Current status of dung beetles (Coleoptera, Scarabaeidae, Scarabaeinae) diversity and conservation in Natural Protected Areas in Chiapas (Mexico)

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Abstract
Natural Protected Areas (NPAs) are consider adequate tools for biodiversity conservation. Currently in Mexico there are 182 federal NPAs classified according to their management objectives. Chiapas is the Mexican state with the highest number of decreed NPAs and also allocates one of the largest territorial extensions for its protection. Unlike other taxa, and despite their proven ability to respond to ecosystem changes, the study of dung beetles within Mexican NPAs has been underestimated, as they are not considered as a priority group within their management and conservation programs. Based on the review of information available in publications and database on dung beetles, a list of 112 species and seven subspecies recorded in 16 of the 19 federal NPAs established in Chiapas is presented. The species recorded by each NPA show a significant correlation with the number of publications, but a
low percentage of them correspond to studies with systematic samplings and most of the species reported in several of the NPAs come from sporadic records, which prevents the study of several basic and applied aspects of dung beetles in the region. Therefore, studies that extensively analyze the communities of arthropod groups, such as the Scarabaeinae, are necessary to understand their response to changes in the ecosystem at local and regional scale. It is advisable that these insects be included in the previous justifying studies for the designation or establishment of NPAs and, in turn, considered in the biological monitoring programs of these areas for their capacity as a bioindicator group.

**Keywords**

bioindicator, biological monitoring, corridor, Faunistic complex, management, NPAs

**Introduction**

Natural Protected Areas (NPAs) are considered the main tool for the conservation of biological diversity worldwide (Bezaury-Creel and Gutiérrez Carbonell 2009). These are defined as areas that have been designated and regulated to achieve specific objectives of conservation, protection and maintenance of biological diversity, as well as associated natural and cultural resources (Dudley and Stolton 2008; Gillespie 2009). Mexican legislation conceptualizes NPAs as areas where the original environments have not been significantly altered by human activities, which need to be preserved or restored and are subject to the protection regime of the General Law of Ecological Balance and Environmental Protection (LGEEPA in Spanish) (SEMARNAT 2018).

The federal NPAs are those that are not restricted to a geopolitical limit within the Mexican territory and are managed by the National Commission of Natural Protected Areas (CONANP 2016). Currently, Mexico has a total of 182 federal NPAs that occupy about 13% of the national territory and are grouped into six different categories according to their management objectives and by the type of zoning that they may be subject to (Table 1) (Íñiguez et al. 2014; CONANP 2016). For now, Chiapas is the Mexican state with the highest number of decreed NPAs (n = 19) being the one that assigns one of the largest territorial extensions for its protection, as it is located in one of the zones richest in biodiversity and natural resources from the country (CONANP 2016).

The dung beetles of the subfamily Scarabaeinae (Coleoptera: Scarabaeidae) are a group of insects with a wide global distribution, finding representatives on all continents (except Antarctica), but whose diversity is mainly concentrated in the tropical and subtropical regions (Scholtz et al. 2009). The ecological functions in which these beetles are involved provide valuable ecosystem services, such as secondary seed dispersal, nutrient cycle and biological control of pests, among others (Nichols et al. 2008). Moreover, different authors have indicated that these arthropods are organisms sensitive to structural changes in habitats caused by disturbances, exhibiting drastic permutations in their development and distribution in the modified landscapes (Halffter and Favila 1993; Halffter and Arellano 2002; Arellano and Halffter 2003; Reyes-Novelo et al. 2007; Otavo et al. 2013; Mannu et al. 2018).
In order to understand the links between ecological functions and ecosystem services they offer, some authors have proposed the subfamily Scarabaeinae as a focus group for applied research in biodiversity conservation (Spector 2006; Nichols and Gardner 2011), categorizing it as a bioindicator that allows adequate monitoring of the impact of anthropic alterations in tropical forests (Halffter and Favila 1993; Favila and Halffter 1997; Spector 2006; Nichols et al. 2007). Despite the bioindicator potential offered by this group of insects, their study in the Mexican protected areas has been underestimated and, unlike other taxa (e.g. mammals and birds), they are not considered within their management and conservation programs. This work aims to provide an overview of the distribution of the Scarabaeinae species in the federal NPAs of the state of Chiapas in order to create a reference point for future biodiversity projects and their monitoring in these territories.

### Materials and methods

#### Data source

Published studies on dung beetles species occurring in the federal NPAs of Chiapas (see Table 2) were checked in the academic databases Google Scholar (www.scholar.google.com), SciELO (www.scielo.org), Web of Science (www.isiwebofknowledge.com) and Scopus (www.scopus.com). This search was performed using commonly

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**Table 1.** Categories and main characteristics of the Mexican Natural Protected Areas, including their representativeness in Chiapas.

| Categories                  | Mexico            | Chiapas          | Characteristics                                                                 |
|-----------------------------|-------------------|------------------|--------------------------------------------------------------------------------|
| N                           | Extension in ha   | n                | Extension in ha (%)                                                            |
| Flora and Fauna Protection Area | 40                | 6,996,864.1      | 4                           | 24,980.7 (0.36) | Its focus is towards the species conservation. The objective is to conserve the habitats where wild flora and fauna live, develop and evolve. |
| Natural Resources Protected Area | 8                | 4,503,345.2      | 2                           | 198,551.5 (4.41) | Areas dedicated to the preservation and protection of soils, watersheds and natural resources of forestlands. It includes protection areas of national water bodies, especially when they are used to supply human populations. |
| Natural Monument            | 5                 | 16,269.1         | 2                           | 6,978.7 (42.90) | Specific sites that contain natural elements with an exceptional value of aesthetic, historical or scientific type. Extractive type exploitation is banned. |
| National Park               | 67                | 16,220,099.3     | 3                           | 29,583.4 (0.18) | They are sites with ecosystems that have mainly scenic beauty, historical, scientific, educational and recreational value, that preserve special flora and fauna and that present, above all, aptitude for tourism development. |
| Biosphere Reserve           | 44                | 62,952,750.5     | 7                           | 932,095.8 (1.48) | They are established in places that represent the diversity of the country’s ecosystems. Representativeness is also taken into account in terms of biological diversity and the presence of endemic, threatened or endangered species. |
| Sanctuary                   | 18                | 150,193.3        | 1                           | 212.5 (0.14)     | They stand out for maintaining a high species richness or species of restricted distribution in delimited sites. This includes ravines, relicts, caves, cenotes, caletas and other specific geographical units. |
| Total                       | 182               | 90,839,521.5     | 19                          | 1,192,402.6 (1.3) |                                                                                           |
Table 2. Characteristics of the 19 federal Natural Protected Areas decreed in Chiapas.

