Chapter 2

Dung Beetles of Chile, with Emphasis in La Araucania Region

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Abstract

Dung beetles are insects that provide a large-scale ecosystem service worldwide through their role in the decomposition of manure from livestock, thereby providing a series of environmental services, such as nutrients recycling, control of internal parasites of livestock whose eggs are in the feces, soil aeration, spreading of seeds and maintenance of ecological balance. Dung beetles are broadly classified according to their nesting behavior in three categories as telecoprids, paracoprids and endocoprids. Telecoprids are the rollers that make balls from feces and roll them into the ground; paracoprids are the tunnellers that bury the dung balls at different depths, forming galleries in the ground below or next to the food source and endocoprids, who are the dwellers that raise their larvae inside feces. There are 10 native species of dung beetles recorded in Chile, apart from 10 species of Aphodiinae, plus two introduced species, such as *Onitis vanderkelleni* and *Onthophagus gazella*. Dung beetles species were prospected in La Araucania Region and registered *Homocopris torulosus*, *Frickius variolosus*, *Podotenus fulviventris* and *Aphodius pseudolividus*. We found that species from genus *Homocopris*, *Podotenus* and *Aphodius* were distributed from 0 to 2000 m above sea level, while *F. variolosus* was distributed over an altitude of 350 m.

Keywords: dung beetles, Scarabaeidae, Geotrupidae, Chile

1. Introduction

Dung beetles (*Coleoptera*: *Scarabaeidae* and *Geotrupidae*) are well known because of their feeding habits, consisting in collecting the dung from various animals. In some countries, they are called scarabs [1–3]. Dung beetles have a worldwide distribution with a range of about 8500 species. They are present in every kind of environment such as deserts, forests, savannas, tropical or cold grasslands and urban areas [4–8]. Dung beetles appeared on Earth during the late Cretaceous, where they began taking advantage of the huge amount of accumulated manure and the absence of other insects or organisms that could play the role as decomposers (see Refs. [5, 8–10]).

The feeding habits of these insects bring significant environmental benefits and ecosystem services, such as recycling of soil nutrients, stimulation of plant development, spreading of seeds, biological control of parasite load in manure and indirect help in pollination [10–14].

In grasslands, the insects activity generates an increase in the rate of manure decomposition, allowing nutrient recycling, and also, the reuse of grassland, once feces have been cleared [15, 16]. The introduction of dung beetles has been used as a grassland management decision in other parts of the world. For example, in Eastern Island, the species *Onitis vanderkelleni* (Lansberge)and *Onthophagus gazella* (Fabricius) were introduced for grassland management purposes, and the last was introduced in Australia and other countries, too [17, 18]. In America, *O. gazella*, native to sub-Saharan Africa, is now introduced in the United States of America, Mexico, Guatemala, Nicaragua, some Caribbean islands, Colombia, Venezuela, Brazil, Peru, Bolivia, Paraguay Uruguay and Eastern Island and has not been recorded from continental Chile.

Dung beetles have received great attention in recent years due to their higher agro-ecological importance in crops and environmental management, especially due to their role in increasing soil fertility and parasites control in cattle. So much so that it is estimated that biological activity of dung beetles reaches an economic contribution to agriculture of US$380 million per year in the USA [19–21]. Dung beetles are also considered key important due to ecosystem services they provide worldwide by eliminating the remains of manure, derived from livestock production systems. These services are directly related to improving yields and crop sustainability; in addition, seeds dispersion become significant importance in reforestation, restoration and conservation of forests [19, 22–24].

