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Dung beetles (Coleoptera: Scarabaeidae) utilizing water buffalo dung on the Black Sea coast of Turkey

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Abstract: There have been few ecological studies of dung beetles (Coleoptera: Scarabaeidae) from the Black Sea Region of Turkey. In the RAMSAR-listed wetland system of the Kızılırmak Delta of Turkey's central Black Sea coast, seasonal grazing by domesticated water buffalo produces plentiful dung from April to November. Twenty-three species of dung beetles from 13 genera of Aphodiinae and 4 genera of Scarabaeinae were collected from their dung on two adjacent soil types in 2013. The species were from three functional groups, namely dung dwelling (12), tunneling (10), and ball rolling (1). Thirteen and fourteen species were collected in spring/summer and autumn, respectively, with only 4 species in common. There was a distinct shift from Scarabaeinae (8 of 13 species) in spring/summer to Aphodiinae (10 of 14 species) in autumn. The ten species collected on the sandy clay loam soil were a subset of the 23 species on the sand dunes. On the sandy clay loam, high water tables in winter and soil cracking in summer may exclude deeper tunneling species. The 3:1 ratio of dung dwelling species on the sand compared to the sandy clay loam may suggest a more appropriate dung moisture regime over time that favors successful breeding on the sand.

Key words: Kızılırmak Delta, insects, community, coprophilous, interspecies competition, season

1. Introduction

The alluvial plains and associated coastal dune systems of the Kızılırmak River Delta in Samsun Province (Turkey) have a long history of free-range grazing by water buffalo (*Bubalus bubalis* L.), cattle (*Bos primigenius taurus* L.), sheep (*Ovis aries* L.), and wild horses (*Equus ferus caballus* L.), which collectively produce large volumes of dung year round, particularly in spring and summer. Grazing, especially by the hundreds of water buffalo, plays a major role in structuring the vegetation in the Kızılırmak Delta, including its permanent and ephemeral wetlands and adjacent coastal sand dune systems. The buffaloes spend a considerable amount of time grazing on aquatic plants, which later provides a large additional amount of dung in the adjoining landscape.

Finn (2001) reported dung, leaf packs in streams, fruits, mushrooms, and carrion as ephemeral resource patches. More specifically, Mohr (1943) described dung pads as scattered microhabitats of high-quality resources of relatively small size and short duration that support complex communities. Factors that collectively influence the composition of dung beetle communities include soil and vegetation type (Lumaret and Kirk, 1987; Krell et al., 2003), source of dung (herbivore, carnivore, and omnivore) (Dormont et al., 2007; Filgueiras et al., 2009; Whipple, 2011), age of dung (Barth et al., 1994; Kryger et al., 2006), size of pad (Peck and Howden, 1984; Finn and Giller, 2000), soil moisture/rainfall events (Kingston, 1977; Lumaret, 1978), altitude (Mittal, 1981; Avila and Pascual, 1987), latitude (Kirk and Ridsdill-Smith, 1986; Hanski, 1991), mean temperature/season (Lumaret, 1979; Davis, 1989), and diel activity (Hernandez, 2002; Krell et al., 2003).

Intense competition at the dung pad has triggered niche splitting and speciation (Halffter and Edmonds, 1982). Most dung beetles use one of three broad nesting strategies: paracoprid (tunneling) species dig burrows and construct nesting chambers, usually below the dung pad;

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telecoprid (ball rolling) species form and transport balls some distance before burial; and endocoprid (dwelling) species live in and brood their offspring inside the dung mass itself (Halffter and Matthews, 1966; Hammond, 1976; Rougon and Rougon, 1980; Halffter and Edmond, 1982; Klemperer, 1983). The fourth group is the kleptoparasites, which steal dung from or deposit their eggs in the broods of paracoprid or telecoprid species (Hammond, 1976). Brussaard (1987) and Doube (1990) used the term 'kleptocoprid' to describe the same group.

Approximately 350 species of Laparosticti, which are mainly dung feeding Scarabaeidae, have been reported from Turkey (Carpaneto et al., 2000; Löbl and Smetana, 2006). However, there have been few dung beetle studies from the Black Sea region (Lodos et al., 1999; Şenyüz et al., 2013). The current study reports dung beetle species from water buffalo dung in the Kızılırmak Delta on the central Black Sea coast of Turkey and discusses aspects of their ecology.

