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Possibilities of using Tenebrionidae species (Insecta: Coleoptera) as biological indicators for habitat description

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Abstract

This study investigated the distribution of eighteen darkling beetles species of (Tenebrionidae) sampled using pitfall traps across six distinct habitats in the Çukurova Delta (Adana, Türkiye), including sand dunes, salt marshes, salt meadows, Pinus spp. forests, *Eucalyptus* spp. afforestation, and beach habitats. The objective was to assess the potential of darkling beetles as indicators for habitat characterization. Beetle abundance was recorded for each habitat, and indicator species analysis identified specific associations: *Zophosis dilatata*, *Erodius oblongus oblongus*, and *Ammobius cyprius* were most abundant in sand dunes; *Phtora reitteri reitteri* in salt marshes; *Gonocephalum rusticum* and *Centorus turcicus* in salt meadows; and *Pimelia bajula solieri* and *Zophosis punctata punctata* in Eucalyptus afforestation areas. The highest indicator values were observed for *C. turcicus* (94.0%) and *P. b. solieri* (84.7%). Although the majority of species were members of the Tenebrionidae family, the results suggest that these beetles are adaptable and can thrive across a range of habitat types within the delta.

Keywords: Insecta, Coleoptera, Çukurova delta, Tenebrionidae, distribution

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Tenebrionidae türlerinin (Insecta: Coleoptera) habitat tanımlamasında biyolojik gösterge olarak kullanılma olanakları

Özet

Bu çalışmada, Çukurova Deltası'nda (Adana, Türkiye) altı farklı habitatta (kumullar, tuzlu bataklıklar, tuzlu çayırlar, *Pinus* spp. ormanları, *Eucalyptus* spp. ağaçlandırma alanları ve plaj habitatları) çukur tuzakları kullanılarak örneklenen on sekiz Tenebrionidae türünün dağılımı incelenmiştir. Çalışmada, tenebrionid böceklerinin habitat karakterizasyonu için gösterge türü olarak kullanılma potansiyeli değerlendirilmmiştir. Her habitat için böcek yoğunluğu kaydedilmiş ve gösterge türü analizi ile belirli ilişkiler tespit edilmiştir: *Zophosis dilatata*, *Erodius oblongus oblongus* ve *Ammobius cyprius* en fazla kumul alanlarında; *Phtora reitteri reitteri* tuzlu bataklıklarda; *Gonocephalum rusticum* ve *Centorus turcicus* tuzlu çayırlarda; *Pimelia bajula solieri* ve *Zophosis punctata punctata Eucalyptus* ağaçlandırma alanlarında en fazla bulunmuştur. En yüksek gösterge değeri *C. turcicus* (94.0%) ve *P. b. solieri* (84.7%) için belirlenmiştir. Örneklenen türlerin yüksek oranda Tenebrionidae familyasına ait olmasına karşın, sonuçlar bu böceklerin delta içindeki çeşitli habitat türlerinde başarılı bir şekilde yaşayabildiklerini göstermiştir.

Anahtar kelimeler: Insecta, Coleoptera, Çukurova deltası, Tebenrionidae, dağılım

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Introduction

Türkiye is home to three global biodiversity hotspots—the Mediterranean, Caucasus, and Irano-Anatolian regions-each exhibiting a higher biodiversity and endemism rate than any other European country [1-2]. However, the populations of many epigean species have experienced significant declines due to factors such as agricultural expansion, pesticide use, and other crop improvement practices [3-10]. Despite these challenges, continues to be a rich source of new species discoveries, particularly within its terrestrial ecosystems and even at depths of up to -1260 meters in its cave ecosystems [11-13].

The Çukurova Delta, located in the southern region of Adana province, covers approximately 5,000 km² and represents the largest lagoon and dune succession in Türkiye, extending 110 km in length. It is considered one of the most important humid biotope systems along the Turkish Mediterranean coast [14]. The delta includes six main biotopes: (i) sand dunes, (ii) salt marshes, (iii) salt meadows, (iv) *Eucalyptus* spp. afforestation, (v) Pinus spp. forests, and (vi) beaches [15]. The Turkish government has proposed designating the delta as the nation's first biosphere reserve. Preliminary studies have highlighted the remarkable diversity of habitats and species present, although habitat classification has predominantly relied on vegetation, a practice commonly adopted in both Çukurova and across the EU (e.g., FFH - Natura 2000). This study seeks to build on this framework by proposing that darkling beetles could serve as valuable indicators for habitat classification in the delta, thus addressing the existing gap in faunal data.

Darkling and ground beetles are widely recognized as key indicator species for biodiversity monitoring and nature conservation [16-17]. However, the Tenebrionidae fauna of southern Anatolia has not been thoroughly studied. In this research, we present data on the darkling beetle species of the Çukurova Delta, obtained through pitfall trap sampling across various habitats within the delta.

A comprehensive and reliable distribution pattern is essential for utilizing darkling beetles in nature conservation efforts or as ecological indicators [18-23]. Therefore, the primary aim of this study is to provide detailed distribution data of Tenebrionidae species in relation to their habitats and to evaluate their potential as indicators for habitat classification within the Çukurova Delta.

2. Materials and methods

The study was conducted in the extended eastern Mediterranean dune and beach regions of the Çukurova Delta. Six main biotopes were investigated: sand dunes, salt marshes, salt meadows, *Eucalyptus* spp. afforestation, *Pinus* spp. forests, and beaches. Sampling was carried out across a total of 18 localities within the delta.

2.1. Sampling method

Darkling beetles were sampled using pitfall traps consisting of plastic cups (15 cm diameter, 20 cm depth) buried into the soil with the upper rim flush with the surface. The traps were spaced approximately 25 meters apart at each sampling site, with a total of 10 traps used in each habitat. Sampling was conducted annually over one-week periods between April and September, coinciding with peak arthropod abundance and diversity. Adult darkling beetles were collected in Falcon tubes (3x10 cm) containing 70% ethyl alcohol and transported to the laboratory for identification. Species identification was performed by Martin Lillig from the Bund für Umwelt und Naturschutz Deutschland Landesverband Saarland, Germany.

