Bulletin of Insectology ***70*** *(1): 101-110, 2017*
ISSN 1721-8861

The hoverfly fauna of the Berici Hills: an area of rich biodiversity in north-eastern Italy

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Abstract

The hoverfly community of the Berici Hills (Northern Italy) is compared with surrounding areas in order to evaluate the biodiversity conservation importance of this area. During the period 2009-2014 thirteen sites were sampled in the Berici Hills by means of Malaise traps, recording 143 species for this area. The syrphid list of species for the Berici Hills is compared with that in the surrounding areas by means of multivariate analysis; the biodiversity of the Berici Hills is set against that in the Po Plain using rarefaction and extrapolation curves. The species recorded in the Berici Hills included 52 not recorded from the adjacent areas, and in particular for the Po Plain. Several species are associated with Mediterranean habitats, in particular xeric grasslands, well represented in the Berici Hills. Particularly interesting is the presence of several species expected for the Po Plain but probably extinct from this area. Despite its small area, the biodiversity of the Berici Hills is significantly higher than that of Po Plain. The sites of the Berici Hills are clearly separate from those of the Po Plain, underlining the peculiarity of the fauna of this area and its importance for nature conservation.

Key words: Syrphidae, biodiversity, Berici Hills, conservation.

Introduction

Hoverflies (Diptera Syrphidae) are well-studied insects mainly thanks to their interesting biology (e.g. Batesian mimicry, hovering ability) and agricultural importance (several ecological services are provided such as pest control and pollination) (Rotheray and Gilbert, 2011). In the last thirty years several authors have considered the Syrphidae to be a useful bioindicator taxon, largely due to the highly differentiated ecology of their larvae (Speight, 1986; Sommaggio, 1999; Speight and Castella, 2001).

Sommaggio and Burgio (2004) and Sommaggio (2005a) underlined the poor knowledge of Syrphidae fauna in Italy, especially in South Italy, Sardinia and Sicily. In the last ten years a large effort has been developed to improve knowledge of Italian fauna (e.g. Birtele *et al*., 2002; 2003; Sommaggio, 2004; 2005b; 2007; Sommaggio and Corazza, 2006; Birtele, 2011; Corazza, 2012; Burgio *et al.,* 2015), but we still know little about hoverfly distribution in several areas of Italy. North-eastern Italy has been the object of recent monitoring schemes and a check list of Eastern Po Plain species has been recently published (Sommaggio, 2010a).

In the flat landscape of the eastern Po Plain, the Berici and Euganei Hills rise as isolated reliefs. The Po Plain is Italy's largest alluvial basin: it occupies an area of 46000 km^2, 71% of all the plain territories in Italy (Pellegrini, 1979). This area is particularly important for agriculture and it has been exploited since Bronze Age (Schneider, 1985; Marchetti, 2002). Since the Middle Ages, the population of the Po Plain has increased, with a progressive removal of natural vegetation. This trend continues to the present day: Falcucci *et al.* (2007) underlined the increased in agricultural and artificial lands in the Po Plain in the period 1960-2000. More than 70% of total Po Plain landscape is used for agriculture or other human infrastructure, while less than 10% is covered with forest and less than 5% with unimproved grassland (Falcucci *et al*., 2007). Such situation has further deteriorated by recent overbuilding: in the eastern Po Plain more than 10% of the soil was used in 2015 to build new infrastructure, reducing soil availability (Munafò *et al*., 2015). The Po Plain is located in the northern Mediterranean Basin, one of the 25 most important hotspots of biodiversity (Myers *et al*., 2000; Cuttelod *et al*., 2008). Especially rich in plants with more than 13000 endemic species, the area is particularly threatened due to high human population density (Cuttelod *et al*., 2008).

The conservation importance of the Berici Hills has been largely underlined by several authors, mainly studying the flora (Béguinot, 1904; Tasinazzo and Fiorentin, 2000; Tasinazzo, 2007; 2014). Few data are available about the invertebrate fauna (Magistretti and Ruffo, 1959; 1960; Osella, 1968; 1969; Cogo and Fontana, 2002).

The objects of the present paper are: (a) to present a list of Syrphidae species from the Berici Hills, obtained from detailed surveys in the period 2009-2014; and (b) to evaluate the Syrphidae fauna of the Berici Hills in comparison to adjacent areas.

Materials and methods

Study area

The Berici Hills cover an area of almost 165 km^2 in north-eastern Italy (figure 1). The higher altitudes are located on the eastern part, but are little higher than 400 m. The Berici Hills originated between the Upper Cretaceous and Early Miocene, and are dominated by carbonate sedimentary rocks. Karst phenomena (e.g. dolina and cave) are common, while surface water is largely reduced, especially on the upper parts. An important exception is Fimon Lake, located at the north-eastern margin and occupying little more than 0.5 km^2 with an average depth of 2 m.

