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Abstract

Farming systems and management regimes of vineyards may affect local biodiversity of plants and invertebrates. While most studies have focused on the overall biodiversity of vineyards, there has been little consideration of the response of different ecological guilds to vineyard management, nor to how vineyard management affects communities of adjacent semi-natural habitats.

We study here two functional guilds of carabids and five of spiders in Langa Astigiana (NW-Italy) with the following aims: *i)* to assess the comparative effects of organic and conventional farming systems, along with associated habitat and landscape variables, on species richness and abundance in vineyards; and *ii)* to compare the same within forest patches *surrounding* organic and conventional vineyards.

The different guilds exhibited distinct preferences for habitat characteristics (i.e. grass cover), landscape context and farming systems. Generalized Linear Mixed Models showed that spider preferences mostly depended upon habitat variables, while carabid preferences depended on small-scale landscape variables. In general, organic farming increased biodiversity and abundance of arthropod predators, even though different guilds of carabids and spiders responded differently. Brachypterous carabids, ambush spiders, ground-hunter spiders and other hunters preferred organic vineyards, whereas macropterous carabids, specialist spiders (mostly ant-eating spiders) and sheet web weavers selected conventional vineyards. The research we report here shows that preferences for vineyards with different farming systems has been driven by farming systems *per se* (i.e. omission of synthetic pesticides), but also by habitat characteristics and small-scale landscape structure. Arthropod diversity was greater in the forest patches adjacent to organic vineyards than to conventional ones. This suggests that organic systems may sustain a higher diversity of carabids and spiders both in vineyards and in the adjacent forest patches as well. We conclude that although conventional systems may promote the diversity of some guilds, organic systems should take priority.

38 **Keywords**

39 Biodiversity, carabids, spiders, organic farming, vineyards, forest patches.

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1. Introduction

Agroecosystems are characterized by diverse inputs, such as human labour and petrochemical energy and products, which replace and supplement the functioning of many ecosystems. While such substitutions may buffer some of these functions, they also run the risk of damaging others. For instance, the use of pesticides may control diseases that have negative impact on crops, but these may also kill non-target organisms with other positive functions such as pollination or soil fertility enhancement (Swift and van Noordwijk, 2004; Power, 2010).

The current intensification of agriculture is leading to growing concern about the sustainability of farming systems, since farmland biodiversity has severely declined (Vickery et al., 2004; Kleijn et al., 2011). Biodiversity is certainly important to the functioning of ecosystems: insights from Biodiversity and Ecosystem Function (BEF) experiments are likely to underestimate, rather than overestimate, the importance of biodiversity to ecosystem functioning and the provision of ecosystem services (Duffy, 2009). One of the major threats to farmland biodiversity is the simplification of landscape structure, with diminution of non-crop habitat deriving from the expansion of intensive arable crops (Stoate et al., 2001; Benton et al., 2003). Organisms at higher trophic levels seem to be more vulnerable to disturbance than those at the lower trophic levels (Kruess and Tscharntke, 1994), suffering decreases both in their diversity and abundance. Disturbance affects predatory arthropods both directly and indirectly through reduced densities of their prey and hosts. This process in turn decreases the *natural* control of important crop pests (Riechert and Lawrence, 1997; Schmidt et al., 2003). Considering that many ecosystem services of particular importance for agriculture such as pollination and natural pest control often depend on the number of species in an ecosystem (Tilman et al., 2002; Cardinale et al., 2012), the impoverishment of natural communities by agriculture should be minimized to avoid negative feedbacks on production (Diaz et al., 2007).

81   Organic systems have been shown to support higher biodiversity than conventional ones across

82   many different taxa (Fuller et al., 2005; Bengtsson et al., 2005). These systems aim to promote

83   beneficial organisms by prohibiting the use of synthetic pesticides, herbicides and mineral

84   fertilizers. Moreover, they minimize tillage in order to reduce soil erosion. Studies on organic

85   farming in vineyards are particularly prominent because these agroecosystems are important not just

86   for agriculture, but for conservation as well. In temperate Europe, vineyards (which typically

87   occupy sites with particularly warm and dry climates) may host rare and endangered species of

88   plants and invertebrates. General biodiversity is also typically high (Costello and Daane, 1998;

89   Gliessman, 2000; Isaia et al., 2006).

90   Vineyards are an ancient crop of Mediterranean mountain environments, cultivated on steep slopes

91   or terraces probably since the early middle ages (Wicherek, 1991; Aldighieri et al., 2006; Cots-

92   Folch et al., 2006). Predicted northward shifts in the climate of European viticultural regions over

93   the coming decades (Kenny and Shao, 1992; Maracchi et al., 2005) may alter both the spectrum and

94   the distribution of grape varieties currently used (Schultz, 2000; Metzger et al., 2008). Several

95   studies have shown that farming systems and regimes of vineyards are important factors

96   determining biodiversity of plants and invertebrates (Di Giulio et al., 2001; Costello and Daane,

97   2003; Thomson and Hoffman, 2007; Bruggisser et al., 2010; Trivellone at al., 2012). Carabids and

98   spiders are important components of the vineyards. They are potentially important natural agents of

99   pest-control because of their predatory polyphagous habits, and they may be helpful to maintain

100   ecosystem functions and services and promote sustainable agriculture (Kromp, 1999).

101   Vineyard landscapes of north-western Italy represent peculiar agroecosystems which deserve high

102   conservation priority because of ecological, historical and economic importance (high quality wine

103   production). The research we report here investigated how species richness and abundance of

104   spiders and carabids respond to organic and conventional farming systems in the context of habitat

105   and landscape variables. We also studied the effects of these systems on spider and carabid diversity

106   in the forest patches surrounding the vineyards because, to our knowledge, little attention has been

107 addressed to study the effect of management on surrounding habitats while more consideration has

108 been addressed to analyze how landscape context influences arthropod communities in organic and

109 conventional farms.

110 Furthermore, while most studies have focused on the overall biodiversity of vineyards, less

111 attention has addressed the effect of organic versus conventional systems on the different ecological

112 guilds (Krauss et al., 2011). Accordingly, we considered functional guild identity of carabids and

113 spiders instead of the overall community, since species with varying ecological requirements may

114 respond differently to different farming systems.

2. Material and methods

2.1. Study area and sampling design

117 The study was carried out in the Langa Astigiana (NW Italy which ranges for about 28.000 ha), a

118 rural region where vineyards cover 19% of the territory (5343 ha). The present landscape is the

119 result of centuries of historically documented activities. Other main land uses include oak (*Quercus*

120 *robur*), chestnut (*Castanea sativa*) and black locust (*Robinia pseudoacacia*) groves/forests (28%,

121 7873 ha), hazelnut orchard areas and other fruit crops (21%, 5905 ha), arable lands (16%, 4499 ha),

122 grasslands and pastures (9.5%, 2671 ha), shrub lands (3%, 843 ha), urban areas (3%, 843 ha), and

123 uncultivated lands (0.11%, 31 ha). The climate belongs to type Cfa (temperate, without dry season

124 and with hot summer), in terms of Köppen-Geiger's classification (Peel et al., 2007). During the last

125 five years, annual precipitation ranged from 567 to 894 mm with minimum values in July, January

126 and February and with a maximum peak in April and November. Total annual rainfall averaged

127 757.4 mm, while the mean annual temperature was 11.9°C (Loazzolo climatic station, 600 m a.s.l.).

128 We investigated 12 vineyards, of which 6 were certified for organic production whereby no

129 chemical treatments except sulphur and copper sulfate spraying were used. In some cases pyrethrum

130 was sprayed against the principal vector (*Scaphoideus titanus*) of flavescence dorèe (*Candidatus*

131 *Phytoplasma vitis* IRPCM 2004) which is a bacterial disease of the vine. The other 6 vineyards

132 were cultivated according to conventional production methods. These involved chemical treatments

133 with pre- and post-emergence herbicides, insecticides (mostly against flavescence dorèe), anti-rot

134 compounds, sulphur, copper and zinc spraying, products with esaconazol and copper oxiclorur

135 sulphate against oidium and rots, carbamate pesticides and fungicide, and the use of mineral

136 fertilizers with average concentration of P, K and N at 6.5 q/ha. In particular, during the study

137 period, conventional vineyards were treated with 1.5 l/ha of chlorpyrifos-ethyl and 1.5 l/ha of

138 chlorpyrifos-methyl against bacterial infection (flavescence dorèe) in the months of June and July

139 respectively. Treatment against downy mildew consisted of three treatments of copper oxychloride

140 (40%) and Dimetomorf 6% (3.5 kg/ha) in June and three treatments of Bordeaux mixture (6 kg/ha).

141 Treatment against Oidium consisted of powdered sulphur (50 kg/ha), one treatment of

142 Trifloxystrobin (125 g/ha), and two treatments of wettable sulphur powder (3 kg/ha) in June and

143 two in July.

144 We placed five pitfall traps in the core of each vineyard and five in the last row of the vines at the

145 edge of the vineyards. For each vineyard, we selected the closest, possibly adjacent, broad leaved

146 forest patch (mixed black locust-oak forest in each site), where we placed five traps as well. Traps

147 were arranged 10 m apart along line transects. Pitfall traps were 7.5 cm in diameter and 9 cm deep,

148 filled with 150 ml of a standard mixture of wine vinegar and saturated sodium chloride solution,

149 designed to preserve individuals. They were placed at the beginning of July 2009 and emptied three

150 times at two-week intervals. Trapped arthropods were sorted and identified, whenever possible, to

151 the species level using updated standard keys or specialist works. For spiders, only adults were

152 considered. Nomenclature follows Platnick, 2014 for spiders and Vigna Taglianti, 2005 for

153 carabids.

