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COLLECTING METHODS AND THE ADEQUACY OF ATTEMPTED FAUNA SURVEYS, WITH REFERENCE TO THE DIPTERA

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ABSTRACT

Ecologists and conservationists are concerned with the survey of the invertebrate faunas of terrestrial habitats. A variety of methods has been employed for this purpose. We report experiments in which we compare water-traps of different colours, pitfall traps and Malaise traps. We chose the Diptera, as a large and diverse order of insects, to enable us to make these comparisons. We examine the efficacy of the different methods at the family level and also at the species level for two families (Agromyzidae and Phoridae). We discuss the problems of achieving worthwhile surveys and suggest that for certain purposes, notably for conservation evaluation, a knowingly selective method is to be preferred provided that its bias is consistent and that it produces replicated samples of quantitative data. For Diptera we suggest that white water traps, or a combination of white and yellow, could be a valuable method for such surveys.

INTRODUCTION

ECOLOGISTS have long been interested in surveying the faunas of different sites and habitats (e.g. Elton, 1950, 1966). More recently conservationists have concerned themselves with surveying particular sites in order to base their policy decisions upon sound data. The requirements of the conservationist are, however, twofold. Firstly, he needs to know which species are present in the site under consideration. Secondly he needs to assess the significance of the occurrence of a particular species with reference to a national context.

The latter requirement is increasingly being met by the Biological Records Centre mapping schemes (Heath and Scott, 1974; Heath and Harding, 1981). When a group of organisms has been adequately mapped defensible statements may be made about "rarity". For example we can now state of a species that it occurred in fewer than 10 of the several hundred 10 Km squares surveyed.

Returning to the question of which species are present in a particular site, one quickly realises that a list of plants is, in principle, relatively easy to obtain. On the other hand invertebrates pose immense practical difficulties with regard to the adequacy of one's sampling procedures. It is these difficulties, coupled with inadequate resources, that serve to explain the dearth of information on the invertebrate faunas of the terrestrial Sites of Special Scientific Interest covered by *The Nature Conservation Review* (Ratcliffe, 1977). These SSSI's have largely been designated on the basis of their flora.

The recent initiative of the Nature Conservancy Council's attempt to identify the most important sites in Britain for invertebrates (The Invertebrate Site Register) is to be welcomed. On the other hand the problems of achieving adequate surveys to enable meaningful comparisons to be made between sites are extremely formidable. Even when one has adequate data, as is frequently the case for the flora, comparisons and evaluations are still beset with problems (see Usher, 1980).

Confining our attention to surveying the terrestrial insects of a site, we are immediately confronted with the question "Which collecting methods shall we use?" It is axiomatic that any particular method for collecting insects will be selective with regard to the species present in a particular habitat.

There is no such thing as a comprehensive method which will procure a complete representation of all species present. The obvious deduction is that a fauna survey of a particular site must employ a variety of collecting methods if one is even to approximate towards a complete species list. Despite the fact that the above assertions are generally accepted by entomologists, we observe that most of those actually engaged in fauna surveys generally use only a few methods and frequently only use a single method. If only a single method is used it needs to be justified. Has the method been shown to give a good return in relation to this economy of effort? In many cases there is little or no evidence that this question has ever been considered. For this reason we decided to explore the selectivity of a few of the collecting methods currently favoured by entomologists. We restricted our attention to the Diptera (flies, midges and gnats) and carried out the main experiments during a single week on the Malham Tarn Estate Nature Reserve in North Yorkshire.

The Diptera are the second largest order of the British Fauna and they exhibit the greatest variety of habits. They present, therefore, an exciting challenge to the would-be fauna-surveyor, although they have often been by-passed by students who have found recognition to the family level daunting. However, one of us has recently provided the means for overcoming the family recognition problem for the uninitiated (Unwin, 1981). The choice of the Malham Tarn Estate was made for various reasons, not the least of which being that it is one of the best-surveyed sites for Diptera in the country (see discussion) and hence a direct comparison could be made of the experimental survey against existing records.

The experiments reported here aim to encourage those engaged in fauna surveys to be more critical of their approach. We also wish to point the way to the almost limitless scope for interesting exercises for students on field courses.

EXPERIMENTS

In those experiments operated for more than 24 hours collections were generally made once a day. However, the relatively low numbers, associated with the poor weather, meant that we ended by lumping the data for each experiment.

Experiment A

In the West Fen of the Malham Tarn Estate (Grid Ref. SD 883671) the following traps were operated from 11-14 September 1980 arranged as in Fig. 1.