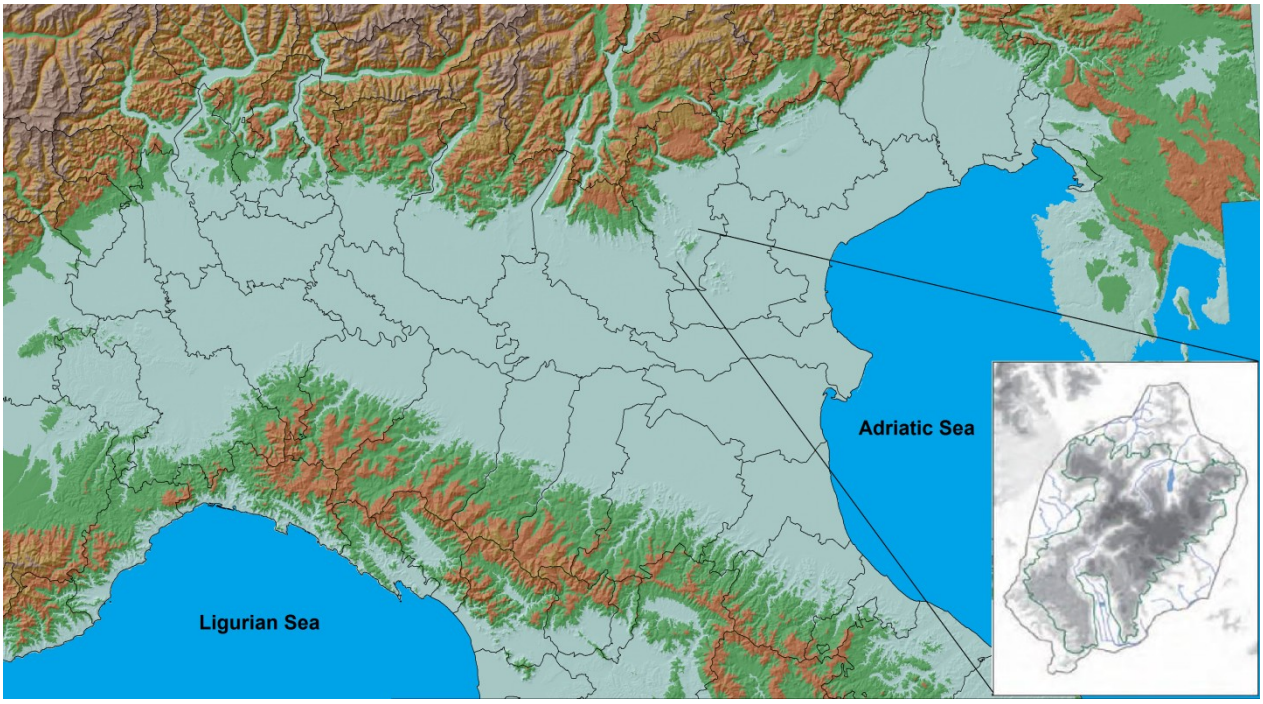

Figure 1. North Italy and Berici Hills.

A large number of different habitats is present (Tasinazzo, 2014). The woody vegetation is dominated by thermophilous oak woods (CORINE biotope: 41.731) on the south-eastern side; on the higher parts and on the north-facing slope *Quercus* and *Carpinus betulus* woods (CORINE biotope: 41.2A) should be the climax vegetation, but they have been largely replaced by *Castanea sativa* (CORINE biotope: 41.9). The landscape is characterized by grasslands, largely due to human activity. In the south side of the district most of the grasslands are dry, belonging to the *Festuco-Brometalia* association (CORINE biotope: 34.75). The natural importance of this habitat has been recognized by the EU, and it has been considered as a priority type (Natura 2000 code: 6210*) if it contains important orchids (European Commission, 2013). In areas with less dry conditions the grassland are more mesic, usually belonging to the *Molinio-Arrhenatheretea* association. On the valley floor, a very rich hydrophilic vegetation was present in the past (e.g. Chiesura and Lorenzoni, 1964; Bracco *et al*., 2004) but due to human activity such diversity has been strongly reduced over the last decades, and a few species have become dominant, such as *Carex acutiformis* and *Phragmites australis*. Agriculture is widespread, but usually farms are small. The area is considered an important wine-growing territory and in fact vineyards can be considered as the dominant cultivation.

Sampling of Syrphidae

Malaise traps were used as the main sampling device to study the Syrphidae of the Berici Hills. During the period 2009-1014, 13 sites in the Berici Hills were sampled. In each site two Malaise traps were settled from March / April to October. The sites were monitored in different years and some were sampled for more than one year (table 1). Malaise traps were supplied with a 70% solution of ethyl alcohol. The sample was collected approximately every two weeks from each trap. Hoverflies were separated and identified, and subsequently dried and preserved. All specimens are kept in the author's collection. All hoverflies were identified to species level, except female *Paragus* subg. *Pandasyopthalmus* and *Pipizella* (except *P. maculipennis*) where examination of the male genitalia is necessary for identification. Species nomenclature follows Speight (2015) and Burgio *et al*. (2015).

Additional occasional sampling by entomological net is mentioned only where additional species not collected by Malaise trap are concerned.

Data analysis

The number of species was compared with similar data collected in the eastern Po Plain in recent monitoring schemes, also using Malaise traps. Rarefaction and extrapolation curves were used to underline differences in biodiversity between the two areas, as suggested in Chao and Jost (2012). 95% confidence intervals were developed for both Berici and Po Plain curves, performed by iNEXT Online Software (Hsieh *et al.*, 2013). To produce both Berici and Po Plain curves, the data from each Malaise trap were used. Po Plain data are obtained from Sommaggio (2010b), Sommaggio and Corazza (2006), Velli *et al.* (2010), Corazza (2012), Sommaggio and Burgio (2014) and unpublished data of the author.

Table 1. Main features of the sampled sites by Malaise trap in the Berici Hills. Surrounding habitat has been calculated on a 500 m buffer area. The identification code (Id. Code) is the abbreviation used for each site in the paper.

