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5 **Use of taxonomic and chorological diversity to highlight the conservation**
6 **value of insect communities in a Mediterranean coastal area: the carabid**
7 **beetles (Coleoptera, Carabidae) of Castelporziano (Central Italy)**

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17
18 **Abstract**

19 We used the carabid beetles inhabiting the Castelporziano Presidential Estate reserve (a
20 natural reserve of some 60 hectares facing the Tyrrhenian sea) to show how chorotypes (i.e.
21 species distribution types) can be used to characterize insect communities. We compared
22 three forms of diversity: species richness, Clarke and Warwick taxonomic diversity, and
23 chorological composition. Chorological composition was modelled using Menhinick,
24 Margalef, Shannon, and Brillouin diversity, Simpson dominance, Pielou evenness, and
25 Buzas and Gibson evenness. Variations in carabid species richness, chorological
26 composition (richness, diversity, dominance and evenness) and taxonomic diversity among
27 biotopes followed different patterns thus providing complementary, not redundant
28 information. Beach, dunes, high maquis, and oak forest were biotopes with low species
29 richness, whereas wet woodlands, mixed forest, wet zones and open areas have high
30 species richness. Low maquis had an intermediate position. This subdivision is
31 substantially confirmed by indices of chorological composition. However, in contrast with
32 large variations in diversity indices, evenness was substantially similar, and relatively high
33 in all biotopes, even those with very small numbers of species. Taxonomic diversity was

34 also similar among biotopes, being however small in oak forests and open areas. When
35 species richness, chorological diversity and taxonomic diversity were used to calculate an
36 index of overall conservation interest, the most important biotopes resulted to be wet zones,
37 wet woodlands, open areas and mixed forest. These results clearly indicate that the carabid
38 communities with high conservation values are those associated with humid environments.
39 This is consistent with the hypothesis that most of the carabids species occurring in the
40 study area are hygrophilous elements, associated with wetlands, which shifted their range
41 southwards during the glacials, and which form a relict component of the carabid fauna of
42 coastal areas.

43

44 **Key words:** Biogeography; Chorotypes; Coastal environments; Conservation; Diversity;
45 Evenness; Ground beetles

46

47 **1. Introduction**

48

49 Structure of animal communities is typically characterized in terms of species diversity,
50 dominance and evenness by using indices based on species abundance obtained from
51 standardized sampling procedures (Magurran 1988, 2003; Hayek and Buzas 2010). This is
52 however problematic for hyperdiverse animal groups, whose communities include species
53 that may have very different ecological characteristics and, hence, require different
54 sampling techniques. This situation is common among insects (Samways et al. 2010). For
55 example, the same insect community, in the sense of a taxocoenosis, may include ground
56 dwelling and arboreal species, which obviously require different sampling methods.
57 Moreover, each sampling method is subject to possible biases towards certain species. In
58 the case of ground dwelling beetles, for example, a common sampling technique is based
59 on the use of pitfall traps (Kotze et al. 2011). Pitfall traps are probably the best method to
60 sample ground dwelling beetles, at least to obtain standardized measures of richness and
61 abundance (Samways et al. 2010). However, it is known that abundance data obtained from
62 these traps can be biased by a number of factors, including differences in species mobility
63 (with more active species being captured in larger numbers) and preference or repulsion for
64 certain substances used to attract and conserve the insects (Thomas et al. 1977; Morrill et
65 al. 1990; Samways et al. 2010). Moreover, pitfall traps are not adequate to obtain
66 abundance data for species that do not live on the ground, such as, for example, arboreal
67 species (Woodcock 2005). Finally, in many contexts, quantitative sampling may be
68 difficult to perform because of various constraints, from logistic to economic. Thus, the
69 most commonly available, and sometimes the only possible, community parameter is
70 species richness, i.e. the number of species that compose a community (Magurran 1988,
71 2003; Hayek and Buzas 2010).

72 Estimates of species richness can be obtained in a number of ways and depend on
73 sampling effort (Gotelli and Colwell 2011). However, in many situations, sampling effort is
74 unknown and species richness is obtained by local species inventories. It is generally
75 difficult to evaluate how complete are these species inventories, but for small areas and
76 well known organisms they are usually assumed to be fairly complete (Guralnick and Van
77 Cleve 2005). In such circumstances, species richness is not the only diversity measure that
78 can be obtained from species lists. Species identity conveys a lot of information that can be
79 used to obtain measures of diversity. First of all, if phylogenetic relationships are known,
80 measures of phylogenetic diversity can be calculated (Faith 1992; Rodrigues and Gaston

81 2002; Cardoso et al. 2014). Although availability of phylogenetic reconstructions is rapidly
82 increasing thanks to the widespread use of molecular techniques, phylogenetic
83 reconstructions may still be unavailable. In these cases, taxonomic relationships, which are
84 frequently assumed as a good surrogate of phylogenetic relationships (Ulrich and Fattorini
85 2013), can be used to obtain measures of taxonomic diversity. Since species taxonomy is
86 usually unambiguously defined (there are only relatively rare cases of species of
87 controversial position) and always known due to the hierarchical system of biological
88 classification, indices of taxonomic diversity (or distinctness) are easy to calculate.
89 Moreover, taxonomic diversity is virtually independent from sampling effort (Magurran
90 2003) and it is considered to be a better indicator of anthropogenic perturbations on
91 communities than species richness, which is more prone to be affected by variation in
92 natural environmental factors (e.g., habitat heterogeneity) (Heino et al. 2005). A third type
93 of diversity measures that can be obtained from species identity is functional diversity
94 (Flynn et al. 2011; Purschke et al. 2013; Cardoso et al. 2014). These measures are aimed at
95 reflecting variability in ecologically important traits among species. All these three types of
96 diversity (phylogenetic, taxonomic and functional) have received increasing attention in the
97 last years (Cardoso et al. 2014). However, there is another type of diversity that can be
98 obtained from species identity and which has been substantially unexplored: the
99 biogeographical diversity.

100 In biogeographical studies, the simplest way to describe species ranges is the use of
101 standardized categories, known as chorotypes (Vigna Taglianti et al. 1999; Fattorini and
102 Fowles 2005). Species with similar distributions are assigned to the same chorotype.
103 Similarly to other methods used to identify recurrent patterns (Fattorini 2007a), chorotype
104 analysis is a purely phenomenological approach based only on the contemporary similarity
105 of the species ranges (Fattorini and Fowles 2005). In fact, the current geographical
106 distribution of species is a reflection of both historical processes (i.e. vicariance, dispersal
107 and extinction phenomena that moulded species distribution in the past) and current
108 ecological constraints (a species cannot be found in an area that cannot be reached or that
109 has unfavourable ecological conditions). Species that belong to the same chorotype may
110 have acquired a similar geographical distribution because of a variety of reasons, and may
111 be, in fact, biogeographically very different. However, it is obvious that species belonging
112 to different chorotypes underwent very different histories and/or have very different
113 ecological characteristics. Thus, the frequency distribution of the various chorotypes shown

114 by the species composing a community can be used to express its biogeographical
115 diversity.

116 The idea of using chorotypes to express biogeographical diversity (Fattorini, 2007b)
117 has been recently used to compare faunas of various regions and to study variations in
118 biogeographical composition along an elevational gradient at a regional level (Fattorini
119 2013). In the present paper we explore the possibility of using chorological diversity at
120 community level. For this, we used a hyperdiverse group of insects in a complex ecomosaic
121 including a variety of landscape-soil units: the carabid beetles (Coleoptera Carabidae) of
122 Castelporziano reserve, a large and well preserved Tyrrhenian coastal area of high
123 conservation concern.

124 Carabid beetle are one of the most diversified families of Coleoptera, including about
125 40,000 species worldwide and about 1300 species in Italy (Vigna Taglianti 2005), and are
126 considered excellent models for biogeographical purposes (Vigna Taglianti, 1998; Casale
127 and Vigna Taglianti, 1999). Carabids represent a conspicuous faunal component of coastal
128 areas in the Mediterranean region (e.g., Vigna Taglianti and Fattorini, 2002), where they
129 can be found in virtually all types of biotopes, such as beach-dune systems, maquis,
130 garrigues, prairies, wetlands and woodlands. These ecological characteristics make carabid
131 beetles excellent model organisms for ecological and biogeographical researches in
132 Mediterranean coastal areas, where a mosaic of vegetation types generally occurs.

133 The protected area of Castelporziano is a well preserved Tyrrhenian coastal area with
134 highly diversified vegetation setting, including psammophilous plant associations, maquis,
135 oak forests, hygrophilous forests and steppe areas. This complex vegetation obviously
136 offers a number of habitats for insects with different ecological preferences.

137 Taking advantage of data collected during a long term project of carabid inventorying
138 and monitoring at local and regional level, we were able to use virtually complete species
139 lists from all main biotopes of Castelporziano (Vigna Taglianti et al. 2001, 2007).
140 Moreover, the overall distribution of all carabid species occurring in the study area is
141 sufficiently known to unambiguously assign them to chorotypes. Finally, taxonomy of
142 carabid beetles is considered sufficiently stable. This allowed us to calculate taxonomic
143 diversity of carabid communities.

144 In particular, in this study we used the distribution of carabid beetles through the
145 various biotopes occurring in the study area to compare three forms of diversity: species
146 richness, taxonomic and chorological diversity. This exercise allowed us not only to
147 explore the feasibility of the use of chorotypes to express community diversity, but also to

148 propose some conservation inferences based on the use of species richness in association
149 with taxonomic and chorological diversity. Conservationists use various measures of
150 biological diversity to identify priority biotopes or areas from local to global scale. The
151 most commonly used measure is simply species richness (Gaston and Spicer 2004;
152 Samways 2005; Dickman et al. 2007). When abundance data are available, conservationists
153 can use values of diversity indices that take into consideration the number of sampled
154 individuals as criteria for measuring conservation value of areas (Pullin 2002; Van Dyke
155 2008; Samways et al. 2010; Chiarucci et al. 2011). This approach is, however, frequently
156 hampered by the aforementioned difficulties in obtaining quantitative data. We will show
157 here how a diversity index based on species distribution can also represent an additional
158 tool in conservation biology studies. Finally, from a more strict biogeographical
159 perspective, we used chorological analysis to test the hypothesis that the wetland species
160 inhabiting the study area originated from populations that shifted their range southwards
161 during Pleistocene glacials (see Fattorini and Vigna 2002).

162

163 **2 Methods**

164 The study area (Castelporziano Presidential Estate) is a natural reserve located about 20 km
165 South of Rome (Central Italy). It covers an area of *ca* 6086 hectares. The area lies on the
166 sandy soils of the mouths of the Tevere River. Beside a pine (*Pinus pinea*) forest, and a
167 man-made mesophilous forest, the forest vegetation of this area is prevalently represented
168 by fragments of oak (*Quercus ilex*) woods, with some patches occupied by *Q. suber* and *Q.*
169 *robur* woods. Temporary and permanent ponds, with associated vegetation types, are
170 widely scattered through the entire area. Along the coast, shrubby sclerophyllous
171 associations and dune vegetation occur.

