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The use of Syrphidae as functional bioindicator to compare vineyards with different managements

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Abstract

Hoverflies (Diptera Syrphidae) were studied in two vineyards in Northern Italy, to characterize the fauna of a conventional farm in comparison with one with organic management. Hoverfly populations were monitored in three different years (2010, 2011 and 2012) using Malaise traps as the sampling technique. In three years, a total of 48 species were recorded in the two vineyards. Among those, seven species found across three years were not expected in accordance with predictions from the nature of the surrounding habitats (via Syrph the Net). Some of these species are usually associated with dry grassland and may be considered as associated with vineyards, increasing the fauna of these productive habitats. The total number of species seem to be highly similar in the two vineyards, despite the different management. The use of functional traits was much more useful in understanding the differences between the two vineyards. Despite the small distance between the two sites, hoverfly populations were different in the three years. The presence of different habitats adjacent to the two vineyards seem to be the main feature affecting hoverfly populations. In addition, the organic vineyard showed a higher percentage of species associated with the herb and root layers. These taxa can be associated with the adjacent wood and/or with the vineyard since the latter is characterized by an improved vegetation management typical of an organic system (e.g. the grass cover technique). The analysis of functional traits in the Syrphidae allowed an ecological interpretation confirmed by the habitat analysis and farm inputs. Functional analysis based on the hoverfly fauna proved to be a synthetic and informative tool to characterize and interpret a number of complex features in a standard and simple way.

Key words: hoverfly, vineyard, Syrph the Net, organic farming.

Introduction

The need for standardized indicators is a crucial issue in the assessment of biodiversity loss and the efficiency of restoration and conservation policies (Noss, 1990; Caro and O'Doherty, 1998; Mace and Baillie, 2007). In sustainable agriculture, the availability of sensitive bioindicators is considered a vital part of the evaluation of farm inputs, quality of agroecosystems and functional biodiversity (De Snoo *et al.*, 2006). In particular, comparisons of ecological sustainability between organic and conventional farming systems seems to be complex, largely as a result of the complexity of, and interactions between, the farming practices that comprise the two systems (Hole *et al.*, 2005; Gomiero *et al.*, 2011). For this reasons, the selection of proper indicators to use in sustainable agriculture has been much debated because the use of a synthetic and flexible taxon could replace a multidisciplinary (and much more expensive!) approach involving a wide range of measures and taxonomic groups.

Here we focus on vineyards, complex agroecosystems which have received increasing attention over the last few decades (Ragusa and Tsolakis, 2006; Altieri *et al.*, 2010). A recent expansion of vineyards has led to landscape simplification in intensive wine areas, with increased vulnerability to insect pests and diseases (Altieri *et al.*, 2010). Vineyards have also been used as an agroecological model to apply sustainable cultivation, both at farm and landscape level (Castagnoli *et al.*, 1999; Altieri *et al.*, 2005; Gurr *et al.*, 2007).

In the present research hoverflies were chosen as bioindicators because of a general consensus about their use in evaluating ecosystem conservation (Speight, 1986; Sommaggio, 1999; Speight and Castella, 2001; Burgio and Sommaggio, 2007; Billeter *et al.*, 2008; Velli *et al.*, 2010; Ricarte *et al.*, 2011). This taxon has long been considered a prime candidate for such work (Speight, 1986) and a focus of conservation in Europe (Rotheray *et al.*, 2001; Marcos-García, 2006). Their widespread distribution, availability of taxonomic keys for species identification (particularly in Europe), and heterogeneity of the environmental requirements for the larvae are features that promote Syrphidae as effective bioindicators (Sommaggio, 1999). Recently an expert system called Syrph the Net (StN) has been developed to standardize the use of Syrphidae as bioindicators (Speight and Castella, 2001; Speight, 2012a). StN uses not only the taxonomic values of each species, but also their functional traits and the relationship between the species and habitats (Speight and Castella, 2001; Speight, 2012a).

The main objective of present study was to compare the variation in hoverfly populations as bio-indicators in two vineyards with different managements (organic and conventional). The efficiency of taxonomic and functional traits were firstly evaluated in comparing different agriculture management. Secondly, we observed the potential role of vineyards in conserving and improving landscape biodiversity, by supporting species that are endangered or otherwise absent in adjacent areas.

Materials and methods

Study sites

The hoverfly fauna was studied in two vineyards with different management (biological vs. conventional) in the province of Modena, Northern Italy, in a study involving three years of sampling. In the present research

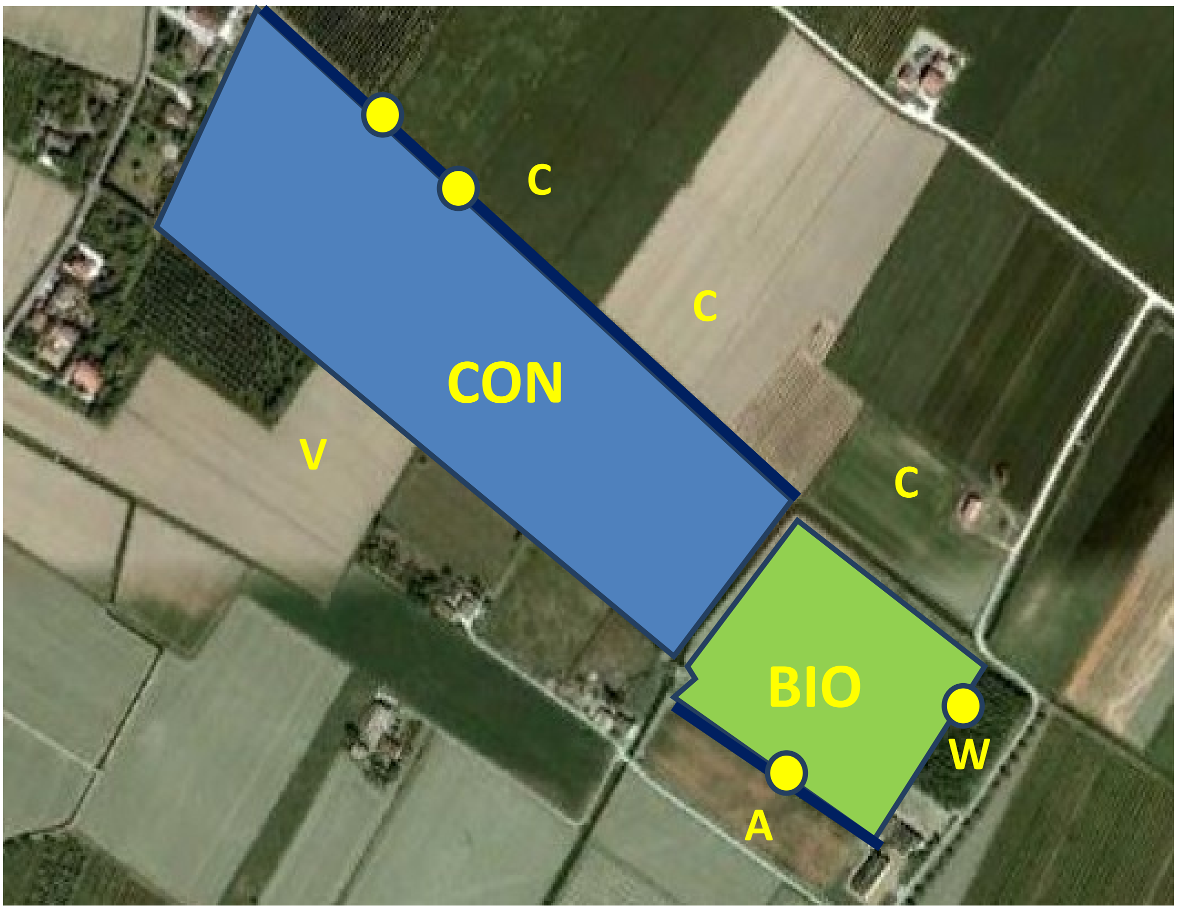

Figure 1. Site map of organic (BIO) and conventional (CON) vineyards. Dots indicate Malaise trap position; C: cereal fields; W: *Quercus* wood; V: other vineyards; A: alfalfa field.

