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## Diversity and abundance of soil arthropods in urban and suburban holm oak stands

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1 **Diversity and abundance of soil arthropods in urban and suburban**  
2 **holm oak stands**

3

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20

21

22 **Running title**

23 Soil arthropod diversity in urban stands

24

25

26 **Abstract**

27 We investigated the soil arthropod communities of urban and suburban holm oak  
28 (*Quercus ilex* L.) stands in a small (Siena) and a large Italian city (Naples) and tested  
29 whether the abundance and diversity of higher arthropod taxa are affected by the biotic  
30 and abiotic conditions of urban forest soils, including pollution. Acarina and  
31 Collembola were the dominant taxa in both cities. In Siena the total number of  
32 arthropod individuals collected in the samples was over 1/3 greater than in Naples, but  
33 all diversity indices scored higher in Naples than in Siena, probably in response to the  
34 higher heterogeneity of microclimatic and pedological conditions found in Naples study  
35 area. Oribatids resulted twice more abundant in Siena and so were the total mites with  
36 respect to Collembola. While “taxonomic richness” per site increased with distance  
37 from road traffic, entropy and evenness indices scored higher at the two ends of the  
38 impact gradient in both cities. The overall variation in basic pedological and  
39 microbiological soil parameters positively correlated with the total abundance of  
40 arthropods, and negatively correlated with their taxonomic richness. At the resolution  
41 employed, no significant relation emerged between anthropogenic factors, such as  
42 traffic load and soil pollution, and the arthropod fauna density and variety. These results  
43 are consistent with conclusions drawn from a previous study on the enchytraeid fauna  
44 examined at species level, which is remarkable considering the different taxonomic  
45 resolutions of the two studies. CCA results suggest that the higher abundance of  
46 Oribatid mites, Protura and Thysanura and the lower abundance of Diplopoda and  
47 Symphyla in Siena could depend on a higher fungi/bacteria ratio. This observation can  
48 be interpreted in terms of differences in fungi and bacteria between the two cities: Siena  
49 is shifted towards the fungal decomposition channel, which supports taxa such as

50 oribatid mites, while Naples is shifted towards the bacterial channel, which supports  
51 chiefly detritivorous groups, such as diplopods.

52

53 **Keywords:** Soil arthropods; Acari; Collembola; Mediterranean urban communities;  
54 holm oak stands

55

56

57 **Introduction**

58

59 Urban areas are spatially heterogeneous and temporally dynamic systems and differ  
60 from their current surroundings and from pristine conditions in terms of imperviousness  
61 of surfaces (e.g. due to soil compaction and paving), pollution (light, noise,  
62 atmospheric, and aquatic), number of exotic species, and changes of local climate (the  
63 urban heat island effect) (Vitousek et al., 1997). Urban agglomerations may be  
64 considered ecosystems in their own right, with fluxes and interactions, and feedback  
65 mechanisms among both natural and anthropogenic forms of physical and biological  
66 components (McIntyre et al., 2001; Liu et al., 2007). Although urbanization has  
67 detrimental effects on many animal taxa, there is often greater invertebrate diversity in  
68 urban green settings than in the rural surroundings (e.g. Erséus et al., 1999; Magura et  
69 al., 2010). This is due to variation in community composition among patches (beta  
70 diversity), which in turn is a result of a high variety of habitat types ranging from semi-  
71 natural to highly anthropogenic ones (Rebele, 1994). At many individual sites,  
72 anthropochorous dispersal and synanthropy mix species that would otherwise never  
73 coexist. It is therefore common to find in urban systems communities consisting of  
74 “irregular” combinations of species (unprecedented in natural habitats), including not  
75 only alien species but also species associated with human habitats, generalists, and  
76 native species that can cope with habitat alteration. At moderate levels of urbanization,  
77 taxonomic richness may actually be higher than in nearby wild lands, and total  
78 numerical abundances can reach high levels (e.g. at roadsides; Jones and Leather,  
79 2012), even without the presence of exotic invaders.

