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Vertical distribution of scuttle flies (Diptera: Phoridae) in a beech forest

Carlos GARCÍA-ROMERA and Jose Antonio BARRIENTOS

Departamento de Biología Animal, de Biología Vegetal y de Ecología (Unidad de Zoología), Facultad de Ciencias, Universidad Autónoma de Barcelona, E-08193 Bellaterra, Barcelona; Spain
Corresponding author. e-mail: cgarci24@xtec.cat

Abstract: The structure of scuttle fly communities in vegetative strata of a beech forest in the Montseny Natural Park (Catalonia, Spain) was compared. Window traps were used from March 1990 to March 1991. Relative abundance and species richness of scuttle flies were higher in the herb and shrub layers than in the canopy, while diversity was not significantly different between strata. Saprophagous species dominated in all strata, while the mycophagous and zoophagous species decreased with height. Herb layer was dominated by *Megaselia pectoralis* and *M. subpleuralis*. Shrub layer was dominated by *M. pectoralis*, *M. pectorella*, *M. diversa*, *M. subpleuralis* and *M. superciliata*. Canopy layer was dominated by *M. pectorella*, *M. pectoralis*, *M. pusilla* and *M. diversa*.

Key words: Phoridae, Montseny, Spain, beech forest, vertical distribution, trophic groups

INTRODUCTION

Phoridae, a very diverse family in the order Diptera, include about 4,000 species distributed nearly 260 genera. It is one of the families of Diptera with the highest diversity of larval life forms, with saprophages, predators, fungivores, parasits or parasitoids species (Disney 1990, Disney et al. 2010).

There are only a few studies on the vertical distribution of Diptera communities in European forests (e.g. Pollet & Grootaert 1991, Kampichler & Teschner 2002). Most of surveys have traditionally analysed the scuttle fly communities of a single stratum (i.e. herb layer) by using emergence traps, pitfall traps, yellow traps and Malaise traps, placed directly on the floor (e.g. Buck 1994, 1997; Durska et al. 2010; Durska 2015). Only a few works assess the Phoridae of tree canopy using yellow traps attached to the trunks of the trees, but without comparing the results with lower levels (Durska 1996, 2001, 2006), so no previous surveys show the vertical distribution of scuttle fly communities in European forests.

The objective of this study is to analyse the vertical distribution of the scuttle fly communities in a beech forest of the Montseny Natural Park (Catalonia). In the deciduous forest studied there was rich litter and decaying organic matter in the soil. Therefore, the dominance of saprophagous species was expected, and thus, lower strata should be richer and more abundant with scuttle flies than higher. The hypothesis of a higher abundance and species richness in the lower strata than upper was tested.

The global scuttle fly data obtained in the survey of the Montseny Natural Park is given by García-Romera & Barrientos (2014a). The new species captured have been described in the paper by García-Romera & Barrientos (2014b).

STUDY AREA

The Montseny massif presents a wide variety of climatic conditions, environments and species, so its protection is of great importance. It was declared biosphere reserve by the UNESCO in 1978 and Natural Park in 1987. It is located in the provinces of Barcelona and Girona, it covers about 400 km^2 and its highest peak reaches 1,712 m (Boada & Ullastres 1998; Boada 2001). Dominant plant communities are the holm oak (*Quercus ilex* L.) (up to 900 m) and beech (*Fagus sylvatica* L.) (from 1,000 to 1,500 m) forests, and scrublands of *Juniperus communis* L. and *Calluna vulgaris* L. (above 1,500 m).

Three plots were selected in the Montseny Natural Park belonging to the acidophile beech forest (ass. *Luzulo Niveae-Fagetum*). Two plots were on humid soil, at 1,130 m a.s.l. (UTM 31TDG530274) and at 1,170 m a.s.l. (UTM 31TDG532273), while the third plot on dry soil at 1,250 m a.s.l. (31TDG540279 UTM).