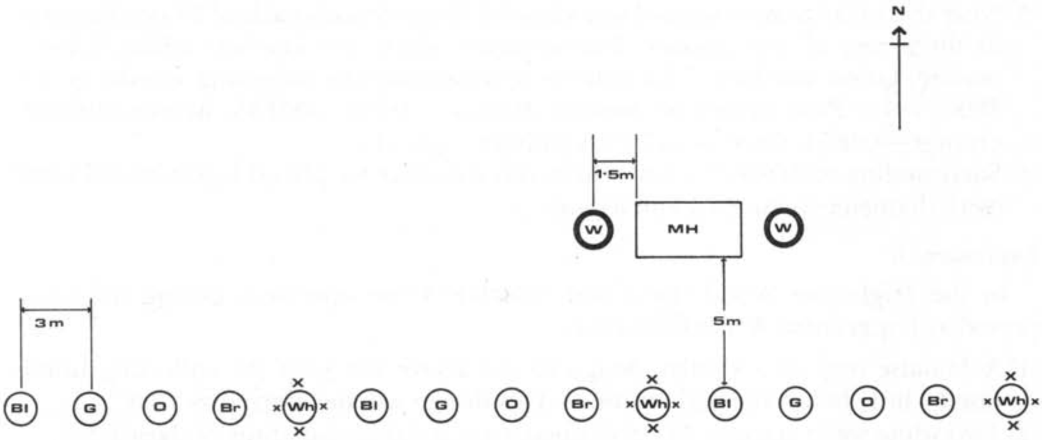

Fig. 1.
Experiment A. Layout of traps. circles = water traps; x = pitfall traps.
MH = Malaise trap; BL = Blue; Br = Brown; G = Green; O = Orange; Wh = White.

(1) A white Malaise trap (as supplied by Marris House Nets, Duxford, Cambridge) (Plate I). This trap has the collecting bottle fitted at the highest point of the trap. This design of Malaise trap will be referred to as "MH".
(2) Two white water traps (i.e. a bowl half-filled with water plus several drops of detergent), of 31 cm diameter, set at either end of the Malaise trap.

Plate I
Malaise trap (MH) set on Tarn House lawn (Experiment C).
Photo by Edward Jackson.

(3) Near this arrangement we laid out a line of 15 water traps each of 21 cm diameter in three sets of five colours. The sequence along the line was white, brown, orange, green and blue. The colours approximate the following standards (BS 4800, 1972, *Paint Colours for Building Purposes*): White—00E55, Brown—06C39, Orange—06E51, Green—12D45, and Blue—20E51).
(4) Surrounding each white water trap in this sequence we placed 4 glass pitfall traps (with diameters between 4 and 6 cms).

Experiment B

In the Highscree Wood (Grid Ref. SD894673) we operated, during the same period as Experiment A, the following:

(1) A Malaise trap of a similar design to the above but with the collecting bottle fitted a little below the highest point. This design will be referred as "PW".
(2) Two white water traps of 31 cm diameter, set at either end of the Malaise trap.
(3) A line of 10 water traps in two sets of five colours, the sequence being the same as above.

Experiment C

On the Tarn House Lawn (Grid Ref. SD894672) we operated the arrangement shown in Fig. 2, employing 2 Malaise traps, 12 glass pitfall-traps (with diameters between 4 and 6 cms), 3 white water traps of 28 cm diameter and 3 yellow water traps of the same size (the yellow being BS colour 08E51). This experiment was carried out for 24 hours on 14-15 September 1980.

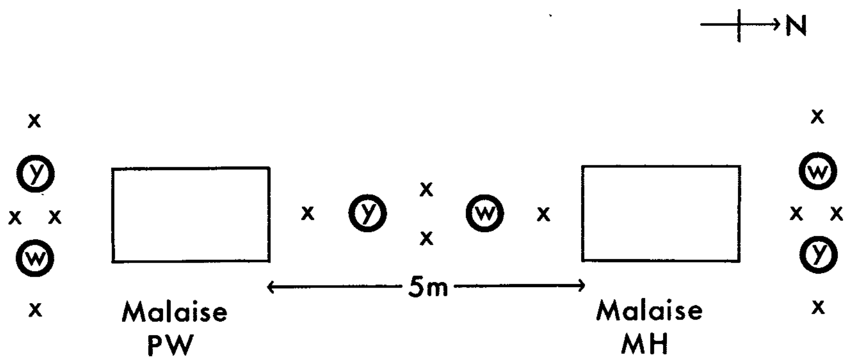

FIG. 2.
Experiment C. Layout of traps. circles = water traps; x = pitfall traps.
W = White; Y = Yellow.

Experiment D

At the edge of the Tarn House Lawn the following line of traps was operated for 48 hours on 20-22 September 1980. Starting at the northern end; the Malaise trap MH followed by 6 water traps of 28 cm diameter of white and yellow in alternate sequence, commencing with white.

Experiment E

The coloured bowls used in experiments A and B were divided into sets of 5 (one of each colour) and operated at the following five localities from 24-27 September 1980. They were set out on lawns as in Fig. 3.

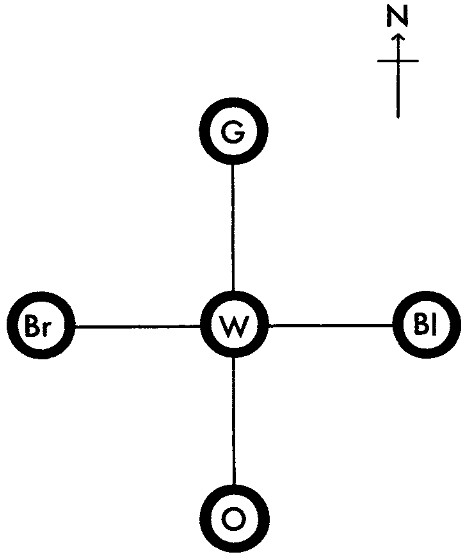

FIG. 3.
Experiment E. Layout of traps. Bowl centres 1 m apart.
W = White; G = Green; Bl = Blue; O = Orange; Br = Brown.