80         The invertebrate soil fauna has rapid generations times, is easy to sample, and its  
81 sampling is not controversial in the public eye. Soil invertebrate communities also play

82 a fundamental role in the cycling of organic matter and nutrients (Bardgett, 2005).  
83 Studying these communities in an urban context is therefore doubly suitable: ecologists  
84 can acquire basic information on biodiversity and evaluate soil quality and/or the impact  
85 of human activities on urban soils and other ecosystem components. Changes in soil  
86 community composition can in fact influence the transfer of persistent pollutants along  
87 food chains because soil invertebrates are food sources for higher trophic levels.

88 In Mediterranean regions, the evergreen holm oak, *Quercus ilex* L., has a wide  
89 natural distribution and has been traditionally used for landscaping of urban and rural  
90 parks. Within the frame of a project addressing the biodiversity of soil-dwelling  
91 invertebrates in Mediterranean urban environments, we investigated the community  
92 patterns of soil arthropods in urban and suburban *Q. ilex* stands in a small (Siena) and a  
93 large city (Naples). This paper describes the composition and abundance of the  
94 arthropod communities at high taxonomic levels, focusing on qualitative/quantitative  
95 aspects of their diversity at various spatial and temporal scales. The effects of relevant  
96 soil variables, including anthropogenic pollutants, on the abundance and distribution of  
97 arthropod taxa were also evaluated. We tested the general hypothesis that the two cities  
98 differ in terms of the abundance and diversity of soil arthropods and that these  
99 differences can be interpreted as an effect of soil abiotic and biotic conditions, and  
100 pollution.

101

102

## 103 **Methods**

104

105 *Study areas*

106 The cities of Siena and Naples are located in two different geological settings: sands,  
107 clays and calcarenites developed from Pliocene marine deposits, and andisols from  
108 pyroclastic volcanic deposits dated at <500 ka BP, respectively. The climate in Siena is  
109 temperate and mild, with average min temperature 2–17 °C, average max 8–28 °C;  
110 precipitation 750 mm yr<sup>-1</sup> (min summer, max autumn). The climate in Naples is slightly  
111 warmer and moister than in Siena, with average min temperature 4–18 °C, average max  
112 12–30 °C; precipitation 1007 mm yr<sup>-1</sup> (min summer, max autumn) (data 1961–1990). In  
113 2009 (the year of sampling) the spring in Siena was rainier than the average and the  
114 summer and autumn were drier than the average. In Naples the spring temperature was  
115 about 3 °C higher and precipitation 3.6 mm lower than typical seasonal average values.  
116 In contrast, September and October 2009 were characterized by frequent and heavy  
117 rainfall. The population density and the motor vehicle traffic volume are very different  
118 between the two cities. The municipality of Siena occupies the same area as the  
119 municipality of Naples (117.3 vs 118 km<sup>2</sup>), but has 1/17<sup>th</sup> of the Neapolitan population  
120 (54 500 vs 957 600). In the province of Naples, whose surface area (1171 km<sup>2</sup>) is one  
121 third that of the Siena province (3821 km<sup>2</sup>), there are many industrial plants and the  
122 total motor vehicles are nearly ten times more numerous (2 320 000 vs 247 000) with  
123 1980 vehicles km<sup>-2</sup> against 65 vehicles km<sup>-2</sup> in Siena.

124

### 125 *Sampling design*

126 In each city, three sampling plots were selected in holm oak (*Q. ilex* L.) stands at  
127 increasing distances from a trafficked road, a fourth plot (control) was established in the  
128 city outskirts, far away from the urban traffic. In Siena, the three urban plots (named S1,  
129 S2 and S3, respectively) were located under large holm oak trees within a 5 ha wide  
130 private park dating from the mid-19th century (Villa Patrizia; 346 m a.s.l., 43°20'13"N,

131 11°18'28"E). The plots were positioned at a distance of 10, 15 and 40 m from the highly  
132 trafficked Via Fiorentina. The suburban plot (S4) was located 3.5 km from Siena city  
133 centre, where a holm oak forest surrounds the 12th century Castle of Belcaro (350 m  
134 a.s.l., 43°18'26"N, 11°17'24"E). Geological, pedological and climatic features are very  
135 similar to those of Villa Patrizia but with minimal air pollution and anthropogenic  
136 disturbance.

