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# A SURVEY OF EPIGEIC ARTHROPODS IN URBAN-INFLUENCED COASTAL ENVIRONMENTS NEAR TO EL ALTET, SOUTHEASTERN SPAIN

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**ABSTRACT**

A preliminary study to characterize epigeic arthropod assemblages was conducted in urban-influenced coastal environments near to El Altet town (Alicante, Spain), including grey dune, heath dune, yellow dune and ruderal vegetation. For such purpose, a series of diversity metrics and multivariate analysis were performed based on a survey conducted since November 2004 to March 2005. Ruderal vegetation habitat (RV) had greater abundance and low diversity of epigeic arthropods, as well as predominance of synanthropic taxa, mainly Dermaptera (Forficulidae) and Isopoda (Armadillidae, Porcellionidae). In contrast, yellow dune habitat (YD) had intermediate abundance and low diversity, with predominance of psammophilous Coleoptera, particularly Tenebrionidae. While, heath and grey dunes habitats (HD+GD) had low abundance and high diversity, with native Chrysomelidae and Tenebrionidae as the most representative taxa.

**Keywords:** Coastal environments, epigeic arthropods, fragmentation, psammophilous beetles, urbanization, Western Mediterranean.

**RESUMEN**

**Un estudio de artrópodos epigeos en entornos costeros con influencia urbana cerca de El Altet, sureste de España**

Se realizó un estudio preliminar para caracterizar ensambles de artrópodos epígeos en entornos costeros con influencia urbana cerca de la ciudad de El Altet (Alicante, España), que incluyen duna fija, tomillar, duna móvil y vegetación ruderal. Para ello, se realizó una serie de métricas de diversidad y análisis multivariado con base en un relevamiento realizado desde noviembre de 2004 a marzo de 2005. El hábitat de vegetación ruderal (RV) tuvo mayor abundancia y baja diversidad de artrópodos epigeicos, así como predominio de taxones sinantrópicos, principalmente Dermaptera (Forficulidae) e Isopoda (Armadillidae, Porcellionidae). En contraste, el hábitat de dunas móviles (YD) tuvo abundancia intermedia y baja diversidad, con predominio de coleópteros psamófilos, particularmente Tenebrionidae. Mientras que los hábitats de tomillar y duna fija (HD + GD) tuvieron baja abundancia y alta diversidad, siendo Chrysomelidae y Tenebrionidae nativos sus taxones más representativos.

**Palabras clave:** Ambientes costeros, artrópodos epigeos, fragmentación, coleópteros psamófilos, urbanización, Mediterráneo occidental.

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## Introduction

Urban areas are deeply modified spaces for human residence, covering almost 600 000 km$^2$ and housing around 40% of the world population (Ellis & Ramankutty, 2008). Urban development involves a syndrome of abiotic and biotic changes at different spatial and temporal scales, including fragmentation, pollution, heath island effect, changing land use and introduction of exotic species (Martinson & Raupp, 2013; Fenoglio *et al.*, 2020). Worldwide, species richness of plants and animals decreases in central urban areas, but sometimes it increases in suburban areas due to intermediate levels of human disturbance (McKinney, 2008).

For terrestrial arthropods, urbanization have overall detrimental effects on abundance and diversity, directly related to age of cities and more severe for species with high dispersal abilities belonging to orders Coleoptera and Lepidoptera (Fenoglio *et al.*, 2020). Particular attention has been devoted to studying the urbanization effects on epigeic carabid assemblages inhabiting fragmented forests within urban-rural gradients in the Northern Hemisphere (Niemela & Kotze, 2009). In most cases, abundance and species richness of Carabidae are reduced from rural surroundings to city cores, notoriously so for brachypterous, larger-sized and stenotopic species (Niemela & Kotze, 2009; Martinson & Raupp, 2013). These general tendencies could be distorted by environmental conditions at plot scale and persistence of local species pool, in fact urbanization doesn't seem to drive to a single synanthropic assemblage (Magura *et al.*, 2010) and management of urban forest fragments could raise abundance and richness (Belskaya *et al.*, 2020).

Urbanization effects on epigeic arthropod assemblages inhabiting sandy soils have been documented for several arid zones and spatial scales. In San Diego County (USA), area and age of native scrub fragments influenced abundance and richness of arthropods, both being lesser in aged and small-sized fragments (Bolger *et al.*, 2000). In Phoenix area (USA), changes of land use from desert environments to agricultural, industrial or residential zones promoted higher abundances of detritivores (springtails) and predators (spiders) sustained by soil nutrient input and supplemental watering (McIntyre *et al.*, 2001; Shochat *et al.*, 2004). Similar outcomes were registered for beetle assemblages in New Damietta city (Egypt), where higher values of abundance, richness and equitability were registered in coastal sandy environments compared to compacted and fertilized soils in urbanized sites (El Surtasi *et al.*, 2012). In fragmented European dunes, psammophilous butterflies, grasshoppers and spiders were on higher risk of local extinction due to their low dispersal abilities and scarce probability to survive in trampled patches (Bonte *et al.*, 2003; Bonte & Maes, 2008), while psammophilous beetles appear to be more resilient in similar scenarios (Comor *et al.*, 2008). Urban development promoted introduction of exotic plant species that alters habitat structure and hence composition of arthropod assemblages as were evidenced in cases of marram grass (Webb *et al.*, 2000) and weed bitou bush (Wilkie *et al.*, 2007) in Australia. Also, urbanization promoted overwhelming abundances of exotic arthropod species that displace native species belonging to same functional guilds, for instance cosmopolitan species of ants, cockroaches, isopods and spiders in coastal areas of California (Suarez *et al.*, 1998; Bolger *et al.*, 2000; Longcore, 2003).