Waltham Abbey, Essex	(Grid Ref. TL 392 005)
Norwood End, Essex	(Grid Ref. TL 567 085)
Melbourn, Cambridgeshire	(Grid Ref. TL 386 441)
Dickleburgh, Norfolk	(Grid Ref. TM 175 825)
Malham Tarn Field Centre, North Yorkshire	(Grid Ref. SD 894 672)

Experiment F

At the edge of the Tarn House Lawn, in unmown rough grassland, the following layout was operated for 24 hours on 2-3 October 1980: two rows of traps, each consisting of 3 glass bowls 23 cm in diameter and 3 white plastic tubs measuring 18 × 18 cm, arranged alternately 1 m apart, with the Malaise trap MH lying immediately to the north. The northern row was operated as a line of normal water traps, with a small patch of soil placed below the three glass bowls to provide a comparable background to the glass pitfall traps; the southern row were all sunk into the ground and thus became pitfall traps.

ANALYSIS

When the catches from the experiments described above were analysed the numbers were frequently too small for the assumption of normal distribution to be made, and non-parametric statistics were required; in these circumstances the Mann-Whitney U-test (Siegel, 1956) has been used.

RESULTS I—COMPARISONS AT THE FAMILY LEVEL

Colour of water trap

In Table I we present an analysis of the findings when the Diptera caught in the coloured bowls (experiments A, B and E) were identified to family and the numbers totalled. This grouping of data from three different experiments needs comment. As

Table 1. *Catch in coloured bowls, as percentage of the catch in the white bowls (mean ± s.e.)*

Group	Brown	Orange	Green	Blue
All flies	46.3 ± 9.9	61.4 ± 15.9	35.9 ± 9.2	72.8 ± 9.9
Nematocera	124.4 ± 18.4 NS	191.8 ± 39.5	79.4 ± 19.3 NS	76.5 ± 12.3 NS
Schizophora	17.8 ± 2.6	19.0 ± 3.6	20.8 ± 4.9	79.9 ± 13.7 NS
Chironomidae	147.8 ± 23.2	161.0 ± 28.5	81.1 ± 17.9 NS	46.5 ± 10.4
Phoridae	2.0 ± 0.8	20.4 ± 2.1	2.5 ± 1.5	39.1 ± 15.4
Syrphidae	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	76.5 ± 21.2 NS
Ephydridae	54.1 ± 19.9	86.4 ± 32.0 NS	147.2 ± 54.4 NS	31.4 ± 11.3
Drosophilidae	3.9 ± 2.1	5.3 ± 2.7	4.2 ± 2.2	77.4 ± 25.2 NS
Muscoidea	14.0 ± 7.9	8.1 ± 2.2	7.6 ± 2.4	100.4 ± 21.6 NS

NS indicates a score not significantly different from that in the white bowls at the 95% confidence level.

we are here concerned with behavioural responses to different colours we have assumed this response will be consistent on different dates and at different localities. We have grouped the data as follows. The catch for bowls of the same colour for each site and each day for experiments A and B were combined to give 6 samples. For Experiment E the same approach produced 3 samples for Malham Tarn, but because of the much lower catches at the other 4 sites it was decided to combine the catches from these sites to produce a further 3 samples. In most cases the numbers for a particular family are too low for any useful patterns to emerge. Table I omits families caught in numbers too low to give significant results.

This analysis shows that only with the family Chironomidae were significant results obtained over 100 per cent: that is to say brown bowls and orange bowls caught significantly more specimens that white bowls. All other significant results in Table I show that white bowls were the most effective of the five colours employed. The high score of Syrphidae in the blue bowls is interesting, in relation to the dearth of hover-flies in brown, orange and green bowls, but is not significantly different from the catch in white bowls.

In Table 3 we present the diversity in terms of families of Diptera for experiments A, B and E. The Index of Diversity employed has been discussed by Yapp (1979). The analysis reinforces the finding that, at the family level, white and yellow water traps produce very similar results.

Pitfall traps (and trap size)

In experiment A the catch in the pitfall traps was extremely low. This was in part due to the fact that there was much rain over the period of the experiment and the site was a wetland.

In experiment C (Fig. 2) we obtained sufficient data to allow useful analysis. Table 2 shows that pitfalls were not very effective for catching Diptera. Only Chironomidae, Sphaeroceridae and Ephydridae (all of which were *Hydrellia modesta*) were caught in any numbers and all three groups were more readily caught by white water traps. Table 3 shows that pitfalls were less than half as effective as white water traps overall.