2.2. Habitat description

Sand Dune: The sampling areas included four distinct dune types: fore dune, fixed dune, secondary shifting dune, and dune slack. The fore dune, located adjacent to the beach, is less stabilized and sparsely vegetated. The fixed dune is higher, more stable, and exhibits the beginning stages of soil formation, with greater vegetation cover compared to the fore dune. The secondary shifting dune, which is not connected to the beach, is characterized by low vegetation and mobility due to factors such as overgrazing, cutting, and strong winds. The dune slack is a ground depression with distinct vegetation compared to the surrounding dune areas. The vegetation of the sand dune complex was composed of the following species: *Bromus* spp., *Cakile maritima*, *Cyperus capitatus*, *Echinops ritro*, *Echium angustifolium*, *Erica manipuliflora*, *Eryngium maritimum*, *Euphorbia paralias*, *Euphorbia peplis*, *Helianthemum stipulatum*, *Imperata cylindrica*, *Inula viscosa*, *Ipomea stolonifera*, *Juncus acutus*, *Medicago marina* [*Pancratium maritimum*], *Myrtus communis*, *Nerium oleander*, *Pancratium maritimum*, *Pistacia terebinthus* [*Pistacia lentiscus*], *Phragmites australis*, *Polygonum equisetiforme*, *Prunus spinosa*, *Rubus sanctus*, *Thymelaea hirsuta*, *Trachomitum venetum*, *Verbascum sinuatum*, *Vitex agnus-castus*, *Xanthium strumarium* and *Zygophyllum album* [24].

Salt Marsh: The vegetation of marine saline mud predominantly consists of shrub species, which grow on clayey/loamy soils that are periodically inundated and characterized by a consistently high groundwater table. The vegetation cover is generally sparse, with certain areas exhibiting a relatively open structure. This habitat is typified by

the presence of the following plant species: *Arthrocnemum fruticosum*, *Arthrocnemum glaucum*, *Halimione portulacoides*, *Halocnemum strobilaceum*, *Salicornia europaea* and *Tamarix smyrnensis* [24].

Salt Meadow: The vegetation of saline environments along lagoon shorelines is primarily dominated by perennial herbaceous species, which thrive on soils that are subjected to only brief periods of flooding. The vegetation cover is typically dense and clumped, exhibiting a caespitose growth form. This habitat is characterized by the presence of the following species: *Juncus maritimus*, *Juncus acutus*, *Aeluropus littoralis*, *Plantago maritima*, *Limonium gmelinii* and *Tamarix smyrnensis* [24].

Forest (Pinus spp.): These habitats are stable dune ecosystems dominated by *Pinus halepensis* and *Pinus brutia*. In the sampled area, *Pinus halepensis* was found to be the predominant species, although other *Pinus* species may also be present [24].

Afforestation (Eucalyptus spp.): These areas, previously characterized by a sand dune vegetation complex, have been subject to afforestation with *Eucalyptus* species [24].

Beach: This refers to an unvegetated sandy beach area located above the drift line [24].

2.3. Statistic analysis

An indicator species analysis [25] using the PC-ORD software package (Version 4.14) was carried out to establish the species groups that were associated with both major cluster groups derived from the flexible-UPGMA, and with a priori defined habitat groups from Table 1.

(1) The proportional abundance of a specific species within a group was calculated in relation to its abundance across all groups. This value was expressed as a percentage, and the intermediate result was presented.

A = sample unit x species matrix
aijk = abundance of species j in sample unit (SU) i of group k
nk = number of sample units in group k
g = total number of the groups
Firstly, the mean abundance xkj of species j in group k is calculated:

$$\mathrm{xkj} = \sum_{\mathrm{i}=0}^{\mathrm{nk}} \mathrm{aijk} \; / \; \mathrm{nk}$$

Then the relative abundance RAkj of species j in group k is calculated:

$$\mathrm{RAkj} = \mathrm{xkj} \; / \sum_{\mathrm{k}=1}^{\mathrm{g}} \mathrm{xkj}$$

(2) The proportional frequency of species within each group was calculated, representing the percentage of sample units in each group that contained the species. This value was also expressed as a percentage, and the intermediate result was presented.

Initially, A was transformed into a presence-absence matrix B:

$$bij = a_{ij}^{0}$$

Then relative frequency RFkj of species j in group k is calculated:

(3) The two proportions calculated in steps 1 and 2 were combined by multiplying them, and the result was expressed as a percentage, yielding an indicator value (IV_{kj}) for each species (j) in each group (k).

(4) The highest indicator value (IV_max) for a given species across all groups was retained as the overall indicator value for that species.

(5) The statistical significance of IV_max was assessed using the Monte Carlo method for each species. This method involved 1.000 randomizations to evaluate the statistical significance of the maximum indicator value recorded for each species.

The habitats included in the study, from which epigean tenebrionid species could be sampled, were classified into six groups to identify indicator species according to Dufrêne and Legendre (1997) [25]. The presence-absence conditions of the tenebrionids were tested for statistical significance using the Monte Carlo technique.

Distribution maps of the darkling beetles presented in this study were generated using ArcView GIS software.

3. Results

A total of eighteen darkling beetle species were identified in the Çukurova Delta. Among these, *Z. dilatata* ($P < 0.01$), *G. rusticum* ($P < 0.05$), *P. b. solieri* ($P < 0.05$), *E. o. oblongus* ($P < 0.05$), *C. turcicus* ($P < 0.05$), *A. cyprius* ($P < 0.05$), *P. r. reitteri* ($P < 0.05$), and *Z. p. punctata* ($P < 0.05$) exhibited statistically significant indicator values for habitat characterization. In contrast, the indicator values of ten other darkling beetle species did not show statistical significance in the Çukurova Delta (Table 1).

