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Pablo-Cea, Jose D.

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## **Functional-groups' approach of scarab beetles (Coleoptera: Scarabaeidae): A low cost alternative for monitoring biodiversity in El Salvador**

José D. Pablo-Cea<sup>1,2</sup>, Cuauhtémoc Deloya<sup>2</sup>, Ian MacGregor-Fors<sup>3</sup>, José L. Navarrete-Heredia<sup>4</sup>, Alejandro Espinosa de los Monteros<sup>5</sup>

<sup>1</sup> Red de Interacciones Multitróficas, Instituto de Ecología, A. C., Xalapa, Veracruz, Mexico, [jose.pablo@ues.edu.sv](mailto:jose.pablo@ues.edu.sv)

<sup>2</sup> Escuela de Biología, Facultad de Ciencias Naturales y Matemática, Universidad de El Salvador, San Salvador, El Salvador.

<sup>3</sup> Ecosystems & Environment Research Programme, Faculty of Biological & Environmental Sciences. University of Helsinki, Finland.

<sup>4</sup> Centro de Estudios en Zoología, CUCBA, Universidad de Guadalajara. Zapopan, Jalisco, Mexico.

<sup>5</sup> Red de Biología Evolutiva, Instituto de Ecología, A. C., Xalapa, Veracruz, Mexico.

**Keywords:** Conservation, Central America, Natural Protected Areas, Parque Nacional El Imposible, Parque El Bicentenario

**Abstract.**

Planning, implementation, and systematic revision of the conservation policies are necessary to protect a territory's biodiversity. This situation is critical in countries heavily impacted by anthropogenic activities, like El Salvador, where conserving biodiversity remnants must be a priority. Monitoring indicator groups represents a feasible option to review the status of biodiversity and the processes taking place in the country's conservation areas. We evaluated the suitability of Scarabaeidae beetles' functional groups as ecological indicators to detect differences in the conservation status of two protected areas in El Salvador. We conducted monthly sampling for one year at each site, using pitfall, aerial, and uv-light traps to capture beetles. We detected differences in species richness, abundance, species composition, and turnover between the two areas. The results suggest the possibility of using this approach to monitor protected areas, to estimate the forest conservation status, and to evaluate the conservation strategies implemented to date. For the future, it is essential to determine if this is possible by replicating studies throughout the territory using standardized methodologies to obtain comparable results. The cost-benefit ratio of using a single indicator group is key in countries like El Salvador, where the economic aspect is a limiting factor for biological prospecting.

## Introduction

In El Salvador, the national biodiversity inventory and monitoring strategy is an important tool for conserving species inhabiting the country (MARN 2003). However, this initiative has not been revised, adapted, or updated to biodiversity conservation needs for two decades. In contrast, other strategies related to conservation have been evaluated, among them, biological corridors, as the most important one, showing that they have not been correctly implemented in the territory (Patel 2021). In this way, it is necessary to evaluate aspects related to the El Salvador's Natural Protected Areas System, such as the representativeness and persistence of biodiversity within natural protected areas. These are essential steps for systematic planning and implementation of conservation strategies (Margules & Pressey 2000); processes, which can be achieved by implementing a correct monitoring network.

In El Salvador, the conversion rate of forest to pasture is very high, causing a significant loss of biodiversity in the process (Monro et al. 2006; Horgan 2008; Crespin & Simonetti 2016). El Salvador's history of disturbance is extensive, which dates back millennia to the establishment of the first human settlements in the territory, which hunted wildlife and gradually deforested the original ecosystems to establish survival crops (Daugherty 1969, 1972, Dull 2007, 2008). The fertile soils and suitable climate for the development of crops allowed the population to grow exponentially in the territory, which brought increased deforestation rates that led to the destruction of natural forests in the country (Daugherty 1969, Dull 2008). Subsequently, export crops, including sugarcane, cotton and coffee as the most important, constituted the *coup de grâce* that led to El Salvador's deforestation rate being one of the highest in continental America (currently estimated at 86%) (Dull 2008; Crespin & Simonetti 2016). Social factors such as civil war (Hecht et al. 2006, Campbell 2016) and natural factors such as disasters have also played an important role in changing the original ecosystems of the territory (González et al. 2004; Rose et al. 2004; Campbell 2016, 2020). Due to all of the above, this country has been considered one of the most

environmentally challenged nations in Latin America (Campbell 2020), and globally it is regarded as the ninth most likely country to experience environmental problems due to climate change (WorldBank 2010; UNU 2013; Son et al. 2020).