In Alicante province, beaches and dunes have been disturbed by a poorly planned urban development since the 1960s to date. Particularly, El Saladar and Arenales del Sol beaches have been rated as very unattractive urban sites because their intensive development and low landscape values (Asensio-Montesinos *et al.*, 2017). Regarding conservation status of vegetation at El Saladar dunes, it was classified as a clearly degraded site, with a mixed coverage of native and non-native species, also an impoverished coast to inland structure (Albertos *et al.*, 2010).

The purpose of this preliminary work is to characterize diversity and structure of epigeic arthropod assemblages inhabiting urban-influenced coastal environments, based on a short sampling made near to El Altet (Alicante, Spain) between November 2004 and March 2005. To our knowledge, this is the first study on epigeic arthropod assemblages influenced by urbanization in coastal environments of Southeastern Spain.

## Material and methods

The field work was done between November 2004 and March 2005, autumn and winter of Mediterranean Region, in a mosaic of dune and anthropogenic habitats at El Saladar dunes and Arenales del Sol urbanization, located near to El Altet, Elche district, Alicante province, southeastern Spain (Fig. 1a).

The sampling area included two urban vegetation fragments covered with a mixture of yellow dune and ruderal vegetation, a small fragment (0.25 ha, 38°15'15" N, 00°31'01" W) and a medium fragment (1.08 ha, 38°15'02" N, 00°30'59" W). Also relatively undisturbed dune vegetation (84 ha) including three dune types, grey (38°15'55" N, 00°31'19" W), heath (38°16'16" N, 00°31'27" W) and yellow (38°15'59" N, 00°31'14" W) (Fig. 1b).

A total of 80 pitfall traps arranged in eight sampling transects were deployed in the following habitat types (Fig. 1c–d):

1) Grey dune (GD), *Crucianellion* phytosociological alliance dominated by *Crucianella maritima* (L.), *Teucrium dunense* Sennen, *Thymelaea hirsuta* (L.) Endl. and *Helichrysum stoechas* (L) DC, semi-consolidated sand substrate, number of transects = 1.
2) Heath dune (HD), covered with *Crucianella maritima*, *Fumana ericoides* (Cavanilles) Gand., *Teucrium dunense*, *Thymelaea hirsute* and *Thymus vulgaris* L., consolidated sand substrate, with signs of past agricultural activity and close to a highway, number of transects = 1.
3) Yellow dune (YD), *Ammophilion* phytosociological alliance dominated by *Ammophila arenaria* (L.) Link, *Elymus farctus* (Viv.) Runemark ex Melderis, *Lotus creticus* L. and *Medicago marina* L., mobile sand substrate, number of transects = 3.
4) Ruderal vegetation (RV), covered with *Carpobrotus* spp., *Echium* sp., *Juncus acutus* (L.) Torr. ex Retz., *Lotus creticus*, *Ononis natrix* L. and *Sporobolus pungens* (Schreb.) Kunth, mobile sand substrate, with scattered domestic waste and household water leaks, number of transects = 3.

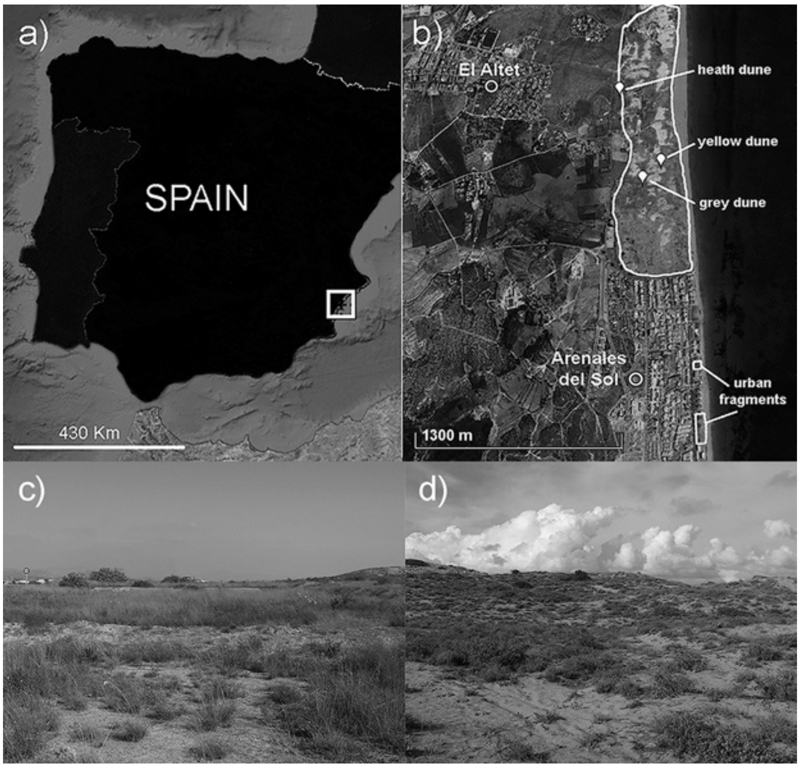


Fig. 1.— Study sites at El Saladar dunes and Arenales del Sol urbanization (Alicante, Spain): a) location of El Altet in Iberian Peninsula, b) location of sampling transects, c) heath dune, d) grey dune.

Fig. 1.— Sitios de estudio en las dunas de El Saladar y la urbanización Arenales del Sol (Alicante, España): a) localización de El Altet en la Península Ibérica, b) localización de transectos de muestreo, c) tomillar, d) duna fija.

In each transect, 10 pitfall traps were installed to collect epigeic arthropods. Traps were disposable plastic glasses (10 cm diameter), buried at ground level, separated each other by 5m distance and half-filled with a preservative solution (70% ethylene glycol, 30% water). Trapped specimens were weekly extracted and preserved in ethanol (70%).