Table 1. The abundance of Tenebrionidae species in selected habitats and their corresponding indicator values (Species highlighted in bold were identified as statistically significant based on the indicator species analysis using the Monte Carlo method)

Species	Group***	InV (%)	P value	1-Sand dune	2-Salt marsh	3-Salt meadow	4-Forest (*Pinus* spp.)	5-Afforestation (*Eucalyptus* spp.)	6-Beach
G. rusticum	**3**	**56.3**	**0.0110***	**18**	**81**	**254**	**33**	**52**	**13**
C. o. oblongiusculus	2	53.5	0.0710	-	122	63	39	4	-
S. p. dlabolai	5	46.0	0.3210	130	-	-	7	306	-
P. b. solieri	**5**	**84.7**	**0.0210***	**-**	**-**	**-**	**53**	**293**	**-**
B. cribrosa	5	58.8	0.2230	17	-	17	174	297	-
D. crenata	5	28.2	0.5510	9	19	20	8	22	-
Z. dilatata	**1**	**74.1**	**0.0080****	**13210**	**19**	**232**	**1260**	**2974**	**133**
E. o. oblongus	**1**	**54.5**	**0.0200***	**2593**	**56**	**36**	**551**	**1497**	**26**
C. turcicus	**3**	**94.0**	**0.0110***	**-**	**9**	**141**	**-**	**-**	**-**
A. cyprius	1	76.9	**0.0200***	**20**	**-**	**-**	**6**	**-**	**-**
S. punctiventris	4	67.9	0.0730	2	4	6	38	6	-
L. p. pumilum	1	58.3	0.1090	7	-	-	-	1	-
O. p. subcylindricus	4	42.1	0.1610	4	3	24	32	13	-
S. humerosum	4	24.2	0.5470	1	-	-	4	6	-
P. r. reitteri	**2**	**72.9**	**0.0190***	**-**	**51**	**4**	**14**	**1**	**-**
P. a. nigriceps	1	33.3	1.0000	1	-	-	-	-	-
Z. p. punctata	**5**	**54.9**	**0.0290***	**22**	**5**	**10**	**373**	**500**	**-**
A.s. sulcatum	5	33.3	1.0000	-	-	-	-	2	-

* $P < 0.05$
** $P < 0.01$
*** The code of habitat names

The data presented in Table 1 and Figs. 1- 4 indicate that certain species, such as *Zophosis dilatata*, *Erodius oblongus oblongus*, *Zophosis punctata punctata*, *Blaps cribrosa*, *Scaurus punctata dlabolai*, *Gonocephalum rusticum*, Pimelia bajula solieri, *Clitobius oblongiusculus oblongiusculus*, and *Centorus turcicus*, were abundant and widespread. In contrast, the species *Leichenum pumilum pumilum*, *Sclerum humerosum*, Ammobius *cyprius*, *Stenosis punctiventris*, *Dailognatha crenata*, *Phtora reitteri reitteri*, *Opatroides unctulatus subcylindricus*, *Phaleria acuminata nigriceps*, and *Adelostoma sulcatum sulcatum* were found to be rare and limited to small areas within the Çukurova Delta. Among the species; *Zophosis dilatata* (Deyrolle, 1867) was the most prevalent species in the Çukurova Delta, occurring in 17 out of 18 sampled locations. A total of 17.828 individuals were collected, with the majority (13.210 individuals, or approximately 74% of the total) obtained from sand dunes. Low numbers of individuals were also collected from other habitats: 2.974 in afforestation areas (*Eucalyptus* spp.), and 1.260, 232, 133, and 19 individuals were found in pine forest, salt meadow, beach, and salt marsh habitats, respectively. *G. rusticum* and *E. oblongus*, along with *Z. dilatata*, were observed in all habitat types across the delta (Table 1 and Figure 1). *Phtora reitteri reitteri* (Seidlitz, 1894) was collected from seven locations within salt marsh, salt meadow, forest (*Pinus* spp.), and afforestation (*Eucalyptus* spp.) habitats, with 51, 4, 14, and 1 individuals recorded, respectively. This species was absent from beach and sand dune habitats (Table 1 and Figure 1). *Gonocephalum rusticum* (Olivier, 1811) was observed across various habitats, including sand dunes, salt marsh, salt meadow, forest (*Pinus* spp.), afforestation (*Eucalyptus* spp.), and beach. A total of 254 individuals were collected from the salt meadow, where this species was most commonly found (Table 1 and Figure 1). *Zophosis punctata punctata* (Brullé, 1832) yielded 910 specimens from nine locations. The highest numbers of individuals were collected from afforestation (*Eucalyptus* spp.) and pine forest habitats, with 500 and 373 specimens,

respectively. This species was also found in salt marsh, salt meadow, and sand dune habitats, with 5, 10, and 22 individuals recorded, respectively (Table 1 and Figure 1).