| Categories                        | Name                  | Acronym | Year of decree | Extension (ha) | Main vegetation types* |
|-----------------------------------|-----------------------|---------|----------------|----------------|------------------------|
| Flora and Fauna Protected Area    | Agua Azul             | APFFAA  | 1980           | 2,580          | TRF                    |
|                                   | Chan-Kin              | APFFCK  | 1992           | 12,184.98      | TRF, MRF, SV, HV       |
|                                   | Metzabok              | APFFM   | 1998           | 3,841.47       | TRF, ECF, OF, SV       |
|                                   | Nahá                  | APFFN   | 1998           | 3,368.36       | TRF, MRF, ECF          |
| Natural Resources Protected Area  | La Frailesca          | APRNF   | 1997           | 177,546.17     | TDF, TRF, MRF          |
|                                   | Villa Allende         | APRNVA  | 1939           | 21,005.27      | TDF, ECF, MRF, OF      |
| Natural Monument                  | Yaxchilán             | MNY     | 1992           | 2,621.25       | TRF                    |
|                                   | Bonampak              | MBN     | 1992           | 4,357.42       | TRF, MRF, ECF          |
| National Park                     | Cañón del Sumidero   | PNCS    | 1980           | 21,789.42      | TDF, MRF, XV, SV       |
|                                   | Lagunas de Montebello | PNLM    | 1959           | 6,022          | OF, ECF, SV            |
|                                   | Palenque              | PNP     | 1981           | 1,772          | TRF, G                 |
| Biosphere Reserve                 | Lacsán-Tun            | REBILA  | 1992           | 61,873.96      | TRF, HV                |
|                                   | Selva El Ocote        | REBISO  | 1982           | 101,288.15     | TRF, MRE, SV           |
|                                   | El Triunfo            | REBITRI | 1990           | 119,177.29     | MRF, ECF, TDF          |
|                                   | La Encrucijada        | REBIEN  | 1995           | 144,868.16     | M, MRF, TDF, CD        |
|                                   | La Sepultura          | REBISE  | 1995           | 167,309.86     | OF, PE, OPF, MRF, SV   |
|                                   | Montes Azules         | REBIMA  | 1978           | 331,200        | TRF, MRE, PO, ECF      |
|                                   | Volcán Tancán         | REBIVTA | 2003           | 6,378.37       | ECF, MRF               |

| Sanctuary                        | Playa de Puerto Arista| SPPA    | 1986           | 212.48         | CD, M, HV, TDF         |

TRF: tropical rainforest; MRF: mountain rainforest; TDF: tropical deciduous forest; ECF: evergreen cloud forest; PF: pine forest; POF: pine-oak forest; OPF: oak-pine forest; SV: secondary vegetation; XV: xerophytic vegetation; HV: hydrophilic vegetation; M: mangrove; CD: coastal dunes; G: grassland. *CONANP (2016). *According Breedlove (1981).

used keywords to name the species of the subfamily Scarabaeinae, as well as terms related to the designations of the NPAs of Chiapas and any possible combination between them (and equivalent terms in Spanish): “dung beetles”, “Scarabaeinae”, “coprophagous”, “necrophilous”, “copronecrophagous”, “Chiapas”, “National Park”, “Biosphere Reserve”, “protected area”, “rain forest”, “cloud forest”, “deciduous forest”, “La-candona rainforest”. Subsequently, a manual search of publications that potentially contained data on dung beetles was carried out to avoid the exclusion of information not contained in the academic databases (i.e. printed papers not available online), but bypassing literature that does not conform adequately to the bibliographic control standards (e.g. thesis or technical reports). According to the studies approach, the selected publications were classified into three general topics: 1) Taxonomic (works containing supra-specific monographic reviews and description of new species), 2) ecological/faunistic (systematic sampling with lists of species and analysis of assemblages of a specific region or location) and, 3) geographical distribution (works that include geographic range extension data). In addition, records were obtained from the Global Biodiversity Information Facility database (GBIF 2019).

Institutional acronyms

The records obtained from the GBIF database come from the following entomological collections:

CACH  Colección Entomológica, Facultad de Ciencias Agronómicas, Universidad Autónoma de Chiapas, Chiapas, México;
The list of species obtained was reviewed and updated according to the suprageneric designation proposed by Bouchard et al. (2011) and although there are 11 recognized tribes, only seven are found in Mexico. Supra-specific revisions of the genera *Canthon* (Rivera-Cervantes and Halffter 1999), *Coprophanaeus* (Edmonds and Zidek 2010), *Deltochilum* (Génier 2012; González-Alvarado and Vaz-de-Mello 2014; Silva et al. 2015), *Dichotomius* (López-Guerrero 2005), *Martinezidium* (Vaz-de-Mello 2008) and *Phanaeus* (Edmonds and Zidek 2012), were also taken into account because they include changes of status for several species on the list. Some species were omitted from the list and those records were considered erroneous or corresponded to incorrect geographic records (see discussion). Finally, a review of the red list of threatened species of the International Union for the Conservation of Nature (IUCN 2018) was carried out to include the status in which the species on the list could be considered.
Data analysis

We use simple linear regressions to determine the influence of the number of publications in each NPA and its area size (has) with the number of species that each one recorded. This analysis was performed in the R software (R Core Team 2019) and using the ggplot2 package (Wickham 2020). To determine any similarities in the species composition between NPAs, a cluster analysis was performed using the unweighted pair group method (UPGMA), calculated with the Simpson index in the software PAST v.3.26 (Hammer et al. 2001). To avoid bias due to faunistic disproportion and aggregation by inclusion, NPAs with a record equal to or less than five species were omitted from the similarity analysis.

Results

A total of 112 species and seven subspecies belonging to 23 genera, seven tribes and four subtribes of the subfamily Scarabaeinae were found (Table 3). Tribe Deltotochilini included the largest number of genera and species (six genera, 27 spp), followed by Ateuchini at the generic level (five genera) and Onthophagini for their number of species (25 spp). Sisyphini is the least representative tribe with only one species. Onthophagus and Canthon are the most diversified genera, with 24 and 15 species, respectively, which together represent 34.82% of the total species, while eight genera are represented by only one species (Fig. 1).

A total of 47 publications provided records of 104 species, of which 48.9% (n = 23) corresponded to taxonomic studies, 31.9% (n = 15) were ecological/faunistic works and only 19.2% (n = 9) presented geographic distribution data. For its part, the GBIF database presented records that corresponded to 94 species. Canthon indicaeus chevrolati (Harold, 1868), Eurysternus plebejus Harold, 1880, Onthophagus championi Bates, 1887, O. corrosus (Bates, 1887), O. guatemalensis Bates, 1887, O. marginicollis Harold, 1880, O. nasicornis Harold, 1869 and O. sharpi Harold, 1875, were not registered in any of the publications, so they were exclusive records from this database (Table 3).

Of the 19 NPAs analyzed, 16 presented records of Scarabaeinae (84.2%), except APFFAA, APFFCK and REBILA (Fig. 2). The species reported showed a significant relation with the number of publications that registered them in each NPA ($R^2 = 0.80$, $F = 56.47$, $P = 0.0001$, Fig. 3A) but not with the area size of each one of them ($R^2 = 0.069$, $F = 1.039$, $P = 0.325$, Fig. 3B). REBIMA and REBISO highlighted for presenting the largest number of registered species, both with 61, while APFFM, REBIEN and SPPA presented records of only one species (Fig. 4). At least 20 taxa (species and subspecies) have been described from organisms collected in ten of the NPAs studied. According to the IUCN red list of threatened species, 13 species are found in two low-risk categories, 12 in the least concern category and only one as near threatened (Table 3).