2. Materials and methods

The climate of coastal areas of Samsun Province in Turkey is moderated by close proximity to the Black Sea and is characterized by relatively dry, warm/hot summers and cool, wet winters. In the late spring (May), early summer (June), and autumn (October, November) of 2013, dung beetles were collected from natural water buffalo dung pads on two soil types in the Kızılırmak Delta wetlands complex. Details of the physical and chemical characteristics of the two soil types are provided in Table 1.

During the study, samples were collected every 2 weeks from ten dung pads of various ages, shapes, and sizes on each soil type at various times of the day and night. Using a method modified from Krell (2007), each dung pad was sampled by collecting approximately 700 g and placing it in a 10-L bucket. The soil directly below and close to 15% of pads was excavated to 10 cm to collect tunneling species that may not have been collected in pads or at the pad/soil interface. Deeper tunnels were excavated to full depth. The excavated soil was added to the dung sample. Samples were flooded and agitated with a wooden paddle to disperse dung material. Beetles that floated to the surface were removed with a fine mesh sieve and collected with flexible forceps or a fine brush, or collected directly from the water surface. The agitation process was continued until no more beetles appeared. The residual material was then sifted to collect any remaining specimens. As per Floate and Kadiri (2013), specimens were stored in 70% ethanol in labeled containers before identification.

A small number of older, drier pads were also sampled by fracturing them into small pieces over a plastic sheet. Additionally, dung beetles were collected from both soil types in CSR-type pitfall traps (5/site) baited with 700 g of fresh water buffalo dung and using ethylene glycol as the preservative (Lobo et al., 1988). Ball rolling dung beetles were also hand-collected from dung pads.

All the species collected were identified by the third author (J-PL), using the keys of Baraud (1985, 1992). Because the closely related species *Onthophagus medius* (Kugelann) has been reported from Turkey (Rossner et al., 2010; Anlaş et al., 2011a), the identification of *Onthophagus vacca* (L.) specimens was confirmed with standard molecular tools, using two genetic markers, CO1 and ITS2.

2.1. Statistical analysis

The Sørensen similarity index (S_S) (Krebs, 1998; Balmer, 2002) was used to compare the dung beetle species from the two soil types in the current study. Sørensen's formula, which is applied to presence/absence data, is:

$$S_S = \frac{2a}{(2a+b+c)},$$

where 'a' is the number of shared species, 'b' is the number of species only in collection 1, and 'c' is the number of species only in collection 2.

Table 1. Chemical and physical characteristics of the locations from which dung beetles were collected in the Kızılırmak Delta, Samsun Province, Turkey, in 2013. S: Sand; SCL: Sandy clay loam; SL: Sandy loam; pH: Soil reaction (1:1, w:v); EC: Electrical conductivity; OM: Organic matter.

Locations	Coordinates	Depth (cm)	Clay (%)	Silt (%)	Sand (%)	Texture	pH (1:1)	EC (dS/m)	OM (%)
I	41°39′26″N 36°04′03″E	0–20	0	0	100	S	8.05	0.03	1.42
		20–40	0	0	100	S	8.51	0.04	1.25
II	41°40′16″N 36°02′29″E	0–20	18.4	7.2	74.4	SCL	8.36	1.26	4.94
		20–40	18.9	11.3	69.4	SL	8.86	0.29	2.45
		40–60	22.7	6.5	70.8	SL	8.58	0.66	2.18

3. Results

Twenty-three species from 17 genera belonging to 2 subfamilies, Aphodiinae and Scarabaeinae, were identified from the 2594 specimens collected. Species were distributed among the three major guilds, namely dwellers (12 species), tunnelers (10 species), and rollers (1 species) (Table 2). No kleptocoprids were collected. Across the two soil types, *Colobopterus erraticus* (L.) and O*nthophagus taurus* (Schreber) were the most common tunneling species, and *Melinopterus consputus* (Creutzer) and *Acanthobodilus immundus* (Creutzer) were the most common dwellers. All the Scarabaeinae species, except *Scarabaeus sacer* L., and *C. erraticus* from Aphodiinae, are tunnelers. All the other Aphodiinae are dwellers, and the one Scarabaeini species, *S. sacer*, is a roller.

