

The hoverfly fauna (Diptera, Syrphidae) from six years of Malaise trapping in an organic barley field and its boundary in southern Norway

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Hågvar, E. B. & Nielsen, T.R. 2007. The hoverfly fauna (Diptera, Syrphidae) from six years of Malaise trapping in an organic barley field and its boundary in southern Norway. *Norw. J. Entomol.* 54, 135-145.

Two Malaise traps, one in an organically grown barley crop and one in its wooded boundary, were collecting syrphids throughout the season in six successive years, 1992-1997, in southern Norway. 88 syrphid species were collected, 95 % having aphidophagous larvae. There was a considerable annual turnover rate in the species complex, and only five of the 88 species were caught all years. Some species dominating one year were absent in other years. The fauna from the crop and from the boundary differed: only 20-40 % of the species were common each year. The abundance of syrphids was generally higher in the crop than in the boundary, but not always the species number. The samples were female biased, indicating that female flight behaviour makes females more vulnerable to Malaise traps than males. The study increases the present knowledge of phenology, habitat preferences and hibernation states of single species of syrphids. The main message from this study is that annual changes in the syrphid complex are considerable, both qualitatively and quantitatively. This is important to know when ecological studies on syrphid fauna are carried out for one season only.

Key words: Syrphidae, Malaise traps, species turnover, phenology, southern Norway

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INTRODUCTION

In 1992-1997 a large project on biodiversity in an organically managed field in Ås, southern Norway, was conducted (Andersen et al. 1999). A part of that project was the study of leaf mining flies (*Chromatomyia fuscula* (Zetterstedt)) in barley and their parasitoids (Hågvar et al. 1998, Hågvar et al. 2000). To register the leaf miners, their parasitoid species and their habitat use, two Malaise traps were collecting insects from the crop and the field border throughout the season for six years.

It is known that Malaise traps also collect syrphids rather efficiently, and specimens from this family were sorted out from the same traps mentioned above. The Norwegian syrphid fauna is fairly well known (Nielsen 1999, 2002, 2003, 2005), but permanent traps throughout the season in six succeeding years in crop and boundary may give additional information on seasonal, annual and sex ratio fluctuations, and also whether a crop and a boundary trap in the same field collect different species assemblages.

More traps would surely have given more consistent results, but our results may still be valuable when comparing with the known biology and phenology of certain species.

MATERIAL AND METHODS

The study site was a 15.5 ha organically managed field at Ås, 30 km south of Oslo. Previously, this field was a conventional meadow, but was transformed during 1991-1994 to an organically-grown field with crop rotation. It had a six course crop rotation, each crop covering a rectangle of about 2.5 ha. In addition to a barley crop, the other five crops in the rotated field were meadow, row crop (beet/rape/oats/barley), green fodder (peas, oats), grass (included red clover) and rape/ryegrass. According to the rotation scheme, the location of the barley crop within the field changed from year to year (Hågvar et al. 1998).

A total of 118 plant species were registered in the field boundaries, including 11 tree species (Andersen et al. 1999). The eastern and southern margins of the field were surrounded by a rich deciduous forest. A semi-natural boundary strip with grasses lay between the field and the forest. The eastern boundary, referred to as “grass boundary”, had a 4 meter broad strip with 69 plant species. The southern boundary, named “forest

boundary”, had only a narrow strip of grasses with less plant diversity.

In each of the years 1992-1997 two black Malaise traps sampled throughout the season, from April/May to August/November. One trap was placed in the barley crop, 60 m from the boundary, the other along the forested boundary of that year’s barley crop. The boundary trap was placed between the trees in 1992, 1993 and 1996 and in the grass boundary in 1995 and 1997. In 1996, an additional trap in the grass boundary collected only early in the season (April – June). In 1994, no boundary trap was used. More detailed descriptions of the studied area and trap positions are given in Hågvar et al. (1998).

The trap had a collecting bottle with 70 % alcohol and was emptied at least once a week. The syrphids were sorted out and conserved in 70 % alcohol for later identification.

Continuous weather data were available from a station 1 km away. June-September were coldest in 1993, whereas 1992 and 1994 had a warm and dry early summer and 1997 a warm late summer. In 1995, June-July was very rainy (Hågvar et al.1998).

