Diversity of the dung beetles (Coleoptera: Scarabaeinae) in an altitudinal gradient in the east slope of los Andes, Napo province, Ecuador

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**ABSTRACT**
We present a preliminary analysis of the diversity of dung beetles in an altitudinal gradient on the East slope of los Andes, Napo province, Ecuador. We sampled 12 localities within a 2200-m altitudinal gradient (400–2600 m a.s.l.) using pitfall traps with 2 different baits. We registered 2215 individuals distributed within 14 genera and 54 species. Ontherus pubens was the most abundant species, with registers in 10 locations that cover an altitudinal gradient of 2021 m. We also found species associated to low, medium, and high elevation levels, as well as species located on either extreme of the altitudinal gradient. The most abundant genus was Onthophagus, and the most speciose Uroxys. This survey provides 14 new registers for the Napo province and 5 novel registers for Ecuador. We present a detailed list of the species present in the Napo province with their distribution ranges, relocation guilds, and food resource preferences.

**Introduction**
Insects are one of the most diverse animal groups present in the tropics [1]. In the Neotropics in particular, there are areas of very high endemicity like the Amazon Region and the high mountain forests of the Andes [2,3]. Despite this great diversity and high endemicity, there are large areas that haven't been inventoried and their species richness remains unknown. This is the case for various regions in Ecuador, especially of the province of Napo for which a comprehensive list of their entomofauna is lacking [4].

One of the better studied insect groups in the Neotropics are dung beetles (Coleoptera: Scarabaeidae: Scarabaeinae). The geographical distribution of many of their species is well documented and there are several complete reviews for various genera [5–10]. Currently, they account for more than 6000 species distributed within 250 genera worldwide [11,12], and 2000 species in 91 genera in the Neotropics [13]. However, there are still many areas that haven't been sampled or that need more detailed catalogs [14,15]. This is especially true for altitudinal gradients in South America, and in particular for the Andean Mountains, for which very few countries in the region present complete surveys (Bolivia [16]; Brazil [17]; Colombia [18–22]; Ecuador [23]; Ecuador-Perú [24]; Perú [25,26]).

Dung beetles have been extensively studied given their fundamental role in ecosystems as recyclers of the organic material produced by vertebrates, contributing to nutrient turnover in the principal biochemical cycles [27]. The majority of their species have coprophagous habits, but there are others that use different resources such as carrión, fungi, or decaying plant material [28]. Functionally speaking, there are three large guilds depending on the type of relocation of their trophic resource: tunnelers (paracoprids, which make tunnels under their trophic resource), rollers (telecoprids, who transport a portion of their trophic resource as a ball), and dwellers (endocoprids, who live within their food resource) [29]. In addition, these beetles are biological indicators in environmental impact assessment given their sensitive response to changes caused by different anthropic pressures such as deforestation, selective logging, burning, fragmentation, and hunting of mammals [27,30]. Our main objective is to describe the diversity pattern of dung beetles along an altitudinal transect in Napo province. We hypothesized a strong reduction on richness and abundance, and a replacement pattern between relocation guilds and food preferences of the dung beetles along the gradient. In addition, we present a list of the dung beetles, which constitutes new registers for the province of Napo and new registers for Ecuador.

**Methods**

**Study site**

The province of Napo, with capital in Tena (00°59′46″ S, 077°48′49″ W), is located in north-central Ecuador within the Amazon Region and presents a surface area of 13,342 km\(^2\) (Figure 1). The area presents a bimodal rainfall regime with two peaks, one in May–June (428 mm/month) and the other in October (339 mm/month). Summer is in August (157 mm/month) and the annual

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The average rainfall is 4039 mm [31]. The altitudinal gradient ranges from 300 to 4000 m above sea level (a.s.l.) given the confluence of three bioregions: Amazon forests in low elevation areas, foothills and mountain forests in intermediate areas, and the Andean region with Andean cloud forests and paramos in high elevation areas [32]. However, the region is under intense anthropic pressure by wood extraction and establishment of pastures for cattle and farming areas causing an increase in deforestation [33].