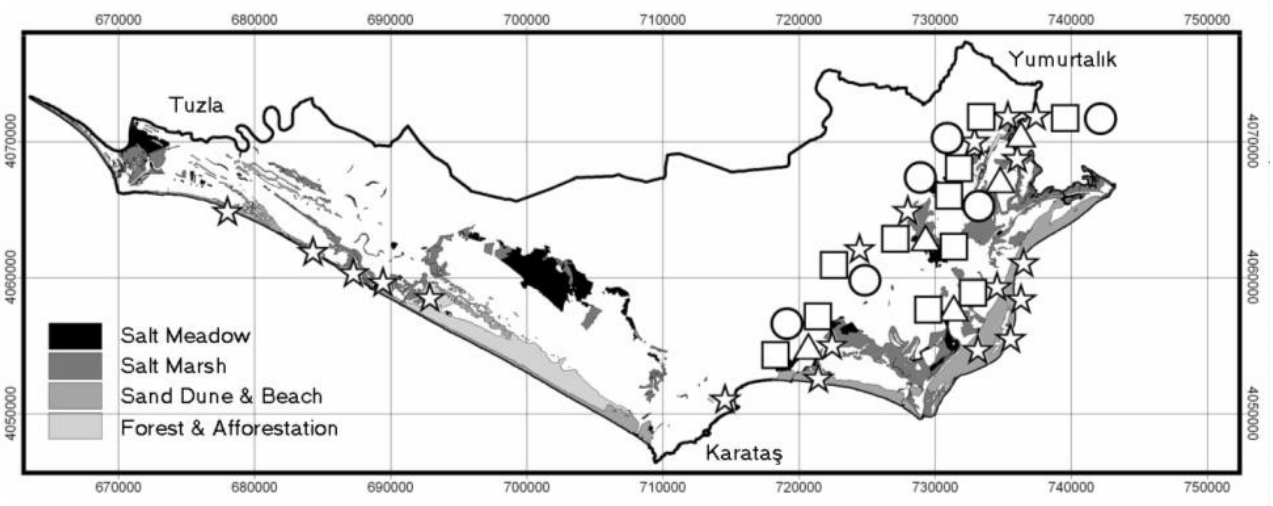

Figure 1. Distribution of *Z. dilatata* (☆), *P. r. reitteri* (△), *G. rusticum* (□) and *Z. p. punctata* (○) in Çukurova Delta in southern Türkiye.

Erodius orientalis oblongus (Solier, 1834) was one of the most widely distributed species, recorded in 16 different locations. A total of 2.593 individuals were collected from sand dune habitats, while 1.497 individuals were found in afforestation areas (*Eucalyptus* spp.) with high sand content. This species was also observed in salt marshes, salt meadows, forests (*Pinus* spp.), and beach habitats, yielding 56, 36, 551, and 26 individuals, respectively (Table 1 and Figure 2). In contrast, *Pimelia bajula solieri* (Mulsant & Wachandru, 1853) was recorded in only four locations, with the highest abundance found in afforestation (*Eucalyptus* spp.) habitats, where 293 individuals were collected. Additionally, 53 individuals were sampled from forest areas. This species was not found in sand dune, salt marsh, salt meadow, or beach habitats (Table 1 and Figure 2). *Clitobius oblongiusculus oblongiusculus* (Fairmaire, 1875) was collected from seven locations across the Çukurova Delta. The majority of individuals were found in salt marsh and salt meadow habitats, with 122 and 63 specimens, respectively. Fewer individuals were collected from forest (*Pinus* spp.) and afforestation (*Eucalyptus* spp.) habitats, with 39 and 4 specimens, respectively (Table 1 and Figure 2). *Opatroides punctulatus subcylindricus* (Ménétriés, 1849) was relatively uncommon in the delta, despite being widespread. This species was recorded in sand dune (4 individuals), salt marsh (3 individuals), salt meadow (24 individuals), forest (*Pinus* spp.) (32 individuals), and afforestation (*Eucalyptus* spp.) (13 individuals) habitats, but it was absent from the beach habitat (Table 1 and Figure 2). *Centorus turcicus* (Kaszab, 1959) was collected from three locations, with 141 individuals sampled from salt marsh habitats and 9 individuals from salt meadow habitats. This species was not observed in sandy habitats, including sand dune, forest (*Pinus* spp.), afforestation (*Eucalyptus* spp.), or beach areas (Table 1 and Figure 2).

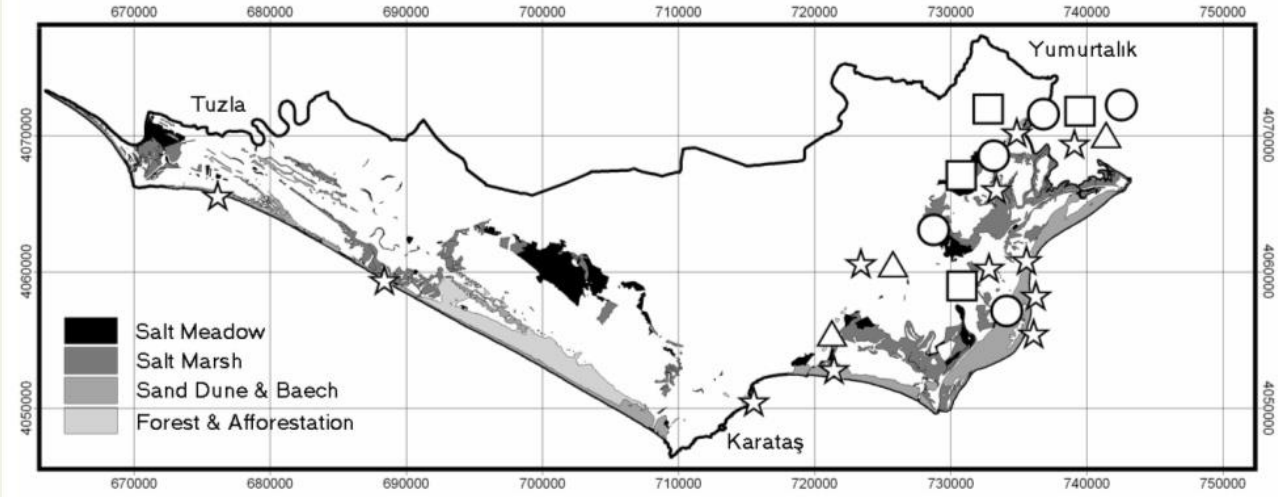

Figure 2. Distribution of *E. o. oblongus* (☆), *P. b. solieri* (△), *C. o. oblongiusculus* (□) and *O. p. subcylindricus* (○) in Çukurova Delta in southern Türkiye

Leichenum pulchellum pumilum (Baudi di Selve, 1876) was identified as a rare species in the delta, occurring in sand dune habitats with 7 specimens and in afforestation (*Eucalyptus* spp.) habitats with a single specimen, both collected from three distinct locations. This species was absent from all other surveyed areas (Table 1 and Figure 3). *Blaps cribrosa* (Solier, 1848) was recorded from 10 different locations, inhabiting all habitat types except salt marsh and beach habitats. It was found in afforestation (*Eucalyptus* spp.) and forest (*Pinus* spp.) habitats with 297 and 174 individuals, respectively. Lower numbers were collected from sand dune and salt meadow habitats, with 17 individuals from each (Table 1 and Figure 3). *Stenosis punctiventris* (Eschscholtz, 1831) was sampled from 10 locations across sand dune, salt marsh, salt meadow, afforestation (*Eucalyptus* spp.), and forest (*Pinus* spp.) habitats, with 2, 4, 6, 6, and 38 individuals recorded, respectively. This species was not found in beach habitats. While its abundance was relatively low, it appears to be an euryoecious species (Table 1 and Figure 3).