A high specificity of species was found for the NPAs, with 33 species (29.5%) registered in a protected area alone: REBIMA (n = 7), REBISO (n = 6), APRNVA
Table 3. List of the dung beetle species registered in the Natural Protected Areas of Chiapas, Mexico.

| Species | NPAs | Resources |
|---------|------|-----------|
| Ateuchini, Ateuchina | | |
| *Ateuchus candaezi* (Harold, 1868) | PNLM, PNP, REBIMA | Kohlmann 1984, 1997, 2000; Morón et al. 1985; Navarrete and Halffter 2008a; Delgado et al. 2012; Sánchez-de-Jesús et al. 2016; Santos-Heredia et al. 2018; GBIF 2019 |
| *Ateuchus chrysopyge* (Bates, 1887) | PNLM, REBIMA, REBISO | Kohlmann 2000; Navarrete and Halffter 2008a, b; Sánchez-de-Jesús et al. 2016; GBIF 2019 |
| *Ateuchus guatemalensis* (Bates, 1887) | REBIVTA | Kohlmann 2000 |
| *Ateuchus iliaeum* (Harold, 1868) | PNLM, REBIMA, REBIVTA | Kohlmann 1984; Coutiño et al. 2005; Santos-Heredia et al. 2018; GBIF 2019 |
| *Ateuchus laetitiae* Kohlmann, 1981 | REBIMA | Kohlmann 1981, 1984 |
| *Ateuchus perezevelai* Kohlmann, 2000 | REBISO | Gómez et al. 2017; Sánchez-Hernández et al. 2018 |
| *Ateuchus rodriguezi* (Preudhomme de Borre, 1886) | REBISO, REBIVTA, APRNV A | Kohlmann 1984, 1997; Arellano et al. 2008, 2009, 2013; Cancino-López et al. 2014; Kohlmann and Solís 2006; Santos-Heredia et al. 2018; GBIF 2019 |
| *Bdelyropsis bowditchi* Paulian, 1939 | REBIMA, MNB, MNY | Navarrete and Halffter 2008a; Sánchez-de-Jesús et al. 2016; Santos-Heredia et al. 2018 |
| *Bdelyropsis newtoni* Howden, 1971 | PNP | Howden 1971 |
| *Uroxys boneti* Pereira & Halffter, 1961 | MNB, PNP, REBIMA, REBISO | Halffter et al. 1992; Delgado and Kohlmann 2007; GBIF 2019 |
| *Uroxys deavilai* Delgado & Kohlmann, 2007 | PNCS, REBISO, APRNV A | Delgado and Kohlmann 2007; Arellano et al. 2008, 2009, 2013; Sánchez-Hernández et al. 2018; GBIF 2019 |
| *Uroxys microcularis* Howden & Young, 1981 | MNB, MNY, REBIMA, REBISO | Delgado and Kohlmann 2007; Navarrete and Halffter 2008a; Sánchez-de-Jesús et al. 2016; Gómez et al. 2017; Sánchez-Hernández et al. 2018; Santos-Heredia et al. 2018; GBIF 2019 |
| *Uroxys micros* Bates, 1887 | MNB, MNY | Delgado and Kohlmann 2007; Sánchez-de-Jesús et al. 2016; Santos-Heredia et al. 2018; GBIF 2019 |
| *Uroxys platypygia* Howden & Young, 1981 | REBIMA | Delgado and Kohlmann 2007; Sánchez-de-Jesús et al. 2016; Santos-Heredia et al. 2018; GBIF 2019 |
| *Uroxys tacanensis* Delgado & Kohlmann, 2007 | REBIVTA | Delgado and Kohlmann 2007 |
| Ateuchini, Scatimina | | |
| *Martinezidium maya* (Vaz-de-Mello, Halffter & Halffter, 2004) | PNCS, APRNV A | Vaz-de-Mello et al. 2004; Vaz-de-Mello 2008; Arellano et al. 2009, 2013; GBIF 2019 |
| Scatimus ovatus* Harold, 1862 | MNB, PNLM, PNCS, REBIMA, REBISE, REBISO, APRNV A | Génier and Kohlmann 2003, Arellano et al. 2008; Navarrete and Halffter 2008a; Arellano et al. 2009, 2013; Sánchez-de-Jesús et al. 2016; Gómez et al. 2017; Sánchez-Hernández et al. 2018; Santos-Heredia et al. 2018; GBIF 2019 |
| Coprini | | |
| Canthidium ardens* Bates, 1887 | REBIMA, REBIVTA, APRNV A | Arellano et al. 2008; Navarrete and Halffter 2008a; Cancino-López et al. 2014; Sánchez-de-Jesús et al. 2016; Santos-Heredia et al. 2018; GBIF 2019 |
| Canthidium centrale* Boucomont, 1928 | MNB, REBIMA, REBISE, REBISO, MNY | Palacios-Ríos et al. 1990; Morón et al. 1985; Kohlmann and Solís 2006; Navarrete and Halffter 2008a; Blas and Gómez 2009; Sánchez-de-Jesús et al. 2016; Sánchez-Hernández et al. 2018; Santos-Heredia et al. 2018; GBIF 2019 |
| Canthidium laetum* Harold, 1867 | APRNV A | Arellano et al. 2009, 2013; GBIF 2019 |
| *Canthidium moroni* Kohlmann & Solís, 2006 | APFFN, REBIMA, REBISO | Kohlmann and Solís 2006; Gómez et al. 2017 |
| *Canthidium pseudoperceptibile* Kohlmann & Solís, 2006 | MNB, APFFN, APRNV A, REBIMA, REBISO | Kohlmann and Solís 2006; Sánchez-Hernández et al. 2018; GBIF 2019 |
| *Canthidium pseudopuncticolle* Solís & Kohlmann, 2004 | REBISO | Kohlmann and Solís 2006; Sánchez-Hernández et al. 2018; GBIF 2019 |
| Canthidium vespertinum* Howden & Young, 1981 | REBIMA | Navarrete and Halffter 2008a; Sánchez-de-Jesús et al. 2016; GBIF 2019 |
| *Copris costarcensis dolichocerus* Matthews, 1961 | REBIVTA | Matthews 1961; Coutiño et al. 2005; Cancino-López et al. 2014; GBIF 2019 |
| Species                                      | NPAs                     | Resources                                                                 |
|----------------------------------------------|--------------------------|---------------------------------------------------------------------------|
| Copris incertus Say, 1835                    | APRNV, REBIVTA, PNCS     | Arellano et al. 2009, 2013; GBIF 2019                                      |
| Copris laeviceps Harold, 1862                | PNP, REBIMA, REBISO, MNY, APRNV, PNCS | Morón et al. 1985; Palacios-Ríos et al. 1990; Arellano et al. 2008; Navarrete and Halffter 2008a; Arellano et al. 2009, 2013; Sánchez-de-Jesús et al. 2016; Gómez et al. 2017; Darling and Génier 2018; Sánchez-Hernández et al. 2018; Santos-Heredia et al. 2018; GBIF 2019 |
| Copris lugubris Boheman, 1858                | APRNV, PNLM, REBISO, REBISE, APFFN, REBIMA, REBITRI, MNY, REBIVTA, APRNV | Morón et al. 1985; Palacios-Ríos et al. 1990; Arellano et al. 2008, 2009; Blas and Gómez 2009; Navarrete and Halffter 2008a; Arellano et al. 2013; Sánchez-de-Jesús et al. 2016; Darling and Génier 2018; Santos-Heredia et al. 2018; GBIF 2019 |
| *Copris matthewsi matthewsi* Delgado & Kohlmann, 2001 | PNLM | Delgado and Kohlmann 2001                                                    |
| *Copris matthewsi pacificus* Delgado & Kohlmann, 2001 | REBITRI, REBIVTA | Delgado and Kohlmann 2001; Coutiño et al. 2005; Cancino-López et al. 2014 |
| Dichotomius ampicollis (Harold, 1869)        | PNLM, PNP, PNCS, REBIMA, REBISO, APRNV, REBITRI, APRNV | Morón et al. 1985; Halffter et al. 1992; Arellano et al. 2008, 2009; Blas and Gómez 2009; Navarrete and Halffter 2008a; Arellano et al. 2013; Sánchez-de-Jesús et al. 2016; Sánchez-Hernández et al. 2018; Santos-Heredia et al. 2018; GBIF 2019 |
| Dichotomius annae Kohlmann & Solis, 1997     | REBIMA, REBISE, REBITRI, REBIVTA | Coutiño et al. 2005; Navarrete and Halffter 2008; Sánchez-de-Jesús et al. 2016; GBIF 2019 |
| Dichotomius colonicus Say, 1835              | PNLM, PNCS, PNP, REBIMA, REBISO, APRNF, APRNV, REBITRI, REBIVTA | Arellano et al. 2008, 2009; Delgado et al. 2012; Arellano et al. 2013, Gómez et al. 2017; GBIF 2019 |
| *Dichotomius maya* Peraza & Deloya, 2006     | REBISO | Sánchez-Hernández et al. 2019                                              |
| *Dichotomius satanas* Harold, 1867           | APRNV, PNLM, PNP, REBIMA, REBISO, APRNF, REBIVTA, MNY | Morón et al. 1985; Palacios-Ríos et al. 1990; Halffter et al. 1992; Navarrete and Halffter 2008; Blas and Gómez 2009; Delgado et al. 2012; Sánchez-de-Jesús et al. 2016; Santos-Heredia et al. 2018; GBIF 2019 |
| *Ontherus azteca* Harold, 1869               | REBIMA, REBISO           | Génier 1996; Navarrete and Halffter 2008a; GBIF 2019                      |
| *Ontherus mexicanus* Harold, 1868            | PNLM, REBISO             | Génier 1996; Gómez et al. 2017                                             |

