MITTEILUNGEN DER SCHWEIZERISCHEN ENTOMOLOGISCHEN GESELLSCHAFT
BULLETIN DE LA SOCIÉTÉ ENTOMOLOGIQUE SUISSE
71, 11 – 20, 1998

Attractiveness of sown weed strips on hoverflies (Syrphidae, Diptera), butterflies (Rhopalocera, Lepidoptera), wild bees (Apoidea, Hymenoptera) and thread-waisted wasps (Sphecidae, Hymenoptera)

THOMAS FRANK

Zoologisches Institut der Universität, Baltzerstr. 3, CH-3012 Bern, Switzerland

In 1992 and 1993 a number of species and individuals of hoverflies, butterflies, wild bees, and thread-waisted wasps in sown weed strips, adjacent fields and a field boundary were investigated in the Swiss plateau near Bern. Insects were directly observed and quantified visually, and caught with yellow pan traps. Observations always revealed distinctly higher numbers of species and individuals in weed strips than in adjacent fields, but in yellow pan traps, opposite results or at least less distinct differences, were noted for some insect groups. In 1992, the two-year-old weed strip contained more species of hoverflies, butterflies and wild bees than the one-year-old strips. This was probably due to the more diverse supply of flowers in the two-year-old weed strip which contained both annual and perennial plants. Weed strips provided suitable nutritional conditions for flower visiting insects and were therefore very attractive habitats for all insect groups investigated in this study.

Keywords: Syrphidae, Rhopalocera, Apoidea, Sphecidae, weed strips, fields, species diversity, density.

INTRODUCTION

A rapid decline in species of different groups of flower visiting insects has been observed in agricultural areas as a consequence of increasing farming intensity (MOLTHAN & RUPPERT, 1988; DOVER, 1989; FUSSELL & CORBET, 1992).

Most investigations of arthropods in arable land deal with predators or pests. Other guilds of arthropods in the agricultural landscape, such as flower visiting insects, have not been sufficiently investigated. In seminatural biotopes such as unimproved meadows, conservation headlands, fallows and margin strips, higher numbers of species and individuals of hoverflies, butterflies and wild bees have been found (AMIET, 1973; ULRICH, 1982; KLINGER, 1987; RASKIN *et al.*, 1992; GATHMANN & TSCHARNTKE, 1993). In contrast to other seminatural biotopes, little is known about the attractiveness of weed strips to flower visiting insects, except for hoverflies (WEISS & STETTMER, 1991; SALVETER & NENTWIG, 1993; SALVETER, 1996).

The creation of sown weed strips can result in a high density of blossoms, rich in nectar and pollen, and a well-structured vegetation: prerequisites for high insect species diversity (HEITZMANN-HOFMANN, 1993). In this paper the attractiveness of sown weed strips on hoverflies, butterflies, wild bees and thread-waisted wasps and their effects on diversity and abundance is studied, because the augmentation of these insect groups may contribute to a faunal enrichment of the agricultural landscape. Differences in attractiveness between one-year-old and two-year-old weed strips were also investigated.

MATERIAL AND METHODS

In 1992 and 1993, observations and captures of arthropods were made in sown weed strips, fields and a field boundary at Zollikofen, 6 km north of Bern, in the Swiss plateau (562 m).

Field areas A and B:

In these areas winter oilseed rape (*Brassica napus*, variety Arabella) was sown at the end of August 1991 and harvested on 17 July 1992. In 1993, these areas were planted with potatoes which were excluded from the research because potatoes generally were not studied in the weed strip project at the University of Bern (Fig. 1).

Weed strips C, E and G:

All weed strips were sown within the fields and consisted of a mixture of about twenty-five weed species. Details of floral composition and percentage cover are found in HEITZMANN (1994). In 1992, weed strip C was in its second year, while strips E and G were one-year-old (Tab. 1).

Field areas D and F:

In these areas maize (*Zea mays*, variety Corso) was sown on 15 May 1992 and not harvested during the investigation. In mid-October 1992, winter wheat (*Triticum aestivum*, variety Arina) was sown in these areas and harvested on 31 July 1993. In this field there were two further weed strips which were not studied because they were sown with a test mixture consisting of other weed species (Fig. 1).

Field areas H, I and K:

In these areas winter wheat (*Triticum aestivum*, variety Arina) was sown at the end of October 1991 and harvested on 2 August 1992. In September 1992, winter oilseed rape (*Brassica napus*, variety Libravo) was sown and harvested on 9 July 1993. Study area K was only established in 1993.