137 In Naples, the three urban plots were located in Capodimonte Park, one of the  
138 largest (130 ha) green areas in Naples, positioned in the northern part of the city on top  
139 of a hill (150 m a.s.l., 40°52'18"N, 14°15'07"E). The park houses the former Bourbon  
140 royal palace which served as a hunting reserve for the kings of Naples as well as  
141 "garden of delights" for the production of fruit for the royal table. The selected locations  
142 in Capodimonte Park are part of a much larger (over 200 times larger) and more  
143 diversified green area than Villa Patrizia, whose long management history goes back to  
144 the early mid-18th century and today the arboreal flora is dominated by holm oaks trees,  
145 chestnut trees, magnolias and elm trees although the park overall harbours 400 species  
146 of plant. Soil samples (named N1, N2 and N3 respectively) were collected at 10, 160  
147 and 380 m from the highly trafficked via Miano. The differences in sampling distances  
148 along the transect at Capodimonte as compared to Villa Patrizia were due to the need to  
149 collect samples under the same type of vegetation cover. The suburban plot (N4) was  
150 located in Astroni (50 m a.s.l., 40°50'52"N, 14°08'59"E), a State Nature Reserve, 250 ha  
151 wide, 8.5 km to the northwest of Naples city centre. The area, an ash-ring crater about  
152 4000 years old, is covered by dense forest vegetation showing a complex zonation  
153 pattern (see Rota et al., 2010). Geo-pedological features are similar to those in  
154 Capodimonte and the soil samples were collected near the Vaccheria (a former royal  
155 hunting lodge), under the canopy of the oldest *Q. ilex* trees surviving in the crater. The



156 overall rationale behind our sampling strategy was that of ensuring comparable length  
157 and steepness in the examined pollution gradient. The distance between sampling plots  
158 in the two cities was therefore based on this choice and preliminary data on the study  
159 areas.

160 Details of the topsoil features and vegetation at the sampling plots and analytical  
161 procedures for soil physico-chemical and microbiological characterization are reported in  
162 Rota et al. (2013, 2014). In this paper, we analysed a selection of the parameters  
163 measured, as we aimed at obtaining an effective and simple descriptor of environmental  
164 variation, which we used to explain variation in diversity indices. The eleven chosen soil  
165 parameters were those maximizing the variance explained by main PCA axes (Suppl.  
166 Table 1): soil basic properties, such as pH, OM (Organic Matter) and water holding  
167 capacity; the total concentrations of Al, Cr, Fe, Ni, accounting above all for soil  
168 geochemistry; the extractable fraction of Zn and the total content of PAHs (Polycyclic  
169 Aromatic Hydrocarbons), as tracers of the different level of traffic-induced pollution;  
170 fungal:bacterial biomass and catabolic evenness, as indicators of the composition and  
171 functional diversity of soil microbiological communities.

172

### 173 *Faunal sampling and data processing*

174 The faunal sampling was conducted in May–June and October–November 2009. From  
175 each plot, five box cores of the top soil layers ( $10 \times 10 \times 5$  cm) were randomly taken  
176 within an area of  $5 \times 5$  m. The animals were extracted using a modified Berlese-  
177 Tullgren funnel for 20 days and were preserved in 75% ethanol. Arthropods were  
178 identified at the level of Class, Order or Family based on the identification of easily  
179 classifiable descriptor taxa with known functional roles (e.g. trophic guild). Abundances  
180 of taxa were recorded for each replicate.

