ISSN: 1989-6581

www.aegaweb.com/arquivos_entomoloxicos

Giraldo-Mendoza (2020)

ARQUIVOS ENTOMOLÓXICOS, **22**: 351-360

ARTIGO / ARTÍCULO / ARTICLE

Preliminary assessment of trampling effects on soil-dwelling insects in coastal dunes of El Saladar, southeastern Spain.

Alfredo E. Giraldo-Mendoza

Museo de Entomología Klaus Raven Büller, Universidad Nacional Agraria La Molina (UNALM), Lima (PERU).
e-mail: aegmendoza@gmail.com

Abstract: The coastal dunes in southeastern Spain have been increasingly disturbed by trampling associated with tourist activities, which causes loss of vegetation cover and soil compaction. A preliminary study to evaluate the effects of trampling on soil-dwelling insects was conducted in El Saladar dunes (Alicante, Spain). Trampling effects on assemblages of soil-dwelling insects were most noticeable in disturbed grey dunes, where lower abundance, higher equitability and severe decline for most taxa were found.
Key words: Coastal dunes, soil-dwelling insects, trampling, Western Mediterranean.

Resumen: Evaluación preliminar de los efectos del pisoteo sobre insectos hipogeos en dunas costeras de El Saladar, sureste de España. Las dunas costeras en el sureste de España han sufrido una creciente perturbación por el pisoteo asociado con actividades turísticas, lo que provoca pérdida de cobertura vegetal y compactación de suelo. Se realizó un estudio preliminar para evaluar los efectos del pisoteo en los insectos del suelo en las dunas de El Saladar (Alicante, España). Los efectos del pisoteo en los ensambles de insectos hipogeos fueron más notables en las dunas grises perturbadas, donde se halló una menor abundancia, una mayor equitabilidad y una disminución severa de la mayoría de los taxones.
Palabras clave: Dunas costeras, insectos hipogeos, pisoteo, Mediterráneo occidental.

Recibido: *8 de julio de 2020*
Aceptado: *3 de octubre de 2020*
Publicado on-line: *8 de octubre de 2020*

Introduction

Tourism is one of the main economic activity in the coastal towns of Alicante province (southeastern Spain), which since the 1960s to date has led to an accelerated reduction of the natural areas (Huete, 2005). In a recent landscape classification of Alicante beaches based on 26 physical and anthropogenic parameters, El Altet beaches (El Saladar and Arenales del Sol) were rated as very unattractive urban sites with intensive development and low landscape values (Asensio-Montesinos *et al.*, 2017). Regarding the conservation status of the dune vegetation in the Valencian Region, dunes near El Altet town were classified as clearly degraded sites, with some patches of relatively well-preserved vegetation, but with extensive cover of nitrophilic or non-native species, and an impoverished coastline to inland structure (Albertos *et al.*, 2010).

The most noticeable effect of tourism on coastal dunes is pedestrian and vehicle trampling to reach recreational areas, besides other anthropogenic impacts as rubbish dumping, beach mechanical cleaning and sand extraction. Trampling effects on sand dune soil and vegetation have been extensively studied, with general tendencies to increasing bulk density, penetration resistance and vegetation cover loss, besides variable or minor changes on other physical and chemical soil properties and plant diversity (Koehler *et al.*, 1996; Kutiel *et al.*, 2000; Bonari *et al.*, 2019). In these studies, trampling effects varied according to perturbation intensity and frequency, but usually promoted dominance of early successional, monocot, hemicryptophyte or xerophyte plant species.

Trampling effects on soil-dwelling arthropods inhabiting dunes have been documented for ants (Chen *et al.*, 2015), beetles (Comor *et al.*, 2008), and microarthropods (Koehler *et al.*, 1996; Bonari *et al.*, 2019). Main findings of these works include compositional changes due to variations insensitivity of different taxa to soil compaction, and idiosyncratic changes on density and diversity. Trampling may also affect the population dynamics and ultimately the survival of cursorial and flying psammophilous species, such as butterflies, grasshoppers, spiders, and scarab beetles (Bonte & Maes, 2008; Van Dam & Van Dam, 2008).

The purpose of the present work is to assess trampling effects on soil-dwelling insect assemblages inhabiting coastal dunes, based on a short sampling made at El Saladar (Alicante, Spain) in 2004.