Dung beetles have had great religious importance since ancient times, at such a point that have been considered as religious symbols in rituals or, as deities. Besides, beetles have been used as food, in medicine, and have played important roles in traditional culture and folklore (see Refs. [25–28]). Egyptians emphasized at that point, who observed dung beetles behavior and their ecology over 5000 years, and even compared a beetle with their deity, god Khepri. Beetles were considered sacred by Egyptians due to the role they played in the renewal, transformation and resurrection of life. There were four aspects that determined the relationship between facts and the biological-theological explanation [29]: (1) beetles looking for droppings, something to what the Egyptians attributed a sacred character; (2) a beetle rolling a ball of dung and burying it in the ground; (3) the fact that most of their metamorphosis occurred underground; and (4) the fact that eggs hatch and restart the life cycle.

Dung beetles have been used as bio-indicators during the last three decades and also in biological models [23, 28, 29]. However, productive practices in croplands, prairies and even forests have lowered significantly the biodiversity of dung beetles, mainly due to the negative effects of chemical control against weeds and pests, such as herbicides and pesticides, as, for example, when controlling the horn fly (*Haematobia irritans*), or internal parasites of cattle (see Ref. [24]).

A decline in the population of dung beetles in prairies has great importance in intensive livestock production systems, where the greatest accumulation of manure cannot be eliminated by native insects. In those cases, as a management measure, entomologists propose the introduction of exotic dung beetle species. However, previous to such decisions, it becomes necessary to carry out studies for assessing possible losses of native species, as it has already happened in other parts of the world, such as in Colombia where the release of *O. gazella* would have produced smaller populations of native dung beetles [30–32]. The exotic *O. gazella* was released in Texas, USA in 1972, and since that year, the species have been widely spread across most of the countries of South America. This fact would indicate this species is affecting native populations of native dung beetles [33].

There are 10 native species identified in the literature as native species of dung beetles in Chile, four paracoprids and five telecoprids with no records of endocoprids [34]. They are *Frickius costulatus*, *Frickius variolosus*, *Taurocerastes patagonicus*, *Homocopris torulosus*, *Homocopris punctatissimus* and 10 species of genus *Aphodius*, plus two introduced species, the *O. vanderkelleni* and *O. gazella* [29, 33]. There are two species from subfamily Aphodiinae in La Araucanía, *Podotenus fulviventris* and *Aphodius pseudolividus* [34, 35]. The native paracoprids and telecoprids are detailed in **Table 1**.

Feeding class	Family	Species
Paracoprids	Geotrupidae	*Frickius costulatus* (Germain, 1897)
		Frickius variolosus (Germain, 1897)
	Scarabaeidae	*Homocopris torulosus* (Eschscholtz, 1822)
		Homocopris punctatissimus (Curtis, 1844)
Telecoprids	Scarabaeidae	*Megathopa villosa* (Eschscholtz, 1822)
		Scybalophagus rugosus (Blanchard, 1843)
		Tesserodoniella elguetai (Vaz de Mello and Halffter, 2006)
		Tesserodoniella meridionalis (Vaz de Mello and Halffter, 2006)
	Geotrupidae	*Taurocerastes patagonicus* (Philippi, 1866)
Endocoprids	Scarabaeidae	No records and there is not any species reported uncertain. *Podotenus* (*Podotenus*) *fulviventris* (Fairmaire and Germain, 1860)

Table 1. Native species of dung beetles in Chile according to nesting behavior.

There are few studies on both native and introduced dung insects in South Central Chile. One study in horse droppings was focused on the biology of *H. torulosus* (previously known as *Pinotus* or *Dichotomius torulosus*) [30, 35–38], *F. costulatus* [31], *A. pseudolividus* and *Megathopa villosa* [33]. In Los Rios region, there are some studies carried out during the autumn season to sample the presence and activity of dung beetles over grasslands [31, 34, 35]. Currently, there are no published records on the distribution and characterization of the environments in which it is possible to find these insects.