Locality	Year	Id. Code	Latitude Longitude	Habitat	Surrounding habitat
Castegnero	2011 2013	Cas11 Cas13	45°26'41"N 11°34'24"E	Dry grassland	Thermophilous oak wood, with clearings and rural area at the margin of buffer
Nanto	2011 2013	Nan11 Nan13	45°26'08"N 11°33'45"E	Dry grassland	Thermophilous oak wood, with clearings and vineyards at the margin of buffer
M. Riveselle	2011	Toa11	45°23'06"N 11°30'40"E	Dry glassland	Thermophilous oak wood, with clearings and rural area at the margin of buffer
M. Piume	2011 2013	Org11 Org13	45°21'20"N 11°27'17"E	Dry grassland	Dry grasslands, thermophilous oak wood, vineyards
M. Piume	2011	Piu11	45°21'14"N 11°27'17"E	Dry grassland	Dry grasslands, thermophilous oak wood, vineyards
Alonte	2012	Alo12	45°22'45"N 11°26'14"E	Clearing in thermophilous oak wood	Thermophilous oak wood, with clearings and rural area at the margin of buffer
Fimon Lake	2012 2013	Fim12 Fim13	45°28'47"N 11°32'31"E	Recently introduced pond in alluvional wood	Agroecosystem, mainly cereal fields; wetland and wood at margin of buffer
Cà Bertoldo	2012	Gra12	45°26'11"N 11°28'38"E	Dry grassland	Grassland and wood
San Rocco	2012	SRo12	45°28'45"N 11°34'59"E	Ravine ash-sycamore forests	Woods with large clearings
San Donato	2013	SDo13	45°24'31"N 11°31'48"E	Dry grassland	Dry grasslands, thermophilous woods, rural areas at margin of buffer
M. Motton	2013	Mot13	45°23'05"N 11°27'21"E	Dry grassland on recently disused vineyard	Thermophilous oak wood, meadows, vineyards
M. Prete	2010 2011 2012 2013 2014	Pre10 Pre11 Pre12 Pre13 Pre14	45°25'35"N 11°26'40"E	Dry grassland and thermophilous oak wood	Vineyards, dry grassland, thermophilous oak woods, mining quarry

Table 2. Species observed in Berici Hills and not recorded in the surrounding areas.

Surrounding areas	Geographical distribution	Habitat	Species
Lessini and Piccole Dolomiti mountains		Forest or Forest / Open ground	*Brachypalpoides lentus*, *Cheilosia mutabilis*, *C. nigripes*, *C. proxima*, *C. soror*, *Chrysotoxum bicinctum*, *C. octomaculatum*, *Eumerus uncipes*, *Melangyna lasiophthalma*, *Meligramma triangulifera*, *Meliscaeva cinctella*, *Microdon analis*, *Milesia crabroniformis*, *Paragus majoranae*, *Platycheirus ambiguus*, *Scaeva dignota*
		Open ground	*Merodon albifrons*, *Pipizella divicoi*
No other areas	Mainly Mediterranean / South Europe	Forest or Forest / Open ground	*Callicera macquarti*, *Doros destillatorius*, *Eumerus basalis*, *Ferdinandea aurea*, *Merodon funestus*, *M. moenium*, *M. natans*, *M. nigritarsis*, *M. trebevicensis*, *Milesia semiluctifera*, *Myolpeta obscura*, *Paragus bradescui*, *P. romanicus*, *Pipizella annulata*, *Sphiximorpha subsessilis*
		Open ground	*Eumerus elaverensis*, *E. ruficornis*, *E. sinuatus*, *E. flaviceps*, *Eupeodes nuba*, *Merodon armipes*, *M. haemorrhoidalis*, *M. longicornis*
	Largely distributed (no Mediterranean)	Forest	*Callicera aurata*, *Eupeodes flava*, *Ferdinandea ruficornis*, *Myolepta dubia*, *Pipiza festiva*, *Xanthogramma laetum*, *X. stackelbergi*
		Wetland	*Cheilosia nebulosa*, *Melanogaster aerosa*, *Neoascia meticulosa*, *N. obliqua*

Main vegetation in Berici Hills and Po Plain is different; in Berici Hills xeric conditions are well represented, while Po Plain is dominated by moist environments and rural landscape. Some exceptions, however, are present, such as for example the Fimon Lake in Berici Hills. Through Speight (2015) the species observed in Berici Hills and absent in Po Plain has been characterized according to their preferred habitats in order to identify the species that potentially could also be present in Po Plain (table 2)

To compare the Syrphidae fauna of the Berici Hills with those of other sites in north-eastern Italy, a multivariate analysis was performed. Only sites monitored with Malaise traps were compared, and only presence/absence data were used because the number of Malaise traps and their active period can be different. Due to the absence of normality in the data matrix, a non-metric multidimensional scaling (NMDS) with a Bray-Curtis dissimilarity index was used as the multivariate technique (Shaw, 2003). In addition, a cluster analysis based on Bray-Curtis dissimilarity index and Ward's method was used. Both analyses were performed using Past 3.04 (Hammer *et al*., 2001). The cluster tree was projected on a map of north-east Italy to highlight the peculiarity of the Berici Hills fauna. The projection of the cluster was performed using GenGIS 2.3 (Parks *et al*., 2013).

Results

In total 16784 specimens belonging to 143 species were collected. The number of species in each site ranged from 31 to 72, while the number of specimens ranged from 166 to 2111 (supplemental material table S1).

The total number of species collected in the eastern Po Plain, where the Berici Hills are located, is actually 121 species (Sommaggio, 2010a). Figure 2 compares the species richness from the extrapolation curves for Berici and the Po Plain derived from the data from one Malaise trap in each year in each area (64 samples in Po Plain and 40 in Berici Hills). The sample coverage, which can be considered as an estimator of sample completeness (Chao and Jost, 2012), is very high in both areas: the C.hat (an estimator of sample coverage as detailed in Chao and Jost, 2012) is 0.98 for Berici Hills and 0.99 for Po Plain. At the same level of coverage the richness of Berici Hills is significantly higher than Po Plain: there is no overlap between the two curves or their 95% confidence intervals (Chao and Jost, 2012; Chao *et al.*, 2014) (figure 2).