The diversity of the syrphid complex was measured by the Shannon-Wiener diversity index (H'): $H' = -\sum(p_i \cdot \ln p_i)$, where p_i is the relative frequency of species i , and by the transformed index: $D = \exp(H')$.

According to Jost (2006), H' is by itself not a diversity, but an entropy, whereas D represent a true diversity, i.e. an expression of the “effective number of species” in the community (MacArthur 1965). D is thus the number of evenly distributed species that is needed to obtain a diversity index similar to the one estimated for the community. Both α - (each year treated separately), γ - (all years lumped together) and β - (species turnover) indices are estimated.

The relations between the indices are:

$$H'_\alpha + H'_\beta = H'_\gamma$$

$$D_\alpha \cdot D_\beta = D_\gamma$$

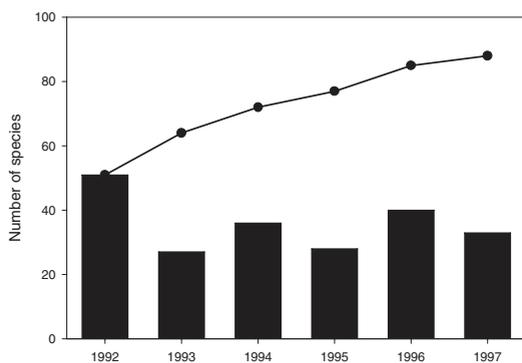


Figure 1. Annual (columns) and cumulative (line) number of Syrphidae species from Malaise traps during 1992-1997. The crop- and boundary trap are treated together.

Table 1. Relative frequencies (%) of Syrphidae caught in Malaise traps from a barley crop and its forest boundary (Fo-Bo) or grass boundary (Gr-Bo) during 1992-1997. Bold: species with rank 1-3 in dominance pr year and habitat.

Year	1992		1993		1994		1995		1996		1997		Tot. ind.
	Fo-Bo	Crop	Fo-Bo	Crop	Crop	Gr-Bo	Crop	Gr-Bo	Fo-Bo	Crop	Gr-Bo	Crop	
Sampling period	7.5- 29.10	13.5- 2.9	5.5- 3.11	10.5- 20.8	1.6.5- 8.8	2.5- 12.9	16.5- 25.8	23.4- 11.6	23.4- 15.10	11.6- 15.10	8.4- 11.11	8.4- 11.11	
Barley sown/thrashed		8.5/ 2.9		30.4/ 20.8	6.5/ 10.8		6.5/ 28.8		15.5/ 6.9		23.4/ 11.8		
<i>Baccha elongata</i> (Fabricius, 1775)	2.0				0.2			1.1	5.3				5
<i>Brachyopa testacea</i> (Fallén, 1817)								15.6		2.2			17
<i>Brachypalpus laphriformis</i> (Fallén, 1816)	2.0							1.1					1
<i>Cheilosia albitarsis</i> (Meigen, 1822)									2.6				1
<i>Cheilosia longula</i> (Zetterstedt, 1838)													1
<i>Cheilosia pagana</i> (Meigen, 1822)	2.0				0.2					1.4			3
<i>Cheilosia rufimana</i> Becker, 1894 ♀								1.1					1
<i>Cheilosia vernalis</i> (Fallén, 1817)	2.0												1
<i>Chrysotoxum arcuatum</i> (Linnaeus, 1758)						0.7	0.2						2
<i>Chrysotoxum bicinctum</i> (Linnaeus, 1758)				1.7	0.6		0.2			1.4			6
<i>Chrysotoxum cautum</i> (Harris, 1776)		0.3											1
<i>Chrysotoxum fasciolatum</i> (De Geer, 1776)	2.0												1
<i>Chrysotoxum festivum</i> (Linnaeus, 1758)				1.7							0.4		2
<i>Dasytyrphus hilaris</i> (Zetterstedt, 1843)	2.0	0.6											3
<i>Dasytyrphus pauxillus</i> (Williston, 1887)		0.3	1.2							1.4			3
<i>Dasytyrphus pinastri</i> (De Geer, 1776)				1.7									2
<i>Dasytyrphus trinctus</i> (Fallén, 1817)	2.0	0.3			0.4		0.2	3.3					2
<i>Dasytyrphus venustus</i> (Meigen, 1822)		0.3											7
<i>Didea fasciata</i> Macquart, 1834						0.7							1
<i>Epistrophe flava</i> Doczkal & Schmid, 1994	2.0												1
<i>Epistrophe grossulariae</i> (Meigen, 1822)	2.0												1
<i>Epistrophella eucroma</i> (Kowarz, 1885)		0.3			0.2	0.7		1.1					4
<i>Episyrphus balteatus</i> (De Geer, 1776)		1.9	7.1	1.7	1.7	44.1	11.6		5.3	2.2			148
<i>Eumerus flavitarsis</i> Zetterstedt, 1843	2.0												1
<i>Eumerus funeralis</i> Meigen, 1822		0.3			0.8		0.2				0.4		2
<i>Eumerus strigatus</i> (Fallén, 1817)		0.9									1.2		11