a multi-year approach was chosen in order to understand and analyze any biodiversity trends and the differences between the two vineyards over and above year differences. In fact variation of hoverfly population in different years has been previously detected (e.g. Gilbert and Owen, 1990; Sommaggio, 2010a). The area is largely anthropized, mainly for agricultural purposes. Both vineyards were planted with Lambrusco, both "Lambrusco di Sorbara" and "Lambrusco Salamino", two varieties which are typical of Modena Province.

Two adjacent vineyards were selected in order to control for landscape and geographic variability; they are separated by a drainage canal (figure 1). The two vineyards differ only in their surrounding habitats (microscale landscape). The organic vineyard (BIO) occupies an area of almost 3 ha surrounded by a small oak wood (0.5 ha), an alfalfa field (almost 1 ha) and arable fields (wheat or maize in different years) (figure 1). A small drainage ditch, usually dry in summer, separated the vineyard and the alfalfa field; a large drainage canal divided the BIO vineyard from the cereal field. The conventional vineyard (CON) occupies an area of 10 ha and was surrounded by infrastructural habitats (mainly farm buildings), a cereal field (9 ha) and another vineyard (4 ha) (figure 1); the CON vineyard was separated from the cereal field by a large drainage ditch; water was present in this ditch throughout the year and aquatic vegetation was largely developed.

The BIO vineyard belonged to a farm which has followed organic methods since 2007, in agreement with EU regulations (CEE 834/2007). Weeds and grass cover between rows were controlled only by cutting (2 or 3 times per year), and only approved pesticides were used (table 1). Different types of grass cover were introduced within the vineyard, including phacelia (*Phacelia tanacetifolia* Benth), alyssum [*Lobularia maritime* (L.)], buckwheat (*Fagopyrum esculentum* Moench), broad bean (*Vicia faba* L.) and a mix of vetch (*Vicia villosa* Roth) and oat (*Avena sativa* L.) (Burgio *et al*., 2012). Grass cover type was randomized between the rows, generating different treatment blocks.

The CON vineyard was managed using integrated pest management methods (table 1).

Sampling protocol

The syrphid fauna was studied using Malaise traps, which can be considered as a standard sampling method for hoverflies (Burgio and Sommaggio, 2007; Speight, 2008; 2012a). Two Malaise traps were situated in each vineyard in the period 2010-2012. In the BIO vineyard, one Malaise trap was set between the oak wood and the vineyard (BIO1), while the second was between the alfalfa field and the vineyard (BIO2) (figure 1). In the CON vineyard, both Malaise traps were set between the vineyard and the arable fields (CON1 and CON2).

Table 1. Plant protection products used in the two vineyards during the sampling period. In brackets are indicated the number of standard treatments in one year.

Pests	BIO Vineyard	CON Vineyard
Erysiphaceae	Antagonist fungi (2-3)	
	Sulphur (10-20)	Sulphur (10-12)
Coccoidea	Mineral oil (1)	
Peronospora	Copper (12-21)	Copper (8-12)
		Fenamidone (2)
		Dithiocarbamate (3-6)
		Iprovalicarb (2)
Botrytis cinerea	-	Pyrimethanil (1)
Scaphoideus titanus	Pyrethrins (2)	Organic phosphate (2-3)
Lobesia botrana	*Bacillus thuringiensis* (3-4)	Epoxiconazol (1)
		Keromix-metil (1)
Adjuvant treatments	Resin (3-5)	

All traps were set in the same positions in all three years with only small differences: BIO1 in the second year was at an angle to the oak wood, in a better position to catch, but in the way of tractor movement; similarly CON1 and CON2 had to be moved in the second and third years to a different position to facilitate tractor movement. The distance between the BIO and CON traps was greater than 500 m. No clear data are available about the sampling range of Malaise traps in hoverfly sampling, but a 100-meter distance has been suggested as suitable to allow two Malaise traps to be considered independent (Gittings *et al*., 2006).

The Malaise sampling was carried out from April to September, except in 2012 when in CON vineyard the strong dry conditions forced the moving of the Malaise trap to permit better access to the drainage ditch. Malaise traps were supplied with 70° alcohol; the sample was collected approximately every 2 weeks from each trap. All hoverflies collected were identified to species except for female *Paragus* subg. *Pandasyophthalmus* (only possible using male genitalia). Species nomenclature was in accordance with Speight (2012b).

Data analysis

Malaise traps are considered a quantitative sampling method, but their efficiency is highly affected by several parameters, including the position of the trap, the local plant cover, the sun exposure and others, leading to bias in estimating population density (Speight, 2012a; Birtele and Handersen, 2012). In addition, their efficacy depends on the ethology of the sampled species: for example several *Eristalis* species are underestimated by Malaise trap (Burgio and Sommaggio, 2007). For these reasons we converted the data to a presence/absence matrix, generating a list of sampled species, as also suggested by the Syrph the Net procedure (Speight, 2012a).

Malaise trap efficiency was calculated as the total number of specimens collected by each trap divided by the total number of days in which the trap was open. Trap efficiency was expressed as species/day (table 2).

The absence of replication prevented us from using any statistical test to compare the two vineyards. Correspondence analysis was used to ordinate and correlate the ecological categories of Syrphidae species on the basis of the two management systems (BIO and CON).

We use the Syrph the Net database (Speight, 2008) to:

- elaborate a list of expected species for each of the surrounding habitats (the list of expected species was obtained by integrating the regional list of species in Sommaggio, 2010b and habitats):
    - ○ Crop (StN code 51);
    - ○ Field margin (StN code 52);
    - ○ Canal edge (StN code 7443);
    - ○ *Quercus* wood (StN code 1122);
- associate each observed species with specific ecological traits; in particular, the following groups were considered:
    - ○ Trophic category; hoverfly larvae can be divided into predators (mainly aphidophagous), phytophages and saprophages;
    - ○ Duration of development; the period necessary to complete the development by hoverfly larvae can be short (less than 2 months), medium (2-7 months) or long (7-12 months). In few species larval development takes more than one year, but these are not expected to occur in vineyards and were not considered here;
    - ○ Voltinism; hoverfly species can be univoltine; bivoltine, polyvoltine (3 or more generations). Parti-voltine species with less than one generation per year were not included;
    - ○ Larval microhabitat; larvae can develop in specific microhabitats, including tree foliage (canopy), herb layer (on the surface of non-woody plants), herb layer (in the living tissue of non-woody plants), ground surface debris (among or under plant debris), root zone (inside or on plant roots), submerged sediment (associated with organic substrates permanently submerged by running or standing water) and water-satured ground.