SAMPLING METHODS

Samplings were conducted from March 1990 to March 1991, every fortnight. The sampling method used in the three plots were window traps. Each interceptor had a transparent glass of 0.80 x 0.40 m (width, height), with a collector plate on each side with 4% formaldehyde and detergent. The material to identification was preserved in 70% ethanol.

Vertical distribution of scuttle flies was analysed on the basis of material derived from eight window traps placed in three plots at herb level (0.10–0.50 m; one on each plot) and shrub level (0.90–1.30 m; similarly: one on each plot) and from two traps placed in a humid plot (1,130 m a.s.l.) at the canopy level (6.00–6.40 m and 11.00–11.40 m). Traps of herb and shrub strata were subject attached on a same stand anchored in the ground, while those located in canopy stratum were subject attached laterally to a 12 m-high tower.

DATA ANALYSIS

Analyses were only based on males, as most females of genus *Megaselia* Rondani, 1856 and *Phora* Latreille, 1796 are not identifiable at species level.

Since the sampling effort varied between periods, we standardized the abundance to the number of individuals who fell into a trap in one day to make the fortnight samples comparable.

We used the index of dominance (D) to compare scuttle fly assemblage structures:

$$D = \frac{n_i}{N} \cdot 100$$

where n_i is the number of individuals of i species in a sample, N is the number of individuals of phorid community in a sample.

Dominant species were considered when the index of dominance was >1 % and accessory (rare) species when it was ≤ 1%.

Species diversity was quantified using the Shannon index (H'):

$$H' = -\sum p_i \ln p_i$$

where $p_i = n_i / N$ (relative abundance).

The differences in the scuttle fly relative abundance among the three strata in the beech forest were assessed performing a PERMANOVA analysis with repeated measures (for fortnight samples) (Anderson 2001). The samples in three plots were taken as replicates in each lower level (herbs or shrubs) and the samples of two upper levels in the humid beech forest were the replicates of canopy level because the prior analysis of the Phoridae didn't show differences between two upper levels. A PERMDISP routine was done for testing the homogeneity of dispersions between habitats. However, we consider that a non-significant result from PERMDISP ($p > 0.05$) is not strictly necessary prior to using PERMANOVA. The analyses was based on two-factors design, one fixed (stratum with three levels) and other random (time). The differences in species richness, diversity (Shannon index) and abundance of species (>100 individuals) among strata were analysed using PERMANOVA analysis with repeated measures with these factors fixed, and the time a random factor. The statistical pseudo-F and p-value in the permutation test were calculated after 9,999 permutations. When the main test was significantly different, it was performed pair-wise comparisons among all pairs of strata; it used the *t* statistic, the square root of pseudo-F. In all analysis, Euclidean distance was used as resemblance measure and significant level was set at $p = 0.05$. Test were performed using the PERMANOVA + for PRIMER software (Anderson et al. 2008).

RESULTS

We identified a total of 6,115 individuals belonging to 158 scuttle fly species. The number of individuals and species decreased from herb to canopy layer. Therefore, the mean number of individuals (*N*) and species (*S*) per plot in herb stratum ($N = 938$, $S = 78$) were almost the same than in the shrub stratum ($N = 890$, $S = 70$). However, lower number of individuals ($N = 316$) and species ($S = 41$) per sample were identified in the canopy stratum.

The mean relative abundance of scuttle flies was significantly different between strata in the main test (pseudo-F = 4.3414, $p = 0.0192$), with homogeneity of dispersions ($p = 0.0669$). The relative abundance of scuttle flies in canopy stratum was significantly lower than in another two strata (herb-canopy, $t = 2.933$, $p = 0.048$ and shrub-canopy, $t = 2.9249$, $p = 0.0097$), but it wasn't different between herb and shrub layers ($t = 0.6646$; $p = 0.5225$) (Fig. 1).