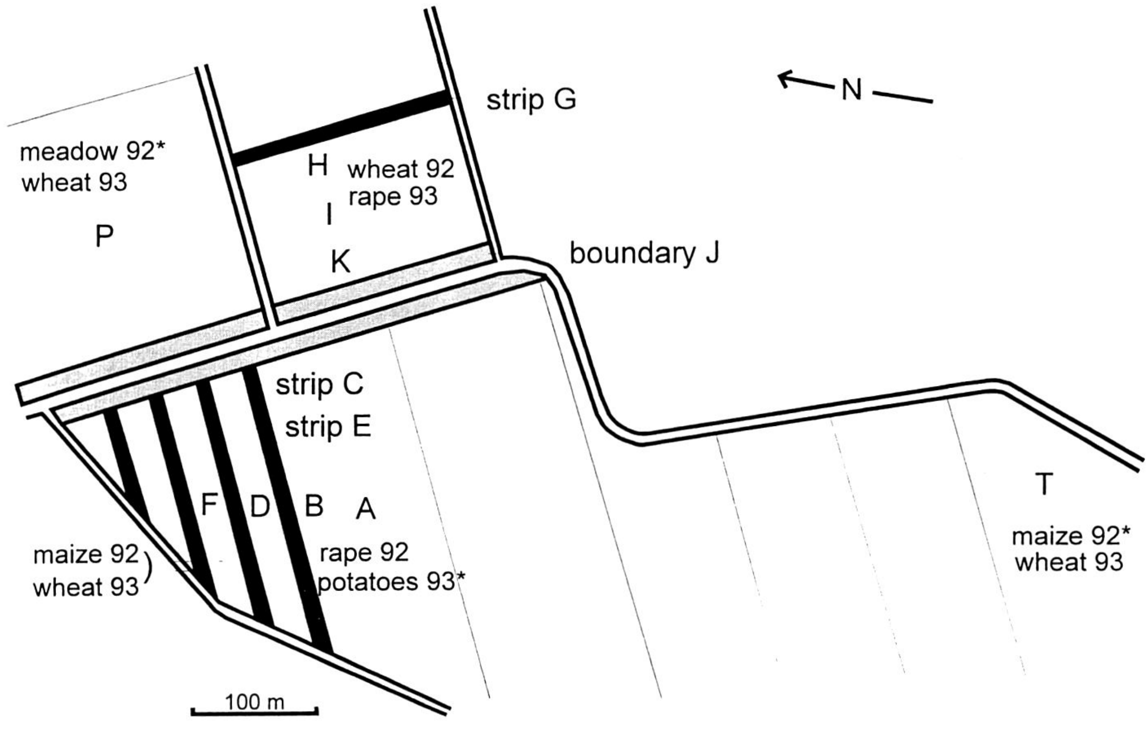

Fig. 1. Schematic overview of study areas A-T. Black areas = weed strips. Grey areas = field boundaries. Fine lines = field borders. Double lines = roads. * = not studied.

Tab. 1. Details of the study areas.

Study areas	Distances between study areas	Crops Foregoing 1991	Crops Studied 1992	Crops Studied 1993	Cropped area (ha)	Farming system
A	50 m from weed strip C, in the centre of cropped area	wheat	rape	potatoes *	1.8	integrated
B	13 m from weed strip C in cropped area	wheat	rape	potatoes *	1.8	integrated
C	weed strip (1.5 x 212 m), sown in spring 1991					
D	13 m from weed strips C and E in cropped area	meadow	maize	wheat	1.75	conventional
E	weed strip (1.5 x 188 m), sown on 27 April 1992					
F	13 m from weed strip E and another weed strip in cropped area	meadow	maize	wheat	1.75	conventional
G	weed strip (1.5 x 155 m), sown on 10 April 1992					
H	13 m from weed strip G in cropped area	meadow	wheat	rape	1.7	integrated
I	50 m from weed strip G and boundary J, in the centre of cropped area	meadow	wheat	rape	1.7	integrated
K	13 m from field boundary J in cropped area	meadow	wheat *	rape	1.7	integrated
J	field boundary (9 x 155 m), about ten years old					
P	control field without weed strips	meadow	meadow *	wheat	5.6	conventional
T	control field without weed strips	rape	maize *	wheat	4.3	conventional

* not studied

Tab. 2. Details of records.

Insect group	Methods of records	Time of records	Study areas	Number of records
Syrphidae	Yellow pan traps	4 June - 8 Sep 92	A - J	7
	Observation of 2 m^2 plots	16 June - 21 Aug 92	A - J	18
	Observation of 2 m^2 plots	17 May - 3 Aug 93	C - T	22
Lepidoptera	Observation by walking along study areas	7 May - 16 Sep 92	A - J	20
	Observation by walking along study areas	31 March - 19 Aug 93	C - P	10
Apoidea *	Yellow pan traps	4 June - 8 Sep 92	A - J	7
	Observation of 1m^2 plots	1 July - 30 Aug 93	C - P	14
Sphecidae	Yellow pan traps	4 June - 8 Sep 92	A - J	7

* excluding *Apis mellifera*

Field boundary J:

This was a grass-dominated area in which a row of apple trees grew. During the study the grass was mown three times in 1992 and twice in 1993.