2. Methodology

The sample was conducted in five agro-ecological areas of La Araucanía Region covering approximately 3,184,200 ha (see Ref. [39]). La Araucania Region is located in Southern Chile and corresponds to a transitional zone between a dry Mediterranean and climate. As most of South Central Chile, the region is divided into five different landscapes: (1) coastal rain fed area (CRF) that includes the coast (west side of coastal range) and the coastal range; (2) the interior rain fed area (IRF) that includes the dry east-side of the coastal range; (3) the central plain (CP) that includes the flat lands of the central valley; (4) the pre-Andean area (PA) that includes lands of the piedmont of the Andes Mountains; and (5) the vo1canic Andean area (VA) that corresponds to Andes Mountains. The Pluviometry varies from west to east, with notorious lower precipitations in the east side of the coastal range. Temperature decreases from west to east in the measure altitude increases to up in the Andes. The differences in temperature and altitude determine some vegetation differences. Therefore, in the coastal range and its east side will be dryer with sclerophyll vegetation; the central valley will be a transition between sclerophyll and rainy temperate and evergreen forests, with these temperate forests covering until the piedmont of the Andes and, with changes in species distribution, leaving space to species better adapted to low temperature. At higher altitude, forests of Chilean monkey puzzle trees (*Araucaria araucana*), lenga birch (*Nothofagus pumilio*) or Ñirre birch (*Nothofagus antarctica*) take place replacing the species of the temperate forests.

In each agro-ecological area described above, we chose between 5 and 15 sampling areas based on the presence in pastures of manure from cattle and horses, and within native and exotic forests. The sampling areas were chosen and marked over the agroecologic map of the Araucanía Region [39].

At the same time, in each of these sampling areas, we chose as many as possible sampling points, where we sampled and measured the presence and abundance of insects in, over and around feces, and prepared a list of dung beetles. The sampling process was conducted during spring, summer and autumn, for 3 years (2008–2010). The observations were made during 30 minutes at each sampling place, and then samples with organic material were taken for analyses to laboratory. Once in the laboratory, the samples were compared against the material of reference (specimens) that are kept at Museum of Entomology, to assure a correct identification and classification of sample specimens. In a parallel procedure, the classification keys were examined in the literature. Insect samples were deposited in the Entomological collection at the Museum of Entomology.[1] Each sampling place was georeferenced using a GPS devise “Garmin”.

In addition to the sampling areas, we had installed two light traps. Such light traps included a container to receive the insects. The traps were 1.1 m high and weighted approximately 5 kg each. The traps contained an ultraviolet illumination tube of 43 cm long and 20 W.

One in a farm located in the urban border of Temuco city, southern Chile and the second in the Experimental and Model Farm Maquehue, located at 38°50′27.20S 72°41′34.32″W at 12 km far from Temuco city. Both traps were set up for 10 years (year 2000–2010). The samples from each light trap were collected on daily basis and taken to the laboratory, for analysis and specimen classification.

In relation to the scientific names, we followed the classification for the Scarabaeoidea of South America and the most recent taxonomy used in the literature [34, 35].

3. Results and discussion

In our prospection performed in the sampling process (2008–2010) and during years 2000 and 2010 (light traps), we found four species of dung beetles in La Araucanía, which are detailed in **Table 2**.

Feeding class	Family	Species
Paracoprids	Geotrupidae	*Frickius variolosus* (Germain, 1897)
	Scarabaeidae	*Homocopris torulosus* (Eschscholtz, 1822)
Endocoprids	Scarabaeidae	*Podotenus fulviventris* (Fairmaire and Germain, 1860)
		Aphodius pseudolividus (Balthasar, 1941)

Table 2. Native species of dung beetles sampled in La Araucanía, Chile, period 2000–2010 according to nesting behavior.

We did not register the rest of dung beetles described in the literature nor the exotic ones. Apart of those detailed in **Table 2**, we would have expected to find in La Araucanía Region, the native species *H. punctatissimus* (Curtis, 1844), a species recently revalidated, *M. villosa* (Eschscholtz, 1822), and *F. costulatus* (Germain, 1897) [29, 33, 35]. In regards the introduced species *O. vanderkelleni* (Lansberge) and *O. gazella* (Fabricius), we did not succeed at registering them, in spite the fact their presence have been previously reported for Easter Island, an insular Chilean territory, and cited for different parts around the world [34, 37–40].