We did not calculate here the Maintenance Biodiversity Function, the main parameter calculated by StN, because the StN database does not include ‘vineyards’ as a habitat and the sampling points were at the borders with other habitats.

Table 2. Relative abundance of syrphid species caught in the three years in the two vineyards.

	Habitats	Biological						Conventional					
		2010		2011		2012		2010		2011		2012	
		BIO1	BIO2	BIO1	BIO2	BIO1	BIO2	CON1	CON2	CON1	CON2	CON1	CON2
Anasimyia transfuga (L.)	1	-	-	-	-	-	-	-	-	0.8	-	-	-
Brachyopa bicolor (Fallen)	4	0.6	-	-	-	-	-	-	-	-	-	-	-
Cheilosia latifrons (Zetterstedt)		0.6	0.7	0.5	4.4	-	0.1	-	0.3	-	-	-	-
Cheilosia ranunculi Dockzal	4	-	-	0.2	1.5	-	-	0.1	0.3	0.4	2	0.2	0.4
Cheilosia soror (Zetterstedt)	4	-	-	0.2	-	-	-	-	-	-	-	-	-
Chrysotoxum cautum (Harris)	3, 4	3.5	0.5	1.7	-	-	0.4	0.1	0.3	0.8	-	-	0.6
Epistrophe nitidicollis (Meigen)	4	-	-	0.2	-	-	-	-	-	-	-	-	-
Episyrphus balteatus (de Geer)	All	6.4	0.3	2.4	-	5	0.7	0.2	0.1	0.4	0.5	5.3	0.4
Eristalinus aeneus (Scopoli)	1	-	0.4	-	-	-	-	0.1	0.3	-	0.5	-	-
Eristalinus sepulchralis (L.)	1, 3	-	0.2	-	-	-	-	0.1	0.4	-	0.5	-	0.4
Eristalis arbustorum (L.)	1, 3	-	0.1	-	-	-	0.2	-	-	-	-	-	0.2
Eristalis similis (Fallen)	4	-	-	-	-	-	-	0.1	-	-	-	-	-
Eristalis tenax (L.)	All	-	-	-	-	-	-	0.1	-	-	-	0.2	-
Eumerus amoenus Loew	3	-	0.1	1.4	1.5	-	-	-	-	-	-	-	0.2
Eumerus funeralis Meigen	3, 4	-	0.4	0.7	1.5	10	0.4	0.2	1.6	2.7	-	1.4	1.3
Eumerus sogdianus Stackelberg	2, 3	5.8	0.7	13.1	29.4	15	1	0.3	3.1	7.8	8.2	0.3	1
Eumerus uncipes Rondani		-	-	-	-	-	-	-	-	-	0.5	-	-
Eupeodes corollae (F.)	All	4.1	1.5	29	10.3	-	0.1	0.3	1.9	3.5	2.5	4.2	2.9
Eupeodes latifasciatus (Macquart)	1, 2, 3	-	-	1.4	1.5	-	0.1	0.1	0.4	0.4	0.5	0.3	-
Eupeodes luniger (Meigen)	1, 3, 4	-	-	-	-	-	0.1	-	-	0.4	-	0.3	-
Ferdinandea cuprea (Scopoli)	4	-	-	0.2	-	-	-	-	-	-	-	-	-
Helophilous pendulus (L.)	1, 2, 3	-	-	0.2	-	-	-	0.1	-	-	-	-	-
Helophilous trivittatus (F.)	3	-	-	-	-	-	-	0.1	-	0.4	2	-	-
Heringia heringi (Zetterstedt)	4	-	-	0.2	-	-	-	-	0.1	-	-	-	-
Melanostoma mellinum (L.)	All	5.8	44.2	7.1	5.8	20	67.2	85.4	37	13.3	30.1	63.8	51.8
Melanostoma scalare (F.)	All	0.6	0.2	0.5	-	5	0.1	-	-	-	-	-	-
Merodon avidus (Rossi)	3, 4	-	0.2	0.2	-	-	-	0.1	0.1	-	-	-	-
Myathropa florea (L.)	3	0.6	0.1	-	-	-	0.1	0.1	-	-	-	-	-
Neoascia interrupta (Meigen)		-	-	-	-	-	-	-	0.1	-	-	-	-
Neoascia podagrica (F.)	1, 3	-	-	0.2	-	-	-	-	-	-	-	-	-
Paragus albifrons (Fallen)	2	-	-	-	-	-	-	-	-	1.2	-	0.1	-
Paragus bicolor (F.)		-	1.1	0.2	4.4	-	1.3	-	0.1	0.8	0.5	-	0.6
Paragus bradescui (Stanescu)	4	-	-	-	-	-	0.1	-	-	-	-	-	-
Paragus haemorrhous Meigen		5.2	-	2.4	1.5	-	0.1	-	-	-	1.5	-	-
Paragus pecchiolii Rondani	2, 4	-	0.3	0.2	3.8	-	0.1	-	-	0.4	0.5	-	-
Paragus quadrifasciatus Meigen	2	-	0.1	-	-	-	-	0.1	-	0.4	-	-	
Paragus tibialis (Fallen)	2	2.9	0.5	1.2	-	5	0.2	0.1	0.3	-	-	0.3	-
Parhelophilus versicolor (F.)	1	-	-	-	-	-	-	-	0.1	0.4	-	-	-
Pipizella maculipennis (Meigen)		18.6	8.9	7.9	10.2	5	1.8	0.3	1.6	1.6	2.5	0.3	1
Pipizella viduata (L.)	3, 4	22.7	2	5	2.9	-	0.4	-	0.6	-	-	0.5	0.2
Platycheirus fulviventris (Macquart)	1, 2	-	-	0.2	-	-	-	0.1	-	-	-	-	-
Scaeva pyrastri (L.)	2, 3, 4	0.6	-	0.2	-	-	-	-	-	0.8	0.5	0.6	-
Sphaerophoria rueppelli Wiedemann	1, 2	0.6	2.6	0.5	8.8	-	0.5	1.6	8.7	6.3	2	0.8	1.1
Sphaerophoria scripta (L.)	2, 3	17.4	35	6.7	8.8	30	24.6	10.8	42.3	56.9	44.9	21.4	37.8
Syritta pipiens (L.)	1, 3	0.6	-	-	-	-	0.1	0.1	-	-	-	0.3	0.2
Syrphus ribesii (L.)	All	-	0.2	-	-	-	0.1	-	-	0.4	-	-	-
Xanthogramma citrofasciatum (de Geer)		3.5	-	-	-	-	-	-	-	-	-	-	-
Xanthogramma dives (Rondani)	4	-	-	15.7	-	5	-	-	-	-	-	-	-
Number of Species		18	23	28	15	9	23	23	21	21	17	17	16
Number of Specimens		172	1064	420	68	20	1623	2656	681	255	196	1004	521
Trap efficiency		1.3	5.7	3	0.9	0.2	17.8	14.4	3.7	1.6	1.7	11.3	5.7

Habitats: 1 Canal edge; 2 Crop; 3 Field margin; 4 *Quercus* wood; no value means that the species is not expected in any of the four habitats considered. BIO1, BIO2, CON1 and CON2 are single Malaise trap.

