Community Structure of Dung Beetles (Scarabaeidae: Scarabaeinae) in The Atlantic Forest of the Reserva Natural Vale (Linhares, Espírito Santo, Brazil)

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Recebido em 22/12/2021 – Aceito em 15/06/2022

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ABSTRACT – There are 7000 species of Scarabaeinae beetles that can be divided into four functional guilds. The aim of this work was to describe the Scarabaeinae community, its functional guilds and fluctuation throughout the year at two sites in the Reserva Natural Vale, municipality of Linhares, Espírito Santo state, Brazil. The samples were carried out monthly, from June 2012 to January 2013, with pitfall traps exposed for 48 hours with human faeces and rotten pig baits. Comparisons between the areas were made through abundance analysis and species richness, besides relating the feeding guilds and nesting of the captured species. A total of 9039 specimens were collected, distributed in 16 genera and 34 species. The most abundant species were *Dichotomius (Selenocopris) irinus* (Harold, 1867) with 34.5%, *Aphengium cupreum* Shipp, 1897 with 24.5% and *Canthon (Peltecanthon) staigi* (Pereira, 1953) with 21.3%. Nine species were recorded in all samples, with 88% of the total species captured during the study. Two out of three most abundant species, *D. irinus* and *A. cupreum* were dominant in the dry season. *C. staigi* was the most abundant in rainy season. Human feces trap was the most effective. In relation to trophic guild, most species were considered specialist. Regarding nesting behavior, the majority are paracoprids, standard pattern of Neotropical region.

Keywords: Biodiversity; baited pitfall-trap; coleoptera; ground fauna; neotropics.

Estrutura da Comunidade de Escaravelhos (Scarabaeidae: Scarabaeinae) na Mata Atlântica da Reserva Natural Vale (Linhares, Espírito Santo, Brasil)

RESUMO – Existem 7.000 espécies de besouros Scarabaeinae que podem ser divididos em quatro guildas funcionais. O objetivo deste trabalho foi descrever a comunidade Scarabaeinae, suas guildas funcionais e flutuação ao longo do ano, em duas áreas florestadas na Reserva Natural Vale, município de Linhares, estado do Espírito Santo, Brasil. As coletas foram realizadas mensalmente, de junho de 2012 a janeiro de 2013, com armadilhas de queda expostas por 48 horas com fezes humanas e iscas de carne de porco em decomposição. Comparações entre as áreas foram feitas por meio de análises de abundância e riqueza de espécies, além de relacionar as guildas alimentares e de nidificação das espécies capturadas. Foram coletados 9.039 espécimes, distribuídos em 16 gêneros e 34 espécies. As espécies mais abundantes foram *Dichotomius* (*Selenocopris*) *irinus* (Harold, 1867) com 34,5%, *Aphengium cupreum* Shipp, 1897 com 24,5% e *Canthon* (*Peltecanthon*) *staigi* (Pereira, 1953) com 21,3%. Nove espécies foram registradas em todas as amostras, com 88% do total de espécies capturadas durante o estudo. Duas das três espécies mais abundantes, *D. irinus* e *A. cupreum* foram dominantes na estação seca. *C. staigi* era o mais abundante na estação chuvosa. A armadilha de fezes humanas foi a mais eficaz. Em relação à guilda trófica, a maioria das espécies foi considerada especialista. Em relação ao comportamento de aninhamento, a maioria é de paracoprídeos, padrão para a região Neotropical.

Palavras-chave: Biodiversidade; coleoptera; fauna terrestre; neotrópico; pitfall iscado.

Estructura Comunitaria de Escarabajos Estercoleros (Scarabaeidae: Scarabaeinae) en el Bosque Atlántico de la Reserva Natural Vale (Linhares, Espírito Santo, Brasil)

RESUMEN – Hay 7000 especies de escarabajos Scarabaeinae que se pueden dividir en cuatro gremios funcionales. El objetivo de este trabajo fue describir la comunidad Scarabaeinae, sus gremios funcionales y su fluctuación a lo largo del año en dos sitios de la Reserva Natural Vale, municipio de Linhares, estado de Espírito Santo, Brasil. Los muestreos se realizaron mensualmente, de junio de 2012 a enero de 2013, con trampas pitfall expuestas durante 48 horas con heces humanas y cebos de cerdo podridos. Se realizaron comparaciones entre las áreas mediante análisis de abundancia y riqueza de especies, además de relacionar los gremios de alimentación y anidación de las especies capturadas. Se recolectaron un total de 9039 ejemplares, distribuidos en 16 géneros y 34 especies. Las especies más abundantes fueron *Dichotomius (Selenocopris) irinus* (Harold, 1867) con 34,5%, *Aphengium cupreum* Shipp, 1897 con 24,5% y *Canthon (Peltecanthon) staigi* (Pereira, 1953) con 21,3%. Se registraron nueve especies en todas las muestras, con un 88% del total de especies capturadas durante el estudio. Dos de las tres especies más abundantes, *D. irinus* y *A. cupreum*, fueron dominantes en la estación seca. *C. staigi* fue la más abundante en época de lluvias. La trampa de heces humanas fue la más efectiva. En relación al gremio trófico, la mayoría de las especies fueron consideradas especialistas. En cuanto al comportamiento de anidación, la mayoría son paracopridos, patrón estándar de la región Neotropical

Palabras clave: Biodiversidad; coleópteros; fauna terrestre; neotrópico; trampa cebada.