**Deltochilini**

| Agamopus lampros Bates, 1887                  | APRNV | Arellano et al. 2008, 2009, 2013 |
|----------------------------------------------|-------|---------------------------------|
| Canthon angustatus Harold, 1867              | PNP, REBIMA | Chamé-Vázquez and Gómez 2005; Navarrete and Halffter 2008a; Halffter et al. 2009; Sánchez-de-Jesús et al. 2016; Santos-Heredia et al. 2018; GBIF 2019 |
| Canthon championi Bates, 1887                | REBISO, REBITRI | Blas and Gómez 2009; GBIF 2019 |
| Canthon cyanellus LeConte, 1859              | REBISO, PNCS, PNP, REBIMA, REBITRA, MNY, REBIVTA | Morón et al. 1985; Palacios-Ríos et al. 1990; Halffter et al. 1992; Arellano et al. 2008, 2009; Navarrete and Halffter 2008a; Blas and Gómez 2009; Arellano et al. 2013; Sánchez-de-Jesús et al. 2016; Sánchez-Hernández et al. 2018; GBIF 2019 |
| Canthon delgadoi Rivera-Cervantes & Halffter, 1999 | APRNV | Arellano et al. 2008, 2009; Halffter and Halffter 2009; Arellano et al. 2013; GBIF 2019 |
| Canthon euryscelis Bates, 1887               | MNB, PNP, MNY, REBISO, REBIMA | Morón et al. 1985; Rivera-Cervantes and Halffter 1999; Navarrete and Halffter 2008a; Sánchez-de-Jesús et al. 2016; Santos-Heredia et al. 2018; GBIF 2019 |
| Canthon femoralis (Chevrolat, 1834)          | PNCS, REBIMA, PNP, REBISO, REBISE, MNY, APRNV | Morón et al. 1985; Palacios-Ríos et al. 1990; Rivera-Cervantes and Halffter 1999; Navarrete and Halffter 2008a; Arellano et al. 2009, 2013; Sánchez-de-Jesús et al. 2016; Sánchez-Hernández et al. 2018; Santos-Heredia et al. 2018; GBIF 2019 |
| Canthon humectus incisus Robinson, 1948      | PNLM, APRNV, PNCS | Delgado et al. 2012; GBIF 2019 |
| Canthon humectus sayi Robinson, 1948         | APRNV, PNCS | Arellano et al. 2008, 2009, 2013; GBIF 2019 |
| *Canthon indicaceus chevrolati* Harold, 1868 | PNCS, REBIEN | GBIF 2019 |
| Species | NPAs | Resources |
|---------|------|-----------|
| *Canthon indicus chiapas* Robinson, 1948 | APRNVA, PNCS, PNLM, REBISE, REBISO | Arellano et al. 2008, 2009; Blas and Gómez 2009; Arellano et al. 2013; GBIF 2019 |
| Canthon leechi (Martínez, Halffter & Halffter, 1964) | PNCS, PNLM, PNP, REBIMA, REBISE, REBISO | Halffter et al. 1992; Rivera-Cervantes and Halffter 1999; Navarrete and Halffter 2008; Sánchez-Hernández et al. 2018; GBIF 2019 |
| *Canthon lituratus* (Germar, 1813) | REBIMA | Navarrete and Halffter 2008a, b; GBIF 2019 |
| *Canthon luciae* Halffter & Halffter, 2009 | APRNVA | Halffter and Halffter 2009; Arellano et al. 2013 |
| Canthon meridionalis (Martínez, Halffter & Halffter, 1964) | REBISO | Gómez et al. 2017 |
| Canthon mosei Howden, 1966 | MNY, PNP, REBIMA, REBISO | Palacios-Ríos et al. 1990; Navarrete and Halffter 2008a; Halffter and Halffter 2009; Sánchez-de-Jesús et al. 2016; GBIF 2019 |
| *Canthon subhyalinus subhyalinus* Harold, 1867 | MNB, MNY, PNP, REBIMA, REBISO | Palacios-Ríos et al. 1990; Halffter and Halffter 1992; Rivera-Cervantes and Halffter 1999; Navarrete and Halffter 2008a; Sánchez-de-Jesús et al. 2016; Santos-Heredia et al. 2018; GBIF 2019 |
| Canthon vazquezeae (Martínez, Halffter & Halffter, 1964) | MNB, MNY, PNCS, PNP, REBIMA, REBISE, REBISO, APRNVA | Palacios-Ríos et al. 1990; Rivera-Cervantes and Halffter 1999; Arellano et al. 2008; Blas and Gómez 2009; Sánchez-Hernández et al. 2018; GBIF 2019 |
| *Cryptocanthon montebello* Cook, 2002 | PNLM | Cook 2002; GBIF 2019 |
| Deltochilum acropyge Bates, 1887 | REBISO, MNY | Cano 1998; Blas and Gómez 2009; GBIF 2019 |
| *Deltochilum carrilloi* González-Alvarado & Vaz-de-Mello, 2014 | REBISO, REBIMA, APRNVA | González-Alvarado and Vaz-de-Mello 2014 |
| Deltochilum densepunctatum Balthasar, 1939 | REBISO | González-Alvarado and Vaz-de-Mello 2014 |
| Deltochilum lobipes Bates, 1887 | REBIMA, APRNVA | Arellano et al. 2008, 2009; Navarrete and Halffter 2008a; Arellano et al. 2013; Sánchez-de-Jesús et al. 2016; Santos-Heredia et al. 2018; GBIF 2019 |
| Deltochilum mexicanum Burmeister, 1848 | PNLM, REBISO, REBITRI, REBITRA | Coutiño et al. 2005; Blas and Gómez 2009; Delgado et al. 2012; Cancino-López et al. 2014; Sánchez-Hernández et al. 2018; GBIF 2019 |
| Deltochilum pseudoparile Paulian, 1938 | PNP, REBIMA, REBISO, MNB, MNY, APRNVA | Morón et al. 1985; Palacios-Ríos et al. 1990; Halffter et al. 1992; Navarrete and Halffter 2008a; Blas and Gómez 2009; Sánchez-de-Jesús et al. 2016; Sánchez-Hernández et al. 2018; Santos-Heredia et al. 2018; GBIF 2019 |
| Deltochilum scabriusculum Bates, 1887 | PNCS, PNLM, PNP, REBIMA, REBISO, REBITRI, MNY, APRNVA | Morón et al. 1985; Palacios-Ríos et al. 1990; Halffter et al. 1992; Arellano et al. 2008, 2009; Navarrete and Halffter 2008a; Génier 2012; Arellano et al. 2013; Sánchez-de-Jesús et al. 2016; Sánchez-Hernández et al. 2018; Santos-Heredia et al. 2018; GBIF 2019 |
| Deltochilum sublaeve Bates, 1887 | PNLM, PNP, MNY, APRNVA, REBIMA, REBISO, REBITRI, REBITRA | Morón et al. 1985; Palacios-Ríos et al. 1990; Halffter et al. 1992; Navarrete and Halffter 2008; Arellano et al. 2009; Blas and Gómez 2009; Arellano et al. 2013; Cancino-López et al. 2014; González-Alvarado and Vaz-de-Mello 2014; Sánchez-de-Jesús et al. 2016; Sánchez-Hernández et al. 2018; Santos-Heredia et al. 2018; GBIF 2019 |
| Megathoposoma candezei Harold, 1873 | MNY, PNP, REBIMA | Morón et al. 1985; Halffter et al. 1992; Navarrete and Halffter 2008a; Sánchez-de-Jesús et al. 2016; Santos-Heredia et al. 2018; GBIF 2019 |
| Pseudocanthon perplexus (LeConte, 1847) | APRNVA, PNCS, PNP | Arellano et al. 2008; GBIF 2019 |

