Land use influences harvestman diversity in northern Spain: a case study involving secondary grasslands and forest plantations (Arachnida: Opiliones)

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Abstract

Harvestmen have a general distribution pattern, with more species and higher abundance in forests than in open habitats, previously verified in mountain Cantabrian areas of northern Spain. The lower altitude areas in the same zone present a more complex mosaic landscape with mixed natural and managed habitats, mainly secondary grasslands and forest plantations, a combination of characteristics that makes a comparison of their harvestman distribution pattern with that of the previously mentioned mountain areas very interesting.

These managed habitats, and also contiguous habitats like natural forests, non-planted young forests, shrublands and habitat boundaries were studied. All these systems were continuously sampled with 7 pitfall traps during one year at 28 sites. Their harvestman assemblages were differentiated with 6 different analyses, and indicator species were identified.

The spatial patterns of harvestman diversity in low managed and natural areas differed from those of mountain areas, despite their having 15 species in common. There was high average harvestman species richness at each site. Shrublands were the richest habitats. The frequency and abundance of harvestman species also varied between the 2 areas.

Grasslands had a unique harvestman composition with significant extraordinary abundances due to *Homalenotus quadridentatus* -indicator species of this habitat- and *H. laranderas. Leiobunum rotundum* was the indicator species of 2 clusters with trees.

H. laranderas, Paroligolophus agrestis and *Ischyropsalis hispanica,* which were indicator species of some open habitats in the low Cantabrian area, were indicators of shady forests in mountain Cantabrian territories.

None of the 16 species found was under threat.

Keywords: Opiliones, Iberian Peninsula, diversity patterns, agroecosystems, indicator species

Introduction

Harvestmen are a common component of terrestrial ecosystems and have higher species diversity in tropical areas, with a decline toward the poles. In temperate areas the number of harvestmen species at any given location is rarely greater than 12 (Curtis and Machado 2007). Many harvestman species are collected with pitfall traps when wandering over the ground and so they have frequently been studied together with other epigean fauna (Zingerle 1999; Ivask et al 2008; Rosa García et al 2009a 2009b).

Some effort has been given to the study of harvestmen in managed habitat areas. Ivask et al. (2008) found statistically significant differences between the number of Opiliones individuals present in fields and on their edges. The influence of agricultural management type (Ivask et al. 2008; Marasas et al. 2001; Stašiov et al. 2011), the grazing history (Dennis et al. 2001; Paschetta et al. 2013), the types of cultivated soils (Ivask et al. 2008) and types of forest plantations (Hicks et al. 2003) on harvestman communities have all been studied.

Northwestern Spain sustains considerable harvestman diversity and a high number of endemic species in the areas that have been studied (Rambla 1974, Prieto 2003, Merino Sáinz and Anadón 2008, 2009). The studies on harvestman assemblages have focused mainly on areas high in the mountains, far from populated nuclei and with few anthropogenic influences. Though there are some taxonomic papers on the harvestmen in low Cantabrian areas (Merino-Sáinz and Anadón 2013) the distribution of their harvestman assemblages had still not been investigated until now.

Here, two types of managed habitats are studied: meadows and forest plantations. Secondary grasslands were formerly natural forests and have now become grasslands due to human activity and may be pastures (for grazing) or meadows (for hay-making). Secondary grasslands are an essential part of Europe´s landscape and account for 35.3% of the utilized agricultural area (Dengler el al. 2014). In Asturias, grasslands account for 25% of land use, meadows representing 21% of the total (García Manteca et al. 2005), whilst forested areas make up 29% of the land surface, 9% being forest plantations.

A comparative study of the distribution patterns of harvestmen in managed *versus* non-managed habitats in different low Cantabrian habitats could reveal the effect of management on general distribution patterns (Curtis and Machado 2007). Furthermore, the inclusion of managed habitats might also provide some information of significance for conservation policies. Included within the scope of this study are the species composition, species richness and abundance of the harvestmen in the habitats of the region and the investigation of differences between the harvestman assemblages.

The hypothesis concerning species richness was that forests and forest plantations would be richer in species than the other open areas studied, whilst the hypothesis concerning abundance was that forests and forest plantations would have greater abundance than open habitats.

The species composition of low Cantabrian areas (Merino-Sáinz and Anadón 2013) was nearly the same as the species composition of Muniellos (Merino Sáinz and Anadón 2008- 2009), so there is an opportunity to search for similarities and differences between the distribution of these harvestman species in low and mountain areas in the Cantabrian region. Muniellos is a "natural" (in the sense of Peterken 1993), forested Biosphere Reserve in the Cantabrian mountains in Asturias. The low Cantabrian areas are in the biogeographic Cantabro-Atlantic Province, while Muniellos is in the Orocantabrian Province. These 2 provinces are to be found in Spain, on the northern fringe of the Iberian Peninsula, adjacent to the Mediterranean basin, which is a biodiversity hotspot (Mittermeier et al. 2011; Myers et al. 2000).

Material and methods

Study area

The study was carried out in low Cantabrian areas in Asturias and Cantabria (Fig. 1). Over a period of one year from March 2009 until April 2010, 26 plots (Table 1) were sampled in Asturias and 2 plots in Cantabria. These plot areas have a temperate hyperoceanic/oceanic submediterranean bioclimate and are included in the Cantabro-Atlantic Province of the Eurosiberian phytogeographic Region (Rivas Martínez et al. 2004), next to the Orocantabrian Province.

The managed habitats were 6 grasslands and 5 forest plantations. All the grassland plots were meadows, located in 3 different municipalities: Oviedo, Muros de Nalón (both in Asturias) and Piélagos (in Cantabria, locality of Vioño). Two of these meadows had fruit trees.

The natural habitats and forest plantations were sampled in Oviedo: 6 forests, 5 young forests, 4 shrublands and 2 boundaries or margins adjacent to 2 grasslands. One of the boundaries was populated with horsetails and the other one with nettles. One plot was in the city and all the other plots were in Monte Naranco, in 5 different areas or zones (Fig. 1): Ajuyán and Brañes (the northern mountainside beside the river Nora), El Violeo (the western top of the mountain), Ules and Naranco (the southern side). Mount Naranco has calcareous, siliceous and mixed soils.

Sampling scheme

Each plot was sampled with 7 pitfall traps which were processed as a single sample. Each pitfall trap consisted of 2 plastic cups 11 cm in height with a diameter of 8 cm at the top and 5 cm at the bottom. The outer cup remained in the ground and the inner cup was used to take the sample and to renew the liquid each time. The pitfall traps had a solution of water and ethylene glycol at 40% as preservative and antifreeze and 15 g/L of CALGON® sodium polymetaphosphate, as emulsifier. A 10 cm long, 6 cm high roof was placed over the traps while functioning, to protect them from the rain.

The samples were collected every 15 days. Harvestmen in the samples were sorted and identified with the bibliography mentioned in the following preliminary studies: Merino-Sáinz and Anadón (2013) and Merino-Sáinz et al. (2013). All the specimens are accessible in the Harvestmen dataset of the BOS-Opi Arthropod Collection of the University of Oviedo, Spain, through the GBIF network.