Data collection
From October to November 2013, a survey was performed in 12 localities covering an altitudinal gradient from 400 to 2600 m a.s.l., which was sampled every 200 m (Figure 1). All localities were accessed through the Pan-American route following the trajectory Papallacta–Baeza–Tena–Misahualli. In each of the 12 localities, 2 parallel linear transects (separated 50 m) were established with 5 sets (separated 25 m) of 2 pitfall traps (500 ml bucket with 250 ml of soap water and separated 1 m): 1 trap containing human dung bait (15 g) and another trap with rotting fish bait (15 g) [34,35]. Overall, a total of 20 pitfall traps were placed per locality, adding up to 240 for the entire gradient. Traps were active for 48 h. The samples collected were stored in ziploc bags containing 75% alcohol and were transported to the laboratory at the National Polytechnic School (Quito-Ecuador). To identify specimens to species level, we used different taxonomical keys [5–7,9,10,13,36], the comparison with material deposited at the Entomological Collection of the Museum, and the assistance of taxonomical experts of this group. All samples collected were deposited (deposit code: SI-MEPN-81) in the public Entomology Collection of the “Gustavo Orces V” National History Museum within the National Polytechnic School (MEPN). Vouchers catalog number goes from MEPN 42324 to MEPN 44439.

Data analysis
For the classification of dung beetles into the three resource allocation guilds (tunnelers, rollers, and dwellers), we follow the traditional arrangement [29] associated to genus information. Food preferences groups were defined by the percentage of individuals collected in each type of bait (dung: coprophages or carrion: necrophages): when the proportion of individuals was less than 75% of one of the two baits, the species was assigned to the generalists group. We decided not to include the information related to the taxonomic level of tribe for each genus because at the moment many Neotropical genera are without tribal affiliation [37].

Results
A total of 2215 individuals distributed within 14 genera and 54 species of dung beetles were registered (Table 1). We validate our initial hypothesis, founding a strong reduction on richness and abundance and an
Table 1. List of dung beetles species recorded along an altitudinal gradient (400–2600 m a.s.l.) in Los Andes, province of Napo, Ecuador.

| Species | RG | Ind. (%) | Altitudinal range | NR |
|---------|----|----------|-------------------|----|
| Canthidium centrale | Tg | 95 (4.3) | 412–587 | – |
| Boucomont, 1928 |
| Canthidium convexifrons | T- | 5 (0.2) | 1376–1872 | – |
| Balthasar, 1939 |
| Canthidium splendidum | Tg | 23 (1.0) | 1868–1872 | – |
| Preudhomme, 1886 |
| Canthidium cf. bicolor | T- | 2 (0.1) | 412 | – |
| Boucomont, 1928 |
| Canthon sp. 1 | Tg | 11 (0.5) | 1572–2079 | – |
| Canthon sp. 2 | T- | 8 (0.4) | 1431, 2079 | – |
| Canthon aberans (Harold, 1868) | R- | 1 (0.1) | 2079 | * |
| Canthon aequinociliatus Harold, 1868 | | | 436 | – |
| Canthon angustatus Harold, 1867 | R- | 2 (0.1) | 436 | – |
| Canthon luteicollis (Erichson, 1847) | Rc | 33 (1.5) | 412–608 | – |
| Canthon politus Harold, 1868 | Rc | 40 (1.8) | 2098–2243 | – |
| Canthon cf. parile Bates, 1867 | Rg | 131 (5.9) | 412–608, 1376–1872 | – |
| Dicotomius batesi (Harold, 1869) | Tc | 13 (0.6) | 608–905, 864 | – |
| Dicotomius inachus (Erichson, 1847) | T- | 2 (0.1) | 436 | – |
| Dicotomius mamillatus (Felsche, 1871) | T- | 8 (0.4) | 587–608 | – |
| Dicotomius ohausi (Luederwaldt, 1922) | Tg | 58 (2.6) | 412–905, 1341–2243 | – |
| Dicotomius podalirius (Felsche, 1901) | T- | 4 (0.2) | 587 | – |
| Dicotomius satanas (Harold, 1867) | Tc | 100 (4.5) | 608 | – |
| Eurysternus caribeus (Herbst, 1789) | Dg | 46 (2.1) | 1868–2433 | – |
| Eurysternus cayennensis Castelnau, 1840 | Dg | 109 (4.9) | 587–726 | – |
| Eurysternus concinnus Jessop, 1985 | D- | 9 (0.4) | 436 | – |
| Eurysternus hirtellus Dalman, 1824 | Dg | 22 (1.0) | 587, 1152 | – |
| Eurysternus plebejus Harold, 1880 | D- | 5 (0.2) | 587–905 | – |
| Eurysternus velutinus Bates, 1887 | Dg | 10 (0.4) | 587–608, 1376 | – |
| Ontherus diabolicus Géneri, 1996 | Tc | 31 (1.4) | 1872 | – |
| Ontherus incisus (Kirsch, 1871) | T- | 1 (0.1) | 905 | – |
| Ontherus pubens Géneri, 1996 | Tc | 331 (14.9) | 412–2433 | – |
| Ontherus teniastrasus Géneri, 1996 | T- | 4 (0.2) | 1866–2098 | – |
| Onthophagus nycticus Bates, 1887 | Tc | 220 (9.9) | 412–1376 | – |
| Onthophagus rhinophilus Harold, 1868 | Tg | 43 (1.9) | 412–1376 | – |
| Onthophagus sp. 1 | T- | 1 (0.1) | 608 | – |
| Onthophagus sp. 2 | Tc | 148 (6.7) | 2098–2243 | – |
| Onthophagus sp. 3 | T- | 2 (0.1) | 587, 2243 | – |
| Oxymeron conspicillatum (Weber, 1821) | Tc | 1 (0.1) | 587 | – |