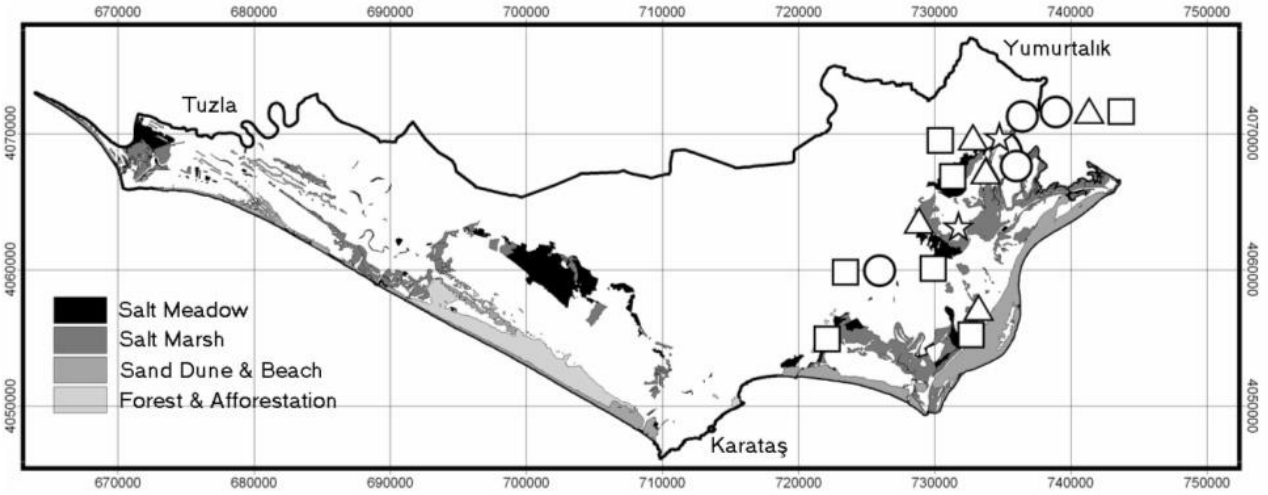

Figure 3. Distribution of *C. turcicus* (☆), *L. p. pumilum* (△), *B. cribrosa* (□) and *S. punctiventris* (○) in Çukurova Delta in southern Türkiye

Ammobius cyprius Grimm, 1991, was recorded in 5 of the 18 selected locations within the Çukurova Delta. The species was found in sand dune and forest (*Pinus* spp.) habitats, with 20 and 6 individuals, respectively. This species was considered rare and confined to small, specific areas within the delta, being absent from other habitats (Table 1 and Figure 4). *Scaurus puncticollis dlabolai* (Kaszab, 1959) was primarily collected in afforestation (*Eucalyptus* spp.) and sand dune habitats, with 306 and 130 individuals, respectively. Seven specimens were found in three separate locations within forest (*Pinus* spp.) habitats. However, this species was not found in salt marsh, salt meadow, or beach habitats, where clay and salt concentrations were high (Table 1 and Figure 4**)**. *Dailognatha crenata* Reiche & Saulcy, 1857, was observed in all habitat types except for beach habitats, although it was infrequently encountered in the delta. The species was sampled from 11 different locations and found in forest (*Pinus* spp.), sand dune, salt marsh, salt meadow, and afforestation (*Eucalyptus* spp.) habitats, with 8, 9, 19, 20, and 22 individuals, respectively. This species may be considered an euryoecious darkling beetle in the delta (Table 1 and Figure 4). *Sclerum humerosum* (Miller, 1861) was found at only four locations: one individual in sand dune habitats, four individuals in forest (*Pinus* spp.) habitats, and six individuals in afforestation (*Eucalyptus* spp.) habitats (Table 1 and Figure 4). *Phaleria acuminata nigriceps* (Mulsant & Wachanru, 1853) was represented by a single individual found in sand dune habitats. *Adelostoma sulcatum sulcatum* Duponchel, 1827, was recorded with only two individuals, both in afforestation (*Eucalyptus* spp.) habitats.