172 As a whole, on the basis of vegetation setting and soil composition (cf. Della Rocca
173 et al. 2001; Fattorini et al. 2015), the following main biotopes can be recognised: (1) beach,
174 (2) dunes, (3) low maquis, (4) high maquis, (5) wetlands, (6) natural (oak) forests, (7) man-
175 made (mesophilous) forests, (8) steppes and cultivated plots (open areas). To compare the
176 carabid communities associated with the aforementioned biotopes, a matrix of species
177 presence–absence in each biotope was compiled using data presented in Vigna Taglianti et
178 al. (2001, 2007) (Table 1). These data included materials collected by several
179 entomologists, especially between 1983 and 2001, with a variety of techniques, including
180 the use of pitfall traps, light traps, Malaise traps, hand searching and sieving. Most of data
181 were collected in the period 1994 – 2001, with a few predating the 1970s.

182 Since we used data also gathered from old sampling, it is possible that species
183 particularly sensitive to anthropogenic alteration have gone extinct in the meantime (see
184 Brandmayr et al. 2009). However, it is difficult to establish if the lack of records of certain
185 species in recent years are due to true local extinction or simply undersampling.
186 Emblematic is the case of *Lebia scapularis*, a species cited from the study area by
187 Magistretti in 1965, and found again only 2005, when it collected for the second time by
188 using a light trap. This indicates that even species not collected in recent times can be
189 actually present. However, to take into account the possibility that some species have gone
190 extinct, we considered as potentially extinct all species for which we do not know records
191 after the 1960s. This led to the identification of the following six species as potentially
192 extinct: *Calosoma inquisitor*, *Carabus coriaceus*, *Eurynebria complanata*, *Ocydromus*
193 *callosus*, *Amara apricaria*, *Epomis dejeani*. We conducted all analyses both including and
194 excluding these species. Since we obtained virtually identical results., only results obtained
195 without these possibly extinct species are presented.

196 We assigned each species to a chorotype using the scheme presented in Vigna
197 Taglianti et al. (1999) (Table 1). Chorotype assignment and species taxonomy (species,
198 genus, tribe, and subfamily) followed Vigna Taglianti (2005), with a few adjustments due
199 to recent advancements in carabid taxonomy.

200 Species richness was calculated as the total number of species recorded from each
201 biotope.

202 Taxonomic diversity was calculated using the method proposed by Clarke and
203 Warwick (1998), which measures the taxonomic relatedness of species in a community.
204 Clarke and Warwick (1998) proposed two different formulations to express taxonomic
205 relatedness, referred to as “taxonomic diversity” and “taxonomic distinctness”,
206 respectively. Both indices can be used with both species abundance and presence–absence
207 data. When applied to species presence–absence data, “taxonomic diversity” and
208 “taxonomic distinctness” reduce to a simpler form that expresses taxonomic relatedness by
209 defining the path length along the taxonomic hierarchy of each species pair in the
210 community and then averaging across all species pairs. Thus, for a presence–absence
211 matrix, taxonomic diversity (TD) can be calculated as

212

$$213 \quad TD = \frac{\sum \sum_{i < j} \omega_{ij}}{s(s-1)/2}$$

214

215 where ω_{ij} is the weight given to the path length linking species i and j in the
216 taxonomy, and s is the number of species present. This index thus describes the average
217 path length between any two randomly chosen species present in the community (Clarke
218 and Warwick 1998; Rogers et al. 1999). Confidence intervals were computed from 200
219 random replicates taken from the pooled data set (all landscape units).

220 To express chorological diversity we applied various indices of diversity commonly
221 adopted in community ecology by using the number of species belonging to a given
222 chorotype instead of species abundances. Namely, we applied the following indices of
223 diversity: Menhinick richness, Margalef richness, Shannon entropy, Brillouin diversity,
224 Simpson dominance (which can be converted to a measure as diversity as 1 – dominance),
225 Pielou evenness, and Buzas and Gibson evenness. These indices can be applied to any sort
226 of objects, and are particularly well known in the context of community ecology to quantify
227 how individuals are distributed among species (Magurran 1988, 2003). In our context,
228 these indices express chorotype frequencies within communities.

229 Menhinick's richness was calculated as $R_{Me} = \frac{C}{\sqrt{n}}$
230 and Margalef's richness was calculated as $R_{Ma} = \frac{(C-1)}{\ln(n)}$,

231 where C was the number of chorotypes, and n was the total number of species of all
232 chorotypes. Both indices express species richness “corrected” for sampling effort.

234 Shannon entropy was calculated as:

$$235 H' = -\sum \frac{n_i}{n} \ln\left(\frac{n_i}{n}\right)$$

236 and Brillouin index was calculated as

$$237 H = \frac{\ln(n!) - \sum_i \ln(n_i!)}{n}$$

238 where n_i was number of species belonging to chorotype i , and n was the total number of
239 species.

240 Both indices express community heterogeneity in terms of information. H' varies from 0
241 for a community including only one chorotype to high values for communities including
242 many chorotypes, each with a similar number of species. Shannon index is considered more
243 appropriate to estimate the diversity of large communities that have been “sampled” but
244 might be not completely censused, whereas Brillouin index is more appropriate for fully
245 censused communities (Pielou 1975). For this reason, H is also considered more appropriate
246 than H' when the randomness of a sample cannot be guaranteed.

247 Simpson dominance was calculated as:

$$248 \quad D = \sum \left(\frac{n_i}{n} \right)^2 .$$

249 D ranges from 0 (all chorotypes are equally represented) to 1 (one chorotype dominates the
250 carabid community completely).

251 Finally, Pielou evenness was calculated as:

$$252 \quad J = H' / \ln C$$

253 and Buzas and Gibson evenness as:

$$254 \quad E = e^{H'} / C.$$

255 For simplicity, we will collectively refer to Menhinick richness, Margalef richness,
256 Shannon entropy and Brillouin diversity as indices of diversity and use “richness” to
257 indicate species richness.

258 Spearman non parametric correlation coefficients (r_s) were used to test correlations
259 between all the aforementioned indices, with significance set at $P < 0.05$. All indices were
260 calculated using the software PAST 2.17 (Hammer et al. 2001).

261 To obtain an overall evaluation of biotope importance for carabid beetles, we
262 adopted the following approach (Figure 1). We transformed values of chorological indices
263 into the respective ranks (with Simpson’s dominance being transformed into diversity).
264 Then we averaged these ranks to obtain for each biotope a synthetic index (which we will
265 refer to as “Overall Chorological Index, OCI”) by calculating the arithmetic mean of these
266 rank values . Values of OCI index were then ranked. Values of species richness and
267 taxonomic diversity were also ranked. Finally, we averaged the ranks of the OCI index
268 values and those of species richness and taxonomic diversity to obtain an index of
269 “Conservation Value”. The rationale is that communities with more species, higher
270 chorological diversity and evenness, higher taxonomic diversity and lower chorological
271 dominance are considered to have potentially higher conservation interest. Recently,
272 Pizzolotto and Brandmayr (2014) proposed an index of biogeographical peculiarity also
273 based on species distribution. However, this index implies that chorological categories are
274 weighted according to their importance, with endemics receiving the highest scores (a
275 procedure which has elements of subjectivity) and can be accurately applied only to areas
276 with a complete knowledge of the biota in question (a condition that can be hardly meet in
277 highly diversified biotopes) since a unique new record of an endemic species can change

278 the score. Our approach does not require that chorotypes are weighted and the use of
279 indices that are specifically designed to work with “sampled” instead of “completely
280 censused” communities, such as the Shannon index, makes it relatively robust against
281 possibly incomplete sampling.

282

283

284 **3 Results**

285 The carabid beetle fauna of Castelporziano includes 179 species (six of which possibly
286 extinct), i.e. *ca* 13% of the Italian fauna. Carabid species richness varied considerably
287 among habitats (Figure 2). The lowest value in carabid richness was recorded for the beach,
288 where only three species were found. Very low richness values (6-7 species) were also
289 recorded for the dune, the high maquis, and the oak forest. Low maquis and mixed forests
290 showed relatively high numbers of species (20 and 27, respectively). Higher species
291 richness values were recorded from wet woodlands (57 species), wet zones (87) and open
292 areas (68).

293 When communities are compared using taxonomic diversity, observed diversity
294 values were relatively similar and within the confidence intervals, except for the
295 communities of the oak forest and open areas, which had lower taxonomic diversity values
296 than expected (Figure 3). Taxonomic diversity was not correlated with species richness (r_s
297 = -0.109, $P > 0.05$).

298 Shannon, Brillouin and Margaleff indices (Figure 4a) gave strongly correlated
299 results ($0.933 < r_s = 1$, $P < 0.001$). These indices were also correlated with species richness
300 ($0.854 < r_s < 0.946$, $0.001 < P < 0.01$). By contrast, Menhinick index was not correlated
301 with other diversity indices ($0.350 < r_s < 0.433$, $P > 0.05$) (Figure 4a). Menhinick index
302 was also not correlated with species richness ($r_s = 0.293$, $P > 0.05$). Pielou evenness was
303 correlated with Buzas and Gibson evenness ($r_s = 0.748$, $P < 0.05$) (Figure 4b). Either Pielou
304 evenness neither Buzas and Gibson evenness were correlated with the aforementioned
305 indices of diversity ($0.075 < r_s < 0.661$ (absolute values), $P > 0.05$). Species richness was
306 negatively correlated with Buzas and Gibson evenness ($r_s = -0.828$, $P < 0.05$), but not with
307 Pielou evenness ($r_s = -0.340$, $P > 0.05$).

308 Simpson dominance (Figure 4c) was negatively correlated with Shannon entropy (r_s
309 = -0.971, $P < 0.001$), Brillouin diversity ($r_s = -0.971$, $P < 0.001$), Margaleff richness ($r_s = -$
310 0.979, $P < 0.001$), and species richness ($r_s = -0.887$, $P < 0.01$).

311 Number of chorotypes (Figure 4a) was positively correlated with species richness
312 ($r_s = 0.958$, $P < 0.001$), Shannon entropy, Brillouin diversity, and Margaleff richness
313 ($0.941 < r_s < 0.992$, $P < 0.001$). Number of chorotypes were negatively correlated with
314 Simpson dominance ($r_s = -0.958$, $P < 0.001$) and Buzas and Gibson evenness ($r_s = -0.700$,
315 $P < 0.001$).

316 In general, diversity indices attained high values in the low maquis, wet woodlands,
317 mixed forests, wet forests and open areas, whereas the beach, dune, high maquis and oak
318 forest were characterized by low diversity values (Figure 4a). The most remarkable
319 exception was Menhinick index, which gave a relatively high value in the oak forest.
320 Where diversity was high, dominance was low (Figure 4b). Evenness had low variation
321 among biotopes, reaching the highest values in the poorest communities (Figure 4c).