In experiment F we counted a few non-Dipteran groups for comparison in the analysis and we attempted to separate the fact of a trap being a pitfall or water trap from the fact of it being a glass trap, as opposed to being white. It is evident from Table 4 that, for Diptera overall, a trap being white is of greater significance than its position in relation to the ground surface ($P < 0.02$). By contrast, for spiders,

Table 2. *Comparison of white and yellow bowls, pitfall and Malaise traps*

Group	Yellow bowls (% of mean no. in white bowls) (mean ± s.e.)	Malaise traps (% of mean no. in white bowls)		Pitfall traps (% of mean no. in white bowls) (mean ± s.e.)
		MH	PW	
All flies	105.9 ± 16.6 NS	528.3	26.1	3.3 ± 0.3
Nematocera	117.1 ± 30.8 NS	441.7	113.4	13.3 ± 1.9
Brachycera	24.2 ± 12.1	317.6	0.0	0.0 ± 0.0
Aschiza	94.0 ± 8.0 NS	27.9	1.3	0.9 ± 0.4
Acalypterates	100.5 ± 27.9 NS	428.0	5.1	6.1 ± 1.0
Calyptrates	132.6 ± 23.9 NS	1069.6	2.8	2.3 ± 0.9
Psychodidae	48.7 ± 12.9	310.5	200.0	0.0 ± 0.0
Chironomidae	143.8 ± 56.7 NS	425.3	67.1	23.5 ± 0.4
Sciaridae	115.7 ± 30.3 NS	309.6	58.1	1.6 ± 1.6
Phoridae	20.1 ± 2.9	42.4	2.8	1.9 ± 0.9
Sphaeroceridae	138.3 ± 10.9	430.4	0.0	17.3 ± 4.3
Syrphidae	167.7 ± 34.4 NS	15.7	0.0	0.0 ± 0.0
Carniidae	40.8 ± 17.1	3.5	0.0	0.0 ± 0.0
Ephydridae	173.3 ± 28.4	69.7	0.0	24.5 ± 4.2
Drosophilidae	56.3 ± 15.4	796.3	3.9	0.5 ± 0.3
Chloropidae	97.3 ± 36.2	2.5	33.9	5.7 ± 3.5
Calliphoridae	57.0 ± 18.5	23.9	4.1	1.4 ± 1.4
Muscoidea	149.0 ± 25.7	1340.0	2.6	2.4 ± 0.6

NS indicates that the score in the yellow bowls is not significantly different from that in the white bowls at the 95% confidence level.

(Araneida), harvestmen (Phalangida) and rove beetles (Staphylinidae) the fact of the trap being a pitfall is more important than of it being white or glass ($p < 0.001$ in all cases).

Amongst individual families of Diptera we find the general preference for white traps versus clear glass ones is confirmed for Anthomyiidae, Drosophilidae, Muscidae and Syrphidae ($p < 0.05$ in each case). In the case of the Syrphidae there were significantly more in the white water traps compared with the white pitfalls ($p < 0.05$), suggesting the degree of exposure of a white trap is significant. The Tipulidae, however, showed a preference for pitfall traps ($p < 0.002$). The Ephydridae showed no preference, giving means as follows: white water traps 27 ± 4.9, white pitfalls 33 ± 4.5, glass water traps 15 ± 5.4, glass pitfalls 27.3 ± 0.33. The catch in fact comprised a single species, *Hydrellia modesta,* which is associated with the water surface of puddles and ponds. It would seem, therefore, that the presence of water is more significant than the nature of the container for this

Table 3. *Diversity in white and yellow bowls, pitfall and Malaise traps*

Trap	No. of families	Yule's Index of Diversity
Malaise MH	27	4.73
Malaise PW	14	6.67
Pitfall	12.0 ± 1.9	4.6 ± 0.5
White bowl	27.6 ± 0.7	9.9 ± 1.4
Yellow bowl	27.0 ± 1.7	8.8 ± 1.1

Table 4. *Experiment F—comparison of pitfalls and water traps (2–3 October 1980)—actual numbers caught*

TAXON	3 white plastic water traps	3 white plastic pitfalls	3 glass water traps	3 glass pitfall traps
NON-DIPTERA				
Araneida	1	9	2	10
Carabidae	0	4	0	1
Homoptera	15	11	21	26
Hymenoptera-Apocrita	19	13	12	3
Phalangida	0	9	0	8
Staphylinidae	0	8	0	12
DIPTERA	—	—	—	—
Agromyzidae	3	1	1	0
Anisopodidae	1	3	1	1
Anthomyiidae	91	39	1	5
Bibionidae	0	2	0	0
Calliphoridae	0	7	0	0
Carniidae	7	4	1	0
Cecidomyiidae	7	4	18	32
Ceratopogonidae	0	5	1	1
Chironomidae	11	2	48	72
Chloropidae	0	0	1	0
Drosophilidae	42	47	4	3
Empididae	1	0	1	1
Ephydridae	81	100	47	82
Lonchopteridae	1	1	0	1
Muscidae	122	25	6	7
Mycetophilidae	1	1	1	0
Phoridae	7	6	1	2
Psychodidae	9	9	6	22
Scathophagidae	13	5	1	0
Sciaridae	13	8	19	10
Sphaeroceridae	2	7	11	11
Syrphidae	166	17	1	1
Tipulidae	0	34	9	80
Trichoceridae	12	7	1	0

species. Furthermore we have analysed the relationship between the surface area of the water and numbers for this species. In experiment C (Fig. 2 Table 2) the difference between pitfalls and white water traps can be used to provide an indirect estimate of this relation between catch size and surface area. The total surface area of pitfalls was 80 cm^2 whilst that of the white water traps was 616 cm^2. The numbers of *H. modesta* were 12.6 ± 2.2 in pitfalls and 72.5 ± 18.5 in white water traps. The numbers were thus roughly proportional to the surface area.