In the laboratory, macroarthropods were sorted to order and families under a stereoscope (20×–40×) and using appropriate taxonomic keys (Barrientos, 1988). Determination level had higher resolution only for 22 abundant Coleoptera species of Carabidae, Chrysomelidae, Scarabaeidae, Staphylinidae and Tenebrionidae families. Ants were excluded because their bulky aggregations, as well as epiphytic and flying insects incidentally collected by pitfall traps.

Statistical analysis were conducted with accumulated data of entire sampling period for each transect and transects were grouped according to their habitat types, yellow dune (YD), ruderal vegetation (RV) and, grey dune and heath dune joined because both are natural habitats with semi-consolidated to consolidate sandy substrates (GD+HD). In following lines, the term abundance is used for the sake of simplicity, but it is clear that the number of individuals caught in pitfall traps reflects “activity-density” and not the real taxa density (Southwood & Henderson, 2009).

Diversity of epigeic arthropod assemblages was assessed for mean abundance of arthropod families in each group of habitat types (YD, RV, GD+HD), with two diversity metrics (Krebs, 1989; Hammer *et al.*, 2001): 1) individual rarefaction, to estimate the number of expected taxa for any sample size smaller than the largest sample, using a log Gamma function for computing combinatorial terms and giving as a result linear plots of sample size vs. number of taxa with 95 percent confidence intervals based on standard errors (square roots of variances); 2) diversity profiles, for to calculate a family of diversity indices dependent upon a single continuous parameter a, derived from the exponential of the so-called Renyi index, obtaining total species number for $\alpha = 0$, Shannon index for $\alpha = 1$ and Simpson index for $\alpha = 2$ and giving as a result a plot of diversity profiles with 95 percent confidence intervals based on 2000 replicates (bootstrapping).

Structure of epigeic arthropod assemblages was assessed for log-transformed abundance of 46 arthropod families and 22 beetle species in each sampling transect, with two multivariate analysis (Legendre & Legendre, 1998; Hammer *et al.*, 2001): 1) Non-metric multidimensional scaling (NMDS) to place sampling transects in a bi-dimensional coordinate system according a their

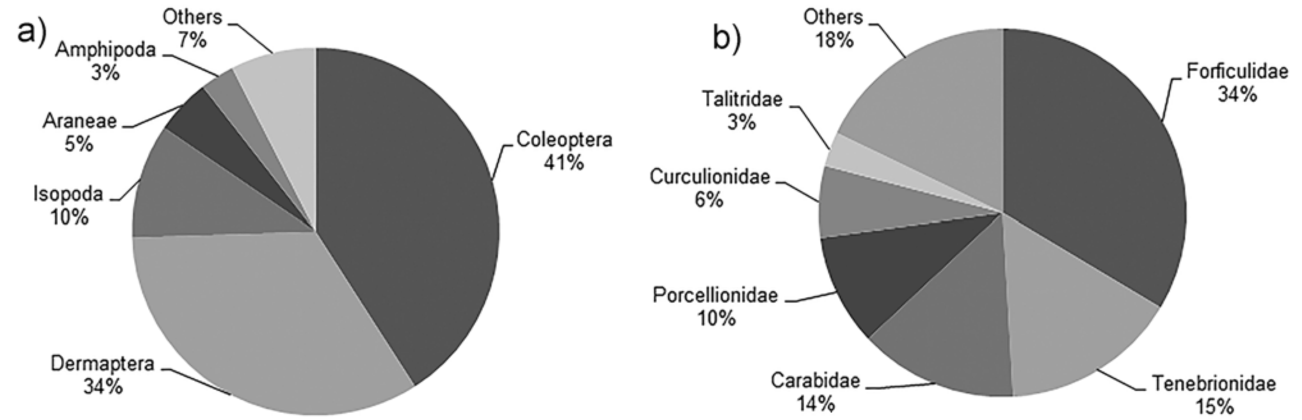


Fig. 2.— Percentages for most abundant orders (a) and families (b) of epigeic arthropods collected in coastal environments near to El Altet (Alicante, Spain).

Fig. 2.— Porcentajes para los órdenes (a) y las familias (b) más abundantes de artrópodos epigeos colectados en ambientes costeros cercanos a El Altet (Alicante, España).

similarities measured with Bray-Curtis distance; 2) Analysis of Similarities (ANOSIM) to test the statistical significance of pre-established groups of habitat types (YD, RV, HD+GD) ($p < 0.05$). Also relationships between scores of NMDS axes with taxa abundances were measured with Spearman rank correlations ($p < 0.05$).

Diversity metrics and multivariate analysis were performed with PAST statistical software (Hammer *et al.*, 2001).

## Results

Overall, 9463 specimens of epigeic arthropods were collected between November 2004 to March 2005 comprising 15 orders and 46 families (Appendix 1). Most abundant orders were Coleoptera, Dermaptera, Isopoda, Araneae and Amphipoda (Fig. 2a). Most abundant families were Forficulidae, Tenebrionidae, Carabidae, Porcellionidae, Curculionidae and Talitridae (Fig. 2b). The subset of 22 Coleoptera species comprised 3041 specimens belonging to following families: Carabidae (seven species), Chrysomelidae (two species), Curculionidae (one species), Scarabaeidae (one species), Staphylinidae (one species) and Tenebrionidae (ten species) (Appendix 2).

Linear plots of sample size (specimens) vs. number of taxa (families) in groups of habitat types (HD+GD, YD, RV) are presented in Fig. 3a. According to these plots, number of families of epigeic arthropods was higher in HD+GD habitat type and was lower in YD and RV habitat types, whose confidence intervals are widely overlapping. Diversity profiles for groups of habitat types are presented in Fig. 3b. Comparison of these profiles shows higher diversity in HD+GD habitat type and lower diversity in YD and RV habitat types, both with confidence intervals entirely overlapped.