322 Averaging ranks of the various chorological indices, the obtained Overall
323 Chorological Index highlighted the importance of wet zones (highest value, OCI = 6.688),
324 followed by open areas (OCI = 6.438), mixed forest (OCI = 6.250) and wet woodlands
325 (OCI = 6.125) (Figure 5). When ranks of OCI values were averaged with those of species
326 richness and taxonomic distinctness, the resulting Conservation Value Index (CVI)
327 prioritized again wet zones (highest value, CVI = 8.333), followed by wet woodlands (CVI
328 = 6.333), and open areas and mixed forest (CVI = 6.00 in both cases).

329 An analysis of endemism levels revealed a high incidence of Italian endemics in
330 the mixed forest (about 60% of the species) (Figure 6).

331

332 **4 Discussion**

333 In general, variations in carabid species richness, chorological composition (richness,
334 diversity, dominance and evenness) and taxonomic diversity among biotopes followed
335 different patterns. Based only on species richness, the studied biotopes might be divided
336 into two groups: beach, dunes, high maquis, and oak forests were biotopes with low
337 richness (less than 20 species: median value), whereas wet woodlands, mixed forests, wet
338 zones and open areas have high richness (28-87 species). Low maquis (20 species) had an
339 intermediate position. This subdivision is substantially confirmed by indices of
340 chorological composition, but the low maquis was found to have a high dominance. In
341 contrast with large variation in diversity indices, evenness was substantially similar, and
342 relatively high in all biotopes, even those with very small numbers of species. Taxonomic
343 diversity was also similar among biotopes, being however small in oak forests and open
344 areas. Thus, richness, chorological composition and taxonomic diversity provided

345 complementary, not redundant information. Taken together, all these indices may help to
346 understand community composition and to evaluate the conservation importance of carabid
347 assemblages associated with the various biotopes. Carabids are typically geophilous and
348 hygrophilous predaceous beetles, thus being speciose in wetlands and open areas with
349 ponds, but poorly represented in dry habitats. However, focusing only on species richness
350 might lead to overlook other, important aspects of community complexity.

351 With only three species (plus an extinct one), the beach was identified as the poorest
352 biotope. However, this biotope host very specialised and sometimes threatened species.
353 Among the species found on the beach, *Eurynebria complanta* has not been recorded after
354 the 60s and it is probably extinct along all coasts of Latium (Vigna Taglianti et al. 2001),
355 whereas *Parallelomorphus laevigatus*, a species strictly linked to the beach habitat, and
356 which feeds on talitrid amphipods, is still widespread. This biotope showed low values of
357 chorological diversity for most of the used indices. However, evenness was high. This is a
358 reflection of the fact that there are few chorotypes, but each species belong to a different
359 chorotype and all chorotypes have identical frequencies. The carabid community inhabiting
360 the beach is also taxonomically very diversified. Thus, although the beach is not a
361 favourable habitat for carabids and hosts few species, other community parameters indicate
362 that this community is very peculiar. Moreover, two (*Calomera littoralis* and *P. laevigatus*)
363 of the three species inhabiting this biotope are likely imperilled in Italy.

364 Similarly to the beach community, the carabid species inhabiting the dune form a
365 small, but taxonomically highly diversified community. With respect to the beach
366 community, the dune community has lower evenness and higher dominance. This indicates
367 that, although the species inhabiting the dune are taxonomically diversified, they tend to be
368 chorologically less diversified than the species inhabiting the beach. In fact, both
369 communities host the same number of chorotypes, but evenness was lower for the dune
370 community because of the dominance of European-Mediterranean species (50% of
371 chorotypes), among which one species, *Cryptophonus melancholicus*, is strictly associated
372 with the dune habitat. Out of the six species recorded from this biotope, *C. littoralis* and
373 *Scarites buparius* are two species of high conservation concern.

374 Compared with the beach-dune system, the low maquis showed a low taxonomic
375 diversity, but higher values of richness and diversity, and a very low dominance.
376 Interestingly, the adjacent high maquis showed a taxonomic diversity similar to that of the
377 low maquis, but lower values of species richness and chorological diversity, and a very
378 high dominance. This suggests that the transitional character of the low maquis, whose

379 vegetation is intermediate between those of the beach-dune system and the high maquis,
380 favours the occurrence of eurytopic carabid species that enhance the diversity of this
381 biotopes, which, however, does not hosts stenotopic species. Thus, both low and high
382 maquis appear to be biotopes of moderate conservation value for carabid beetles, as also
383 found, on very different basis, for the tenebrionid beetles (Fattorini et al. 2015).

384 The wet woodland was characterised by very high values of species richness and
385 number of chorotypes, which can be explained by the high incidence of mesophilous and
386 hygrophilous species typically found among carabids (e.g., hydrophiles *sensu* Darlington
387 1971; Casale and Vigna Taglianti 1999). Most probably, such species largely colonised
388 Italian coastal areas during Pleistocene glaciations, as a consequence of a colder climate
389 that favoured the dispersal of mesophilous species from northern and inland regions to
390 southern and coastal areas. When the climate became drier and warmer, these species were
391 forced to assume more northern distributions. However, some populations were able to
392 survive in areas where favourable habitats (such as wetlands with mesophilous vegetation)
393 persisted (Fattorini and Vigna Taglianti 2002). In addition to this mesophilous and
394 hygrophilous component (represented by species such as *Carabus granulatus*, *C. italicus*,
395 *Pterostichus nigrum*, *P. anthracinum*, *P. gracilis*, *P. oenotrius*, *P. aterrimus*, *Anthracus*
396 *quarnerensis*, *A. transvesalis*, and *Badister dilatatus*), the wet woodland host many
397 eurytopic species that further increase its diversity.

398 By contrast, the oak forest resulted to have few species, a very low taxonomic
399 diversity and low values of chorological diversity for most of the used indices. This
400 suggests that this biotope is not particularly favourable for carabids, as also indicated by the
401 lack of stenotopic species (cf. Fattorini and Vigna Taglianti 2002).

402 Mixed forests and wet zones had relatively high values of taxonomic diversity, high
403 values of chorological diversity for most of the indices, relatively high values of evenness,
404 and low dominance. In particular, wet zones were the biotope with the highest number of
405 species and chorotypes. Thus, both wet woodland and mixed forests were biotopes of high
406 importance for carabid beetles, with values of diversity indices, evenness and dominance
407 comparable with those of the wet woodland. It is important to note that the mixed forests
408 host various Italian endemics, such as *Carabus lefebvrei*, *Platyderus neapolitanus* and
409 *Calathus montivagus* (all shared with other biotopes) and *Cycrus italicus* (only found in
410 this biotope). Wet zones showed values of chorological and taxonomic diversity slightly
411 higher than the mixed forests, but evenness was slightly lower. This biotope hosts a very
412 heterogeneous community (as shown by Shannon entropy), including both hygrophilous

413 species associated with river banks (*Omophron limbatum*) and many mesophilous species
414 (such as *Elaphrus uliginosus*, *Trepanes articulatus*, *Acupalpus parvulus*, *A. luteatus*,
415 *Chlaeniellus tristis*, *Oodes helopioides*, and *Microlestes minutulus*), but also many
416 thermophilous species, one of which, *Epomis circumscriptus*, is of high conservation
417 concern (Vigna Taglianti et al. 2001).

418 Finally, the open areas showed high values of chorological diversity for most of the
419 indices, relatively high values of equitability and evenness, and low dominance, but also a
420 low taxonomic diversity, which diminishes its conservation interest. This community is
421 chorologically very heterogeneous and includes a number of eurytopic species belonging to
422 the genera *Poecilus*, *Amara*, *Zabrus* (Pterostichini), *Ophonus*, *Cryptophonus*,
423 *Pseudophonus* and *Harpalus* (Harpalini).

424 When species richness, chorological diversity (as expressed by indices of diversity,
425 dominance, and evenness) and taxonomic diversity are used to calculate an index of overall
426 conservation interest, the most important biotopes resulted to be wet zones, wet woodlands,
427 open areas and mixed forest. These results clearly indicate that the carabid communities
428 with high conservation values are those associated with humid environments. This is
429 consistent with the hypothesis that most of the carabid species occurring in the study area
430 are hygrophilous elements, associated with wetlands, which shifted their range southwards
431 during the glacials, and which form a relict component of the carabid fauna of coastal areas
432 (Fattorini and Vigna 2002).

433 The conservation importance of wet zones highlighted by our analysis, is also
434 supported by the presence in this biotope of several species of conservation concern, such
435 as *Agonum sordidum*, *Carabus alysidotus*, *Epomis circumscriptus* and *Harpalus cupreus*.
436 The conservation importance given to mixed forest is supported by the high incidence of
437 Italian endemics, which constitute about 26% of the carabid community of this biotope. By
438 contrast, wet woodlands and open areas do not seem to be important biotopes in terms of
439 presence of endemics and species of conservation concern. In particular, open areas host a
440 community of carabid beetles with a high number of opportunistic species. Following
441 Brandmayr et al.(2005), among the species found in open areas, at least *Anchomenus*
442 *dorsalis*, *Zabrus tenebrioides*, *Cicindela campestris*, *Metallina lampros*, *Pseudophonus*
443 *rufipes*, *Harpalus* spp., *Amara* spp. and *Carabus* spp. should be considered as polyphagous
444 species. This would imply that about 30-35% of the species living in this biotope are
445 polyphagous. The high percentage of polyphagous and eurytopic species in this biotope
446 strongly diminishes its conservation interest.

447 We are aware of the limitation of the approach used in our analysis, which is based
448 only on species richness and chorological categories. In the future, it would be interesting
449 to compare our approach with analyses based on the conservation values of single species
450 or species traits (Gobbi and Fontaneto 2008; Pey et al. 2014), such as niche breadth
451 (Kotze, O'Hara 2003), feeding habits (Brandmayr et al. 2005), wing development
452 (Brandmayr 1991), etc.

453

454 **5 Conclusions**

455 The results presented in this study highlight the importance of preserving coastal wet areas.
456 Ponds, lagoons and lowland forests that were formerly widely distributed along the
457 Mediterranean coasts are now reduced to sparse and highly isolated fragments (Blondel and
458 Aronson 1999). The biogeographical approach presented in this study indicates that the most
459 important carabid communities are those associated with these biotopes. These biotopes are
460 well preserved in the study area, but should be carefully monitored and protected. In
461 particular, because of their dependence from the persistence of humid environment, they
462 might be negatively affected by any reduction in water availability.

463

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470

471 **Compliance with Ethical Standards**

472 The authors declare that this research was conducted without funding, that they have no
473 potential conflicts of interest (financial or non-financial), and that the research did not
474 involve living animals, because primary data were entirely extracted from literature.