154 Three habitat variables were recorded in vineyards around each pitfall in a circular area of 5 meter

155 radius: the percentage of grass cover, leaf litter cover (estimated by eye), and the mean grass height

156 (ten random measurements, in centimeters). Five habitat variables were recorded in the forests close

157 to the vineyards around each pitfall in a circular area of 5 meter radius: the percentage of grass

158 cover, leaf litter cover, bare ground cover and dead wood cover (estimated by eye), and the mean

159 grass height (ten random measurements, in centimeters).

2.2. Data analysis

161 We used land cover data digitized from 1:10000 aerial photographs to describe the landscape

162 composition and structure. We considered a small scale (focused on the vineyard and forest

163 patches) and a large scale (focused on the landscape, i.e. vineyard and adjacent land uses). At the

164 small scale, we created a buffer of 200 m of radius with the center coincident with the third trap (i.e.

165 in the middle of the transect) of each transect. At the large scale, we created a buffer of 1500 m of

166 radius with the center coincident with the centroid of the triangle whose vertices coincided with the

167 third trap of each of the three transects (two in the vineyard and one in the forest patch).

168 Thirteen local landscape variables were measured using Geographical Information System (ESRI,

169 2006): the area of forests, grasslands, shrubs, vineyards, croplands, hazelnut orchards, urban and

170 uncultivated patches, total number of patches, Shannon diversity index of patches, total mean area

171 of patches, the distance from the closest patch of forest (in meters) and the largest patch index

172 (LPI). LPI corresponds to the area of the largest patch (m^2) of the corresponding patch type divided

173 by total landscape area (m^2), and multiplied by 100. In other words, LPI equals the percentage of

174 the landscape comprised within the largest patch. The number of collinear variables was reduced by

175 applying a Principal Component Analysis (PCA) with a Varimax rotation (Kaiser 1958). At large

176 scale we considered the areas of forests, grasslands, shrubs, vineyards, croplands, hazelnut orchards,

177 urban and uncultivated patches.

178 Differences in landscape and habitat between conventional and organic systems were tested using a

179 Kruskal-Wallis test due to evidence of a non- Normal distribution.

The diversity of carabid and spider assemblages was described in terms of species richness and total abundance. Two functional guilds were considered for carabids: the macropterous and the brachypterous. We identified seven functional guilds for spiders according to the recent classification provided by Cardoso et al., 2011. Specifically, we considered: ambush hunters (namely Thomisids), ground hunters (dominated by Gnaphosids and Lycosids), sheet web weavers (mostly Agelenids), space web weavers (Theridiids), specialists (mostly Zodariids - ant-eating spiders), sensing web weavers (Atypids) and the mixed group of other hunters either runners and stalkers (Philodromids and Salticids) or small ballooners (Erigonids).

The relative contribution of vineyard systems (conventional or organic), transect location (core or edge of the vineyard), habitat variables (grass cover, grass height, leaf litter cover) and landscape variables on species richness and abundance *in the vineyards* were tested using generalized linear mixed models, GLMMs (Zuur et al., 2009). Vineyards (N=12) and pitfalls inside each transect (N=5) were considered as random factors. The fixed factors were represented by: farming systems (organic or conventional), transect location (core or edge of the vineyard), sampling period, habitat variables and landscape variables. Conditioning scatter plots were used to evaluate possible interactions among these variables. The significance of factor levels in the models was tested through maximum likelihood methods, and model simplification was undertaken. Akaike's information criteria (AIC) was used to test the goodness of fit of the estimated statistical models, and a model with a lower AIC was preferred to one with a higher AIC. Likelihood ratios were used for testing the explanatory power of the models and, using the *drop1* function, we selected the minimum adequate model best explaining the data (Crawley, 2002). A Poisson distribution of errors was specified since variables were based on count data. All models were checked for overdispersion via the ratio between Pearson residuals of the model and the degrees of freedom. Observation level was treated as a random factor when models showed overdispersion (Elston et al., 2001).

The effects of farming systems, habitat and landscape structure *on the adjacent forest patches* were also tested on the abundance and species richness of carabids and spiders using univariate GLMMs.

206 The farming system, habitat and landscape variables were set as fixed factors, while the vineyards

207 (N=12) and the pitfalls inside each transect (N=5) as random effects.

208 In all GLMM analyses, the pitfall was the basic sampling unit, and the number of species and the

209 abundance of arthropods per trap was measured.

210 All statistical analyses were run using R package (R Core Team, 2013; Roberts, 2012).

3. Results

3.1. Assemblage composition

213 A total of 1541 carabids and 1204 adult spiders were collected, corresponding to 49 and 95 species

214 respectively (Table. 1). Juveniles of spiders (261) were also collected; however, they were excluded

215 from the analyses because they could not be identified at the species level.

216 In organic systems, the average number of individuals per pitfall was 3.73±6.09 in vineyards and

217 5.62±7.5 in forest patches. In conventional systems, the average number of individuals was

218 5.59±14.69 in vineyards versus 1.33±2.54 in forest patches.

219 Most of the arthropods were collected inside the vineyards (85% of individuals and 74% of

220 species), because the sampling effort was twice as high in vineyards (two transects, ten pitfall traps)

221 than in adjacent forest patches (one transect, five traps). Macropterous carabids were the most

222 abundant guild in vineyards with 64% of sampled individuals. *Calathus fuscipes graecus* and

223 *Brachinus crepitans* were the predominant brachypterous species, while *Harpalus dimidiatus* was

224 the most abundant macropterous species.

225 Spiders were dominated by the ground hunters guild with 58% of sampled individuals, followed by

226 specialists (14.7%), space web weavers (8.8%), ambush hunters (8.3%), other hunters (5.8%) and

227 sheet web weavers (4.6%). Sensing web weavers were very poorly represented (only one individual

228 found in a conventional vineyard) and were therefore discarded from analyses. *Zodarion rubidum*,

229 an ant-eating specialist, and the ground hunter, *Haplodrassus dalmatensis*, were the predominant

230 spider species. The lists of carabid and spider species are given in supplementary material Appendix
231 A and B, respectively.

232 ## *3.2. Landscape and habitat characterization of vineyards*

233 On a large scale within the 1.5 km radius buffer, landscape variables did not differ significantly
234 between organic and conventional systems. On the contrary, on a small scale within a 200 m radius
235 buffer, the area of vineyards was smaller (Kruskal-Wallis chi-squared = 4.20, df = 1, residual
236 df=26, p-value = 0.04), while the area of adjacent forests (Kruskal-Wallis chi-squared = 10.17, df =
237 1, residual df=26, p-value = 0.001), and Shannon- Wiener diversity index (Kruskal-Wallis chi-
238 squared = 3.84, df = 1, residual df=26, p-value = 0.05) were greater in organic than in conventional
239 landscapes.

240 Since organic and conventional vineyards were located in the same contexts, as shown by landscape
241 analysis on a large scale, only small scale variables were used to identify landscape factors affecting
242 species richness and total abundance/trap in vineyards. The first four principal components (PC1,
243 PC2, PC3, PC4) accounted for 81.8% of the total variation in the landscape structure matrix, with
244 eigenvalues > 1 (Table. 2). The Shannon diversity index along with grassland, crop and shrubland
245 areas were positively correlated with PC1 while vineyards areas and largest patch index (LPI) were
246 negatively correlated with PC1. This shows a gradient from landscapes dominated by vineyards to
247 more diverse and rich landscapes. PC2 was correlated negatively with woodland areas and
248 positively with the distance from woodland. PC3 was positively correlated with patch richness,
249 urban and uncultivated areas, and PC4 was positively correlated with hazelnut orchards.

250 Habitat analyses showed that grass height (Kruskal-Wallis chi-squared = 12.27, df = 1, residual
251 df=26, p-value = 0.0005) and the percentage of leaf cover (Kruskal-Wallis chi-squared = 13.98, df =
252 1, residual df=26, p-value = 0.0002) were significantly higher in organic than in conventional
253 vineyards.

3.3. Factors affecting diversity in vineyards

GLMM models regarding the richness and abundance of carabid and spider species are shown in Table 3a-3b. Sampling period was included in most of the models (with the exception of those relative to spider specialists and sheet web weavers), with total abundance and species richness higher in the first than in the second and third periods. Carabid species richness and abundance were higher in the core transect (fig. 1) and were negatively correlated with PC2, increasing therefore when forests were larger and closer to the vineyards. Spider species richness was lower in conventional vineyards, and increased according to grass cover and PC3. That is, it increased with urban and uncultivated areas and patch richness. Spider abundance responded in the same way as the species richness (fig. 2), in addition to being greater in the core transect.

Carabid functional guilds

Species richness and abundance of brachypterous species were negatively correlated with PC2, increasing therefore when forests were larger and closer to the vineyards. Also, the abundance was significantly lower in the core than in the edge transect.

The number of macropterous species was higher in the core than in the edge transects. Abundance of macropterous species was higher in conventional than organic vineyards and in core than in edge transects; it also increased with taller grass and a lower percentage of grass cover. Finally, abundance was positively correlated with PC1 and negatively correlated with PC4, meaning that it increased with larger grassland, shrubland and crop areas and smaller hazelnut areas (Table. 3a).