Field areas P and T:

These areas lay in the centres of two winter wheat fields (*Triticum aestivum*, variety Arina) and served as control fields in 1993.

Details of all study areas are found in Tab. 1. Insecticides were never used in either farming system. The input of herbicides was slightly higher in conventionally cultivated fields than in integrated ones. This different input of herbicides had no provable impact on the number of insect individuals or species.

Syrphidae, Apoidea and Sphecidae were caught with yellow pan traps. Yellow pan traps were rectangular (33 x 25 cm = 825 cm^2 surface) and filled with 4 % formaldehyde plus detergent. Traps were set up from June to mid-September 1992 in areas A-J (Tab. 2). Traps were emptied fortnightly. Two traps were used per study area, one trap was placed on the soil surface and the other in the stratum of highest inflorescences. After the harvest of crops or after mowing the field boundary, both traps were set up on the soil surface.

In addition to yellow pan traps, hoverflies were also observed in randomly selected 2 m^2 plots (Tab. 2). Each observation lasted seven minutes per study area. All individuals landing on plants in the plots were counted visually. Unknown species were caught by sweep-netting and identified in the laboratory. In both years, observations took place from 8.30–12.00 a.m. in rotating sequences so that all areas were observed at different times.

Butterflies were recorded by walking along each study area for ten minutes, noting all specimens on the plants. In 1993, fewer observations were made because there were conspicuously fewer species and individuals present in the area of investigation (Tab. 2). Observations took place in rotating sequences on sunny days in the morning or in the afternoon. Butterflies investigated in this study belong to the group of day-active Rhopalocera; but, if the scientific name is used later on, they are called Lepidoptera.

In 1993, individuals of wild bees were observed in the same way as hoverflies. However, wild bees were counted in $1 m^2$ plots because they were more difficult to identify than hoverflies. Therefore, they were not identified to species. Observations were made in rotating sequences on sunny days in the morning (10.00–12.30) or in the afternoon (13.30–16.00).

Thread-waisted wasps were only recorded in yellow pan traps because it was not possible to accurately identify this insect group in the field.

For statistical analysis, a Wilcoxon matched-pairs signed-ranks test was applied, as described by SIEGEL (1987).