Data analyses

Species richness, abundance, frequency and “true” diversity of harvestmen were obtained for the different sites and habitats. Diversity was studied as: $^{2}D = 1/\lambda$ (Hill 1973; Jost 2007; Tuomisto 2010), called by Tuomisto “true” diversity. This diversity measure is the inverse of the Simpson index of evenness; p_i being the proportional abundance of the *i*th species. This index increases as diversity intuitively increases. ANOVA (Analysis of Variance) was used to discard the null hypothesis of no differences between the means of different habitats or clusters. When the existence of differences had been proved, post hoc or “a posteriori”, multiple comparisons, including the HSD test of Tukey, Scheffé and Fischer LSD (Least Significant Difference), were used to determine between which habitats or clusters differences were found. The relationship between the harvestman species richness and the harvestman abundance of the sites was studied with the linear correlation coefficient r.

The smooth accumulation curves were produced to assess the quality of the inventory. The sampling dates were taken as measures of sampling effort, and they were randomized 999 times. The Simplex and Quasi-Newton method (Hortal et al. 2004) with the program Statistica V6 (StatSoft 2001) fitted the Clench function to the smoothed curves to estimate the asymptotes. These asymptotes predicted the estimated species richness (Hortal et al. 2004) and the ratio observed/estimated species richness (q) gives the proportion of the known inventories. When the value of the final slope was lower than 0.1 and the percentage of collected species was over 70, the inventory was considered reliable enough and well sampled (Hortal and Lobo 2005). The accumulation curves and Clench function (Table 2) confirmed that the inventories can be considered reliable enough and well sampled, except for three sites that were insufficiently sampled. The sampling efficiency percentage of these three sites was above 70% but the final slope of the curves was greater than 0.1: 0.12, 0.13 and 0.16.

The relative position of sites and species was visualized in a correspondence analysis, run using the PAST.exe statistical program (Hammer et al. 2001).

The hierarchical clustering (CLUSTER) was carried out with average group linkage and it used the triangular matrices of the distances between sampling sites (according to their species assemblages). The distance between two sites was measured with the Bray-Curtis coefficient of similarity based on square root transformed abundance data of harvestmen. These matrices were also used in the non-metric multidimensional scaling (MDS), which represents the distances between the sites in a geometric space.

The dissimilarity between samples from different groups was obtained with the similarity percentage analysis (SIMPER). The PRIMER V6 program (Clarke and Gorley 2006) was used to obtain species accumulation curves, hierarchical clustering, multidimensional scaling, analysis of similarity and similarity percentages.

Indicator species analyses for a cluster of sites were obtained using the package "indicspecies" 1.7.3 2014-07-10 (De Cáceres and Jansen 2014) in R (R Development Core Team 2012). The indicator value indexes (IndVal) (De Cáceres and Legendre 2009; Dufrêne and Legendre 1997), measured the association of a species for a given clustering of sites.

Results

The total number of epigean harvestmen studied were 12,208 specimens, of the following 16 species. Their distribution was Ho, holarctic, Eu, European or IE, Iberian endemic.

Suborder Eupnoi Hansen & Sørensen 1904

Superfamily Phalangioidea Latreille 1802

Family Phalangiidae Latreille, 1802

Subfamily Oligolophinae Banks, 1893

1.- *Paroligolophus agrestis* (Meade, 1855). Ho

2.- *Odiellus simplicipes* (Simon, 1879). IE

3.- *Odiellus seoanei* (Simon, 1878). IE

Subfamily Phalangiinae Latreille, 1802

4.- *Phalangium opilio* Linnaeus, 1761. Ho

Family Sclerosomatidae Simon, 1879

Subfamily Gyinae Šilhavý, 1946

5.- *Gyas titanus* Simon, 1879. Eu

Subfamily Leiobuninae Banks, 1893

6.- *Leiobunum rotundum* (Latreille, 1798). Eu

7.- *Leiobunum blackwalli* Meade, 1861. Eu

Subfamily Sclerosomatinae Simon, 1879

8.- *Homalenotus quadridentatus* (Cuvier, 1795). Eu

9.- *Homalenotus laranderas* Grasshoff, 1959. IE

Suborder Dyspnoi Hansen & Sørensen 1904

Superfamily Ischyropsalidoidea Simon 1879

Family Ischyropsalididae Simon 1879

10.- *Ischyropsalis hispanica* Roewer, 1953. IE

Family Sabaconidae Dresco, 1970

11.- *Sabacon franzi* Roewer, 1953. IE

Superfamily Troguloidea Sundevall 1833

Family Nemastomatidae Simon, 1872

Subfamily Nemastomatinae Simon, 1872

12.- *Nemastomella dentipatellae* (Dresco, 1967). IE

13.- *Nemastoma hankiewiczii* (Kulczynski, 1909). IE

Family: Trogulidae Sundevall, 1833

14- *Anelasmocephalus cambridgei* (Westwood, 1874). Eu

15.- *Trogulus nepaeformis s.l.* Eu?

Suborder Laniatores Thorell, 1876

Superfamily Travunioidea Absolon & Kratochvil 1932

Family Travuniidae Absolon & Kratochvil, 1932

16.- *Hadziana clavigera* (Simon, 1879). IE

This check-list is very similar to the list of the Opiliones fauna of Muniellos, since there are 15 shared species. *H. quadridentatus* is the sole species absent from Muniellos, which had 4 species not present in this catalogue. The Analysis of Variance of the distribution of the relative abundance and the relative frequency of occupancy of sites of these 16 harvestman species in low Cantabrian territories and Muniellos (Table 3), gave significant differences (p-value 0.015) only for the frequencies. The relative frequency of many species was high in low Cantabrian areas (Table 4). Half of the 16 harvestman species studied were found in many habitats and were eurychorous, with a wider ecological niche: *L. blackwalli*, *T. nepaeformis s.l.*, *N. dentipatellae*, *O. simplicipes* and *N. hankiewiczii* were very abundant, while *A. cambridgei*, *P. opilio* and *L. rotundum* were not abundant. The first 2 species were collected in all the sites. The species with a smaller range, stenochorous, were *G. titanus* and *H. clavigera*, rare; *O. seoanei*, *P. agrestis*, *I. hispanica* and *S. franzi*, not abundant species and *H. quadridentatus* and *H. laranderas*, very abundant.

European species represent more than half the total harvestman abundance in low Cantabrian areas, followed by endemic Iberian species (see last lines of Table 3).

Harvestman species richness and abundance will be treated separately here, since the linear correlation coefficient was near to zero (r = 0.007), indicating that their values were independent.

Species richness.- Each sampled site had between 6 and 12 harvestman species (Table 4) and each species was found in a minimum of 2 to a maximum of 28 sites (average 16.4 sites). The average harvestman species richness/site in these low Cantabrian areas, 9.6 ± 1.7 species/site, was higher than in Muniellos, which had 6.2 ± 3.5 species/site. The specific inventories for the different zones include 14 species in Violeo, 13 in Brañes, 13 in Ules, 12 in Ajuyán, 11 in Muros and 9 species in Vioño.

The average harvestman species richness in the different habitats was always above 8 species (Table 5). The managed habitats had the lowest average values: 8.4 for forest plantations and 8.8 for grasslands. The highest number of species was found in boundaries and shrublands.

In the low Cantabrian area, the average species richness was 1.09 times greater in habitats which were not forests: forests had 9.2 ± 1.9 species/site. In Muniellos, however, the non-forest habitats had only 0.48 times the number of species/site that the forest environments had;

Muniellos forests had 8.3 ± 3.1 harvestman species. The forest plantations with chestnuts and pedunculate oaks had 6 to 9 harvestman species, while the eucalyptus plantation had 11 species.