Spider functional guilds

Species richness of ground hunters, ambush hunters and other hunters was greater in organic than in conventional vineyards as well as the abundance of ground and other hunters.

The abundance of ambush and other hunters increased with larger grass cover. Ambush hunters showed also a significant interaction _grass cover * farming system', suggesting a negative effect of

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grass cover in conventional vineyards. Species richness of ground hunters also increased with taller grass.

Species richness and abundance of specialists (namely ant-eating spiders) were higher in conventional than in organic vineyards, while species richness and abundance of sheet web weavers were associated with grass height only, decreasing significantly with taller grasses (Table. 3b).

3.4. Differences between organic and conventional forest patches

Univariate GLMMs showed that diversity parameters of the overall carabid community (species richness and abundance of individuals), macropterous (species richness) and brachypterous carabids (species richness and abundance) were lower in the forest patches adjacent to conventional than in the patches close to organic vineyards, and their values increased along with the size of the forest patch (supplementary material Appendix C). Carabid species richness was also positively correlated with leaf litter and dead wood cover and negatively correlated with grass cover and mean grass height. Macropterous carabids were also positively correlated with bare ground and dead wood cover, shrub areas and heterogeneous landscape. Brachypterous species richness was also positively correlated with the size of the forest patch, litter and dead wood cover, and negatively correlated with grass cover and grass height.

Concerning spiders, the overall community (abundance and species richness), ambush hunters (abundance) and specialists (abundance and species richness) increased significantly in forest patches adjacent to organic vineyards compared to those adjacent to conventional vineyards (supplementary material Appendix D). The diversity parameters of the overall community (abundance and species richness) were also positively correlated with grassland area, forest patch area, heterogeneous landscape, and negatively correlated with LPI and vineyard area. Also, the abundance of spiders significantly increased with shrubland area.

301 Species richness of ground hunters responded positively to bare ground cover, forest patch and

302 grassland area, while their abundance was positively correlated with bare ground, grassland and

303 shrubland area, grass cover and Shannon patch diversity index. Abundance was also negatively

304 correlated with the area of the vineyards, LPI and grass height. Ambush hunters (species richness

305 and abundance) were positively correlated with bare ground, grass height, the area of shrubs and

306 heterogeneous landscape. Sheetweb weavers (species richness and abundance) were positively

307 correlated with grassland and shrub area and heterogeneous landscape. The diversity parameters of

308 the specialist guild showed a positive correlation with litter and dead wood cover and a negative

309 correlation with grassland cover, grass height and homogenous landscapes (i.e. LPI).

4. Discussion

311 In our study, we considered carabid and spider functional guilds to monitor the effects of two

312 farming systems in addition to habitat characteristics and landscape context. Our approach allowed

313 us to take into account the heterogeneity of the ecological requirements of distinct functional groups

314 within carabid and spider assemblages (Cole et al., 2002, Clough et al., 2007, Negro et al., 2009,

315 Batáry et al., 2012). Our results confirmed the robustness of this approach, because different guilds

316 of carabids and spiders responded in different ways to habitat, landscape and farming systems.

317 Considering all the species of carabids or spiders together may be misleading in two ways: the

318 ecological preference of the dominant guild may become representative of the overall assemblage;

319 or the ecological preferences of different groups may mask a potential trend in the community

320 response to a possible disturbance. As a caveat, we acknowledge that, by using pitfall traps,

321 sampling was not exhaustive for spiders, as we mainly detected ground dwelling spiders.

4.1. Habitat variables

323 Habitat variables appeared to have minimal influence on carabids. Only the abundance of

324 macropterous species were linked to grass cover and grass height. On the contrary, spiders seemed

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325 to be more dependent on habitat structure. In particular, species richness and abundance of ambush,

326 ground and other hunters were positively linked to grass cover and/or grass height, while species

327 richness and abundance of sheet web weavers were negatively correlated with grass height. Higher

328 grass height and grass cover may provide protection and favorable thermal conditions for prey,

329 which may attract a large number of spider species in turn. In particular, the preference of ambush

330 hunters for higher grass cover accords with their hunting strategy, since they typically lie

331 motionless in ambush for prey. Ambush hunters were mainly represented by *Xysticus kochi*

332 (Thomisidae) whose abundance has also been shown to increase with higher litter and grass cover

333 in other studies (Clark et al. 1994, Zrubecz et al. 2008). Ground hunters are dominated by species

334 such as *Haplodrassus dalmatensis* and *Pardosa hortensis* belonging to the Gnaphosidae and

335 Lycosidae families, respectively, while other hunters are mainly represented by *Thanatus arenarius*

336 (Philodromidae). This species is known to select typically open and dry habitats. The negative

337 correlation of sheet web weavers with grass height seems to be related to their preference to

338 construct webs at low heights (Janetos, 1982).

339 ## *4.2. Landscape structure*

340 On a large scale, conventional and organic vineyards did not differ with respect to landscape

341 structure variables, suggesting that they were located in the same general landscape context.

342 Nonetheless, small scale analysis showed that *landscape structure* in organic farms differed

343 significantly from the conventional ones: the former were characterized by smaller vineyards, larger

344 forest areas and greater landscape heterogeneity. Moreover, organic systems favored the

345 maintenance of bushes, trees and small forest patches. In this framework, carabids appeared to

346 depend on landscape structure, while no guild of spiders seemed to be affected by the small scale

347 landscape. This result seems to contrast with Isaia et al., 2006, in which landscape heterogeneity

348 and distance from forest patches affected significantly the composition of the spider assemblage,

349 both on the ground (pitfall trapped) and on the vines (visual standardized search).

350   Species richness and abundance of brachypterous carabids increased with large forest patches close

351   to the vineyards; while abundance of macropterous carabids was linked to large grassland,

352   shrubland and crop areas and to small hazelnut areas. Brachypterous species are mainly predators.

353   They are medium-large body size species, either wingless or with reduced wings, and hence

354   incapable of long movements or dispersal by flight (den Boer, 1970; Negro et al. 2009). It is

355   sensible that they are mainly associated with less managed sites (Ribera et al., 2001). Large forests

356   represented a potential source habitat for this functional guild. A greater proximity of the forests to

357   vineyards allowed them to disperse with short movements and reach areas with high availability of

358   prey. On the contrary, macropterous species are small body sized, flying, pioneer species which

359   prefer open and disturbed areas and are able to colonize new habitats (Negro et al., 2009, Ribera et

360   al., 2001)

361   *4.3. Farming systems*

362   In general, organic farming exhibited greater biodiversity and abundance of arthropod predators,

363   allowing us to assume a better top-down control of insect pests. However, it need to be considered

364   that generalist predators like several species of carabids and spiders may strongly reduce pest

365   insects, but they may also act as an intraguild predator, reducing the control by other specialist

366   predators or parasitoids (Snyder et al., 2001). The different guilds of carabids and spiders showed

367   different preferences according to farming system.

368   For example, macropterous carabids were more abundant in conventional vineyards than the

369   organic ones. On the contrary, brachypterous species richness and abundance were explained

370   mainly by landscape context in the models instead of farming system (Table. 3a), suggesting that

371   the main driver influencing brachypterous carabids was the small scale landscape structure

372   surrounding the vineyards. Conventional vineyards which cover larger areas and have less ground

373   cover were selected by macropterous species. These commonly prefer disturbed habitat (Ribera et

374   al., 2001). Apart from differences in farming system, macropterous and brachytpterous species

375   showed different patterns of abundance according to its location: the former were more abundant in

376   the core transect, while the latter in the edge transect. The vineyard cores are probably the most

377   disturbed habitat in terms of natural vegetation development. For this reason they might be more

378   attractive to macropterous species. Conversely, field edges may have benefitted from lower farming

379   intensities and from edge effects from the forest patches close to the vineyards (Rand et al., 2006).

380   Our results showed that field edges and field cores may often contain communities that vary in

381   diversity and abundance according to functional group, with consequent provisioning of ecosystem

382   service varying in the edge compared to the core. Brachypterous species are indeed predators, while

383   most of phytophagous carabids belong to macropterous species.(Brandmayr et al., 2005). Moreover,

384   the surrounding landscape matrix, and specifically the distance of forests to the vineyard edges, may

385   act as a source for farmland brachypterous carabids in that they provide refuges and corridors for

386   beetles dispersing between and across fields.

387   The effect of farming system in addition to habitat variables was particularly evident in spiders

388   since variations in the community indices were explained in most of the models by organic versus

389   conventional systems (Table. 3b). The influence of farming system on spider communities implies

390   that some unmeasured factor such as pesticides may affect spiders. Omitting pesticides would both

391   directly reduce spider mortality, and increase food availability through a reduction in the mortality

392   of spider prey (Schmidt et al., 2005). However, the different guilds of spiders exhibited opposite

393   preferences in relation to farming system. In particular, organic farming enhanced predators like

394   ground, ambush and other hunters, relevant for ecosystem services. In contrast to our expectations,

395   specialists (mostly ant eating spiders) appeared to prefer conventional vineyards. However such a

396   trend appears unclear: considering the negative effect of conventional management on ants (Lobry

397   de Bryuyn 1999, Dauber 2001), a positive effect on ant spiders would have been expected. On the

398   other hand, conventional farming may favor ant nesting for two reasons: (1) the use of herbicides in

399   conventional vineyards may determine more open soil surface that is favorable for ants, strongly

400 depending on high soil temperatures; (2) mechanical treatments for the weed control in organic

401 vineyards may increase soil disturbance. Less soil disturbance in conventional vineyards because of

402 the use of herbicides could favor the ground-nests of ants.