There are 52 species that were collected in the Berici Hills but not recorded in the eastern Po Plain (table 2). Eighteen species have been recorded previously in the mountainous areas not too distant from the Berici Hills, such as Summano or Pastello Mountains (Sommaggio, 2004; 2005b). Eleven species have not been recorded from adjacent mountains, but are widely distributed in Europe. Seven of these are usually associated with forest and three of them (*Callicera aurata*, *Ferdinandea ruficornis* and *Myolepta dubia*) are saproxylic, with larvae developing in association with overmature trees in

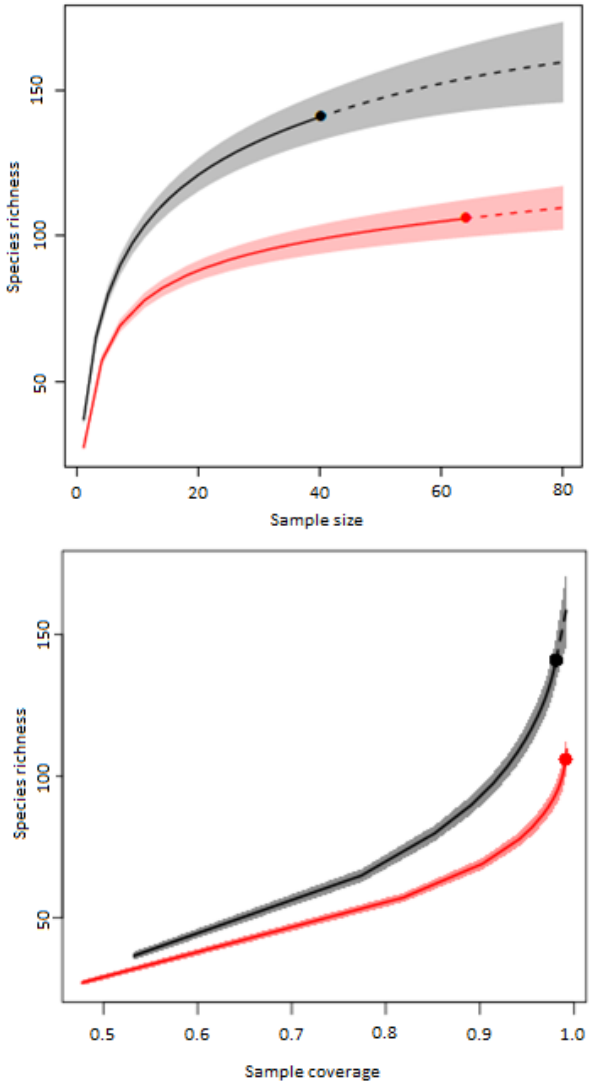

Figure 2. Comparison of the biodiversity of the Berici Hills and the eastern Po Plain, using rarefaction and extrapolation curves. Berici Hills - black; Eastern Po Plain - red. Solid line - rarefaction line; dashed line - extrapolation curve. Grey and reddish area - 95% confidence intervals calculated by iNEXT Online Software (Hsieh *et al.*, 2013).

Quercus forest. They are rare species, and Speight (2015) consider *F. ruficornis* to be a threatened species in Western Europe. Four species (*Cheilosia nebulosa*, *Melanogaster aerosa, Neoascia meticulosa* and *N. obliqua*) are typical of wetland; despite the presence of several humid areas in Po Plain, these species have not been previously recorded (Sommaggio, 2010a). According to Speight (2015), *C. nebulosa* is a species associated with humid forest (e.g. *Alnus* or *Salix* woods). This species has been recorded from north-central Europe, where it seems to be well distributed even if not common (Speight, 2015). In the Balkans it seems to be present in the central mountain areas (Vujić, 1996). The presence of this species in Italy was uncertain: according to Dirickx (1994) the only record is that of Bezzi (1900), under the name *Cheilosia langhofferi* (Becker 1894). In Bezzi's collection, preserved in the Museum