For Diptera as a whole this relationship between surface area and catch size appears to be similar. For example in experiment A (Table I) where two sizes of white bowl were used (surface areas of 755 cm^2 and 346 cm^2) the number of flies caught per unit of surface area was not significantly different in the two types of bowl ($p < 0.005$).

Malaise traps

Table 2 reveals the remarkable finding that the small difference in design between Malaise traps MH and PW altered the total number of flies caught by a factor of 20.

The Malaise MH is clearly highly effective for catching certain families, particularly of Calyptrates. However a cursory glance at the catches shows that the total for a particular family is frequently made up of relatively few species. For example, the large numbers of Drosophilidae were represented almost entirely by *Scaptomyza pallida*. It seems that the Malaise trap is effective for trapping swarms of particular species. This means that the labour involved in sorting through the catch for any other species becomes somewhat tiresome. It would also appear that for some families, notably Carniidae and Syrphidae, the Malaise trap was less effective than white water traps.

Table 3 indicates that overall (i.e. in terms of numbers of families caught) a Malaise trap gives comparable results to a white water trap, but due to the "swamping" of the catch by swarms of certain species the Index of Diversity is lower and the labour of sorting the catch is higher.

Results II—Comparisons at the Species Level

Table 5 summarises the analysis of the data on Agromyzidae and Phoridae taken to the species level, for Experiment C. Fig. 4 presents the detailed data for those species whose totals exceed 10 per cent of the family figure for the exercise. Table 6 and Fig. 5 provides a similar presentation of data for the Phoridae obtained in Experiment D, but in Fig. 5 species represented by totals of 10 or more specimens were selected. Table 7 presents the analysis of the Phoridae for Experiment E. At three sites the catches were dominated by *Metopina oligoneura*. The figures for this species are presented in Table 8. Table 9 provides the analysis of the Phoridae for Experiment F. By the beginning of October the numbers at the upland site of Malham Tarn are falling off rapidly so that the totals for the individual species are too low to allow a more detailed analysis.

Table 5. *Experiment C—The numbers of species of Agromyzidae and Phoridae obtained in the different types of trap*

Trap type	Pitfalls	3 Yellow Water	3 White Water	Malaise PW	Malaise MH	TOTALS
No. of Agromyzidae	1	61	13	2	15	92
No. of species of Agromyzidae	1	12	7	1	5	16
No. of Phoridae	2	20	106	1	15	144
No. of species of Phoridae	1	8	9	1	7	15

Colour of water traps

Table 5 indicates that the yellow water traps were more effective than the white ones for surveying Agromyzidae. By contrast, the Phoridae were more numerous in the white traps, although the difference in the numbers of species was not significant. Fig. 4 suggests that yellow traps are significantly more attractive to *Cerodontha denticornis* and *Phytomyza nigra* than are white traps, whereas this tendency is less marked for *P. milii*. By contrast *Triphleba (= Citrago) citreiformis, Conicera dauci* and *Phora stictica* were clearly attracted by the white traps, but this was less marked for *Megaselia pulicaria*. In Experiment D the preference for white traps over yellow is no longer obvious (Table 6). However at the level of individual species (Fig. 5) the reason becomes apparent. Two species common in Experiment C, *T. citreiformis* and *P. stictica,* show the same strong preference for white traps. The increase in the