403 The different farming systems, chemical treatments and habitats did not affect ambush hunter

404 abundance, but only species richness. This was probably due to the higher diversification of

405 microhabitats found in organic vineyards and to the high sensitivity of spiders to pesticides (Ripper

406 1956, Mansour 1987, Mansour & Nentwig 1988, Pekar 1998, Fountain et al. 2007). A similar

407 explanation can be given concerning ground hunters (both diurnal and nocturnal spiders) and for the

408 mixed guild of other hunters (foliage dwellers and stalkers).

409 Ecosystem services provided by the increasing abundance and number of functional guilds in

410 organic fields may benefit farmers due to better top-down control of pest species (Krauss et al.,

411 2011).

412 The preference patterns of spiders for farming systems is strongly linked to the habitat features

413 characterizing organic and conventional vineyards. Organic vineyards, for instance, were

414 characterized by higher grass height and leaf cover which provide higher structural complexity and

415 hence refuges at the soil surface, and may potentially increase the availability of herbivore prey

416 (Zrubecz et al., 2008; Purtauf et al., 2005).

417 The functional guild of the specialists showed a preference for conventional vineyards. Since most

418 of the specialists are ant-eating spiders (Zodariidae) (Pekar, 2004), we hypothesize that the

419 conventional vineyards might have higher availability of specialist prey.

420 A rather surprising result of this study was that species richness and abundance of carabids and

421 spiders were higher in forest patches adjacent to organic than in patches close to conventional

422 vineyards, irrespective of functional guilds. It should be noted that forest patches were usually

423 located below the vineyards. This result could be determined by a possible leaching of chemicals

424 and fertilizers coming from conventional systems and/or smaller forest patch areas surrounding

425 conventional vineyards. The possible leaching of chemicals may have caused arthropod mortality

426 and/or a decrease of food availability for predators such as spiders and carabids in forest patches

427 adjacent to conventional vineyards. Other drivers influencing the arthropod community in the forest

428 patches were characterized by habitat and landscape variables. In carabids, the flying macropterous

429 are strongly influenced by landscape features such as presence of bushes and patch richness,

430 showing the importance of the hedges for the maintenance of good disperses in the agricultural

431 landscape (Fischer et al., 2013), which may enhance the biological pest control for adjacent

432 agricultural crops via carabids' colonisation potential (Niemelä, 2001). Conversely, brachypterous

433 which have a limited dispersal abilities are mainly influenced by habitat variables and by the size of

434 forest patches (Pearce et al., 2005). However, the models ranked based on the AIC value showed

435 that in most cases species richness in carabids was mainly influenced by the farming system while

436 abundance of individuals responded to habitat/landscape variables. Moreover, our results showed

437 that spiders are strongly influenced by landscape heterogeneity and in particular by the presence of

438 grasslands (Lacasella et al., 2014).

439 Many studies have considered how landscape context in organic and conventional farms influences

440 arthropod communities (Schimdt et al., 2005; Purtauf et al., 2005), but much less consideration has

441 been devoted to evaluating the effects of farming systems on the communities of the surrounding

442 habitats and the spillover in the managed to natural direction (Blitzer et al., 2011).

443 Here, we evaluated both the effect of landscape context on arthropods sampled inside the vineyards,

444 and the effect of vineyard systems on the arthropod communities sampled outside the vineyards.

445 The preservation of forest patches surrounding the farmland is likely to be useful for biodiversity

446 conservation in all types of agro-ecosystems. In crop ecosystems, for instance, forest patches, field

447 margins and grasslands are important refuges for shelter, breeding and dispersal, as well as for

448 hibernation, especially for spring breeding carabids (Holland & Luff, 2000; Wamser et al., 2011;

449 Jonason et al., 2013).

5. Conclusions

Vineyard landscapes of north-western Italy (Langhe, Roero and Monferrato, in Piedmont region) are included among World Heritage Sites listed by UNESCO. These areas form a spectacular expanse of rolling hills where the various combinations of climate, cultivation techniques, type of graft and grape variety determine the development of a wide range of agro-ecosystems. Our results showed that organic farming systems enhance arthropod predators belonging to several functional guilds, and influence the diversity of carabids and spiders in adjacent forest patches as well. Therefore, although conventional systems may promote the diversity of macropterous carabids and specialist spiders, we suggest organic systems should take priority. Our conclusions are also supported by several general considerations. The presence of predator carabids and spiders in crops is particularly important because the control of herbivores depends on high predator densities (Landis et al., 2000; Symondson et al., 2002; Schmidt et al., 2003). The increase, or even the mere preservation of species richness and abundance of spider and carabid predator guilds through organic farming may improve natural pest control, contributing thereby to enhanced agricultural productivity (Östman et al., 2003). Furthermore, conventional farming systems can severely reduce the economic value of some ecosystem services in agriculture (supporting and regulating services, explained in Millennium Ecosystem Assessment, 2005), whereas organic practices may enhance their value (Sandhu et al., 2010). Finally, several studies have shown that organic agriculture enhances the nutritional value of plant foods themselves, the dry matter, the minerals and anti-oxidant micronutrients such as phenols and salicylic acid (Brandt and Mølgaard, 2001; Lairon, 2010).

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6. References

Aldighieri, B., Bonardi, L., Comolli, R., Conforto, A., Mariani, L., Mazzoleni, G., Rizzotti, T., 2006. La viticoltura in Valchiavenna (SO): il progetto Pianazzola. Boll. Della Soc. Geol. Ital. Vol. Spec. 17–27.

Batáry, P., Holzschuh, A., Orci, K.M., Samu, F., Tscharntke, T., 2012. Responses of plant, insect and spider biodiversity to local and landscape scale management intensity in cereal crops and grasslands. Agric. Ecosyst. Environ. 146, 130–136. doi:10.1016/j.agee.2011.10.018

Bengtsson, J., Ahnström, J., Weibull, A.C., 2005. The effects of organic agriculture on biodiversity and abundance: a meta-analysis. J. Appl. Ecol. 42, 261–269. doi:10.1111/j.1365-2664.2005.01005.x

Benton, T.G., Vickery, J.A., Wilson, J.D., 2003. Farmland biodiversity: is habitat heterogeneity the key? Trends Ecol. Evol. 18, 182–188. doi:10.1016/S0169-5347(03)00011-9

Boer, P.J.D., 1970. On the significance of dispersal power for populations of carabid-beetles (Coleoptera, Carabidae). Oecologia 4, 1–28. doi:10.1007/BF00390612

Blitzer, E.J., Dormann, C.F., Holzschuh, A., Klein, A.M., Rand, T.A., Tscharntke, T., 2012. Spillover of functionally important organisms between managed and natural habitats. Agriculture, Ecosystems & Environment, 146, 34-43

Brandmayr, P., Zetto, T., Pizzolotto, R., Casale, A., Vigna Taglianti, A., 2005. I Coleotteri Carabidi per la valutazione ambientale e la conservazione della biodiversità — Italiano, Manuale operativo. APAT, Roma.

496   Brandt, K., Mølgaard, J.P., 2001. Organic agriculture: does it enhance or reduce the nutritional

497   value of plant foods? J. Sci. Food Agric. 81, 924–931. doi:10.1002/jsfa.903

498   Bruggisser, O.T., Schmidt-Entling, M.H., Bacher, S., 2010. Effects of vineyard management on

499   biodiversity at three trophic levels. Biol. Conserv. 143, 1521–1528.

500   doi:10.1016/j.biocon.2010.03.034

501   Cardinale, B.J., Duffy, J.E., Gonzalez, A., Hooper, D.U., Perrings, C., Venail, P., Narwani, A.,

502   Mace, G.M., Tilman, D., Wardle, D.A., Kinzig, A.P., Daily, G.C., Loreau, M., Grace, J.B.,

503   Larigauderie, A., Srivastava, D.S., Naeem, S., 2012. Biodiversity loss and its impact on humanity.

504   Nature 486, 59–67. doi:10.1038/nature11148

505   Cardoso, P., Erwin, T.L., Borges, P.A.V., New, T.R., 2011. The seven impediments in invertebrate

506   conservation and how to overcome them. Biol. Conserv. 144, 2647–2655.