475

476 **References**

477 Blondel J, Aronson J (1999) *Biology and Wildlife of the Mediterranean Region*, Oxford
478 University Press, Oxford

- 479 Brandmayr P. (1991) The reduction of metathoracic alae and of dispersal power of carabid
480 beetles along the evolutionary pathway into the mountains. In: Lanzavecchia G, &
481 Valvassori (eds.): Form and function in zoology. Mucchi, Modena, pp. 363-378.
- 482 Brandmayr P, Pizzolotto R, Colombetta G, Zetto T (2009) In situ extinction of carabid
483 beetles and community changes in a protected suburban forest during the past
484 century: the "Bosco Farneto" near Trieste (Italy). *J Insect Conserv* 13: 231-243.
- 485 Brandmayr P, Zetto T, Pizzolotto R (2005). I Coleotteri Carabidi per la valutazione
486 ambientale e la conservazione della biodiversità. Manuale operativo. APAT,
487 Manuali e linee guida 34
- 488 Cardoso P, Rigal F, Borges PAV, Carvalho JC (2014) A new frontier in biodiversity
489 inventory: a proposal for estimators of phylogenetic and functional diversity.
490 *Methods Ecol Evol* 5(5): 452-461
- 491 Casale A, Vigna Taglianti A (1999) Carabid beetles (excl. Cicindelidae) of Anatolia, and
492 their biogeographical significance (Coleoptera, Caraboidea). *Biogeographia Lav*
493 *Soc ital Biogeogr (n.s.)* 20: 277-406
- 494 Chiarucci A, Bacaro G, Scheiner SM (2011) Old and new challenges in using species
495 diversity for assessing biodiversity. *Phil Trans R Soc B* 366: 2426- 2437
- 496 Clarke KR, Warwick RM (1998) A taxonomic distinctness index and its statistical
497 properties. *J Appl Ecol* 35: 523-531
- 498 Darlington PJ (1971) The Carabid Beetles of New Guinea. Part IV. General
499 Considerations; Analysis and History of Fauna; Taxonomic Supplement. *Bull Mus*
500 *Comp Zool* 142: 129-337
- 501 Della Rocca AB, Pignatti S, Mugnoli S, Bianco PM (2001) La Carta Vegetazionale della
502 Tenuta di Castelporziano. In: Il Sistema Ambientale della Tenuta Presidenziale di
503 Castelporziano. Ricerche sulla complessità di un ecosistema forestale costiero
504 mediterraneo, Vol. II. Accademia delle Scienze detta dei XL, Roma, pp. 709-748
- 505 Dickman C, Pimm S, Cardillo M (2007) 'The pathology of biodiversity loss: the practice of
506 conservation', In: Macdonald DW, Service K (ed.), *Key Topics in Conservation*
507 *Biology*, Blackwell Publishing, Malden, pp. 1-16
- 508 Faith DP (1992) Conservation evaluation and phylogenetic diversity. *Biol Conserv* 61: 1-
509 10

- 510 Fattorini S (2007a) A statistical method for idiographic analyses in biogeographical
511 research. *Diversity Distrib* 13: 836-844
- 512 Fattorini S (2007b) The tenebrionid beetles of Mt Vesuvius: species assemblages and
513 biogeographic kinetics on an active volcano (Coleoptera Tenebrionidae). In: Nardi
514 G, Vomero V (eds.) *Ricerche preliminari sugli Artropodi del Parco Nazionale del*
515 *Vesuvio. Conservazione Habitat Invertebrati*, 4. Cierre edizioni, Verona, pp. 221-
516 242
- 517 Fattorini S (2013) Variation in zoogeographical composition along an elevational gradient:
518 the tenebrionid beetles of Latium (Central Italy). *Entomologia* 1 (e6): 33-40.
- 519 Fattorini S, Fowles A (2005) A biogeographical analysis of the tenebrionid beetles
520 (Coleoptera, Tenebrionidae) of the island of Thasos in the context of the Aegean
521 Islands (Greece). *J Nat Hist* 39 (46): 3919-3949
- 522 Fattorini S, Vigna Taglianti A (2002) Ecological and historical factors affecting carabid
523 and tenebrionid communities (Coleoptera Carabidae and Tenebrionidae) in a
524 Mediterranean coastal area. *Biogeographia Lav Soc ital Biogeogr* (n.s.)23:81-102.
- 525 Fattorini S, Maltzeff P, Salvati L (2015) Use of insect distribution across landscape-soil
526 units to assess conservation priorities in a Mediterranean coastal reserve: the
527 tenebrionid beetles of Castelporziano (Central Italy). *Rend Fis Acc Lincei*. DOI:
528 10.1007/s12210-015-0391-8
- 529 Flynn DFB, Mirotchnick N, Jain M, Palmer MI, Naeem S (2011) Functional and
530 phylogenetic diversity as predictors of biodiversity–ecosystem-function
531 relationships. *Ecology* 92: 1573-1581
- 532 Gaston KJ, Spicer JJ (2004) *Biodiversity: an introduction*. 2nd edition. Blackwell
533 Publishing, Oxford.
- 534 Gobbi M, Fontaneto D (2008) Biodiversity of ground beetles (Coleoptera, Carabidae) in
535 different habitats of the Italian Po Lowland. *Agric Ecosyst Environ* 127:273-276
- 536 Gotelli NJ, Colwell RK (2011) Estimating species richness. In: Magurran AE, McGill BJ
537 (eds) *Frontiers in Measuring Biodiversity*. Oxford University Press, Oxford, pp. 39-
538 54
- 539 Guralnick R, Van Cleve J (2005) Strengths and weakness of museum and national survey
540 data sets for predicting regional species richness: comparative and combined
541 approaches. *Divers Distrib* 11:349-359

542 Hammer Ø, Harper DAT, Ryan PD (2001) PAST - PALaeontological STatistics, ver. 2.17.
543 Palaeontologia Electronica 4(1): 1–9. User's Guide and application published at:
544 <http://folk.uio.no/ohammer/past>. Accessed: 2013, February, 2

545 Hayek LC, Buzas MA (2010) Surveying natural populations. Quantitative tools for
546 assessing biodiversity. Columbia University Press, New York

547 Heino J, Soininen J, Lappalainen J, Virtanen (2005) R The relationship between species
548 richness and taxonomic distinctness in freshwater organisms. *Limnol Oceanogr* 50:
549 978-986

550 Kotze DJ, O'Hara RB (2003) Species decline - but why? Explanations of carabid beetle
551 (Coleoptera, Carabidae) declines in Europe. *Oecologia* 135: 138–148.

552 Kotze J, Brandmayr P, Casale A, Dauffy-Richard E, Dekoninck W, Koivula M, Lovei G,
553 Mossakowski D, Noordijk J, Paarmann W, Pizzolotto R, Saska P, Schwerk A,
554 Serrano J, Szyszko J, Taboada A, Turin H, Venn S, Vermeulen R, Zetto Brandmayr
555 T (2011) Forty years of carabid beetle research in Europe - from taxonomy,
556 biology, ecology and population studies to bioindication, habitat assessment and
557 conservation. *ZooKeys* 100: 55-148

558 Magurran AE (1988) Ecological diversity and its measurements. Princeton University,
559 Princeton

560 Magurran A (2004) Measuring biological diversity. Blackwell Publishing, Malden

561 Morrill WL, Lester DG, Wrona A E (1990) Factors affecting efficacy of pitfall traps for
562 beetles (Coleoptera: Carabidae and Tenebrionidae). *J Entomol Sci* 25:284-293

563 Pey B, Nahmani J, Auclerc A, Capowiez Y, Cluzeau D, Cortet J, Decaëns T, Deharveng L,
564 Dubs F, Joimel S, Briard C, Grumiaux F, Laporte M, Pasquet A, Pelosi C, Pernin C,
565 Ponge J, Salmon S, Santorufo L, Hedde M (2014) Current use of and future needs
566 for soil invertebrate functional traits in community ecology. *Basic Appl Ecol*
567 15:194-206.

568 Pielou EC (1975) Ecological diversity. John Wiley & Sons, New York.

569 Pullin AS (2002) Conservation Biology. Cambridge University Press, New York, NY

570 Purschke O, Schmid BC, Sykes MT, Poschlod P, Michalski SG, Durka W, Kühn I, Winter
571 M, Prentice HC (2013), Contrasting changes in taxonomic, phylogenetic and
572 functional diversity during a long-term succession: insights into assembly
573 processes. *J Ecol* 101:857-866.

574 Rodrigues ASL, Gaston KJ (2002) Maximising phylogenetic diversity in the selection of
575 networks of conservation areas. *Biol Conserv* 105:103-111

576 Rogers SI, Clarke K, Reynolds JD (1999) The taxonomic distinctness of coastal bottom-
577 dwelling fish communities of the Northeast Atlantic. *J Anim Ecol* 68:769-782

578 Samways M J (2005) Insect diversity conservation. Cambridge University Press,
579 Cambridge

580 Samways, MJ, McGeoch M, New TR (2010) Insect conservation. A handbook of
581 approaches and methods. Oxford University Press, Oxford

582 Thomas DB, Sleeper EL (1977) The use of pit-fall traps for estimating the abundance of
583 arthropods, with special reference to the Tenebrionidae (Coleoptera). *Ann Entomol*
584 *Soc Am* 70:242–248

585 Ulrich W, Fattorini S (2013) Longitudinal gradients in the phylogenetic community
586 structure of European Tenebrionidae (Coleoptera) do not coincide with the major
587 routes of postglacial colonization. *Ecography* 36: 1106-1116

588 Van Dyke F. (2008) Conservation Biology: Foundations, Concepts, Applications, 2nd ed.
589 Springer. Berlin

590 Vigna Taglianti A (1998) I carabidi nella faunistica e biogeografia. *Atti Accad Naz*
591 *Entomol Rendiconti* 46:245-276

592 Vigna Taglianti A (2005) Appendice B. Checklist e corotipi delle specie di Carabidi della
593 fauna italiana. In: Brandmayr P, Zetto T, Pizzolotto R (Eds). *I Coleotteri Carabidi*

- 594 per la valutazione ambientale e la conservazione della biodiversità. Manuale
595 operativo. APAT, Manuali e linee guida 34, pp. 186-225.
- 596 Vigna Taglianti A, Fattorini S (2002) Aspetti biogeografici delle cenosi a carabidi dei
597 sistemi costieri italiani. *Biogeographia Lav Soc ital Biogeogr* (n.s.) 23:127-138.
- 598 Vigna Taglianti A, Audisio PA, Biondi M, Bologna MA, Carpaneto GM, De Biase A,
599 Fattorini S, Piattella E, Sindaco R, Venchi A, Zapparoli M (1999) A proposal for a
600 chorotype classification of the Near East fauna, in the framework of the Western
601 Palearctic region. *Biogeographia Lav Soc ital Biogeogr* (n.s.) 20: 31-59
- 602 Vigna Taglianti A, Bonavita P, Di Giulio A, Todini A, Maltzeff P (2001) I Carabidi della
603 Tenuta Presidenziale di Castelporziano (Coleoptera, Carabidae). *Boll Ass Romana*
604 *Entomol* 56:115-173
- 605 Vigna Taglianti A, Bonavita P, Maltzeff P (2007) I Carabidi della Tenuta Presidenziale di
606 Castelporziano. Addenda (Coleoptera, Carabidae). *Boll Ass Romana Entomol*
607 62:101-103
- 608 Woodcock BA (2005) Pitfall trapping in ecological studies. In: Leather S (ed). *Insect Sampling in*
609 *Forest Ecosystems*. Blackwell, Oxford, pp. 37-57.