of Natural History of Milan, three specimens (one male and two females) labelled *C. langhofferi* are present. Examination of these specimens confirms that they belong to *C. nebulosa*. The collecting localities of the three specimens are quite different: one female was collected near Pesaro (central Italy), the only published record (Bezzi, 1900). The other female was collected by A. Fiori in Modena province; unfortunately this province includes both territories in the Po Plain and in the hills surrounding its southern margin. The male bears a label "S Anna 29.III.88". Unfortunately these data are too generic; the specimens in Bezzi collection are from the personal collection of the author, but also the outcome of exchanges with several entomologists, not only Italian. According to these data the species can be confirmed from north and central Italy, even if only from a few records: no data are available about the ecology of this species. *C. nebulosa* was recorded in the Berici Hills in four localities: three xeric meadows and one clearing in a thermophilous oak wood. Not one of these localities agrees with the stated habitat of the species (Speight, 2015). The specimens recorded may be a different species; unfortunately no males were collected, but the females show no differences from those from northern Europe (Claussen personal communication). Perhaps the habitat requirements of the species in the southern part of its range may be different. Almost no information is available about the larval ecology, although Doczkal (2002) reported egg-laying on *Centaurea nigra*. *Neoascia obliqua* is widely distributed in central Europe, but it is less common in southern Europe. In Italy it has been recorded from the northern and central parts, even if only by a few records (Dirickx, 1994; Daccordi and Sommaggio, 2002); this species is also present in Sardinia (Daccordi and Sommaggio, 2002; Birtele, 2011). In the Berici Hills only one female was collected, from a dry grassland which is a habitat not typical for *N. obliqua* (Speight, 2015). Both *Neoascia meticulosa* and *Melanogaster aerosa* were collected only from near Fimon Lake, their typical habitat (Speight, 2015). Both species are more common in central Europe, even if the real distribution of *M. aerosa* is still uncertain due to possible confusion with *Melanogaster parumplicata* (Loew 1840). Until now *N. meticulosa* has been recorded only in northern Italy (Burgio *et al.*, 2015), but with no specific locality; this species, under the name *Neoascia aenea* (Meigen 1822), was not recorded as present in Italy by Dirickx (1994). *M. aerosa* has been included in the Italian checklist of species only in the last revision (Burgio *et al.*, 2015), and actually has been recorded only for the north Appennines. In some cases this species was confused in previous records of *Chrysogaster macquarti* Loew 1843. Despite the large number of monitoring schemes in the Po Plain, including several in wetlands (Sommaggio and Corazza, 2006; Corazza, 2012), these two species have not been recorded from this area, although *M. aerosa* was included in the list of expected species for Ferrara province (Sommaggio, 2012). Only four widespread species not recorded in the Po Plain have aphidophagous larvae (*Epistrophe flava*, *Pipiza festiva*, *Xanthogramma laetum* and *X. stackelbergi*). The distributions of *E. flava*, *P. festiva* and *X. stackelbergi* are still uncertain due to confusion with similar species or for taxonomic problems inside the genus (Speight and Sommaggio, 2010; Vujić *et al*., 2013; Speight, 2015). *X. laetum* is present in central and southern Europe; in Italy it is known mainly from central Italy (Sommaggio, 2005a).

Twenty-two of the 52 species observed in the Berici Hills but not recorded in the eastern Po Plain, have a geographical distribution typical of southern Europe / Mediterranean Basin. Eight species are associated with open areas (table 2). The presence of *Eumerus elavarensis* is very interesting: this species is known in Italy only from the Berici Hills (Burgio *et al*., 2015). *Merodon armipes* is a species frequent in south-eastern Europe (Dirickx, 1994; Speight, 2015): in Italy it has been recorded everywhere except Sardinia (Dirickx, 1994; Burgio *et al*., 2015), but records from the Alps are rare. *M. longicornis* is also known only from the Mediterranean Basin; no record of this species is known for the Alps. *Eumerus ruficornis* has been recorded from all of Italy except Sardinia; according to Speight (2015), this species is present in all Europe from the south parts of Sweden. Recent records of this species from central Europe are very rare: Johansson (2011) suggested that its disappearance can be explained by the reduced cultivation of *Scorzonera humilis*, where the larvae develop. According to Speight (2015), *E. ruficornis* is associated with humid areas, usually lowland seasonally flooded grassland. Here only one specimen of *E. ruficornis* was recorded from one of the localities of M. Prete, in a clearing of young *Quercus* wood: this is unlike the typical habitat of the species. Two additional specimens were collected from similar habitat in the Adige Valley (personal unpublished data). In the Berici Hills *S. humilis* has not been recorded; *Scorzonera austriaca* is the only species belonging to this genus present in the Berici Hills (Tasinazzo, 2007). The specimens collected in these dry habitats may be different from the *Eumerus ruficornis* species in north-central Europe or perhaps in the southern part of its range the species can have different environmental requirements. *Eumerus sinuatus* is known from south-eastern Europe, and although it has been recorded from central and southern France, it seems to be more common in the Balkan Peninsula. The species has been recorded in Italy only from the north-eastern Alps (Daccordi and Sommaggio, 2002). A similar distribution (East Europe) is present in *Merodon haemorrhoidalis*; this species is actually not included in the check list of Italian species, even if its type locality is Poland and Italy. Until recently it was considered a synonym of *M. constans* (e.g. Maibach *et al*., 1998), but van Steenis *et al*. (2015) clearly highlighted that it is a separate species. *M. haemorrhoidalis* seem to be a Pannonian species which extends its range to the lowland part of northern Italy. While all the previous species are phytophagous, *Eupeodes flaviceps* and *E. nuba* are two aphidophagous species. *E. nuba* has a wide distribution (including Afrotropical Africa and southern Asia), but it extends northwards only until Switzerland; the species was included in the Italian checklist only recently (Burgio *et al.*, 2015), following Speight (2015) who re-

corded it from Sicily. *E. flaviceps* has been recorded also in central Europe, but it is more common in southern Europe; in Italy it has been recorded in few alpine localities and in southern Italy (Sommaggio, 2005a).