507   doi:10.1016/j.biocon.2011.07.024

508   Clark, M.S., Luna, J.M., Stone, N.D., Youngman, R.R., 1994. Generalist Predator Consumption of

509   Armyworm (Lepidoptera: Noctuidae) and Effect of Predator Removal on Damage in No-Till Corn.

510   Environ. Entomol. 23, 617–622.

511   Clough, Y., Kruess, A., Tscharntke, T., 2007. Organic versus conventional arable farming systems:

512   Functional grouping helps understand staphylinid response. Agric. Ecosyst. Environ. 118, 285–290.

513   doi:10.1016/j.agee.2006.05.028

514   Cole, L.J., McCracken, D.I., Dennis, P., Downie, I.S., Griffin, A.L., Foster, G.N., Murphy, K.J.,

515   Waterhouse, T., 2002. Relationships between agricultural management and ecological groups of

516   ground beetles (Coleoptera: Carabidae) on Scottish farmland. Agric. Ecosyst. Environ. 93, 323–

517   336. doi:10.1016/S0167-8809(01)00333-4

518   Costello, M., Daane, K.M., 2003. Spider and Leafhopper (Erythroneura spp.) Response to Vineyard

519   Ground Cover. Environ. Entomol. 32, 1085–1098.

520   Costello, M.J., Daane, K.M., 1998. Influence of ground cover on spider populations in a table grape

521   vineyard. Ecol. Entomol. 23, 33–40. doi:10.1046/j.1365-2311.1998.00108.x

522   Cots-Folch, R., Martínez-Casasnovas, J.A., Ramos, M.C., 2006. Land terracing for new vineyard

523   plantations in the north-eastern Spanish Mediterranean region: Landscape effects of the EU Council

524   Regulation policy for vineyards' restructuring. Agric. Ecosyst. Environ. 115, 88–96.

525   doi:10.1016/j.agee.2005.11.030

526   Crawley, M.J., 2002. Statistical Computing: An Introduction to Data Analysis using S-Plus. Wiley.

527   Di Giulio, M., Edwards, P.J., Meister, E., 2001. Enhancing insect diversity in agricultural

528   grasslands: the roles of management and landscape structure. J. Appl. Ecol. 38, 310–319.

529   doi:10.1046/j.1365-2664.2001.00605.x

530   Dauber, J., 2001. Ant communities of an agricultural landscape: Relationships to landscape

531   structure and land-use management, Ph.D. thesis, Justus Liebig- University of Giessen, Germany,

532   120 p

533   Díaz, S., Lavorel, S., Bello, F. de, Quétier, F., Grigulis, K., Robson, T.M., 2007. Incorporating plant

534   functional diversity effects in ecosystem service assessments. Proc. Natl. Acad. Sci. 104, 20684–

535   20689. doi:10.1073/pnas.0704716104

536   Duffy, J.E., 2008. Why biodiversity is important to the functioning of real-world ecosystems. Front.

537   Ecol. Environ. 7, 437–444. doi:10.1890/070195

538   Elston, D.A., Moss, R., Boulinier, T., Arrowsmith, C., Lambin, X., 2001. Analysis of aggregation, a

539   worked example: numbers of ticks on red grouse chicks. Parasitology 122, 563–569.

540 ESRI (Environmental Systems Research Institute), 2006. ArcGIS 9.2.

541 Fischer, C., Schlinkert, H., Ludwig, M., Holzschuh, A., Gallé, R., Tscharntke, T., Batáry, P., 2013.

542 The impact of hedge-forest connectivity and microhabitat conditions on spider and carabid beetle

543 assemblages in agricultural landscapes. J Insect Conserv 17, 1027–1038. doi:10.1007/s10841-013-

544 9586-4

545 Fountain, M.T., Brown, V.K., Gange, A.C., Symondson, W.O.C., Murray, P.J., 2007. The effects of

546 the insecticide chlorpyrifos on spider and Collembola communities. Pedobiologia 51, 147–158.

547 doi:10.1016/j.pedobi.2007.03.001

548 Fuller, R. J., Norton, L. R., Feber, R. E., Johnson, P. J., Chamberlain, D. E., Joys, A. C., Mathews,

549 F., Stuart, R.C., Townsend, M.C., Manley, W.J., Wolfe, M.S., Macdonald, D.W., Firbank, L. G.,

550 2005. Benefits of organic farming to biodiversity vary among taxa. Biology Lett, 1(4), 431-434.

551 doi: 10.1098/rsbl.2005.0357

552 Gliessman, S.R., 2000. Agroecosystem Sustainability: Developing Practical Strategies, 1 edition.

553 ed. CRC Press, Boca Raton, Fla.

554 Holland, J.M., Luff, M.L., 2000. The Effects of Agricultural Practices on Carabidae in Temperate

555 Agroecosystems. Integr. Pest Manag. Rev. 5, 109–129. doi:10.1023/A:1009619309424

556 IRPCM 2004 Phytoplasma/Spiroplasma Working Team – Phytoplasma Taxonomy Group

557 (IRPCM). 2004.

558 Isaia, M., Bona, F., Badino, G., 2006. Influence of Landscape Diversity and Agricultural Practices

559 on Spider Assemblage in Italian Vineyards of Langa Astigiana (Northwest Italy). Environ.

560 Entomol. 35, 297–307. doi:10.1603/0046-225X-35.2.297

561 Janetos, A.C., 1982. Foraging tactics of two guilds of web-spinning spiders. Behav. Ecol. Sociobiol.

562 10, 19–27. doi:10.1007/BF00296392

563   Jonason, D., Smith, H.G., Bengtsson, J., Birkhofer, K., 2013. Landscape simplification promotes

564   weed seed predation by carabid beetles (Coleoptera: Carabidae). Landsc. Ecol. 28, 487–494.

565   doi:10.1007/s10980-013-9848-2

566   Kaiser, H.F., 1958. The varimax criterion for analytic rotation in factor analysis. Psychometrika 23,

567   187–200. doi:10.1007/BF02289233

568   Kenny, G.J., Shao, J., 1992. An assessment of a latitude-temperature index for predicting climate

569   suitability for grapes in Europe. J. Hortic. Sci. 67, 239–246.

570   Kleijn, D., Rundlöf, M., Scheper, J., Smith, H.G., Tscharntke, T., 2011. Does conservation on

571   farmland contribute to halting the biodiversity decline? Trends Ecol. Evol. 26, 474–481.

572   doi:10.1016/j.tree.2011.05.009

573   Krauss, J., Gallenberger, I., Steffan-Dewenter, I., 2011. Decreased Functional Diversity and

574   Biological Pest Control in Conventional Compared to Organic Crop Fields. Plos One 6, e19502.

575   doi:10.1371/journal.pone.0019502

576   Kromp, B., 1999. Carabid beetles in sustainable agriculture: a review on pest control efficacy,

577   cultivation impacts and enhancement. Agric. Ecosyst. Environ. 74, 187–228. doi:10.1016/S0167-

578   8809(99)00037-7

579   Kruess, A., Tscharntke, T., 1994. Habitat Fragmentation, Species Loss, and Biological Control.

580   Science 264, 1581–1584. doi:10.1126/science.264.5165.1581

581   Lacasella, F., Gratton, C., Felici, S.D., Isaia, M., Zapparoli, M., Marta, S., Sbordoni, V., 2014.

582   Asymmetrical responses of forest and ‒beyond edge‖ arthropod communities across a forest–

583   grassland ecotone. Biodivers Conserv 1–19. doi:10.1007/s10531-014-0825-0

584   Lairon, D., 2010. Nutritional quality and safety of organic food. A review. Agron. Sustain. Dev. 30,

585   33–41. doi:10.1051/agro/2009019

586 Landis, D.A., Wratten, S.D., Gurr, G.M., 2000. Habitat Management to Conserve Natural Enemies

587 of Arthropod Pests in Agriculture. Annu. Rev. Entomol. 45, 175–201.

588 doi:10.1146/annurev.ento.45.1.175

589 Lobry de Bruyn, L.A., 1999. Ants as bioindicators of soil function in rural environments.

590 Agriculture, Ecosystems & Environment 74, 425–441. doi:10.1016/S0167-8809(99)00047-X

591 Mansour, F., 1987. Effect of pesticides on spiders occurring on apple and citrus in Israel.

592 Phytoparasitica 15, 43–50. doi:10.1007/BF02980518

593 Mansour, F., Nentwig, W., 1988. Effects of agrochemical residues on four spider taxa: Laboratory

594 methods for pesticide tests with web-building spiders. Phytoparasitica 16, 317–325.

595 doi:10.1007/BF02979507

596 Maracchi, G., Sirotenko, O., Bindi, M., 2005. Impacts of Present and Future Climate Variability on

597 Agriculture and Forestry in the Temperate Regions: Europe, in: Salinger, J., Sivakumar, M.V.K.,

598 Motha, R.P. (Eds.), Increasing Climate Variability and Change. Springer Netherlands, pp. 117–135.

599 Metzger, M.J., Schröter, D., Leemans, R., Cramer, W., 2008. A spatially explicit and quantitative

600 vulnerability assessment of ecosystem service change in Europe. Reg. Environ. Change 8, 91–107.

601 doi:10.1007/s10113-008-0044-x

602 Millennium Ecosystem Assessment, 2005. Millennium ecosystem assessment synthesis report.

603 Millennium Ecosystem Assessment.

604 Negro, M., Isaia, M., Palestrini, C., Rolando, A., 2009. The impact of forest ski-pistes on diversity

605 of ground-dwelling arthropods and small mammals in the Alps. Biodivers. Conserv. 18, 2799–2821.

606 doi:10.1007/s10531-009-9608-4

607 Niemelä, J., 2001. Carabid beetles (Coleoptera: Carabidae) and habitat fragmentation: a review. Eur

608 J Entomol 98:127–132.

609 Östman, Ö., Ekbom, B., Bengtsson, J., 2003. Yield increase attributable to aphid predation by

610 ground-living polyphagous natural enemies in spring barley in Sweden. Ecol. Econ. 45, 149–158.