Table 1. (Continued).

| Species | RG | Ind. (%) | Altitudinal range | NR |
|---------|----|----------|-------------------|----|
| Oxyystemon silenus (Castelnau, 1840) | Tg | 48 (2.2) | 412–905 | – |
| Phanaeus chalcoreus (Perty, 1830) | T- | 1 (0.1) | 1431 | – |
| Phanaeus haroldi Kirsch, 1871 | T- | 5 (0.2) | 412, 905 | – |
| Scolybacanthus maculatus (Schmidt, 1822) | Rg | 71 (3.2) | 905–1431 | * |
| Sylvicathanus bridilli Martinez, 1949 | Rc | 39 (1.8) | 1431–1872 | * |
| Uroxys boneti Pereira & Halfier, 1961 | Tc | 136 (6.1) | 436, 1872–2243 | * |
| Uroxys rugatus Boucomont, 1928 | Tg | 25 (1.1) | 1431–2433 | – |
| Uroxys cf. micros Bates, 1887 | Tc | 46 (2.1) | 1872–2243 | – |
| Uroxys sp. 1 | T- | 1 (0.1) | 1872 | – |
| Uroxys sp. 2 | T- | 7 (0.3) | 436–587 | – |
| Uroxys sp. 3 | T- | 1 (0.1) | 587 | – |
| Uroxys sp. 4 | T- | 5 (0.2) | 2098 | – |
| Uroxys sp. 5 | T- | 7 (0.3) | 1431 | – |
| Total abundance | | | 2215 | – |

RG: relocation guild (T: tunneler, R: roller, and D: dweller) and bait preference (c = coprophagous, n = necrophagous, and g = generalists). Ind. (%): abundance and relative total abundance in brackets for each species. Altitudinal range in meters (m a.s.l.); for each species. NR: *new state record, **new country record.

