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A study of fungus flies (Diptera: Mycetophilidae) in beech woodland

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ABSTRACT. 1. A study was made of larval and adult Mycetophilidae in coppiced beech woodland in southern England. Adult mycetophilids were trapped throughout 1968 using sticky traps at ground level. Larvae inhabiting terrestrial fungi were collected from all sporophores from a defined area of the woodland floor between August and October 1968.

2. Larval mycetophilids were extracted from only 12.6% of all sporophores collected and from fifteen of thirty-eight species of fungi present. Some species of fungi were never inhabited by larval mycetophilids while others appeared to be highly attractive to them. Since it was not possible to identify the larvae beyond the level of tribe it was impossible to ascertain host preferences for different species. Peak numbers of larvae occurred at the beginning of September and the beginning of October.

3. Adult mycetophilids had two peaks of activity, the first in March and April when the dominant species were *Boletina gripha* and *Phronia basalis* and the second in autumn when species of the genus *Mycetophila* were dominant. *Phronia basalis* is a species whose larvae inhabit dead wood and the abundance of this species (40% of all adults) probably reflects the amount of rotting wood in this type of habitat. The autumn peak of adult activity was due to species known to inhabit agaric sporophores and came about 1 month after the peak of larval numbers in fungi.

4. The adult fauna was rich with 107 species representing about a quarter of the known British fauna. However, only twelve species were trapped in sufficient numbers to allow deductions concerning seasonal activity.

5. The results were discussed with respect to the problems of assessing populations of insects inhabiting fungal sporophores and to the previous work on this neglected group.

Introduction

During the course of a study of the role of insect larvae in energy flow in woodland soils, adult Diptera were trapped to obtain information on the species present and their periods of flight activity. Continuous trapping over a year revealed that the dominant group present was the Mycetophilidae which constituted 65% of all species obtained. This led to an interest in the larvae many of which feed on the fruiting bodies of higher fungi. During the period of the autumn flush of agarics a survey was made of an area of woodland to estimate the numbers and species of agarics present together with the larvae feeding on them. While it was hoped to be able to correlate larval and adult stages of the life history the difficulties of specific identification of the larvae rendered this impossible.

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Since, however, no previous data are available on the abundance of larvae in the field the results are presented here.

Sampling Area and Methods

The sampling site was in an area of coppiced Beech woodland in Blean Woods NNR, Kent (Healey & Russell-Smith, 1972) and both the fungal sampling area and the traps for adult flies were located immediately adjacent to the sampling area mentioned there. Fungal fruiting bodies were collected from an area of the woodland floor measuring 25 x 35 m and marked out in 5 m squares using 6 in. wooden pegs as corner posts. Fungi were collected at 2 week intervals between 15 August and 30 October 1968. On each sampling occasion each 5 m square in the grid was carefully searched for fungi by two observers. The position of each fruiting body was noted and the species identified. All fungi recorded were immediately checked in the field for signs of insect activity by breaking open the pileus and stipe and examining the characteristic larval burrows and the larvae themselves. Those showing such damage were placed individually in small, sealed plastic for return to the laboratory.

In the laboratory two methods of extracting larvae from the fungi were tested. The first was the wet funnel technique previously used for extraction of nematodes and enchytraeid worms from soils (O'Connor, 1955) and the second involved sieving the fungi in water followed by hand sorting of larvae after removal of the fungal material by flotation in water. Only twenty fungi were available for the tests but the results showed that the wet funnel procedure was approximately 90% efficient (based on the proportion of dead larvae remaining unextracted) while the flotation and hand sorting appeared to be at least 99% efficient. The latter procedure involved breaking up the fungi on a coarse sieve of 10 mm mesh and using a diffuse spray of water to wash the larvae and fine fragments of fungi onto a fine sieve of 0.1 mm mesh. This material was transferred to a beaker of water and agitated when the majority of the fungal material rose to the surface and was decanted. The remaining material was transferred to a petri dish and the larvae sorted and counted under a stereoscopic microscope. This technique had the advantages of being relatively rapid, recovering pupae and eggs as well as larvae and of recovering the majority of larvae alive. It was therefore used throughout this study.