Table 2. Shannon –Wiener diversity (α , γ and β) indices of Syrphidae from Malaise traps in a barley field and its boundary. $D = \exp(H')$. Total: the crop and boundary traps treated together. For further explanation, see material and methods

Diversity index	Crop	Boundary	Total
D_{α}	7.38	9.58	9.77
D_{γ}	11.24	20.69	14.73
D_{β}	1.50	2.15	1.50

The minimum of the D_{γ} is 1 if all years have identical species complex and the maximum is 6 if all the 6 years are completely distinct and equally weighted (Jost 2006). Effects of habitat on sex ratio was estimated by Fischer’s exact test, two tailed (conservative test).

RESULTS

Annual variations in species complex and specimen numbers

A total of 88 syrphid species were collected during the six seasons (Table 1). There was considerable species turnover from year to year. Figure 1 illustrates the species number each year together

with the cumulative species number through the six years. In 1992, with very warm and dry June, the complex was most specious, and 19 of the total 51 species (37 %) were never caught again. This was the first year after the start of transformation to organical management. A less distinct turnover occurred in 1993-1997, when only 2-8 species were exclusive for one year (8-20 %).

Only 5 of the 88 species were caught all years: *Eupeodes corollae*, *Melanostoma mellinum*, *M. scalare*, *Platycheirus clypeatus* and *Sphaerophoria scripta*. Different species dominated in different years, but *S. scripta* was one of the two dominating species every year. Some of the highest ranked species one year were nearly or completely absent other years, e.g. *Platycheirus peltatus* (rank 1 in 1992, absent in 1993), *Syrphus ribesii* (rank 1 in 1993, absent in 1995), *Episyrphus balteatus* (rank 2 in 1995, absent in 1997) and *Brachyopa testacea* (rank 4 in 1996, absent all other years). Table 2 gives the diversity indices. Each year the diversity was somewhat larger in the boundary than in the crop (D_{α}). But the considerable difference in the “total diversity” between the two habitats is mainly due to the annual variations (D_{γ}). The species turnover is higher in the boundary, representing two distinct communities over the 6 years ($D_{\beta} = 2.15$). An ecological interpretation is that the complex is more stable through years in the crop than in its boundary.

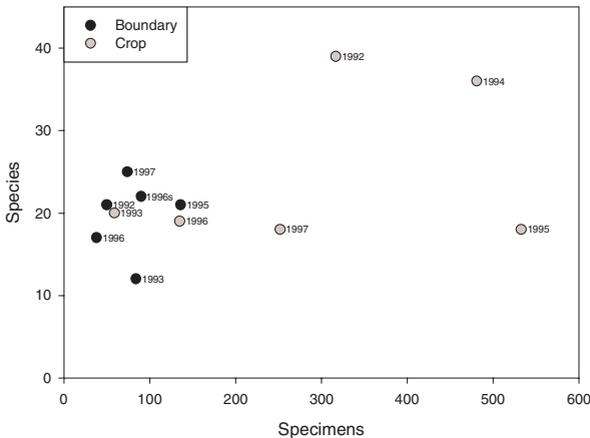


Figure 2. Annual specimens/species relationships in Syrphidae from crop- and boundary Malaise traps in 1992-1997. No boundary trap in 1994, but the spring boundary trap in 1996 (1996s) is included.