**Oniticellini, Eurysternina**

| Eury sternus angustulus Harold, 1869 | APFFM, MNB, PNP, REBIMA, REBISO, MNY | Morón et al. 1985; Palacios-Ríos et al. 1990; Halffter et al. 1992; Navarrete and Halffter 2008a; Génier 2009; Sánchez-de-Jesús et al. 2016; Gómez et al. 2017; Sánchez-Hernández et al. 2018; Santos-Heredia et al. 2018; GBIF 2019 |
| Eury sternus caribaeus Herbst, 1789 | MNB, PNLM, PNP, REBIMA, REBISO, MNY | Morón et al. 1985; Palacios-Ríos et al. 1990; Halffter et al. 1992; Navarrete and Halffter 2008a; Blas and Gómez 2009; Génier 2009; Delgado et al. 2012; Sánchez-Hernández et al. 2018; Santos-Heredia et al. 2018; GBIF 2019 |
| Species | NPAs | Resources |
|---------|------|-----------|
| *Eurysternus foedus* Guérin, 1844 | REBIMA, REBISO | Morón et al. 1985; Navarrete and Halffter 2008a; Génier 2009; Sánchez-de-Jesús et al. 2016; Sánchez-Hernández et al. 2018; Santos-Heredia et al. 2018; GBIF 2019 |
| *Eurysternus magnus* Castelnau, 1840 | APRNF, PNLM, PNCS, PNP, REBIMA, REBISO, APRNVA, MNY | Coutiño et al. 2005; Génier 2009; Sánchez-de-Jesús et al. 2016; Sánchez-Hernández et al. 2018; GBIF 2019 |
| *Eurysternus maya* Génier, 2009 | MNB | Génier 2009 |
| *Eurysternus mexicanus* Harold, 1869 | PNLM, PNP, REBIMA, REBITRI, APRNVA, MNY | Morón et al. 1985; Palacios-Ríos et al. 1990; Halffter et al. 1992; Navarrete and Halffter 2008a; Arellano et al. 2009; Génier 2009; Arellano et al. 2013; Sánchez-de-Jesús et al. 2016; Santos-Heredia et al. 2018; GBIF 2019 |
| *Eurysternus plebejus* Harold, 1880 | REBIMA | GBIF 2019 |
| *Eurysternus velutinus* Bates, 1887 | REBIMA | Morón et al. 1985 |
| Oniticellini, Oniticellina | | |
| *Euoniticellus intermedius* (Reiche, 1849) | REBISE, REBISO, REBITRI, APRNVA, REBITRI, APRNVA | Morales et al. 2004; Coutiño et al. 2005; Arellano et al. 2008, 2009, 2013; GBIF 2019 |
| Onthophagini | | |
| *Digitonthophagus gazella* (Fabricius, 1757) | REBISO, REBITRI, SPPA, PNP, APRNVA, APRNF | Morales et al. 2004; Arellano et al. 2008; GBIF 2019 |
| *Onthophagus acuminatus* Harold, 1880 | REBIMA, APRNVA | Delgado 1997; Navarrete and Halffter 2008a; Arellano et al. 2009, 2013; Sánchez-de-Jesús et al. 2016; Santos-Heredia et al. 2018; GBIF 2019 |
| *Onthophagus anthracinus* Harold, 1873 | REBISO, REBITRI | Coutiño et al. 2005; Cancino-López et al. 2014; Gómez et al. 2017; GBIF 2019 |
| *Onthophagus batesi* Howden & Cartwright, 1963 | PNLM, PNCS, REBIMA, REBITRI, REBITRI, PN, MNY, APRNVA | Palacios-Ríos et al. 1990; Halffter et al. 1992; Arellano et al. 2008; Navarrete and Halffter 2008a; Delgado et al. 2012; Arellano et al. 2013; Sánchez-de-Jesús et al. 2016; Gómez et al. 2017; Santos-Heredia et al. 2018; GBIF 2019 |
| *Onthophagus belorhinus* Bates, 1887 | REBISE | GBIF 2019 |
| *Onthophagus carpophilus* Pereira & Halffter, 1961 | APFFN, REBIMA, REBITRI, MNY, PNP | Navarrete and Halffter 2008a; Sánchez-de-Jesús et al. 2016; Sánchez-Hernández et al. 2018; Santos-Heredia et al. 2018; GBIF 2019 |
| *Onthophagus championi* Bates 1887 | REBISE | GBIF 2019 |
| *Onthophagus chiapanecus* Zunino & Halffter, 1988 | REBISE, REBITRI | Zunino and Halffter 1988; GBIF 2019 |
| *Onthophagus cospitanaeus* Bates, 1887 | REBIMA | Delgado 1997; Navarrete and Halffter 2008a; Sánchez-de-Jesús et al. 2016; Santos-Heredia et al. 2018; GBIF 2019 |
| *Onthophagus corrugatus* Bates, 1887 | PNP | GBIF 2019 |
| *Onthophagus crinitus* Bates, 1889 | PNP, REBIMA, REBITRI, REBITRI, APRNVA | Morón et al. 1985; Palacios-Ríos et al. 1990; Halffter et al. 1992; Arellano et al. 2008; Navarrete and Halffter 2008a; Blas and Gómez 2009; Arellano et al. 2013; Sánchez-de-Jesús et al. 2016; Sánchez-Hernández et al. 2018; Santos-Heredia et al. 2018; GBIF 2019 |
| *Onthophagus cyanellus* Bates, 1887 | PNLM, REBITRI, APRNVA, MNY, PNP | Coutiño et al. 2005; Delgado et al. 2012; Cancino-López et al. 2014; GBIF 2019 |
| *Onthophagus cyclographus* Bates, 1887 | PNLM, REBITRI, MNY, REBITRI, MNY | Navarrete and Halffter 2008a; Sánchez-Hernández et al. 2018 |
| *Onthophagus denticulatus* Bates, 1887 | REBITRI, MNY, PNP | GBIF 2019 |
| *Onthophagus denticulatus* Bates, 1887 | APRNVA, PNCS, PNP, REBITRI, MNY | Arellano et al. 2008, 2013; GBIF 2019 |
| *Onthophagus incensus* Say, 1835 | REBITRI, MNY, PNP, REBITRI, MNY | Coutiño et al. 2005; Navarrete and Halffter 2008a; Cancino-López et al. 2014; Gómez et al. 2017; Sánchez-Hernández et al. 2018; GBIF 2019 |
| Species                        | NPAs                      | Resources                                                                 |
|-------------------------------|---------------------------|---------------------------------------------------------------------------|