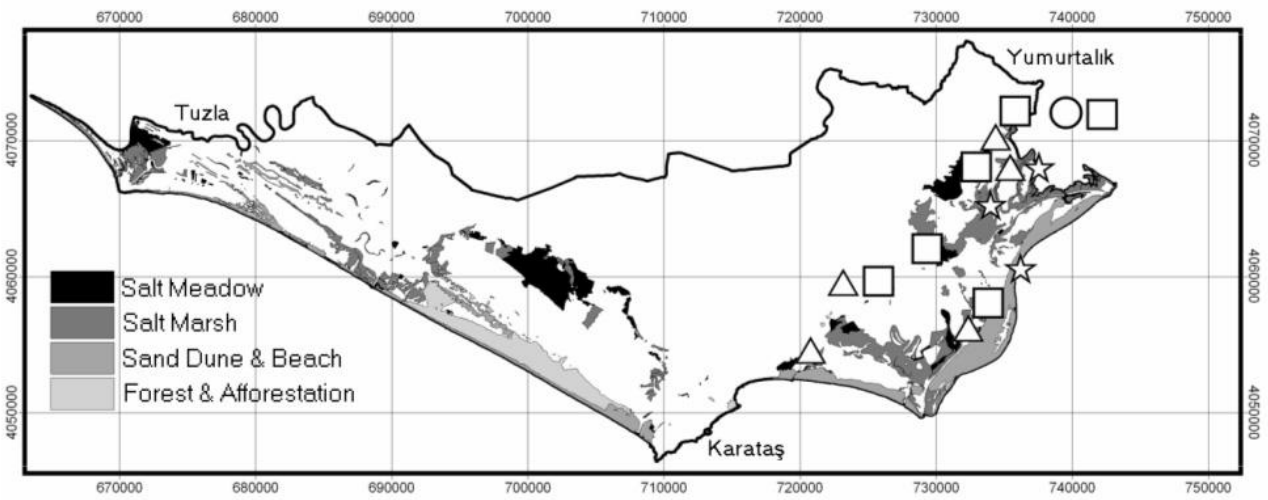

Figure 4. Distribution of A. cyprius (☆), S. p. dlabolai (△), D. crenata (□) and S. humerosum (○) in Çukurova Delta in southern Türkiye

4. Conclusions and discussion

The following species exhibited a significant indicator value for habitat description in the Çukurova Delta: *Zophosis dilatata* (Deyrolle, 1867) (sand dune) (P<0.01), *Gonocephalum rusticum* (Olivier, 1811) (salt meadow) (P<0.05), *Pimelia bajula solieri* (Mulsant & Wachandru, 1853) (afforestation with *Eucalyptus* spp.), *Erodius orientalis oblongus* (Solier, 1834), *Centorus turcicus* (Kaszab, 1959) (salt meadow), *Ammobius cyprius* Grimm, 1991 (sand dune), *Phtora reitteri reitteri* (Seidlitz, 1894) (salt marsh), and *Zophosis punctata punctata* (Brullé, 1832) (afforestation with *Eucalyptus* spp.). These eight species were identified as indicators for sand dune, salt marsh, salt meadow, and afforestation (*Eucalyptus* spp.) habitats (Table 1). The indicator values of five species ranged from 72.9% to 94.0%, while the indicator values for *G. rusticum*, *Z. punctata punctata*, and *E. orientalis oblongus* were determined as 56.3%, 54.9%, and 54.5%, respectively.

Aydın and Kazak (2010) reported that the indicator species value of *Zophosis dilatata* was statistically significant in describing sand dune habitats within the delta [26]. *Phtora reitteri reitteri*, which was undetectable in both sand dune and beach habitats, was identified as an indicator species for salt marsh habitats, exhibiting an indicator value of 78.6% [26]. Similarly, *Gonocephalum rusticum* is known to flourish in a wide range of ecological conditions (euryoecious), akin to *Z. dilatata* and *Erodius orientalis oblongus*, both of which were observed across all habitat types in the delta. The indicator value of *G. rusticum* for salt meadow habitats was recorded at 60.7% [26]. In a study conducted on Davraz Mountain (Isparta), *Gonocephalum granulatum pusillum* was described as a xerophilic, geophilic, and detritivorous subspecies, predominantly found in steppe habitats and areas characterized by reddish-brown Mediterranean soils. This subspecies was deemed uncommon in Mount Davraz, with its presence being more frequent in arid regions compared to moist areas [27]. *Zophosis punctata punctata* has been described as inhabiting open land with sandy soil in the hinterland of the coast [28]. However, Lillig observed this species not only in coastal hinterlands but also in desert areas. Fattorini (2009) noted that *Z. punctata punctata* is commonly found on rocky substrates, while Korkmaz and Gök (2018) characterized it as psammophilic, geophilic, and eurytopic [27]. This species was also reported to be widespread in arid and semi-arid habitats spanning from the Mediterranean region to Western China [28]. Despite an indicator value of 55.1%, *E. orientalis oblongus* was found to be statistically significant indicator for sand dune habitats [26]. The indicator values of *Pimelia bajula solieri* were calculated to be 86.5% and 79.1% for the description of afforestation (*Eucalyptus* spp.) habitats [26]. A subspecies of *Pimelia*, *Pimelia subglobosa polita*, was described as euryecious and geophilic, commonly found in diverse habitats such as steppe, shrubland, and forest. Samples of this subspecies were more frequently collected from moist, sun-exposed areas rather than from dry ones in Davraz Mountain (Isparta), where it was also abundant in areas with brown forest soil [27]. *Opatroides punctulatus* subcylindricus was not found to be statistically significant for habitat identification, yet it has been reported as a pest species affecting pistachios in Gaziantep province, Türkiye [31]. Although the ecological characteristics of *Centorus turcicus* remain poorly understood, members of the *Centorus* genus are known to inhabit saline environments [32]. *Leichenum p.p.*, which did not show statistical significance due to its rarity, has been classified as a stenotopic species by Fattorini (2002) [33]. Soldati (1995) associated the species with valleys between dune crests [34], while Castelfusano noted its presence in a narrow strip of seashore between the eulittoral zone and the first dune [33]. *Ammobius cyprius* is known to inhabit the roots of various plant species within dune systems [35]. In conclusion, the findings of this study align with those of previous research, confirming the ecological roles and habitat preferences of the species examined.

Although the indicator value is crucial for identifying indicator species, there is no definitive threshold or clear demarcation to determine which species are more important indicators. Well-known insect species in biology typically have an advantage in being used as indicators compared to less-studied species. The utilization of insect species as bio-indicators requires detailed data regarding their distribution and population dynamics [9]. Our study represents one of the initial steps in this direction within the Mediterranean region of Türkiye. Based on the findings of this study, the following species can be considered significant indicators for habitat description in the Çukurova Delta: (1) *Zophosis dilatata* and *Ammobius* cyprius, (2) *Pimelia bajula solieri*, and (3) *Centorus turcicus* and *Phtora reitteri reitteri*, which correspond to sand dune, afforestation areas with *Eucalyptus* spp., and saline biotypes, respectively. In relation to *Gonocephalum rusticum*, *Erodius orientalis oblongus*, and *Zophosis punctata* punctata, these species may be categorized as euryoecious. While Schawaller (1996) [28] previously characterized *Z. punctata punctata* as inhabiting open land in the coastal hinterland on sandy soils, our observations and the findings of the current study indicate that this species demonstrates a wide ecological tolerance, thriving in both sandy and saline habitats within the delta. *Z. dilatata*, another euryoecious species, was found abundantly (13.210 individuals) in sand dune habitats across all habitat types in the delta, it was determined to be highly statistically significant in habitat description analysis.