Results

In three years, 8564 hoverflies belonging to 48 species were collected (table 2). The number of Syrphidae specimens per year in each Malaise trap was highly variable, ranging from 16 to 2659. The lowest number of specimens was recorded in BIO1 during the 2012 season; in this year this trap was set in a covered position inside the small woody area, to allow machine movement. A low efficiency in trapping was found also in BIO2 during 2011: in this case the Malaise trap was uprooted several times by adverse climatic condition and by the farmers. With the exception of these two cases, the efficiency of the Malaise traps was greater than 1.3 specimens per day, with a maximum of 16.6 specimens per day in CON1 during 2010.

Melanostoma mellinum and *Sphaerophoria scripta* were the most abundant species collected in the two vineyards: their abundances together comprise 14.3-91.1% of the total abundance in BIO and 70.6-96.2% in CON (table 2). Some of the rare species recorded only once or by a few specimens can be considered interesting records for the Po Valley fauna, including *Eumerus uncipes* (first record for eastern Po Valley), *Anasimyia transfuga* and *Paragus bradescui* (Sommaggio, 2010b).

Most species collected in vineyards were 'expected' (by StN) in accordance with their predicted occurrence in the surrounding habitats (table 2). Only seven species were not expected: *Cheilosia latifrons*, *Eumerus uncipes*, *Neoascia interrupta*, *Paragus bicolor*, *Paragus haemorrhous*, *Pipizella maculipennis* and *Xanthogramma citrofasciatum*. Two species (*E. uncipes* and *N. interrupta*) were only represented by a single specimen and their presence seems to be very sporadic. *E. uncipes* is not rare on hills in northern Italy, but not recorded in the Po Valley (Sommaggio, 2010b). *N. interrupta* is usually associated with standing water, rich in water vegetation; in the Po Valley it is not rare. *X. citrofasciatum* was collected only in 2010 in BIO1 (6 specimens). This species is expected in open habitat, in particular on well-drained grassland (Speight, 2012b). The other four species were collected several times in the three years of sampling: all are expected in open ground, usually in dry grassland, and hence vineyards can represent a possible habitat for these species.

The number of species showed no difference between the two management regimes: in 2012 the same number of species was recorded in the two vineyards; in 2011 the BIO vineyard was richer (four species more); while in 2010, one more species was collected in the CON vineyard (figure 2). The total number of species collected across the three years was very similar (40 in BIO, 39 in CON).Thus species richness seems uninformative with respect to the two different types of management.

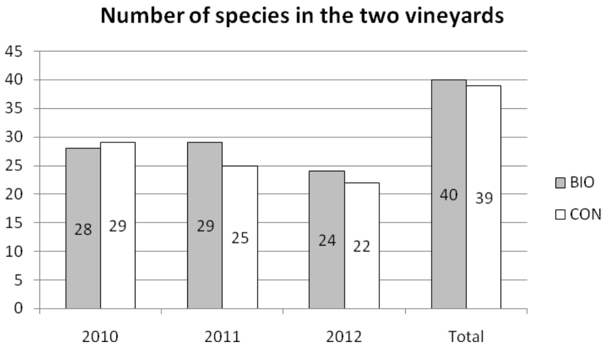

Figure 2. Total number of Syrphidae species in BIO and CON vineyards in each year and in the pooled years.

Syrphid populations seem to be strongly affected by the type of surrounding habitat. For each vineyard, the percentage of species belonging to surrounding habitats was calculated. Correspondence Analysis applied to the percentage of species belonging to the surrounding habitats allowed separation of the BIO and CON vineyards (figure 3). In particular, the CON vineyard was characterized by a higher percentage of species associated with canal edge and more in general with humid habitat; on the other hand, in the BIO vineyard there were more species associated with *Quercus* wood than in the CON vineyard (table 3).

Table 3. Syrphid richness (number of species) and percentage of species belonging to different trophic, voltinism and larval microhabitat categories.

Syrphidae categories	BIO Mean (SE)	CON Mean (SE)
Species richness (total number of species)	27.0 (1.5)	25.3 (2.6)
Species associated with canal edge (%)	33.5 (3,8)	43.6 (1.2)
Species associated with crop (%)	45.9 (2.1)	46.5 (2.6)
Species associated with field hedge (%)	58.7 (3.6)	60.0 (6.4)
Species associated with *Quercus* wood (%)	50.9 (4)	41.1 (2.2)
Saprophagous (%)	14.7 (3.4)	24.2 (5.2)
Phytophagous (%)	18.2 (3.3)	17.1 (0.6)
Aphidophagous (%)	67.1 (4.2)	59.8 (4.0)
Larval development short (lower than 2 months) (%)	51.0 (3.9)	49.5 (7.2)
Larval development medium (between 2 and 6 months) (%)	88.1 (4)	82.1 (4.5)
Larval development long (higher than 6 months) (%)	77.3 (4.6)	73.3 (3.3)
Univoltine (%)	23.0 (4.2)	21.7 (4.7)
Bivoltine (%)	82.9 (2.6)	72.7 (2.4)
Polyvoltine (%)	61.1 (6.7)	54.5 (3.2)
Tree foliage (%)	17.2 (1.9)	16.2 (3.0)
On herb layer (%)	49.6 (2.3)	42.8 (6.2)
In herb layer (%)	19.3 (4.4)	17.1 (0.6)
Soil (%)	22.2 (1.4)	22.6 (5.8)
Root layer (%)	42.0 (0.4)	34.5 (3.7)
Submerged sediment/debris (%)	9.8 (2.3)	21.6 (5.1)
Water-saturated ground (%)	12.4 (3.2)	16.8 (4.7)

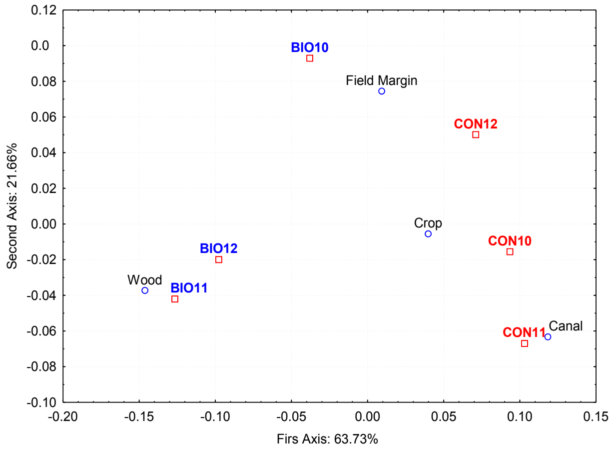

Figure 3. Correspondence analysis applied to the species belonging to the surrounding habitats of the BIO and CON vineyards.