611 Table 1. Distribution of carabid beetles across biotopes in Castelporziano reserve and their taxonomic arrangement.

612

Subfamily	Tribe	Genus	Species	Chorotype	Beach	Dune	Low maquis	High maquis	Wet woodland	Oak forest	Mixed forest	Wet zones	Open areas
Brachininae	Brachinini	<i>Brachinus</i>	<i>crepitans</i>	PAL	0	0	0	0	0	0	0	0	1
Brachininae	Brachinini	<i>Brachinus</i>	<i>elegans</i>	MED	0	0	0	0	0	0	0	1	1
Brachininae	Brachinini	<i>Brachinus</i>	<i>plagiatus</i>	MED	0	0	0	0	0	0	0	1	0
Brachininae	Brachinini	<i>Brachinus</i>	<i>immaculicornis</i>	MED	0	0	0	0	0	0	0	1	1
Brachininae	Brachinini	<i>Brachinus</i>	<i>sclopeta</i>	EUM	0	0	0	0	0	0	0	1	1
Brachininae	Brachinini	<i>Brachinus</i>	<i>italicus</i>	WME(APPE)	0	0	0	0	0	0	0	0	1
Omophroninae	Omophronini	<i>Omophron</i>	<i>limbatum</i>	PAL	0	0	0	0	0	0	0	1	0
Cicindelinae	Cicindelini	<i>Cicindela</i>	<i>campestris</i>	PAL	0	0	0	0	0	0	0	0	1
Cicindelinae	Cicindelini	<i>Calomera</i>	<i>littoralis</i>	CEM	1	1	0	0	0	0	0	0	0
Cicindelinae	Cicindelini	<i>Myriochila</i>	<i>melancholica</i>	AIM	0	0	0	0	0	0	0	1	0
Carabinae	Carabini	<i>Calosoma</i>	<i>inquisitor</i>	SIE	0	0	0	0	0	0	1	0	0
Carabinae	Carabini	<i>Calosoma</i>	<i>sycophanta</i>	PAL	0	0	0	0	0	0	1	0	0
Carabinae	Carabini	<i>Calosoma</i>	<i>maderae</i>	MED	0	0	0	0	0	0	0	0	1
Carabinae	Carabini	<i>Carabus</i>	<i>granulatus</i>	ASE	0	0	1	0	1	0	0	1	0
Carabinae	Carabini	<i>Carabus</i>	<i>italicus</i>	SEU(ALAP)	0	0	0	0	1	0	0	1	0
Carabinae	Carabini	<i>Carabus</i>	<i>alysidotus</i>	WME	0	0	0	0	0	0	0	1	1
Carabinae	Carabini	<i>Carabus</i>	<i>rossii</i>	SEU(APPE)	0	0	0	1	0	0	1	0	1
Carabinae	Carabini	<i>Carabus</i>	<i>convexus</i>	SIE	0	0	0	0	1	0	1	0	0
Carabinae	Carabini	<i>Carabus</i>	<i>lefebvrei</i>	SEU(APPE)	0	0	0	1	1	0	1	0	0
Carabinae	Carabini	<i>Carabus</i>	<i>violaceus</i>	EUR	0	0	0	0	0	0	1	0	1
Carabinae	Carabini	<i>Carabus</i>	<i>coriaceus</i>	EUR	0	0	0	0	0	0	0	0	1
Carabinae	Cychrini	<i>Cychrus</i>	<i>italicus</i>	SEU(ALAP)	0	0	0	0	0	0	1	0	0
Nebriinae	Nebriini	<i>Leistus</i>	<i>fulvibarbis</i>	EUM	0	0	0	0	1	0	0	0	0
Nebriinae	Nebriini	<i>Nebria</i>	<i>brevicollis</i>	TUE	0	0	0	0	0	0	0	1	0
Nebriinae	Nebriini	<i>Eurynebria</i>	<i>complanata</i>	WME	1	0	0	0	0	0	0	0	0
Nebriinae	Notiophilini	<i>Notiophilus</i>	<i>geminatus</i>	MED	0	0	0	0	0	0	1	0	0
Nebriinae	Notiophilini	<i>Notiophilus</i>	<i>rufipes</i>	EUR	0	0	0	1	1	1	1	0	0
Nebriinae	Notiophilini	<i>Notiophilus</i>	<i>substriatus</i>	EUR	0	1	1	0	1	0	1	0	0
Elaphrinae	Elaphrini	<i>Elaphrus</i>	<i>uliginosus</i>	ASE	0	0	0	0	0	0	0	1	0
Siagoninae	Siagonini	<i>Siagona</i>	<i>europaea</i>	AIM	0	0	0	0	0	0	0	0	1
Scaritinae	Scaritini	<i>Distichus</i>	<i>planus</i>	AIM	0	0	0	0	0	0	0	1	0
Scaritinae	Scaritini	<i>Scarites</i>	<i>buparius</i>	MED	0	1	0	0	0	0	0	0	0
Scaritinae	Scaritini	<i>Parallelomorphus</i>	<i>laevigatus</i>	MED	1	0	0	0	0	0	0	0	0
Scaritinae	Clivinini	<i>Clivina</i>	<i>fossor</i>	ASE	0	0	0	0	1	0	0	1	1

Scaritinae	Dyschiriini	<i>Dyschiriodes</i>	<i>globosus</i>	SIE	0	0	0	0	1	0	0	0	0
Scaritinae	Dyschiriini	<i>Dyschiriodes</i>	<i>chalybaeus</i>	MED	0	0	0	0	1	0	0	1	0
Trechinae	Trechini	<i>Trechus</i>	<i>fairmairei</i>	SEU(ALAP)	0	0	0	0	1	0	0	1	0
Trechinae	Trechini	<i>Trechus</i>	<i>quadristriatus</i>	TEM	0	0	0	1	1	0	0	1	1
Trechinae	Bembidiini	<i>Paratachys</i>	<i>bistriatus</i>	WPA	0	0	0	0	1	0	0	1	0
Trechinae	Bembidiini	<i>Paratachys</i>	<i>fulvicollis</i>	TUE	0	0	0	0	1	0	0	1	0
Trechinae	Bembidiini	<i>Tachyta</i>	<i>nana</i>	OLA	0	0	0	0	1	0	0	0	0
Trechinae	Bembidiini	<i>Sphaerotachys</i>	<i>haemorrhoidalis</i>	AFM	0	0	0	0	1	0	0	1	0
Trechinae	Bembidiini	<i>Ocys</i>	<i>harpaloides</i>	EUM	0	0	0	0	1	0	0	1	0
Trechinae	Bembidiini	<i>Asaphidion</i>	<i>curtum</i>	WME	0	0	0	0	1	0	0	0	0
Trechinae	Bembidiini	<i>Asaphidion</i>	<i>stierlini</i>	MED	0	0	0	0	0	0	0	1	0
Trechinae	Bembidiini	<i>Metallina</i>	<i>ambigua</i>	WME	0	0	0	0	0	0	0	1	0
Trechinae	Bembidiini	<i>Metallina</i>	<i>lampros</i>	PAL	0	0	0	0	1	0	0	1	1
Trechinae	Bembidiini	<i>Phyla</i>	<i>tethys</i>	MED	0	0	0	0	1	0	0	1	0
Trechinae	Bembidiini	<i>Trepanes</i>	<i>articulatus</i>	ASE	0	0	0	0	0	0	0	1	0
Trechinae	Bembidiini	<i>Trepanes</i>	<i>assimilis</i>	WPA	0	0	0	0	1	0	0	1	0
Trechinae	Bembidiini	<i>Trepanes</i>	<i>octomaculatus</i>	PAL	0	0	0	0	1	0	0	1	0
Trechinae	Bembidiini	<i>Philochthus</i>	<i>escherichi</i>	MED	0	0	0	0	0	0	0	1	0
Trechinae	Bembidiini	<i>Philochthus</i>	<i>inoptatus</i>	SEU	0	0	0	0	1	0	0	1	0
Trechinae	Bembidiini	<i>Philochthus</i>	<i>lumulatus</i>	EUM	0	0	0	0	1	0	0	1	0
Trechinae	Bembidiini	<i>Ocydromus</i>	<i>latinus</i>	SEU	0	0	0	0	0	0	0	1	0
Trechinae	Bembidiini	<i>Ocydromus</i>	<i>callosus</i>	MED	0	0	0	0	0	0	0	1	0
Trechinae	Bembidiini	<i>Ocydromus</i>	<i>genei</i>	EUM	0	0	0	0	0	0	0	1	0
Trechinae	Bembidiini	<i>Sinechostictus</i>	<i>dahlia</i>	WME	0	0	0	0	0	0	0	1	0
Trechinae	Bembidiini	<i>Sinechostictus</i>	<i>elongatus</i>	SEU	0	0	0	0	1	0	0	0	0
Pterostichinae	Pterostichini	<i>Poecilus</i>	<i>cupreus</i>	ASE	0	0	0	0	0	0	0	1	1
Pterostichinae	Pterostichini	<i>Poecilus</i>	<i>koyi</i>	SIE	0	0	0	0	0	0	0	0	1
Pterostichinae	Pterostichini	<i>Pterostichus</i>	<i>cursor</i>	SEU	0	0	0	0	1	0	0	1	0
Pterostichinae	Pterostichini	<i>Pterostichus</i>	<i>vernalis</i>	PAL	0	0	0	0	1	0	0	0	0
Pterostichinae	Pterostichini	<i>Pterostichus</i>	<i>strenuus</i>	ASE	0	0	0	0	1	0	0	1	0
Pterostichinae	Pterostichini	<i>Pterostichus</i>	<i>aterrimus</i>	WPA	0	0	0	0	1	0	0	0	0
Pterostichinae	Pterostichini	<i>Pterostichus</i>	<i>macr</i>	ASE	0	0	0	0	0	0	0	0	1
Pterostichinae	Pterostichini	<i>Pterostichus</i>	<i>nigrum</i>	ASE	0	0	0	0	1	0	0	0	0
Pterostichinae	Pterostichini	<i>Pterostichus</i>	<i>anthracinus</i>	CAE	0	0	0	0	1	0	0	0	0
Pterostichinae	Pterostichini	<i>Pterostichus</i>	<i>gracilis</i>	ASE	0	0	0	0	1	0	0	1	0
Pterostichinae	Pterostichini	<i>Pterostichus</i>	<i>nigrita</i>	PAL	0	0	0	0	1	0	0	1	0
Pterostichinae	Pterostichini	<i>Pterostichus</i>	<i>oenotrius</i>	SEU	0	0	0	0	1	0	0	0	0

