

Effects of land use types and seasons on species diversity and abundance of dung beetles in Eldoret, Kenya

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Abstract

Dung beetles are crucial in livestock systems due to their contribution to dung removal, nutrients cycling, carbon sequestration and sustainable pasture production. There are limited studies to elucidate abundance and species diversity across different ecosystems. Since utilization of dung beetles in promoting ecosystem functions such as dung removal, nutrients cycling and carbon sequestration is hinged on the above two community attributes, lack of such information limits their exploitation in management of pasturelands and hence need for further studies. This study aimed at evaluating the effects of seasons and land use types (LUTs) on abundance and biodiversity of dung beetles. Dung beetles were captured using 10 dung-baited pitfall traps per each LUT. Collection was done after 24 hours. Dung beetles were present across all diverse LUTs. Season and LUT significantly influenced the abundance and species diversity of coprophagous beetles at $p < 0.001$. They were significantly higher during the wet season and in LUTs under grazing influence such as the grazed pastureland and mixed woodland plantation. Some species showed high preference for LUTs and seasons. Some of these included the nocturnal *Milichus picticollis* which preferred cool environments, the roller *Sisyphus barbarosa* and tunneler *Euoniticellus triangulatus* both present in environments with high cattle dung availability. In conclusion, this research provided the first enumeration of community attributes of dung beetles (abundance and species diversity) across different LUTs and seasons. Therefore, it forms an integral baseline over which future monitoring of biodiversity can be based. Finally, species-specific contribution of *M. picticollis*, *S. barbarosa* and *E. triangulatus* to ecosystem functions need to be elucidated for further exploitation in management of pasturelands.

Key words: Coprophagous, *Euoniticellus triangulatus*, nocturnal, rollers, tunnelers

Résumé

Les coléoptères sont essentiels dans les systèmes d'élevage en raison de leur contribution à l'élimination des excréments, au cycle des nutriments, à la séquestration du carbone et à la production durable de pâturages. Il existe peu d'études pour élucider l'abondance et la diversité des espèces dans différents écosystèmes. Étant donné que l'utilisation des coléoptères dans la promotion de fonctions éco-systémiques telles que l'élimination des

excréments, le cycle des nutriments et la séquestration du carbone dépend des deux attributs communautaires ci-dessus, le manque de telles informations limite leur exploitation dans la gestion des pâturages et, par conséquent, nécessite des études supplémentaires. Cette étude visait à évaluer les effets des saisons et des types d'utilisation des terres (TUT) sur l'abondance et la biodiversité des bousiers. Les bousiers ont été capturés à l'aide de 10 pièges appâtés à la bouse pour chaque TUT. La collecte a été effectuée au bout de 24 heures. Les bousiers étaient présents dans toutes les TUT. La saison et la TUT ont significativement influencé l'abondance et la diversité des espèces de coléoptères coprophages à $p < 0,001$. Ils étaient significativement plus élevés pendant la saison des pluies et dans les TUT sous l'influence des regards tels que les pâturages et les plantations forestières mixtes. Certaines espèces ont montré une grande préférence pour les TUT et les saisons. Certaines d'entre elles comprenaient le *Milichus picticollis* nocturne qui préférait les environnements frais, le rouleau *Sisyphus barbarosa* et le tunnelier *Euoniticellus triangulatus*, tous deux présents dans des environnements à forte disponibilité en fumier de bovins. En conclusion, cette recherche a fourni la première énumération des attributs communautaires des bousiers (abondance et diversité des espèces) à travers différentes TUT et saisons. Par conséquent, il constitue une base de référence intégrale sur laquelle la surveillance future de la biodiversité peut être basée. Enfin, la contribution spécifique de l'espèce de *M. picticollis*, *S. barbarosa* et *E. triangulatus* aux fonctions de l'écosystème doit être élucidée pour une exploitation ultérieure dans la gestion des pâturages.

Mots-clés: Coprophage, *Euoniticellus triangulatus*, nocturne, rouleaux, tunneliers

Introduction

Dung beetles are defined as those feeding, although not exclusively, on animal excreta. They are Coleopterans belonging to the Scarabaenae, Coprinae, Aphodiinae and Geotrupinae sub families of the Scarabaeidae and Geotrupidae families respectively. However, majority of the dung beetles belong to the Scarabaenae sub family. They mainly dominate tropical regions colonizing mammalian dung ranging from herbivores such as cattle and sheep to omnivores such as human beings and pigs. Some dung beetles are generalists, feeding on various resources such as carcass and animal dung based on availability (Hanski and Camberfort, 2014; Correa *et al.*, 2016).