There were no great differences in species richness between either sites or clusters. Analysis of Variance showed differences in richness which were close to being significant (p = 0.065, between habitats and p = 0.067 between clusters).

Abundance.- Each sampled site had between 41 and 1817 specimens (Table 4). The average abundance value was close to the standard deviation: 436 ± 470.3 specimens/site. The mean harvestman abundance was 2.6 times greater in the 5 habitats which were not forests (Table 5). Shrublands and young forests followed grasslands in abundance. The Analysis of Variance showed there are significant differences in harvestman abundance comparing habitats (p-value 0.000) and comparing clusters (p-value 0.000). Multiple comparisons "a posteriori" with HSD Tukey and Scheffé of the abundance between all the habitats and all the clusters showed the grasslands, which constitute one of the clusters, had significant differences, p-value of 0.000, with respect to all the remaining habitats and clusters. The differences in abundance between any of the other habitats or clusters were not significant.

Grasslands housed well-defined harvestman assemblages which had 3.73 times greater average abundance than shrublands. There was a gradual decrease in the average number of specimens from shrublands to young forests, boundaries, forests and forest plantations. Forest populations were slightly more abundant and diverse than those of forest plantations (Table 4).

Diversity.- Harvestman diversity $1/\lambda$ values/site ranged between 1.38 and 7.67 (Table 4). The highest mean values (Table 5) were obtained in cluster C2.1, which includes shrublands plus adjacent young forest at the top of and on the southern side of Monte Naranco. The lowest mean value was for grasslands. The Analysis of Variance showed there are significant differences in the diversity values between clusters (p-value 0.018) and between habitats (p-value 0.037).

The analysis "a posteriori" found significant differences between the diversity of the cluster of grasslands (A) and cluster C2.1. Regarding the differences in diversity between the habitats, only the test for multiple comparisons "a posteriori" Fischer LSD (Least Significant Difference) gave some difference: between grasslands and boundaries (p-value 0.015), grasslands and shrublands (p-value 0.011) and grasslands and young forests (p-value 0.010).

Differences between harvestman assemblages.- The harvestman assemblages of grasslands were clearly differentiated from the rest of habitats by all the analyses carried out in order to investigate the differences: correspondence analysis, cluster, MDS, ANOSIM and SIMPER.

In the correspondence analysis (CA) (Fig. 2) all the grasslands, plus 3 harvestman species, *Homalenotus quadridentatus*, *H. laranderas* and *Odiellus seoanei*, were isolated to the left, on the first axis. The two *Homalenotus* spp. were the most abundant of the sampled species; *O. seoanei*, however, was not abundant and it was present in only 2 sampling sites, one of which was grassland; nonetheless, this species was present in 47% of sites in Muniellos.

The Pyrenean oak young forest of Naranco, a very small number of trees on the Naranco mountain, was also separated to the upper right of the CA with *Hadziana clavigera* and *Paroligolophus agrestis*. *Gyas titanus* was also isolated in the lower right. The rest of the places had a more central position in the CA, together with 10 frequent species (see Table 4). *L. blackwalli*, present in 100% of the sites and *Nemastoma hankiewiczii*, present in 72% of the sites, had an intermediate position in CA, between grasslands and the central sites: they were quite abundant in grasslands, more abundant than in other clusters (Table 4).

The cluster analyses of sites with harvestman abundance data discriminate between the assemblages better, giving 5 sets of sites (Fig. 3, Table 4). Only one cluster included sites with just one habitat type: cluster A included all the grasslands but no other habitat. The other clusters had a mixture of habitats, and 4 habitat types were scattered in different clusters.

Cluster C1 included most of the forests and 2 young forests (one bay young forest and one hazelnut young forest, shaded, humid with calcareous soil and a northern orientation). They were all in Ajuyán and Brañes, on the northern side of the mountain, except for one oligotrophous forest in Violeo, with northwestern orientation.

Cluster C2.1 included all the shrublands and 2 young forests of Pyrenean oaks and one young forest of willow trees, all in Naranco and Violeo, at over 400 m altitude and in sunny orientations.

Cluster C2.2 included 2 boundaries with 3 forest plantations, one of eucalyptus and 2 plantations of pedunculate oaks and chestnuts, in a lower, southern position on the mountain, all in Ules, except one of the boundaries, which was in Oviedo. The area was a characteristic site for Pyrenean oak trees.

Cluster B had the places that were poorest in abundance, quite near each other, one forest plantation and one eutrophous gallery forest at the head of a stream, high up in Violeo.

In the MDS (Fig. 4) all the grasslands were grouped to the left, separated from the other habitats. The sites with the same habitat type were near to each other, except for forest plantations and young forests. Harvestman assemblages of forest plantations were scattered in the MDS (Fig. 4).

The ANOSIM tests showed that the harvestman assemblages of grasslands and forests were the most clearly differentiated from those of the other habitats (Table 6). Boundaries had the least distinct harvestman assemblages since they only differed from grasslands.

The highest dissimilitude percentages between harvestman assemblages were found between the grasslands and the other habitats (Table 6) with the SIMPER analysis of similitude.

Forest harvestman assemblages were different from the harvestman assemblages of all the other types of habitats, excluding boundaries populated with horsetails or nettles. There was a gradual increase in differences between forests and boundaries, young forests, forest plantations, shrublands and finally grasslands (Table 6).

Indicator species.- Seven indicator species for certain habitats, for certain clusters or a combination of habitats or clusters have been identified. *H. quadridentatus* was an indicator species of cluster A, grasslands. This species was also indicator species of grasslands + herbaceous boundaries. *H. laranderas* was in turn an indicator species of the sum of 2 clusters and indicator of the combination of grasslands + shrublands + herbaceous boundaries (Table 7). *H. laranderas* was present in surprisingly high numbers in grasslands.

Leiobunum rotundum was an indicator species of the sum of clusters C1 + C2.2, 2 clusters which include forests, most forest plantations and boundaries (Table 6).

Ischyropsalis hispanica was an indicator species of the sum of open habitats: boundaries plus shrublands and young forests, excluding grasslands. *Sabacon franzi* was indicator species only of shrublands plus some young forests. *Paroligolophus agrestis* was an indicator species of the cluster C2.1, which includes all the shrublands and 3 young forests. *Odiellus simplicipes* was an indicator species of the sum of clusters with all the shrublands, boundaries, grasslands and 3 young forests (Table 4).

Discussion

The independence of the species richness and abundance of harvestmen seen in this study has already been described in a National Park in the Czech Republic (Klimeš 1999) and the Pre-Pyrenees with the linear correlation coefficient (r= 0.039) near to zero calculated from the data of Rambla (1985). The abundance/site and diversity 1/λ in the habitats studied in the low Cantabrian area differed between sites, as in the Pre-Pyrenees, where 12 different habitats studied with a similar sampling device to ours showed a high standard deviation in average harvestman abundance, 441 ± 352.6 (obtained from Rambla 1985 data).

Managed habitats had their own harvestman peculiarities, and both managed and natural habitats in the low Cantabrian area of the biogeographic Cantabro-Atlantic Province had different harvestman distribution patterns to the habitats of the mountain Cantabrian area of the Orocantabrian Province. Among managed habitats, grasslands were clearly differentiated from the remaining habitats, while forest plantations did not have characteristic harvestman assemblages.

Managed habitats

The species richness and abundance of harvestman species in managed habitats were quite unexpected. They had greater average harvestman species richness than natural habitats in the Orocantabrian Province.