The year 1995 had the highest catches of specimens in both the crop- and boundary trap (Table 1). Although the trap period varied between years (Table 1), no obvious correlation was seen between number of specimens and trap period.

Probably weather conditions and density of aphids were more important factors. The barley was infested with aphids (mostly *Rhopalosiphum padi* L.) all the years, with low infestations in 1992 and 1997 (max 11 % and 1 % of plants infested, respectively) and modest infestations the other 4 years (Andersen et al 1999). The highest infestation rate (max 36-70 % of the plants) was noted in 1995, the same year with the highest number of syrphid specimens.

Species complex in the crop and the boundary

The crop trap generally had higher catches of specimens than the boundary trap, but not always more species (Figure 2). Species dominating in the crop did not always dominate in the boundary: *Sphaerophoria*, *Platycheirus* and *Melanostoma* were most numerous in the crop traps, which thus reflected their known preference (Pollard 1971, Stubbs & Falk 2002) for open, grassy habitats. Species composition in the crop and boundary trap differed considerably: Each year only 20-40 % of the species were found in both habitats. Of the total species complex, 22 and 23 species were registered exclusively from the boundary and the crop, respectively, through all years.

The type of boundary obviously matters: The grass boundary had generally more individuals and species than the forest boundary (e.g. compare the two 1996 boundaries), but not always higher diversity (Table 1). The Shannon-Wiener diversity was lowest in the forest boundary in 1993 (few species) and in the crop in 1995 (highest specimen numbers, but high dominance). The grass boundary in 1997 had the highest diversity (many species and low dominance), this boundary being identical with that in 1995 and early 1996 (see Hågvar et al. 1998).

Sex ratios

Typically, more females than males were caught in the traps (Figure 3). In the crop, the ratio was less female biased in the years with highest number of specimens (1992, 1994, 1995).

Nearly all species with more than 3 specimens in

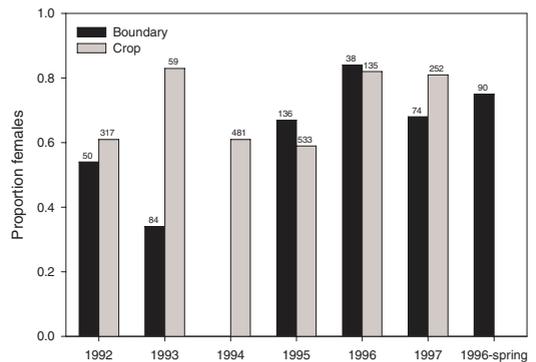


Figure 3. Total annual sex ratio in Syrphidae from Malaise traps in crop and boundary. Numbers above columns: total number of males + females.

total had both sexes represented during the study period. Exceptions were *Melangyna lasiophthalma* (n=15 females), *Volucella pellucens* (n=13 females) and *Platycheirus cf. scutatus* (n=8 females) with only females. In *Sphaerophoria taeniata* (n= 23 males) only males are identifiable.

Effects of habitat on sex ratios, all years combined, were indicated for the species that were rather common in both crop and boundary:

Syrphus ribesii: 19 % females in boundary (n=68) and 69 % females in the crop (n=88); p=0.0042.