They are classified into three functional groups namely rollers/telecoprids, dwellers/endocoprids and tunnelers/paracoprids. These functional groups are critical in predicting the amount of ecological functions they carry out in the ecosystem. Dung beetles contribute to key ecological services such as nutrients cycling, control of parasites, decomposition of mammalian dung and improvement of soil porosity and aeration (Nichols *et al.*, 2008). Through burial of mammalian dung, they contribute to reduction in the emission of greenhouse gases (Slade *et al.*, 2016).

Most efficient tunneler species could be utilized to promote sustainable pasture production while maximizing the above ecological services. However, such utilization is hinged on their abundance and species diversity. Unfortunately, there are limited studies elucidating the biodiversity and abundance of dung beetles in Kenya hindering their exploitation in management of pasturelands. This research focused at enumerating the effects of LUTs and seasons on abundance and species diversity in Eldoret, Kenya.

Materials and Methods

Description of the study site. The study was carried out in Eldoret (University of Eldoret farm) during the dry and wet seasons. Eldoret is located in latitude 0° 34' N and longitude 35° 18' E within Uasin Gishu County. The area has an elevation of 2141 m above sea level. It is under Lower Highland zone 3 (LH3) with an annual temperature range of 15.1 – 17.9 C. Annual rainfall range from 900 to 1100 mm and the main soil type is Rhodic Ferralsols. Dung beetles were sampled across five land use types namely; wattle plantation (WP), grazed pastureland (GP), eucalyptus plantation (EP), wetland (S) and mixed woodland plantation (MW). WP was located between two grazed pasturelands, one of which was burnt in March. GP was under cattle grazing during the first and third sampling period only. EP was located between two farms under previous cropping of maize and canola. Finally, MW comprised of a mixture of several tree species with the understorey cover being grass. It was under occasional cattle grazing and human excreta were observed on the lower parts.

Pitfall traps. Line transects measuring about 300 m were randomly established per each LUT perpendicular to the wind direction. Within each transect, 10 baited pitfall traps were laid at equal distance of 30 m. This was preferred since none of the LUTs measured at least 500 m in length ideal to install traps at 50 m inter-distance. This spacing was ideal in avoiding trap interferences (Larsen and Forsyth, 2005). The pitfall traps constituted of plastic containers measuring 13 cm in diameter and 9 cm depth. All the pit-fall traps were buried into the ground with the top rim being in flush with the soil surface.

Fresh cow dung (100 ± 5 g) was used as bait. The beetle collection was done at an interval of $24 \text{ h} \pm 30 \text{ min}$ for 4 days (Larsen and Forsyth, 2005). Baits were replaced immediately after collecting beetles for the second time (after 48 h) to maintain their attractiveness (Braga *et al.*, 2013). The dung beetles captured were placed in labelled plastic cups and taken to the laboratory for enumeration and identification. Species were identified to the species level using several taxonomic keys and inventory at the Department of Invertebrate Zoology of the National Museum of Kenya, Nairobi.

Data collection. Climatic data. Rainfall and temperature data were obtained from Eldoret Meteorological station located in Eldoret for the period starting from November 2016 to July 2017. Data on abundance and species diversity of dung beetles was collected. Species diversity was measured using species richness and Shannon-wiener index (H'). H' was preferred over other diversity index because both rare and abundant species are equally important. The H' index was given by;

$$H' = -\sum p_i \ln p_i$$

Where H' is the Shannon-Wiener index and p_i was the proportion of individuals of each species belonging to the i th species of the total number of individual beetles. Species diversity and richness was done at trap level since functions influenced by the two attributes takes place at the point of dung pat manipulation (Braga *et al.*, 2013).

Data analysis. All data were checked for normality using Shapiro-Wilk test (*W* test). The abundance data was square root transformed before analysis. Two way analysis of variance (ANOVA) was conducted to determine the effects of LUTs and season on abundance and species diversity (species richness and diversity index). Mean separation was carried out using protected Fisher's test at $p \leq 0.05$.

Results and Discussion

Abundance and distribution of dung beetles across LUTs and seasons in Eldoret. A total of 538 dung beetles, comprising of 18 species from 8 genera, were collected during the dry season (January 2017) across all the LUTs. The major genera were *Euoniticellus*, *Onthophagus* and *Milichus* in decreasing order. *Euoniticellus triangulatus* Harold, *Onthophagus raffrayi* Harold and *Milichus picticollis* Gerstaecker were the most dominant species in decreasing order. *Sisyphus barbarosa* Wiedemann was only identified in grazed pastureland while *O. astrofasciatus* Orbiny, *Onitis arrowi* Reiche and *Caccobius convexifrons* Raffray were only present in the wattle plantation (Table 1).