A major problem was the identification of larval Mycetophilidae since no keys were available. In most cases identification was only available to sub-family or tribe but the material has been retained in case more detailed keys become available in the future.

Adult flies were trapped between February 1968 and January 1969 using sticky traps at ground level. The traps consisted of plate glass rectangles 6.3 mm thick and measuring 45.7 x 30.5 cm. An area 30 cm square was coated with a thin layer of 'Sticktite' fruit tree banding gum (Bugge's Insecticides Ltd, Kent) and the plates placed vertically in the ground. Four traps were used throughout the study facing north, south, east and west respectively. The traps were exposed for periods of 2 weeks before removal of the catches. Insects were removed by dissolving the banding gum in a bath of acetone and filtering off the floating insects. After washing with fresh acetone to remove any adhering gum the insects were stored in 70% ethanol for subsequent counting and identification.

Results

1. *Larvae in fungi*

During the 10 week period of study a total of 619 fungi were collected of which seventy-eight (12.6%) were infected with insect larvae. The fungi represented thirty-eight species of which only fifteen were infected. The total number of fungi collected and the proportion infested at each sampling occasion is shown in Fig. 1. The first sample produced the greatest number of fungi but numbers then declined until late September after which they remained fairly constant. The highest proportion of fungi containing larvae occurred at the end of August. Throughout the period of study the proportion of fungi with larvae was low and ranged from 2% to 22% of the total.

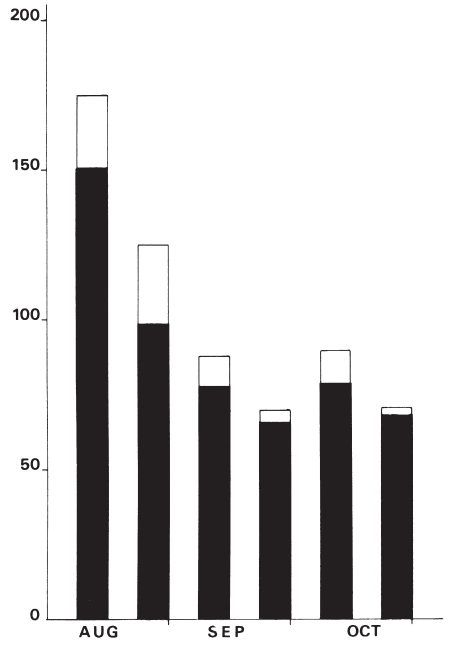

FIG. 1. Numbers of sporophores containing larvae. Solid bars = uninfected sporophores, open bars = infected sporophores.

The fungi collected may be divided into three groups according to the substrates on which they grow (Table 1). The litter-inhabiting forms included one abundant species, *Collybia peronata*, which was never inhabited by larvae. The wood-inhabiting species included *Armillaria mellea*, *Oudemansiella radicata* and *Hypholoma fasciculare*. Of these only *O.radicata*, with 40% of sporophores inhabited, showed a high rate of infestation while *H.fasciculare*, the commonest of all fungi, was never infested. The remaining species belonged to a 'terrestrial' group which included both mycorrhizal symbionts of forest trees and humus growing species. Amongst these the genus *Russula* was prominent and showed the highest rate of infestation; in *R.fellea* as high as 57% of the total. Other genera such as *Lactarius*, *Cortinarius* and *Amanita* showed a low infestation rate.

From infested fungi a total of 3663 larvae and twenty-eight pupae were extracted and their distribution through the sampling season, expressed as mean number of larvae per infested sporophore, is shown in Fig. 2. Mycetophilidae accounted for 71% of all larvae, Phoridae for 15% and the remaining 14% belonged to at least two unidentified cyclorraphan families. Total numbers of larvae were highest at the beginning of the survey and fell throughout the period of study except for a secondary peak in mid-September. This second peak was very largely due to Phoridae, 300 larvae of which were extracted from a single sporophore on this date. Numbers of mycetophilid larvae fell throughout the period except for a minor peak at the end of September. Apart from the mid-September sample, mycetophilids always predominated in each sporophore.