Grasslands were expected to be the poorest in both harvestman species and abundance and forest plantations were expected to have quite high harvestman species richness and abundance. However, the managed habitats were the two poorest in harvestmen species, and grasslands, among all the habitats studied, were the most abundant in harvestmen.

Forest plantations had the lowest average harvestman species richness of all the habitats (8.4 species, 70% of that of the boundaries, with the highest harvestman richness), and they also had the lowest average harvestman abundance of all the habitats (10% of that of the grasslands). Since forest plantations are wooded or forested habitats, they were expected to have, in some degree, greater harvestman species richness and abundance than open habitats in low Cantabrian areas, considering the ratio found in mountain Cantabrian areas (Merino-Sáinz and Anadón 2015) and the generally observed patterns. Muniellos in the Cantabrian mountains had a ratio of harvestman species richness of forests/open habitats of 2.06 and a ratio of harvestman abundance forests/open habitats of 2.79. Curtis and Machado (2007) provided a general pattern of harvestman distribution: they compiled the local richness of harvestman species in 89 forested and 70 open habitats from the data of many authors and found that the average harvestman species richness in forested habitats was 2.8 times higher than in open habitats.

Forest plantation harvestman assemblages were different from the harvestman assemblages of grasslands, forests and shrublands but presented no differences with harvestman assemblages of young forests or boundaries. These forest plantations did not have a characteristic harvestman assemblage but their populations seemed to be dependent on the harvestmen of neighbouring habitats.

Grasslands in low Cantabrian areas had the next poorest average harvestman species richness, 8.8 species. However, this value was higher than the average harvestman species richness of the forests in Muniellos, the richest habitat in the mountains, and was also higher than the harvestman species richness of grasslands in mountain sites (Fig.1) of similar latitude such as Muniellos (Merino-Sáinz and Anadón 2015), Illano (Rosa García et al. 2010a), open areas of the Pre-Pyrenees (Rambla 1985) and Eastern Pyrenees (Ledoux and Emerit, 2006). In mountains, the low number of harvestmen in the grasslands could be explained because grasslands are more exposed than forests to changes in climatic factors (Curtis and Machado 2007).

The poorer harvestman species richness of grasslands was expected but, on the contrary, the surprising abundance of harvestmen that was observed was most unexpected. The harvestman abundance of grasslands significantly exceeded the abundance recorded in any other of the habitats studied and this high abundance was due to the 2 *Homalenotus* species. There is some previous knowledge of harvestman abundance in grazing grasslands in Alpine pastures and from grazing experiments in the Cantabrian mountains, where the dominance of certain species has been shown, but together with poorer overall harvestmen abundance. In the Northwest of Italy *Mitopus morio* dominated all pastoral types in an Alpine environment, together with *Dasylobus ligusticus*. In the Cantabrian mountains *H. laranderas* dominated the grazing heathlands of Illano, whether the predominant vegetation was heather and heaths, gorse or grass, though it was less abundant in grass (Rosa García et al 2010b). In Illano, shrublands had 97% of the opilionid abundance and 10 species, while grasslands had only 3% of abundance and 7 species in experimental plots grazed by sheep or cattle (Rosa García et al 2010a). In Muniellos, grasslands had only 4 species and very few specimens (Merino-Sáinz and Anadón 2015).

Grasslands in low Cantabrian areas had rich, unique and exclusive harvestman assemblages very different to those of all the other habitats and they had the lowest diversity 1/λ. Their high species richness could be related to the biodiversity of secondary grasslands which house many plant species in Europe (Dengler et al. 2014) and to the structure of these grasslands (Morris 2000). Asturias and Cantabria are well known for their rich meadows within the association *Lino biennis* - *Cynosuretum cristatus* Tüxen & Oberdorfer 1958 (Díaz González and Fernández Prieto 1994). These are permanent grasslands which are not ploughed, two conditions which favour higher species richness in harvestman communities (Ivask et al. 2008; Stašiov et al. 2011).

Natural areas.-

The natural habitats studied in the low Cantabrian area also had unexpected harvestman assemblages with higher species richness and abundance than the habitats in the Orocantabrian Province. Semi-natural areas tend to have much greater arthropod abundance than adjacent arable fields (Pfiffner and Luka 2000).

Forests in low Cantabrian areas were not the habitats richest in harvestman species, as had been expected, and neither were they the most abundantly populated habitats. However, they had higher average harvestman species richness than mountain forests in Muniellos and the Pre-Pyrenees. Mountain forests were the most abundantly populated habitats, though not all the forests had the same abundance: those forests with a sunny orientation in Muniellos (Merino-Sáinz and Anadón 2015) or with Mediterranean characteristics in the Pre-Pyrenees (Rambla 1985) were less abundant in harvestmen than the remainder of the forests. The riverside forests of Muniellos had the most abundant harvestman assemblages of all the habitats studied there, the opposite case to low Cantabrian gallery forests, which had low harvestman abundance when compared to the other habitats.

The harvestman assemblages of low Cantabrian forests were different to harvestman assemblages of all the other habitats except boundaries. The diversity of forests was similar to the harvestman diversity in forest plantations and it was intermediate among all the habitats.

Shrublands, young forests and boundaries had the highest harvestman richness and an intermediate abundance between forests and forest plantations on one end and grasslands on the other end, probably related to a more complex structure and greater capacity for shelter than grasslands. As a consequence, these 3 intermediate open habitats had the highest harvestman diversity values ($1/\lambda$). Really, they constituted a transition between the most differentiated grasslands and forests, as seen with ANOSIM and SIMPER analyses. In Illano a higher abundance and richness of harvestmen in shrubland experimental plots compared to grassland plots was found (Rosa García et al. 2010a). The discovery of the highest species richness in herbaceous boundaries resembles the greater number of harvestmen found in Estonia along field edges than in the centre of the fields with three different types of soils, (Ivask et al. 2008) and on the field margins of Northern Europe (Marshall and Moonen 2002).

General considerations.

The number of 16 harvestman species found in low Cantabrian areas is quite high for temperate areas (see Curtis and Machado 2007). The harvestman species richness found in mountain areas of approximately the same latitude (Fig. 1) were: 11 in Pre-Pyrenees (Rambla 1985), 12 in Pyrenees (Rambla and Perera 1989), 16 in Montseny mountain in Catalonia (Rambla and Perera 1995) and 14 in France (Ledoux and Emerit 2006). In western Asturias Illano had 14 species and Muniellos had 19 species.

The most abundant harvestman species, the indicator species of some habitats, and the frequencies of the species were different in the 2 Cantabrian territories. *H. quadridentatus* was the most abundant species in the low Cantabrian areas (Table 3), while *P. agrestis* was the most abundant species in Muniellos. *P. agrestis*, *H. laranderas* and *I. hispanica*, which in low Cantabrian areas were indicators of open habitats, including young forests, were, in Muniellos, indicators of the lower forest sites in shady habitats (Merino-Sáinz and Anadón 2015).

The mosaic landscape in low Cantabrian territories may have facilitated the presence of many species in different habitats, which, in turn, could be related to the high relative frequency of many species. The species may find shelter in adjoining areas, and may move easily between adjacent, small-sized patches of different vegetation structure. In cultivated areas of Switzerland, a mosaic landscape of small-sized crop fields and semi-natural habitats maximizes arthropod diversity and may decrease the probability of overall extinction even of rare species (Duelli 1990).