During the dry season (March 2017), there was a drop in total abundance from 538 to 461. Species decreased from 18 to 13. *Onthophagus filicornis* Harold was the dominant species with relative abundance of 40.8 % and was present across all LUTs. *Sisyphus Barbarosa* Wiedemann, *Liatongus militaris* Casteinau and *O. miricornis* Orbiny were only present in the grazed pastureland. Species total abundance in the grazed pastureland decreased from 260 to 73 (Table 1).

During the wet season (May 2017), individual dung beetles increased from 447 to 873. *Onthophagus gazella* Fabricius, *Milichus picticollis* Gerstaecker, *Onthophagus Sagittarius* Fabricius and *Euoniticellus triangulatus* Harold were the dominant species in decreasing order. Surprisingly, *Milichus picticollis* Gerstaecker and *Sisyphus barbarosa* Wiedemann which were seen to have high preference for mixed woodland and grazed pasturelands respectively were found in other LUTs. *Milichus picticollis* Gerstaecker was observed in Eucalyptus and Wetland LUTs. Some species were present across all LUTs such as *Onthophagus gazellas*, *Onthophagus Sagittarius* Fabricius, *Aphodius ictericus* Laicharting while others were only present in specific LUTs such as grazed pasturelands. *Onthophagus* and *Euoniticellus* were the dominant genera (Table 1).

Majority of the dung beetles (*Onthophagus*, *Euoniticellus*, *Milichus*, *Copris* and *Catharsius* genera) observed were tunnelers concurring with previous findings (Campos and Hernandez, 2013). Some species such as *Milichus picticollis*, *Sisyphus barbarosa*, and *Euoniticellus triangulatus* were among those with high specificity to LUTs. The nocturnal species (*Milichus picticollis*) preferred the cool environments under mixed woodland while the more versatile species such as *Onthophagus* and *Euoniticellus triangulatus* preferred open environments such as the grazed pastureland. The roller species (*Sisyphus barbarosa*) was specific to grazed pasturelands. Dung resources and vegetation cover have been reported as among the factors influencing the assemblage of dung beetles (Campos and Hernandez, 2013).

Table 1. Species abundance of dung beetles across LUTs and seasons in Eldoret

Land use types (LUTs)	GP			S			MW			WP			EP			R (%)		
Seasons	D	D	W	D	D	W	D	D	W	D	D	W	D	D	W	D	D	W
<i>Species</i>	2	0	0	20	0	0	14	0	0	61	0	0	7	0	0	19.3	0	0
<i>Onthophagus raffrayi</i> Harold, 1886	222	24	60	0	3	2	4	7	8	0	0	0	2	1	0	42.4	7.6	8.0
<i>Euniticellus triangulatus</i> Harold, 1873	31	8	36	0	0	1	0	0	0	0	0	0	0	0	0	5.8	1.7	4.2
<i>Sisyphus Barbarossa</i> Wiedemann, 1823	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0	2.0	0	0
<i>Onthophagus bidens</i> Olivier, 1789	1	0	0	0	0	0	2	0	0	8	0	0	0	0	0	0.6	0	0
<i>Drepanocerus abyssinicus</i> Pinna, 1979	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.7	0	0
<i>Onthophagus rufonotus</i> Gagne, 1997	0	0	0	13	0	0	6	0	0	2	0	0	5	0	0	5.0	0	0
<i>Aphodius ardens</i> Harold, 1886	0	4	0	3	2	0	5	2	0	3	0	0	1	2	0	4.5	3.7	0
<i>Onthophagus fimetarius</i> Roth, 1851	0	5	0	0	7	0	61	41	80	15	7	0	2	3	30	16.0	14.1	16.0
<i>Milichus picticollis</i> Gerstaecker, 1871	0	1	4	0	1	4	1	2	0	23	9	30	0	0	0	0.2	0.9	0.9
<i>Onthophagus fraticornis</i> Harold, 1873	1	0	0	1	0	0	3	0	0	0	0	0	0	0	0	1.3	0	0
<i>O. lamelliger</i> Gerstaecker, 1871	0	0	100	1	0	58	1	0	94	2	0	0	0	0	39	0.4	0	36.3
<i>O. gazellas</i> Fabricius, 1787	0	0	0	1	0	0	0	0	0	0	0	26	0	0	0	0.6	0	0
<i>Caccobius</i> sp. Ratzeburg, 1852	0	12	0	1	0	0	0	15	0	0	0	0	0	1	0	0.2	12.8	0
<i>Caccobius obtusus</i> Fahraeus, 1857	0	4	0	1	9	0	0	42	0	2	0	0	0	44	0	0.2	40.8	0
<i>O. filicornis</i> Harold, 1873	0	0	0	0	0	0	0	0	0	0	31	0	0	0	0	0.2	0	0
<i>O. atrofasciatus</i> D. Orbigny, 1905	0	0	4	0	0	0	0	0	1	0	89	0	0	0	2	0.6	0	1.0
<i>Caccobius convexifrons</i> Raffray, 1877	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0.2	0	0
<i>Onitis arrowi</i> Reiche, 1884	0	2	4	0	7	2	0	6	0	3	0	2	0	8	0	0	9.3	0.7
<i>O. negriventris</i> D. Orbigny, 1905	0	5	0	0	4	0	0	2	0	1	0	0	0	2	0	0	3.9	0
<i>O. semiasper</i> D. Orbigny, 1905	0	7	7	0	0	0	0	0	0	0	20	0	0	0	0	0	1.5	0.8
<i>Liatongus militaris</i> Casteinau 1840	0	1	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0.2	0
<i>O. miricornis</i> D. Orbigny, 1902	0	0	3	0	2	0	0	1	2	0	0	0	0	0	0	0	0.7	0.6
<i>Copris amyntor</i> Klug, 1855	0	0	4	0	0	0	0	0	4	0	0	0	0	0	0	0	0	1.3
<i>Copris harrisi</i> Waterhouse, 1891	0	0	0	0	1		0	11	0	0	0	0	0	0	0	0	2.8	0
<i>Aphodius angustatus</i> Mulsant, 1842	0	0	0	0	0	1	0	0	19	0	0	0	0	0	3	0	0	7.9
<i>Aphodius obliterates</i> Panzer, 1823	0	0	51	0	0	9	0	0	18	0	0	3	0	0	4	0	0	9.7
<i>O. Sagittarius</i> Fabricius	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0.2
<i>Catharsius neptunus</i> Kolbe, 1893	0	0	8	0	0	0	0	0	2	0	0	46	0	0	1	0	0	1.4