From the four species recorded in the study, *F. variolosus* and *H. torulosus* were found present in most of the samples along the year, while *P. fulviventris* always was recorded in early spring

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and in huge amounts, with approximately 1800 individuals per feces, from both cattle and equine. However, *A. pseudolividus* was always recorded in the period from late February until mid-May to June, with counts of 4000 individuals per feces from cattle and equine. According to our literature review, there is no other record on this behavior; therefore, the current sample observations are the very first time this behavior is observed.

Regarding the seasonal flight of the two species *Aphodius* registered in this study (**Figure 1**), it is seen that, adult specimens of *A. pseudolividus* appeared between February and April, with a higher population peak in March. However, the adult specimens of *P. fulviventris* appeared in large quantity, in feces from cattle and equine, only between September and October.

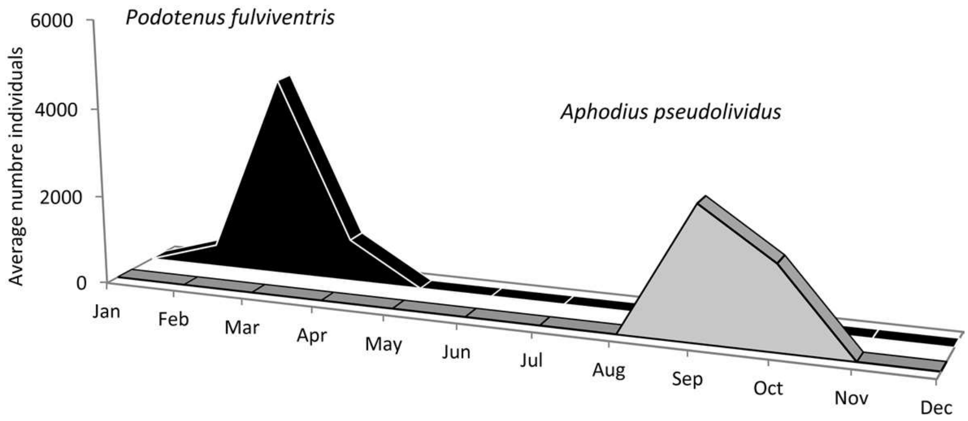

Figure 1. Flight and seasonal abundance of adults *of A. pseudolividus* and *P. fulviventris*.

Results indicate these species have completely unknown behavior in regards their univoltine life cycle. At least, one can know where they are when adults do not appear. It is interesting the fact that adults of both species coexist with adults of *H. torulosus* and *F. variolosus*. Apparently, there would be competition for the resource (feces) by having each species, a different feeding strategy (Paracropid and endocropid).

Regarding the samples collected with the light traps (**Figures 1** and **2**), specimens of *A. pseudolividus* and *H. torulosus* showed to be strongly attracted to light. However, it must be noted that specimens of *P. fulviventris* were not captured by these traps, but by manual collection. Adult specimens of *H. torulosus* showed to have a seasonal flight over the year, with a decrease in population in winter (July), when no adults flight, and an increasing population from August onwards, reaching a higher peak of individuals in late summer (February–March). It was difficult to determine the quantity of generations per year, given the fact that adults flight almost the whole year; however, we assume that there were present at least two generations a year (bivoltine). This situation should be validated and checked in the field in future research.

It was found that *H. torulosus* was sharing the food resource with *F. variolosus*, *P. fulviventris* and *A. pseudolividus* as adults. It was usual to find specimens of *H. torulosus* and *F. variolosus* together in the same dung, from equine and cattle. The number of individuals varied greatly from one sample to another, at sampling altitude near 500 m, was the two species are sympatric (**Figure 3**).