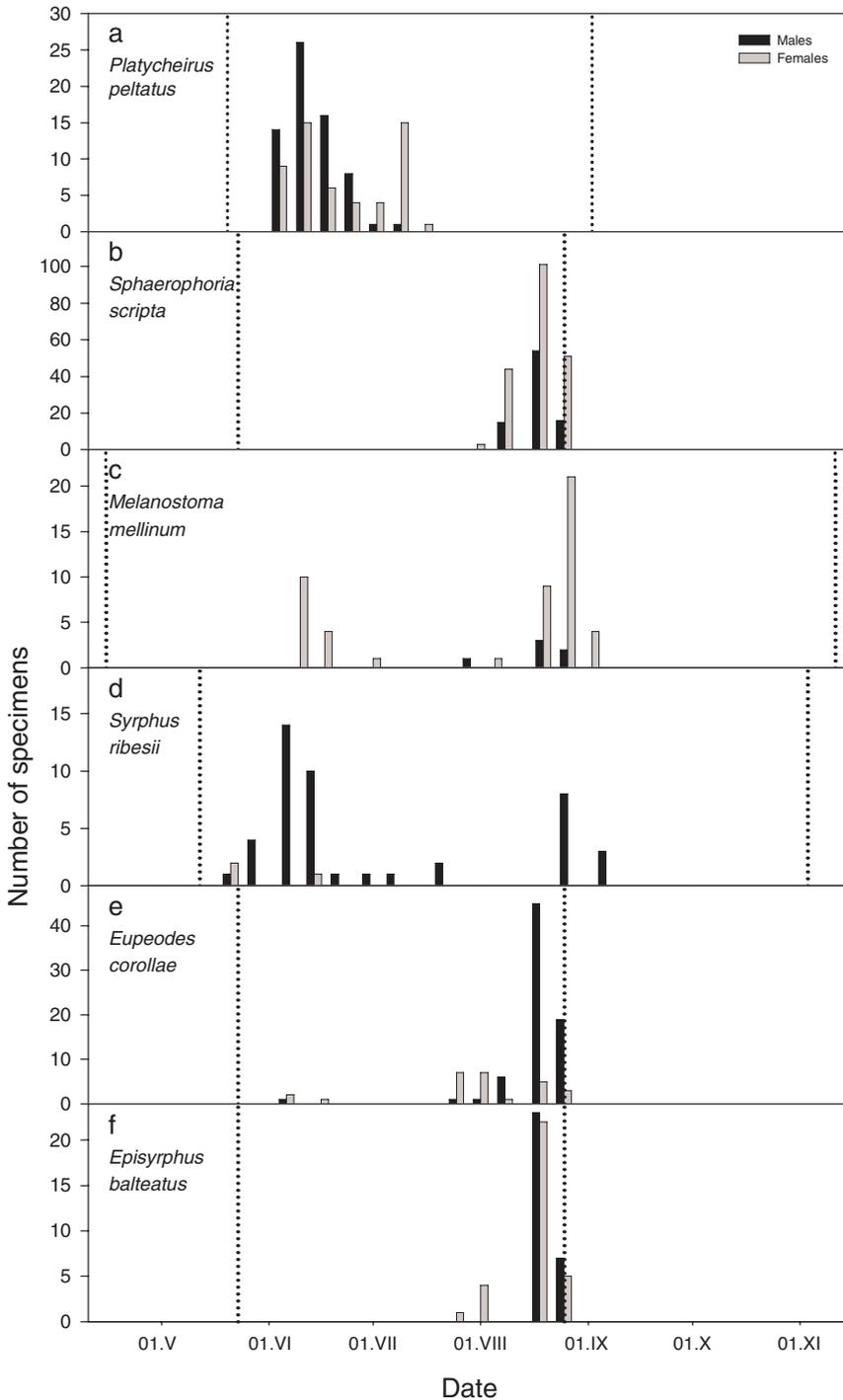
Eupeodes corollae: 73 % females in boundary (n= 22) and 37 % females in the crop (N=125); p<0.0001

Episyrphus balteatus: 53 % females in boundary (n= 68) and 57 % females in the crop (n=80); p=0.6208

Phenology

Figure 4 shows male and female phenology of the 6 species that were most numerous throughout the whole 6 years period. For each species, the year when it ranked highest in the two habitats combined was chosen (i.e. rank 1 in a,b and d, rank 2 in c and e, rank 3 in f), but the phenology is illustrated from the habitat in which it was most numerous (Figure 4).

The two traps give a picture apparently in accordance with the known phenology of these species (Pollard 1971):



Figur 4. Male and female phenology of six species dominating in Malaise traps in a particular year and habitat. a: crop 1992; b, e, f: crop 1995; c: crop 1997; d: forest boundary 1993. Dotted vertical lines: start and end of the sampling period.

P. peltatus (Figure 4a): Broadly present from June in 1992. Almost all males were caught in June, whereas females were about equally common in June and July. When crop data from all six years are combined, 96 % of all males were caught in June (n=75) compared to 55 % females (n=75). The rest was caught in July. During the six years, the only two specimens found in the boundary traps were females (1997).