In El Salvador, the first proposal to establish a Sistema de Áreas Naturales Protegidas (SANP) dates back to the 1940s (Bourne 1946). However, it took thirty years for the first Parques Nacionales (a special type of Área Natural Protegida (ANP) that allows recreational activities in its territory) to be declared (LANPES 2005, MARN 2010, Medrano and Hernández 2017). And it is until 2005 that the Ley de Áreas Naturales Protegidas de El Salvador was officially declared, in which the ANPs are defined as legally protected territories destined for the conservation, sustainable management and restoration of wildlife, with the function of guaranteeing and preserving the integrity of nature. The ANPs are immersed in Conservation Areas (a group of ANPs close to each other), which include buffer zones, biological corridors, and zones of influence located around the areas (LANPES 2005). The SANP protects 318.78 km<sup>2</sup>, 1.52% of El Salvador's total area (21,041 km<sup>2</sup>), and is by far the smallest system in the Central American region (Komar 2002).

Throughout its history the SANP has presented several drawbacks in its establishment (Medrano & Hernández 2017). Nowadays, among the main weaknesses lies in the lack of constant monitoring of the diversity found in the areas, mainly due to social instability (violence), lack of local specialists, and financial limitations and due to the high levels of deforestation and environmental degradation experienced in the country, El Salvador (included the SANP) is under high risk of ecosystem collapse (Komar 2002; Hecht et al. 2006, Monro et al. 2006; Crespín and Simonetti 2015). Because of this, the SANP of El Salvador is usually considered to be of no conservation interest (Komar 2002, Hecht et al. 2006), nonetheless, locally it is estimated that it contains the last representative patches of life zones, habitat, ecosystems and biodiversity of the territory (MARN 2010, Medrano and

Hernández 2017), which makes it a key component for conserving the species that remain in the country and nearby areas (Komar 2002, Williams et al. 2002).

More than two decades ago, environmental authorities and researchers presented two critical initiatives. First, it was proposed a strategy for future biodiversity inventories and monitoring in the country (MARN 2003). The second was to use birds as a model group and it demonstrated that the country's two most important priority areas for biodiversity conservation were the Parque Nacional Montecristo and El Imposible (Komar 2002). Since then, those proposals have not been re-evaluated. Above all, it is vital to consider the importance of other areas (inside and outside the SANP) that are smaller in size but still suitable for protecting biodiversity. An example of those sites is Parque El Bicentenario. Unlike most protected areas, which are usually established in remote or unproductive areas (Margules & Pressey 2000), this park is located within the metropolitan area of San Salvador, the main socio-political area of El Salvador (Maria et al. 2017). Despite the ecosystem services that the park provides (e.g. oxygen purifier, aquifer reservoir), anthropogenic activity has constantly fragmented the forested area (Martínez 2004), a process that continues to this day. Due to population growth in the area, the urban agglomeration of San Salvador has exceeded twice the size of the official metropolitan limits (Maria et al. 2017). If this expansion continues and the nearby forests continue to be fragmented, several changes will occur, including a change in local climate, with the consequent increase in average temperature (Son et al. 2020); and the permanent loss of diversity, with the consequent loss of the natural heritage of the area and the country.

A helpful tool for determining the conservation status, ecological integrity, and monitoring the habitats' diversity is the use of ecological indicators (Niemi & McDonald 2004; Moreno et al. 2007; Siddiga et al. 2016). Among them, the diversity of the Family Scarabaeidae and especially the Subfamily Scarabaeinae is a recognized ecological indicator due to its

characteristics (e.g. high ecological diversification, high rates of ecological fidelity and endemism, good taxonomic, biological, ecological, and biogeographical knowledge), which lead to conclusions about the degree of conservation and heterogeneity of the habitat in which they are found (Halffter & Favila 1993, Morón 2014; Noriega et al. 2021). Worldwide, Scarabaeidae is a diverse group, well represented in the American continent, where more than 6000 species are described (Bochard et al. 2017, Deloya & Gasca-Alvarez 2018). At least 232 species of the family occur in El Salvador (Pablo-Cea 2021). The great diversity of Scarabaeidae is reflected in the variety of food resources they can use (Ratcliffe & Jameson 2002). Thirteen trophic guilds are recognized in the family (Morón & Deloya 1991), distributed in four functional groups (Deloya et al. 2007), separated according to the ecosystem's processes they perform when using a resource.