The pool of harvestman species studied in mixed managed and natural habitats is not in danger in the low Cantabrian area. Furthermore, these species have also been found in mountain Orocantabrian areas, which ensures their persistence in the region during future years, bearing in mind that they have been shown to live at different altitudes and many of them in a variety of habitats.

The harvestmen assemblages in low Cantabrian areas, -of different habitats and different clusters-, were closer to each other than in Muniellos, where some groups of habitats were clearly separated from each other in the analyses such as CA and MDS. The absolute exception in low Cantabrian areas was the distinguished position of grassland assemblages, widely separated from all the other assemblages in all the analyses performed, despite the fact that the grasslands studied were spread across 3 different municipalities.

The different distribution of harvestman species in areas that are not widely separated, like mountain Cantabrian and low Cantabrian territories warns against making easy generalizations and shows that regional or even local features must be considered in conservation policies.

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Figure captions

Fig. 1

Location of sampling places and localities. Centre: 22 sampling points (black triangles) around the city of Oviedo and their local zones, numbered according to Table 1. Lower left corner, Iberian Peninsula with the communities of Asturias and Cantabria delimited. Upper right corner Asturias and its municipalities. Black crosses: six localities whose harvestmen were compared: PI Parque Integral Natural; PNO, Parque Nacional de Ordesa y Monte Perdido; SJP, Macizo de San Juan de la Peña, PNM, Parque Natural del Montseny and RPM, Rèserve Naturelle de Prats-de-Mollo.

Fig. 2

Correspondence analysis of the sampling sites and their harvestman species. Grasslands are within the left ellipse. Most sites are within the right ellipse. Abbreviated and complete name of the sites and their characteristics are in Table 1. Harvestman species complete names are in the text.

Fig. 3

Cluster analysis of harvestman assemblages of the sites, obtained with abundance data. Abbreviated and complete name of the sites and their characteristics are in Table 1. The names of each cluster are below.

Fig. 4

Multidimensional scaling (MDS) of the harvestman assemblages of the sites studied. Each type of habitat has a different tag and the clusters of Figure 3 are marked.

Table 1. Position and characteristics of the sites studied. Ab., abbreviation; (Nar), Naranco; (Ul), Ules; (Vle), Violeo; (Bra), Brañes; (Aju), Ajuyán; (Ovi), Oviedo; (Mur), Muros de Nalón; (Vio), Vioño; DD Coo., Decimal Degrees coordinates; m: altitude in meters. Sites beginning with E, boundary; F, forest; G, grassland; P, forest plantation; S, shrubland; Y, Young forest.

Site Ab.	DD Coo.	Habitat	Phytosociological association	m
1.- SbN (Nar)	43.3815,-5.8573	Shrub: furze	*Ulici europaei-Genistetum occidentalis*	460
2.- SgN (Nar)	43.3836,-5.8535	Shrub: heather-gorse	*Ulici europaei-Ericetum vagantis*	547
3.-YpN (Nar)	43.3835,-5.8536	Young forest: Pyrenean oaks	Previous to *Blechno spicanti-Quercetum roboris* facies *Q. pyrenaica*	540
4.-PoU (Ul)	43.3785,-5.8869	For. Plantation: oaks & chestnuts	Corresponding to *Polysticho setiferi-Fraxinetum excelsioris*	350
5.PooU (Ul)	43.3793,-5.8880	For. Plantation old: oaks & chestnuts	Corresponding to *Polysticho setiferi-Fraxinetum excelsioris*	379
6.-EhU (Ul)	43.3786,-5.8874	Herb. border: horsetail	*Picridio hieracioides-Eupatorietum cannabini* subasociation *equisetosum telmateia*	355
7.- PecU (Ul)	43.3788,-5.8893	For. Plantation: eucalyptus	*Eucalyptus globulus*	363
8.- ShV (Vle)	43.3922,-5.9087	Shrub: heather	*Ulici europaei-Ericetum vagantis*	428
9.-YwV (Vle)	43.3922,-5.9092	Young forest: willow trees	*Betula-Salicetum atrocinerea*	423
10.- SgV (Vle)	43.3929,-5.9092	Shrub: gorse edge	*Ulici europaei-Ericetum vagantis*	421
11.- FeV (Vle)	43.3927,-5.9082	Forest: eutrophous forest	*Polysticho setiferi-Fraxinetum excelsioris*	418
12.-PchV (Vle)	43.3939,-5.9087	For. plantation: chestnut trees	Derived from *Blechno spicanti-Quercetum roboris* facies *Q. pyrenaica*	411
13.-YpV (Vle)	43.3948,-5.9133	Young forest: Pyrenean oaks	Previous to *Blechno spicanti-Quercetum roboris* facies *Q. pyrenaica*	339
14.- FolV (Vle)	43.3981,-5.9131	Forest: oligotrophous forest	*Blechno spicanti-Quercetum roboris* facies *Q. pyrenaica*	354
15.-FeB (Bra)	43.4117,-5.9156	Forest: gallery eutrophous forest	*Polysticho setiferi-Fraxinetum excelsioris*	126
16.- FmB (Bra)	43.4112,-5.9163	Forest: mixed forest transition	*Polysticho setiferi-Fraxinetum excelsioris to Hyperico androsaeni- Alnetum glutinosae*	126
17.- FaB (Bra)	43.4113,-5.9164	Forest: gallery alder tree forest	*Hyperico androsaeni- Alnetum glutinosae*	125
18.- YhA (Aju)	43.4083,-5.8987	Young forest: hazel-nut tree forest	*Rubu ulmifoli- Tametum communis*	242
19.-YlA (Aju)	43.4098,-5.8960	Young forest: bays	*Hedero helicis-Lauretum nobilis*	231
20.-GcA (Aju)	43.4098,-5.8941	Grassland with cherry tree	*Lino biennis-Cynosuretum cristati*	226
21.- FeA (Aju)	43.4125,-5.8925	Forest: eutrophous forest	*Polysticho setiferi-Fraxinetum excelsioris*	199
22.-PoA (Aju)	43.4055,-5.8923	For. plantation: oaks & chestnuts	*Derived from Polysticho setiferi-Fraxinetum excelsioris*	244
23.-EnO (Ovi)	43.3525,-5.8551	Herb. border: nettle-elder tree	*Urtico dioicae-Sambucetum ebuli*	224
24.-GO (Ovi)	43.3556,-5.8744	Grassland: meadow	*Lino biennis-Cynosuretum cristati Subassociation brometosum erecti*	314
25.-GaM (Mur)	43.5545,-6.0916	Grassland with apple trees	*Lino biennis-Cynosuretum cristati*	115
26.- GM Mur)	43.5542,-6.0920	Grassland: meadow	*Lino biennis-Cynosuretum cristati*	115
27.-G1Vi (Vio)	43.3616,-3.9780	Grassland: meadow	*Lino biennis-Cynosuretum cristati*	43
28.-G2Vi (Vio)	43.3613,-3.9773	Grassland: meadow	*Linno biennis-Cynosuretum cristati*	46

Table 2. Accumulation curves and Clench equation parameters. Sampling sites as in Table 1 (number of samples with harvestman specimens in brackets); S harvestman species richness; S_{EXP} (a/b), expected richness according to Clench equation; r^2, determinant coefficient; q proportion of the inventory; % sampling efficiency percentage; f.s. final slope of the curve; E.V. explained variance.