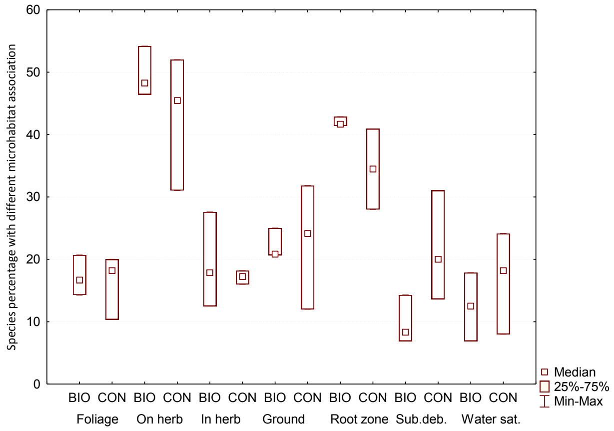

Figure 5. Median value and 25-75 % range calculated for microhabitat categories. Each year has been considered a replicate.

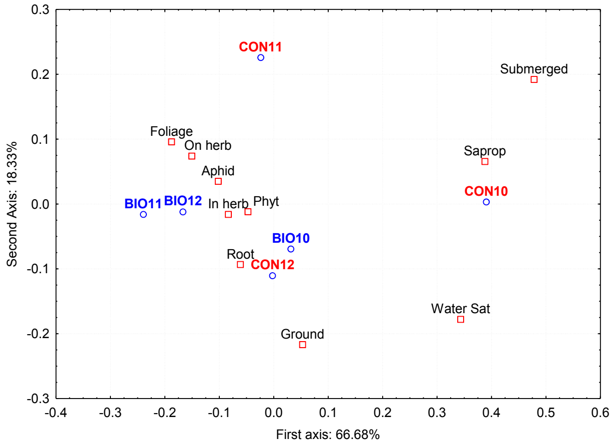

Figure 7. Correspondence analysis applied to Syrphidae matrix calculated for each year in the two vineyard, in accordance with trophic habitus and microhabitat types used by larvae. Numbers after vineyard label are the sampling year.

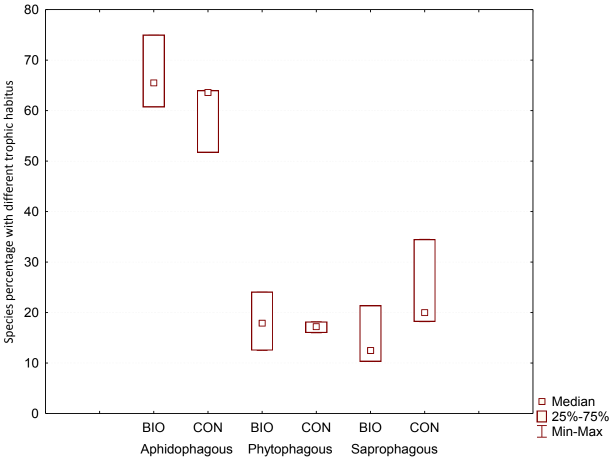

Figure 4. Percentage of species (median value and 25-75 % range) with different trophic habitus. Each year has been considered as a replicate.

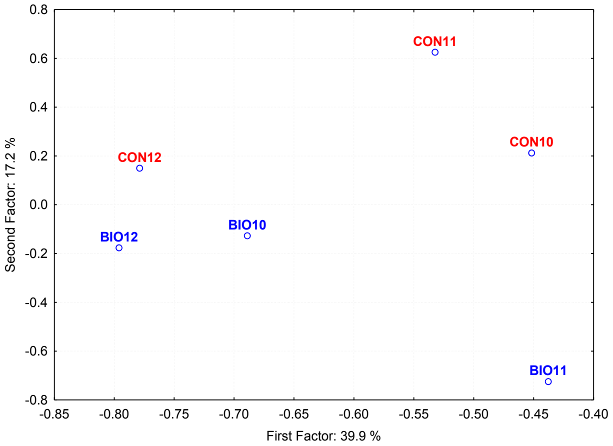

Figure 6. Principal component analysis applied to the presence/absence matrix of Syrphidae. Numbers after vineyards labels are sampling year.

The mean number of aphidophagous species were higher in BIO in comparison with CON, while saprophagous were higher in the CON vineyard (figure 4).

Concerning the length of larval development and the number of generations similar values were found in the two vineyards in the three years, with the exception of 'bivoltine' and 'medium larval development (2-6 months)' species, with higher values in BIO than in CON (table 3).

Regarding microhabitat categories, three different trends were detected. Species with larvae associated to herb and root layers seem to have higher percentage presence in BIO than in CON. The percentage of species associate with ground debris, tree foliage and in herb layer had similar values in BIO and CON. Finally the percentage of species associated with submerged sediment/debris and water satured ground was higher in CON than in BIO (table 3, figure 5).

Multivariate analysis was applied separately to the matrices of (a) presence/absence; and (b) to the trophic and microhabitat categories. Principal component analysis applied to the presence/absence matrix seemed largely to be affected by sampling year. For example the BIO fauna in 2011 was strongly different both from CON fauna and BIO fauna in the other two years (figure 6). The CON fauna in 2012 was closer to the BIO fauna in 2010 and 2012 than to the other two CON data. Using Correspondence Analysis applied to the functional traits (trophic habitus and microhabitat association) (figure 7), the BIO cases grouped together and they seem to be characterized by the higher percentage of aphidophagous and phytophagous species and by larvae developing in herb and root layers. The CON fauna is less homogeneous: in 2012 the species list in CON was similar to the BIO fauna, while in 2010 the fauna of the CON vineyard was characterized by a high percentage of saprophagous species and those associated with submerged debris and water-saturated ground. Using ecological traits, the percentage of the variation in the data explained is higher than using the presence/absence matrix: the first two axes explained 97.8% of total variance in the case of ecological traits, but only 54.65% in the case of the presence/absence matrix.

Discussion and conclusions

A large range of indices and multivariate methods have been proposed in biodiversity evaluation; most of these mainly focused on taxonomic aspects, such as the total number of species or the combination of the number of species with relative abundance (Vandewalle *et al*., 2010). However, a lot of information about functional components of communities are lost when biodiversity is reduced just to its taxonomic composition (Moretti *et al*., 2009; de Bello *et al*., 2010; Vandewalle *et al*., 2010), often generating uninformative list of species. On the contrary, because of its importance in environmental policy-making, a functional evaluation of biodiversity should generate a parameter that is easy to use and to interpret (Norton, 1998; Büchs, 2003).

The use of ecological features of species to evaluate ecosystems has been largely developed in plants (e.g. Cornelissen *et al*., 2003) and freshwater invertebrates (e.g. Bonada *et al*., 2006; Diaz *et al*., 2008). Concerning terrestrial animals, even if some studies point out the importance of the functional approach (e.g. Yeats and Bongers, 1999; Steffan-Dewenter and Tscharntke, 2004; Driscoll and Weird, 2005; Vanbergen *et al*., 2005; Lambeets *et al*., 2008; Moretti *et al*., 2009; Billeter *et al*., 2008), the selection of the taxa and the criteria to evaluate functional biodiversity are still neglected issues. In this scenario, there is no agreement about which taxa and methods should be used in order to generate informative and standardized responses (Vanderwalle *et al*., 2010).