These findings have significant implications for (i) habitat description, (ii) the identification of priority areas, and (iii) decision-making regarding the conservation status of specific habitats. Consequently, the methodology outlined in this study can be replicated to enhance the management of conserved areas and improve environmental management practices. Additionally, this approach can support decision-making processes aimed at identifying critical areas within ecosystems that require conservation efforts. This study is the first to use Tenebrionidae species for habitat type determination through indicator species analysis with the Monte Carlo technique. The method could be applied to other taxa and, when used in protected areas, offers insights into the presence and population dynamics of key species, reflecting the level of protection. Subsequent studies could validate this approach and assess habitat changes over time.

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References

[1] Aydın, G. & Şen, İ. (2020). Determination of arthropod biodiversity and some ecological parameters of Erdal Şekeroğlu (Isparta, Turkey) and Kadıini (Antalya, Turkey) cave ecosystems with evaluation of usability of insects in cave mapping. *Turkish Journal of Entomology*, 44 (4), 539-557. https://doi.org/10.16970/entoted.770018

[2] Aydın, G. (2021). Comparison of insect biological diversity parameters in natural and degraded habitats in Gölcük Nature Park Forest (Isparta, Turkey). *Turkish Journal of Forestry*, 22 (4), 362-365. https://doi.org/10.18182/tjf.1006039

[3] Aydın, G. (2005). Distribution of the Dune Cricket *Schizodactylus inexpectatus* (Orthoptera: Schizodactylidae) in the Çukurova Delta, southern Turkey. *Zoology in the Middle East*, 36, 111-113. https://doi.org/10.1080/09397140.2005.10638136

[4] Şekeroğlu, E. & Aydın, G. (2002). Distribution and habitats of the tiger beetle *Megacephala euphratica* in the Çukurova Delta, southern Turkey (Coleoptera: Cicindelidae). *Zoology in the Middle East*, 27(1), 87-90. https://doi.org/10.1080/09397140.2002.10637943

[5] Aydın, G. (2011). Vulnerability of *Megacephala* (*Grammognatha*) *euphratica euphratica* Latreille & Dejean, 1822 (Coleoptera: Cicindelidae) in natural and disturbed salt marsh and salt meadow habitats in Turkey. *African Journal of Biotechnology*, 10 (29), 5692-5696.

[6] Aydın, G. & Karaca, İ. (2018). The effects of pesticide application on biological diversity of ground beetle (Coleoptera: Carabidae). *Fresenius Environmental Bulletin*, 27 (12A), 9112-9118.

[7] Aydın, G. (2011). Conservation status of the Tiger Beetle *Calomera aphrodisia* (Baudi di Selve, 1864) in Turkey (Coleoptera: Cicindelidae). *Zoology in the Middle East*, 52(1), 121-123. https://doi.org/10.1080/09397140.2011.10638489

[8] Aydın, G. & Karaca, İ. (2011). Human threats to population of endemic sand dune cricket (*Schizodactylus inexpectatus*). *International Journal of Agriculture & Biology*, 13 (6), 1016-1020.

[9] Aydın, G. & Kazak, C. (2007). Evaluation of insect as bio-indicators for human activities in biotopes of Çukurova Delta (Adana). *Turkish Journal of Entomology*, 31(2), 111- 128.

[10] Ergene, Ş. E., & Aydın, G. (2022). Calculation of biodiversity parameters of epigean Hexapoda species in different anise (*Pimpinella anisum* L.) and fennel (*Foeniculum vulgare* Mill.) agro-ecosystems in Burdur province. *Biological Diversity and Conservation*, 15(3), 385-391. https://doi.org/10.46309/biodicon.2022.1198394

[11] Lillig, M. & Aydın, G. (2006). Three species of Tenebronidae new to the Turkish fauna (Insecta: Coleoptera). *Zoology in the Middle East*, 37, 118-120. https://doi.org/10.1080/09397140.2006.10638158

[12] Özbek, M. & Aydın, G. (2023). A new amphipod from the depths of the Morca Sinkhole (Anamur, Türkiye): *Gammarus morcae* n. sp. (Amphipoda: Gammaridae), with notes on cavernicolous amphipods of Türkiye.*Turkish Journal of Zoology*, 47(2), 81-93. https://doi.org/10.55730/1300-0179.3118

[13] Yaşar, B., Aydın G. & Denizhan, E. (2003). Doğu Anadolu Bölgesi illerinde [Ağrı, Bitlis, Erzurum, Iğdır, Kars ve Muş] bulunan Diaspididae (Homoptera: Coccoidea) familyasına bağlı türler. *Türkiye Entomoloji Dergisi*, 27(1), 3-12 (in Turkish with English abstract).

[14] Yılmaz, K.T., Çakan, H. & Szekely, T. (2003). Management Needs of Coastal Areas in the Eastern Mediterranean. - Proceedings of MEDCOAST 03 *International Conference*, 2, 877-888.

[15] Altan, T., Artar, M., Atik, M. & Çiftçioğlu, G.C. (2004): Cukurova Delta Biosphere Reserve Management Plan/ Çukurova Deltası Biyosfer Rezervi Yönetim Planı. Çukurova Üniversitesi Basım Evi. Adana. 372 p. (in Turkish with English abstract).