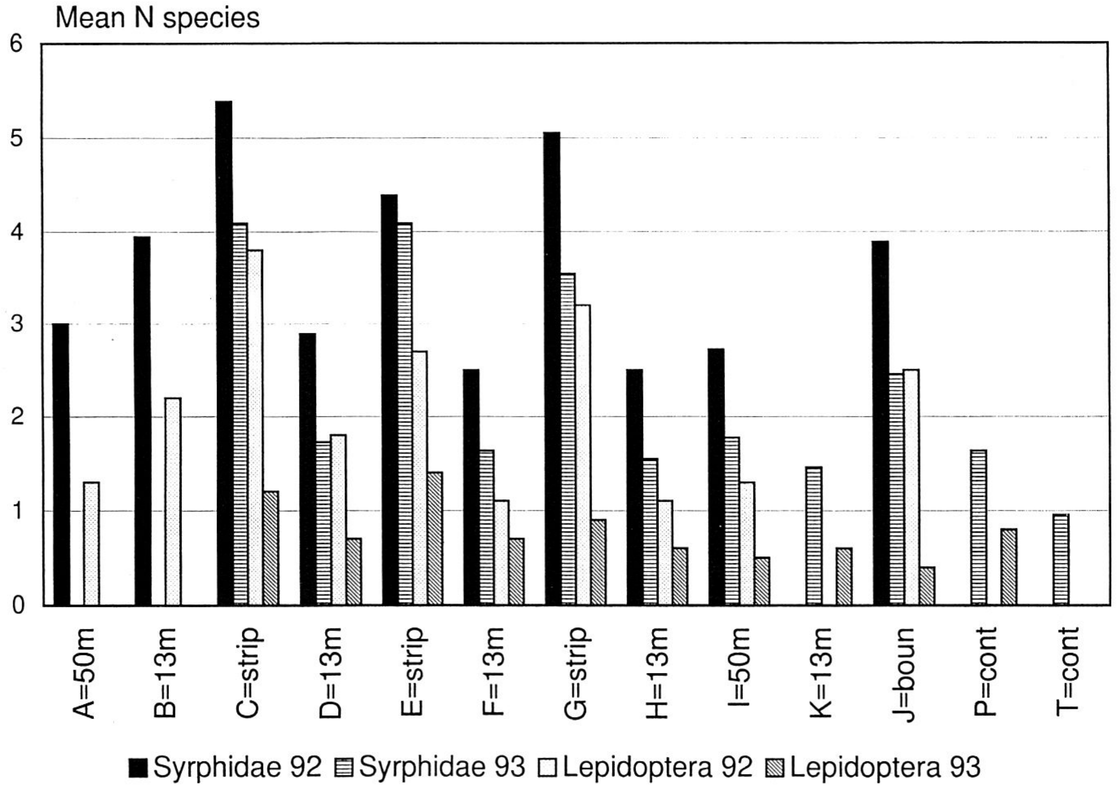

Fig. 2. Mean number of species of Syrphidae (18 observations for 7 min / 2 m^2 in 1992 and 22 observations in 1993) and Lepidoptera (20 observations for ten minutes in 1992 and 10 observations in 1993) in areas A-T. boun = field boundary, cont = control. Species numbers of Syrphidae (92,93) and Lepidoptera (92) were significantly higher in the weed strips than in the adjacent fields ($P<0.05$; Wilcoxon test). In 1993, there were no significant differences in species numbers of Lepidoptera ($P>0.05$).

Tab. 3. Mean number of individuals of Syrphidae (18 observations for 7 min / 2 m^2 in 1992 and 22 in 1993) and Apoidea (14 observations for 7 min / 1 m^2 in 1993) in areas A-T in 1992 and 1993. Number of individuals in both insect groups was always significantly higher in weed strips than in adjacent fields ($P<0.01$; Wilcoxon test). Differences between field boundary J and the adjacent field were never significant ($P>0.05$).

	A 50m rape 92	B 13m rape 92	C strip	D 13m maize 92 wheat 93	E strip	F 13m maize 92 wheat 93	G strip	H 13m wheat 92 rape 93	I 50m wheat 92 rape 93	K 13m rape 93	J bound.	P wheat 93	T wheat 93
Syrphidae													
individuals 92	9.1	12.3	20.1	6.7	15.8	7.2	17.6	7.1	6.1		11.1		
individuals 93			12.6	2.8	15.1	3.1	9	3	2.6	2.5	4.2	3.3	1.8
Apoidea *													
individuals 93			8.8	0	4.6	0	7.3	0.2	0.4	0.6	0.8	0.1	

* *excluding A. mellifera*

RESULTS

Syrphidae

In both years, higher numbers of hoverfly species were observed in the weed strips than in the adjacent fields (Fig. 2). In 1992, the older weed strip C contained the highest number of species, whereas in 1993 species diversity was the same in weed strips C and E.

In both years, hoverflies were more abundant in weed strips than in adjacent fields; the differences in number of individuals between weed strips and adjacent fields were always significant (Tab. 3). In 1992, rape areas A and B contained significantly more syrphid individuals than maize areas D and F or wheat areas H and I ($P<0.01$; $n=18$; Wilcoxon test). But in 1993, no significant difference in number of individuals between rape areas H, I and K and wheat areas D and F was observed. Control area P, which was closer to the weed strips than control area T, had significantly more individuals and species than area T ($P<0.05$; $n=22$; Wilcoxon test). In contrast to the number of individuals, significantly more species were observed in wheat areas D and F than in area T in 1993 ($P<0.05$; $n=22$; Wilcoxon). In 1992, the significantly higher number of species ($P<0.01$) and individuals ($P<0.05$) in rape area B (13 m from weed strip C) compared with area A (50 m from strip C) was striking because between wheat areas H (13 m from weed strip G) and I (50 m from strip G) no significant differences in terms of number of species and individuals were observed.

Lepidoptera and Apoidea

In both years, a higher number of butterfly species was observed in the weed strips than in the fields (Fig. 2). In 1992, the weed strips and also the field boundary contained distinctly more species than the field areas. In 1993, however, a less distinct difference in number of species between the weed strips and the field areas was observed; in this year generally fewer species of butterflies were seen in all areas than in 1992. In 1992, the older weed strip C showed the highest number of species, but in 1993 weed strip E contained a higher number of species than weed strip C.

In 1993, significantly more individuals of wild bees were observed in all weed strips than in adjacent fields (Tab. 3). The same applied to all strips compared with the control wheat area P. Between wheat areas D, F and control area P, no comparisons were made due to the near absence of wild bees from wheat.

Tab. 4. Mean number of species and individuals (yellow pan traps) of Syrphidae, Apoidea and Sphecidae in areas A-J in 1992. See text for significant differences.