Material and methods

The field work was carried out in March and August 2004 in El Saladar dunes, a relatively well preserved coastal dune system located between Urbanova and Los Arenales del Sol urbanizations, in El Altet town (Elche district, Alicante province, southeastern Spain; 38°16'15"N 00°31'17"W) (Fig. 1). A total of 60 sampling quadrats (1 m^2) were placed in four site types differing in soil and vegetation conditions (Fig. 2):

1) 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, average vegetation cover = 46%, CV = 59%, quadrats = 10.
2) Grey dune (GD), *Crucianellion* phytosociological alliance dominated by *Crucianella maritima* (L.), *Teucrium dunense* Sennen, *Thymelaea hirsuta* (L.) Endl., and *Helichrysum stoechas* (L.) DC, consolidated sand substrate, average vegetation cover = 56%, CV = 57%, quadrats = 30.
3) Trampled yellow dune (YDt), pedestrian path adjacent to *Ammophilion* covered with herbs and grasses, mobile sand substrate, average vegetation cover = 7%, CV = 101%, quadrats = 10.
4) Trampled grey dune (GDt), pedestrian path adjacent to Crucianellion covered with herbs and grasses, consolidated sand substrate, average vegetation cover = 33%, CV = 78%, quadrats = 10.

In each quadrat, soil-dwelling insects were extracted by digging sand samples (1 m^2 area, 15 cm depth), sieved through a wire mesh sifter (30 cm diameter, 1.5 mm^2 mesh), picked with forceps and preserved in 70% ethanol.

In the laboratory, the specimens were sorted considering higher taxonomic groups and developmental stages under a stereoscope (20X – 40X), using appropriate taxonomic keys (Barrientos, 1988). The most abundant taxa in the samples were determined at genus and species level, including darkling beetles (Español, 1954; Marcuzzi *et al.*, 1978; López-Sánchez *et al.*, 1985), and scarab beetles (Veiga & Martín-Piera, 1988).

Abundance data from each 10 sampling quadrats were pooled according to site conditions into six spatial units: YD, YDt, GD1, GD2, GD3, and GDt. A set of 8 univariate metrics were calculated for each spatial unit, including: total and mean abundance, observed and expected richness (rarefaction), heterogeneity indices of Simpson (1-D) and Shannon (H´), Lloyd-Ghelardi's equitability index (J´ = H´/M´) and fitting of abundance distributions to MacArthur's broken stick model. Statistical significance measurements performed were Wilcoxon's test for mean abundance, bootstrapping for observed richness, t-test for heterogeneity indices and chi-squared test for MacArthur's broken stick model. A matrix of log-transformed taxa abundance x spatial units was processed in a four stages analysis proposed by Giraldo-Mendoza (2015) to explore the relationship between assemblage structure and environmental conditions:

1) Non-metric multidimensional scaling (NMDS) to place spatial units in a bidimensional coordinate system, measuring similarity with chord distance, as in the next two stages.
2) Cluster analysis (UPGMA) to generate spatial units groups.
3) Analysis of Similarities (ANOSIM) to test the statistical significance of groups recognized in cluster analysis ($p < 0.05$).
4) Rank correlations between scores of NMDS axes with taxa abundances (Spearman, $p < 0.05$ or $p < 0.1$).

Univariate metrics and multivariate analysis were applied following Krebs (1989) and Legendre & Legendre (1998), and performed with PAST statistical software (Hammer *et al.*, 2001).

Results

Overall, 1366 specimens of soil-dwelling insects were collected, including 14 taxa at order, superfamily or family levels (Table 1). Immature stages of holometabolous insects comprised the highest number of individuals (777) as compared to adults of holometabolous taxa (570) and hemimetabolous insects (75). The most abundant groups, including both larvae and adults, were Scarabaeidae and Tenebrionidae, particulary *Ammobius rufus* (Lucas, 1846), *Erodius carinatus* Solier, 1834 larvae, *Pachychila frioli* Solier, 1835 adults and larvae, *Paratriodonta alicantina* (Reitter, 1890) larvae, *Psammodius porcicollis* (Illiger, 1803) adults and larvae, and *Tentyria elongata* Waltl, 1839 larvae (Fig. 3).