There is a great number of species associated with forest that have a mainly Mediterranean distribution and that are not present in the eastern Po Plain list. Five of these (*Callicera macquartii*, *Ferdinandea aurea*, *Milesia semiluctifera*, *Myolepta obscura*, *Sphiximorpha subsessilis*) are saproxylic and two of them (*F. aurea* and *M. semiluctifera*) are associated with thermophilous *Quercus pubescens* forest. Both are typical of the Mediterranean Basin and have been recorded from across Italy except *M. semiluctifera*, which is absent from Sardinia. These species are rare in northern Italy. *C. macquartii* too is a Mediterranean species; until recently in Italy it had been recorded only in the south, but there have been recent additional records from Sicily, Sardinia and northern Italy (Burgio *et al.*, 2015). In the north it has previously been recorded only for the north Appennines (Sommaggio, 2010a); no data are available for the Alps. *S. subsessilis* and *M. obscura* are species associated with humid forest, in particular alluvial forest with *Populus* or *Salix* trees. *M. obscura* has been recorded from Italy only recently, and actually it was known only from north-east, near the border with Slovenia (Reemer *et al*., 2005). In the Berici Hills it has been recorded only from Fimon Lake, in accordance with its biology. The presence of *S. subsessilis* in several localities in the Berici Hills is interesting. This species has been recorded in lowland Po forest surrounding cities in the 19th century (Sommaggio, 2007). In the last few decades the several surveys in the remains of the Po Plain forests have not recorded it (Birtele *et al*., 2002; Corazza, 2012). Of the four species belonging to the genus *Merodon* (*M. funestus*, *M. natans*, *M. nigritarsis* and *M. trebevicensis*), *M. funestus* and *M. natans* are currently known from the Mediterranean Basin; no reliable data are known further north than the Alps (Speight, 2015). *M. funestus* is known from all Italy, but the records from the Alps are very old and uncertain (Bezzi, 1894; Funk and Gräffe, 1895; Sommaggio, 2007). *M. natans* has not been collected in the Alps. *M. nigritarsis* and *M. trebevicensis* have also been collected in central Europe (e.g. *M. nigritarsis* in Austria and Poland, and *M. trebevicensis* in Austria and Slovakia), but their presence is more frequent in southern Europe (Speight, 2015). In Italy, *M. nigritarsis* is known all over the country, including the Alps (e.g. Sommaggio, 2007). *M. trebevicensis* has been added to the Italian checklist only since the revision by Daccordi and Sommaggio (2002), known only from an old record from the eastern Alps. *Eumerus basalis* is present in the eastern part of the Mediterranean Basin, and its geographical range extends to Iran; no data are available for central Europe (Speight, 2015). In Italy this species is common in the south, while the only record for the Alps is from the Valle d'Aosta (van der Goot, 1969). The four remaining species with Mediterranean distributions that are associated with wood, found in the Berici Hills and not included in the eastern Po Plain, are aphidophagous. *Doros destillatorius* is known from the Mediterranean Basin and no data are available for central Europe; in Italy it is an uncommon species, recorded from the Alps, Appennines and recently also from Sardinia (Birtele, 2011). *Paragus bradescui* is present in the Mediterranean Basin, but its range extends into Asia until Turkmenistan and Tajikistan. In Italy it is an uncommon species, and no data are available for the Alps. *Pipizella annulata* and *Paragus romanicus* are more common in southern Europe, but there are records from central Europe (Speight, 2015). Both species have been recorded from peninsular Italy, including the Alps. The distribution of *P. romanicus* is uncertain due to confusion with the similar *Paragus bicolor* (Speight, 2015).

Comparing the fauna of the Berici Hills with other sites in north-eastern Italy shows the Berici Hills to be clearly separate from all other sites (figure 3). Despite the presence in the studied sites of different habitats (xeric meadows, humid areas, woods) the Berici fauna seems to be well differentiated from those of other sites, both in the Po Plain and in the Alps near the Berici Hills (Prealpi). Applying NMDS, three groups can be identified (figure 3). On the first axis, which explains 39.5% of the total variance, the sites from the Po Plain (circles) are separated from those of the Berici Hills (squares) and the Prealps (triangles). The Po sites can be separated further into groups according to the type of habitat (e.g. the humid areas or the pine woods), albeit with some overlap. On the second axis, which explains 21% of the total variance, the sites from the Berici Hills are separated from those of the Prealps. Despite its geographical position, the Berici syrphid fauna is well differentiated from those of the surrounding sites (figure 4). The eastern Po Plain sites, despite the large geographic area, are characterized by the type of habitat; in particular, the humid sites form a well-defined cluster, despite their being distantly located from one another. On the other hand, the Berici sites separate as a clear cluster, well differentiated even from sites that are geographic neighbours.

Discussion

The Po river forms the largest plain area of Italy, and its landscape has been modified by man since the Bronze Age, with particularly large changes after the Middle Ages. The Po Plain covers 15% of all Italian territory, but it includes more than 70% of all plain area in the country (Pellegrini, 1979; Marchetti, 2002). Currently this area is one of the most densely populated areas in Italy and in Europe (Ruffo, 2002). Increasing human density represents one of the most important threats for biodiversity, exacerbated by the fact that several areas of high human density are located in rich biodiversity hotspots (McKinney, 2002; Luck, 2007). The Po Plain has been extensively modified and now no area with more natural vegetation can be found. The flora and fauna of this region can be considered as particularly simplified (Ruffo, 2002).

The Berici Hills form a protected area in the eastern part of the Po Plain quite isolated from other similar natural areas (e.g. Euganei Hills, Prealpi Venete, Lessini Mountains). They appear to represent a very important