In our study total biodiversity (i.e. total number of species) seems to be uninformative, suggesting no difference between the two different vineyards. The use of functional traits seems to be much more useful in understanding the difference between the two vineyards. Despite the small distance between the two sites and the flight ability of Syrphidae, the hoverfly populations in the two vineyards were different in the three years. The main feature affecting the composition of the hoverfly community was the presence of particular adjacent habitats: a small *Quercus* wood for the organic vineyard, and a ditch canal for the conventional vineyard. The correspondence analysis applied to the percentage of species associated with adjacent habitat showed a clear differentiation of the two vineyards, despite the annual variability (figure 3). The conventional vineyard displayed a higher diversity of species with saprophagous larvae, which are associated with submerged sediment/debris and water-saturated ground. These features can be explained by the peculiar presence of ditch and aquatic vegetation, which are associated habitats of the conventional vineyard, but are not expected in vineyards. On the other hand, the organic vineyard showed a stronger association with aphidophagous species and a higher percentage of species associated with the herb and root layers. These species can be associated with the adjacent wood and/or with the vineyard characterized by the improved vegetation management typical of organic systems (e.g. the grass-cover technique).

Agriculture inputs (e.g. use of chemicals, land use) are considered one of the main factors affecting biodiversity loss (Paoletti and Pimentel, 1992; Pimentel *et al*., 1995; Krebs *et al*., 1999; Foley *et al*., 2005; Butler *et al*., 2007). Sustainable organic farming has been assumed to be a key way of improving biodiversity (Stockdale *et al*., 2001; Bengston *et al*., 2005; Fuller *et al*., 2005; Hole *et al*., 2005; Norton *et al*., 2009; Gomiero *et al*., 2011), and several studies confirm a general higher biodiversity in biological vs. conventional agriculture (e.g. Pfiffner and Niggli, 1996; Pfiffner and Luka, 2003; Bengston *et al*., 2005; Gabriel *et al*., 2006; Clough *et al*., 2007; Hawesa *et al*., 2010). In spite of this general trend, not all taxa seem to be affected by organic farming in the same manner, generating variable responses not always in the same direction. For example Bengston *et al*. (2005) and Fuller *et al*. (2005) recorded higher benefits for plants than animals. Otherwise some taxa showed different responses to agriculture farming: for example Pfinner and Niggli (1996) and Pfinner and Lukas (2003) found higher abundance and biodiversity of Carabidae in organic vs. conventional farming, while no effect was recorded by Clark *et al*. (2006); in contrast, Weibull *et al*. (2003) found higher richness in conventional vs. organic farming. Hole *et al*. (2005), assessing the impacts of organic farming on biodiversity through a review of comparative studies, analysed a number of technical and methodological aspects related to the evaluation of the benefits in comparison to conventional management.

Viticulture is an intensively managed agroecosystem, usually characterized by a high chemical input. Recently the importance of functional biodiversity in improving vineyard production has been stressed (Altieri *et al*., 2005; 2010; Gurr *et al*., 2007). Some studies have investigated the effect of viticulture management and landscape on biodiversity (Isaia *et al*., 2006; Schmitt *et al*., 2008; Brittain *et al*., 2010; Bruggiser *et al*., 2010; Kehinde and Samways, 2012) but their results were in disagreement. For example Bruggiser *et al.* (2010) observed no difference between organic and conventional vineyards in plants, herbivores and predators. Kehinde and Samways (2012) in South Africa found no effect of organic management on total bee diversity, but a positive effect on scarabaeid pollinators. Schmitt *et al.* (2008) in Germany found that a landscape with a mosaic of vineyards and fallows of abandoned vineyards can support a rich butterfly population, with several species included in regional and national Red Data Books. In our three-year study, 48 Syrphidae species were found in vineyards and their surrounding habitats. Considering that the total number of species recorded in the Eastern Po Valley is 121 (Sommaggio, 2010b), the fauna collected in the present research can be considered as consistent. In addition, seven species were recorded that were not expected in accordance with the habitats present in the surrounding of vineyards. Several of these species are associated with dry grassland and it is possible that they can be considered as species typical of vineyards.

The use of ecological traits allowed us to separate syrphid communities in the two vineyards studied over three years. The analysis of functional traits of this taxon leads to an ecological interpretation confirmed by habitat analysis of the farms and farm inputs. Functional analysis based on Syrphidae proved to be a synthetic and informative tool to synthesize and interpret a number of complex bits of information in a standard way. Our study only used two farms over three years; considering the economic importance of vineyards, it would be interesting to validate this method on a landscape scale, using a sample of vineyards with different ecological features and management. The capacity of StN to interpret the peculiarities of each farm from its context (i.e. the associated habitats, soil management, presence of border effects such as ditches) can lead to consistent interpretations supported by the ecological characteristics of the sites.

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References

ALTIERI M. A., NICHOLLS C. I., PONTI L., YORK A., 2005.- Designing biodiverse, pest-resilient vineyards through habitat management.- *Practical Winery and Vineyards*, 27: 16-30.

ALTIERI M. A., NICHOLLS C. I., WILSON H., MILES A., 2010.- *Habitat management in vineyards. A growers manual for enhancing natural enemies*.- Laboratory of Agroecology, http://agroecology.berkeley.edu, College of Natural Resources University of California, USA.

BENGTSSON J., AHNSTROM J., WEIBULL A.-C., 2005.- The effects of organic agriculture on biodiversity and abundance: a meta-analysis.- *Journal Applied Ecology*, 42: 261-269.

BILLETER R., LIIRA J., BAILEY D., BUGTER R., ARENS P., AUGENSTEIN I., AVIRON S., BAUDRY J., BUKACEK R., BUREL F., CERNY M., DE BLUST G., DE COCK R., DIEKOTTER T., DIETZ H., DIRKSEN J., DORMANN C., DURKA W., FRENZEL M., HAMERSKY R., HENDRICKX F., HERZOG F., KLOTZ S., KOOLSTRA B., LAUSCHA., LE COEUR D., MAELFAIT J. P., OPDAM P., ROUBALOVA M., SCHERMANN A., SCHERMANN N., SCHMIDT T., SCHWEIGER O., SMULDERS M. J. M., SPEELMANS M., SIMOVA P., VERBOOM J., VAN WINGERDEN W. K. R. E., ZOBEL M., EDWARDS P. J., 2008.- Indicators for biodiversity in agricultural landscapes: a pan-European study.- *Journal of Applied Ecology*, 45: 141-150.

BIRTELE D., HANDERSEN S., 2012.- Analysis of vertical stratification of Syrphidae (Diptera) in an oak-hornbeam forest in northern Italy.- *Ecological Research*, 27: 755-783.

BONADA N., PRAT N., RESH V. H., STATZNER B., 2006.- Developments in aquatic insect biomonitoring: a comparative analysis of recent approaches.- *Annual Review of Entomology*, 51: 495-523.