Univariate metrics for the six sampled sites are presented in Table 2. Mean abundance was significantly higher in untrampled yellow dune YD and grey dune GD1, intermediate in trampled yellow dune YDt and untrampled grey dune GD2, GD3, and lower in trampled grey dune GDt. Observed richness was only significantly higher in untrampled grey dune GD1. Expected richness was indistinguishable for most sampling plots (GD1, GD2, GD3, GDt), and slightly lower for trampled and untrampled yellow dune (YD, YDt). Simpson and Shannon heterogeneity indices had significantly higher values for untrampled yellow and grey dune (YD, GD1), intermediate in trampled and untrampled grey dune (GD2, GD3, GDt), and lower in trampled yellow dune (YDt). Equitability index (J´) was higher in trampled grey dune (GDt), intermediate in untrampled grey dunes (GD1, GD2, GD3) and lower in trampled and untrampled yellow dune (YD, YDt). Only abundance distribution in trampled grey dune (GDt) was significantly fitted to broken stick model, while the others departed significantly from that model, particularly trampled and untrampled yellow dune (YD, YDt).

The graphical display of multivariate analysis is presented in Fig. 4. The six plots were significantly clustered in three groups composed by trampled grey dune (GDt), untrampled grey dunes (GD1, GD2, GD3) and trampled and untrampled yellow dunes (YD, YDt) respectively. Rank correlations between scores of NMDS axes with taxa abundances are presented in Table 3. Most correlations with first axis were negative (14 out of 18 correlations), significant only for Tenebrionidae adults and Scarabaeidae larvae, and strong but not significant for Tenebrionidae larvae, Scarabaeidae adults, Myrmeleontidae larvae, and Lepidoptera larvae. Half of the correlations with the second axis were positive (9 out of 18), significant only for Carabidae adults and Muscoidea pupae, and strong but not significant for Histeridae adults, Asiloidea pupae, and Curculionidae larvae.

Discussion

The hypogean fauna collected at El Saladar dunes was mainly composed of immature stages, which made taxonomic determination below family level very difficult. Most specimens belonged to two beetle families well represented in Mediterranean coastal dunes, Scarabaeidae (Kim & Lumaret, 1981; Martín-Cantarino & Seva-Román, 1992) and Tenebrionidae (Sauleda-Parés, 1985; Martín-Cantarino & Seva-Román, 1990).

According to the univariate metrics and multivariate analysis performed, soil-dwelling insects in the trampled grey dune (GDt) were the most deeply affected, while the assemblage in the trampled yellow dune (YDt) was apparently more resilient. Apart from human disturbance effects, assemblages were distinguished according to taxa preferences for different substrates, i.e. mobile sand (YD, YDt) or consolidated sand (GD1, GD2, GD3).

The outcomes of the univariate metrics allows to distinguish three patterns in our soil-dwelling insect assemblages: 1) high to medium abundance and low equitability in trampled and untrampled yellow dunes (YD, YDt), 2) high to medium abundance and medium equitability in untrampled grey dunes (GD1, GD2, GD3), and 3) low abundance and high equitability in trampled grey dune (GDt). Richness and heterogeneity values showed less evident patterns, although the untrampled grey dune GD1 showed higher values. In trampled grey dune (GDt), soil-dwelling insect abundances were severely diminished, most taxa being represented by a low number of specimens and, consequently, provoking a high equitability in the assemblage. This response contrasts with previous assessments of insects in disturbed dunes, in which population outbreaks of dominant or invasive species were registered (Comor *et al.*, 2008; Chen *et al.*, 2015).

In agreement with the results from the univariate metrics, the four stages multivariate analysis suggested that most taxa decreased or disappeared in the trampled grey dune (GDt) and also that taxa were distributed in the remaining spatial units according to their preferences for mobile (YD, YDt) or consolidated (GD1, GD2, GD3) sands. In the NMDS plot, YD and YDt remained close despite trampling evidence in the latter area. This maybe due to eolian dynamics of mobile sands and the ability of psammophilous taxa to persist below-ground in these harsh edaphic conditions (Comor *et al.*, 2008).