S. scripta (Figure 4b): Dominating species in late summer.

M. mellinum (Figure 4c): The figure indicates two generations, but there may be two species involved (taxonomy unclear) (Speight et al. 2006).

S. ribesii (Figure 4d): Appears early and late in the season, hibernates as larva, emerges in late May and has probably two generations.

E. corollae and *E. balteatus* (Figure 4e and 4f): Immigration in late summer from more southern countries in continental Europe (Gatter & Schmid 1990, Torp 1994, Stubbs & Falk 2002), but some specimens of *E. corollae* can be found in spring and may have hibernated in Norway.

The species caught early in the season (May) are given below, with first collection date:

Eupeodes lapponicus (5 May); *Dasysyrphus pauxillus* and *Meligramma triangulifera* (both 12 May); *Pipiza luteitarsis* (13 May); *Melangyna lasiophthalma* (14 May); *Melanostoma mellinum* and *Parasyrphus macularis* (both 18 May); *Cheilosia pagana*, *Cheilosia vernalis*, *Dasysyrphus venustus* and *Syrphus ribesii* (all 20 May); *Eupeodes corollae*, *Syrphus torvus* and *Syrphus vitripennis* (all 21 May); *Epistrophella eucroma*, *Eupeodes lundbecki* and *Parasyrphus punctulatus* (all 26 May); *Baccha elongata*, *Brachypalpus laphriformis*, *Eupeodes bucculatus*, *Epistrophe flava*, *Platycheirus clypeatus* and *Rhingia campestris* (all 27. May); *Cheilosia rufimana*, *Orhonevra geniculata* and *Platycheirus jaerensis* (all 28 May).

DISCUSSION

The main message from this study is that annual changes in the syrphid complex are considerable, both qualitatively and quantitatively. This is important when ecological studies on syrphid fauna are carried out for one season only.

A reason why certain species dominating one year are absent other years can be weather conditions. *E. balteatus* and *E. corollae*, which immigrate from southern countries (Gatter & Schmid 1990, Torp 1994, Speight et al. 2006) may also depend on the weather further south and the wind direction.

Food conditions may also influence the annual variations. The larval biology and habitats of the species in Table 1 can be grouped in six main types:

- aphidophagous larvae (*Baccha*, *Dasysyrphus*, *Didea*, *Epistrophe*, *Epistrophella*, *Episyrphus*, *Eupeodes*, *Melangyna*, *Melanostoma*, *Meligramma*, *Meliscaeva*, *Paragus*, *Parasyrphus*, *Pipiza*, *Platycheirus*, *Sphaerophoria*, *Syrphus*; 58 species, 2137 specimens)
- larvae in nests of bumble bees (*Bombus* spp.) and wasps (*Vespa* spp.). (*Volucella*; 3 species, 16 specimens)
- larvae in/near nests of ants (*Chrysotoxum*; 5 species, 12 specimens)
- herbivorous or fungi-eating larvae (*Cheilosia*, *Eumerus*, *Merodon*; 9 species, 22 specimens)
- larvae in dead wood (*Brachyopa*, *Brachypalpus*, *Ferdinandea*, *Sphagina Temnostoma*, *Xylota*; 8 species, 50 specimens)
- saprophagous larvae in cow dung (*Rhingia*; 1 species, 1 specimen), saprophagous larvae in water (*Helophilus*, *Melanogaster*, *Myathropa*, *Orhonevra*, *Sericomyia*; 5 species, 12 specimens).

Thus, 95 % of the specimens (n= 2249) and 66 % of the species (n=88) had aphid-feeding larvae, including the dominating species. Aphids were present on barley, but probably also on other crop and boundary plants.

The generally very common *Episyrphus balteatus*, *Syrphus ribesii* and *Eupeodes corollae* are generalists, with number of registered prey taxa 234, 128 and 124, respectively (Gilbert 2005). Gilbert points out three possible ways to be a generalist: different populations specialize on different food, different individuals specialize on different food or all individuals are generalists. He suspects a higher degree of specialization in *S. ribesii* on population level than expected for this very widespread species. The genera have also some specializations: *Episyrphus* is best adapted to aphids on Gramineae, whereas *Syrphus* prefer aphids on herbs surrounding the wheat fields (Gilbert 2005). However, since these species are rather polyphagous, food condition is probably not the most important reason for their annual fluctuations. In addition, parasitization rate may be a factor that needs more investigations.