181 Taxon richness and the entropy and evenness of the communities were measured  
182 using the following diversity indices: Menhinick's richness index:  $S/\sqrt{n}$ ; Shannon's  
183 entropy index:  $-\sum p_i \ln(p_i)$ ; Simpson's interspecific encounter probability:  $1-\sum(p_i)^2$ , and  
184 Pielou's "relative evenness" index:  $H'/\ln(S)$ , respectively. The significance of these  
185 indices was tested by randomization tests, and for Shannon's also by the Hutcheson t-  
186 test. A Principal Component Analysis (PCA) of the 11 soil parameters measured at the 8  
187 plots (correlation matrix) was performed to find new variables (components) accounting  
188 for at least 70-75% of the variance in the environmental data and to verify their  
189 correlation with the observed faunal diversity. To detect the main pattern in the relations  
190 between the environment and the abundance of the arthropod taxa at the 8 plots in the  
191 two seasons, a Canonical Correspondence Analysis (CCA) was used. Statistical  
192 significance of CCA axes was assessed by a permutation approach using 100 iterations.  
193 All statistical analyses were performed using the free software PAST version 2.17  
194 (Hammer et al., 2001, available at <http://folk.uio.no/ohammer/past>). The calculation of  
195 diversity indices is consistent with Magurran (2004), while our main reference for the  
196 sampling design and statistical analysis was Quinn and Keough (2002)

197

198

## 199 **Results**

200

201 From the 80 soil samples we extracted a total of 79,634 mesofaunal arthropods.  
202 Population densities (Tables 1–2) were much higher (on average one-third higher) in  
203 Siena than in Naples. Both in Siena and in Naples the highest total densities of soil  
204 arthropods on seasonal and annual bases were recorded at the station most exposed to  
205 the vehicular traffic (S1 and N1, respectively).

206

207 *Community structure*

208 Dominant taxa in the collection were: Acari (56,874 individuals: Oribatida 44%; others  
209 27%) and Collembola (18,195: 23%). The remaining 16% was represented by 21  
210 different taxa, two of which (Diptera and Coleoptera) were separately counted as adults  
211 and larvae. Ranked in order of abundance: Diplopoda (0.98%), Diptera larvae (0.85%),  
212 Protura (0.84%), Symphyla (0.69%) and Formicidae (0.56%), Diptera (0.43%),  
213 followed by smaller percentages of Chilopoda, Pauropoda, Diplura, Coleoptera larvae,  
214 Araneae, Thysanoptera, Isopoda, Pseudoscorpiones, Coleoptera, Hemiptera,  
215 Hymenoptera, and by occasional Orthoptera, Psocoptera, Dermaptera and Thysanura.

216 In Siena the total number of soil arthropods in the samples was 48,039  
217 individuals against 31,595 in Naples (Table1), and among mites the Oribatida in Siena  
218 were twice more abundant than in Naples (Oribatida/other Acari ratio scored 2.0 in this  
219 city, as compared to 1.1 in Naples), and so was the Acari/Collembola ratio (3.9 in Siena,  
220 against 2.3 in Naples) (Table 2). Protura were abundant in Siena but not so in Naples;  
221 similarly, Diplopoda and Symphyla were more abundant in Naples than in Siena.  
222 Thysanura were only collected in Siena, whereas Dermaptera, Orthoptera and  
223 Psocoptera were only found in Naples (Table 1).

224 In Siena, the urban communities consisted of 16–18 taxa in spring, against 15–  
225 19 taxa in autumn. S2 and S3 sites were the only locations for Thysanura (in spring),  
226 Mecoptera and Hemiptera (in autumn). The S4 control community consisted of 15 taxa  
227 in spring and 19 taxa in autumn. In the urban district, Protura, Diplura, Symphyla,  
228 Pauropoda, Diplopoda, Araneae, Thysanoptera and Hemiptera increased numerically in  
229 the autumn sampling. At the control station, instead, all groups increased in the autumn,  
230 except Protura and Diptera. Among Siena sites, the Oribatida/other Acari ratio and