Table 2. Effects of season and LUT on the abundance of dung beetles in Eldoret

LUT	Seasons			Means
	Dry (January 2017)	Dry (March 2017)	Wet (May 2017)	
Eucalyptus	1.00	5.29	6.25	4.18 c
Wetland	3.61	2.89	7.29	4.60 c
Wattle plantation	10.89	13.69	11.56	12.04 b
Mixed woodland	7.84	10.89	24.01	14.25 ab
Grazed pastureland	24.01	6.76	28.09	19.62 a
Means	9.47 b	7.90 b	15.44 a	
Season	p < 0.001			
LUTs	p < 0.001			
Seasons*LUTs	p < 0.001			

These are detransformed means after conducting ANOVA using square root transformed data

Table 3. Effects of season and LUTs on species richness in Eldoret

LUT	Seasons			Means
	Dry (January 2017)	Dry (March 2017)	Wet (May 2017)	
Grazed pastureland	2.3	4.5	8.0	4.9 a
Wattle plantation	4.3	4.5	4.5	4.4 a
Mixed woodland	3.0	4.7	5.3	4.3 a
Wetland	2.3	2.7	2.5	2.5 b
Eucalyptus plantation	1.3	2.5	2.9	2.2 b
Means	2.6 c	3.8 b	4.6 a	
LSD (season)	0.7	p < 0.001		
LSD (LUTs)	0.9	p < 0.001		
LSD (seasons*LUTs)	1.5	p < 0.001		

Means followed by the same letter are not significantly different at $p \leq 0.05$

Table 4. Effects of season and LUTs on species diversity (H') in Eldoret

LUT	Seasons			Means
	Dry (January 2017)	Dry (March 2017)	Wet (May 2017)	
Grazed pastureland	2.3	4.5	8.0	4.9 a
Wattle plantation	4.3	4.5	4.5	4.4 a
Mixed woodland	3.0	4.7	5.3	4.3 a
Wetland	2.3	2.7	2.5	2.5 b
Eucalyptus plantation	1.3	2.5	2.9	2.2 b
Means	2.6 c	3.8 b	4.6 a	
LSD (season)	0.7	p < 0.001		
LSD (LUTs)	0.9	p < 0.001		
LSD (seasons*LUTs)	1.5	p < 0.001		

Means followed by the same letter are not significantly different at $p \leq 0.05$

Conclusion

This research provided the first enumeration of community attributes of coprophagous beetles (abundance and species diversity) across different LUTs and seasons. Therefore, it forms an integral baseline over which future monitoring of biodiversity can be based. LUTs and season significantly affected the abundance and species diversity of dung beetles. Some species showed high preference for LUTs and seasons. Some of these included the nocturnal *Milichus picticollis* which preferred cool environments, the roller *Sisyphus barbarosa* and tunneler *Euoniticellus triangulatus* both present in environments with high cattle dung availability and LUTs with grassland vegetation. Finally, species-specific contribution of *Milichus picticollis*, *Sisyphus barbarosa* and *Euoniticellus triangulatus* to ecosystem functions need to be elucidated for further exploitation in management of pasturelands.

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