| Onthophagus landolti Harold, 1880 | PNP, REBISO, APRNVA       | Halffter et al. 1992; Kohlmann and Solís 2001; Arellano et al. 2009, 2013; Gómez et al. 2017; Sánchez-Hernández et al. 2018; GBIF 2019 |
| Onthophagus longimanus Bates, 1887 | REBISO                   | Sánchez-Hernández et al. 2017; Sánchez-Hernández et al. 2018             |
| Onthophagus marginicollis Harold, 1880 | PNP                     | GBIF 2019                                                                 |
| *Onthophagus maya* Zunino, 1981 | REBIMA, REBISE, REBISO, MNY, PNP | Morón et al. 1985; Palacios-Ríos et al. 1990; Blas and Gómez 2009; Navarrete and Halffter 2008a; Sánchez-de-Jesús et al. 2016; Sánchez-Hernández et al. 2018; Santos-Heredia et al. 2018; GBIF 2019 |
| Onthophagus nasicornis Harold, 1869 | REBIMA, PNP               | GBIF 2019                                                                 |
| Onthophagus rhinolophus Harold, 1869 | PNLM, PNP, REBIMA, REBISO, MNY | Morón et al. 1985; Palacios-Ríos et al. 1990; Halffter et al. 1992; Navarrete and Halffter 2008a; Blas and Gómez 2009; Delgado et al. 2012; Sánchez-de-Jesús et al. 2016; Sánchez-Hernández et al. 2018; Santos-Heredia et al. 2018; GBIF 2019 |
| Onthophagus sharpi Harold, 1875  | PNP                      | GBIF 2019                                                                 |
| Onthophagus violetae Zunino & Halffter, 1997 | APRNVA, APFFN           | Arellano et al. 2009, 2013; GBIF 2019                                      |
| Onthophagus yucatanus Delgado, Peraza & Deloya, 2006 | REBIMA, REBISO            | Navarrete and Halffter 2008a, b; Sánchez-de-Jesús et al. 2016; Gómez et al. 2017; Sánchez-Hernández et al. 2018; Santos-Heredia et al. 2018 |

**Phanaeini**

*Coprophanaeus corythus* Harold, 1863  
| Species                        | NPAs                      | Resources                                                                 |
|-------------------------------|---------------------------|---------------------------------------------------------------------------|
| *Coprophanaeus corythus* Harold, 1863 | MNB, PNP, REBIVTA, REBIMA, REBISO, MNY, APRNVA | Morón et al. 1985; Palacios-Ríos et al. 1990; Halffter et al. 1992; Coutiño et al. 2005; Arellano et al. 2008, 2009; Navarrete and Halffter 2008a; Blas and Gómez 2009; Edmonds and Zidek 2010; Arellano et al. 2013; Cancino–López et al. 2014; Sánchez-de-Jesús et al. 2016; Sánchez-Hernández et al. 2018; Santos-Heredia et al. 2018; GBIF 2019 |
| *Coprophanaeus gilli* Arnaud, 1997 | MNB, REBIMA, REBISO, PNP  | Navarrete and Halffter 2008a, Edmonds and Zidek 2010; Sánchez–Hernández et al. 2018; GBIF 2019 |
| *Coprophanaeus pluto* Harold, 1863 | REBITRI                  | Edmonds and Zidek 2010; GBIF 2019                                           |
| *Phanaeus amethystinus* Harold, 1863 | MNY, PNLM, REBISE, REBITRI | Edmonds 1994; GBIF 2019                                                    |
| *Phanaeus demon* Castelnau, 1840 | REBISE, APRNVA, PNCS     | Edmonds 1994; Arellano et al. 2009, 2013; GBIF 2019                        |
| *Phanaeus endymion* Harold, 1863 | MNB, PNCS, PNLM, PNP, MNY, REBIMA, REBISO, REBIVTA, MNY, APRNVA | Morón et al. 1985; Palacios-Ríos et al. 1990; Halffter et al. 1992; Edmonds 1994; Navarrete and Halffter 2008a; Blas and Gómez 2009; Arellano et al. 2013; Cancino–López et al. 2014; Sánchez-de-Jesús et al. 2016; Sánchez-Hernández et al. 2018; Santos-Heredia et al. 2018; GBIF 2019 |
| *Phanaeus guatemalensis* Harold, 1871 | REBIVTA                 | Coutiño et al. 2005; Cancino–López et al. 2014; GBIF 2019                  |
| *Phanaeus melampus* Harold, 1863 | REBIMA                   | Navarrete and Edmonds 2006; Navarrete and Halffter 2008a; GBIF 2019       |
| *Phanaeus pilatei* Harold, 1863  | MNY                      | Palacios-Ríos et al. 1990                                                 |
| *Phanaeus pyrois* Bates, 1887   | REBISO, REBIVTA, APRNVA  | Delgado 1997; Arellano et al. 2008, 2009; Blas and Gómez 2009; GBIF 2019 |
| *Phanaeus saltator* Harold, 186  | MNB, MNY, PNP, PNLM REBIMA, REBISO | Morón et al. 1985; Halffter et al. 1992; Edmonds 1994; Navarrete and Halffter 2008a; Palacios-Ríos et al. 1990; Sánchez-de-Jesús et al. 2016; Sánchez-Hernández et al. 2018; Santos-Heredia et al. 2018; GBIF 2019 |
| *Phanaeus tridens* Laporte-Castelnau, 1840 | REBISE, REBISO, REBITRI, PNCS, APRNVA | Edmonds 1994; Arellano et al. 2009, 2013; GBIF 2019                        |
| *Phanaeus wagneri* Harold, 1873  | PNLM, PNCS, APRNVA       | Edmonds 1994; Arellano et al. 2008, 2009, 2013                             |
| Sulcophanaeus chryseicollis (Harold, 1863) | MNB, REBIMA, REBISO, PNP | Halffter et al. 1992; Edmonds 2000; Navarrete and Halffter 2008a; Sánchez-de-Jesús et al. 2016; GBIF 2019 |