NMDS plot for the eight sampling transects based on epigeic arthropod families data is presented in Fig. 4a. Sampling transects were arranged from relatively undisturbed dunes (GD, YD1) to ruderal vegetation (RV1, RV2, RV3) along the first axis, and also from sandy soil sites (YD1, YD2, YD3) to compacted soil sites (HD) along the second axis. Also, transects

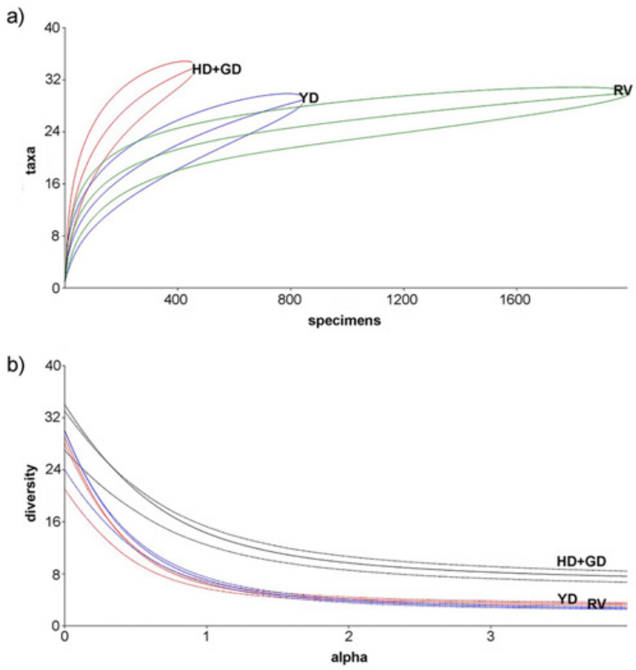


Fig. 3.— Diversity metrics for three habitat types based on arthropod family data: a) individual rarefaction, linear plots of sample size (specimens) vs. number of taxa (families), b) diversity profiles, linear plots of alpha vs diversity measures. Significant differences indicated with 95% confidence intervals. Abbreviations as in Appendix 1.

Fig. 3.— Métricas de diversidad para tres tipos de hábitats a partir de datos de familias de artrópodos: a) rarefacción individual, gráficos lineales de tamaño de muestra (especímenes) vs. número de taxones (familias), b) perfiles de diversidad, gráficos lineales de alpha vs medidas de diversidad. Diferencias significativas indicadas con intervalos de confianza de 95%. Abreviaturas como en Apéndice 1.

were grouped in NMDS plot according to their habitat type, ruderal vegetation (RV1, RV2, RV3), yellow dunes (YD1, YD2, YD3) and semi-consolidated to consolidate dunes (GD, HD). Results of ANOSIM test are depicted in Fig. 4a (global) and Appendix 3 (global, mean ranks and pairwise comparisons). Correlations between log-transformed abundances of epigeic arthropod families with NMDS axes are presented in Table 1. Significant correlations with first axis were positive for Dysderiidae, Curculionidae, Staphylinidae, Forficulidae, Pyrrhocoridae and Porcellionidae, and were negative only for Myrmeleontidae and Phalangiidae. While with second axis, positive significant correlations were established for Lycosidae, Julidae and Cydnidae, and negative significant correlations for Carabidae, Scarabaeidae and Tenebrionidae.

NMDS plot for the eight sampling transects based on Coleoptera species data is presented in Fig. 4b. Sampling transects were arranged from sandy soil sites (YD1, YD2, YD3) to compacted soil sites (HD) along the first axis, and also from undisturbed dunes (GD, YD) to ruderal vegetation (RV1, RV2, RV3) along the second axis. Also, transects were grouped in NMDS plot according to their habitat type, ruderal vegetation (RV1, RV2, RV3), yellow and grey dunes (YD1, YD2, YD3, GD) and heath dune (HD). Results of ANOSIM test are depicted in Fig. 4b (global) and Appendix 3 (global, mean ranks and pairwise comparisons). Correlations between log-transformed abundances of Coleoptera species with NMDS axes are presented in Table 2. Significant correlations with first axis were negative for *Harpalus fulvus* Dejean, 1829, *Masoreus wetterhalli* Gyllenhal, 1813, *Psammodius porcicollis* (Illiger, 1803), *Erodius carinatus* Solier, 1834, *Halammobia pellucida* (Herbst, 1799), *Pachychila frioli* Solier, 1835, *Pseudosericius pruinosus* (Dufour, 1820) and *Xanthomus pellucidus* Mulsant & Rey, 1856, and positive only for *Ocypus olens* (Müller, 1764). While with second axis, significant correlations were positive for *Macrothorax morbillosus* (Fabricius, 1792), *Ocypus olens* (Müller, 1764), *Leichenum pulchellum* (Lucas, 1849) and *Tentyria laevis* Solier, 1835, and negative for *Timarcha espagnoli* Bechyné, 1948 and *Tentyria elongata* Waltl, 1835.

Table 1.— Spearman (rs) correlations between log-transformed abundance of 24 families of epigeic arthropods with NMDS axes performed for eight transects. Correlations higher than 0.55 highlighted in bold, when significant with one ($p < 0.1$) or two ($p < 0.05$) asterisks.