Introduction

Considering all the regions of the planet, the Neotropics is the region known for having the highest ratio of species richness by area (Dirzo & Raven, 2003; Lagomarsino & Frost, 2020). In contrast, this region is under great pressure from environmental changes caused by human activities (Dirzo & Raven, 2003; Palmeirim *et al*., 2017; Zimbres *et al*., 2017). The main fraction of biodiversity in the world is attributed to insects (Basset *et al*., 2012) and this high biodiversity is no different in South America (Santos *et al*., 2018; Chamorro *et al*., 2019; Fernández *et al*., 2019; Silva *et al*., 2022). Among the insects with the potential to use in monitoring environmental changes caused by human activities, dung beetles (Coleoptera, Scarabaeinae) and ants (Hymenoptera, Formicidae) are the most used taxonomic group (e.g.: Storck-Tonon *et al*., 2020; Przybyszewski *et al*., 2020; Arruda *et al*., 2022) because of their abundance and extremely important roles played in the ecosystems (Halffter & Favila 1993; Del Toro *et al*., 2012).

Regarding beetles, the subfamily Scarabaeinae (Coleoptera: Scarabaeidae) is composed of beetles popularly known as "dung-beetles" (Vaz-de-Mello, 2000). This popular name is due to the behavior of making dung balls that are transported to the nests in the shape of tunnels in the soil, which will serve as substrate for oviposition and food reserve for both adults and larvae (Halffter & Matthews, 1966; Philips, 2011). Depending on how the resource is used in reproduction, Scarabaeinae can be divided into four functional guilds: (1) residents or endocoprids, (2) tunnelers or paracoprids, (3) rollers or telecoprids, and the (4) kleptoparasites or kleptocoprids. The residents or endocoprids feed and nest inside the resource and deposit their eggs directly thereon. Tunnelers or paracoprids, building galleries on the ground just below or next to the resource. The rollers or telecoprids, making dung balls that can be made by an individual or by the couple that transports it for a certain distance to then be buried. Finally, the kleptoparasites or kleptocoprids, have the behavior of laying their eggs in nest balls of other species (Halffter & Matthews, 1966; Halffter & Edmonds, 1982; Doube, 1990; Cambefort & Hanski, 1991; Simmons & Ridsdill-Smith, 2011).

The nidification and alimentary behavior of Scarabaeinae make them play a fundamental role in the functioning of terrestrial ecosystems getting involved in important ecological processes such as the decomposition and nutrient cycling (Nichols *et al*., 2008). They are detritivores and its food pellets are made mainly on vertebrate excrement (coprophagous), also being able to feed and nest in dead animals (necrophagous) and decaying plant material, such as fruits (saprophagous), with generalist species that feed on more than one of these resources (Halffter & Matthews, 1966; Halffter & Favila, 1993). Considering this trait, passive collection methods have been used to sample the fauna of Scarabaeinae with the aid of a trap with biological or physical attractions (Milhomem *et al*., 2003). In the tropical region, surveys of Scarabaeinae have been carried out with different types of baits, such as: rotting meats, rotting fruits and human feces, the latter being the most used to attract these beetles, as it captures a greater number of individuals (Silva *et al*., 2015; Cajaiba *et al*., 2017; Vieira *et al*., 2017; Silva, 2018; Storck-Tonon *et al*., 2020).

Dung-beetles are recommended as indicators of environmental quality because they present well-defined guilds, are easily sampled, have high diversity and are sensitive to the effects of natural and anthropogenic disturbances (Halffter & Favila, 1993; Favila & Halffter, 1997; Nichols *et al*., 2007). These studies throughout the world reveal a diversity of approximately 7000 species of the subfamily Scarabaeinae (Lima *et al*., 2015). In Brazil, 700 species are currently recognized with 323 endemic species, mainly in the Atlantic Forest (Vaz-de-Mello, 2000; Vaz-de-Mello *et al*., 2017; Silva *et al*., 2020). Of these, 81 species are known for the state of Espírito Santo, Brazil, six of which are considered endemic to the state (Vaz-de-Mello, 2000).

In the last few years there has been a significant increase in the number of studies in Scarabaeinae in Brazil, but in the Southeast region, more work is still needed on this subfamily. The Brazilian state of Espírito Santo, despite being located close to research centers, has few studies on the Scarabaeinae diversity (Louzada *et al*., 1996; Vaz-de-Mello, 2000; Schiffler *et al*., 2003; Vieira *et al*., 2008, 2011) and the knowledge of the biodiversity in this region is urgent, given the large number of threatened species, number that has been increasing in recent years, with some species considered extinct locally (Fraga *et al*., 2019; Mezzonato-Pires *et al*., 2021). Knowing about (being aware of) this biodiversity gap, in this paper we sampled the dung beetle fauna in the Reserva Natural Vale (RNV) (Linhares, Espírito Santo), a significant remnant of the Atlantic Forest considered an to be area of extreme importance in the conservation of biodiversity and located in the Central Corridor of the Atlantic Forest. The principal objective of this work was to describe the Scarabaeinae community, its functional guilds and fluctuation throughout the year at two sites (primary and secondary forest), for this we used two types of baits in the pitfall traps for 8 months.