Mean numbers of larvae per sporophore varied between species from none to as many as 289. Very high figures for *Russula*

TABLE 1. Numbers of sporocarps collected, per cent containing larvae, total numbers of larvae and mean numbers of larvae per sporocarp

Species	Total number	Per cent infected	Total larvae	Mean larvae/ basidium
Collybia peronata	78	0	0	0
Armillaria mellea	37	16	15	3.0
Oudemansiella radicata	30	40	451	37.5
Hypholoma fasciculare	176	0	0	0
Russula marii	57	23	26	2.0
Russula fellea	35	57	251	12.0
Other *Russula* spp.	14	28	317	79.3
Lactarius blennius	41	10	42	10.5
Tricholoma spp.	35	6	7	3.5
Cortinarius spp.	25	16	37	9.2
Amanita spp.	22	23	1445	289.0
Hydnum repandum	19	0	0	0
Other genera	40	18	31	4.4

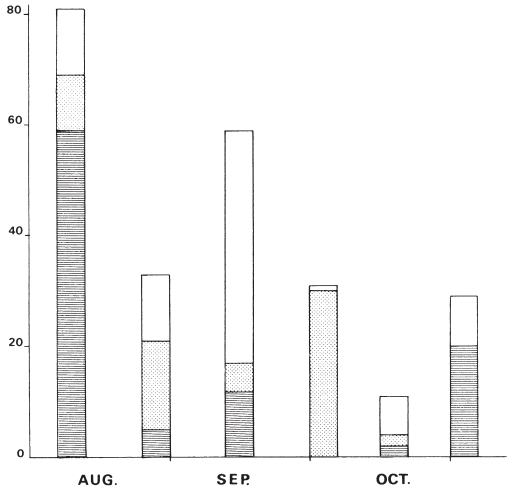

FIG. 2. Mean numbers of larvae per sporophore on each sampling occasion. ▤, Mycetophilini; □, Exechiini; ☐, other Diptera.

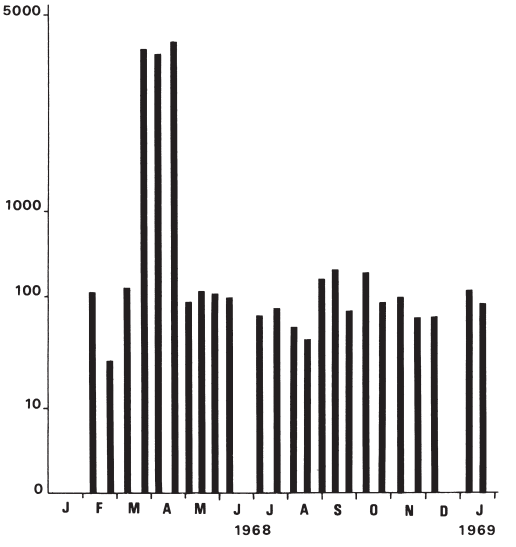

FIG. 3. Numbers of all adult mycetophilids trapped during 1968.

atropurpurea and *Amanita rubescens* resulted from large numbers of first instar larvae in individual fruiting bodies. If these exceptional sporophores were ignored then the mean number of larvae in all infected sporophores over the whole 10-week period was thirty-one which was equivalent to about 2.8 larvae m^{-2}. This low figure is a reflection of the small proportion of infested sporophores collected since if all sporophores had been infested at this rate there would have been 22 larvae m^{-2}. Table 1 shows that the genera *Russula* (except *R.marii*), *Amanita* and *Oudemansiella* were all relatively highly infested but that most others were not or only slightly so. The larvae were identified to tribe, only two of which, Mycetophilini and Exechiini, were found in the fungi. Over the whole sampling period exactly one third of these belonged to the Exechiini and the remainder to the Mycetophilini. Consequently the overall pattern of numbers of larvae was determined largely by the Mycetophilini while the Exechiini showed a peak in numbers at the end of August and then declined during the remainder of the sampling period. There was no indication from the data that either of the two tribes was more abundant in particular species or genera of fungi.