BRITTAIN C., BONMARCO R., VIGHI M., SETTELE J., POTTS S. G., 2010.- Organic farming in isolated landscapes does not benefit flower-visiting insects.- *Biological Conservation*, 148: 1860-1867.

BRUGGISER O. T., SCHMIDT-ENTLING M. H., BACHER S., 2010.- Effects of vineyard management on biodiversity at three trophic level.- *Biological Conservation*, 143: 1521-1528.

BÜCHS W., 2003.- Biodiversity and agri-environmental indicators-general scopes and skills with special reference to the habitat level.- *Agriculture, Ecosystems and Environment*, 98: 35-78.

BURGIO G., SOMMAGGIO D., 2007.- Diptera Syrphidae as landscape bioindicators in Italian agoecosystems.- *Agriculture Ecosystems and Environment*, 120: 416-422.

BURGIO G., SOMMAGGIO D., MARCHESINI E., REGGIANI B., SCHIATTI P., 2012.- L'uso di piante nettarifere contro i fitofagi del vigneto.- *Agricoltura*, 40: 64-66.

BUTLER S. J., VICKERY J. A., NORRIS K., 2007.- Farmland biodiversity and the footprint of agriculture.- *Science*, 315: 381-384.

CARO T. M., O'DOHERTY G., 1998.- On the use of surrogate species in conservation biology.- *Conservation Biology*, 13: 805-814.

CASTAGNOLI M., LIGUORI M., NANNELLI R., 1999.- Influence of soil management on mite populations in a vineyard ecosystem, pp. 617-623. In: *Ecology and evaluation of the acari* (BRUIN J., VAN DER GEEST L. P. S., SABELIS M. W. Eds), Series Entomologica 55.- Kluwer Academic Publishers, Dordrecht, The Netherlands.

CLARK S., SZLAVECZ K., CAVIGELLI M. A., PURRINGTO F., 2006.- Ground beetle (Coleoptera: Carabidae) assemblages in organic, no-till, and chisel-till cropping systems in Maryland.- *Environmental Entomology*, 35: 1304-1312.

CLOUGH Y., HOLZSCHUH A., GABRIEL D., PURTAUF T., KLEIJN D., KRUESS A., STEFFAN-DEWENTER I., TSCHARNTKE T., 2007.- Alpha and beta diversity of arthropods and plants in organically and conventionally managed wheat fields.- *Journal Applied Ecology*, 44: 804-812.

CORNELISSEN J. H. C., LAVOREL S., GARNIER E., DIAZ S., BUCHMANN N., GURVICH D. E., REICH P. B., TERSTEEGE H., MORGAN H. D., VAN DER HEIJDEN M. G. A., PAUSAS J. G., POORTER H., 2003.- A handbook of protocols for standardized and easy measurement of plant functional traits worldwide.- *Australian Journal Botany*, 51: 335-380.

de Bello F., Lavorel S., Diaz S., Harrington R., Cornelissen J. H. C., Bardgett R. D., Berg M. P., Cipriotti P., Feld C. K., Hering D., Martin Da Silva P., Potts S. G., Sandin L., Sousa J. P., Storkey J., Wardle D. A., Harrison P. A., 2010.- Towards an assessment of multiple ecosystem processes and services via functional traits.- *Biodiversity Conservation*, 19: 2873-2893.

De Snoo G. R., Burgio G., Eggenschwiler L., Gerowitt B., 2006.- Success stories in landscape management for functional biodiversity: an assessment from 5 west-European countries.- *IOBC/WPRS Bulletin*, 29 (6): 29-32.

Diaz A. M., Alonso M. L. S., Gutierrez M. R. V. A., 2008.- Biological traits of stream macroinvertebrates from a semiarid catchement: patterns along complex environmental gradient.- *Freshwater Biology*, 53: 1-21.

Driscoll D. A., Weir T., 2005.- Beetle responses to habitat fragmentation depend on ecological traits, habitat condition and remnant size.- *Conservation Biology*, 19: 182-194.

Foley J. A., De Fries R., Asner G. P., Barford C., Bonan G., Carpenter S. R., Chapin F. S., Coe M. T., Daily G. C., Gibbs H. K., Helkowski J. H., Holloway T., Howard E. A., Kucharik C. J., Monfreda C., Patz J. A., Prentice I. C., Ramankutty N., Snyder P. K., 2005.- Global consequences of land use.- *Science*, 309: 570-574.

Fuller R. J., Norton L. R., Feber R. E., Johnson P. J., Chamberlain D. E., Joys A. C., Matthews F., Stuart R. C., Townsend M. C., Manley W. J., Wolfe M. S., Macdonald D. W., Firbank L. G., 2005.- Benefits of organic farming to biodiversity vary among taxa.- *Biological Letters*, 1: 431-434.

Gabriel D., Roschewitz I., Tscharntke T., Thies C., 2006.- Beta diversity at different spatial scales: plant communities in organic and conventional agriculture.- *Ecological Applications*, 16: 2011-2021.

Gilbert F. S., Owen J., 1990.- Size, shape, competition, and community structure in hoverflies (Diptera: Syrphidae).- *Journal of Animal Ecology*, 59: 21-39.

Gittings T., O'halloran J., Kelly T., Giller P. S., 2006.- The contribution of open spaces to the maintenance of hoverfly (Diptera, Syrphidae) biodiversity in Irish plantation forests.- *Forest Ecology and Management*, 237: 290-300.

Gomiero T., Pimentel D., Paoletti M. G., 2011.- Environmental impact of different agricultural management practices: conventional vs. organic agriculture.- *Critical Reviews in Plant Sciences*, 30: 95-124.

Gurr G. M., Scarratt S. L., Jacometti M., Wratten S. D., 2007.- Management of pests and diseases in New Zealand and Australian vineyards, pp. 392-398. In: *Biological control a global perspective* (Vincent C., Goettel M. S., Lazarovits G., Eds).- CAB International Oxfordshire, UK.

Hawesa C., Squirea G. R., Hallett P. D., Watsomb C. A., Young M., 2010.- Arable plant communities as indicators of farming practice.- *Agriculture, Ecosystems and Environment*, 138: 17-26.

Hole D. G., Perkins A. J., Wilson J. D., Alexander I. H., Grice P. V., Evans A. D., 2005.- Does organic farming benefit biodiversity?- *Biological Conservation*, 122: 113-130.

Isaia M., Bona F., Badino G., 2006.- Influence of landscape diversity and agricultural practices on spider assemblage in Italian vineyards of Langa Astigiana (Northwest Italy).- *Environmental Entomology*, 35: 297-307.

Kehinde T., Samways M. J., 2012.- Endemic pollinator response to organic vs. conventional farming and landscape context in the Cape Floristic Region biodiversity hotspot.- *Agriculture, Ecosystems and Environment*, 146: 162-167.

Krebs J. R., Wilson J. D., Bradbury R. B., Siriwardena G. M., 1999.- The second silent spring?- *Nature*, 400: 611-612.