Material and Methods

Study area

Sampling was carried out at Reserva Natural Vale (RVN), located 30km north of the Rio Doce, covering part of the municipalities of Linhares and Jaguaré (19 ° 06 '- 19° 18' S and 39 ° 45 '- 40 ° 19 'W – Figure 1), in the north of the state of Espírito Santo, Brazil (Srbek-Araujo & Chiarello, 2008). RVN is inserted in one of the most important areas for conservation of the biodiversity of the Atlantic Forest, being part of the Central Corridor of the Atlantic Forest (Ministério do Meio Ambiente, 2000). The Reserve has an area of approximately 21787ha, representing a significant portion of the State's Primary Atlantic Forest (Jesus & Rolim, 2005). The RNV is surrounded by other conservation areas such as Reserva Biológica de Sooretama, RPPN Recanto das Antas and RPPN Mutum Preto, that emerged to reduce the effects of landscape modification in the region and its synergistic effects (Martins-dos-Santos, 2021).

The predominant vegetation cover is the Atlantic Forest of Tabuleiro and Mussununga, with a forest of great physiognomic variation, with sparse and smaller trees, which accompany strands of sandy soils and palms (Meira Neto *et al*., 2005). Two areas were selected inside the reserve, one of primary forest with phytophysiognomy of Tabuleiro and Mussununga forest, called "Primary forest", where visitation is restricted, about 2.873km away from the headquarters. The second area called "Secondary forest" is an advanced stage of regeneration area, with enormous phytophysiognomic variation and anthropic pressure where the flow of people was large (between employees and visitors), close to the administrative headquarters, about 348m.

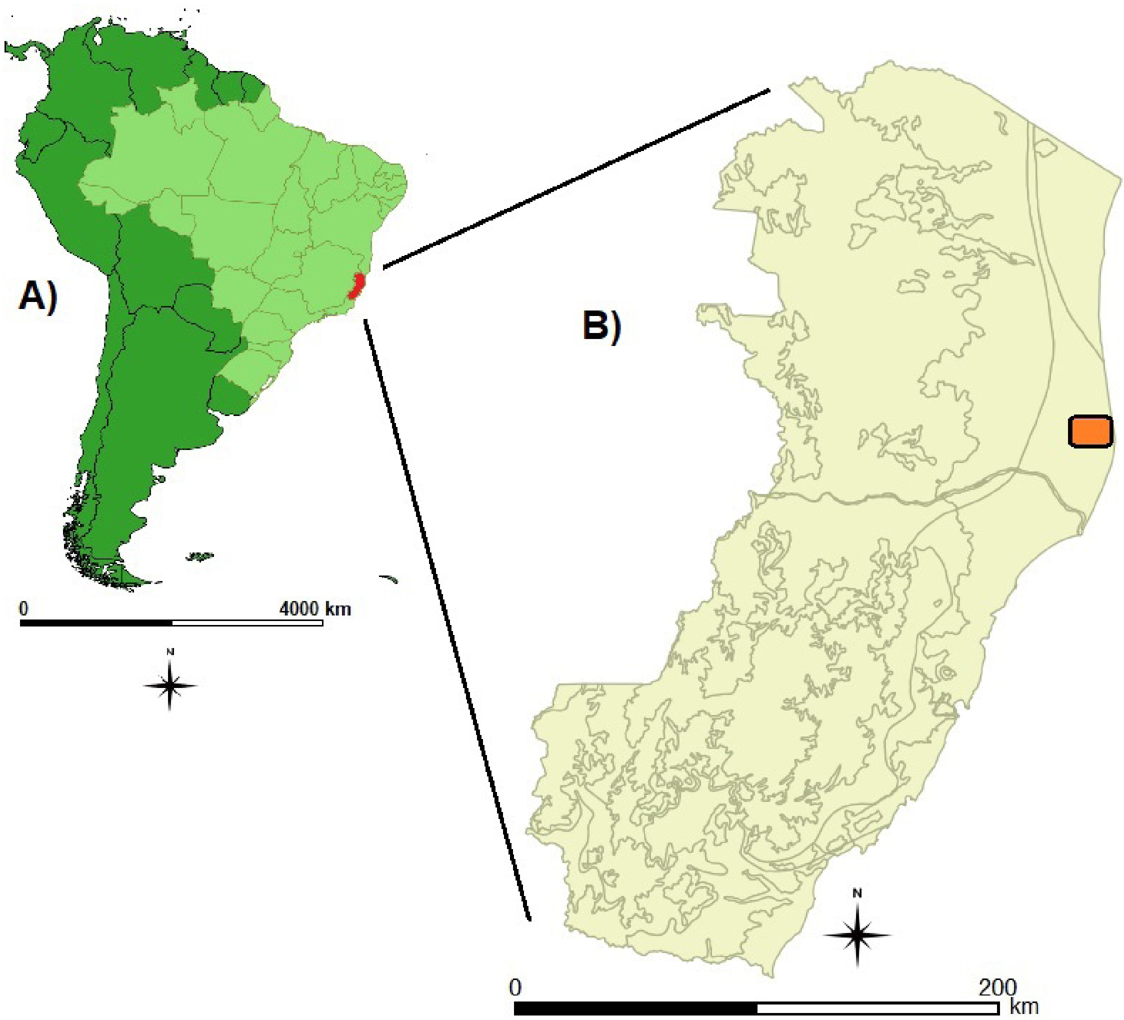

Figure 1 – Map of the South America (A) expanding to the Espírito Santo state; and (B) highlighting for the Reserva Natural Vale (orange square).

Sampling methods

The Scarabaeinae sampling was conducted from June 2012 to January 2013 with baited pitfall traps. The pitfalls were made with plastic pots 17.5cm in diameter and 18cm high, buried at ground level, containing 250ml of 4% formaldehyde solution. Inside each container, a plastic cup of 50ml (coffee cup) containing the bait was suspended within. The traps were covered by a 30x30cm sheet of zinc supported by three rods to prevent the entry of other larger animals and to protect against rain (Figure 2).