[16] Macagno, H.B., Cruz, I.G., Rodríguez-Artigas, S.M., Corronca J.A. & Flores, G.E. (2023). Environmental factors determining the diversity of darkling beetles (Coleoptera: Tenebrionidae) in arid, high-altitude environments in Northwestern Argentina. *Anais da Academia Brasileira de Ciências*, 95(2), e20201185. https://doi.org 10.1590/0001-3765202320201185

[17] Alimova, L.K., Umurzakova, M.S., Zokirova, D.F., Khamzaev, R.A., Normuradova, G., Otakulov, B., Pazilov, A., Kudratov, J.A., Urazova, R.S. & Khalimov, F.Z. (2024). Diversity and features of the fauna of herpetobiont beetles (Carabidae, Tenebrionidae, Elateridae, Scarabaeidae) of the Lower Zeravshan, Uzbekistan. *Biosystems Diversity*, 32 (1), 73-82. https://doi.org/10.15421/012407

[18] McGeoch, M.A. (1998). The selection, testing and application of terrestrial insects as bioindicators. *Biological Review*, 73, 181-201. https://doi.org/10.1111/j.1469-185X.1997.tb00029.x

[19] Aydın, G. & Avcı, A. (2010). Burdur ili anason (*Pimpinella anisum* L.), Aydin (*Coriandrum sativum* L.) ve rezene (*Foeniculum vulgare* Mill.) agro-ekosistemlerinde böcek biyolojik çeşitliliklerinin belirlenmesi. *Süleyman Demirel Üniversitesi Fen Bilimleri Enstitüsü Dergisi*, 14 (1), 38-45. https://doi.org/10.19113/sdufbed.53846 (in Turkish with English abstract).

[20] Aydın, G. & Karaca, İ. (2009). Balcalı-Adana'da farklı habitatlarda çukur tuzak örnekleme yöntemi kullanılarak hesaplanan biyolojik çeşitlilik parametrelerinin karşılaştırılması. 5.Ulusal Meslek Yüksekokulları Sempozyumu, Konya 163-177 (in Turkish with English abstract).

[21] Aydın, G., Şekeroğlu, E. & Arndt, E. (2005). Tiger beetles as bioindicators of habitat degradation in the Çukurova Delta Southern Turkey. *Zoology in the Middle East*, 36(1), 51-58. https://doi: 10.1080/09397140.2005.10638127

[22] Dinç Ortaç, Ö., Yaşar, B. & Aydın, G. (2015). Organik ve konvansiyonel yağ gülü *Rosa damascena* Miller (Rosales: Rosaceae) yetiştiriciliğinde böcek biyolojik çeşitlilik değerlerinin hesaplanması. *Süleyman Demirel Üniversitesi Fen Bilimleri Enstitüsü Dergisi*, 19 (2), 161-173.

[23] Oğuz, G., Aydın, G. & Ulusoy, M.R. (2021). Balcalı (Adana)'da farklı ekosistemlerdeki epigean Hexapoda türlerinin biyolojik çeşitlik parametrelerinin karşılaştırılması. *Turkish Journal of Science and Engineering*, 3(2), 69-76 (in Turkish with English abstract).

[24] Altan, T. & Tischew, S. (2002). Biotope Mapping In Coastal Planning and the Case of Çukurova Delta Biosphere Reserve Planning. International Conference on the Environmental Problems of the Mediterranean Region. 12-15 April, 2002. Near East University, Nicosia, TRNC. p. 96.

[25] Dufrêne, M. & Legendre, P. (1997). Species assemblages and indicator species: the need for a flexible asymmetrical approach. *Ecological Monograph*, 67, 345-366. https://doi.org/10.1890/0012-9615(1997)067[0345:SAAIST]2.0.CO;2.

[26] Aydın, G. & Kazak, C. (2010). Selecting indicator species habitat description and sustainable land utilization: A case study in a Mediterranean Delta. *International Journal of Agriculture & Biology*, 12(6), 931-934.

[27] Korkmaz, D. & Gök, A. (2018). Contributions to the knowledge of darkling beetles (Coleoptera: Tenebrionidae) of mount Davraz (Isparta): Along with ecological and zoogeographical notes. *Journal Entomological Research Society*, 20(2), 79-90.

[28] Schawaller, W. (1996). Tenebrionidae (Coleoptera) aus Nord-Griechenland: Habitate, artengesellschaften und verbreitung. *Entomologische Blätter*, 92, 3-18.

[29] Fattorini, S. (2009). Darkling beetle communities in two geologically contrasting biotopes: testing biodiversity patterns by microsite comparisons. *Biological Journal*, 98, 787-793. https://doi.org/10.1111/j.1095-8312.2009.01330.x

[30] Iwan D., Löbl I., Bouchard P., Bousquet Y., Kamiński M. J., Merkl O., Ando K. & Schawaller W. (2020). Family Tenebrionidae Latreille, 1802, pp. 104–475. In: Catalogue of Palaearctic Coleoptera. Volume 5, Revised and

updated second edition. Tenebrionoidea (D. Iwan and I. Löbl, editors). Brill, Leiden, 945 pp. https://doi.org/10.1163/9789004434998

[31] Açıkgöz, M., Aslan, M.M. & Çiftçi, D. (2022). A new pistachio pest in Turkey: *Opatroides punctulatus subcylindricus* (Menetries, 1849) (Coleoptera: Tenebrionidae). *Munis Entomology & Zoology*, 17 (2), 1129-1135.

[32] Skopin, N.G. (1974). Zur Revision der eurasiatischen arten der gattung *Belopus* GB. – *Entomologische Abhandlungen*, 40 (2), 65-103.

[33] Fattorini S. (2002). The Tenebrionidae (Coleoptera) of a Tyrrhenian coastal area: Diversity and zoogeographicalcComposition. *Biogeographia*, 23, 103-126. https://doi.org/10.21426/B6110109

[34] Soldati, F. (1995). Les Tenebrionidae del'Herault: Inventaire et ecologie (Coleoptera). *Bulletin de la Société Entomologique de France*, 100 (3), 38-49.

[35] Grimm, R. (1991). Tenebrioniden von der insel Zypern (Insecta: Coleoptera). *Biocosme Mésogéen*, 8 (1), 15-49.