Tabla 1.— Correlaciones de Spearman (rs) entre abundancias transformadas logarítmicamente de 24 familias de artrópodos epigeos con los ejes del NMDS para ocho transectos. Correlaciones mayores que 0.55 resaltadas en negrita, cuando son significativas con uno ($p < 0.1$) o dos ($p < 0.05$) asteriscos.

| Orders | Families | Axis 1 | | Axis 2 | |
|---|---|---|---|---|---|
| Amphipoda | Talitridae | **0.65** | 0.14 | 0.16 | 0.75 |
| Araneae | Dysderidae | **0.97** | **0.00**** | -0.07 | 0.87 |
| | Gnaphosidae | 0.10 | 0.82 | 0.35 | 0.40 |
| | Lycosidae | 0.47 | 0.24 | **0.70** | **0.06*** |
| | Sparassidae | **-0.58** | 0.15 | 0.09 | 0.86 |
| | Thomisidae | 0.32 | 0.43 | 0.08 | 0.85 |
| Coleoptera | Apionidae | **0.61** | 0.12 | -0.17 | 0.70 |
| | Carabidae | 0.05 | 0.93 | **-0.83** | **0.01**** |
| | Chrysomelidae | -0.20 | 0.65 | **0.56** | 0.16 |
| | Curculionidae | **0.90** | **0.00**** | 0.07 | 0.84 |
| | Scarabaeidae | -0.30 | 0.46 | **-0.76** | **0.04**** |
| | Staphylinidae | **0.71** | **0.06*** | 0.26 | 0.54 |
| | Tenebrionidae | -0.02 | 0.98 | **-0.79** | **0.03**** |
| Dermaptera | Forficulidae | **0.90** | **0.00**** | -0.24 | 0.54 |
| Diplopoda | Julidae | -0.23 | 0.58 | **0.87** | **0.01**** |
| Embioptera | Oligotomidae | 0.41 | 0.31 | 0.51 | 0.21 |
| Heteroptera | Cydnidae | -0.04 | 0.94 | **0.84** | **0.02**** |
| | Pyrrhocoridae | **0.91** | **0.01**** | -0.16 | 0.71 |
| Isopoda | Armadillidae | **0.65** | 0.14 | 0.16 | 0.75 |
| | Porcellionidae | **0.83** | **0.01**** | -0.07 | 0.84 |
| Neuroptera | Myrmeleontidae | **-0.75** | **0.05*** | -0.45 | 0.28 |
| Opiliones | Phalangiidae | **-0.76** | **0.07*** | 0.08 | 0.86 |
| Orthoptera | Catantopidae | 0.55 | 0.17 | 0.55 | 0.17 |
| | Pyrgomorphidae | -0.07 | 0.87 | **0.56** | 0.16 |

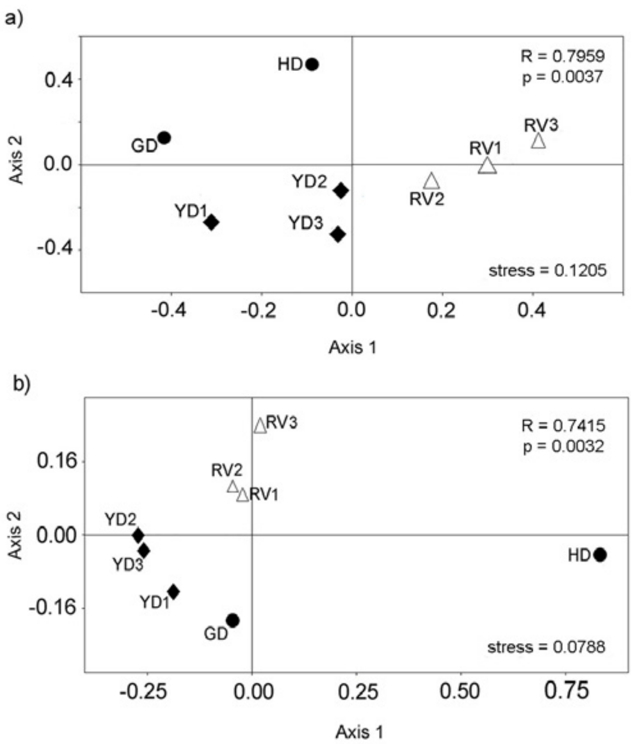


Fig. 4.— NMDS plots for eight sampling transects based on epigeic arthropod family data (a) and Coleoptera species data (b). Abbreviations as in Appendix 1. Habitat types tested with ANOSIM indicated with different symbols: grey dune and heath dune (black circles), yellow dune (black diamonds), ruderal vegetation (white triangles).

Fig. 4.— Gráficos de NMDS para ocho transectos muestrales a partir de datos de familias de artrópodos epigeos (a) y datos de especies de coleópteros (b). Abreviaturas como en Apéndice 1. Tipos de hábitat probados con ANOSIM indicados con símbolos diferentes: duna fija y tomillar (círculos negros), duna móvil (rombos negros), vegetación ruderal (triángulos blancos).

Table 2.— Spearman (rs) correlations between log-transformed abundance of 22 Coleoptera species with NMDS axes performed for eight transects. Correlations higher than 0.55 highlighted in bold, when significant with one (p < 0.1) or two (p < 0.05) asterisks.

Tabla 2.— Correlaciones de Spearman (rs) entre abundancias transformadas logarítmicamente de 22 especies de Coleoptera con los ejes del NMDS para ocho transectos. Correlaciones mayores que 0.55 resaltadas en negrita, cuando son significativas con uno (p < 0.1) o dos (p < 0.05) asteriscos.