All 23 species were collected on the sand and a subset of 6 tunnelers and 4 dwellers was collected on the sandy clay loam. In the spring/summer, there were 8 tunnelers, 4 dwellers, and 1 roller on the sand and 6 tunnelers and 2 dwellers on the sandy clay loam. In the autumn, an additional 8 dwellers and 2 tunnelers, and 2 dwellers, were collected on the sand and the sandy clay loam, respectively. Fourteen species were collected in autumn and 13 species in spring/summer, with 4 species present at both times (Table 2).

There was a distinct shift from Scarabaeinae (8 of 13 species) in spring/summer to Aphodiinae (10 of 14 species) in autumn. In other words, in autumn, the number of Scarabaeinae species fell from 8 to 4 and the number of Aphodiinae species rose from 5 to 10. Additionally,

Table 2. Dung beetle species collected from water buffalo (*Bubalus bubalis* L.) dung pads, dung-baited pitfall traps, and from the ground in the Kızılırmak Delta of Samsun Province, Turkey, in 2013, with guild (*: dweller; **: tunneler; ***: roller), season, and location (present/absent: +/-).

Subfamily	Species	Season		Location	
		Spring/ summer	Autumn	I	II
				Sand	Sandy clay loam
Aphodiinae	*Acanthobodilus immundus* (Creutzer)*	+	+	+	+
	Aphodius fimetarius (L.)*	-	+	+	-
	Bodiloides ictericus subsp. *ghardimaouensis* Balthasar*	-	+	+	-
	Bodilus lugens (Creutzer)*	-	+	+	-
	Chilothorax distinctus (Muller)*	-	+	+	-
	Colobopterus erraticus (L.)**	+	-	+	+
	Labarrus lividus (Olivier)*	+	-	+	-
	Melinopterus consputus (Creutzer)*	-	+	+	+
	Nialus varians (Duftschmidt)*	-	+	+	-
	Nimbus contaminatus (Herbst)*	-	+	+	-
	Otophorus haemorrhoidalis (L.)*	-	+	+	+
	Phalacronothus quadrimaculatus (L.)*	+	-	+	+
	Subrinus sturmi (Harold)*	+	+	+	-
Scarabaeinae	*Caccobius schreberi* (L.)**	+	-	+	+
	Euoniticellus fulvus (Goeze)**	+	-	+	+
	Euoniticellus pallipes (Fabricius)**	+	+	+	-
	Onthophagus furcatus (Fabricius)**	-	+	+	-
	Onthophagus nuchicornis (L.)**	+	-	+	-
	Onthophagus opacicollis Reitter**	-	+	+	-
	Onthophagus ruficapillus Brullé**	+	-	+	+
	Onthophagus taurus (Schreber)**	+	+	+	+
	Onthophagus vacca (L.)**	+	-	+	+
	Scarabaeus sacer L.***	+	-	+	-

only 2 of 13 species of Aphodiinae and 2 of 10 species of Scarabaeinae were collected in both autumn and spring/summer (Table 2). For the two soil types,

$$Ss = \frac{2x10}{(2x10 + 13 + 0)} = 0.61 \,,$$

where the number of species on both sand and sandy clay loam was 10, the number of species only on the sand was 13, and the number of species only on the sandy clay loam was 0.