231 Acari/Collembola ratio were lowest at the control station in both sampling periods  
232 (Table 1).

233 In Naples, the urban communities consisted of 19–22 taxa in spring, against 16–  
234 17 taxa in autumn. The N4 control community consisted of 19 taxa in both sampling  
235 periods, although Araneae were only collected in spring and were replaced by  
236 Hemiptera in autumn. Protura, Diplura, Symphyla and Pauropoda increased in general  
237 in autumn, whereas Dermaptera, Orthoptera, Mecoptera and Psocoptera were only  
238 found at Capodimonte in spring. Pseudoscorpiones were most abundant at Astroni in  
239 spring. N1 yielded the highest number of Diplopoda and Diptera, whereas N2 scored the  
240 lowest Oribatida/other Acari ratio and the highest Acari/Collembola ratio, in both  
241 sampling periods. Both these ratios remained nearly unchanged and close to the unit for  
242 N4 in both sampling periods (Table 1).

243

#### 244 *Diversity indices*

245 When comparing seasons (Table 1), Menhinick's index (number of taxa per square-  
246 rooted individual) ranged within 0.18–0.26 for Siena, and 0.24–0.34 for Naples. At  
247 none of the plots, however, we found significant differences of Menhinick's index  
248 between spring and autumn. Minimal values were recorded at S1 and N1 in both  
249 seasons, maximal values at S3 and S4 and at N3 and N4. Thus, the overall “taxonomic  
250 density” per site (regardless of the relative abundance of the various groups) increased  
251 in both cities with distance from the traffic road. The seasonal values of Shannon's  
252 entropy index (Table 1) were also lower in Siena (1.1–1.3) with respect to Naples plots  
253 (1.2–1.6), but they were significantly higher at plots 1 and 4 as compared to the other  
254 plots in both cities and seasons. The same trend also applied to evenness, whether

255 expressed as Simpson's interspecific encounter probability, or as Pielou's "relative  
256 evenness" index.

257 At the annual scale (Table 2), values of Shannon's entropy were significantly  
258 different ( $P < 0.005$ ) among plots, but not for the couples N2–N3 and N1–N4 in Naples.  
259 Significant differences in Menhinick's richness were only found for the whole Naples  
260 urban district (Capodimonte plots) between seasons, but not when comparing the two  
261 urban districts (Villa Patrizia vs. Capodimonte) or the whole cities (Siena vs. Naples).  
262 Shannon's entropy was instead significantly different when comparing the two urban  
263 districts or the whole cities, at both seasonal and annual temporal scales (Table 2).

264

#### 265 *PCA analysis*

266 The selected set of environmental variables (concentrations of Al, Cr, Fe, Ni, e-Zn and  
267 total PAHs; soil pH, OM and WHC; fungal:bacterial biomass and catabolic evenness;  
268 Suppl. Table 1) measured at the eight sampling plots (Rota et al., 2013) well  
269 summarizes expectations on the different environmental settings in which the  
270 investigated faunal communities live: volcanic soils from Naples had significantly  
271 higher Al and Fe concentrations and those from Siena much higher Cr and Ni  
272 concentrations. Soil pH, OM and WHC were on average higher at Siena than at Naples,  
273 the water holding capacity was related to soil texture, soil depth and to the OM content  
274 which strongly affects the water storage capacity. The soil fungal biomass prevailed  
275 over bacterial biomass in Siena, but the overall microbial communities appeared  
276 functionally more diverse in Naples (Rota et al., 2013).