Only two traps per year prevent general conclusions and proper statistical analyses. In addition, the Malaise trap collects selectively, as most traps do. Only species and individuals flying up to about 1 m above ground are trapped. Thus, the female biased sex ratio can partly be an effect of males often flying higher up than females. Whereas syrphid males often show territorial hovering high up in the air, the females have a more ground level flight behaviour in her search for pollen, nectar and aphids.

Hibernation state is not known for all the species. Several of our observations support present assumptions on the life cycle of certain species:

Melangyna lasiophthalma (Zetterstedt, 1843)

All specimens (females) except 2 were caught from both boundaries in May. This is in accordance with its biology since the species hibernates as pupa (and probably also other early species of this genus) (P. Láska pers. comm.). It is a spring species that emerges in April/May and forage on pollen from *Salix* and *Corylus avellana*, which were present in the boundaries in this study.

Eupeodes corollae (Fabricius, 1794)

Along the coast of SW Norway, a female *corollae*

has been collected in early April, just after a long period of low temperatures (Nielsen, unpublished). This leads us to believe that *corollae* can hibernate as imago under favourable climatic conditions. The earliest record in the present study was 21 May, which supports this possibility.

Syrphus ribesii (Linnaeus, 1758), *S. torvus* Osten Sacken, 1875 and *S. vitripennis* Meigen, 1822

All probably hibernate as larvae, but due to some early observations of *S. ribesii* and *S. torvus* occasionally also as pupae. They were first registered on 20 and 21 May in this study. Gilbert (2005) found that larvae of *S. ribesii* exploited both the early (May-June) and the late (July-August) aphid population peak, i.e. on nettle aphids in spring and hogweed aphids in late summer. In contrast, *Episyrphus balteatus* exploited only the late aphid period. The difference between these two species is supported by the present study (Figures 4d and f).

The hibernation state of other early species, like *Pipiza luteitarsis*, *Parasyrphus macularis* uncertain, but is probably the larva. They were collected first time on 13 and 18 May, respectively.

Some notes on some less common species from the sampling area (EIS 28) are given below:

Cheilosia rufimana Becker, 1894

Previously recorded from only one locality in Norway (AK, Bærum: Ostøya; Nielsen 1999). An early summer species. In our study registered 18 May from the boundary.

Chrysotoxum cautum (Harris, 1776)

Another early summer species, known from the Oslofiord area (Nielsen 1999). In our study registered 11 June from the crop.

Epistrophe flava Doczkal & Schmid, 1994

Known from seven localities in eastern Norway (Nielsen 1999, 2005). In our study registered 27 May from the boundary.

Platycheirus jaerensis Nielsen, 1971

In southern Norway the imago is on wings from mid May to late June. An aphidophagous species, and the female has been observed ovipositing on the underside of *Vaccinium uliginosum* leaves (Nielsen, unpublished).

In our study registered on 4 June from the boundary.

Leaf miners and their parasitoids were collected from the same traps as the syrphids (Hågvar et al. 1998). However, populations of the leaf miners/parasitoids and the aphids/syrphids did not show parallel annual fluctuations. For instance, the crop trap of 1995 had the lowest specimen number of parasitoids but the highest of syrphids of all crop traps during the six seasons. The leaf miner parasitoid complex was most specious in 1997 compared with 1992 as the most specious for the syrphids. Both adult leaf miner parasitoids and syrphids eat pollen, whereas their larvae depend on very different prey: hidden leaf miner larvae or pupae inside the leaves and freeliving aphids, respectively. Prey abundance certainly matters: the number of leaf miner parasitoids in the traps correlated with the number of adult leaf miners (Hågvar et al. 1998), whereas the syrphid number was highest in the year with maximum aphid infestation.

Acknowledgements: We would like to thank Pavel Láska, Olomouc, Czech Republic for valuable information on the overwintering of *Melangyna lasiophthalma*.

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Received 13 September 2007,
accepted 15 November 2007