The pitfall traps were placed in transects inside the forest, in the two previously chosen areas. Each transect was installed more than 300m from the edge, and it has six collection points spaced 10m from each other, one containing rotting pig for 48 hours and the other with human feces. Sampling was carried out monthly for eight months, considering June to September the dry season and October to January the rainy season. The traps remained with the bait for 48 hours; after that period the material was removed from the traps and placed in glass containers, containing 70% alcohol and labeled according to the sampled area, trap number, type of attraction and date of collection, for later screening, at the Laboratório de Entomologia e Fitopatologia (LEF) in the Centro de Ciências e Tecnologias Agropecuárias (CCTA) of the Universidade Estadual do Norte Fluminense Darcy Ribeiro (UENF). The traps, already without the material, were then washed and kept in place without the attractive baits until the next collection. All the insects captured were mounted on an entomological pin, labeled, identified at the species level and were deposited at the Museu de Entomologia of the Laboratório de Entomologia e Fitopatologia, Universidade Estadual do Norte Fluminense Darcy Ribeiro (MLEF / UENF) and at the Seção de Entomologia da Coleção Zoológica, Departamento de Biologia e Zoologia, Universidade Federal de Mato Grosso (CEMT/UFMT).

Figure 2 – Baited pitfall trap used to sample in the Reserva Natural Vale.

Data analysis

To characterize the feed habits of Scarabaeinae, the species were defined according to the incidence of capture of at least 80% in traps baited with feces and rotten pig (Silva *et al.*, 2012a; Silva & Di Mare, 2012). In this way, it was possible to establish the trophic guild of the species, grouping them into: coprophagous (greater occurrence in the trap with human feces), necrophagous (greater occurrence in the trap with rotten pig) and generalists (abundance of similar individuals in more than a type of trap) (Halffter & Favila, 1993; Halffter & Arellano, 2002).

To assess diversity, the Shannon index was used, which is suitable for random samples, giving greater value to less found species. The Margalef index was used to calculate the wealth of Scarabaeinae (Magurran, 2003). Community dominance was calculated using the Berger-Parker index and uniformity of abundance distribution between species was obtained using the Pielou index (Magurran, 2003). The probable richness of RNV, in the areas of collection and types of attractions (human feces and rotten pig) was estimated with the aid of the EstimateS 8.2.0 program for Windows (Colwell, 2009), by calculating the estimator Jackknife1. Rarefaction curves were developed to assess the efficiency of the attractions in attracting dung beetles. The curves were applied and compared as proposed by Magurran (2003).

Results

We captured 9,039 specimens of Scarabaeinae, distributed in 16 genera and 34 species (Table 1). Species sampled with only one individual (singletons) were *Eutrichillum hirsutum* (Boucomont, 1928) in the Primary forest and *Trichillum* sp.1 in the Secondary forest. The species with only two specimens captured (doubletons) were *Deltochilum* (*Aganhybona*) *trisignatum* Harold, 1881 and *Canthidium* sp. 3 (Table 1), both captured in the Secondary forest.

The more abundant species were *Dichotomius (Selenocopris) irinus* (Harold, 1867) with 34.5%, *Aphengium cupreum* Shipp, 1897 with 24.5% and *Canthon (Peltecanthon) staigi* (Pereira, 1953) with 21.3%. These three species, added up to 7,258 individuals (80.3%). The remaining 31 species are represented by 1,781 specimens (19.7%). Of the 34 species collected at RNV, only seven could not be identified at a specific level. The most effective trap was that containing human feces, where 7,330 individuals were captured. In the rotten pig traps, 1,709 specimens were captured. In the two types of bait the most abundant species were the three previously mentioned. The greatest richness was also found in human feces traps, with 31 species collected while in the traps with rotten pig bait, 26 species occurred (Table 1).

Table 1 – Species composition and absolute (T) and relative (%) abundance, functional guild (GF) and trophic guild (GT) of Scarabaeinae captured in the Reserva Natural Vale, Linhares, Espírito Santo, Brazil. **GF:** E, endocoprid; P, paracoprid; T, telecoprid **GT:** G, generalist; C, coprophagous; N, necrophagous.