	A 50m rape 92	B 13m rape 92	C strip	D 13m maize 92 wheat 93	E strip	F 13m maize 92 wheat 93	G strip	H 13m wheat 92 rape 93	I 50m wheat 92 rape 93	J bound.
Syrphidae										
species	5.6	6.0	6.0	5.3	6.9	3.9	6.6	5.7	6.6	6.0
individuals	40.3	37.9	17.3	14.4	21.0	6.3	16.6	28.7	23.6	28.1
Apoidea *										
species	6.0	4.9	9.7	5.9	7.1	4.0	7.4	6.4	5.1	5.0
individuals	13.4	11.7	29.1	12.9	18.1	8.9	11.7	11.3	10.7	11.0
Sphecidae										
species	0.1	0.4	2.1	0.6	1.3	0.0	1.4	1.0	1.0	2.0
individuals	0.1	0.6	2.7	0.6	1.4	0.0	2.7	1.3	1.1	2.6

* excluding A. mellifera

Visual observations compared with yellow pan traps

Results obtained by visual observations differed clearly from those in yellow pan traps. In both years, the greatest number of hoverfly individuals was observed in the weed strips (Tab. 3), whereas in yellow pan traps (1992) weed strips C and G contained fewer individuals than the adjacent field areas A, B, H and I (Tab. 4). In terms of species diversity of hoverflies, differences between observations and yellow pan trap collections were smaller (Fig. 2; Tab. 4), but numbers of species, caught with yellow pan traps, were never significantly higher in the weed strips than in the adjacent fields. Tab. 3 shows that numbers of individuals of wild bees obtained by observations in 1993 were clearly higher in weed strips than in fields; the ratio between numbers of individuals in weed strips and those in fields was 32 to 1. However, the same comparison made for captures with yellow pan traps in 1992 showed a ratio of only 1.7 to 1. For thread-waisted wasps caught with yellow pan traps in 1992, more species and individuals were found in the weed strips and the field boundary than in the fields (Tab. 4). Numbers of species and individuals in weed strip C were significantly higher than in the adjacent rape field ($P<0.05$; Wilcoxon test), whereas differences between the other weed strips and the field boundary and their adjacent fields were not significant. In this group, the high number of species compared with individuals was striking because the ratio between the number of individuals and the number of species was 4 to 1.

DISCUSSION

Syrphidae

A typical species composition of hoverflies for arable land was found in this study. The most abundant hoverflies (*Sphaerophoria scripta* L., *Episyrphus balteatus* DE GEER, *Eristalis arbustorum* L., *E. tenax* L., *Eupeodes corollae* FABRICIUS, *Melanostoma mellinum* L., *Platycheirus peltatus* MEIGEN) are eurytopic species and also common in agricultural areas elsewhere (GROSSER & KLAPPERSTÜCK, 1977; HAGVAR, 1983; MOLTHAN, 1990; SALVETER & NENTWIG, 1993).

Both the weed strips and the field boundary proved to be very attractive habitats for hoverflies. Seminatural biotopes rich in flowers, such as fallows (SSYMANK, 1993), conservation headlands (KÜHNER, 1988; RASKIN *et al.*, 1992), field boundaries (MOLTHAN & RUPPERT, 1988) and margin strips (KLINGER, 1987; LAGERLÖF &

WALLIN, 1993) have also been shown to be very attractive to hoverflies. Biotopes with a high density of flowers enable adult hoverflies to gather more nectar and pollen within a small area.

Due to the markedly larger supply of weed and rape blossoms, the number of syrphid individuals was significantly higher in rape than in wheat or maize in 1992. In that year, rape area B (13 m from weed strip C) contained significantly more species and individuals than the rape centre (area A). This may be due to the higher density of flowering weeds in the rape area close to the weed strip C than in the rape centre. Some weed species with large blossoms, such as *Tripleurospermum inodorum* or *Matricaria chamomilla*, invaded the rape area B from weed strip C. Therefore, some large syrphid species (*E. arbustorum* L., *Merodon equestris* FABRICIUS, *Myathropa florea* L., *Scaeva selenitica* MEIGEN), which prefer large flowers, were observed in B but not in A. After the rape was harvested, these weeds and the large hoverflies disappeared from rape area B. In 1993, the number of syrphid individuals in rape was not higher than in wheat. Since rape provided more flowering plants than wheat, the reason for that result was unclear. The relatively short distance between the control wheat field P and the weed strips appeared to be responsible for the significantly higher number of species and individuals in control area P versus wheat field T in 1993.