2. *Activity of adults*

Activity of adult flies was monitored throughout a year during which time 10 835 adult mycetophilids were trapped. The seasonal activity of these is shown in Fig. 3 plotted as histograms of total numbers trapped in each 2 week period. Two peaks of adult activity are distinguishable, the first and major peak in March and April, and a second much smaller peak between August and October. The spring peak of activity was due almost entirely to two species, *Phronia basalis* and *Boletina gripha* (Fig. 4a, b). *P.basalis* had a peak of activity at the end of March approximately 1 month before the very sharp and restricted peak for *B.gripha*. However, the period of activity of these two species overlaps considerably. The autumn peak of activity was due to a number of species of the genus *Mycetophila* of which *M.fungorum*, *M.ruficollis* and *M.luctuosa* were the most abundant (Fig. 4c, d, e). *M.fungorum* had an extended period of maximum activity from the end of August to the middle of November with a peak at the beginning of October. *M.luctuosa* showed a peak of activity at the end of August and declined thereafter while *M.ruficollis* had a more sharply defined peak in mid-September. All these species also showed some minor activity in the spring at the same time as *Boletina gripha* and the *Phronia* species. Seven other species were trapped in sufficient numbers (fifty or more)

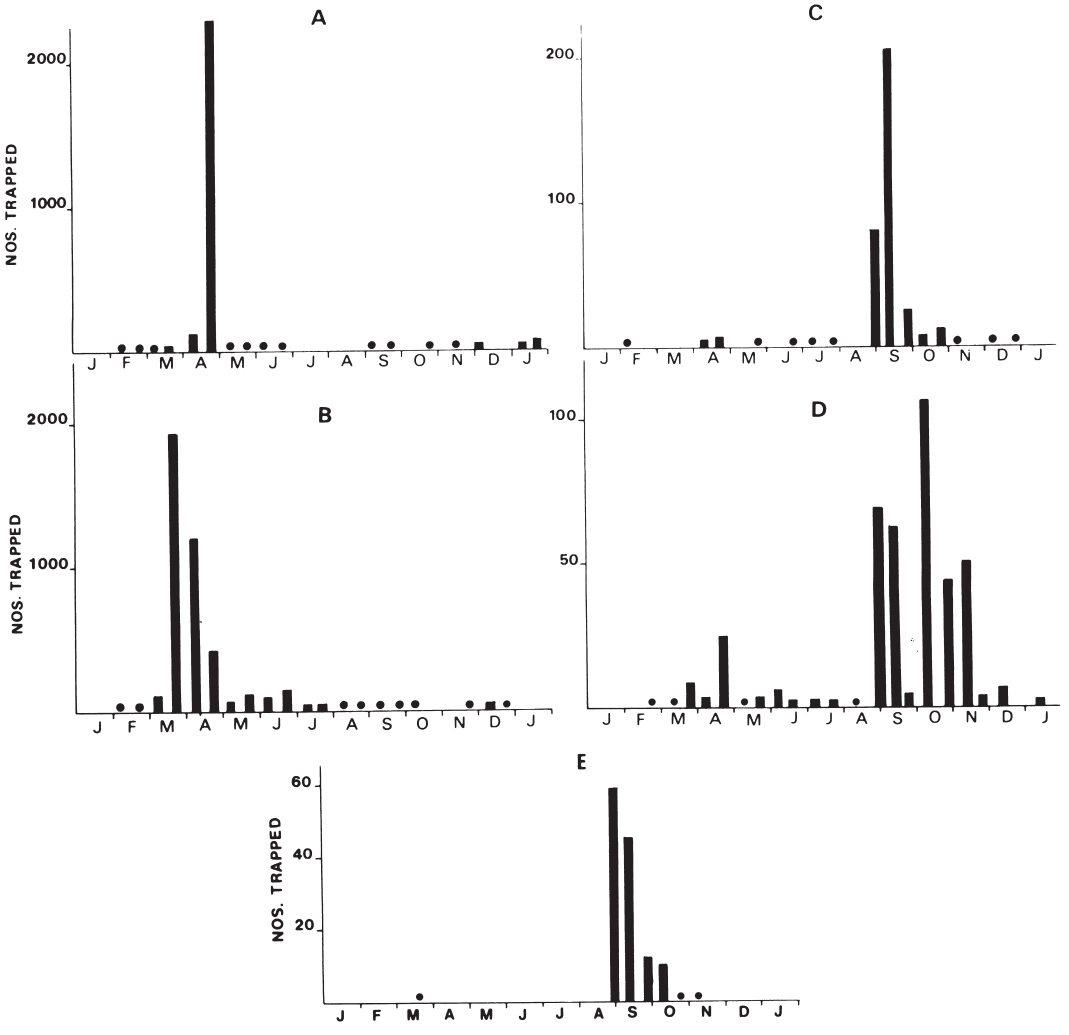

FIG. 4. Numbers of adults of the more abundant species of mycetophilids trapped during 1968. (A) *Boletina gripha*; (B) *Phronia basalis*; (C) *Mycetophila ruficollis*; (D) *M.fungorum*; (E) *M.luctuosa*. •, Less than twenty individuals trapped.