Sampling sites	S	S_{EXP} (a/b)	r^2	q	%	f.s	E.V.
SbN (25)	11	11.73	0.99	0.94	93.78	0.04	98.98
SgN (24)	12	13.57	0.99	0.9	90.36	0.05	99.91
YpN (25)	10	11.2	0.99	0.89	89.2	0.04	99.8
PoU (23)	8	8.57	0.99	0.93	93.35	0.03	99.27
PooU (24)	9	10.23	0.99	0.88	87.98	0.05	99.8
EhU (24)	12	13.77	0.99	0.9	90.7	0.05	99.9
PecU (24)	11	12.28	0.99	0.89	89.57	0.04	99.73
ShV (25)	9	9.64	0.99	0.93	93.36	0.02	98.77
YwV (25)	11	11.8	0.96	0.93	93.22	0.02	96.08
SgV (24)	11	11.8	0.99	0.93	93.22	0.04	99.99
FeV (16)	9	12.43	0.99	0.72	72.4	0.16	99.5
PchV (16)	6	6.7	0.99	0.89	89.55	0.04	99.7
FolV (25)	8	8.32	0.99	0.96	96.15	0.02	99.46
YpV (25)	11	11.72	0.99	0.94	93.86	0.03	99.58
FeB (19)	8	9.07	0.99	0.88	88.23	0.05	99.82
FmB (22)	11	14.48	0.99	0.76	75.97	0.13	98.78
FaB (24)	12	14.53	0.99	0.83	82.59	0.09	99.47
YhA (23)	8	9.05	0.99	0.88	88.4	0.03	99.54
YlA (21)	11	13.29	0.99	0.83	82.77	0.09	99.98
GcA (25)	9	9.45	0.99	0.95	95.24	0.01	99.49
FeA (23)	7	7.69	0.99	0.9	91.03	0.03	99.65
PoA (19)	8	10.88	0.98	0.73	73.53	0.12	98.25
EnO (24)	12	13.59	0.99	0.88	88.3	0.07	98.56
GO (24)	8	8.36	0.99	0.96	95.69	0.02	98.66
GaM (25)	10	10.01	0.96	0.99	99.9	0.01	95.57
GM (25)	11	11.74	0.99	0.94	93.7	0.03	98.98
G1Vi (23)	7	7.28	0.99	0.96	96.15	0.02	98.93
G2Vi (23)	8	8.76	0.97	0.91	91.32	0.04	97.43

Table 3. Relative abundance percentage (Abu) and relative frequency percentage (Fr) of the harvestman species found in low Cantabrian areas (LC) and Muniellos Reserve (Mu). European (Eu), Holarctic (Ho) or Iberian endemic (IE) species distribution.

	Species	Abu LC	Abu Mu	Fr LC	Fr Mu
1	*Anelasmocephalus cambridgei* Eu	1.4	0.5	79	11
2	*Gyas titanus* Eu	0.05	0.4	7	5
3	*Hadziana clavigera* EI	0.06	0.3	11	5
4	*Homalenotus laranderas* EI.	21.6	7.3	64	47
5	*Homalenotus quadridentatus* Eu	27.7	0	47	0
6	*Ischyropsalis hispanica* EI	2.27	3.5	61	53
7	*Leiobunum blackwalli* Eu	11.8	11.8	100	58
8	*Leiobunum rotundum* Eu	1.2	10	61	47
9	*Nemastoma hankiewiczii* EI	4.9	2.6	79	21
10	*Nemastomella dentipatellae* EI	5.8	0.5	93	5
11	*Odiellus seoanei* EI	0.6	3.3	7	47
12	*Odiellus simplicipes* EI	9.2	6.7	58	53
13	*Paroligolophus agrestis* Ho.	2	23.3	32	53
14	*Phalangium opilio* Ho.	2	14.3	82	74
15	*Sabacon franzi* EI	1	0.9	61	16
16	*Trogulus nepaeformis s.l.* Eu	8.5	6.7	100	42
17	*Dicranopalpus* sp.	0	0.3	0	11
18	*Oligolophus hansenii* (Kraepelin, 1896) EU	0	7.3	0	58
19	*Paramiopsalis ramblae* Benavides & Giribet, 2017 IE	0	0.1	0	5
20	*Megabunus diadema* (Fabricius, 1779) Eu	0	0.1	0	5
	European species combined	50.6	36.6		
	Iberian Endemic species combined	45.5	25.1		
	Holarctic species combined	3.9	37.5		

Table 4. Number of harvestmen at each site and global diversity values. Lower lines: abundance and number of sites for each species. Sites described by their abbreviations in Table 1 and ordered according to the cluster analysis in Figure 3. Sites beginning with E boundary; F, forest; G, grassland; P, forest plantation; S, shrubland; Y Young forest.

Cluster	Sites	*Sabacon franzi*	*Paroligolophus agrestis*	*Ischyropsalis hispanica*	*Phalangium opilio*	*Odiellus simplicipes*	*Leiobunum blackwalli*	*Trogulus nepaeformis s.l.*	*Nemastoma hankiewiczii*	*Nemastomella dentipatellae*	*Anelasmocephalus cambridgei*	*Leiobunum rotundum*	*Homalenotus quadridentatus*	*Homalenotus laranderas*	*Hadziana clavigera*	*Gyas titanus*	*Odiellus seoanei*	tot abundance	sp. richness	Diversity 1/λ
	G1Vi						46	9	8	2	6		944	101				1116	7	1.38
	G2Vi				1		44	7	4		5	3	720	235				1019	8	1.8
	GM	6		4		77	23	4	125	5	17	1	551	613				1426	11	2.9
	GcA				11	44	184	32	52	12	7		866	609				1817	9	2.84
	GaM	3		1		367	230	7	129	58	30		192	240				1257	10	5.21
A	GO				19		115	2	19		1		54	643			54	907	8	1.9
	ShV	50		151	17	105	39	7	5	97				6				477	9	4.77
	SbN	4	13	54	12	48	94	7		33	2	2		82				351	11	5.54
	SgN	4	8	5	61	119	27	15	1	12	2	1		12				267	12	3.71
	YpN		183	5	22	68	45	3		20	3			9	5			363	10	3.2
	YwV	15	6	17	13	47	50	49	12	23				11			20	263	11	7.67
	SgV	11		8	9	30	72	56	8	40	2	3		17				256	11	5.68
C2.1	YpV	15	9	18	8		60	109	30	53		1		36				339	11	5.58
	EnO		2	1	12	72	27	70	1	12	5	4	33	7				246	12	4.92
	EhU	1	2	1		24	39	56	10	16	7	16	7	8				187	12	5.81
	PecU	1		3	1	16	115	27	2	12	9		6	8				200	11	2.74
	PooU		14		5	34	52	11	4	1	1	9						131	9	4.31
C2.2	PoU				2	57	31	48	7	19		1	4					169	8	4.11
	PoA	1			2		37	2		4	1	17		1				65	8	2.5
	FolV	1			3	14	13	160	145	28	15							379	8	2.99
	YlA	5		1	6	4	13	12	14	55	4	11	1					126	11	4.23
	FeA	7			3		12	12		29	13	5						81	7	4.75
	FmB	1			13		1	101	1	38	6	6			2	2		171	11	2.51
	FaB	1		1	1		8	75	2	43	12	8	3	3		4		161	12	3.32
	FeB				11		20	42		39	13	45	1					171	8	5.03
C1	YhA	4		3	5		24	85		22	9	18						170	8	3.3
	FeV		1	3	1		2	6	5	22					1			41	9	3.13
B	PchV			1			11	20	10	10								52	6	4.01
	Abun.	130	238	277	238	1126	1434	1034	594	705	170	151	3382	2641	8	6	74	12208		
	Sites	17	9	17	23	16	28	28	22	26	22	17	13	18	3	2	2			

Table 5. Harvestman average abundance, average species richness and average true diversity (1/λ) of the clusters and the habitats. N, number of sites studied.