Lepidoptera and Apoidea

In 1992, conspicuously more species of butterflies were recorded in the weed strips and the field boundary than in the adjacent fields. However, in 1993, this difference was minor due to the decrease in both species richness and abundance of individuals noted in the Zollikofen area. The small number of butterflies may have been a result of the fairly wet spring with several cold periods in 1993. Such unfavourable climatic conditions presumably caused a high larval mortality and a shortened flight period of several species. Therefore, it is possible that some species were overlooked in 1993. Weather conditions can have a strong influence on fluctuations in the abundance of butterflies (POLLARD, 1984). THOMAS (1984) also emphasized that short-term fluctuations in several species were occasionally or mostly attributable to the weather.

The creation of weed strips counteracts the decline in numbers of butterfly species which has been observed over the recent decades in agricultural areas, and which continues today (DOVER, 1989). The weed strips attracted species of butterflies typical of open areas such as field edges, fallows and meadows (ULRICH, 1982; RANDS & SOTHERTON, 1986; HAUSER, 1993; STEFFAN-DEWENTER & TSCHARNTKE, 1994). Most of the sixteen species recorded in this study were common mobile or migratory species as described in THOMAS (1983), SCHWEIZERISCHER BUND FÜR NATURSCHUTZ (1988), and WOIWOD & STEWART (1990). Since the majority of butterflies invading newly created habitats are widespread or mobile species (DAVIS, 1989; WOIWOD & STEWART, 1990), the species community found in the weed strips seemed to be characteristic of seminatural biotopes in arable land.

Weed strips contain nectar providing flowers and, therefore, are attractive feeding places for butterflies. Many species may have used the weed strips as breeding sites because of the presence of many species of larval host plants. Although larval development was not part of this investigation, some caterpillars of *Papilio machaon* L. were observed in the strips on *Daucus carota* and *Pastinaca sativa*. *Pieris napi* L. was observed to use areas A and B for mating after the harvest of rape in 1992, and it can be assumed that this species passed its whole development in all areas. In May 1992 *Aglais urticae* L. used weed strip C for mating.

In general, bumble-bees require more energy than hoverflies and butterflies because they forage for their brood as well as for themselves (FUSSELL & CORBET, 1992). Weed strips provided much nectar and pollen due to the huge supply of flowering plants there. Therefore, it was not unexpected that bumble-bees and other wild bees were observed almost exclusively in the weed strips.

Visual observations compared with yellow pan traps

In this study, yellow pan traps served as a supplement to visual observations in order to provide data on insect species which were not directly observed in the plots. Therefore, only two yellow pan traps were used per study area, and consequently, the results obtained by yellow pan traps must not be overemphasized. Results obtained by direct observations showed that numbers of species and individuals in weed strips were distinctly higher than in adjacent fields. These differences were much smaller if yellow pan traps were used. It is likely that field captures were artificially high compared with those in weed strips because yellow pan traps set up in fields appeared to have a greater attracting effect on hoverflies than those in weed strips. It is possible that yellow pan traps are generally more attractive to flower visiting insects in more or less one-coloured crops than in colourful weed strips. SCHAAB (1990) pointed out the limitations of yellow pan traps for quantifying aphidophagous syrphids because the attractiveness of yellow pan traps declined with increasing flower densities.

In 1992, wild bees were fairly numerous in yellow pan traps in field areas compared with weed strips. Thus, it seems that the attractiveness of yellow pan traps in fields was greater than in weed strips. The reasons for that were probably the same as mentioned above. In addition to weed strips, other seminatural biotopes such as meadows, fallows and margin strips have also been shown to be attractive to many species of wild bees and thread-waisted wasps (AMIET, 1973; GATHMANN & TSCHARNTKE, 1993; LAGERLÖF & WALLIN, 1993).

In 1992, the two-year-old weed strip C contained more species of hoverflies, butterflies (observations), wild bees, and thread-waisted wasps (yellow pan traps) than the one-year-old strips E and G. This was most likely due to the more diverse supply of flowers in the two-year-old weed strip, which contained not only annuals but also flowering perennials. Thus, it seems that two-year-old weed strips can attract more species of flower visiting insects than one-year-old ones.

CONCLUSIONS

The fact that higher numbers of species of flower visiting insects were observed in weed strips than in adjacent crop fields may not be surprising. However, it is very important to provide several positive arguments in order to convince decision-makers, responsible for the financial support for establishing weed strips or other ecological compensation areas in Switzerland, of their benefit. This paper makes a contribution to that theme in terms of species diversity, as has been done for epigeic arthropod groups (e.g. LYS & NENTWIG, 1992; FRANK & NENTWIG, 1995). The results of this investigation show that weed strips are of great importance for many flower visiting insect species because they provide nectar and pollen as well as suitable vegetative structures. Since weed strips counteract the general trend of declining species numbers in the agricultural landscape (TIVY, 1993), they can play a significant role in species conservation.