Although soil and vegetation conditions were not exhaustively measured, field observations and previous studies indicate that the main consequences of trampling are increase of bulk density and decrease of vegetation cover. Therefore, these parameters can be used to explain changes observed in abundance, equitability and composition. Population viability and interspecific coexistence of soil arthropods ultimately depends on available volume of macropores, as evidenced by some field surveys and laboratory assays performed with mites and springtails (Koehler *et al.*, 1996; Larsen *et al.*, 2004). In arid environments, clumped distributions of sand-burrowing arthropods under vegetation has been described as "island effect", namely shrub rhizospheres are keystone structures providing microclimatic stability and food resources (Crawford, 1981). This close connection has been documented for all kinds of dune-inhabiting arthropods: ants (Chen *et al.*, 2015), epigeic beetles (Comor *et al.*, 2008), oribatid mites (Bonari *et al.*, 2019), sand-burrowing arthropods (Slobodchikoff & Doyen, 1977), and scarab beetles (Van Dam & Van Dam, 2008). For *Psammodius porcicollis*, clumped distribution was reported in French dunes, where most specimens were found in the rhizosphere of *Artemisia* shrubs to a depth of 4 cm (Kim & Lumaret, 1981).

According to findings of present and previous works, some collected species could be classified as psammophilous and would deserve conservation efforts due to their restricted distributions. Based on this short sampling, this is the case of *Erodius carinatus*, *Pachychila frioli*, *Psammodius porcicollis* and *Tentyria elongata* (adults and larvae), *Ammobius rufus* (adults), and *Paratriodonta alicantina* (larvae).

Trampling not only has deleterious effects on digging arthropods, but also on other groups with greater locomotion abilities, including ballooning, jumping or flying. In this way, populations of butterflies, grasshoppers, and spiders are in higher risk of local extinction in trampled and isolated dune patches (Bonte & Maes, 2008) and scarabs populations are depleted in dune areas crossed by vehicle paths (Van Dam & Van Dam, 2008). Likewise, *Paratriodonta alicantina* is a flying-active pollinator of the psammophyte *Launaea fragilis* (Asso) Pau according to observations made in El Saladar dunes (Martín-Cantarino & Seva-Román, 1992), but immature stages are vulnerable to trampling as suggested by the present study.

Restoration or stabilization of trampled dunes is directly involved with soil and vegetation conditions, although effects on invertebrate fauna are expected. Restoration practices promoting natural regeneration of dunes with fenced areas have been more successful to recover endemic arthropod assemblages, although previous studies indicate that decades are required for that achievement (Comor *et al.*, 2008; Bonari *et al.*, 2019). In comparison, stabilization practices based on planting or sowing alien plant species, hardly recover arthropod composition registered in undisturbed areas (Slobodchikoff & Doyen, 1977; Chen *et al.*, 2015).

Conclusions

Trampling effects on assemblages of soil-dwelling insects were most noticeable in disturbed grey dunes, while assemblages inhabiting yellow dunes appear to be more resilient.

In trampled grey dunes, assemblages of soil-dwelling insects showed lower abundance, more equitability and most taxa were severely diminished.

Because grey dunes may be more susceptible to trampling, these areas deserve a greater attention both in research and in conservation measurements.

Acknowledgments

The author was awarded with a Mutis IIb - AECI grant (November 2003 - August 2004) during his research internship at Universidad de Alicante (Alicante, Spain). To Carlos Martín–Cantarino for reviewing the manuscript and providing valuable suggestions to improve it.

References

Albertos, B., San Miguel, E., Draper, I., Garilleti, R., Lara, F. & Varela, J.M. 2010. Estado de conservación de la vegetación dunar en las costas de la Comunidad Valenciana. *Ingeniería Civil*, **158**: 121-134.

Asensio-Montesinos, F., Anfuso, G. & Corbí, H. 2017. Evaluación paisajística de las playas de Alicante (Mediterráneo occidental) mediante parámetros físicos y antropogénicos: implicaciones para la gestión. *Geo–Temas*, **17**: 183-186.

Barrientos, J.A. (ed.). 1988. *Bases para un curso práctico de Entomología*. Asociación española de Entomología, Barcelona (España).

Bonari, G., Těšitel, J., Migliorini, M., Angiolini, C., Protano, G., Nannoni, F., Schlaghamerský, J. & Chytrý, M. 2019. Conservation of the Mediterranean coastal pine woodlands: How can management support biodiversity? *Forest Ecology and Management*, **443**: 28-35.