| Families | Species | Axis 1 | | Axis 2 | |
|---|---|---|---|---|---|
| Carabidae | *Cicindela lunulata* | -0.01 | 1.00 | **0.63** | 0.11 |
| | *Cymindis lineola* | 0.25 | 0.55 | **-0.58** | 0.15 |
| | *Harpalus fulvus* | **-0.93** | **0.00**** | -0.26 | 0.52 |
| | *Licinus punctatulus* | 0.42 | 0.30 | 0.17 | 0.66 |
| | *Macrothorax morbillosus* | 0.16 | 0.70 | **0.76** | **0.04**** |
| | *Masoreus wetterhalli* | **-0.83** | **0.01**** | -0.06 | 0.90 |
| | *Scarites buparius* | -0.10 | 0.80 | -0.46 | 0.27 |
| Chrysomelidae | *Timarcha espagnoli* | 0.19 | 0.65 | **-0.85** | **0.04**** |
| | *Timarcha intermedia* | 0.44 | 0.36 | **-0.59** | 0.18 |
| Curculionidae | *Coniocleonus excoriatus* | 0.55 | 0.19 | 0.35 | 0.40 |
| Scarabaeidae | *Psammodius porcicollis* | **-0.97** | **0.00**** | -0.24 | 054 |
| Staphylinidae | *Ocypus olens* | **0.83** | **0.02**** | **0.66** | **0.09*** |
| Tenebrionidae | *Asida (Granulasida) ricoi* | **0.58** | 0.38 | -0.25 | 0.75 |
| | *Erodius carinatus* | **-0.82** | **0.02**** | 0.11 | 0.81 |
| | *Halammobia pellucida* | **-0.75** | **0.09*** | 0.02 | 1.00 |
| | *Leichenum pulchellum* | 0.41 | 0.39 | **0.76** | **0.07*** |
| | *Pachychila frioli* | **-0.85** | **0.02**** | 0.02 | 0.98 |
| | *Pimelia baetica* | **0.58** | 0.38 | -0.25 | 0.75 |
| | *Pseudosericius pruinosus* | **-0.85** | **0.01**** | 0.14 | 0.70 |
| | *Tentyria elongata* | -0.48 | 0.27 | **-0.71** | **0.08*** |
| | *Tentyria laevis* | 0.55 | 0.16 | **0.85** | **0.01**** |
| | *Xanthomus pellucidus* | **-0.99** | **0.00**** | -0.29 | 0.46 |

## Discussion

Percentage composition of orders and families shows in general terms a resource apportionment between a native epigeic fauna typical of arid ecosystems composed mainly by psammophilous Coleoptera and instead, another promoted by human disturbances composed mainly by exotic or invasive Dermaptera and Isopoda. This general appreciation about the epigeic fauna and its relationships with human disturbances will be confirmed in diversity metrics and multivariate analysis discussed in following lines.

The synthetic interpretation of individual rarefaction and diversity profiles shows three different scenarios: 1) high abundance and low diversity of epigeic arthropods in sites disturbed by fragmentation and land use change (RV), 2) intermediate abundance and low diversity of epigeic arthropods in relative undisturbed sites with mobile sand substrates (YD), 3) low abundance and high diversity of epigeic arthropods in relative undisturbed sites with semi-consolidated to consolidated sand substrates (HD+GD). These findings coincide with known effects of land use change on epigeic arthropods from other arid environments, where increased productivity is an extraordinary amount of energy that supports a greater abundance of arthropods, particularly some detritivores (Collembola, Dermaptera) and predators (Araneae) (McIntyre *et al.*, 2001; Shochat *et al.*, 2004). In other scenarios, abundance of exotic or invasive arthropods is directly related to area and age of native vegetation fragments surrounded by an urban matrix (Bolger *et al.*, 2000). In the present study, detritivores particularly abundant in ruderal vegetation were Talitridae, Forficulidae, Armadillidae and Porcellionidae, which would be displacing native detritivores of family Tenebrionidae. In turn, phytophagous Apionidae, Curculionidae and Pyrrhocoridae would be taking advantage of exotic plants, and predators Dysderiidae and Staphylinidae would be feeding on new available prey.

The significant correlations between family abundances and scores of NMDS axes suggest associations between these taxa and disturbance, substrate and vegetation observed in each habitat type. If non-significant correlations but greater than 0.55 and previous ecological studies for Mediterranean island entomofauna (Español, 1958, 1965) are taken into account, four family-groups could be distinguished: 1) psammophilous, associated with mobile sands, including Carabidae, Myrmelontidae, Phalangiidae, Scarabaeidae, Sparassidae and Tenebrionidae, 2) synanthropic or eurytopic, associated with ruderal vegetation, including Apionidae, Armadillidae, Curculionidae, Dysderidae, Forficulidae, Porcellionidae, Pyrrhocoridae, Staphylinidae and Talitridae, 3) associated with semi-consolidated and consolidated sand, including Chrysomelidae, Cydnidae, Julidae, Lycosidae and Pyrgomorphidae, 4) generalists, not clearly associated with any particular condition, including Catantopidae, Gnaphosidae, Oligotomidae, and Thomisidae.

About family-groups, psammophilous would be potential indicators of dune conservation status, being taxa with a high degree of endemism and specialization in all desert ecosystems (Crawford, 1981). Families associated with ruderal vegetation included detritivores, phytophages and predators that took advantage of the increased productivity and with regard to Dysderidae, Forficulidae and Porcellionidae are the same ones recorded in urban-influenced North American desert ecosystems (Bolger *et al.*, 2000; Longcore, 2003). Apionidae and Curculionidae associations with ruderal vegetation can be explained by greater availability and nutritional value of host plants, however these taxa have several dune-associated species that deserve further research in Alicante province (Velázquez de Castro & Martín-Cantarino, 1992). The classification of Catantopidae and Pyrgomorphidae as generalists coincides with spatial patterns observed in orthopteran assemblages from other southeastern Spain dunes (Clemente *et al*., 1985; Badih *et al.*, 1997).