Since more than one group of flower visiting insects was studied, these observations were almost completely confined to the attractiveness of weed strips as feeding places. Further investigations are necessary to observe whether weed strips are not only used by several species as feeding places, but also as places for mating, oviposition and larval development. Possible positive effects of weed strips on the augmentation of aphidophagous hoverflies were recently studied by SALVETER (1996). Therefore, aspects dealing with the augmentation of predacious hoverflies, which can be of importance for integrated pest management, are not discussed in this paper.

ACKNOWLEDGEMENTS

I am grateful to P. GOELDLIN DE TIEFENAU (Lausanne) for checking doubtful Syrphidae and especially to F. AMIET (Solothurn) for his friendly help in determining Apoidea and Sphecidae, D. LANDIS (Michigan USA) and W. NENTWIG (Bern) for valuable advice. Further thanks to G. THOMAS (Bristol UK) for correcting the English and F. PÖLTL-FRANK (Bern) for assistance in the field.

ZUSAMMENFASSUNG

In den Jahren 1992 und 1993 wurden die Arten- und Individuenzahlen von Schwebfliegen, Tagfaltern, Wildbienen und Grabwespen in angesäten Ackerkrautstreifen, angrenzenden Feldern und einem Feldrain im Schweizerischen Mittelland, nahe Bern, untersucht. Insekten wurden mittels Beobachtung und Gelbschalen erfasst. In den Ackerkrautstreifen wurden stets höhere Arten- und Individuenzahlen beobachtet als in den Feldern. Gelbschalenfänge zeigten diese Unterschiede nicht oder nur undeutlich. Der zweijährige Ackerkrautstreifen enthielt vermutlich 1992 mehr Schwebfliegen-, Tagfalter- und Wildbienenarten als die einjährigen Streifen, weil in ihm neben ein- auch zweijährige Pflanzen blühten. Ackerkrautstreifen boten blütenbesuchenden Insekten günstige Nahrungsbedingungen und erwiesen sich daher als sehr attraktiv für alle untersuchten Insektengruppen.

REFERENCES

AMIET, F. 1973. Untersuchung über den Einfluss der Landwirtschaft auf die Bienenfauna. *Naturforsch. Ges. Kanton Solothurn 26*: 25-27.

DAVIS, B.N.K. 1989. Habitat creation for butterflies on a landfill site. *Entomologist 108*: 109-122.

DOVER, J.W. 1989. The use of flowers by butterflies foraging in cereal field margins. *Entomologist's Gaz. 40*: 283-291.

FRANK, T. & NENTWIG, W. 1995. Ground dwelling spiders (Araneae) in sown weed strips and adjacent fields. *Acta Oecol. 16*: 179-193.

FUSSELL, M. & CORBET, S.A. 1992. Flower usage by bumble-bees: a basis for forage plant management. *J. appl. Ecol. 29*: 451-465.

GATHMANN, A. & TSCHARNTKE, T. 1993. Bienen und Wespen in Nisthilfen auf eingesäten Flächen und selbstbegrünten Brachen (Hymenoptera Aculeata). *Verh. Ges. Ökol. 22*: 53-56.

GROSSER, N. & KLAPPERSTÜCK, J. 1977. Ökologische Untersuchungen an Syrphiden zweier Agrobiozönosen. *Hercynia 14*: 124-144.

HAGVAR, E.B. 1983. Phenology and species composition of Syrphidae (Dipt.) in a meadow habitat. *Fauna norveg., Ser. B 30*: 84-87.

HAUSER, E. 1993. Ökologische Bewertung verschiedener Lebensraumtypen im Südosten der Stadt Linz mittels tagaktiver Schmetterlinge. *ÖKO L, Z. Naturkundl.Station Linz 15/2*: 3-10.

HEITZMANN-HOFMANN, A. 1993. Einsatz und Sukzession ausgewählter, nützlingsfördernder Pflanzenarten in Acker(rand)streifen. *Verh. Ges. Ökol. 22*: 65-72.

HEITZMANN, A. 1994. Die Vegetationsdynamik in angesäten Ackerkrautstreifen in Abhängigkeit verschiedener Saatmischungen. *Z. PflKrkh. PflSchutz 14*: 75-83.

KLINGER, K. 1987. Auswirkungen eingesäter Randstreifen an einem Winterweizen-Feld auf die Raubarthropodenfauna und den Getreideblattlausbefall. *J. appl. Ent. 104*: 47-58.

KÜHNER, C. 1988. Untersuchungen in Hessen über Auswirkung und Bedeutung von Ackerschonstreifen. 2.: Populationsentwicklung der Getreideblattläuse und ihrer spezifischen Gegenspieler. *Mitt. biol. Bundesanst. Land- Forstwirtsch. Berlin-Dahlem 247*: 43-54.