Pterostichinae	Pterostichini	<i>Pterostichus</i>	<i>melas</i>	EUR	0	0	1	0	1	0	1	1	1
Pterostichinae	Pterostichini	<i>Pterostichus</i>	<i>micans</i>	SEU(ALAP)	0	0	0	0	0	0	1	0	0
Pterostichinae	Pterostichini	<i>Abax</i>	<i>parallelepipedus</i>	EUR	0	0	0	0	1	0	1	0	0
Pterostichinae	Zabrini	<i>Amara</i>	<i>concinna</i>	EUR	0	0	0	0	0	0	0	1	0
Pterostichinae	Zabrini	<i>Amara</i>	<i>aenea</i>	PAL	0	0	0	0	0	0	1	0	1
Pterostichinae	Zabrini	<i>Amara</i>	<i>anthobia</i>	EUR	0	0	0	0	0	0	0	1	0
Pterostichinae	Zabrini	<i>Amara</i>	<i>apricaria</i>	PAL	0	0	0	0	0	0	0	0	1
Pterostichinae	Zabrini	<i>Zabrus</i>	<i>tenebrioides</i>	TUE	0	0	0	0	0	0	0	0	1
Panagaeinae	Panagaeini	<i>Panagaeus</i>	<i>cruxmajor</i>	SIE	0	0	0	0	0	0	0	1	0
Chlaeniinae	Chlaeniini	<i>Dinodes</i>	<i>decipiens</i>	EUM	0	0	0	0	0	0	0	0	1
Chlaeniinae	Chlaeniini	<i>Chlaeniellus</i>	<i>nigricornis</i>	ASE	0	0	0	0	0	0	0	1	0
Chlaeniinae	Chlaeniini	<i>Chlaeniellus</i>	<i>nitidulus</i>	CAE	0	0	0	0	0	0	0	1	0
Chlaeniinae	Chlaeniini	<i>Chlaeniellus</i>	<i>olivieri</i>	SEU	0	0	0	0	0	0	0	1	0
Chlaeniinae	Chlaeniini	<i>Chlaeniellus</i>	<i>tristis</i>	PAL	0	0	0	0	0	0	0	1	0
Chlaeniinae	Chlaeniini	<i>Chlaeniellus</i>	<i>vestitus</i>	EUM	0	0	0	0	0	0	0	1	0
Chlaeniinae	Chlaeniini	<i>Epomis</i>	<i>circumscriptus</i>	AFM	0	0	0	0	1	0	0	1	0
Chlaeniinae	Chlaeniini	<i>Epomis</i>	<i>dejeanii</i>	EME	0	0	0	0	0	0	0	1	0
Chlaeniinae	Chlaeniini	<i>Chlaenius</i>	<i>spoliatus</i>	PAL	0	0	0	0	0	0	0	1	0
Chlaeniinae	Chlaeniini	<i>Chlaenius</i>	<i>festivus</i>	TUE	0	0	0	0	0	0	0	1	0
Chlaeniinae	Chlaeniini	<i>Chlaenius</i>	<i>chrysocephalus</i>	WME	0	0	0	0	0	0	0	1	1
Oodinae	Oodini	<i>Oodes</i>	<i>helopioides</i>	SIE	0	0	0	0	0	0	0	1	0
Licininae	Licinini	<i>Licinus</i>	<i>silphoides</i>	SEU	0	0	0	0	0	0	0	0	1
Licininae	Licinini	<i>Badister</i>	<i>meridionalis</i>	SEU	0	0	0	0	0	0	0	1	0
Licininae	Licinini	<i>Badister</i>	<i>dilatatus</i>	SIE	0	0	0	0	1	0	0	0	0
Harpalinae	Anisodactylinae	<i>Scybalicus</i>	<i>oblongiusculus</i>	MED	0	0	0	0	0	0	0	0	1
Harpalinae	Anisodactylinae	<i>Anisodactylus</i>	<i>binotatus</i>	ASE	0	0	0	0	0	0	0	1	0
Harpalinae	Anisodactylinae	<i>Gynandromorphus</i>	<i>etruscus</i>	SEU	0	0	0	0	0	0	0	0	1
Harpalinae	Anisodactylinae	<i>Diachromus</i>	<i>germanus</i>	TEM	0	0	0	0	0	0	0	0	1
Harpalinae	Stenolophini	<i>Stenolophus</i>	<i>mixtus</i>	PAL	0	0	0	0	1	0	0	1	0
Harpalinae	Stenolophini	<i>Stenolophus</i>	<i>persicus</i>	EME	0	0	0	0	0	0	0	1	0
Harpalinae	Stenolophini	<i>Stenolophus</i>	<i>skrimshiranus</i>	EUM	0	0	0	0	1	0	0	1	0
Harpalinae	Stenolophini	<i>Stenolophus</i>	<i>teutonus</i>	TEM	0	0	0	0	0	0	0	1	0
Harpalinae	Stenolophini	<i>Bradycellus</i>	<i>verbasci</i>	TUE	0	0	1	0	0	0	0	1	0
Harpalinae	Stenolophini	<i>Acupalpus</i>	<i>brunnipes</i>	EUM	0	0	0	0	1	0	0	1	0
Harpalinae	Stenolophini	<i>Acupalpus</i>	<i>elegans</i>	TEM	0	0	0	0	0	0	0	1	0
Harpalinae	Stenolophini	<i>Acupalpus</i>	<i>luteatus</i>	SIE	0	0	0	0	1	0	0	1	0
Harpalinae	Stenolophini	<i>Acupalpus</i>	<i>maculatus</i>	EUM	0	0	0	0	0	0	0	1	0

Harpalinae	Stenolophini	<i>Acupalpus</i>	<i>meridianus</i>	EUR	0	0	0	0	0	0	0	1	0
Harpalinae	Stenolophini	<i>Acupalpus</i>	<i>notatus</i>	MED	0	0	0	0	0	0	0	1	0
Harpalinae	Stenolophini	<i>Acupalpus</i>	<i>paludicola</i>	MED	0	0	0	0	0	0	0	1	0
Harpalinae	Stenolophini	<i>Acupalpus</i>	<i>parvulus</i>	ASE	0	0	0	0	0	0	0	1	0
Harpalinae	Stenolophini	<i>Anthracus</i>	<i>quarnerensis</i>	SEU	0	0	0	0	1	0	0	0	0
Harpalinae	Stenolophini	<i>Anthracus</i>	<i>transversalis</i>	EUR	0	0	0	0	1	0	0	0	0
Harpalinae	Harpalini	<i>Ophonus</i>	<i>ardosiacus</i>	EUM	0	0	0	0	0	0	0	0	1
Harpalinae	Harpalini	<i>Ophonus</i>	<i>sabulicola</i>	TUE	0	0	0	0	0	0	0	0	1
Harpalinae	Harpalini	<i>Ophonus</i>	<i>azureus</i>	CEM	0	0	0	0	0	0	0	0	1
Harpalinae	Harpalini	<i>Ophonus</i>	<i>subquadratus</i>	MED	0	0	0	0	0	0	0	0	1
Harpalinae	Harpalini	<i>Ophonus</i>	<i>puncticeps</i>	TUE	0	0	0	0	0	0	0	0	1
Harpalinae	Harpalini	<i>Ophonus</i>	<i>schaubergerianus</i>	EUR	0	0	0	0	0	0	0	0	1
Harpalinae	Harpalini	<i>Ophonus</i>	<i>incisus</i>	MED	0	0	0	0	0	0	0	0	1
Harpalinae	Harpalini	<i>Cryptophonus</i>	<i>melancholicus</i>	EUM	0	1	0	0	0	0	0	0	0
Harpalinae	Harpalini	<i>Cryptophonus</i>	<i>tenebrosus</i>	WPA	0	0	0	0	0	0	0	0	1
Harpalinae	Harpalini	<i>Pseudoophonus</i>	<i>griseus</i>	PAL	0	0	0	0	0	0	0	0	1
Harpalinae	Harpalini	<i>Pseudoophonus</i>	<i>rufipes</i>	PAL	0	0	0	0	1	0	0	0	1
Harpalinae	Harpalini	<i>Harpalus</i>	<i>anxius</i>	PAL	0	0	0	0	1	0	0	0	1
Harpalinae	Harpalini	<i>Harpalus</i>	<i>attenuatus</i>	MED	0	0	1	0	0	0	0	0	1
Harpalinae	Harpalini	<i>Harpalus</i>	<i>cupreus</i>	SEU	0	0	0	0	0	0	0	1	0
Harpalinae	Harpalini	<i>Harpalus</i>	<i>dimidiatus</i>	EUR	0	0	0	0	0	0	0	1	1
Harpalinae	Harpalini	<i>Harpalus</i>	<i>distinguendus</i>	PAL	0	0	0	0	0	0	0	1	1
Harpalinae	Harpalini	<i>Harpalus</i>	<i>oblitus</i>	TEM	0	0	0	0	0	0	0	1	1
Harpalinae	Harpalini	<i>Harpalus</i>	<i>pygmaeus</i>	SEU	0	0	0	0	0	0	0	0	1
Harpalinae	Harpalini	<i>Harpalus</i>	<i>rubripes</i>	ASE	0	0	1	0	0	0	0	0	1
Harpalinae	Harpalini	<i>Harpalus</i>	<i>serripes</i>	PAL	0	0	0	0	0	0	0	0	1
Harpalinae	Harpalini	<i>Harpalus</i>	<i>smaragdinus</i>	TEM	0	0	0	0	0	0	0	0	1
Harpalinae	Harpalini	<i>Harpalus</i>	<i>sulphuripes</i>	EUM	0	0	1	0	0	0	0	1	1
Harpalinae	Harpalini	<i>Harpalus</i>	<i>tardus</i>	ASE	0	0	0	0	1	0	1	1	0
Harpalinae	Harpalini	<i>Acinopus</i>	<i>picipes</i>	TUE	0	0	0	0	0	0	0	0	1
Harpalinae	Harpalini	<i>Parophonus</i>	<i>hispanus</i>	WME	0	0	0	0	0	0	0	0	1
Harpalinae	Harpalini	<i>Parophonus</i>	<i>maculicornis</i>	SEU	0	0	0	0	0	0	0	0	1
Harpalinae	Harpalini	<i>Parophonus</i>	<i>mendax</i>	SEU	0	0	0	0	0	0	0	0	1
Harpalinae	Harpalini	<i>Carterus</i>	<i>dama</i>	MED	0	0	0	0	0	0	0	0	1
Harpalinae	Harpalini	<i>Carterus</i>	<i>gilvipes</i>	MED	0	0	0	0	0	0	0	0	1
Harpalinae	Harpalini	<i>Ditomus</i>	<i>calydonius</i>	TUE	0	0	0	0	0	0	0	0	1
Platyninae	Sphodrini	<i>Synuchus</i>	<i>vivalis</i>	ASE	0	0	0	0	0	1	1	0	0