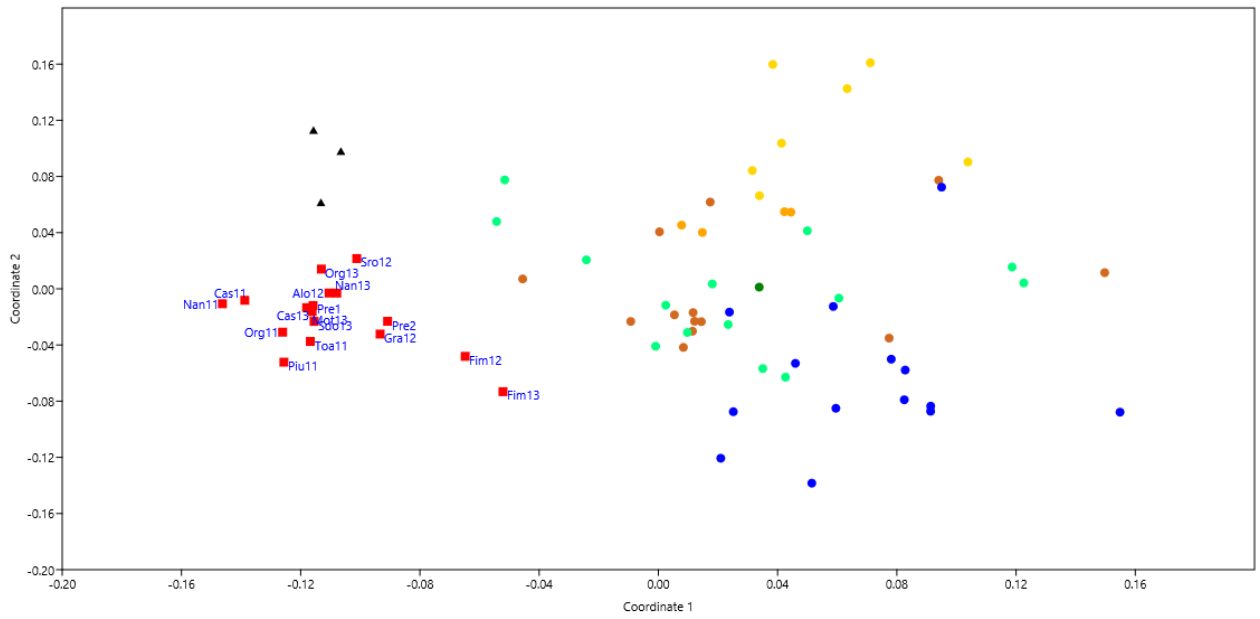

Figure 3. Non-metric multidimensional scaling (NMDS), with a Bray-Curtis dissimilarity index applied to 71 sites sampled with Malaise traps in north-eastern Italy. (Red squares) sites from the Berici Hills, identified with a single label as in table 1. (Black triangles) Lessini Mountains. (Circles) sites from the Po Plain, different colours in circles identify different types of habitat: (blue) humid areas; (green) agroecosystems; (brown) lowlands, mainly alluvial woods; (orange) dry meadows, particularly on sandy soils.

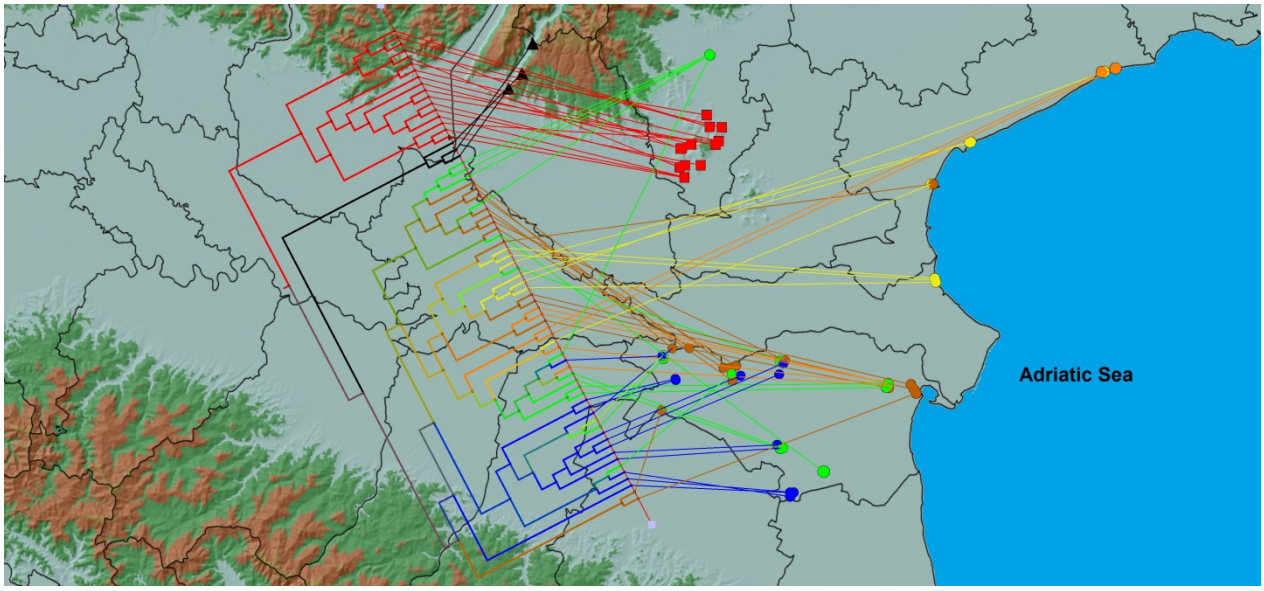

Figure 4. Cluster analysis based on Bray-Curtis dissimilarity index and Ward's method, projected onto a map of north-eastern Italy. Legend as in figure 3.

natural area. The flora has been largely studied (e.g. Béguinot, 1904; Tasinazzo and Fiorentin, 2000; Tasinazzo, 2001; 2007; 2014), and almost 1200 plant species have been recorded, including *Saxifraga berica*, endemic to this area. The flora is characterized by the high number of species typical of the Mediterranean basin: according to Tasinazzo (2007), 249 species, 20.5% of the total number of species, can be considered as Mediterranean. This is similar to neighbouring areas in north-eastern Italy, in particular in the hills near Verona (Bianchini *et al*., 1998), Brione Mountain near Garda Lake (Prosser, 2002) and the Euganei Hills (Masin and Tietto, 2005). Twelve plant species (e.g.. *Barlia robertiana*, *Phillyrea latifolia*) recorded in the Berici Hills are considered to be stenomediterranean, well distributed in southern and central Italy, but rare in northern Italy.