Species	Abundance		T	%	GF	GT	Feces	Pig
	Primary Forest	Secondary forest						
Aphengium cupreum Shipp, 1897	288	1,926	2214	24.5	P	G	1988	226
Ateuchus sp. 1	85	69	154	1.7	P	G	141	13
Ateuchus aff. *vigilans* Lansberge, 1874	6	13	19	0.21	P	G	13	6
Eutrichillum hirsutum (Boucomont, 1928)	0	1	1	0.01	E	S	1	0
Trichillum sp. 1	1	0	1	0.01	E	S	1	0
Uroxys sp. 1	86	7	93	1.03	P	C	89	4
Canthidium (Canthidium) aff. *sulcatum* Perty, 1830	2	13	15	1.16	P	N	2	13
Canthidium (Eucanthidium) aterrimum Harold, 1867	18	13	31	0.34	P	C	31	0
Canthidium (Eucanthidium) aff. *rufipes* Harold, 1867	219	135	354	3.91	P	C	351	3
Canthidium sp. 1	35	23	58	0.64	P	G	11	47
Canthidium sp. 2	1	2	3	0.03	P	C	3	0
Canthidium sp. 3	0	2	2	0.02	P	D	0	2
Chalcocopris hesperus Olivier, 1789	8	4	12	0.13	P	C	12	0
Dichotomius (Dichotomius) camposeabrai Martinez, 1974	1	2	3	0.03	P	C	3	0
Dichotomius (Dichotomius) depressicollis (Harold, 1867)	2	6	8	0.08	P	C	8	0
Dichotomius (Dichotomius) mormon (Ljungh, 1799)	1	3	4	0.04	P	C	4	0
Dichotomius (Selenocopris) irinus (Harold, 1867)	836	2,282	3118	34.5	P	G	2379	739
Dichotomius (Selenocopris) schiffleri Vaz-de-Mello, Louzada & Gavino, 2001	96	57	153	1.69	P	G	106	47
Dichotomius (Cephagonus) aff. *bicuspis* (Germar, 1824)	3	5	8	0.08	P	N	0	8
Ontherus azteca Harold, 1879	4	8	12	0.13	P	C	11	1
Canthon (Canthon) nigripennis Lansberg, 1874	0	13	13	0.14	T	N	1	12
Canthon (Goniocanthon) smaragdulus subviridis Schmidt, 1922	59	123	182	2.01	T	G	168	14
Canthon (Peltecanthon) staigi (Pereira, 1953)	717	1,209	1926	21.3	T	G	1541	385
Canthon (Peltecanthon) sulcatus Castelnau, 1840	25	170	195	2.15	T	G	173	22
Canthonella silphoides (Harold, 1867)	1	21	22	0.24	T	G	7	15
Deltochilum (Aganhyboma) trisignatum Harold, 1881	0	2	2	0.02	T	D	0	2
Deltochilum (Parahyboma) granulosum Paulian, 1933	2	1	3	0.03	T	I	1	2
Deltochilum sp. 1	20	32	52	0.57	T	N	3	49
Eurysternus caribaeus (Herbst, 1789)	41	89	130	1.44	E	C	129	1
Eurysternus hirtellus Dalman, 1824	18	34	52	0.57	E	G	36	16
Onthophagus (Onthophagus) aff. *catharinensis* Paulian, 1936	36	39	75	0.83	P	C	74	1
Coprophanaeus (Megaphanaeus) bellicosus (Olivier, 1789)	16	59	75	0.83	P	N	6	69
Coprophanaeus (Metallophanaeus) punctatus (Olsoufieff, 1924)	1	4	5	0.05	P	N	1	4
Phanaeus (Notiophanaeus) splendidulus (Fabricius, 1781)	19	25	44	0.48	P	C	36	8
Specimens number	2,647	6,392	9039				7,330	1,709
Species number	30	33	34				31	26

Nine of the 34 species were recorded in all collections (88% of individuals collected), the three most abundant species ever cited were *Ateuchus* sp.1, *Uroxys* sp.1, *Canthon (Goniocanthon) smaragdulus subviridis*, *Canthon (Peltecanthon) sulcatus*, *Dichotomius (Selenocopris) schiffleri* and *Onthophagus (Onthophagus)* aff. *catharinensis* (Table. 2).

In the rainy season, 4,893 individuals were captured and in the dry season, 4,146. Of the three most abundant species, *D. irinus* (1,663 specimens, 53% of the total) and *A. cupreum* (1,201 specimens, 54% of the total) had a dominant distribution in the dry season and *C. staigi* (1.143 specimens, 59% of the total) in the rainy season (Table 2).

Table 2 – Temporal distribution of Scarabaeinae species collected at Reserva Natural Vale, Linhares, Espírito Santo, Brazil.

Species	Number of sampled Scarabaeinae individuals							
	Jun/12	Jul/12	Aug/12	Sep/12	Oct/12	Nov/12	Dec/12	Jan/13
Aphengium cupreum	294	465	68	374	89	81	650	193
Ateuchus aff. *vigilans*	0	5	2	2	0	2	6	2
Ateuchus sp. 1	9	9	1	17	4	3	92	19
Eutrichillum hirsutum	0	0	0	1	0	0	0	0
Trichillum sp. 1	0	0	0	1	0	0	0	0
Uroxys sp. 1	21	15	6	19	3	11	15	3
Canthidium aterrimum	0	5	3	6	1	13	2	1
Canthidium aff. *rufipes*	0	6	4	6	15	320	0	3
Canthidium sp. 1	0	16	1	0	4	20	12	5
Canthidium sp. 2	0	0	1	1	0	0	0	1
Canthidium sp. 3	0	0	0	0	0	2	0	0
Canthidium aff. *sulcatum*	0	0	0	2	3	7	0	3
Chalcocopris hesperus	0	0	0	0	0	8	1	3
Dichotomius aff. *bicuspis*	1	0	0	1	1	5	0	0
Dichotomius camposeabrai	2	0	0	0	0	0	1	0
Dichotomius depressicollis	0	0	1	0	0	4	3	0
Dichotomius irinus	536	452	331	344	347	262	511	335
Dichotomius mormon	0	1	0	0	0	1	2	0
Dichotomius schiffleri	12	31	33	47	12	3	8	7
Ontherus azteca	0	3	0	0	0	0	8	1
Canthon nigripennis	0	0	1	1	2	0	9	0
Canthon smaragdulus subviridis	5	18	4	2	55	29	49	20
Canthon staigi	259	257	128	139	205	166	367	405
Canthon sulcatus	16	36	17	20	13	11	49	33
Canthonella silphoides	1	1	0	14	1	1	2	2
Deltochillum granulosum	0	0	0	1	1	0	0	1
Deltochillum sp. 1	2	0	2	0	6	9	10	23
Deltochillum trisignatum	1	0	0	0	1	0	0	0
Eurysternus caribaeus	0	3	0	6	5	8	69	39
Eurysternus hirtellus	3	19	8	6	7	8	1	0
Onthophagus aff. *catharinensis*	2	5	1	2	5	3	29	28
Coprophanaeus bellicosus	1	1	0	1	5	14	10	43
Coprophanaeus punctatus	0	0	0	0	0	2	2	1
Phanaeus splendidulus	1	2	3	2	0	8	16	12
Specimens number	1,166	1,350	615	1,015	785	1,001	1,924	1,183
Species number	17	20	19	24	22	26	25	24