**Sisyphini**

*Sisyphus mexicanus* Harold, 1863 | REBITRI | Gómez and Chamé-Vázquez 2003; GBIF 2019 |

*Species/subspecies described from organisms collected in Natural Protected Areas of Chiapas. *Invasive species. 'Least concern and 'Near threatened in the IUCN Red List.
Figure 1. Number of species registered by genus in the Natural Protected Areas of Chiapas.

Figure 2. Natural Protected Areas of Chiapas grouped into five categories according to the number of species they register. See acronym in Table 2.
Dung beetles in protected areas of Chiapas, Mexico

(\(n = 4\)), PNP (\(n = 4\)), REBIVTA (\(n = 4\)), PNLM (\(n = 2\)), REBISE (\(n = 2\)), REBITRI (\(n = 2\)), MNB (\(n = 1\)) and MNY (\(n = 1\)). The similarity analysis indicated the formation of three large groups of reserves with faunistic similarities (Fig. 5). One of them is formed by the reserves in the Sierra Madre de Chiapas, where montane forests predominate (REBISE and REBITRI) with approximately 87% similarity; another group corresponding to tropical rain forests consisted of five reserves (MNB, MNY, PNP, REBIMA and REBISO) with about 73% similarity; and the last was composed of two NPAs of deciduous forests (APRNVA and PNCS) with 60% similarity. PNLM

\[\text{Figure 3. Simple linear regression analysis between the (A) species recorded and the publications that register them; and (B) with the area size of each natural protected areas.}\]

\[\text{Figure 4. Number of species and genera of Scarabaeinae registered by Natural Protected Area in Chiapas.}\]
was more related to the rain forests and shared 50% of its fauna with this group, but with typical elements of montane forests that separated it from the group; while REBIVTA was isolated from the rest of the reserves, sharing a low percentage of its fauna with all of them.

**Discussion**

**Biodiversity of Scarabaeinae in the NPAs of Chiapas**

The 112 species reported in the federal natural protected areas correspond to 91% of the Scarabaeinae fauna of Chiapas and 38.1% of the 294 species estimated for Mexico (Sánchez-Hernández and Gómez 2018; Sánchez-Hernández et al. 2019). While the numbers reported here are high, knowledge about dung beetles in Chiapas is far from complete. Of the total publications revised, there were few studies that correspond to inventory works with systematic sampling (32.6%), restricted to only seven of the protected areas (APRNV A, MNY, REBIMA, REBISO, REBIVTA, PNLM and PNP). The NPAs with the highest number of registered species (i.e. REBIMA and REBISO) were, in the same way, the ones that present the greatest number of studies, while most of them lacked studies that extensively analyze the Scarabaeinae communities. This greatly prevents the study of several basic and applied aspects
of dung beetles, from diversity and distribution to conservation. The above also shows evidence that a greater sampling effort focused on the least studied reserves would increase the possibility of discovering unregistered or described species and, thereby, broadening the knowledge of the dung beetle diversity in Chiapas, regardless of the area size of the NPAs.

REBIVTA, the reserve with the lowest faunistic affinity in the study, is located in an area with Central American influence that emerged during the volcanism in the Pliocene (Halffter 2003). This reserve is located at a point of confluence of three tectonic plates (Cocos, North American and Caribbean) and is limited by the trench of Central America and the Motagua-Polochic fault system (García-Palomo et al. 2006). Cano et al. (2018) consider its geology as a biogeographic barrier that separates the Passalidae (Coleoptera) faunas between Central America (including the Tacaná volcano) and southeastern Mexico. Similarly, they recognize that the Motagua-Cuilco dry valleys system and the Motozintla-Comaltitlán suture zones represent barriers involved in beetles vicariance processes, including other genera of Passalidae (Schuster 1993; Schuster et al. 2003), Scarabaeidae (Micó et al. 2006), and Carabidae (Sokolov and Kavanaugh 2014). This would explain the isolation of the fauna found in the REBIVTA against the other Chiapas reserves, because its function as a biogeographic barrier that prevents Central American elements from crossing northwards on the Pacific slope.

PNP, REBISO, MNY, REBIMA and MNB, formed a faunistic complex of rain forests located on the gulf slope with a high percentage of similarity (above 70%). They became a group of reserves clearly different from the other group formed by the interaction of two areas (PNCS and APRNVA) characterized by dry forests. Both NPAs groups are made up of fauna with neotropical affinity that is distributed over the biogeographic province of the Gulf of Mexico (Morrone 2006), but which diverge by the type of vegetation they present. Finally, the PNLM is a reserve that presents transition characteristics between the rain forests (Gulf of Mexico province) and the temperate forests (Chiapas province) formed by species with Central American and central Mexico origin (Delgado 2011), thereby separating it from the Gulf of Mexico NPAs groups.

Species with doubtful distribution in Chiapas

We consider that seven species cited by some of the reviewed works do not have a presence in Chiapas, or that their distribution needs to be confirmed in some of the reserves studied. The reports of *Dichotomius centralis* (Harold, 1869) in the works of Morón et al. (1985), Palacios-Ríos et al. (1990) and Halffter et al. (1992) correspond to *D. amplicollis* (Harold, 1869). The overlap area of these species is in Guatemala and *D. centralis* is likely to be marginally on the Pacific slope, however its presence in Chiapas has not been confirmed (López-Guerrero 2005).