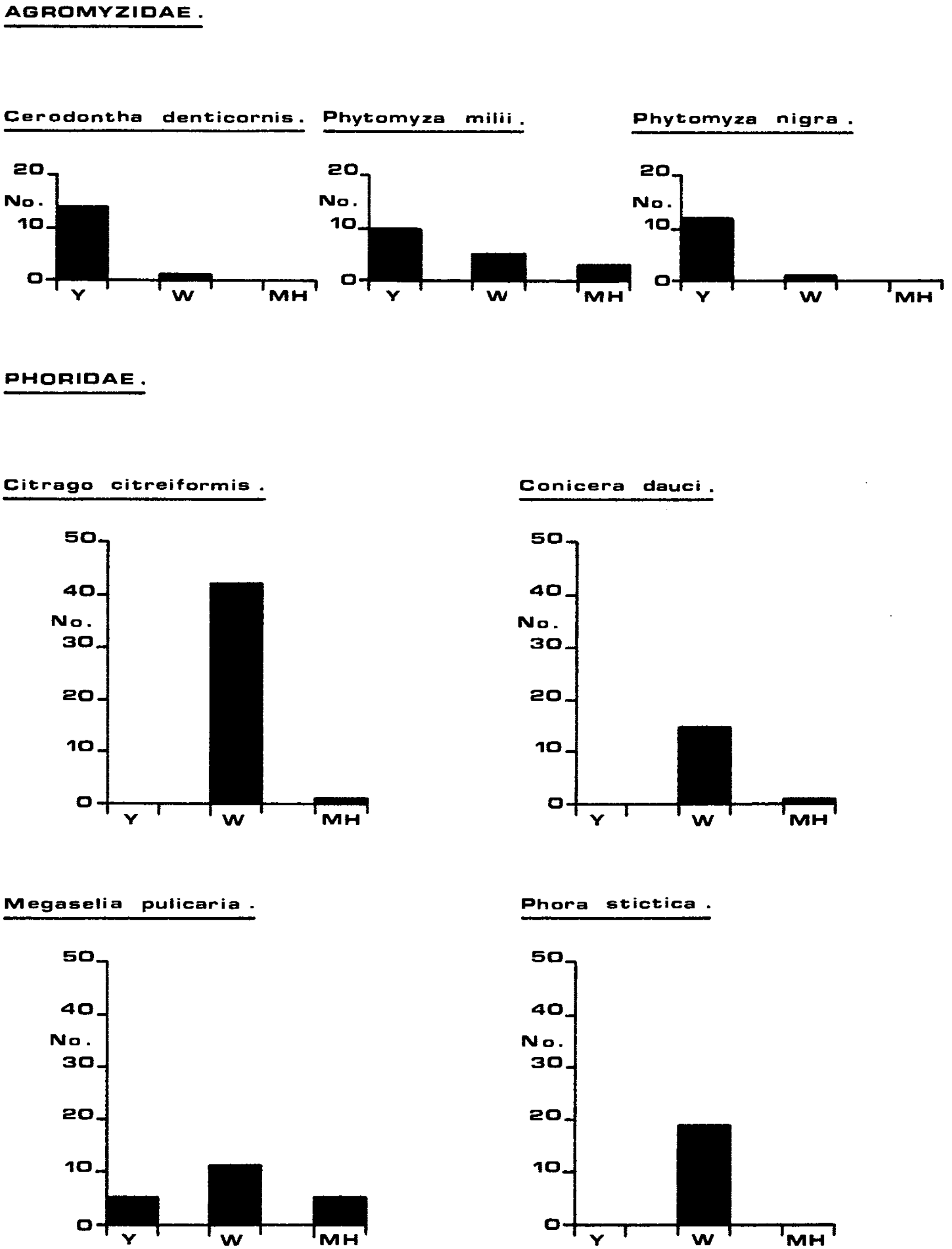

FIG. 4.

Experiment C—observations on selected species (see text) of Agromyzidae and Phoridae (none of which were procured in pitfalls or Malaise PW). Y = 3 yellow water traps. W = 3 white water traps. MH = Malaise trap. No. = number of flies.

(Note: while the paper was in press *Citrago* was synonymised with *Triphleba*—see Disney, 1982.)