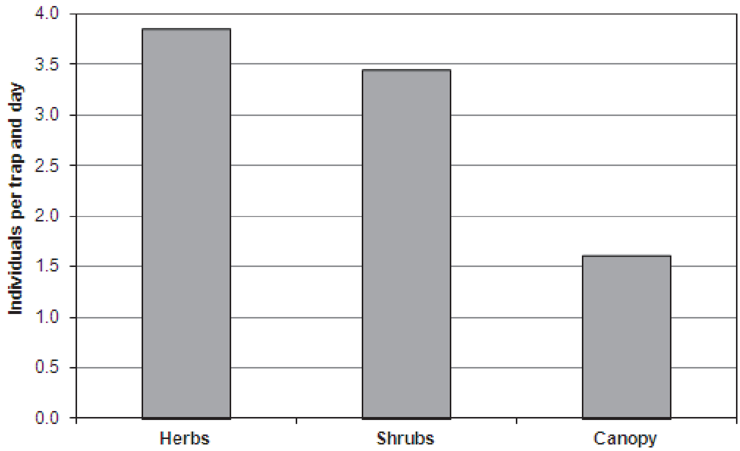

Fig. 1. Mean relative abundance of scuttle flies in different strata of the studied beech forest plots.

Species richness was significantly different between strata in the main test (pseudo-F = 5.7654, $p = 0.0093$), although without homogeneity of dispersions ($p = 0.0272$). The species richness of the canopy layer was significantly lower than in the herb layer ($t = 2.5668$; $p = 0.0242$) and in the shrub layer ($t = 2.8292$; $p = 0.0169$), however it wasn't different between the herb and the shrub layers ($t = 1.3586$; $p = 0.201$). In the main test, diversity (Shannon index) wasn't significantly different between strata (pseudo-F = 3.2343, $p = 0.0514$) (Fig. 2).

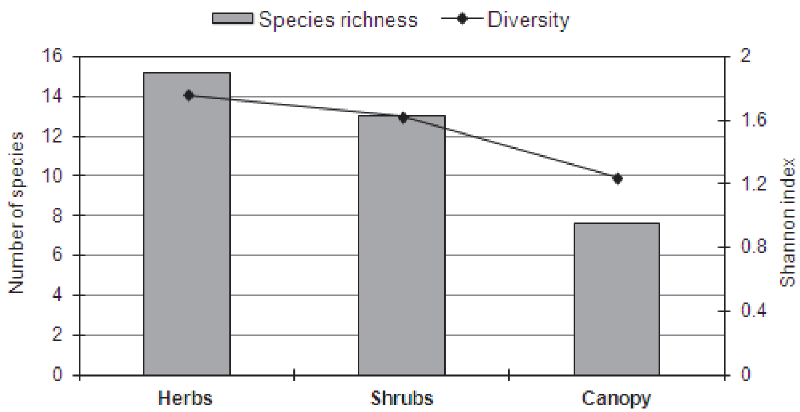

Fig. 2. Mean species richness (number of species) and diversity (Shannon index values) of scuttle flies collected in different strata of the studied beech forest plots.

Larval habit is known for only about 60% of the collected species. The saprophages were the most abundant trophic group in all the strata, followed by the polyphages. Likewise, the number of individuals of zoophages and mycophages decrease with the height (Table 1, Fig. 3a). There were no differences in the species richness among strata by trophic groups. However, the zoophages had a greater number of species in the two lower levels (Table 1, Fig. 3b).

Table 1. Average number of individuals (N) and species (S) per trap of scuttle flies by trophic groups and strata in sampling year

Stratum	Herbs		Shrubs		Canopy	
Trophic group	N	S	N	S	N	S
Saprophages	436.33	17.33	309.66	13.67	196.00	14.50
Polyphages	91.33	7.33	78.67	7.33	45.00	6.50
Mycophages	64.33	12.00	38.00	10.33	14.00	8.00
Zoophages	18.33	4.33	6.67	4.33	3.00	1.50
Total (known species)	610.33	41.00	433.00	35.67	258.00	30.50
Unspecified	327.67		456.33		58.00	