277 The first two PCA components account for nearly 80% of the variance, allowing  
278 most of the information to be visualized in two dimensions. The biplot (Fig. 1) shows  
279 Siena stations far separate from Naples stations and a clear tendency of the

280 environmental conditions to be less varied in Siena than in Naples. PCA1 accounts for  
281 60% of the variance and reflects the different geological, textural and microbiological  
282 properties of the two cities. The two control stations (S4 and N4) are situated at the  
283 opposite ends of this axis. The second principal component, PCA2 (18% of the  
284 variance), appears strongly related to the anthropogenic impact. The stations closest to  
285 the trafficked roads (S1 and N1) and the highly contaminated innermost station N3  
286 (Suppl. Table 1; Rota et al., 2013) appear segregated in the upper half of the PCA  
287 biplot.

288           We analysed the correlation between the annual averages of the arthropod  
289 diversity indices at the eight stations and the overall environmental variation as  
290 reflected in the first component of the environmental data. PCA1 turned out to be highly  
291 (positively) correlated with the total abundance of arthropods ( $r = 0.92$ ,  $P = 0.001$ ) and  
292 even more strongly (negatively) correlated with Menhinick's richness index ( $r = -0.93$ ,  
293  $P = 0.0007$ ). No significant correlation was found instead between the annual averages  
294 of the diversity indices and PCA2.

295

#### 296 *CCA analysis*

297 The distribution of the 23 arthropod taxa in the 16 seasonal samples (five replicates  
298 cumulated) were analysed by Canonical Correspondence Analysis, with the aim to  
299 identify the environmental variables (among the 11 analysed) shaping the local  
300 arthropod communities (Fig. 2). The resulting first two ordination gradients, CCA1 and  
301 CCA2, accounted for over 84% of the variance in the arthropod data matrix and were  
302 both significant at  $P < 0.01$ . Scaling type 2 was used to emphasize relationships between  
303 taxa and sites. Three taxa mark two perpendicular trends: Thysanura contrast with  
304 Pseudoscorpionida on the first axis and the latter contrast with Psocoptera on the second

305 one. The CCA1 gradient correlates strongly with the fungal:bacteria ratio and places the  
306 urban stations of Siena, in general richer in fungal biomass, on the same side as  
307 fungivorous groups such as Thysanura (exclusive of Siena), Protura and Oribatida  
308 (more abundant in Siena), all situated on the left side of the graph. Siena control station  
309 (S4) is positioned on the right side of the graph, along with all Naples stations. Naples  
310 stations are more diversified from one another and on average richer in taxa than Siena  
311 urban stations, particularly in spring. Astroni appears best characterised by the lack of  
312 pollution and the high numbers of Pseudoscorpiones in spring, whereas the most  
313 impacted stations in Naples are best defined by their abundance in Diptera, both adults  
314 and larvae, Diplopoda and Isopoda.

315 Both the Oribatida/other Acari ratio and the Acari/Collembola ratio, as well as  
316 Shannon's index, scored in Belcaro (Siena control station) within the range recorded for  
317 Naples stations. Furthermore Belcaro in autumn (2S4) yielded a number of arthropod  
318 taxa as high as Astroni (Naples control). These results are consistent with S4 being  
319 located in the upper right half of the graph.

320

321

## 322 **Discussion**

323

324 The holm oak stands of the two targeted cities (Siena and Naples) are supported by soils  
325 that differ in basic parameters such as pH, concentrations of major and trace elements  
326 and microbiological features (e.g. the fungi/bacteria ratio). Previous studies on oak  
327 stands (e.g. Sharon et al., 2001; Sadaka and Ponge, 2003; Moreno et al., 2008) indicated  
328 that these parameters are key determinants of the distribution of major arthropod taxa.  
329 Accordingly, we found remarkably different arthropod communities between Siena and

