison of the results of pitfall trapping and D-vac sampling for spiders. The precise proportion of any particular species caught in the pitfalls or D-vac is not important or meaningful in itself, but large differences in these proportions between closely related species which mature at the same season are of interest, as are indications of a species or group of species being caught almost entirely by one method alone. The results given here show that these two methods are largely complementary in assessing the number of species and their relative abundance in spider communities. There are few species which are not caught frequently by either method; some of the large *Araneus* species which appear to be too heavy to be sucked up by the D-vac and which are rarely active at ground level are the most obvious examples.

In view of the considerable differences between the numbers and species of spiders caught by the two methods, it is perhaps surprising that in general the groupings of the indices of similarity derived from them are so similar. The most striking differences in the indices occur in the sites with very tall heather where the results from the two methods would be expected to differ most strongly. It seems that combining the D-vac and pitfall results produces the most consistent set of similarity indices, the grouping of sites indicated in Table 3 corresponding well with that suggested by the physical and vegetational characters shown in Table 1.

The small amount of hand-collecting that was done suggested that this method is probably better than the D-vac in terms of the number of species collected, but that fewer individuals are likely to be taken. This difference is probably caused partly by a subconscious bias when collecting by hand to favour a "new" species if several different individuals are seen together. More of the larger species characteristic of lower strata are also likely to be collected by hand than in the D-vac. Hand-collecting, however, suffers from the disadvantage of being extremely laborious and time-consuming, and its efficiency varies considerably according to the individual collector and his degree of tiredness.

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