Platyninae	Sphodrini	<i>Platyderus</i>	<i>neapolitanus</i>	SEU(APPE)	0	0	1	1	1	1	1	0	0
Platyninae	Sphodrini	<i>Calathus</i>	<i>fuscipes</i>	EUM	0	0	1	0	1	0	1	1	1
Platyninae	Sphodrini	<i>Calathus</i>	<i>montivagus</i>	SEU(APPE)	0	0	1	1	0	0	1	0	0
Platyninae	Sphodrini	<i>Calathus</i>	<i>cinctus</i>	WPA	0	0	1	0	0	0	1	1	1
Platyninae	Sphodrini	<i>Calathus</i>	<i>circumseptus</i>	WME	0	0	0	0	0	0	0	1	1
Platyninae	Sphodrini	<i>Laemostenus</i>	<i>venustus</i>	EME	0	0	0	0	0	1	1	0	0
Platyninae	Sphodrini	<i>Laemostenus</i>	<i>latialis</i>	WME(APPC)	0	0	0	0	0	0	1	0	0
Platyninae	Sphodrini	<i>Laemostenus</i>	<i>algerinus</i>	WME	0	0	1	1	1	1	0	0	0
Platyninae	Platynini	<i>Olisthopus</i>	<i>fuscatus</i>	MED	0	0	1	0	0	0	0	0	1
Platyninae	Platynini	<i>Olisthopus</i>	<i>glabricollis</i>	EME	0	0	1	0	0	0	0	0	1
Platyninae	Platynini	<i>Agonum</i>	<i>marginatum</i>	WPA	0	0	0	0	1	0	0	1	0
Platyninae	Platynini	<i>Agonum</i>	<i>nigrum</i>	TEM	0	0	0	0	1	0	0	1	0
Platyninae	Platynini	<i>Agonum</i>	<i>permoestum</i>	SEU	0	0	0	0	1	0	0	1	0
Platyninae	Platynini	<i>Agonum</i>	<i>sordidum</i>	EME	0	0	0	0	0	0	0	1	0
Platyninae	Platynini	<i>Agonum</i>	<i>viridicupreum</i>	TUE	0	0	0	0	0	0	0	1	0
Platyninae	Platynini	<i>Anchomenus</i>	<i>dorsalis</i>	PAL	0	0	0	0	0	0	0	0	1
Platyninae	Platynini	<i>Paranchus</i>	<i>albipes</i>	EUM	0	0	0	0	1	0	0	1	0
Lebiinae	Cymindidini	<i>Pseudomasoreus</i>	<i>canigoulensis</i>	WME	0	0	1	0	0	0	1	0	0
Lebiinae	Dromiini	<i>Syntomus</i>	<i>impressus</i>	MED	0	0	1	0	0	0	1	0	1
Lebiinae	Dromiini	<i>Syntomus</i>	<i>obscuroguttatus</i>	EUM	0	1	0	0	0	0	1	1	0
Lebiinae	Dromiini	<i>Microlestes</i>	<i>corticalis</i>	TUM	0	0	0	0	0	0	0	0	1
Lebiinae	Dromiini	<i>Microlestes</i>	<i>fissuralis</i>	TUE	0	0	0	0	0	0	0	0	1
Lebiinae	Dromiini	<i>Microlestes</i>	<i>fulvibasis</i>	TUM	0	0	1	0	0	0	0	0	1
Lebiinae	Dromiini	<i>Microlestes</i>	<i>luctuosus</i>	TUM	0	0	0	0	0	0	0	0	1
Lebiinae	Dromiini	<i>Microlestes</i>	<i>minutulus</i>	OLA	0	0	0	0	0	0	0	1	1
Lebiinae	Dromiini	<i>Paradromius</i>	<i>linearis</i>	EUM	1	0	1	0	1	0	0	1	0
Lebiinae	Dromiini	<i>Dromius</i>	<i>meridionalis</i>	SIE	0	0	0	0	1	0	1	0	0
Lebiinae	Dromiini	<i>Philorhizus</i>	<i>crucifer</i>	MED	0	0	0	0	0	0	1	0	0
Lebiinae	Dromiini	<i>Philorhizus</i>	<i>melanocephalus</i>	TEM	0	0	1	0	0	1	1	0	0
Lebiinae	Demetriadini	<i>Demetrias</i>	<i>atricapillus</i>	EUM	0	1	1	0	1	0	0	1	0
Lebiinae	Lebiini	<i>Lebia</i>	<i>scapularis</i>	CEM	0	0	0	0	0	0	0	0	1
Lebiinae	Lebiini	<i>Lamprias</i>	<i>fulvicollis</i>	WME	0	0	0	0	0	0	0	0	1
Dryptiinae	Dryptini	<i>Drypta</i>	<i>dentata</i>	AFP	0	0	0	0	0	0	0	1	0
Dryptiinae	Zuphiini	<i>Zuphium</i>	<i>olens</i>	AIM	0	0	0	0	0	0	0	0	1

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614 Chorotype acronyms: AFM = Afrotropico-Mediterranean, AFP = Afrotropical + Palearctic, AIM = Afrotropico-Indo-Mediterranean, ASE =

615 Asiatic-European, CAE = Centralasiatic-European, CEM = Centralasiatic-Europeo-Mediterranean, EME = E-Mediterranean, EUM = Europeo-

616 Mediterranean, EUR = European, MED = Mediterranean, OLA = Holarctic, PAL = Palearctic, SEU = S-European, SIE = Sibero-European, TEM =
617 Turano-Europeo-Mediterranean, TUE = Turano-European, TUM = Turano-Mediterranean, WME = W-Mediterranean, WPA = W-Palearctic; ALAP
618 = Alpino-Apenninic endemic; APPE= Apenninic endemic; APPC = Central-Apenninic endemic.

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Figures

Figure 1 Flow chart explaining the calculation of the Overall Chorological Index (OCI) and the Conservation Value Index (CVI).

Figure 2 Variation in carabid species richness and number of chorotypes across biotopes in Castelporziano reserve.

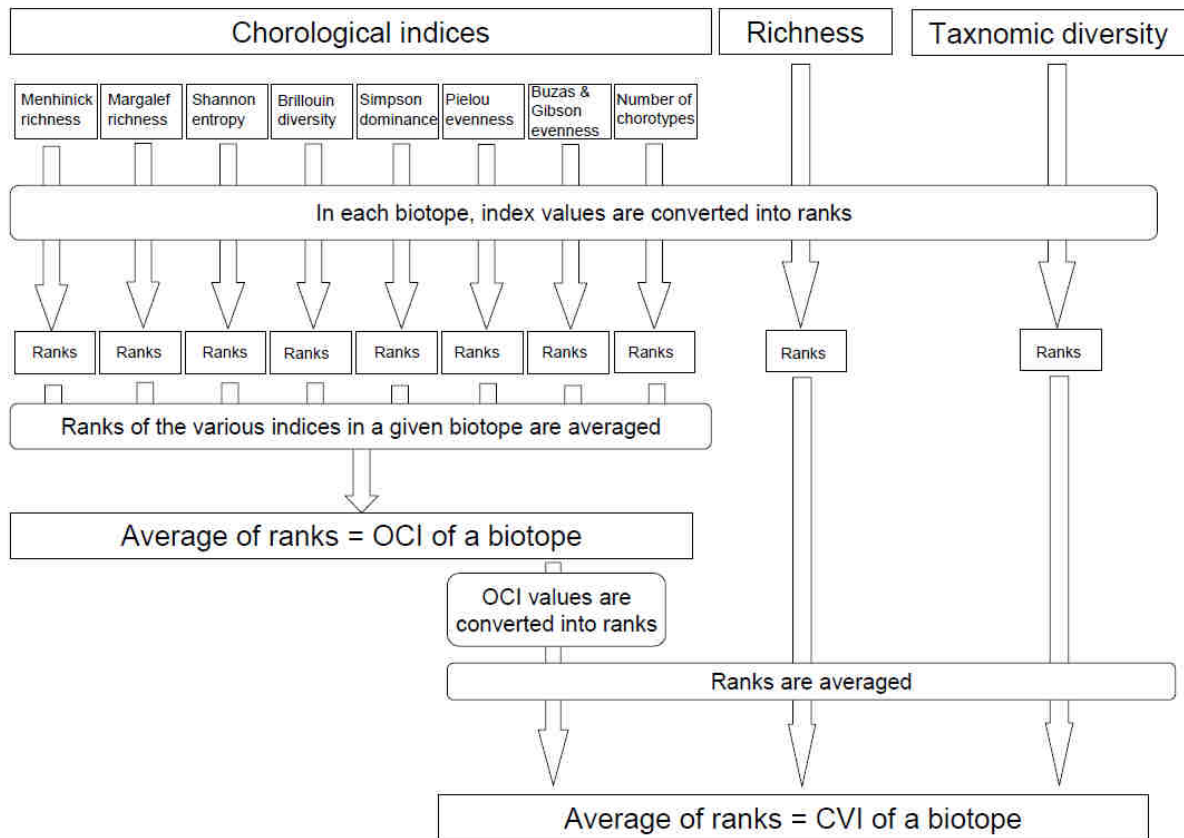
Figure 3 Variation in carabid taxonomic diversity across biotopes in Castelporziano reserve. Dotted lines are confidence intervals.

Figure 4 Variation in carabid diversity (a, Shannon, Brillouin,), dominance (b) and evenness (c) across biotopes in Castelporziano reserve.

Figure 5 Overall Chorological Index and Conservation Value Index for carabid communities in Castelporziano reserve.

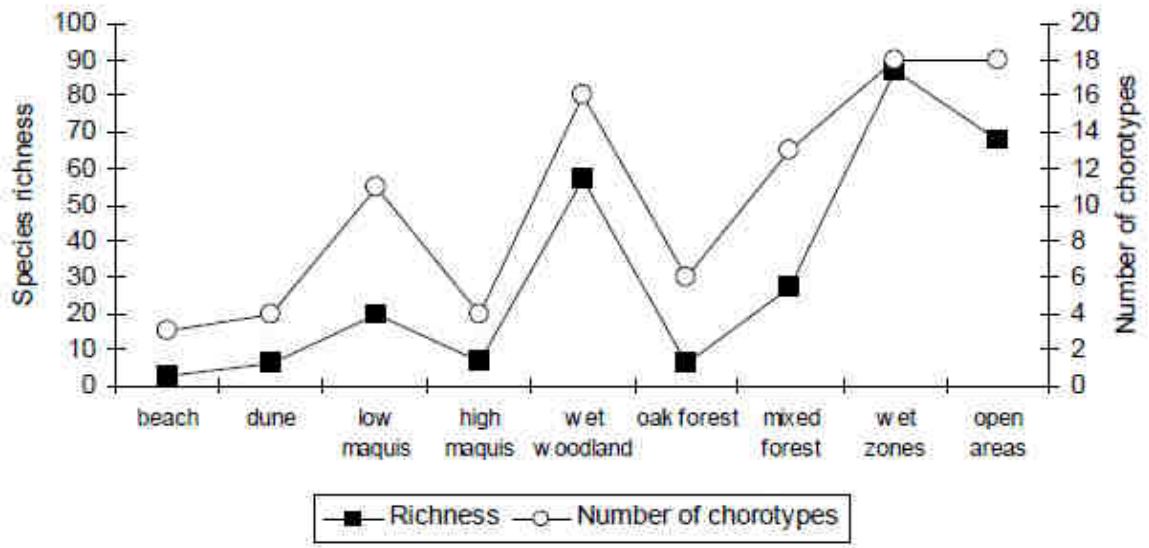
Figure 5 Number and per cent of Italian endemic carabids in the biotopes of Castelporziano reserve.