to allow deductions about their period of activity to be made. Three further *Phronia* species, *P.johannae*, *P.forcipata* and *P. cinerascens* had activity peaks in early spring coincident with that of *P.basalis*. *M.ocellus* had an autumn peak of activity at the same time as the other *Mycetophila* species while *Exechia nana* showed a small peak slightly later in mid-October. Of the remaining two species *Allodia ornaticollis* had a peak of activity in May while *A.lugens* was most active in January.

The relationship between larval numbers and adult activity during the autumn is shown in Fig. 5. Two separate peaks of adult activity were observed, one in the first part of September (about a month after the peak in larval numbers in fungi) and the second at the beginning of October. The first of these two peaks was dominated by *Mycetophila ruficollis* (44% of all adults) and the second by *M.fungorum* (36% of all adults). Both these species are known to have larvae which feed on a wide range of agarics (Buxton, 1960).

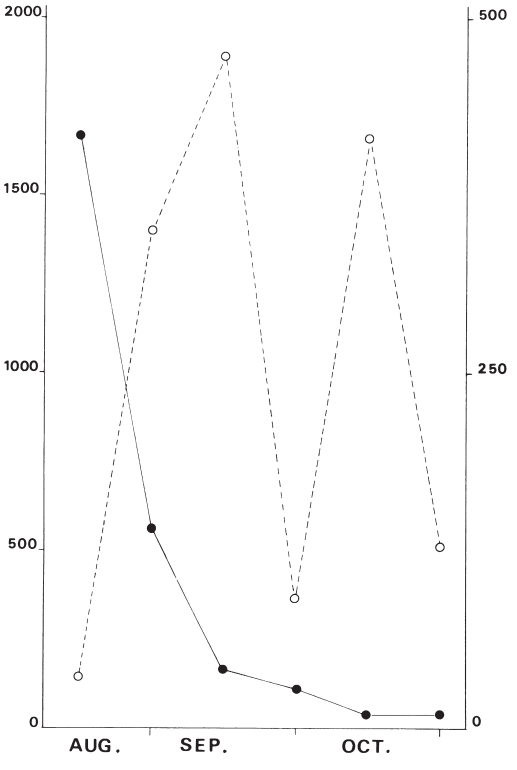

FIG. 5. The relationship between numbers of adult flies trapped and numbers of larvae in sporophores during autumn 1978. ●, Numbers of larvae; ○, numbers of adults.

The adult fauna was remarkably rich with 107 species from thirty-three genera trapped over a year (Appendix). The best represented genera were *Mycetophila* with twenty-two species and *Phronia* with seventeen species while four other genera were represented by five or more species. The numbers of individuals trapped were very unevenly distributed between species with *Phronia basalis* and *Boletina gripha* together forming 67% of the total and eighty-three other species represented by less than ten individuals (less than 0.1% of the total). However, without a better knowledge of the ecology of the larvae the significance of the considerable diversity of adults and inequitable distribution of individuals between species remains obscure. The 107 species trapped include at least two new to science and represent a little under a quarter of the known British species.