Bonte, D. & Maes, D. 2008. Trampling affects the distribution of specialised coastal dune arthropods. *Basic and Applied Ecology*, **9**: 726-734.

Chen, X., Adams, B., Bergeron, C., Sabo, A. & Hooper–Bui, L. 2015. Ant community structure and response to disturbances on coastal dunes of Gulf of Mexico. *Journal of Insect Conservation*, **19**: 1-13.

Comor, V., Orgeas, J., Ponel, P., Rolando, C. & Delettre, Y.R. 2008. Impact of anthropogenic disturbances on beetle communities of French Mediterranean coastal dunes. *Biodiversity and Conservation*, **17**: 1837-1852.

Crawford, C.S. 1981. *Biology of Desert Invertebrates*. Springer-Verlag Berlin Heidelberg, New York, USA.

Español, F. 1954. Los tenebriónidos (col.) de Baleares. *Trabajos del Museo de Ciencias Naturales de Barcelona, Nueva Serie Zoológica*, **1**(5): 3-93.

Giraldo–Mendoza, A.E. 2015. La suficiencia taxonómica como herramienta para el monitoreo de artrópodos epígeos: una primera aproximación en el desierto costero peruano. *Ecología Aplicada*, **14**(2): 147-156.

Hammer, O., Harper, D.A.T. & Ryan, P.D. 2001. *PAST: Paleontological statistics software package for education and data analysis.* Available on: https://folk.uio.no/ohammer/past/ [Accessed on April 20, 2020].

Huete, R. 2005. *Factores de atracción de Alicante como destino residencial: el punto de vista de los residentes europeos*, pp. 375–390. En: Mazón, T. & Aledo, A. (eds.). *Turismo residencial y cambio social. Nuevas perspectivas teóricas y empíricas.* Aguaclara Libros S. L., Alicante (España).

Kim, J.I. & Lumaret, J.P. 1981. Écologie de *Psammodius porcicollis* (Ill.) [Col. Aphodiidae], insecte sabulicole des dunes littorales du golfe du Lion. *Annales de la Société Entomologique de France (N.S.),* **17**(4): 449-462.

Koehler, H.H., Harder, H., Meyerdirks, J. & Voigt, A. 1996. *The effect of trampling on the microarthropod fauna of dune sediments. A case study from Jutland, Denmark*, pp. 221-231. In: Jones, P.S., Healey, M.G. & Williams, A.T. (eds.). *Studies in European Coastal Management.* Samara Publishing Limited, Cardigan (UK).

Krebs, C.J. 1989. *Ecological Methodology*. Harper Collins Publishers, New York (USA).

Kutiel, P., Eden, E. & Zhevelev, Y., 2000. Effect of experimental trampling and off–road motorcycle traffic on soil and vegetation of stabilized coastal dunes, Israel. *Environmental Conservation*, **27**(1): 14-23.

Larsen, T., Schjonning, P. & Axelsen, J. 2004. The impact of soil compaction on euedaphic Collembola. *Applied Soil Ecology*, **26**: 273-281.

Legendre, P. & Legendre L. 1998. *Numerical Ecology. Second English Edition.* Developments in Environmental Modelling 20. Elsevier Science B. V. Amsterdam.

López-Sánchez, S., de los Santos, A. & Montes, C. 1985. Estudio morfológico de la forma larvaria de *Tentyria platyceps* Stev., 1829. *Eos, Revista Española de Entomología*, **61**(1–4): 173-182.

Marcuzzi, G., Cravera, C. & Faccini, E. 1978. III Contributo alla conoscenza delle forme larvali dei Tenebrionidi (col. Heteromera). *Eos, Revista Española de Entomología*, **54**(1–4): 167-206.

Martín-Cantarino, C. & Seva-Román, E. 1990. Ciclos estacionales de actividad y modelos espaciales en las poblaciones de Coleoptera Tenebrionidae de las dunas costeras de la playa de El Saladar (Alicante-Elche, SE. de España). *Mediterránea Serie de Estudios Biológicos*, **12**: 97-112.

Martín-Cantarino, C. & Seva-Román, E. 1992. Datos sobre la ecología de *Paratriodonta alicantina* (Reitter) (Col. Melolonthidae) y su papel como polinizador en un ecosistema de dunas costeras del SE Ibérico. *Boletim da Sociedade Portuguesa de Entomología*, **2**(3): 41-50.