The species accumulation curve for the two sampled areas reveals that they did not differ statistically in terms of species richness due to overlapping accumulation curves. However, in Primary forest, there is a tendency towards stabilization, while in Secondary forest the curve continues to increase, meaning that more species could be collected in this environment (Figure 3).

As for trophic guilds, of the 34 species of Scarabaeinae collected at RNV, 11 species were classified as generalists, 12 species as coprophagous and six species as necrophagous. Five species could not be classified in any of the guilds due to the low sampling of individuals (Table 1). According to the functional guilds for the use of food resources, of the 34 species sampled, 22 were classified as paracoprid. Eight species were considered telecoprid and four species from the endocoprid group (Table 1).

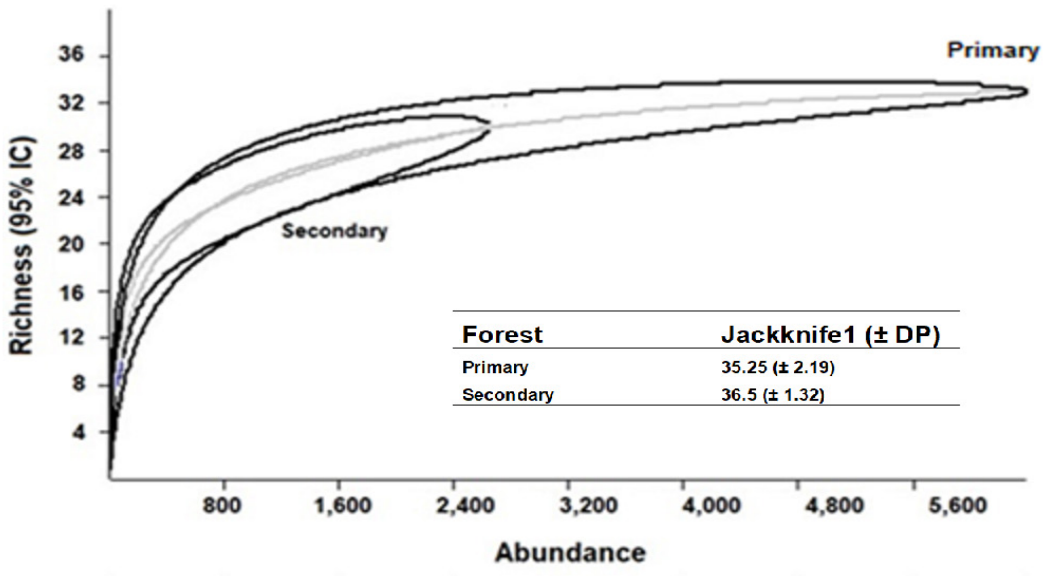

Figure 3 – Accumulation curve for Scarabaeinae richness in the Reserva Natural Vale, Linhares, Espírito Santo, Brazil. Confidence interval of 95%.

By the Jackknife 1 estimator, Primary forest could collect from three to seven species and in Secondary forest from two to five species, in the case of increased sampling effort. The accumulation curve for Scarabaeinae species richness was obtained by comparing the efficiency of the two types of attractions used in the collections (human feces and rotten pig), it was found that none of the curves tended to stabilize (Figure 4). For the Jackknife 1 value, pitfall traps baited with feces could still collect from 1 to 9 species and the trapwith rotten pig could collect from 1 to 8 more species.

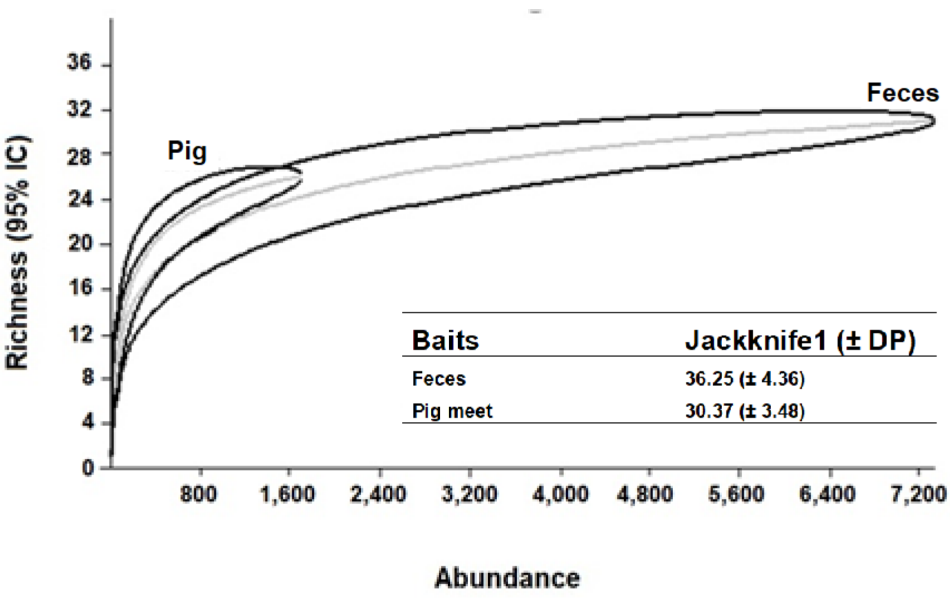

Figure 4 – Accumulation curve for Scarabaeinae wealth found in traps baited with human feces and rotten pig in Reserva Natural Vale, Linhares, Espírito Santo, Brazil. Confidence interval of 95%.