TABLE 2. Larval micro-habitats of adult Mycetophilidae trapped in Blean Woods. Data collated from Edwards (1925) and Buxton (1960).

Larval microhabitat	No. of species recorded	Per cent of total
In or on decaying wood	7	21
In wood-encrusting fungi	10	30
In sporocarps of Polyporaceae	3	10
In sporocarps of agarics	12	36
Other microhabitats	1	3

Using published data (Edwards, 1925; Buxton, 1960) an attempt was made to assess the proportion of the total adult fauna which could be assigned to particular larval microhabitats. Of the 107 species, data on larval microhabitats were only available for thirty-three and these are summarized under five headings in Table 2. About 20% of the species are recorded as feeding either in or on the surface of decaying wood and a further 30% are recorded as feeding on wood-encrusted fungi. One third of the species have been recorded from agaric sporophores.

Discussion

Little attention has been given in this country to the ecology of Mycetophilidae. Edwards (1925) provided some records of larval microhabitats and Buxton (1960) summarized our knowledge of the species inhabiting fungal fruiting bodies. As far as the author is aware, no previous attempt has been made to assess numbers of either larvae or adults from a single well-defined habitat.

The results from the present study should be interpreted with some caution owing to the limitations of the methods used. It is almost certain that the proportion of fungi infected with larvae has been underestimated due to the difficulty of detecting first instar larvae (or their burrows) in the fungi under field conditions. The use of emergence traps placed over individual fruiting bodies in the field might avoid this problem but would not of course provide information on the abundance of the larvae.

Sticky traps provide information on adult activity rather than on numbers per unit area of habitat. However, alternatives, such as the use of emergence traps, present problems of operation with ephemeral micro-habitats such as fungi. Further problems with the use of sticky traps arise from the possibility of either selective trapping of particular species or selective removal from the traps. While it is known that some insects are attracted by particular colours or odours there was no evidence for this with the transparent plates coated with an apparently odourless adhesive used in the present study. There was some evidence that insects were occasionally washed from the traps by heavy rainfall but this appeared to affect the catch as a whole rather than individual species. There was also evidence for predation on the catch by wood ants (*Formica rufa* L.) during the summer months. However, these seemed to prefer larger flies such as muscids and tipulids and probably did not significantly affect the numbers of mycetophilids recovered.

An important problem in the present study was our inability to identify the larvae of mycetophilids to species. As a result it was not possible to establish firmly the relationship of larval numbers to those of the adults since there was no guarantee that the peaks in adult activity corresponded to the periods of peak emergence. However, for the short period during autumn 1968 for which both larval numbers and adult activity were known (Fig. 5) it seems probable that the adults were derived from larvae present in agarics about a month previously.

An alternative hypothesis, that these larvae survived in an inactive state from the previous autumn until stimulated by the presence of suitable fungal sporophores, cannot be rejected on the available evidence. Adults are able to overwinter, even under snow (Plassman, 1975). In the case of the much larger peak in adult activity in the spring the situation is much less clear since no data for larval numbers are available for this period. It is unlikely that these adults derived from larvae feeding in agarics because very few were observed in the wood at this period. Previous records for *Phronia basalis,* the dominant species active in spring, indicate decaying logs as a larval micro-habitat (Edwards, 1925). If this is so then the large numbers of adults of this and other *Phronia* species active in spring were possibly a reflection of the abundance of dead wood on the forest floor of this part of Blean Woods. In 1969 this amounted to some $185\,g\,m^{-2}$ average standing crop excluding small twigs (Healey & Swift, 1972). Nothing is known of the larval habitat of *Boletina gripha.* Further evidence for the possible importance of dead wood as a larval micro-habitat is provided in Table 2. For those species for which published records are available, over 50% have larvae living either in (or on) dead wood or fungi growing on dead wood. The remaining species with peak activity in autumn or winter belonging to the genera *Mycetophila, Exechia* and *Allodia* have all been raised from a wide variety of agarics (Edwards, 1925; Buxton, 1960) with the exception of *M.ocellus* which appears to be restricted to wood-encrusting fungi.