The functional groups of Scarabaeidae are: 1) saprophagous-decomposers (animal matter), beetles that degrade matter mainly of animal origin, they reincorporate nutrients available in vertebrate's dung and carcasses into the ecosystem (Halffter & Matthews 1966, Hanski & Cambefort 1991); 2) phytophagous-primary consumers, beetles that incorporate the energy captured by primary producers, they feed mainly on living tissues of plant origin (Ritcher 1958); 3) saprophytophagous-decomposers (plant matter), beetles that degrade plant material, reintegrating nutrients from fruits, wood, and other dead plant tissues into the ecosystem (Ritcher 1958); 4) predators-secondary consumers, in the case of Scarabaeidae, beetles that in their larval stage degrade dead plant material (wood) and in their adult stage can facultative feed on other invertebrates (controlling other's insects population) (Tribe Phileurini) (Velázquez et al. 2006, Deloya 2006, McCleve 2007, Ratcliffe & Cave 2017). The importance of knowing the structure of functional groups in the ecosystem lies in obtaining information about their processes (Blondel 2003). Deloya et al. (2007) proposed this approach to analyze faunal studies and determine the state of the ecosystem health. In this study, we evaluated the applicability of the functional groups' approach of the Family

Scarabaeidae as a tool for monitoring the conservation status of the forests of El Salvador. In this sense, we compared species richness and structure of the beetle assemblage in Parque Nacional El Imposible (PN-El Imposible) and Parque El Bicentenario (P-El Bicentenario), two areas with different conservation status. Considering that the diversity of Scarabaeidae is conditioned by the degree of conservation and habitat heterogeneity, the richness, abundance, and diversity of the beetles were expected to be greater in the area with better conservation status.

## **Material and Methods**

**Topographic and political description of El Salvador.** El Salvador (21,041 km<sup>2</sup>) is the smallest country in Central America. The country is bordered to the west by Guatemala, to the north and east by Honduras, and to the south by the Pacific Ocean. The country has a marked seasonality, with six months of dry season (November-April) and six months of rainy season (May-October). It is divided into 14 departments, distributed in three zones: western, central, and eastern. In addition, it is divided into four topographic zones: The Coastal Plain, the Coastal Volcanoes, and the Inland Valley (Daugherty 1969; Campbell 2020) which belong to the Pacific Lowlands Province (Morrone 2014), and the Northern mountains (Daugherty 1969) which belong to the Chiapas Highlands Province (Morrone 2014). In addition, there are 19 life zones where the Subtropical Rainforest is the most abundant (Romero 2013).

**Study areas.** P-El Bicentenario and PN El Imposible have similar sites concerning vegetation type (according to the vegetation map of El Salvador, Subtropical Rainforest) (Romero 2013), they are located in the same topographic zone (Coastal Volcanoes). Collection sites were settled between 800-900 m of elevation, immersed in a conservation area of size  $\geq 35$  km<sup>2</sup> and with a similar past of land use disturbance (abandoned coffee farms).