330 Naples, and in each city a comparable number of taxa between urban and periurban  
331 control sites. We deem the differences remarkable because we employed a fairly coarse  
332 taxonomic level, although it is known that arthropods can in some cases respond to  
333 environmental variation already at the level of higher taxa (Caruso and Migliorini,  
334 2006). Oribatid mites, the major Acari taxon, were by far the most abundant taxon in  
335 Siena (accounting for over 50% of the collected arthropods), whereas in Naples their  
336 numbers were comparable to those of other mites and springtails. Other taxa also  
337 showed significant differences: Thysanura were only encountered in Siena, while  
338 Dermaptera, Orthoptera and Psocoptera were only sampled in Naples. Protura were well  
339 represented in Siena but less abundant in Naples, as much as Diplopoda and Symphyla  
340 were well represented in Naples but less abundant in Siena. Diplura, Pauropoda and  
341 Araneae were more abundant in Siena, whereas Naples yielded more numerous  
342 Pseudoscorpiones, Formicidae, Diptera, Thysanoptera and Coleoptera. Abundances of  
343 these taxa were generally very low compared to those of Acari and Collembola, and  
344 their relatively poorer representation in the communities might be partly due to a  
345 sampling effect. However, the sampling effort in this study was remarkable (a total of  
346 80 sampling units across different locations and two seasons) and some of the observed  
347 differences must be due to some genuine ecological process. For example, in soil  
348 samples from Siena the fungi/bacteria ratio was much higher and correlates with the  
349 high abundance of Oribatid mites, Protura and Thysanura and the low abundance of  
350 Diplopoda and Symphyla. Although oribatid mites and collembolans show a variety of  
351 feeding habits, ranging from decomposers of low quality organic materials to predators  
352 on fungivorous nematodes (Maraun *et al.* 2004, 2011; Schneider *et al.* 2004;  
353 Heidemann *et al.* 2011), a large part of Oribatid mites, as well as Protura and  
354 Thysanura, are fungivorous while diplopods and symphylans are detritivorous



355 (Coleman et al., 2004). If the Siena system is shifted towards the fungal decomposition  
356 channel, while the Naples system towards the bacterial channel (see Bardgett, 2005 for  
357 an exhaustive discussion of these two channels), then we might reasonably expect taxa  
358 such as oribatids to be more abundant in Siena. For the same reason, we expect the  
359 chiefly detritivorous groups, such as diplopods, to be more abundant in Naples. Higher  
360 fungi/bacteria ratios imply a more recalcitrant litter, slower rate of decomposition of  
361 organic matter and possibly a more complex soil food web (Bardgett, 2005; Bardgett  
362 and Wardle, 2010). Testing our hypothesis will therefore require an assessment of  
363 feeding spectra using suitable markers, such as stable isotopes (Scheu, 2002).

364         As previously observed for the assemblages of enchytraeid species at the same  
365 sampling sites (Rota et al., 2013), the different climatic and pedological features, more  
366 than the level of urban pollution, seem the main factors affecting the structure of soil  
367 arthropod communities, this being true besides trophic ecology. Although in Naples  
368 urban soils are much more polluted by heavy metals and PAHs than in Siena, Naples  
369 city soils harbour higher numbers of arthropod taxa, similar to those recorded in  
370 samples from Astroni State Nature Reserve. Arthropod diversity does not therefore  
371 seem related to levels of traffic intensity or to soil pollution, at least at the taxonomic  
372 resolution of the present study. In both cities the highest total number of individuals was  
373 observed at the stations that were most exposed to the vehicular traffic. This result  
374 might be due to the fact that the opportunistic species can take over specialist species  
375 under stress/disturbance (e.g. Walker, 2012). Although the overall taxonomic density  
376 (regardless of the relative abundance of the various groups) increased with distance  
377 from the traffic road, none of the diversity indices correlated with levels of soil  
378 pollutants. Some authors have proposed that mites/collembolans ratios should be lower  
379 in disturbed soils, whereas in more stable communities there should be a switch from

380 the generally r-strategist Collembola to the K-strategist Oribatida (Acari) (Coleman and  
381 Crossley, 1996). In this study, the Acari/Collembola ratio, while scoring higher in the  
382 less polluted city (Siena), showed the lowest values at the two control stations, which  
383 questions the reliability of this ratio as an indicator of soil pollution or other  
384 anthropogenic impacts. The ratio could nevertheless be a valid tool in other systems  
385 because effects are context and method dependent (Knoepp et al., 2000).