611 doi:10.1016/S0921-8009(03)00007-7

612 Pearce, J.L., Venier, L.A., Eccles, G., Pedlar, J., McKenney, D., 2005. Habitat islands, forest edge

613 and spring-active invertebrate assemblages. Biodivers. Conserv. 14, 2949–2969.

614 Peel, M.C., Finlayson, B.L., McMahon, T.A., 2007. Updated world map of the Köppen-Geiger

615 climate classification. Hydrol Earth Syst Sci 11, 1633–1644. doi:10.5194/hess-11-1633-2007

616 Pekár, S., 1998. Effect of selective insecticides on the beneficial spider community of a pear

617 orchard in the Czech Republic. In Selden, P.A. (ed.) Proceedings of the 17th European Colloquium

618 of Arachnology, Edinburgh.

619 Pekár, S., 2004. Predatory behavior of two European ant-eating spiders (Araneae, Zodariidae). J.

620 Arachnol. 32 (1): 31-41.

621 Platnick, N., 2014. The World Spider Catalog, Version 14.5, American Museum of Natural History.

622 Power, A.G., 2010. Ecosystem services and agriculture: tradeoffs and synergies. Philos. Trans. R.

623 Soc. B Biol. Sci. 365, 2959–2971. doi:10.1098/rstb.2010.0143

624 Purtauf, T., Roschewitz, I., Dauber, J., Thies, C., Tscharntke, T., Wolters, V., 2005. Landscape

625 context of organic and conventional farms: Influences on carabid beetle diversity. Agric. Ecosyst.

626 Environ. 108, 165–174. doi:10.1016/j.agee.2005.01.005

627 R Development Core Team, 2013. R: A language and environment for statistical computing. R

628 Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-

629 project.org.

630   Rand, T.A., Tylianakis, J.M., Tscharntke, T., 2006. Spillover edge effects: the dispersal of

631   agriculturally subsidized insect natural enemies into adjacent natural habitats. Ecol. Lett. 9, 603–

632   614. doi:10.1111/j.1461-0248.2006.00911.x

633   Ribera, I., Dolédec, S., Downie, I.S., Foster, G.N., 2001. Effect of land disturbance and stress on

634   species traits of ground beetle assemblages. Ecology 82, 1112–1129. doi:10.1890/0012-

635   9658(2001)082[1112:EOLDAS]2.0.CO;2

636   Riechert, S.E., Lawrence, K., 1997. Test for predation effects of single versus multiple species of

637   generalist predators: spiders and their insect prey. Entomol. Exp. Appl. 84, 147–155.

638   doi:10.1046/j.1570-7458.1997.00209.x

639   Ripper, W.E., 1956. Effect of Pesticides on Balance of Arthropod Populations. Annual Review of

640   Entomology 1, 403–438. doi:10.1146/annurev.en.01.010156.002155

641   Roberts, D.W., 2012. labdsv: Ordination and Multivariate Analysis for Ecology. R package version

642   1.5-0. http://CRAN.R-project.org/package=labdsv

643   Sandhu, H.S., Wratten, S.D., Cullen, R., 2010. Organic agriculture and ecosystem services.

644   Environ. Sci. Policy 13, 1–7. doi:10.1016/j.envsci.2009.11.002

645   Schmidt, M.H., Lauer, A., Purtauf, T., Thies, C., Schaefer, M., Tscharntke, T., 2003. Relative

646   importance of predators and parasitoids for cereal aphid control. Proc. R. Soc. Lond. B Biol. Sci.

647   270, 1905–1909. doi:10.1098/rspb.2003.2469

648   Schmidt, M.H., Roschewitz, I., Thies, C., Tscharntke, T., 2005. Differential effects of landscape

649   and management on diversity and density of ground-dwelling farmland spiders. J. Appl. Ecol. 42,

650   281–287. doi:10.1111/j.1365-2664.2005.01014.x

651 Schultz, H., 2000. Climate change and viticulture: A European perspective on climatology, carbon

652 dioxide and UV-B effects. Aust. J. Grape Wine Res. 6, 2–12. doi:10.1111/j.1755-

653 0238.2000.tb00156.x

654 Snyder, W.E., Ives, A.R. Generalist Predators Disrupt Biological Control by a Specialist Parasitoid.

655 Ecology, 82 (3), 705-716

656 Stoate, C., Boatman, N.D., Borralho, R.J., Carvalho, C.R., Snoo, G.R. de, Eden, P., 2001.

657 Ecological impacts of arable intensification in Europe. J. Environ. Manage. 63, 337–365.

658 doi:10.1006/jema.2001.0473

659 Swift, M.J., Izac, A.-M.N., van Noordwijk, M., 2004. Biodiversity and ecosystem services in

660 agricultural landscapes—are we asking the right questions? Agric. Ecosyst. Environ. 104, 113–134.

661 doi:10.1016/j.agee.2004.01.013

662 Symondson, W.O.C., Sunderland, K.D., Greenstone, M.H., 2002. Can Generalist Predators Be

663 Effective Biocontrol Agents?. Annu. Rev. Entomol. 47, 561–594.

664 doi:10.1146/annurev.ento.47.091201.145240

665 Thomson, L.J., Hoffmann, A.A., 2007. Effects of ground cover (straw and compost) on the

666 abundance of natural enemies and soil macro invertebrates in vineyards. Agric. For. Entomol. 9,

667 173–179. doi:10.1111/j.1461-9563.2007.00322.x

668 Tilman, D., Cassman, K.G., Matson, P.A., Naylor, R., Polasky, S., 2002. Agricultural sustainability

669 and intensive production practices. Nature 418, 671–677. doi:10.1038/nature01014

670 Trivellone, V., Paltrinieri, L.P., Jermini, M., Moretti, M., 2012. Management pressure drives

671 leafhopper communities in vineyards in Southern Switzerland. Insect Conserv. Divers. 5, 75–85.

672 doi:10.1111/j.1752-4598.2011.00151.x

673   Vickery, J.A., Bradbury, R.B., Henderson, I.G., Eaton, M.A., Grice, P.V., 2004. The role of agri-

674   environment schemes and farm management practices in reversing the decline of farmland birds in

675   England. Biol. Conserv. 119, 19–39. doi:10.1016/j.biocon.2003.06.004

676   Vigna Taglianti, A., 2005. Checklist e corotipi delle specie di Carabidae della fauna italiana.

677   Appendice B. In: Brandmayr P., Zetto T. & Pizzolotto R. (a cura di): I Coleotteri Carabidi per la

678   valutazione ambientale e la conservazione della biodiversità. Manuale operativo. APAT, Manuali e

679   linee guida, 34, 186-225.

680   Wamser, S., Dauber, J., Birkhofer, K., Wolters, V., 2011. Delayed colonisation of arable fields by

681   spring breeding ground beetles (Coleoptera: Carabidae) in landscapes with a high availability of

682   hibernation sites. Agric. Ecosyst. Environ. 144, 235–240. doi:10.1016/j.agee.2011.08.019

683   Wicherek, S., 1991. Viticulture and soil erosion in the north of Parisian basin. Example: The mid

684   Aisne region. Z Geomorph Nf Suppl-Bd 83, 115–126.

685   Zrubecz, P., Toth, F., Nagy, A., 2008. Is Xysticus kochi (Araneae: Thomisidae) an efficient

686   indigenous biocontrol agent of Frankliniella occidentalis (Thysanoptera: Thripidae)? BioControl 53,

687   615–624. doi:10.1007/s10526-007-9100-6

688   Zuur, A., Ieno, E.N., Walker, N., Saveliev, A.A., Smith, G.M., 2009. Mixed effects models and

689   extensions in ecology with R. Springer.

690   **Fig. 1**. Average number of individuals of carabids sampled per pitfall, in each transect. Bars stand

691   for standard errors. OF: Forest patch transect close to organic vineyards; OE: Edges transect in

692   organic vineyards; OC: Core transect in organic vineyards; CF: Forest patch transect close to

693   conventional vineyards; CE: Edges transect in conventional vineyards; CC: Core transect in

694   conventional vineyards.