accentuated replacement pattern between relocation guilds and food preferences of the dung beetles along the altitudinal gradient (Figure 2-4). Of the all species collected along the altitudinal gradient, we found 14 new records for the province of Napo (Table 1) and 5 were new records for Ecuador: Canthidium convexifrons, Canthidium splendidum, Deltochilum howdeni, Ontherus teniastrasus, and Onthophagus nyctopus. The most abundant species of the survey was Ontherus pubens (n = 331, 14.9%), also with the higher number of localities (n = 10), and with the wider altitudinal range (412–2433 m a.s.l., r = 2021 m), followed by O. nyctopus (n = 220, 9.9%) and Deltochilum spinipes (n = 158, 7.1%). Of the 54 registered species, 8 (14.81%) are represented by only 1 individual (Canthon aberans, Deltochilum orbiculare, Ontherus incisus, Onthophagus sp. 1, Oxymeron conspicillatum, Phanaeus chalcoreus, Uroxys sp. 1, and Uroxys sp. 2). In addition, 17 species were registered in a unique locality, the most abundant of them being Ontherus diabolicus (n = 31, 1.4%). Along the altitudinal gradient, we observed species that were associated to low elevation areas (Dichotomius mamillatus, Dichotomius podalirius, Canthon aequinociliatus, Deltochilum amazonicum, Deltochilum barbipes, D. howdeni, Eurysternus caribeus, and Eurysternus confusus), intermediate altitudes (C. splendidum, O. diabolicus, Scolybacanthus maculatus, and Syllicchanthus bridilli), and high elevation areas (Uroxys cf. micros, Canthon politus, and D. spinipes) (Table 1). A couple of species, Canthidium cf. bicolor (412/2098 m a.s.l.) and Onthophagus sp. 3 (587/2243 m a.s.l.), were collected only on the extremities of the altitudinal gradient, being absent in intermediate levels.
Onthophagus was the most abundant genus (\(n = 414, 18.7\%\)), followed by Ontherus (\(n = 367, 16.6\%\)) and Deltochilum (\(n = 325, 14.7\%\)). The scarcest genus was Phanaeus with only six individuals (0.3%). The most speciose genus was Uroxys (\(n = 8, 14.8\%\)), followed by Canthidium, Dichotomius, Deltochilum, and Eurysternus, each one with six species. Contrariwise, four genera were represented by only one species (Coprophanaeus, Cryptocanthon, Scybalocanthon, and Sylvicanthon). Five genera (Canthon, Dichotomius, Deltochilum, Ontherus, and Onthophagus) presented the broadest elevational range along the gradient, from 412 to 2433 m a.s.l. (\(r = 2021\) m). Two genera associated to intermediate elevations presented relatively narrow altitudinal ranges along the gradient: Cryptocanthon (1376–2079 m a.s.l., \(r = 703\) m) and Scybalocanthon (905–1431 m a.s.l., \(r = 526\) m). The genus with the most restricted altitudinal range (1431–1872 m a.s.l., \(r = 441\) m) was Sylvicanthon. The genera Oysternus and Eurysternus disappeared rapidly along the gradient; only one species was found above 1200 m a.s.l. (Eurysternus velutinus), and only in the locality at 1376 m a.s.l. (Figure 2).

In relation to trophic resource relocation guilds, we found that tunnelers (\(n = 1441, 65.1\%\)) were the most abundant, then rollers (\(n = 573, 25.8\%\)), and lastly dwellers (\(n = 201, 9.1\%\)). In terms of species richness, this order was maintained with tunnelers (\(n = 34, 62.9\%\)), rollers (\(n = 14, 25.9\%\)), and dwellers (\(n = 6, 14.8\%\)).
11.1% (Figure 3). Tunnelers were present at all altitudes (412–2433 m a.s.l.), while rollers only reached the 2243 m a.s.l. and were absent in the last localities. The dwellers’ altitudinal range was more restricted as they were last seen at 1376 m a.s.l.

Resource food preference groups (coprophages, necrophages, and generalists) displayed differential altitudinal distributions. We observed that coprophages were more abundant at 1200 m a.s.l. and at the 2000–2400-m a.s.l. interval, necrophages are only found at three altitudes (400, 600, and 1400 m a.s.l), and generalists were more abundant at two intervals: 400–600 and 1400–1600 m a.s.l (Figure 4). At 800, 1000, and 1800 m a.s.l., the proportion of coprophages to generalists was near to 1:1.