Lambeets K., Vanegehuchte M. L., Maelfait J. P., Bonte D., 2008.- Understanding the impact of flooding on trait-displacements and shifts in assemblage structure of predatory arthropods on river banks.- *Journal Animal Ecology*, 77: 1162-1174.

Mace G. M., Baillie J. E. M., 2007.- The 2010 biodiversity indicators: challenges for science and policy.- *Conservation Biology*, 21: 1406-1413.

Marcos-García M. A., 2006.- *Caliprobola speciosa* (Rossi, 1790), *Mallota dusmeti* Andreu, 1926 and *Meligramma cingulata* (Egger, 1860), pp. 173-176. In: *Libro rojo de los invertebrados de Espana* (Verdù J. R., Galante E., Eds).- Dirección General para la Biodiversidad, Ministerio de Medio Ambiente, Madrid, Spain.

Moretti M., De Bello F., Roberts S. P. M., Potts S. G., 2009.- Taxonomical vs. functional responses of bee communities to fire in two contrasting climatic regions.- *Journal Animal Ecology*, 78: 98-108.

Norton B. G., 1998.- Improving ecological communication: the role of ecologists in environmental policy formation.- *Ecological Application*, 8: 350-364.

Norton L., Johnson P., Joys A., Stuart R., Chamberlain D., Feber R., Firbank L., Manley W., Wolfe M., Hart B., Mathews F., Macdonald D., Fuller R. J., 2009.- Consequences of organic and non-organic farming practices for field, farm and landscape complexity.- *Agriculture, Ecosystems and Environment*, 129: 221-227.

Noss R.F., 1990.- Indicators for monitoring biodiversity – a hierarchical approach.- *Conservation Biology*, 4: 355-364.

Paoletti M. G., Pimentel D., 1992.- *Biotic diversity in agroecosystems*.- Elsevier, Amsterdam, The Netherlands.

Pimentel D., Harvey C., Resosudarmo P., Sinclair K., Kurz D., McNair M., Crist S., Sphpritz L., Fitton L., Saffouri R, Blair R., 1995.- Environmental and economic costs of soil erosion and conservation benefits.- *Science*, 267: 1117-1123.

Pfiffner L., Niggli U., 1996.- Effects of bio-dynamic, organic and conventional farming on ground beetles (Col. Carabidae) and other Epigaeic arthropods in winter wheat.- *Biological Agriculture and Horticulture*, 12: 353-364.

Pfiffner L., Luka H., 2003.- Effects of low-input farming systems on carabids and epigeal spiders - a paired farm approach.- *Basic and Applied Ecology*, 4: 117-127.

Ragusa S., Tsolakis H., 2006.- *La difesa della vite dagli artropodi dannosi*.- Università degli Studi di Palermo, Italy.

Ricarte A., Marcos-García M. A., Moreno C. E., 2011.- Assessing the effects of vegetation type on hoverfly (Diptera: Syrphidae) diversity in a Mediterranean landscape: implications for conservation.- *Journal Insect Conservation*, 15: 865-877.

Rotheray G. E., Hancock G., Hewitt S., Horsfield D., MacGowan I., Robertson D., Watt K., 2001.- The biodiversity and conservation of saproxylic Diptera in Scotland.- *Journal Insect Conservation*, 5: 77-85.

Schmitt T., Augenstein B., Finger A., 2008.- The influence of changes in viticulture management on the butterfly (Lepidoptera) diversity in a wine growing region of southwestern Germany.- *European Journal Entomology*, 105: 249-255.

Sommaggio D., 1999.- Syrphidae: can they be used as environmental bioindicators?- *Agriculture, Ecosystems and Environment*, 74: 343-356.

Sommaggio, 2010a.- Il ruolo dei Sirfidi nell'agricoltura sostenibile: analisi del potenziale delle specie afidifaghe nella lotta conservativa. 126 pp. *PhD Thesis in Agricultural Entomology, Alma Mater Studiorum* University of Bologna, Italy.

Sommaggio D., 2010b.- Hoverflies in the "Guido Grandi Collection" of DiSTA, University of Bologna.- *Bulletin of Insectology*, 63: 99-114.

SPEIGHT M. C. D., 1986.- Criteria for the selection of insects to be used as bioindicators in nature conservation research, pp. 485-488. In: *Proceedings of 3^{rd} European congress of entomology* (VELTHUIS H. H. W., Ed.).- Amsterdam, August 1986. Amsterdam, The Netherlands.

SPEIGHT M. C. D., 2008.- Database of Irish Syrphidae (Diptera).- *Irish Wildlife Manuals*, 36. National Parks and Wildlife Service, Department of Environment, Heritage and Local Government, Dublin, Ireland.

SPEIGHT M. C. D., 2012a.- The Syrph the Net database of European Syrphidae (Diptera).- *Quaderni della Stazione di Ecologia del Civico Museo di Storia Naturale di Ferrara*, 20: 23-44.

SPEIGHT M. C. D., 2012b.- *Species accounts of European Syrphidae (Diptera),* 2012. Syrph the Net, the database of European Syrphidae, vol. 69, 296 pp., Syrph the Net publications, Dublin, Ireland.

SPEIGHT M. C. D., CASTELLA E., 2001.- An approach to interpretation of lists of insects using digitised biological information about the species.- *Journal of insect Conservation*, 5: 131-139.

STEFFAN–DEWENTER I., TSCHARNTKE T., 2004.- Butterfly community structure in fragmented habitats.- *Ecology Letters*, 3: 449-456.

STOCKDALE E. A., LAMPKIN N. H., HOVI M., KEATINGE R., LENNARTSSON E. K. M., MACDONALD D. W., PADEL S., TATTERSALL F. H., WOLFE M. S., WATSON C. A., 2001.- Agronomic and environmental implications for organic farming systems.- *Advances in Agronomy*, 70: 261-327.

VANBERGEN A. J., WOODCOCK B. A., WATT A. D., NIEMELÄ J., 2005.- Effect of land-use heterogeneity on carabid communities at the landscape scale.- *Ecography*, 28: 3-16.

VANDEWALLE M., DE BELLO F., BERG M., BOLGER T., DOLÉDEC S., DUBS F., FELD C. F., HARRINGTON R., HARRISON P. A., LAVOREL S., DA SILVA P. M., MORETTI M., NIEMELÄ J., SANTOS P., SATTLER T., SOUSA J. P., SYKES M., VANBERGEN A. J., WOODCOCK B. A., 2010.- Functional traits as indicators of biodiversity response to land use changes across ecosystems and organisms.- *Biodiversity Conservation*, 19: 2921-2947.

VELLI A., SOMMAGGIO D., MACCAGNANI B., BURGIO G., 2010.- Evaluation of environment quality of a protected area in Northern Italy using Syrph the Net method.- *Bulletin of Insectology*, 63 (2): 217-224.

WEIBULL A. C., OSTMAN O., GRANQVIST A., 2003.- Species richness in agroecosystems: the effect of landscape, habitat and farm management.- *Biodiversity Conservation*, 12: 1335-1355.

YEATES G. W., BONGERS T., 1999.- Nematode diversity in agroecosystems.- *Agriculture Ecosystems and Environment*, 74: 113-135.

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