695
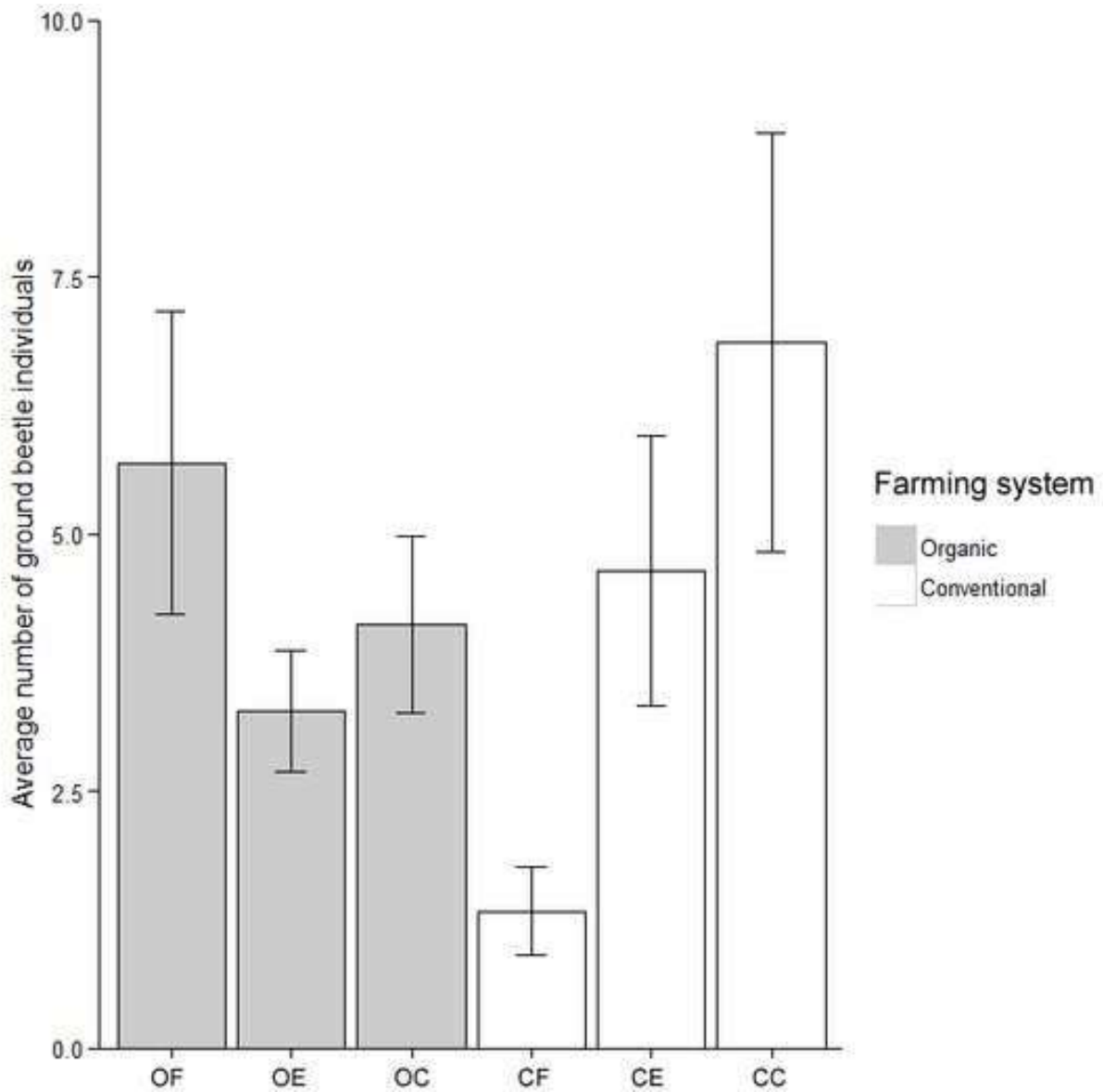
696
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698 **Fig. 2**. Average number of individuals of spiders sampled per pitfall, in each transect. Bars stand for

699 standard errors. OF: Forest patch transect close to organic vineyards; OE: Edges transect in organic

700 vineyards; OC: Core transect in organic vineyards; CF: Forest patch transect close to conventional

701 vineyards; CE: Edges transect in conventional vineyards; CC: Core transect in conventional

702 vineyards.

703 **Table 1**. Number of individuals and number of species (in brackets) of carabid and spider

704 functional guilds in organic and conventional vineyards, and in forest patches close to organic and

705 conventional vineyards.

706

707 **Table 2**. Results of Principal Component Analysis carried out on small scale landscape variables.

708 The highest loadings are given in bold type.

709

710 **Table 3a**. GLMM results of carabid species richness and abundance, in organic and conventional

711 vineyards. PC: principal component; SP: sampling period.

712

713 **Table 3b**. GLMM results of spider species richness and abundance, in organic and conventional

714 vineyards. PC: principal component; SP: sampling period.

715 **Appendix A** List of carabid species collected in each transect (core, edge, forest) of organic and

716 conventional vineyards. OF: Forest patch transect close to organic vineyards; OE: Edges transect in

717 organic vineyards; OC: Core transect in organic vineyards; CF: Forest patch transect close to

718 conventional vineyards; CE: Edges transect in conventional vineyards; CC: Core transect in

719 conventional vineyards. The functional guild of each species is specified (B: Brachypterous, M:

720 Macropterous).

721 **Appendix B**: List of spider species collected in each transect (core, edge, forest) of organic and

722 conventional vineyards. OF: Forest patch transect close to organic vineyards; OE: Edges transect in

723 organic vineyards; OC: Core transect in organic vineyards; CF: Forest patch transect close to

724 conventional vineyards; CE: Edges transect in conventional vineyards; CC: Core transect in
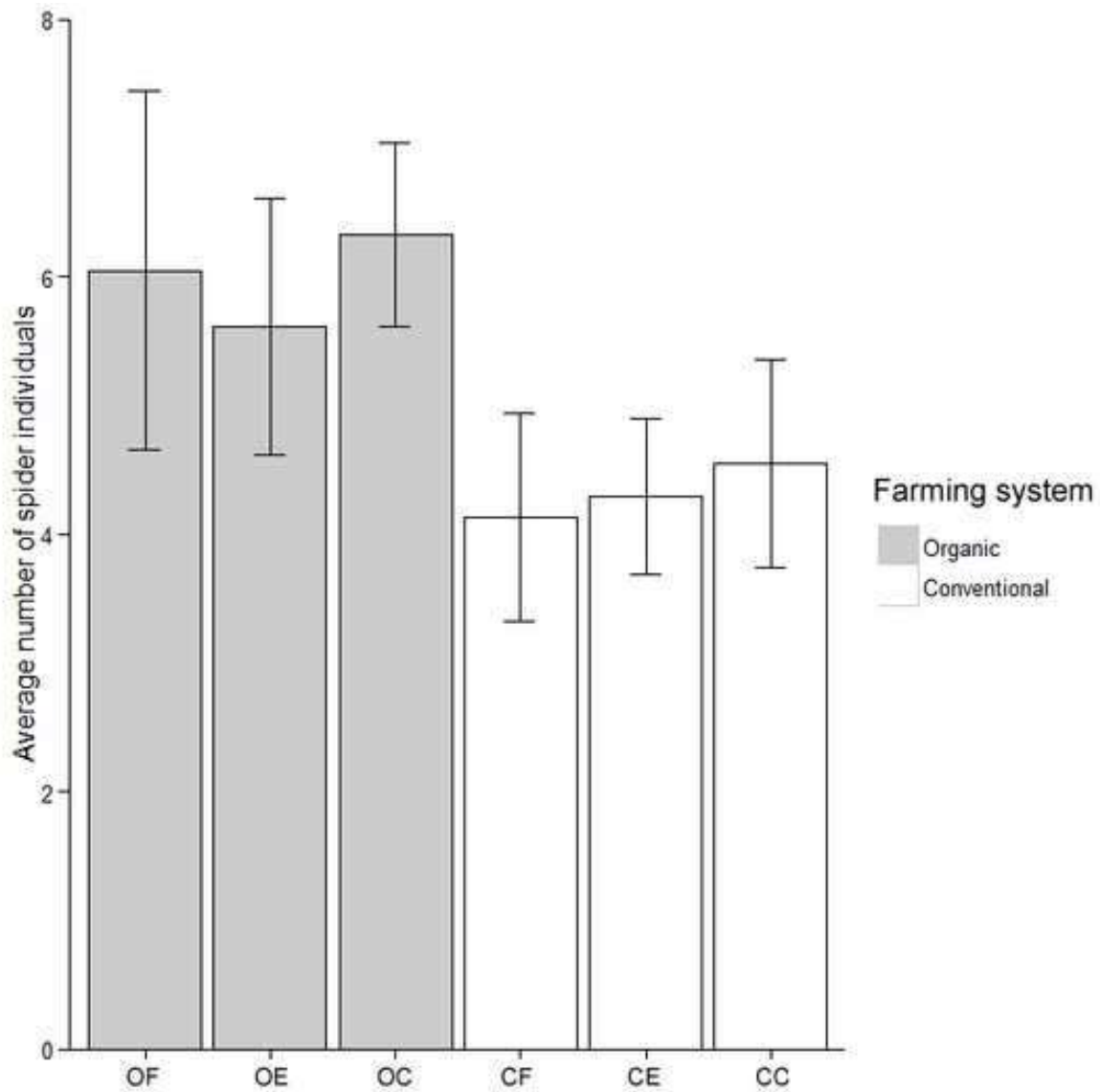
725 conventional vineyards. The functional guild of each species is specified (AH: Ambush hunters,

726 GH: Ground hunters, OH: Other hunters, SEW: Sensing web weavers, SHW: Sheet web weavers,

727 SP: Specialists, SPW: Space web weavers).

728 **Appendix C:** Univariate GLMM results of carabid species richness and abundance in forest patches

729 close to organic and conventional vineyards. PC: principal component; SP: sampling period.

730 **Appendix D:** Univariate GLMM results of spider species richness and abundance in forest patches

731 close to organic and conventional vineyards. PC: principal component; SP: sampling period.

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Table 1. Number of individuals and number of species (in brackets) of carabid and spider functional guilds in organic and conventional vineyards, and in forest patches close to organic and conventional vineyards.