The significant correlations between species abundances and scores of NMDS axes suggest associations between these taxa and disturbance, substrate and vegetation observed in each habitat type. If non-significant correlations but greater than 0.55 and previous ecological studies for Carabidae (Sauleda-Pares, 1985a), Curculionoidea (Velázquez de Castro & Martín-Cantarino, 1992) and Tenebrionidae (Sauleda-Pares, 1985b; Martín-Cantarino, 1994) in Alicante province are taken into account, six species-groups could be distinguished: 1) psammophilous, associated with mobile sands, including *Erodius carinatus* Solier, 1834, *Halammobia pellucida* (Herbst, 1799), *Harpalus fulvus* Dejean, 1829, *Masoreus wetterhalli* Gyllenhal, 1813, *Pachychila frioli* Solier, 1835, *Psammodius porcicollis* (Illiger, 1803), *Pseudosericius pruinosus* (Dufour, 1820), *Tentyria elongata* Waltl, 1835 and *Xanthomus pellucidus* Mulsant & Rey, 1856; 2) synanthropic or eurytopic, associated with ruderal vegetation, including *Leichenum pulchellum* (Lucas, 1849), *Macrothorax morbillosus* (Fabricius, 1792), *Ocypus olens* (Müller, 1764) and *Tentyria laevis* Solier, 1835; 3) associated with semi-consolidated sand, including *Cymindis lineola* Dufour, 1820, *Timarcha espagnoli* Bechyné, 1948 and *Timarcha intermedia* Herrich-Schaeffer, 1838; 4) associated with heath dune, including *Asida* (*Granulasida*) *ricoi* Martinez, 1873 and *Pimelia baetica* Solier, 1836; 5) halophiles, associated with wet sands represented by *Cicindela lunulata* Fabricius, 1781; 6) generalists, not clearly associated with any particular condition, including *Coniocleonus excoriatus* (Gyllenhal, 1834), *Licinus punctatulus* (Fabricius, 1792) and *Scarites buparius* (Forster, 1771).

At species level, it should be noted that psammophilous darkling beetles are taxa particularly vulnerable to habitat loss, as has been observed in other urban influenced environments on Mediterranean coast (Fattorini, 2011; El Surtasi *et al.*, 2012). However, some species with good dispersal abilities could survive in dune patches with relatively undisturbed soil and vegetation conditions (Comor *et al.*, 2008). A similar ecological pattern can be expected for *P. porcicollis*, a small, detritivore, sand-digger and flying dispersal aphodine inhabiting dunes along Mediterranean coast (Kim & Lumaret, 1981). Regarding species of *Timarcha* genus, both were associated with grey and heath dunes, perhaps due to their strict food preference on some native host plant, as has been observed in other Iberian species (González-Megías & Gómez, 2001). Regarding species associated with patches of ruderal vegetation, *M. morbillosus* and *O. olens* were opportunistic predators favored by prey availability at disturbed sites. Likewise, *O. olens* coincides with the predicted traits for ruderal rove beetles in European urban-rural gradients, namely large body size, eurytopic and good migratory ability (Bohac, 1999).


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Appendix 1.— Orders and families of epigeic arthropods collected at eight transects in coastal environments near to El Altet (Alicante, Spain). Abbreviations: GD = grey dune, HD = heath dune, YD = yellow dune, RV = ruderal vegetation.

Apéndice 1.— Órdenes y familias de artrópodos epigeos colectados en ocho transectos en ambientes costeros cercanos a El Altet (Alicante, España). Abreviaturas: GD = duna fija, HD = tomillar, YD = duna móvil, RV = vegetación ruderal.

| Orders | Families | GD | YD1 | YD2 | YD3 | RV1 | RV2 | RV3 | HD |
|---|---|---|---|---|---|---|---|---|---|
| Amphipoda | Talitridae | 0 | 0 | 0 | 0 | 0 | 25 | 261 | 0 |
| Araneae | Agelenidae | 1 | 2 | 0 | 1 | 0 | 4 | 1 | 0 |
| | Ctenizidae | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| | Dysderidae | 0 | 0 | 1 | 1 | 6 | 5 | 19 | 0 |
| | Gnaphosidae | 4 | 8 | 3 | 11 | 16 | 2 | 11 | 19 |
| | Lycosidae | 4 | 0 | 0 | 3 | 37 | 3 | 59 | 8 |
| | Nemesiidae | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 31 |
| | Oxyopidae | 1 | 0 | 0 | 0 | 0 | 2 | 2 | 0 |
| | Phylodromiidae | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| | Salticidae | 3 | 3 | 2 | 1 | 0 | 3 | 0 | 2 |
| | Sicariidae | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| | Sparassidae | 6 | 8 | 0 | 1 | 0 | 0 | 2 | 1 |
| | Theridiidae | 0 | 3 | 4 | 0 | 0 | 1 | 1 | 7 |
| | Thomisidae | 1 | 4 | 8 | 23 | 18 | 25 | 8 | 63 |
| Chilopoda | Geophilidae | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 |
| | Scolopendridae | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 |
| Coleoptera | Apionidae | 2 | 4 | 2 | 2 | 10 | 3 | 9 | 1 |
| | Carabidae | 107 | 195 | 142 | 389 | 229 | 123 | 91 | 43 |
| | Chrysomelidae | 46 | 7 | 47 | 6 | 7 | 7 | 9 | 43 |
| | Curculionidae | 2 | 5 | 51 | 14 | 232 | 204 | 54 | 31 |
| | Histeridae | 0 | 1 | 3 | 2 | 0 | 1 | 1 | 0 |
| | Scarabaeidae | 26 | 28 | 51 | 29 | 7 | 18 | 11 | 0 |
| | Staphylinidae | 1 | 4 | 2 | 0 | 37 | 13 | 50 | 3 |
| | Tenebrionidae | 54 | 142 | 473 | 340 | 132 | 179 | 45 | 103 |
| Dermaptera | Forficulidae | 0 | 14 | 294 | 15 | 1323 | 886 | 644 | 1 |
| Dictyoptera | Blattidae | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 0 |
| Diplopoda | Julidae | 23 | 1 | 1 | 0 | 14 | 0 | 10 | 127 |
| Embioptera | Oligotomidae | 2 | 0 | 4 | 0 | 0 | 6 | 24 | 5 |
| Heteroptera | Cydnidae | 7 | 1 | 0 | 0 | 2 | 1 | 3 | 2 |
| | Lygaeidae | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| | Nabidae | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| | Pyrrhocoridae | 0 | 0 | 1 | 3 | 123 | 3 | 5 | 0 |
| | Reduviidae | 1 | 0 | 0 | 0 | 3 | 0 | 0 | 0 |
| | Scutelleridae | 0 | 24 | 2 | 0 | 0 | 0 | 0 | 0 |
| Isoptera | Armadillidae | 0 | 0 | 0 | 0 | 0 | 1 | 20 | 0 |
| | Porcellionidae | 21 | 10 | 65 | 42 | 40 | 71 | 648 | 32 |
| Microcoryphia | Machilidae | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 |
| Neuroptera | Myrmeleontidae | 5 | 9 | 1 | 1 | 0 | 0 | 0 | 0 |
| Opiliones | Phalangiidae | 7 | 3 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Sclerosomatidae | 0 | 0 | 0 | 1 | 0 | 0 | 84 | 0 |
| Orthoptera | Acridiidae | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 13 |
| | Catantopidae | 10 | 9 | 7 | 1 | 54 | 20 | 19 | 16 |
| | Gryllidae | 0 | 0 | 1 | 2 | 0 | 0 | 1 | 0 |
| | Oecanthidae | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| | Pyrgomorphidae | 8 | 0 | 3 | 0 | 0 | 2 | 3 | 2 |
| Zygentoma | Lepismatidae | 2 | 9 | 0 | 0 | 0 | 0 | 1 | 1 |