Entomological research in this area is quite scarce, mainly relegated to sporadic collections. Few studies have focused on the entomology of the Berici Hills. Cogo and Fontana (2002) studied the orthopteroid

fauna, and found 65 species. A detailed list of species also is available for surrounding areas such as the Euganei Hills (Cogo *et al*., 2002) and the Lessini Mountains (Fontana, 1999). According to Cogo and Fontana (2002), the Berici Hills orthopteroid fauna is more similar to that of the Euganei Hills than any other mountain area in the Veneto region. The Berici orthopteroid fauna is particularly rich, denoting an elevated local biodiversity of this taxon. Two components are present: species associated with xeric areas, particularly abundant in the grasslands of the southern slopes, and species associated with colder climatic conditions, well represented on the northern slopes.

The hoverfly community confirms the peculiar fauna present in the Berici Hills. The number of recorded species is 143, larger that the total syrphid fauna known from the eastern Po Plain (Sommaggio, 2010a). Unfortunately a list of species from the neighbouring Euganei Hills is not available. Accordingly to Speight (2015), fifteen species are mainly associated with thermophilous *Quercus* wood, an habitat not expected in the Po Plain, and consequently these species are not expected in this area. In any case, 37 species collected from the Berici Hills and not found in surrounding areas might be expected in the Po Plain habitats, but the highly modified landscape prevents it. The case of *Sphiximorpha subsessilis* is interesting: accordingly to Speight (2015), this species is endangered in Europe due to its strict ecological requirements. It is usually associated with alluvial, humid woods, such as, for example, *Populus* or *Alnus*/*Salix* woods. Its presence at least in the western part of the Po Plain has been confirmed by studying 19th century collections (Sommaggio, 2007). Recent research in well-preserved woods in the Po Plain (e.g. Birtele *et al*., 2002; Corazza, 2012) has failed to detect this species, which can therefore be considered locally extinct, at least in the eastern part of the Po Plain. However, it is present in the Berici Hills, where it has been collected in three sites in different years. These specimens may represent an important relict population, from which recolonization could hypothetically occur to the eastern Po Plain when ecological conditions can be restored.

The application of multivariate analysis underlined the peculiarity of hoverfly population in Berici Hills, well differentiated by that in adjacent areas, despite in some cases the type of habitat are similar. The Berici Hills population of hoverflies is characterized by the presence of species absent from Po Plain. Several species typical of Mediterranean basin are present in the Berici Hills, thanks to xeric habitats, absent from the Po Plain. Interesting is the presence of several rare species, associated with overmature forest, expected also for the Po Plain but to date not recorded for this area. The absence of these species can be explained by the fact that the Po Plain has been largely modified by human activity since the Bronze Age, even if this is much evident in the last 400 year. During 16th century the population in North Italy dramatically increased: for example from 1550 to 1600 the population increased by about a million, an increased by 18.2% (Alfani, 2010). The main consequence was the reclamation of land for agriculture: in this period in Eastern Po Plain large part of wet areas was filled with solid matter and irrigation channels were build to maintain agricultural fields (Guidobuoni, 1998). The landscape was largely modified by human activities with the disappearance of more natural habitats, in particular forest and wetland. Several species strongly associated with this habitats probably became locally extinct in this area, while the reduced human pressure on Berici Hills probably allowed their presence.

The hoverfly fauna of the Berici Hills confirms the very peculiar nature of this area, well differentiated from adjacent areas. It includes several species that are at the very least rare in northern Italy. To date these Hills represent unique records in Italy for two species, *Eumerus elaverensis* and *Merodon haemorrhoidalis*. In addition, some species (such as *Myolepta obscura* or *Neoascia meticulosa*) have not previously been recorded in northern Italy and/or seem to be particularly rare. Several species common in southern and central Italy are present on these Hills, such as, for example, *Eupeodes nuba*, *Merodon funestus*, *M. natans* and *Eumerus basalis*. Hoverfly biodiversity in this site is higher than in the sourrounding, largely modified, Po Plain. Similar results have been found for other taxa (Tasinazzo, 2007; Cogo and Fontana, 2002). All these data suggest that the Berici Hills represent a very important area of high biodiversity, isolated by the human-dominated Po Plain. The importance of the Berici Hills from the point of view of nature conservation has been recognized by its inclusion as SCI (Site of Community Importance) place (Buffa and Lasen, 2010). The presence of hoverfly species now probably extinct in the Po Plain suggests that the Berici Hills not only represent a site with high biodiversity, but potentially at least could be a reservoir for future recolonization of the surrounding areas.

Acknowledgements

I would like to thank Roberto Fiorentin, Stefano Tasinazzo, Michele Carta, Cesare Cariolato, Elvio Cerato: they help me in a better knowledge of the wonderful area of Berici Hills. Francis Gilbert kindly read a first draft of the paper: his suggestions has been very important. Claus Claussen and Ante Vujić supported me on some critical specimens. Robert Beiko help in the use of Gengis software has been enlightening. Fabrizio Rigato allowed me to study the *Cheilosia* specimens in Bezzi's collection (Museum of Natural History in Milan). The present research has been partly financially supported by the Vicenza Province through the Life Project Colli Berici.

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Received August 19, 2016. Accepted January 31, 2017.