386 In Siena and Naples urban parks, the sampling locations were chosen in order to  
387 collect under the same type of vegetation cover, underbrush composition and density,  
388 and forest floor. It must be noted, however, that the two urban parks are different in  
389 size, history, morphology and structure. The woodland at Villa Patrizia offers  
390 throughout rather homogeneous habitats for soil arthropods as compared to the interplay  
391 of spontaneous and irregular vegetation characterizing Capodimonte Park (La Valva et  
392 al., 1996). All this implies that in Naples the microclimatic and pedological differences  
393 between the three urban sites and the control are more remarkable than in Siena (see  
394 Rota et al., 2013). These differences appear to be reflected by qualitative and  
395 quantitative differences in soil higher arthropod taxa, as well as in the enchytraeid fauna  
396 examined at species level (Rota et al., 2013).

397

398

### 399 **Conclusions**

400

401 We investigated the soil arthropod faunas of urban and periurban holm oak stands in  
402 two Italian cities (Siena and Naples), representative of different pedological features,  
403 levels of environmental pollution and urban park structures. Acarina and Collembola  
404 dominated in both cities and although the total number of arthropod individuals and the

405 mites/collembolans ratios were higher in Siena than in Naples (a much more polluted  
406 urban environment), in both cities the highest numbers of individuals were observed in  
407 soils more exposed to the vehicular traffic. Diversity indices, too, scored higher in  
408 Naples than in Siena. In agreement with a previous study on the enchytraeid species  
409 communities at same sampling sites (Rota et al., 2013), the results on the arthropod  
410 fauna at coarse taxonomic level indicate that soil pollution may exert an indirect and  
411 subtle impact on soil invertebrates. An analysis of the arthropod communities at species  
412 level will be required to achieve more exhaustive conclusions; nevertheless the present  
413 study suggests that basic pedological and microbiological soil features, the trophic  
414 ecology of organisms, and the variability of available habitats (resulting from the size,  
415 morphology, history, structure and management of parks) are the main factors affecting  
416 the diversity and abundance of major arthropod taxa in urban soils.

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418

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503

504 **Figure captions**

505

506 Fig. 1 – Principal Component Analysis of eleven soil properties measured at the eight  
507 sampling plots (based on log-transformed data and the correlation matrix). The  
508 diagram shows the first two ordination axes, accounting for 59.6% and 18.1% of the  
509 variance, respectively. pH based on water extracts. OM = Soil Organic Matter. WHC  
510 = Water Holding Capacity (gravimetric). Al, Cr, Fe, Ni = total metal concentrations.  
511 Zn-e = EDTA-extractable fraction of Zn. PAHs = total concentration of 16 EPA  
512 Polycyclic Aromatic Hydrocarbons. fu:baPLFA = fungal/bacterial PhosphoLipid  
513 Fatty Acids ratio. Catab.\_Ev. = Catabolic Evenness. Siena sites: S1–S4; Naples sites:  
514 N1–N4.

515

516 Fig. 2 – CCA (Canonical Correspondence Analysis) ordination triplot of arthropod taxa  
517 (seasonal counts), environmental descriptors, and Siena and Naples sites at the two  
518 sampling times (site codes preceded by 1= spring sampling, by 2= autumn sampling).  
519 Total inertia in matrix of arthropod taxa = 0.12643. Eigenvalues are 0.076 (P =  
520 0.005), 0.031 (P = 0.004) and 0.009 (P = 0.47) for first (horizontal), second (vertical)  
521 and third axes, respectively. They explain 59.8%, 24.4% and 7.2% of the variance in  
522 the matrix of arthropod taxa, respectively. Scaling type 2 was used, to emphasize the  
523 relationships among taxa and sites, and the length of the environmental vectors was  
524 tripled for clarity of the diagram. For abbreviations of environmental descriptors see  
525 Fig. 1, for codes of taxa see Table 1.

526