Appendix 2.— Subset of six families and 22 species of epigeic beetles collected at eight transects in coastal environments near to El Altet (Alicante, Spain). Abbreviations as in Appendix 1.

Apéndice 2.— Subconjunto de seis familias y 22 especies de coleópteros epigeos colectados en ocho transectos en ambientes costeros cercanos a El Altet (Alicante, España). Abreviaturas como en Apéndice 1.

| Families | Species | GD | YD1 | YD2 | YD3 | RV1 | RV2 | RV3 | HD |
|---|---|---|---|---|---|---|---|---|---|
| Carabidae | *Cicindela lunulata* | 0 | 1 | 5 | 0 | 0 | 12 | 7 | 0 |
| | *Cymindis lineola* | 2 | 1 | 1 | 1 | 3 | 0 | 0 | 11 |
| | *Harpalus fulvus* | 50 | 93 | 67 | 269 | 21 | 50 | 22 | 1 |
| | *Licinus punctatulus* | 43 | 7 | 5 | 12 | 38 | 37 | 39 | 9 |
| | *Macrothorax morbillosus morbillosus* | 0 | 0 | 3 | 0 | 121 | 5 | 1 | 0 |
| | *Masoreus wetterhalli* | 5 | 66 | 52 | 106 | 27 | 11 | 5 | 0 |
| | *Scarites buparius* | 3 | 20 | 0 | 0 | 2 | 1 | 0 | 0 |
| Chrysomelidae | *Timarcha espagnoli* | 41 | 1 | 0 | 0 | 0 | 0 | 0 | 3 |
| | *Timarcha intermedia* | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 13 |
| Curculionidae | *Coniocleonus excoriatus* | 0 | 0 | 0 | 0 | 12 | 11 | 0 | 9 |
| Scarabaeidae | *Psammodius porcicollis* | 26 | 27 | 50 | 29 | 6 | 18 | 11 | 0 |
| Staphylinidae | *Ocypus olens* | 1 | 0 | 0 | 0 | 36 | 12 | 37 | 2 |
| Tenebrionidae | *Asida (Granulasida) ricoi* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 17 |
| | *Erodius carinatus* | 11 | 16 | 30 | 17 | 11 | 24 | 2 | 0 |
| | *Halammobia pellucida* | 0 | 0 | 54 | 7 | 0 | 0 | 0 | 0 |
| | *Leichenum pulchellum* | 0 | 0 | 0 | 0 | 0 | 5 | 9 | 0 |
| | *Pachychila frioli* | 0 | 9 | 43 | 12 | 1 | 3 | 0 | 0 |
| | *Pimelia baetica* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 59 |
| | *Pseudosericius pruinosus* | 3 | 49 | 182 | 169 | 35 | 38 | 4 | 0 |
| | *Tentyria elongata* | 21 | 16 | 1 | 0 | 0 | 0 | 0 | 0 |
| | *Tentyria laevis* | 0 | 0 | 10 | 6 | 83 | 102 | 27 | 24 |
| | *Xanthomus pellucidus* | 19 | 50 | 151 | 128 | 2 | 6 | 1 | 0 |

Appendix 3.— Results of ANOSIM tests performed for epigeic arthropod family data (a) and Coleoptera species data (b). Values of test statistic (R) and significance (p) for pairwise comparisons placed diagonally right and left respectively. Other abbreviations as in Appendix 1.

Apéndice 3.— Resultados de las pruebas ANOSIM realizadas para datos de familias de artrópodos (a) y datos de especies de Coleoptera (b). Los valores de la estadística de prueba (R) y la significancia (p) para las comparaciones por pares se colocan en diagonal a la derecha y a la izquierda, respectivamente. Otras abreviaturas como en Apéndice 1.

| **a) Family data** | **global** | **R = 0.7959** | | **p = 0.0037** | |
|---|---|---|---|---|---|
| | **mean rank** | within | = 6.143 | between | = 17.29 |
| | **pairwise comparisons** | | YD | RV | HD+GD |
| | | YD | | 0.78 | 0.75 |
| | | RV | 0.099 | | 1.00 |
| | | HD+GD | 0.101 | 0.101 | |
| **b) Coleoptera data** | **global** | **R = 0.7415** | | **p = 0.0032** | |
| | **mean rank** | within | = 6.714 | between | = 17.10 |
| | **pairwise comparisons** | | YD | RV | HD+GD |
| | | YD | | 1.00 | 0.75 |
| | | RV | 0.098 | | 0.50 |
| | | HD+GD | 0.099 | 0.097 | |