Sauleda-Parés, N. 1985. Tenebriónidos halófilos y psammófilos de la provincia de Alicante. *Anales de la Universidad de Alicante*, **2**: 265-272.

Slobodchikoff, C.N. & Doyen, J.T. 1977. Effects of *Ammophila arenaria* on sand dune arthropod communities. *Ecology*, **58**: 1171-1175.

Van Dam, A.R. & Van Dam, M.H. 2008. Impact of off–road vehicle use on dune endemic Coleoptera. *Annals of Entomological Society of America*, **101**(2): 411-417.

Veiga, C.M. & Martín-Piera, F. 1988. Claves para la identificación de la fauna española: Las familias, tribus y géneros de los Scarabaeoidea (Col) ibero-baleares. *Cátedra de Entomología Facultad de Biología Universidad Complutense*, **26**: 1-88.

Table 1.- Higher taxa of soil-dwelling insects collected at six spatial units in El Saladar dunes (Alicante, Spain). Abbreviations: YD = yellow dunes, GD = grey dunes, t = trampled.

Tabla 1.-Taxones supraespecíficos de insectos hipogeos colectados en seis unidades espaciales en las dunas de El Saladar (Alicante, España). Abreviaturas: YD = dunas móviles, GD = dunas fijas, t = pisoteado.

Orders	**(Super) Families**	**stages**	**YD**	**YDt**	**GD1**	**GD2**	**GD3**	**GDt**
Coleoptera	Carabidae	adults	1	0	6	3	3	1
		larvae	2	1	2	1	2	1
	Curculionidae	adults	9	0	3	2	2	1
		larvae	0	7	27	16	8	6
		pupae	0	0	1	0	0	0
	Histeridae	adults	2	2	1	0	0	0
	Scarabaeidae	adults	108	93	47	49	45	1
		larvae	96	14	48	76	78	1
	Tenebrionidae	adults	84	39	2	3	5	2
		larvae	52	45	35	25	26	13
	Indet.	larvae	1	1	3	0	0	0
Diptera	Asiloidea	pupae	17	4	8	2	2	3
	Muscoidea	pupae	2	0	1	4	7	0
	Indet.	larvae	14	4	15	11	11	5
Heteroptera	Cydnidae	adults /nymphs	36	6	20	9	3	1
Lepidoptera	Indet.	larvae	2	10	14	7	3	5
		pupae	3	0	3	2	2	0
Neuroptera	Myrmeleontidae	larvae	12	2	1	2	8	3

Table 2.- Univariate metrics for soil-dwelling insect assemblages in six spatial units at El Saladar dunes (Alicante, Spain). Abbreviations as in Table 1. Highest values for each metric are shown in bold case. Lowercase letters indicate significant differences from Wilcoxon's test (mean abundance), bootstrapping (observed richness) or t-test (heterogeneity indices). Numbers for expected richness are 95% confidence intervals estimated for the lowest sample size (n = 43). Numbers for Chi-square test are x^2 and p values.
Tabla 2.- *Métricas univariadas para los ensambles de insectos hipogeos en seis unidades espaciales en las dunas de El Saladar (Alicante, España). Abreviaturas como en Tabla 1. Valores más altos para cada métrica en negrita. Letras minúsculas indican diferencias significativas para la prueba de Wilcoxon (abundancia media), bootstrapping (riqueza observada) o prueba t (índices de heterogeneidad). Números para riqueza esperada son intervalos de confianza estimados para el tamaño muestral más bajo (n = 43). Números para prueba de Chi-cuadrado son valores de x^2 and p.*

Metrics	YD	YDt	GD1	GD2	GD3	Gdt
Abundance						
total	**441**	228	237	212	205	43
mean	**24.50a**	12.67c	13.17b	11.78c	11.39c	2.39d
Richness						
observed	16b	13b	**18a**	15b	15b	13b
expected	6.60-11.59	6.03-11.02	**8.34-13.93**	7.08-12.57	7.35-13.00	---
Heterogeneity						
Simpson	**0.83a**	0.76c	**0.87a**	0.79b	0.78b	0.85b
Shannon	2.02b	1.77d	**2.27a**	1.95c	1.95c	2.18c
Equitability						
Chi-square test	91.76	57.16	26.94	47.45	52.89	1.09
for broken-stick model	1.76E-13	3.11E-08	0.02921	3.90E-06	4.31E-07	**0.9819**
Lloyd-Ghelardi	0.24	0.24	0.31	0.27	0.27	**0.45**