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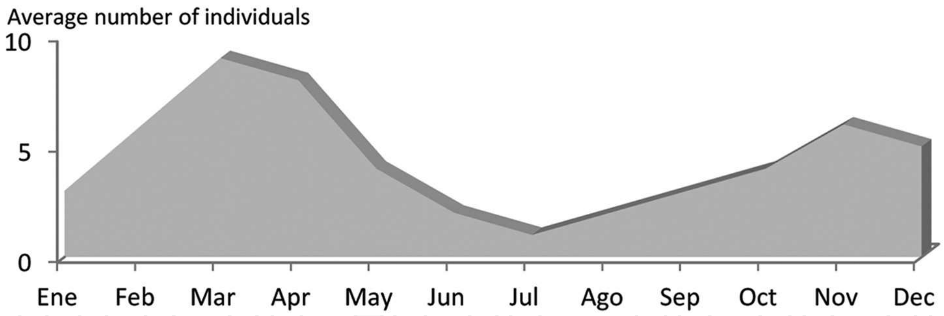

Figure 2. Flight and seasonal abundance of *Homocopris torulosus*, 10-year average 2000–2010 of monthly average registered by light traps at Maquehue, Temuco.

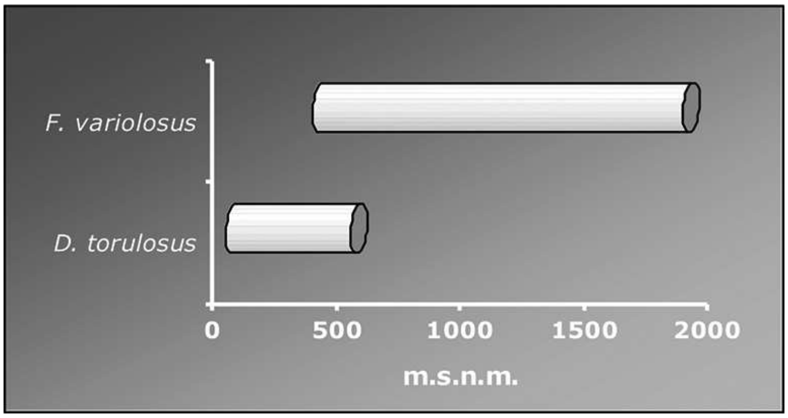

Figure 3. Altitudinal distribution pattern of *H. torulosus* and *F. variolosus*.