In general it seems that many mycetophilids that utilize agarics show little specificity in the fungi they feed on and this may well be related to the ephemeral nature of agaric sporophores which could enforce a highly opportunistic approach to the selection of egg-laying sites by the adult flies. Despite this the survey of larvae in fruiting bodies clearly demonstrated that certain species of fungi are rarely, if ever, utilized by mycetophilids. Buxton (1960) gave two groups of fungi which he found 'unattractive' to insects. The first included species with hard or dry sporophores, such as those of *Polyporus* or *Stereum,* and the second included those with very small sporophores. While none of the species examined in this study fell into the first group, *Collybia peronata* and possibly *Russula marii* would come under the second category. Why such species as *Hydnum repandum* and *Hypholoma fasciculare* were not infested by mycetophilids at Blean Woods is not clear, particularly as Buxton (1960) reared adults from four out of five collections of the latter species. The species of fungi that showed a high frequency of infestation in this study all belong to genera which have previously been recorded as suitable larval microhabitats (Edwards, 1925; Buxton, 1960).

The only other study of mycetophilids of a defined area of which the author is aware is that of Plassman (1969), who used light traps

to study the distribution of adults in the Vogelsberg massif in Germany. This included a number of quite different major habitats ranging from beechwoods at lower altitudes to upland moorland. Because of the different technique used and because times and frequencies of operation of the traps were not given, it is difficult to make valid comparisons between the two sets of data. Among the 159 species trapped by Plassman, only twelve were sufficiently abundant in both study areas for comparisons of activity periods to be made. In most cases the general pattern of activity was similar in both studies but with a shorter period of flight activity in the Vogelsberg than at Blean Woods. This is no doubt associated with the much colder winter conditions in the Vogelsberg massif where there is a continuous snow cover between November and February.

Acknowledgments

I am particularly grateful to Mr L. N. Kidd who identified the adult flies and without whose careful work this paper would have been impossible. I would also like to thank Dr M. J. Swift who identified the fungi and Mr S. Trifourkis who provided a key to the tribes of larval Mycetophilidae and helped in their identification. Thanks are due to the Nature Conservancy (SE region) for permission to work in Blean Woods NNR. This work was done while the author was in receipt of a N.E.R.C. research assistantship.

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APPENDIX. List of adult mycetophilids trapped, with months when active and total numbers caught

Species	Period of activity	No. trapped
Bolitophila saundersii (Curtis)	VIII, XI–I	39
Antlemon servulum (Walker)	VII	7
Orfelia nemoralis (Mg)	VI	1
Mycomya marginata (Mg)	II, III	1
M.winnertzii (Dz.)	XI, XII	1
M.cinerascens (Macq.)	I, II, IV, VIII, XI	9
M.tenuis (Walk.) or *duplicata* Edw.	XI	1
M.incisurata (Zett.)	VIII–X	11
M.maura (Walk.)	IV–VII	19
Neompheria pictipennis (Hal.)	VIII, IX	2
Phthinia humilis Winn.	IX	1
Acnemia nitidicollis (Mg.)	II, III	6
Coelosia silvatica Landr.	II, III	2
Palaeodocosia janickii (Dz.)	VI, VII	1
Boletina dispecta Dz. sensu Edwards	VII–IX	30
B.pallidula Edw.	X	3
B.nigricans Dz.	X, XI	3
B.gripha Dz.	I–XII	2852