LAGERLÖF, J. & WALLIN, H. 1993. The abundance of arthropods along two field margins with different types of vegetation composition: an experimental study. *Agriculture, Ecosystems and Environment 43*: 141-154.

LYS, J.-A. & NENTWIG, W. 1992. Förderung von Laufkäfern (Coleoptera, Carabidae) in einem Getreidefeld durch künstlich angesäte Krautstreifen. *Mitt. Dtsch. Ges. allg. angew. Ent. 8*: 128-132.

MOLTHAN, J. 1990. Artenspektren, Dominanzverhältnisse und Abundanzdynamik von Schwebfliegen (Diptera: Syrphidae) in Feldrandbiotopen im Hessischen Ried. *Mitt. Dtsch. Ges. allg. angew. Ent. 7*: 368-379.

MOLTHAN, J. & RUPPERT, V. 1988. Zur Bedeutung blühender Wildkräuter in Feldrainen und Äckern für blütenbesuchende Nutzinsekten. *Mitt. biol. Bundesanst. Land- Forstwirtsch. Berlin-Dahlem 247*: 85-99.

POLLARD, E. 1984. Fluctuations in the abundance of butterflies, 1976-82. *Ecol. Ent. 9*: 179-188.

RANDS, M.R.W. & SOTHERTON, N.W. 1986. Pesticide use on cereal crops and changes in the abundance of butterflies on arable farmland in England. *Biol. Conserv. 36*: 71-82.

RASKIN, R., GLÜCK, E. & PFLUG, W. 1992. Floren- und Faunenentwicklung auf herbizidfrei gehaltenen Agrarflächen - Auswirkungen des Ackerrandstreifenprogramms. *Natur und Landschaft 67*: 7–14.

SALVETER, R. 1996. *Populationsaufbau aphidophager Schwebfliegen (Diptera: Syrphidae) in der Agrarlandschaft*. Diss. Univ. Bern, 117 pp.

SALVETER, R. & NENTWIG, W. 1993. Schwebfliegen (Diptera, Syrphidae) in der Agrarlandschaft: Phänologie, Abundanz und Markierungsversuche. *Mitt. Naturforsch. Ges. Bern 50*: 147-191.

SCHAAB, R. 1990. *Die Wirksamkeit verschiedener Insektenfallen zur Ermittlung der Aktivitätsdichte und des Artenspektrums von Schwebfliegen (Diptera, Syrphidae)*. Diplomarbeit, Univ. Hohenheim.

SCHWEIZERISCHER BUND FÜR NATURSCHUTZ 1988. *Tagfalter und ihre Lebensräume. Arten, Gefährdung, Schutz*. 2. Aufl. Holliger, Egg (Zürich), 516 pp.

SIEGEL, S. 1987. *Nichtparametrische statistische Methoden*. 3. Aufl. Fachbuchhandlung für Psychologie, Frankfurt/M., 320 pp.

SSYMANK, A. 1993. Zur Bewertung und Bedeutung naturnaher Landschaftselemente in der Agrarlandschaft. Teil 1: Schwebfliegen (Diptera, Syrphidae). *Verh. Ges. Ökol. 22*: 255-262.

STEFFAN-DEWENTER, I. & TSCHARNTKE, T. 1994. Tagschmetterlinge als Indikatoren für Ackerbrachen. *Mitt. Dtsch. Ges. allg. angew. Ent. 9, 1-3*: 75-78.

THOMAS, J.A. 1983. - A "watch" census of common British butterflies. *J. biol. Education 17*: 333-338.

THOMAS, J.A. 1984. The conservation of butterflies in temperate countries: past efforts and lessons for the future. *In*: WRIGHT, R. & ACKERY, P. (eds.), *The biology of butterflies*. Symposium Royal Entomol. Soc. London, 11: 333-353.

TIVY, J. 1993. *Landwirtschaft und Umwelt*. Spektrum, Heidelberg, 344 pp.

ULRICH, R. 1982. Vergleich von bewirtschafteten Wiesen und Brachen hinsichtlich des Wertes für unsere Tagfalter. *Natur und Landschaft 57*: 378-382.

WEISS, E. & STETTMER, C. 1991. Unkräuter in der Agrarlandschaft locken blütenbesuchende Nutzinsekten an. *Agrarökologie 1*: 1-104.

WOIWOD, I. P. & STEWART, A.J.A. 1990. Butterflies and moths - migration in the agricultural environment. *In*: BUNCE, G.H. & HOWARD, D.C. (eds.), *Species dispersal in agricultural habitats*, pp. 189-202. Belhaven Press, London.

(received September 18, 1996; accepted after minor revision December 10, 1997)