Table 3.- Spearman rank correlation coefficients (r_s) between log-transformed abundance of 18 higher taxa of soil-dwelling insects with NMDS axes performed for six spatial units. Correlations equal to or higher than 0.60 highlighted in bold, when significant with one (p < 0.1) or two (p < 0.05) asterisks.
Tabla 3.- *Coeficientes de correlación de Spearman (r_s) entre las abundancias transformadas logarítmicamente de 18 taxones supraespecíficos de insectos hipogeos con los ejes del NMDS para seis unidades espaciales. Correlaciones iguales o mayores que 0.60 resaltadas en negrita, cuando son significativas con uno (p < 0.1) o dos (p < 0.05) asteriscos.*

Higher taxa		Axis 1		Axis 2	
Carabidae	adults	0.24	0.68	**0.79**	**0.08***
	larvae	-0.49	0.40	0.29	0.70
Curculionidae	adults	-0.38	0.48	0.23	0.67
	larvae	0.37	0.42	**0.60**	0.18
	pupae	0.39	0.67	0.13	1.00
Histeridae	adults	-0.46	0.37	**-0.80**	0.10
Scarabaeidae	adults	**-0.66**	0.14	-0.54	0.24
	larvae	**-0.83**	**0.03****	0.31	0.56
Tenebrionidae	adults	**-0.93**	**0.02****	-0.41	0.43
	larvae	**-0.71**	0.14	-0.54	0.24
Coleoptera indet.	larvae	-0.09	0.87	-0.49	0.30
Asiloidea	pupae	-0.20	0.70	**-0.70**	0.14
Muscoidea	pupae	-0.52	0.30	**0.78**	**0.08***
Diptera indet.	larvae	-0.14	0.77	0.35	0.51
Cydnidae	adults/nymphs	-0.43	0.36	-0.20	0.66
Lepidoptera indet.	larvae	**0.60**	0.18	-0.09	0.80
	pupae	-0.36	0.53	0.24	0.71
Myrmeleontidae	larvae	**-0.64**	0.19	-0.03	0.98

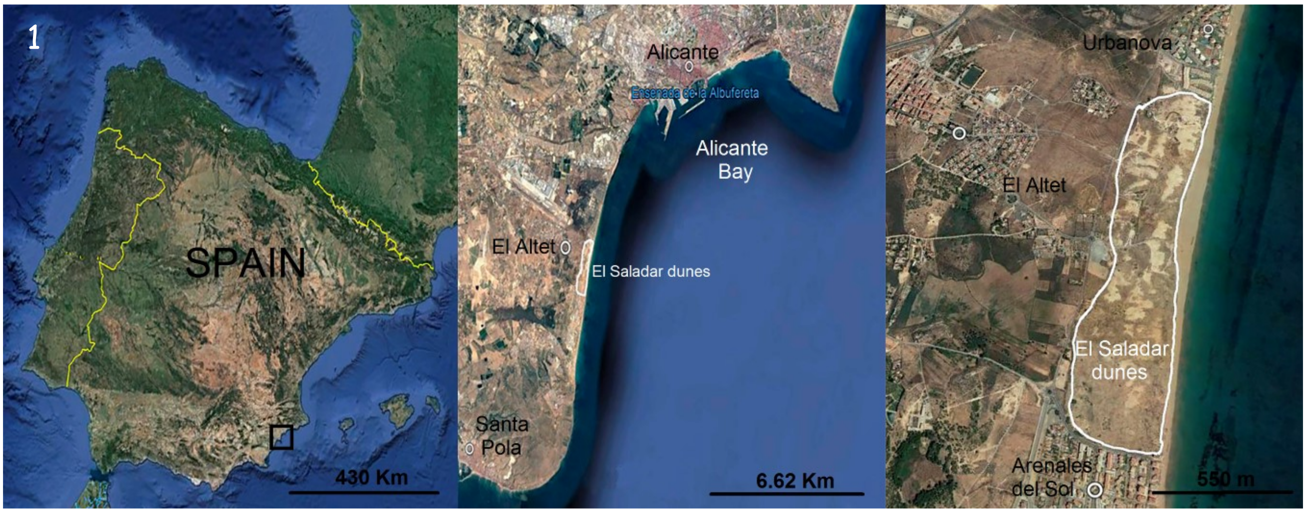

Fig. 1.- Location of El Saladar dunes (Alicante, Spain).
Fig. 1.- Localización de las dunas de El Saladar (Alicante, España).