The diversity of Scarabaeinae obtained by the Shannon index, in human feces, was equivalent to that found in rotten pig. The same was true for wealth and dominance, assessed by the Margalef and Berger-Parker index respectively, where both baits were similar. In the distribution of species captured in feces and rotten pig, obtained by the Pielou index, it was observed that there was no significant difference (Table 3).

Table 3 – Diversity index (Shannon), Richness (Margalef), equitability (Pielou) and dominance (Berger-Parker) in relation to the types of attractive baits (human feces and rotten pig) used in the capture of Scarabaeinae in the Reserva Natural Vale.

Index	**Baits**	
	Feces	**Rotten pig**
Shannon (H')	1.834	1.831
Pielou (J')	0.5341	0.562
Berger-Parker (d)	0.3246	0.4324
Margalef (D_{Mg})	3.371	3.359

Discussion

In this study, it is important to note that among the 34 species sampled, 11 species (32%) are probably new species (since the non-determination of a valid species by the recognized expert in the area, Dr. Fernando Vaz-de-Mello), demonstrating that this area of the Reserva Natural Vale comprises a very important region for the preservation of the biodiversity of the much-threatened Atlantic Forest. The identified species is similar to those sampled in surveys carried out in the Neotropical Region, regardless of the collection period and the number of individuals captured (Spector & Ayzama, 2003; Schiffler *et al*., 2003; Celi *et al*., 2004; Endres *et al*., 2007; Hamel-Leigue *et al*., 2008; Lopes *et al*., 2011; Silva *et al*., 2012a, 2012b; Salomão & Iannuzzi, 2015;

Viegas *et al*., 2014; García *et al*., 2016; Noriega & Realpe, 2018). *D. irinus, A. cupreum* and *C. staigi*, predominant species in RNV, demonstrated predominance in other regions of its occurrence (Schiffler *et al*., 2003; Endres *et al*., 2007; Lima *et al*., 2013; Salomão & Iannuzzi, 2015). In a study developed by Hernández *et al*. (2014) in Paraíba, *D*. aff. *irinus* is cited as the most abundant, but it is probably another species of the complex, since the distribution of *D. irinus* reaches Bahía (Valois *et al*., 2017).

Almost all the works published before the taxonomic revision of the *Dichotomius sericeus* species group (Valois *et al*., 2017), both in the Northeast, Southeast and Southern regions, mention the related species as *D*. aff. *sericeus* (Costa *et al*., 2009; Campos & Hernández, 2013; Lima *et al*., 2015; Salomão & Iannuzzi, 2015), thus being able to contain several species of the complex, making it difficult to discuss at the level species of this group. The species of the "*sericeus*" group predominates in Atlantic Forest and Restinga and their distribution comprises the entire tropical Brazilian coast, being able to reach areas of Atlantic Forest in Paraguay and Argentina (Valois *et al*., 2017). However, the specie *D. irinus*, has its distribution in the Atlantic Forest and Restinga between the states of Bahía, Espírito Santo, Minas Gerais and Rio de Janeiro (Valois *et al*., 2017). In a study carried out in the Contendas do Sincorá National Forest in Bahía, *D. irinus* identified as one of the seven habitat indicator species in the region, not occurring in the preserved zone (Vieira *et al*., 2017). In RNV although the species of the "*Irinus*" group occur in both studied areas, being more abundant in Secondary forest, anthropized. *This shows a preference for less preserved environments by "Irinus" group.*

A. cupreum is restricted to the Atlantic Forest in the states of Espírito Santo and Minas Gerais to the present day, and may extend to fields in the north of Rio de Janeiro and south of Bahía, but still without any record (Silva & Vaz-de-Mello, 2015). Another important fate of this work is that one of the specimens of *A. cupreum* donated to the Coleção CEMT/UFMT, was determined to be a Neotype and deposited at the London Natural History Museum, England (NHML) (Silva & Vaz-de-Mello, 2015).

It is common to obtain a small number of abundant species and a large number of species with few individuals, in samples of communities in tropical forests (Halffter, 1991). This was observed in this work, in which three species were very abundant (88% of the individuals collected), as well as in most works mentioned so far, between one and six being the most abundant species.

Seasonality in tropical regions is regulated by dry and rainy periods, with little temperature variation (Wolda, 1988). It is also a determining factor in the distribution of Scarabaeinae in terms of variation in abundance and richness, since these insects are greatly affected by the temperature and humidity of the soil, being the rainy season where abundance and richness are greatest (Janzen, 1983; Hernández, 2007; Lopes *et al*., 2011). In RNV the number of individuals and species was lower during the dry season, but the difference in the number of individuals caught between the two periods was small, differing from the work of Salomão & Iannuzzi (2015), where the number of individuals collected in the dry season was almost half that found in the rainy season. Of the three most abundant species in the RNV, *D. irinus* and *A. cupreum* were more abundant in the dry season and *C. staigi* in the rainy season, in Pernambuco only one of the most abundant species occurred in the dry season and two in the rainy season (Salomão & Iannuzzi, 2015). Probably *D. irinus* and *A. cupreum* have adapted, over time, to the dry environment with less availability of resources, thus standing out in the competition for habitat and food, during the driest months, even having occurred throughout the collection period (Ocampo & Philips, 2005; Halffter & Halffter, 2009).