Two species clearly dominated in the herb stratum: *Megaselia pectoralis* (Wood, 1910) and *M. subpleuralis* (Wood, 1909), with a accumulate index of dominance about 45%, other six species were collected with percentage more than 3 %, including *M. diversa* (Wood, 1909), *M. pectorella* Schmitz, 1929 and *M. pusilla* (Meigen, 1830). Five species: *M. subpleuralis*, *M. pectoralis*, *M. pectorella*, *M. diversa*, and *M. superciliata* (Wood, 1910) dominated in the shrub stratum accounting more than 65% of all scuttle flies. Four species dominated in canopy stratum: *M. pectorella, M. pectoralis, M. pusilla* and *M. diversa*, accounted for about 58%. (Table 2). Significant differences between strata were revealed for five species in their mean abundance. *M. subpleuralis* and *M. longicostalis* (Wood, 1912) had a greater abundance in the shrub layer, while they were represented by only a few individuals in the canopy layer. *Diplonevra florescens* (Tuton, 1801) was more abundant in the herb layer. The dominance of *M. pectoralis* and *M. lata* (Wood, 1910) decreased with the height. The abundances of another five species were not significantly different between strata. However, *M. pectorella* was the only species that had a higher abundance in the shrub and canopy layers than in the herb layer, although without statistically significant differences between strata (Table 3).

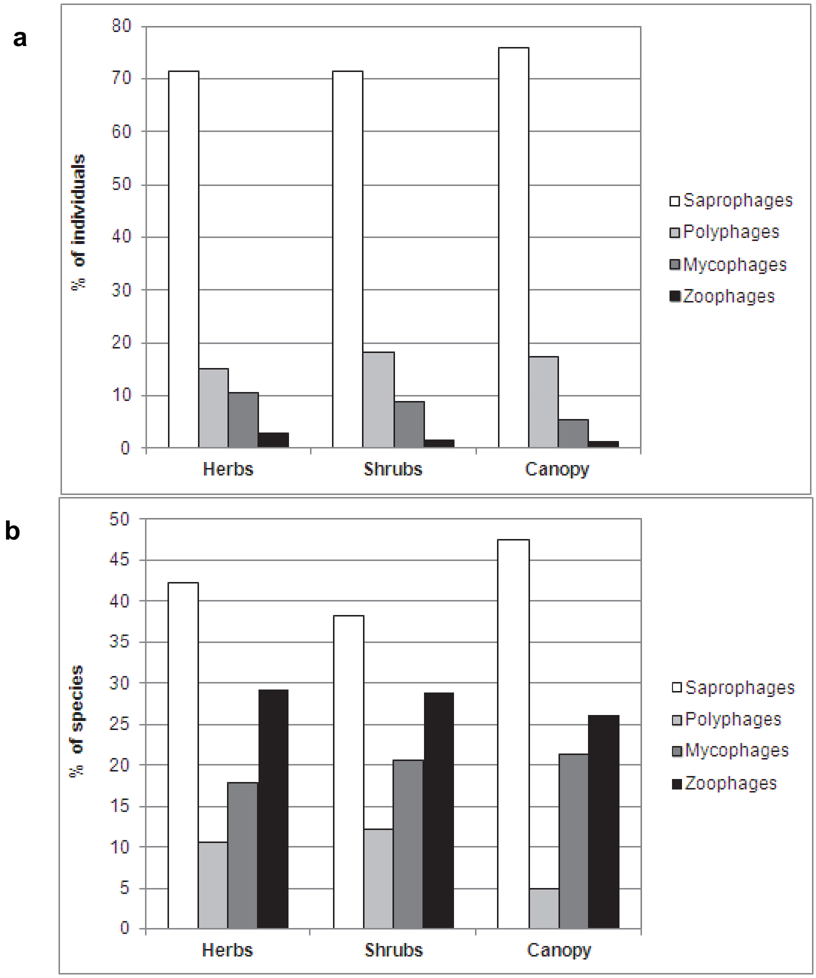

Fig. 3. Mean percentage of trophic groups of scuttle flies collected in different strata of the studied beech forest plots, in relation to individuals (a) and species (b).