Clusters	N	Abundance	Richness	1/λ
Cluster A	6	1257	8.8	2.7
Cluster B	2	46.5	7.5	3.6
Cluster C1	8	165.5	9.1	3.6
Cluster C2.1	7	330.9	10.8	5.2
Cluster C2.2	5	186.6	10.4	4.4
Habitats				
Grasslands	6	1257	8.8	2.7
Shrublands	4	337.8	10.8	4.9
Young forests	5	252.2	10.2	4.8
Forest plantations	5	123.4	8.4	3.5
Forests	5	167.2	9.2	3.6
Boundaries	2	216.5	12	5.4

Table 6. Analyses of similarities ANOSIM with Bray-Curtis index of dissimilarity between the harvestman assemblages of the aggregate sites for each habitat. S significance level, *, differences error ≤ 0.05); **, differences error ≤ 0.01). % dissimilarity percentages between the harvestman assemblages based on SIMPER analyses.

	Grasslands		Shrublands		Y. forests		Bound.		Forests	
	S	%	S	%	S	%	S	%	S	%
Shrublands	0.005 **	62.1								
Y. forests	0.002 **	64.4	0.452	41.0						
Boundaries	0.036 *	57.1	0.133	37.1	0.714	33.8				
Forests	0.002 **	73.8	0.005 **	58.4	0.048 *	46.4	0.25	44.2		
For. Plant.	0.002 **	70.5	0.032 *	53.1	0.246	47.7	0.81	41.6	0.013 *	50.8

Table 7. Indicator species of the clusters of sites and the habitats. B, boundaries populated with horsetail or nettle; GRASS, grasslands, SR, shrubland, YF, young forest. Ind. v., indicator value; p, probability; s.l., significance level.

Indicator species	Clusters	Ind. v.	p	s.l.
Homalenotus quadridentatus	A	0.916	0.002	**
Homalenotus laranderas	A + C2.1	0.993	0.001	***
Paroligolophus agrestis	C2.1	0.866	0.028	*
Leiobunum rotundum	C1 + C2.2	0.882	0.012	*
Odiellus simplicipes	A + C2.1 + C2.2	0.876	0.013	*
	Habitats			
Homalenotus quadridentatus	B + GRASS	0.998	0.001	***
Homalenotus laranderas	B + GRASS + SR	0.985	0.002	**
Ischyropsalis hispanica	B + SR + YF	0.983	0.001	***
Sabacon franzi	SR + YF	0.874	0.03	*

Figure 1 pdf

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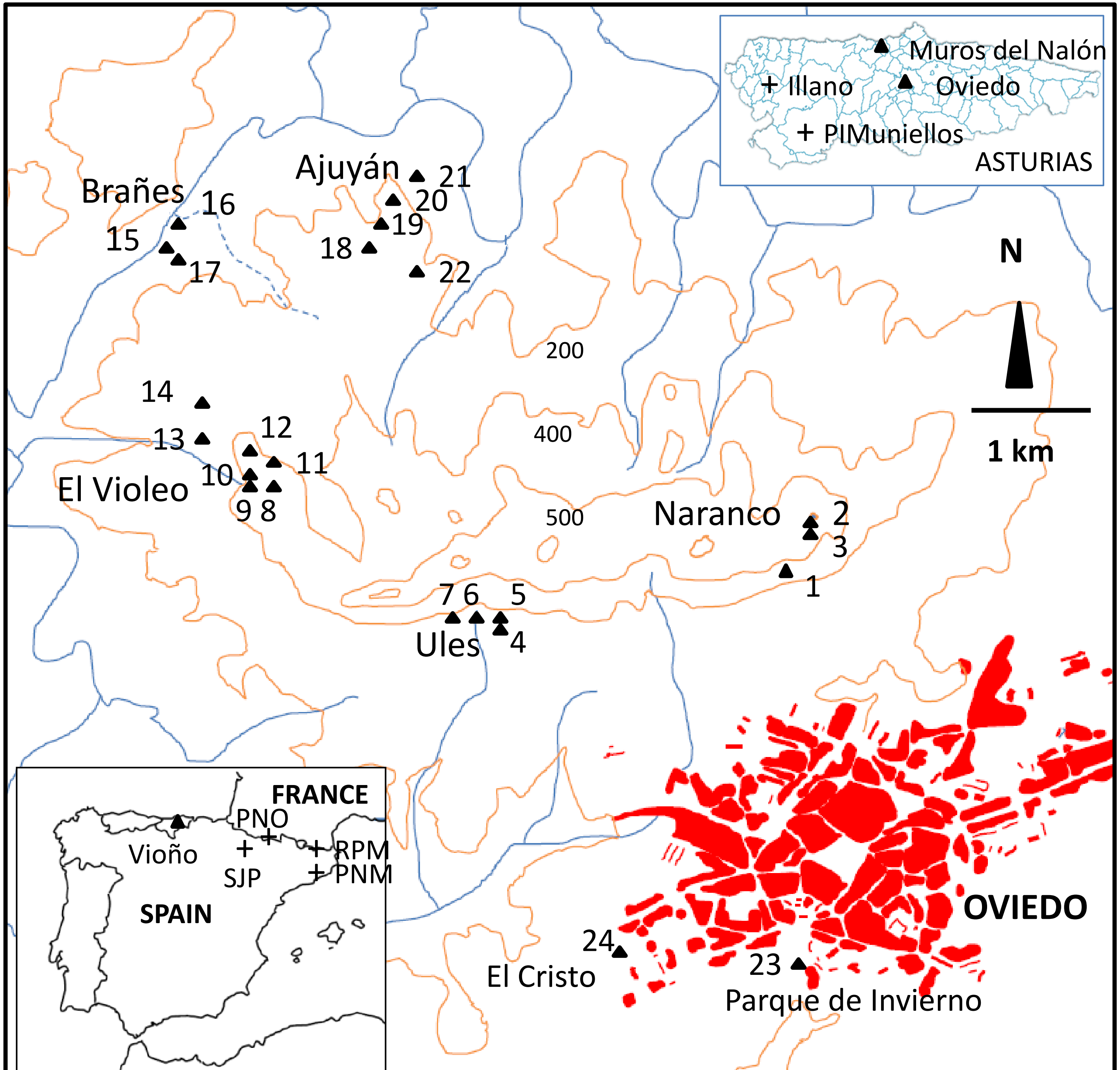