Gomez et al. (2017) reported to *Dichotomius carolinus* (Linnaeus, 1767) and *Dichotomius amicitiae* Kohlmann & Solís, 1997, but none of these species has been
corroborated in Mexico. *Dichotomius carolinus* is distributed exclusively in the United States and the individuals rather correspond to *D. colonicus*, a species with which it relates and is widely distributed in Mexico. On the other hand, *D. amicitiae* is a species whose distribution is restricted to Costa Rica and Panama (Kohlmann and Solís 1997), hence this record was confused with *D. annae*, a closely related Mexican species (Peraza and Deloya 2006).

Similarly, Morón et al. (1985) cited *Onthophagus nasicornis* Harold, 1869 but the species is only known in central Mexico and, this record has not been corroborated in Chiapas. *Onthophagus nitidior* Bates, 1887 is distributed in the low deciduous and subdeciduous forests of the Mexican Central Pacific slope (Hernández and Navarrete-Heredia 2018), so that, the report by Palacios-Ríos et al. (1990) on the Gulf of Mexico slope, is possibly incorrect record and corresponds to other species of the same group (*hirculus* species group) reported in Chiapas.

We also consider that *Onthophagus rhinophyllus* Harold, 1868, a species that is distributed only in Venezuela and Colombia (Delgado et al. 2006), constitutes an erroneous record of Halffter et al. (1992). *Onthophagus atrosericeus* Boucomont, 1932, is another species erroneously cited in Mexico. The distribution of this species is restricted to mountains of elevation greater than 1,700 m in Costa Rica and Panama (Kohlmann and Solís 2001), while the record of Halffter et al. (1992) is in a locality at ~100 m altitude, approximately 1,000 km from its nearest record in Costa Rica.

**Monitoring and conservation**

Biodiversity monitoring in natural protected areas represents an integral component to assess its performance and provide the information necessary for effective management (Halffter et al. 2015). In this sense, Schuster et al. (2000) mention that the use of a group that meets the bioindicator requirements can save time and money in conservation strategies and, at the same time, give objective and reliable criteria for the prioritization of areas, especially when the change in land use is accelerated and the need for conservation is urgent. One of the key reasons to conserve and monitor invertebrates in these areas is to ensure adequate protection of rare and threatened species and communities. Furthermore, many of them are appropriate and highly effective and informative indicators of other elements of biodiversity, ecosystem health and associated threats (McGeoch et al. 2011; Gerlach et al. 2013).

Due to the great variety of ecological functions in which they intervene (Nichols et al. 2008), their ability to respond in the short term to forest fragmentation (Nichols et al. 2007), its developed correlation and direct dependence on the presence of mammals in the ecosystem (Nichols et al. 2009; Bogoni et al. 2016; Mannu et al. 2018), the inclusion of the subfamily Scarabaeinae in these types of studies has been widely justified. They are well defined from a taxonomic and functional viewpoint, and methods for their sampling has been standardized (Spector 2006; Nichols and Gardner 2011). In addition, the analysis of their communities allows different and more detailed results which can be obtained in relation to works based only
Dung beetles in protected areas of Chiapas, Mexico

In the study of vertebrates and plants (Kohlmann et al. 2007), inventories and monitoring of Scarabaeinae communities can be useful during several stages of NPAs management, but statistically rigorous estimates of species richness, information on their spatial and temporal distribution are required, or their design should target to threatened and rare species or to identify possible indicator and/or invasive species (Engelbretch 2010). However, despite its characteristics as a bioindicator group, in Mexico the dung beetles are not included among the priority groups within the monitoring programs that support the management of NPAs, underestimating their results compared to those that produce studies on vertebrates and plants.

On the other hand, conservation efforts through NPAs would be much more relevant and effective when they are linked at a landscape or ecosystem scale (Moctezuma et al. 2018), because the resulting connectivity is essential for the biological diversity of the areas included, as it allows genetic and energy exchange through a greater geographical extent (Roy et al. 2010). For Scarabaeinae, these ecosystem complexes can promote the dispersion and survival of populations of certain common species in conserved areas of the region and, at the same time, maintain the optimal conditions for species with a restricted range of distribution. For instance, although the 13 species indicated on the IUCN red list of threatened species (see Table 3) do not meet the criteria to be considered in some type of immediate risk, most of these species present isolated populations in habitats with a high degree of vulnerability and reduced geographical range, some of them, known only from the material used for its description. Due to these characteristics, these species could be considered rare and indicators of conservation, which makes it necessary to consider adaptation measures to guarantee the survival of their populations. However, at present, there are no conservation strategies for any of them (IUCN 2018). Likewise, it would be important to establish strategies for monitoring the populations of D. gazella and E. intermedius, two invasive alien species widely distributed in Mexico that have been reported in several NPAs of Chiapas and that have probably been established in other contiguous reserves, since they have a high dispersal capacity, and can negatively affect the abundance of most native species, favoring the local extinction of species with similar nesting behavior (Montes de Oca and Halffter 1998; Filho et al. 2018).

In Chiapas, the ecosystem-scale conservation approach through corridors that link protected areas has recently emerged. An example of this is the “Complejo Selva Zoque of Natural Protected Areas”, whose objective is to enable the connectivity and conservation of biodiversity between five protected areas, three federal NPAs (REBISO, APRNVA and PNCS) and two state-protected areas (La Pera and Cerro Meyapac) (RAC 2015). This can be taken as a reference to establish connectivity strategies that allow the genetic flow between NPAs from other regions with similar characteristics. For example, in the Lacandona rainforest, a region that has been seriously affected by the accelerated change in land use, mainly due to the rapid expansion of oil palm crops, replacing large areas of forest in Chiapas (Castellanos-Navarrete and Jansen 2018). Unlike other tree crops, oil palm is a particularly poor
substitute for either primary or degraded forests and especially damaging to biodiversity (Fitzherbert et al. 2008), including the functional (Edwards et al. 2014) and taxonomic diversity of dung beetles (Gray et al. 2014; Harada et al. 2020).

Data presented in this work can be used as a reference to monitor dung beetle communities in the NPAs of Chiapas, both to conduct research in areas that have not been investigated and to continue monitoring in the NPAs explored, and thus analyze the dynamics of the communities over time. These studies can help to understand their response to ecosystem alterations, since indirectly reducing the beetles’ diversity through different factors of anthropic origin puts ecosystems at risk and promotes the loss of biodiversity. These changes will have significant negative impacts on the functional and ecological services that this insect group provide. Therefore, it is recommended that groups of arthropods such as the Scarabaeinae should be included in the previous justifying studies for the designation or establishment of NPAs and in turn considered in the biological monitoring programs of these reserves since they meet the characteristics of an efficient bioindicator group.

Acknowledgements

We are grateful to Bridget Davis for reviewing the English grammar of the manuscript. We also thank the two reviewers and subject editor for their useful comments and suggestions to the manuscript. Finally, we want to recognize the work that the Comisión Nacional de Áreas Naturales Protegidas (CONANP) does to conserve the natural heritage of Mexico.

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