642 Figure 1



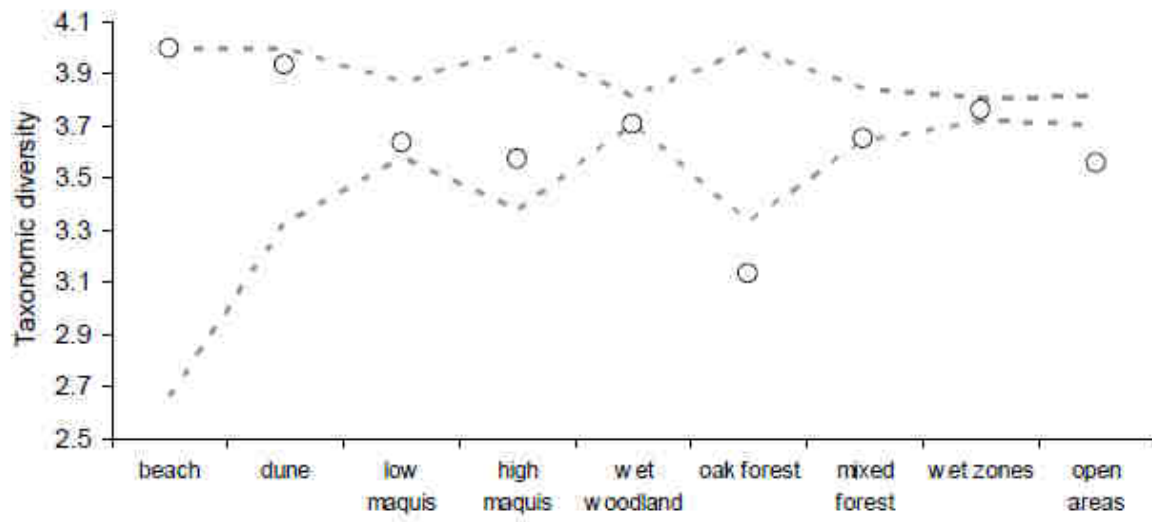
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644 Figure 2



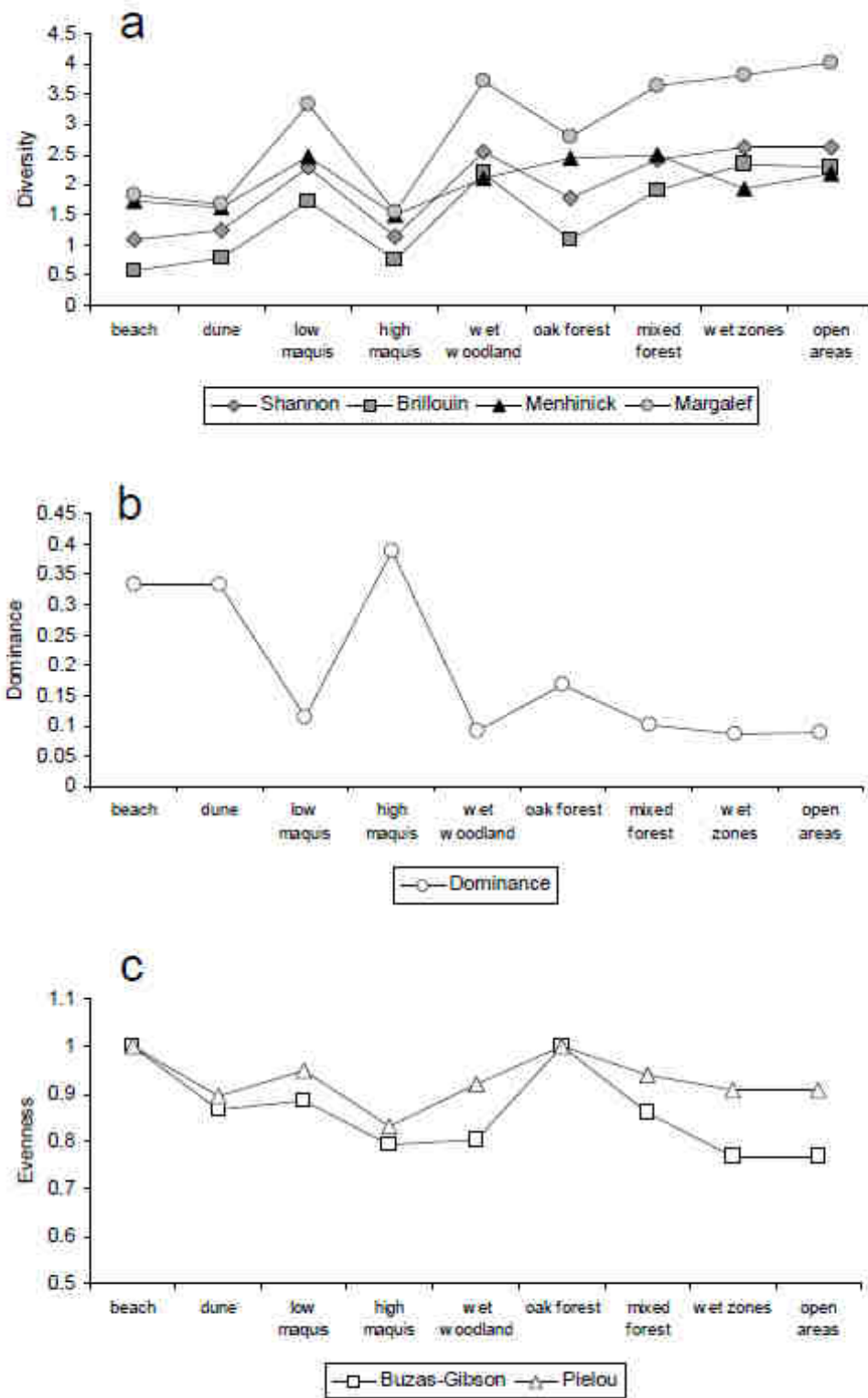
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646 Figure 3



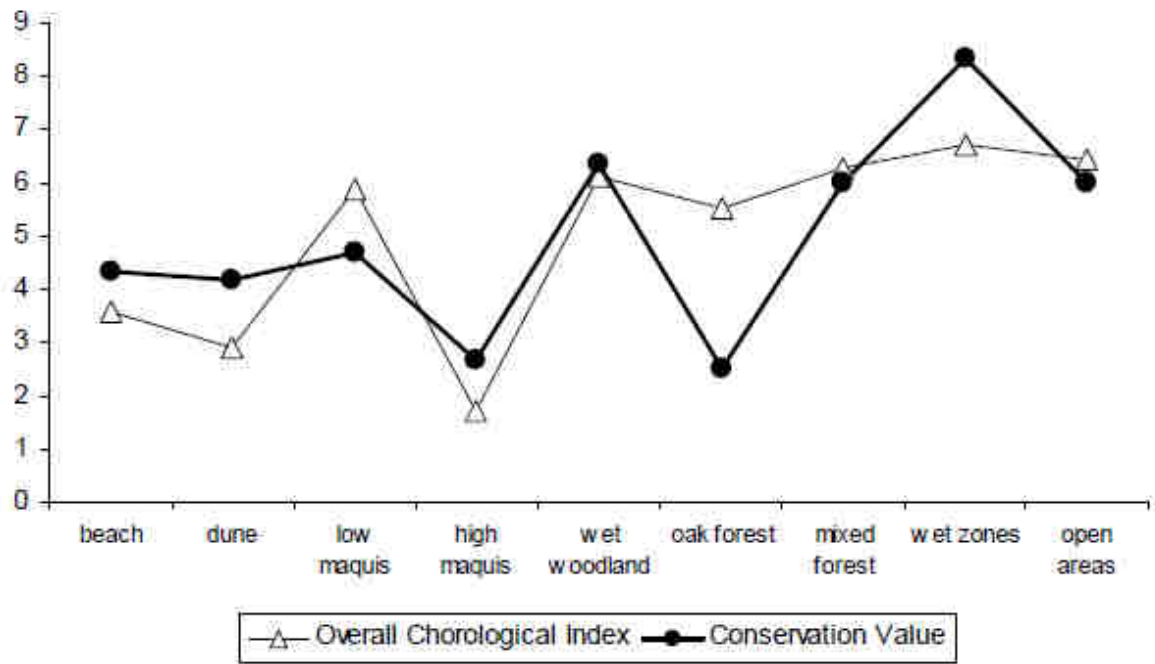
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648 Figure 4



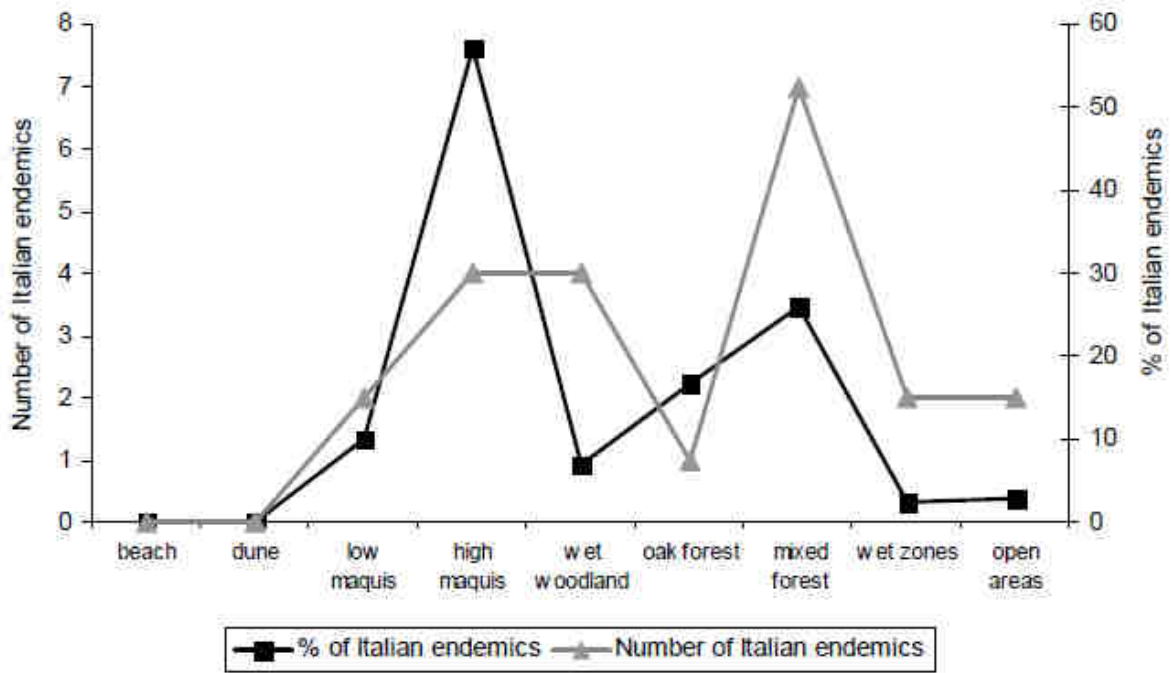
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651 Figure 5



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653 Figure 6



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