Vineyards	ORGANIC VINEYARDS	CONVENTIONAL VINEYARDS	**Forest patches**	CLOSE TO ORGANIC	CLOSE TO CONVENTIONAL
Carabids			**Ground beetles**		
Brachypterous	292 (11)	194 (11)	Brachypterous	129 (7)	34 (5)
Macropterous	194 (36)	675 (27)	Macropterous	14 (6)	9 (6)
Spiders			**Spiders**		
Ambush hunters	57 (4)	25 (4)	Ambush hunters	6 (4)	3 (3)
Ground hunters	363 (36)	207 (37)	Ground hunters	60 (16)	54 (21)
Other hunters	45 (12)	12 (12)	Other hunters	13 (3)	7 (7)
Space web weavers	40 (4)	47 (7)	Space web weavers	2 (2)	13 (3)
Sheet web weavers	13 (2)	33 (2)	Sheet web weavers	15 (3)	14 (1)
Sensing web weavers	0	1 (1)	Sensing web weavers	0	0
Specialists	21 (2)	124 (3)	Specialists	25 (4)	4 (2)

Table 2. Results of Principal Component Analysis carried out on small scale landscape variables. The highest loadings are given in bold type.

LAND USE TYPE	PC1	PC2	PC3	PC4
Urban areas	0.351	0.502	**0.644**	0.014
Woodland areas	0.365	**-0.849**	-0.23	0.048
Uncultivated areas	0.028	-0.111	**0.894**	0.007
Hazelnut orchard areas	0.027	-0.06	0.028	**0.969**
Grassland areas	**0.757**	0.05	0.007	-0.05
Crops areas	**0.83**	0.292	-0.015	-0.213
Shrubland areas	**0.735**	-0.231	0.138	-0.291
Vineyard areas	**-0.908**	0.373	-0.01	-0.134
LPI	**-0.918**	0.256	-0.059	-0.169
Mean areas of patches	-0.74	-0.188	-0.203	-0.107
Patch Richness	0.699	0.013	**0.564**	0.051
Shannon Diversity Index	**0.92**	-0.167	0.279	0.118
Distance from woodland	0.053	**0.848**	-0.172	-0.031
Eigenvalues	5.612	2.116	1.757	1.15
Total variance %	43.166	16.281	13.514	8.847

Table 3a. GLMM results of carabid species richness and abundance, in organic and conventional vineyards.

PC: principal component; SP: sampling period.

CARABIDS				
Overall community species richness				
Fixed Factors	Estimate	Std. Error	z value	Pr(>|z|)
Intercept	0.689	0.171	4.018	***
Transect location-Core	0.246	0.098	2.491	*
PC2	-0.201	0.082	-2.503	*
SP 2	-1.257	0.131	-9.565	***
SP 3	-0.991	0.118	-8.356	***
Overall community abundance of individuals				
Fixed Factors	Estimate	Std. Error	z value	Pr(>|z|)
Intercept	1.183	0.268	4.42	***
Transect location-Core	0.355	0.175	2.025	*
PC2	-0.316	0.129	-2.45	*
SP 2	-1.857	0.211	-8.792	***
SP 3	-1.736	0.206	-8.422	***
Brachypterous				
Species richness				
Fixed Factors	Estimate	Std. Error	z value	Pr(>|z|)
Intercept	-0.375	0.182	-2.065	*
PC2	-0.209	0.091	-2.281	*
SP 2	-0.803	0.204	-3.944	***
SP 3	-0.772	0.202	-3.823	***
Abundance				
Fixed Factors	Estimate	Std. Error	z value	Pr(>|z|)
Intercept	-0.00142	0.324	0	0.997
PC2	-0.336	0.159	-2.11	*
Gradient-Core	-0.981	0.1743	5.627	***
SP 2	-1.359	0.266	-5.12	***
SP 3	-1.631	0.274	-3.823	***
Macropterous				
Species richness				
Fixed Factors	Estimate	Std. Error	z value	Pr(>|z|)
Intercept	0.115	0.215	0.54	0.591
Transect Location-Core	0.376	0.187	2.9	**
SP 2	-1.557	0.187	-8.33	***
SP 3	-1.101	0.155	-7.12	***
Abundance				
Fixed Factors	Estimate	Std. Error	z value	Pr(>|z|)
Intercept	-0.899	0.647	-1.39	0.165
System-Conventional	1.273	0.747	1.7	*
Transect Location-Core	0.549	0.229	2.39	*
Grass %	-0.01	0.007	-1.55	**
Grass height	0.063	0.0089	7.12	***
PC1	0.421	0.148	2.84	**
PC4	-0.655	0.111	-5.88	***
SP 2	-2.461	0.29	-8.48	***
SP 3	-1.782	0.233	-7.65	***

Table 3b. GLMM results of spider species richness and abundance, in organic and conventional vineyards.

PC: principal component; SP: sampling period.

SPIDERS				
Overall community specie richness				
Fixed Factors	Estimate	Std. Error	z value	Pr(>|z|)
Intercept	0.899	0.172	5.22	***
System-Conventional	-0.203	0.098	-2.07	*
Grass %	0.008	0.002	3.52	***
PC 3	0.114	0.054	2.11	*
SP 2	-0.43	0.117	-3.66	***
SP 3	-0.187	0.094	-1.98	*
Overall community abundance				
Fixed Factors	Estimate	Std. Error	z value	Pr(>|z|)
Intercept	1.5731	0.18	8.73	***
System-Conventional	-0.203	0.098	-2.07	*
Transect location-Core	0.138974	0.069813	3.52	*
Grass%	0.007301	0.001812	2.11	**
PC3	0.067	0.012	2.373	*
SP 2	-0.68	0.166	-4.11	***
SP 3	-0.19	0.13	-1.42	NS
Ambush hunters				
Species Richness				
Fixed Factors	Estimate	Std. Error	z value	Pr(>|z|)
Intercept	-0.694	0.254	-2.734	**
System-Conventional	-0.894	0.294	-3.042	**
SP 2	-1.7675	0.607	-2.909	**
SP 3	0.15	0.279	0.57	NS
Abundance				
Fixed Factors	Estimate	Std. Error	z value	Pr(>|z|)
Intercept	-1.579	0.552	-2.859	**
System-Conventional	0.451	0.673	0.67	NS
Grass %	0.018	0.008	2.422	*
Grass %: Systems (Conventional)	-0.025	0.01	-2.511	*
SP 2	-2.036	0.606	-3.359	***
SP 3	-0.025	0.01	-2.365	.
Ground hunters				
Species Richness				
Fixed Factors	Estimate	Std. Error	z value	Pr(>|z|)
Intercept	0.796	0.242	3.285	**
System-Conventional	-0.449	0.113	-3.972	***
Hgrass	0.027147	0.007	3.626	***
SP 2	-1.019	0.146	-6.989	***
SP 3	-1.056	0.141	-7.474	***
Abundance				
Fixed Factors	Estimate	Std. Error	z value	Pr(>|z|)
Intercept	0.952	0.294	3.238	**
System-Conventional	-0.615	0.149	-4.126	***
Hgrass	0.032	0.009	3.351	***
SP 2	-1.226	0.185	-6.624	***
SP 3	-1.206	0.174	-6.895	***
Other hunters				
Species Richness				
Fixed Factors	Estimate	Std. Error	z value	Pr(>|z|)
Intercept	-0.537	0.26	-2.066	*

Fixed Factors	Estimate	Std. Error	z value	Pr(>|z|)
System-Conventional	-0.512	0.25	-2.04	*
SP 2	-1.02	0.3697	-2.76	**
SP 3	-0.561	0.292	-1.922	NS

Abundance

Fixed Factors	Estimate	Std. Error	z value	Pr(>|z|)
Intercept	-1.646	0.53	-3.105	**
System-Conventional	-0.626	0.317	-1.979	*
Grass%	0.014	0.0064	2.28	*
SP 2	-1.031	0.445	-2.319	*
SP 3	-0.669	0.37	-1.81	NS

Sheet Web Weavers

Species Richness

Fixed Factors	Estimate	Std. Error	z value	Pr(>|z|)
Intercept	-2.29413	1.2525	-1.832	0.067
Hgrass	-0.06292	0.02755	-2.284	*

Abundance

Fixed Factors	Estimate	Std. Error	z value	Pr(>|z|)
Intercept	-2.20571	1.25809	-1.753	0.0796
Hgrass	-0.06319	0.02705	-2.336	*

Specialists

Species Richness

Fixed Factors	Estimate	Std. Error	z value	Pr(>|z|)
Intercept	-1.8954	0.4193	-4.521	***
System-Conventional	0.7933	0.2749	2.885	***

Abundance

Fixed Factors	Estimate	Std. Error	z value	Pr(>|z|)
Intercept	-2.718	0.583	-4.663	***
System-Conventional	1.258	0.37	3.399	***

Table 4. Indicator Values for functional guilds in organic and conventional vineyards and in forest patches close to organic and conventional vineyards.

	Functional Guilds	Organic vineyards	Conventional vineyards	pval	Forest patches - Organic	Forest patches - Conventional	pval
Carabids	Brachypterous	**42.15**	**28.36**	**	**65.46**	**23.91**	**
	Macropterous	33.48	41.21	NS	5.31	26.72	NS
Spiders	Ambush Hunters	**28.02**	**4.56**	***	11.03	4.11	NS
	Ground Hunters	**57.76**	**23.12**	***	45.95	37.18	NS
	Other Hunters	20.96	8.52	NS	21.29	19.19	NS
	Sensing Web Spiders	0	1.09	NS	NA	NA	NA
	Sheet Web Weavers	2.52	9.72	NS	16.94	16.85	NS
	Space Web Weavers	14.08	16.15	NS	1.59	23.15	NS
	Specialists	**2.87**	**29.06**	***	**36.81**	**1.72**	*