Figure 2 EPS

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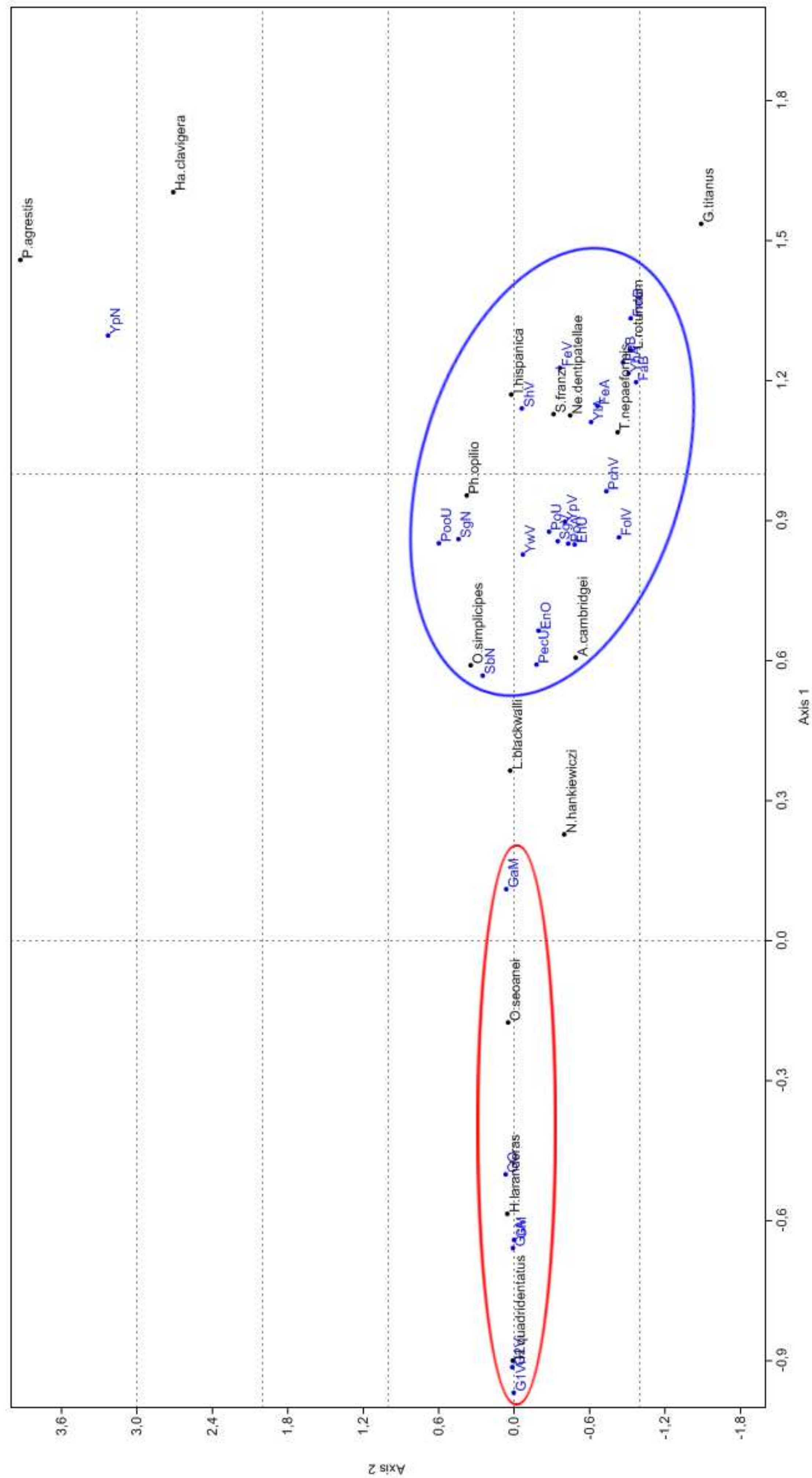

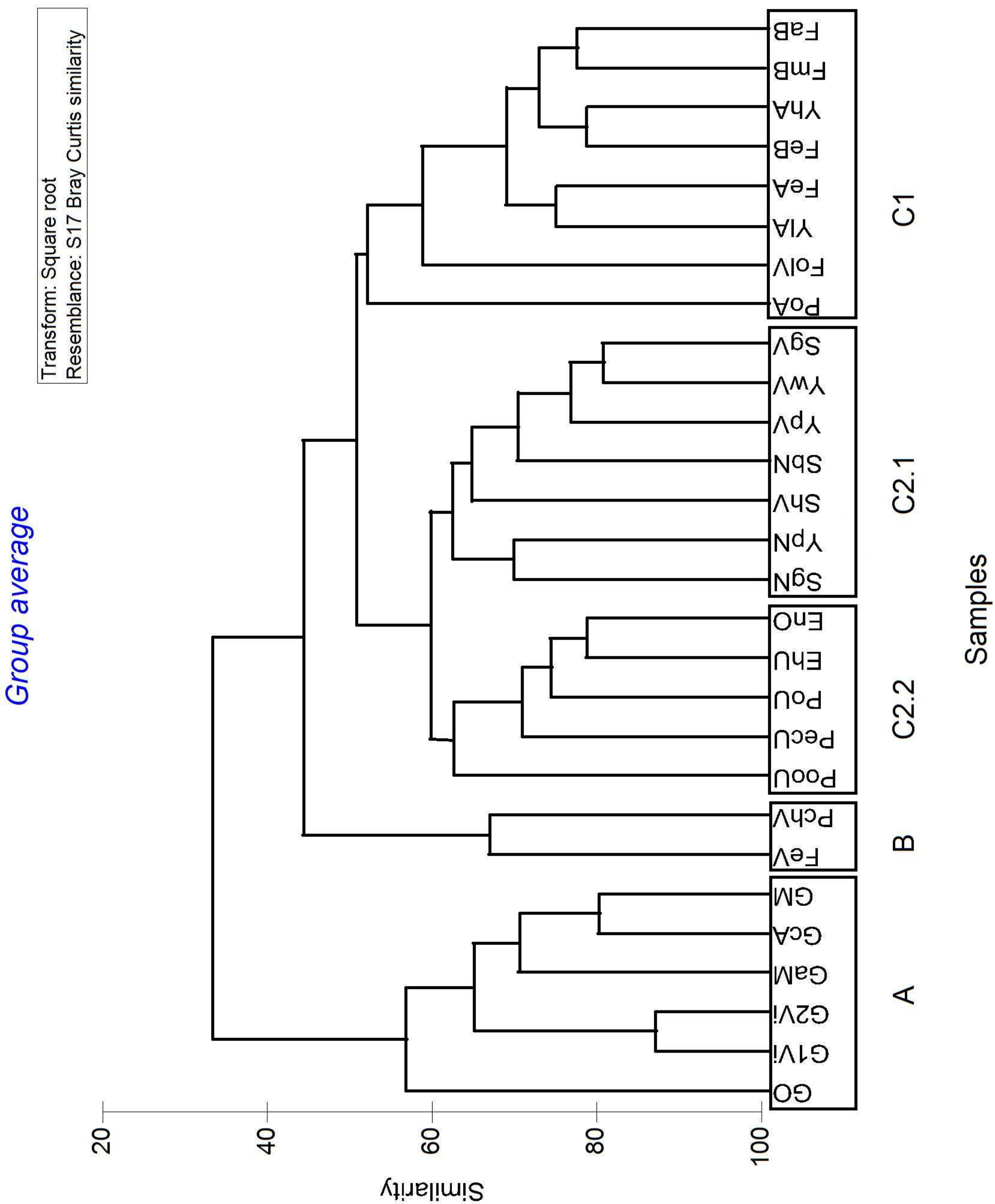
Group average
Transform: Square root
Resemblance: S17 Bray Curtis similarity
FaB
FmB
YhA
FeB
FeA
YlA
FolV
PoA
SgV
YwV
YpV
SbN
ShV
YpN
SgN
EnO
EhU
PoU
PecU
PooU
PchV
FeV
GM
GcA
GaM
G2Vi
G1Vi
GO
C1
C2.1
C2.2
B
A
Samples
20
40
60
80
100
Similarity

Figure 4 EPS

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