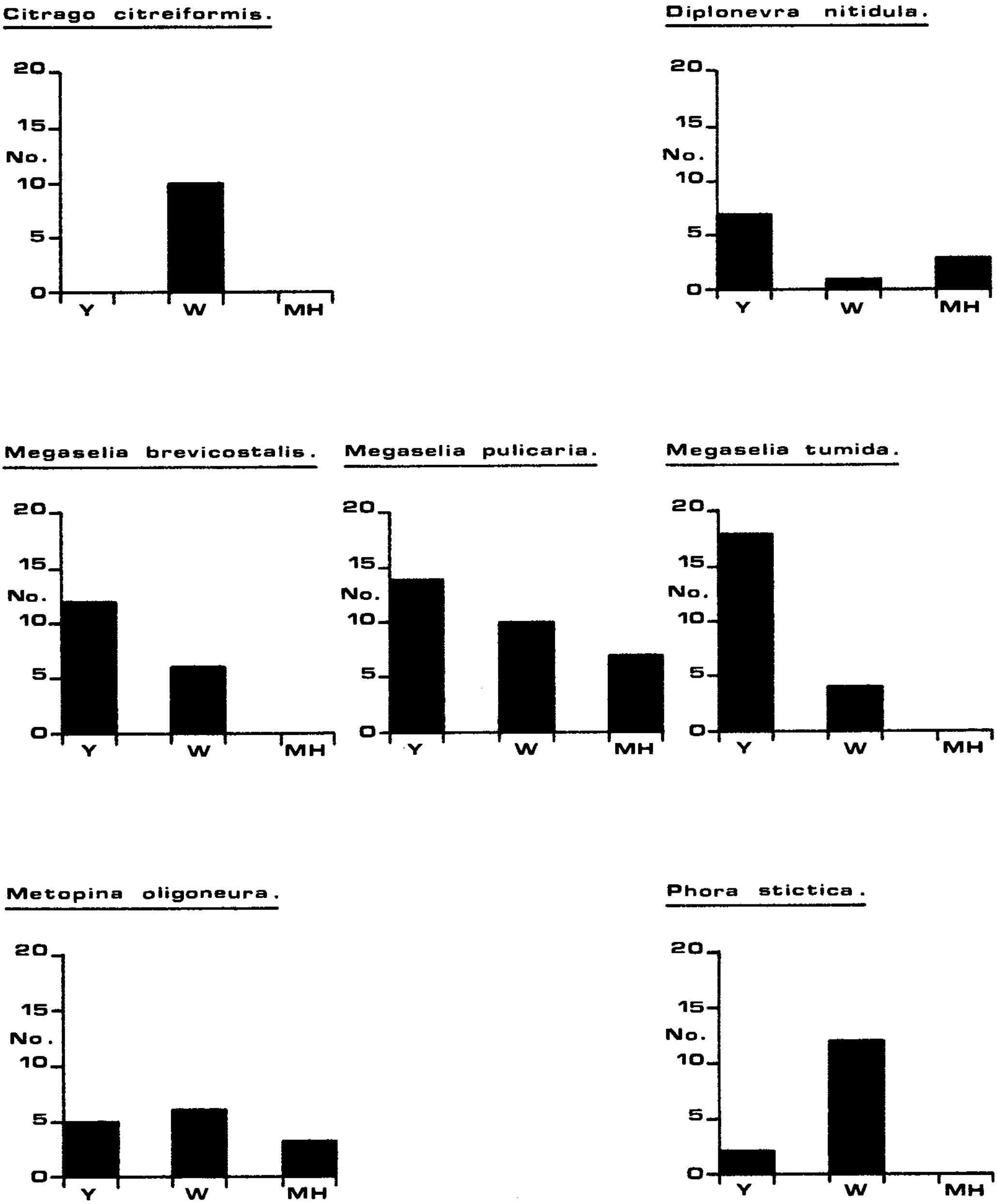

FIG. 5.

Experiment D—observations on selected species (see text) of Phoridae. Y = 3 yellow water traps. W = 3 white water traps. MH = Malaise trap. No. = number of flies.

(Note: while the paper was in press *Citrago* was synonymised with *Triphleba*.)

Table 6. *Experiment D—The numbers of species of Phoridae obtained in the different types of trap*

Trap type	3 Yellow water traps			3 white water traps			Malaise MH	TOTALS
No. of flies	25	21	21	11	15	38	20	151
No. of species	9	9	6	7	8	13	10	20

relative abundance of other species leads to the lack of an overall bias towards white bowls for the Phoridae as a whole. Experiment E (Table 7) shows that of the 5 colours used, white is clearly the most effective, but with significant numbers of individuals in both blue and orange bowls. The white bowls caught more species than the blue, green or brown bowls ($p < 0.025$), but not significantly more than the orange bowls. The white bowls also caught more individuals per species than the blue, green or brown bowls ($p < 0.001$), and more individuals per species than the orange bowls ($p < 0.025$). At three sites *Metopina oligoneura* was the dominant species of Phorid. Analysis of the data for this species (Table 8) indicates its sequence of preference to be white, followed by blue, followed by orange.

Pitfall traps

The data presented above have shown that glass pitfalls are an inefficient method of sampling Phoridae. Experiment F reinforces this finding and emphasises that to a Phorid it is of more significance that a trap be white as opposed to transparent than that it be sitting on the ground as opposed to being sunk into the ground.

Of the 5 Phoridae caught in the glass pitfalls, (in experiment A, C and F) 4 were *Megaselia longicostalis*. This ratio of 4 *M. longicostalis* to 1 other species contrasts with the ratio of 0.042:1 for this species in the total of 123 Phoridae procured in the white water traps in the same experiments. The dominance of this species in pitfall collections of Phoridae is well established (Disney *et al.*, 1981). The observations presented above suggest that the bias is not so much in favour of this species, as against the other Phoridae.

Table 7. *Experiment E—The numbers of Phoridae obtained in 5 different colours of water traps at 4 different sites*

	Trap Colour					
	White	Brown	Orange	Green	Blue	TOTALS
No. of flies at MT	44	1	9	2	1	57
No. of species at MT	(10)	(1)	(4)	(1)	(1)	(12)
No. of flies at MH	27	1	7	1	19	55
No. of species at MH	(4)	(1)	(4)	(1)	(2)	(5)
No. of flies at NE	270	1	32	10	172	485
No. of species at NE	(5)	(1)	(4)	(2)	(2)	(8)
No. of flies at WA	11	0	3	0	5	19
No. of species at WA	(4)	(0)	(2)	(0)	(3)	(5)

MT = Malham Tarn, N. Yorks
NE = Norwood End, Essex
MH = Melbourn, Herts
WA = Waltham Abbey, Essex

Table 8. *Experiment E—The numbers of* Metopina oligoneura *at three different sites in 5 different colours of water traps*

Locality	White	Brown	Orange	Green	Blue
Melbourn	22	1	3	1	18
Norwood End	260	1	41	9	171
Waltham Abbey	7	0	0	0	3

Malaise traps

Experiment C (Table 5 and Fig. 4) suggests that yellow water traps were more effective than the malaise trap for Agromyzidae ($p < 0.05$). For Phoridae, however, 3 white water traps caught many more specimens ($p < 0.01$), although the number of species in yellow water traps, white water traps and the Malaise MH were not significantly different. At the species level only *Megaselia pulicaria,* of the four species in Fig. 4, did not show a clear preference for white water traps over the Malaise MH.

In Experiment D (Table 6) there is no clear distinction between the Malaise and either white or yellow water traps. Analysis of the data for individual species (Fig. 5) suggests that some, *Triphleba (=Citrago) citreiformis, Megaselia brevicostalis* and *Phora stictica,* are not attracted to the Malaise. Others, *Diplonevra nitidula, Megaselia pulicaria* and *Metopina oligoneura,* appear to be as easily captured in Malaise traps as in water traps.