Discussion

We found a higher activity and species richness of scuttle flies in the herb and shrub strata of beech forest. Most species in this habitat are saprophagous or mycophagous, with larvae that live mainly in soil. Adults continue their activity near their emergence site, visiting flowers or feeding on other dead insects or decaying litter. However, the most saprophagous species emerge in herb stratum (soil), but they were dominants in all strata. Their presence in the canopy layer could be casual, as a place for mating or feeding on the honeydew of aphids (Disney 1994).

Table 2. Dominance structure of scuttle flies species (with D>1%) in different strata.

Herbs		Shrubs		Canopy	
Species	D	Species	D	Species	D
Megaselia pectoralis	30.81%	*Megaselia subpleuralis*	30.36%	*Megaselia pectorella*	23.42%
Megaselia subpleuralis	14.78%	*Megaselia pectoralis*	15.07%	*Megaselia pectoralis*	22.63%
Megaselia diversa	3.80%	*Megaselia pectorella*	10.16%	*Megaselia pusilla*	7.12%
Diplonevra florescens	3.73%	*Megaselia diversa*	5.55%	*Megaselia diversa*	5.38%
Megaselia pectorella	3.73%	*Megaselia superciliata*	5.13%	*Megaselia angusta*	3.32%
Megaselia superciliata	3.52%	*Megaselia basispinata*	3.04%	*Megaselia subpleuralis*	3.01%
Megaselia pusilla	3.41%	*Megaselia longicostalis*	2.85%	*Conicera floricola*	2.85%
Megaselia basispinata	2.42%	*Megaselia pusilla*	2.51%	*Megaselia monochaeta*	2.69%
Megaselia longicostalis	2.31%	*Borophaga femorata*	1.42%	*Diplonevra florescens*	2.22%
Megaselia lata	1.95%	*Megaselia lata*	1.42%	*Megaselia basispinata*	2.06%
Megaselia flavicans	1.85%	*Megaselia subtumida*	1.27%	*Megaselia giraudii*	1.90%
Megaselia monochaeta	1.63%	*Megaselia monochaeta*	1.16%	*Megaselia aculeata*	1.42%
Megaselia angusta	1.60%	*Megaselia pleuralis*	1.16%	*Megaselia lata*	1.42%
Diplonevra nitidula	1.31%	*Megaselia pedatella*	1.05%	*Megaselia meconicera*	1.42%
Megaselia scutellaris	1.21%			*Megaselia involuta*	1.27%
Borophaga femorata	1.10%				
In sum	79.18%	In sum	82.16%	In sum	82.12%
Other species ($D_{\leq}$ 1%)	20.82%	Other species ($D_{\leq}$ 1%)	17.84%	Other species ($D_{\leq}$ 1%)	17.88
Total	100.00%	Total	100.00%	Total	100.00%

Table 3. Comparisons of mean number of male individuals of dominant scuttle fly species per trap in each stratum with the results of main test and pair-wise comparisons in PERMANOVA analysis; * significant *p*-values at 0.05; in italics the homogeneity of dispersion by strata in the main test ($p > 0.05$ in the PERMDISP analysis); her = herb layer, shr = shrub layer, can = canopy layer.

	Mean abundance			Main test	Pair-wise comparisons		
Species\Strata	her	shr	can	*p*-value	her-shr	her-can	shr-can
Megaselia pectoralis	21.79	10.31	5.46	0.0226 *	0.0404 *	0.0682	0.1415
Megaselia subpleuralis	10.36	20.64	0.73	0.0137 *	0.1606	0.0256 *	0.006 *
Megaselia pectorella	2.69	6.95	5.54	0.3832			
Megaselia diversa	2.69	3.74	1.23	0.0929			
Megaselia superciliata	2.51	3.49	0.23	0.1679			
Megaselia basispinata	1.72	2.08	0.50	0.1609			
Megaselia pusilla	2.46	1.72	1.00	0.1045			
Megaselia longicostalis	1.62	1.95	0.15	*0.0321* *	0.4841	0.0888	0.0406 *
Diplonevra florescens	2.67	0.44	0.54	0.0315 *	0.059	0.0887	0.674
Megaselia lata	1.38	0.95	0.35	*0.0113* *	0.0941	0.0125 *	0.1041

The polyphages, that can use different resources, were found in similar percentage of individuals in each strata, although they were slightly more abundant in two upper strata.