The accumulation curves did not reach stability in either of the two sampled areas, except for the accumulation of species in preserved forest, with a tendency to stability. To achieve stabilization, a longer collection period or greater sampling effort would be necessary. Silva *et al*. (2012a) in Rio Grande do Sul performed collections for one year, with two methods for capturing Scarabaeinae, and also did not reach the asymptote, but obtained a tendency towards stabilization.

The most efficient bait to attract Scarabaeinae was the one with human excrement, both in richness and in the abundance of species. These data corroborate with other studies carried out in forests in Brazil (Milhomem *et al*., 2003; Schiffler *et al*., 2003; Filgueiras *et al*., 2009; Silva *et al*., 2012a, 2012b; Vieira & Silva, 2012; Silva *et al*., 2013; Lima *et al*., 2015; Cajaiba *et al*., 2017; Vieira *et al*., 2017). The preference for mammal feces, used in feeding larvae and adults, seems to be related to evolutionary processes (Silva & Di Mare, 2012). Specialization in coprophagy may be related to the greater availability of feces from mammals and other vertebrates in ecosystems (Halffter & Matthews, 1966; Falqueto *et al*., 2005; Larsen *et al*., 2006; Filgueiras *et al*., 2009; Campos & Hernández, 2013; Silva *et al*., 2015; Cajaiba *et al*., 2017).

The results on the trophic guilds in this work differ from that expected for a community of Scarabaeinae in the Neotropical Region, that is, a higher proportion of generalist species than specialists (Halffter & Matthews, 1966). The number of coprophagous and necrophagous species corresponded to 18 species, being greater than that of the generalists who added 11 species. Similar results were found by Almeida & Louzada (2009) in Minas Gerais, Silva *et al*. (2012a, 2012b) and Lima *et al*. (2015) in Rio Grande do Sul, and Cajaiba *et al*. (2017) in Pará. Many of the species considered as coprophagous or necrophagous, still do not have their eating habits known or described and therefore classified as generalists (Almeida & Louzada, 2009). The three most abundant species in the RNV were considered generalists, not being sensitive to a specialization of the diet. Trophic generalization may lead to a decrease in competition for scarce and ephemeral foods such as feces, carcasses and rotten fruits, allowing Scarabaeinae species to better use local resources, as specificity seems to restrict the species' ability to occupy new habitats, where their food does not occur (Andresen, 2005; Halffter & Halffter, 2009; Silva & Di Mare, 2012; Campos & Hernández, 2013).

The pattern of Scarabaeinae functional guilds found in RNV is similar to that found by Louzada & Lopes (1997) and Almeida & Louzada (2009) in Minas Gerais; Silva *et al*. (2015) in two areas in Mato Grosso and Lima *et al*. (2015) in Rio Grande do Sul. This distribution model, where a greater number of species of paracoprids is obtained, is very common in the Neotropical region (Halffter *et al*., 1992; Louzada & Lopes, 1997; Lima *et al*., 2015). This structure reinforces that there is a taxonomic and functionality determination for each region (Silva *et al*., 2015).

Conclusion

The results found in the Reserva Natural Vale contribute to the knowledge of Coleoptera fauna in the state of Espírito Santo.

Among the captured species, rare species were found, some are bioindicators of environmental quality, such as *D. schiffleri*, indicating that the conservation and preservation measures of the reserve are having good results.

The area considered to be in the best state of preservation (Primary forest) presented greater diversity in relation to the less preserved area (Secondary forest), despite the latter having presented greater abundance of the species present.

Traps containing human feces bait showed to be more efficient in attracting Scarabaeinae, compared to rotten pork traps, both in the number of species and individuals. Regarding the functional guild, the paracoprids were the most representative and the specialist beetles were superior to the generalists.

This work is a contribution to the knowledge of the Scarabaeinae fauna in the state of Espírito Santo. However, studies are needed that lead to more comprehensive knowledge of the biology, distribution, and diversity of Scarabaeinae to contribute towards preservation in this region.

Acknowledgements

We would like to thank the Management of the Reserva Natural Vale for allowing collections to be made on their premises and for providing accommodation during the work. Also, we thank to Cíntia C. L., Teixeira and Gilson Silva-Filho to the laboratory help and to Prof. Dr. Fernando Z. Vaz-de-Mello from the Universidade Federal do Mato Grosso (UFMT) for the identification of Scarabaeinae. To the Universidade Estadual Norte Fluminense Darcy Ribeiro (UENF) for the opportunity to study at this institution and to the Fundação de Amparo à Pesquisa do Estado do Rio de Janeiro (FAPERJ) for the Master scholarship. This work was also carried out with the support of the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – Brazil (CAPES). REV thanks the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) of the Ministério da Ciência, Tecnologia e Inovações (MCTI) by the support provided by the Programa de Capacitação Institucional (PCI/INMA).

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Biodiversidade Brasileira – BioBrasil.
Fluxo Contínuo
n.4, 2022

http://www.icmbio.gov.br/revistaeletronica/index.php/BioBR

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ISSN: 2236-2886