Fig. 2.- Soil and vegetation conditions at El Saladar dunes (Alicante, Spain). **a.-** Yellow dune (YD) crossed by pedestrian path (YDt). **b.-** Grey dune (GD) crossed by pedestrian path (GDt).
Fig. 2.- Condiciones de suelo y vegetación en las dunas de El Saladar (Alicante, España). **a.-** Duna móvil (YD) cruzada por un camino peatonal (YDt). **b.-** Duna fija (GD) cruzada por un camino peatonal (GDt).

Fig. 3.- Percentages (pie chart) and proportions (bars) for the most abundant taxa of soil-dwelling insects collected at El Saladar dunes (Alicante, Spain).
Fig. 3.- Porcentajes (gráfico circular) y proporciones (barras) para los taxones más abundantes de insectos hipogeos colectados en las dunas de El Saladar (Alicante, España).

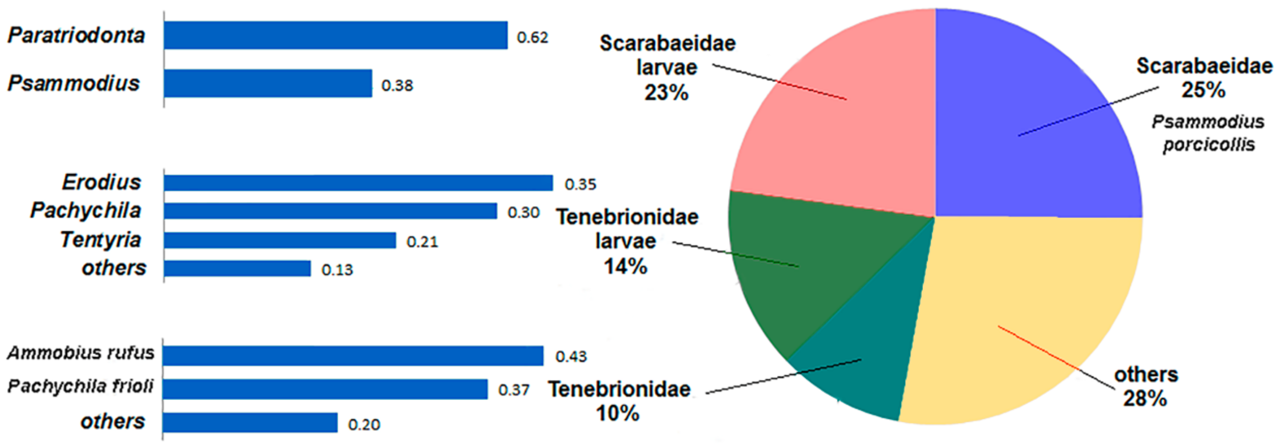

Fig. 4.- NMDS plot for soil-dwelling insect assemblages in the six spatial units sampled at El Saladar dunes (Alicante, Spain). Abbreviations as in Table 1. Groups generated by cluster analysis and tested with ANOSIM indicated with different symbols: trampled and untrampled yellow dunes (yellow triangles), untrampled grey dunes (green diamonds) and trampled grey dune (red circle). Image of *Erodius* larva in left corner.
Fig. 4.- Diagrama del NMDS para ensambles de insectos hipogeos en seis unidades espaciales en las dunas de El Saladar (Alicante, España). Abreviaturas como en Tabla 1. Grupos generados por análisis cluster y probados con ANOSIM indicados con símbolos diferentes: dunas móviles pisoteadas y no pisoteadas (triángulos amarillos), dunas fijas no pisoteadas (rombos verdes) y duna fija pisoteada (círculo rojo). Imagen de la larva de *Erodius* en la esquina izquierda.