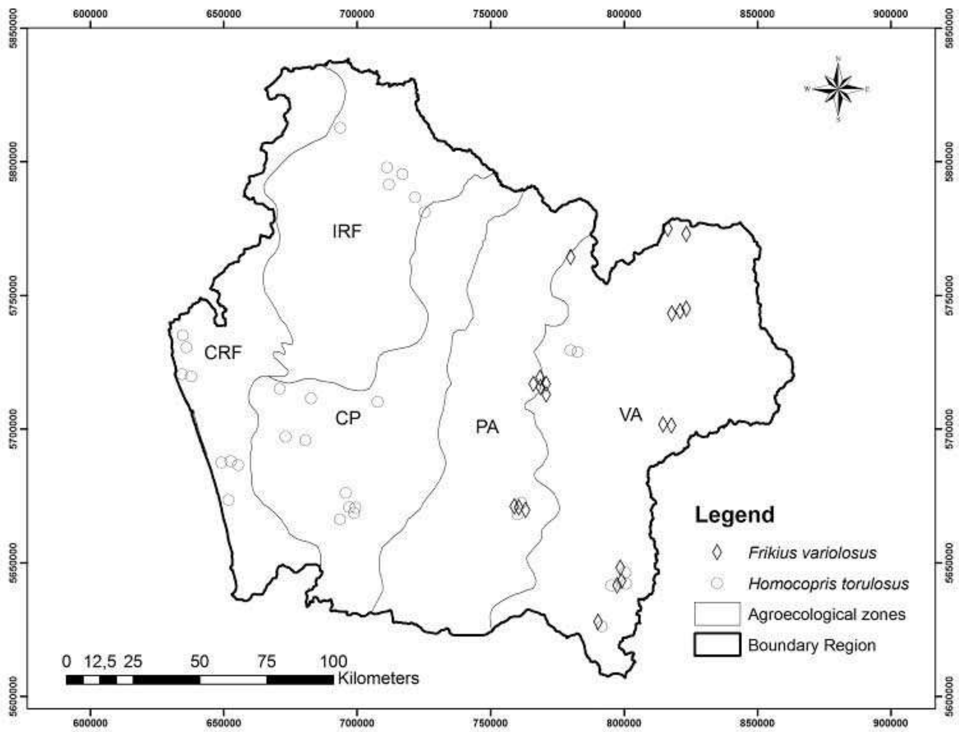

Figure 4. Distribution of *H. torulosus* and *F. variolosus*, across agro-ecological areas (CRF—coastal rain fed; IRF—interior rain fed; CP—central plain; PA—Pre Andean; VA—Vo1canic Andean).

Regarding the distribution of species in La Araucanía Region (**Figures 4–6**), it should be noted that according to the sampling methodology, where the observations were made at different times, we were able to describe the sample distribution of *H. torulosus* and *F. variolosus* over time.

Figure 5. Adults of *Homocopris torulosus*.

Figure 6. Adults of *Frickius variolosus*.

In **Figure 4**, we can see that both species are well distributed across the region, but *H. torulosus* is distributed between 0 and 850 m above level and *F. variolosus* was recorded as present between 400 and 2000 m above sea level (**Figure 3**). We registered between 1 and 50 specimens per dung (**Figure 2**) with a marked tendency of insects to prefer horse feces, in occurrence and abundance. On the other hand, *F. variolosus* was registered at altitude higher than 500 m. We could not identify a preference of *F. variolosus* for dung from a particular animal. Sample indicated that specimens of *F. variolosus* preferred sectors in the piedmont of the Andes. The registered abundance of *F. variolosus* was from a couple up to 250 of specimens per dung, which coincides with previous reports (see Ref. [29]).

In regards the preference for a type of vegetation, samples were taken in both native forest and forestry plantations and, according to registered data, both specimens of *H. torulosus* and *F. variolosus* preferred native forest to plantations.

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4. Conclusions

According to the present study, we found evidence that dung beetles are well distributed in La Araucania region, where we were able to collect specimens from four species. They are *H. torulosus*, *F. variolosus*, *P. fulviventris* and *A. pseudolividus*.

All the species registered in this study are native. It is worth to mention that we did not find any specimen of those introduced species two decades ago. Besides, we could not find any record of previous studies that have found any specimen from such introduced species, which help in confirming our findings.

Also, we could not find any evidence, as mentioned in the literature, that dung beetles are present in higher frequency in manure located in native forests. We only could confirm that dung beetles are abundantly present in manure, independently of the type of cattle or type of forest (native or exotic) or vegetation cover, that is, they are present in forests, grasslands or any vegetation cover where there is manure that have been directly deposited over the ground by cattle. It is worth to note that dungs from wild animals like puma or foxes were not checked as part of this study.

The distribution of *H. torulosus* across La Araucania regions goes from 0 to 2000 m above sea level, while *F. variolosus* is distributed from 350 m and higher. In this study, we have registered for very first time the behavior of adults' specimens of *A. pseudolividus* that showed a higher abundance of higher than 1500 individuals per feces in the period from end of summer until late mid-Autumn (February until mid-May).

Finally, in the particular case of *P. fulviventris*, on who there is no previous published records on its habits, this study constitutes the first publication describing aspects on its biology, for example, that adults appear in very high densities in September and that they share the good substrate with *F. variolosus* and *H. torulosus*, and apparently, without any competition problems for the food resource.

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