APPENDIX – *Continued*

Species	Period of activity	No. trapped
B.sciarina Staeg.	XII, I	4
B.lundstroemi Landr.	III, X–I	13
Synapha vitripennis (Mg.)	V, VI	3
S.fasciata (Mg.)	VI, VII	1
Rondaniella dimidiata (Mg.)	VIII	1
Leia sp. cf *cylindrica* (Winn.)	VIII, XI	2
Tetragoneura sylvatica (Curt.)	V, VI	11
Docosia gilvipes (Walk.)	I, III, IV	25
Anatella ciliata Winn.	III–V, VIII, IX	5
Anatella sp. indet.	III–V	3
Exechia fusca (Mg.)	I–XII	18
Exechia cf. *lundstroemi* Landr.	I	1
Exechia nana (Staeg.)	VIII–I	68
E.repanda Joh.	XI	2
E.contaminata Winn.	XI	1
Pseudexechia trivittata (Staeg.)	VIII	1
P.trisignata (Edw.)	I	1
Exechiopsis subulata (Winn.)	X	2
E.pulchella (Winn.)	XI	1
Rymosia fasciata (Mg.)	X, XI	2
R.virens Dz.	III, IV	1
Tarnania tarnanii (Dz.)	XI	1
Allodia lugens (Wied.)	II–IV, IX–I	106
A.ornaticollis (Mg.)	I–XII	115
Brevicornu crassicorne (Stann)	II, III	1
B.fuscipenne (Staeg.)	IV, XI	5
B.ruficorne (Mg.)	XI–I	9
B.sericoma (Mg.)	III–V, XI–I	15
Pseudobrachypeza helvetica (Walk.)	VI	1
Cordyla semiflava (Staeg.)	I–VII	49
C.murina Winn.	I–VII	27
C.brevicornis (Staeg.)	X, XI	3
C.flaviceps (Staeg.)	V–X	19
Trichonta terminalis (Walk.)	I, II	1
T.atricauda (Zett.)	III, VII, VIII	6
T.melanura (Staeg.)	IX	1
Phronia flavipes Winn.	IX–I	9
P.exigua (Zett.)	XI	1
P.johannae Steenberg	I–XII	214
P.humeralis Winn.	I–IV	5
P.basalis Winn.	I-XII	4238
P.braueri Dz.	III	1
P.forcipata Winn.	I–XII	114
P.cinerascens Winn.	I–XII	77
P.tenuis Winn.	I, II, IV	4
P.conformis (Walk.)	I–V	5
P.nigricornis (Zett.)	I–IV, VII, VIII	33
P.obtusa Winn.	III, IV, VII	4
P.triangularis Winn.	III	1
P.notata Dz.	III, IV, VIII	6
P.flavicollis Winn.	III, IX	4
P.disgrega Dz.	III, IV	1
P.tarsata (Staeg.)	III, IV	3
Dynatosoma fuscicorne (Mg.)	III	2
D.reciprocum (Walk.)	III, IV	2
Mycetophila fungorum (Deg.)	I–XII	437
M.ruficollis Mg.	I–XII	381
M.ichneumonea Say	VIII, IX	4
M.brittanica Lastovka & Kidd	VIII–XI	29
M.semifusca Mg.	V–VII	3

APPENDIX – *Continued*

Species	Period of activity	No. trapped
M.ocellus Walk.	I–IV, VII–XII	101
M.formosa Lund.	III, IV, VII–I	7
M.sordida v.d. Wulp	V	1
M.pumila Winn.	III	1
M.edwardsi Lund.	II, III, VI–VIII	5
M.vittipes Zett.	II, III, VIII–X	9
M.forcipata Lund.	III, IV	6
M.ornata Steph.	III	1
M.spectabilis Winn.	III	1
M.curviseta Lund	III, IV	2
M.marginata Winn.	I–III	3
M.luctuosa Mg.	III, VII–I	131
M.signatoides Dz.	IX	5
M.alea (Laffoon)	IV, VIII	3
M.occultans Lund.	III	1
M.rudis Winn.	I	1
M.trinotata Staeg.	I–III	2
Zygomyia pictipennis (Staeg.)	IV–XI	15
Z.vara (Staeg.)	III, X	2
Z.valida Winn.	III, IV	2
Z.humeralis (Wied.)	VII	1
Zygomyia sp. A indet.	IV–VII	15
Zygomyia sp. B indet.	IX	2
Sceptonia nigra (Mg.)	III–IX	6
S.costata (v.d. Wulp)	VIII	2
S.concolor Winn. or *S.tenuis* Edw.	IX	1
Epicypta aterrima (Zett.)	IV, XI	2
Platurocypta punctum (Stann.)	VII	2
P.testata (Edw.)	IV, VIII, IX	4