4. Discussion

All 23 species reported in the present study (Table 2) have been reported previously from Turkey (Balthasar, 1952, 1963; Durand, 1970; Tuatay et al., 1970, 1972; Pehlivan, 1988, 1989, 1992; Baraud, 1992; Lodos et al., 1999; Carpaneto et al., 2000; Tauzin, 2000, 2001, 2002; Dellacasa and Kirgiz, 2002; Şenyüz, 2004; Löbl and Smetana, 2006; Bellmann, 2007; Rozner and Rozner, 2009; Şenyüz and Şahin, 2009; Anlaş et al., 2011a, 2011b; Şenyüz et al., 2013; Ziani and Sama, 2013). Lodos et al. (1999) reported 36 species from a general survey of the western Black Sea region of Turkey, with only 10 Aphodiinae species in common with the present study. Anlaş et al. (2011a) reported 33 species from cow dung in a 2-year study in Manisa Province in western Anatolia of Turkey, with 12 species in common with the present study. The species counts from the present study and that of Anlaş et al. (2011a), which are from very different grazing environments in Turkey, are much higher than from pastures in Hawaii (Harris et al., 1982), South Africa (Davis, 1987), Mexico (Anduaga, 2004), Australia (Edwards, 2009), and Canada (Kadiri et al., 2014), where there are normally less than 10 species. In addition, Galante et al. (1991) reported 18 species (only rollers and tunnelers) from Spain and Lumaret et al. (1992) reported 43 species from France.

Furthermore, the current study reports 13 species of Aphodiinae (57% of all species), compared to the 8 species (24% of all species) reported by Anlaş et al. (2011a). Rowjewski (1983) reported that *C. erraticus* is a tunneler, which makes it the only nonendocoprid Aphodiinae species in the current study. Additionally, species from the same three functional groups as in the current study were reported from Turkey by Lodos et al. (1999) and Anlaş et al. (2011a).

In the present study, there was a 2.3:1 ratio of dung beetle species on the pure sand (23 species) compared to the sandy clay loam (10 species), which is a substantial disproportionality. The greater ease of tunneling in the sand and/or the risks attached to tunneling in the silty loam (Lumaret and Kirk, 1987) is indicated by the almost 2:1 ratio of tunnelers plus roller on the sand dunes (11 species) compared to the sandy clay loam site (6 species). That difference may reflect the seasonal inundation and elevated water tables of the sandy clay loam site in winter. Additionally, there were 12 and 4 dwellers collected on the sand dunes and sandy clay loam, respectively. It appears that high sand substrates are more favorable for dwellers; after the dung pad is deposited on the sand surface, some of the excess moisture is absorbed into the macropores in the sand immediately beneath the pad, which dries it and allows it to quickly reach the appropriate moisture content for oviposition by Aphodiinae (Lumaret, 1975). Thereafter, the dung pad gradually reabsorbs moisture from the damp sand under the dung, which helps keeps the inside of the dung moist for a relatively longer period. The interior of the dung pad also retains moisture by the rapid formation of a crust on the surface that quickly becomes almost impermeable, hence limiting the evaporation of moisture. Thus, water is trapped inside the dung for long enough for larvae to reach the pupal stage. On clay soils, the water present immediately after dung deposition (ruminant dung contains approximately 80% water initially) is less easily lost to the underlying soil. Paradoxically, especially in summer, the dung dries faster because moisture gradually moves by capillary action into the micropores of the clay particles and cannot be reabsorbed by the pad later, making such substrates less favorable for the breeding of Aphodiinae (Lumaret and Kirk, 1987).

Lumaret and Kirk (1991) stated that Mediterranean dung beetles are most active before and after the summer drought, with the major peak of activity occurring at the end of spring (May and June) and a smaller peak in autumn. Haloti et al. (2006) also reported that some species are active in late autumn and winter. Even though the summer drought is generally less pronounced in the current study area in the Black Sea region than in the Mediterranean region, late spring/early summer and autumn surveys were conducted in anticipation of those same peaks. The majority of sampling was undertaken in May and June when mean daily temperatures were increasing and after several substantial rainfall events. The rest of the sampling (40% of all pads) was conducted in autumn (October and November). This was done on the expectation of a second increase in dung beetle activity driven by rain periods (Lumaret and Kirk, 1991). This strategy proved fruitful as a greater number of species was collected in autumn (14) than spring/summer (13). The phenomenon of higher diversity of Scarabaeinae and Aphodiinae species in summer and autumn, respectively, was also reported by Lumaret and Kirk (1991) and Errouissi et al. (2011).

In conclusion, the current research provides further confirmation that diel activity, season, and soil type influence the composition of local dung beetle species assemblages and establishes a baseline by which ecosystem changes can be measured in the face of climate change.

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