In Experiment F (Table 9) the Malaise trap appears to have been much more effective than the water traps. When the Phorid fauna is analysed it is found that this October collection was considerably different from the September collections in terms of species representation. Thus *Triphleba citreiformis* was only represented by a single specimen (in a white water trap). 9 of the specimens caught were *Megaselia ciliata,* a species common at Malham Tarn but of erratic occurrence in white water traps (experiments A–C procured none in white water traps, but one in a Malaise trap; Experiment E procured 2 in the orange water trap and Experiment F also produced 1 in a glass water trap). A similar situation seems to characterise *Megaselia pumila.* 6 were procured in Experiment F, all in the Malaise trap.

It would seem that Malaise traps are as inefficient as pitfall traps for catching many species of Phoridae when compared with white water traps. For other species the situation is reversed. In terms of effort, the labour involved in sorting out

Table 9. *Experiment F—The numbers of species of Phoridae obtained in the different types of trap*

Trap type	Malaise MH	3 White water	3 White pitfall	3 Glass water	3 Glass pitfall	TOTAL
No. of flies	35	7	6	1	2	51
No. of species	12	5	4	1	2	17
No. of species (white/glass)		8		3		11
No. of species in water traps						6
No. of species in pitfall traps						6

Phoridae from the mass of Calyptrates and other flies (like *Scaptomyza*) makes the use of white water traps much more attractive. However this should not lead to the neglect of the Malaise trap for surveying Phoridae.

DISCUSSION

The survey of the Diptera on Malham Moor was initiated in 1954–1958 (See Flint, 1963). This produced a list of 436 species. Since 1972 one of us (R.H.L.D.) has conducted an annual course on Diptera on Malham Moor. These courses and other efforts had increased the list to 854 species in 59 families by the end of 1980. The real total is probably in excess of 1,000 species. The incompleteness of the initial survey was due to three factors. Firstly, only a limited amount of time was spent on the survey. Secondly, only a limited range of collecting methods was employed and, thirdly, a number of families presented insurmountable identification problems in relation to the available keys. The increase in the list is partly due to the availability of more recent keys and partly to a diversification of collecting methods used, apart from the input of many more hours of effort.

In the experiments reported above we added several previously unrecorded species as well as adding a family (the Acartophthalmidae) despite the fact that Experiments A to C were carried out in a week of appallingly wet weather and Experiment F was carried out after the onset of frosts.

One of the consequences of sorting any trap collection is that one is forced to abandon the selectivity that characterises collecting by net and pooter, which has a tendency to turn into a hunt for "goodies". However a diversity of collecting methods is essential if one is aiming to produce a complete list for a site. Several species have only been recorded by pooting flies off the windows of buildings, and several unusual records have been added to the Malham Tarn list by rearing from material brought into the laboratory. For example *Calliphora loewi* was first added in this way (Disney, 1973) and the only subsequent record was on 14 September 1980 when two of us (Y.Z.E. and P.W.) hung up a dead gull in the woodland and at intervals collected the flies visiting it. It is evident, therefore, that a comprehensive list of the species inhabiting a particular site can only be procured by using a diverse range of collecting methods over all seasons and several years. Nevertheless, it is worthwhile to attempt a complete list for a range of representative sites such as the Malham Tarn Estate, Wicken Fen or Wytham Woods.

For many purposes the return on a given effort will be better if one is deliberately selective. The first approach to selectivity is to limit oneself to a small group. Select a particular family and use a diverse range of collecting methods over all seasons and several years. This concentration of effort will be more likely to produce a complete list (eventually) but it will still demand great effort. Thus the original survey at Malham Tarn (Flint, 1963) produced a list of 48 species of Syrphidae, to cite a popular group, while, at the end of 1980, the list stood at 78 species one of which was added during the experiments reported above. We do not believe it is yet complete.

The alternative approach to selectivity is in terms of methods of collecting. For such an approach to have value we suggest a particular method needs to have consistent bias in terms of selectivity and should produce replicated samples of quantitative data. Only thus does one allow the possibility of objective comparisons of one site with another or between collections at the same site at different seasons.

In view of the urgency in matters pertaining to conservation we believe such a deliberately selective approach is all we have time for, if we are critically to evaluate large numbers of sites before it is too late to save the "best" from the ravages of habitat destruction. In the light of our limited investigations we suggest that the use of white water traps, or white plus yellow in combination, would be most likely to produce worthwhile data on Diptera on the basis of which defensible evaluations could be made. For other groups of invertebrates, e.g. Arachnida, pitfall traps would probably prove to be the method which gives the maximum return for the least effort. They would also appear to be effective for a few Diptera, such as Tipulidae, but we have not examined their selectivity at the species level.

There remains considerable scope for further comparisons of other collecting methods (e.g. baited traps) along the lines we have introduced above. The continuation of any experiments for longer periods (or the use of larger numbers of traps), in order to procure larger numbers, would enable more detailed comparisons at the species level. One could also carry out further types of analysis. For example the use of an Index of Similarity might be of interest when comparing two collecting methods.

There is obvious scope for comparing Malaise traps of different designs. Likewise an interesting exercise would be an examination of the effect of bowl size in relation to species representation, to see which size of water trap gives the best results for the least effort. Are 5 larger bowls more effective than 10 smaller ones, or *vice-versa*? A greater range of colours could be examined. There are some studies for particular insect species (see Southwood, 1978) but we are not aware that this has been considered in relation to the general survey of larger taxa.

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