The mycophagous species were trapped in less abundance in the upper strata, as the larvae feed on sporophores and mycelium from fungi, mainly closer to soil, and fungal spores could be a resource for adult of some species (Disney 1994).

The parasitoids (zoophages) were more abundant in lower levels because most their hosts inhabit in the soil, such as *Megaselia aequalis* (Wood, 1909) (parasitoid of slug eggs), *M. annulipes* (Schmitz, 1921), *M. longifurca* (Lundbeck, 1921) and *M. nasoni* (Malloch, 1914) (parasitoids of spiders or their eggs), *M. mallochi* (Wood, 1909) (parasitoids of Sciaridae pupae), *M. elongata* (Wood, 1914) (parasitoids of Diplopoda), *Borophaga incrassata* (Meigen, 1830) (parasitoids of Bibionidae larvae) and *Diplonevra nitidula* (Meigen, 1830) (parasitoids of earthworms). In addition, adults of some species are flower-visiting (Robinson 1971, Disney

1994, 1999, Disney & Pagola-Carte 2009). Only one specimen of *Phalacrotophora fasciata* (Fallen, 1823), a parasitoid of Coccinellidae pupae (Disney 1994), was captured in the canopy layer.

Megaselia superciliata, with unknown larval habit and flower-visiting species (Disney 1994), was more abundant in lower strata.

The four saprophagous species, *M. pectoralis*, *M. pectorella*, *M. diversa*, and *D. florescens* (Disney 1994, Buck 1997, Durska et al. 2010), were more abundant in two lower strata, although also were present in the canopy stratum. The polyphagous *M. longicostalis*, have a saprophagous or mycophagous larvae and adult flower-visiting, so that it was scarce in the canopy layer, while the polyphagous *M. pusilla*, with saprophagous and parasitic larvae of Cerambycidae and Coccinellidae, was active in all strata, being dominant in the canopy layer (Buck 1997, Disney 1999). The mycophagous species *M. flava* (Fallén, 1823), *M. flavicans* Schmitz, 1935, *M. rubella* (Schmitz, 1920) and *M. berdseni* (Schmitz, 1919) had a higher abundance in the herb stratum, where the mushrooms occur (Disney 1994).

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STRESZCZENIE

[**Warstwowe rozmieszczenie zadrowatych (Diptera, Phoridae) lasu bukowego (Park Narodowy Montseny, Katalonia, Hiszpania)**]

W pracy zostały przedstawione wyniki badań z okresu 1990–1991 nad strukturą zgrupowań zadrowatych (Diptera, Phoridae) zasiedlających trzy warstwy roślinności lasu bukowego w Parku Narodowym Montseny (Katalonia, Hiszpania). W oparciu o zebrany materiał stwierdzono, że względna liczebność i bogactwo gatunkowe zadrowatych koron drzew było znacznie niższe w porównaniu z warstwą krzewów i ziół, a różnorodność zgrupowań zasiedlających porównywane warstwy (indeks Shannona) nie różniła się istotnie. Gatunki o larwach saprofagicznych dominowały we wszystkich trzech warstwach. Natomiast, liczebność gatunków związanych rozwojowo z grzybami (mykofagi) oraz zoofagów zmniejszała się wraz z poziomem porównywanych warstw roślinności. We wszystkich warstwach dominowały gatunki z rodzaju *Megaselia*. Ponadto, *M. pectoralis* został stwierdzony w grupie dominantów wszystkich trzech warstw roślinności (runo, krzewy, drzewa).

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