**Discussion**

In comparison to other nearby localities or to other altitudinal gradients in the Neotropics, this location has been determined a region of high biodiversity for Ecuador (Table 2). In this study, we found 14 new records for the province of Napo, and 5 new records for Ecuador (*C. convexifrons, C. splendidum, D. howdeni, O. tenuistriatus*, and *O. nyctopus*), that hadn’t been cited before in the existing references [4,23,24,38–47]. For *C. cf. bicolor* and *Onthophagus* sp. 3 that were collected on the extremities of the altitudinal gradient, we believe further revision is necessary, advocating an increased sampling effort and cryptic species verification. It is also possible that the extreme range distribution observed for these species is a result of the complex orography (i.e. steep slopes) at intermediate elevation levels within the altitudinal gradient, which complicated access and sampling at these sites.

Resource food preference groups displayed differential altitudinal distributions. Coprophages were more abundant at high levels, while necrophages were only present at specific altitudes (400, 600, and 1400 m a.s.l.) not revealing a clear pattern, and generalist species were more abundant at middle levels (1400–1600 m a.s.l.). We believe that the main food source along the altitudinal gradient is excrement, preferentially coming from

![Figure 4. Dung beetles species bait preference (coprophagous, necrophagous, and generalists) in the altitudinal gradient (400-2600 m a.s.l.) in Los Andes, province of Napo, Ecuador.](image)

| Country        | Locality             | Sp. | Altitude range (m a.s.l.) | References |
|----------------|----------------------|-----|--------------------------|------------|
| Bolivia        | Mosetenes            | 30  | 1250–1600 (350)          | [16]       |
| Brazil         | Serra do Cipo        | 56  | 800–1400 (600)           | [17]       |
| Colombia       | Eastern Cordillera a | 101 | 1000–2500 (1500)         | [18]       |
| Colombia       | Sierra Nevada b      | 57  | 0–2600 (2600)            | [19]       |
| Colombia       | Sierra Nevada        | 29  | 50–940 (890)             | [20]       |
| Colombia       | Narino paramos 5     | 4   | 2800–3750 (950)          | [21]       |
| Colombia       | Sierra Nevada        | 43  | 480–2890 (2410)          | [22]       |
| Ecuador        | Cordillera de Cutucú | 105 | 500–2000 (1500)          | [23]       |
| Ecuador        | Napo                 | 54  | 400–2600 (2200)          | (this work) |
| Ecuador-Perú   | Cordillera del Condor| 18  | 1000–1500 (500)          | [24]       |
| Perú           | Reserva Megantoni    | 71  | 730–2210 (1480)          | [25,26]    |
| Perú           | Valle Koshihata      | 82  | 650–3200 (2550)          | [25,26]    |

*a* This study includes five different localities on the eastern slope of the Eastern cordillera of the Andes.

*b* This study includes a complete biogeographic province.

*c* This study includes a big biogeographic area covering the whole department.
primates in low elevation areas, but supplemented by cattle excrement in high elevation areas.

We propose certain species that have a limited altitudinal range due to their association with pristine habitats as potential bioindicators for monitoring and conservation plans such as *S. bridarolli*, *Eurysternus cayennensis*, and *E. caribaeus*. Species like *Oxysternon silenus* and *Coprophanaeus telamon* are typically found in coffee plantations, and we propose *Canthidium aff. bicolor* as a species that prefers riverside habitats and swamp forests.

It is necessary to study deeply the collected material that could not be identified up to the species-level and the species that need confirmation (“cf.” and “aff.”), in order to finish the list for this region. Likewise, it is important to keep performing this type of studies in other localities and during different times of year, not only to complete the species inventory of Napo and Ecuador but also to understand the spatiotemporal dynamics of the altitudinal transects in the Neotropics.

**Acknowledgments**

The authors thank the “Gustavo Orces V.” National History Museum and the National Polytechnic School. We thank Vladimir Carvajal for his priceless help during the identification process of the samples. To the Ministry of the Environment, and the Provincial Direction of Napo for providing the scientific investigation permit Number 36-IC-FAU/FLO-DPAN/MA. We are grateful for the comments of two anonymous reviewers who improve the quality of the manuscript. VE was supported by a COLCIENCIAS-Colombia PhD scholarship.

**Disclosure statement**

No potential conflict of interest was reported by the authors.

**Funding**

This work was supported by the Colciencias [COLCIENCIAS/JAN]; Senescyt [SENESCYT/VRE].

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