**Parque Nacional El Imposible - PN-El Imposible.** It is located in the department of Ahuachapán, southwestern El Salvador, at the western end of the Sierra de Apaneca-Illamatepec, more than 70 km from the metropolitan area of San Salvador (Fig. 1). It is part of the El Imposible - Barra de Santiago conservation area (77.24 km<sup>2</sup>) (Gallo 2006). It is divided into four sectors: Cerro Campana, La Fincona, San Francisco Menéndez and San Benito (SalvaNATURA 2008). It has a globally threatened ecosystem: Tropical Dry Forest and Tropical Dry Premontane Forest (Álvarez & Komar 2003), as well as Subtropical Rainforest (Romero 2013). In the park there are the last remnants of preserved vegetation in the country (Álvarez & Komar 2003; Kernén & Serrano 2010). The park is dominated by closed vegetation with some patches of open vegetation and riparian vegetation. In the park, 984 vascular plant species, 13 fish species, 13 amphibian species, 43 reptile species, 286 bird species, and 104 mammal species have been recorded (SalvaNATURA 2008). The park's past is miscellaneous and includes areas that were used as coffee and corn plantations and even used for cattle breeding. The collection site (13.829190 N, -89.944788 W) is located in the San Benito Sector (11.25 km<sup>2</sup>). Dominant plant species on the site include *Calophyllum brasiliense* Cambess, *Clethra mexicana* DC, *Guazuma ulmifolia* Lam, *Licania retifolia* Blake, *Monteverdia chiapensis* (Lundell) Biral, *Tonduzia longifolia* (A. DC.). The collection site had a coffee plantation past, which has been allowed to regenerate for the last fifty years.

**Área Natural Protegida El Espino - Bosque Los Pericos - P-El Bicentenario.** It is located in the capital metropolitan area, between the departments of San Salvador and La Libertad, on the slopes of the Volcán de San Salvador (Fig. 1). It is part of the El Playón conservation area (36.36 km<sup>2</sup>) (Gallo 2006), it is the largest forested area in the urban center of San Salvador (Romero 2013). The Finca El Espino was part of a complex of coffee farms located where one of the main native settlements in the territory of El Salvador was once located. It is considered "the last lung of San Salvador" for the ecosystem services it provides to

Antiguo Cuscatlán, Santa Tecla and the urban area of San Salvador (Martínez 2004; Linares 2011). In 1980 the government of El Salvador in the “Reforma Agraria” expropriated it. At that time, the area had 8.04 km<sup>2</sup> (Martínez 2004; Velis-Polío 2012). Subsequently, since 1986, its tenure was subject to different illegal acts, which gradually led to its fragmentation (Martínez 2004). A small remnant of El Espino is the P-El Bicentenario (13.689958 N, - 89.251657 W) with an area of 0.90 km<sup>2</sup> (SalvaNATURA 2012). Over 100 families have inhabited the park for nearly 40 years (DCL 2021). The site has recorded 536 species of vascular plants (Linares 2011), ten species of amphibians, 11 species of reptiles (Henríquez 2011), 106 species of birds (Andino & Galán 2011), and 41 species of mammals (Rodríguez 2011). The area is dominated by secondary growth vegetation, including native, invasive and exotic plants, immersed in a coffee plantation landscape (Linares 2011). Dominant plant species on the site include *Damburneya martinicensis* (Mez) Trofimov, *Inga edulis* Mart, *Persea americana* Mill, *Spathodea campanulata* Beauv (Linares 2011).

**Sampling.** Monthly sampling at each site for one year (August 2018- June 2019) was conducted. For the capture process of the scarab beetles in both sites, different traps were used: a) Baited pitfall traps (30 in total per site), which consisted of a 5-L transparent plastic container buried in the ground, with water mixed with non-odour liquid soup, above which was placed a plastic 100-ml container with holes and containing 60 g of the following baits: ten fresh human excrement, ten squid carrion (48 hours of decay), and ten fermented fruit (banana, papaya and pineapple) (48 hours of fermentation) (Horgan 2008). Traps were randomly distributed along the transect, separated by 50 m to ensure their independence (Larsen & Forsyth 2005). Traps remained active for 48 hours; during this time the bait was not replaced. b) Aerial traps baited with fermented fruit (banana, papaya and pineapple) for 48 hours with yeast and dark beer (ten per site at 10 m height). Traps were randomly distributed in two linear transects, 100 m apart (Aguilar-July 2010). Traps remained active for 48 hours; during this time the bait was not replaced. c) Ultraviolet light traps (one per site),

which consisted of two ultraviolet fluorescent bulbs in front of two vertical white sheets. They were activated from 18:00 to 23:00 hours on days close to the new moon to ensure efficiency (Aguilar-July 2010).

**Processing of collected material.** Beetles were preserved in 70% alcohol and transferred to the laboratory of the Escuela de Biología de la Universidad de El Salvador. They were mounted on pins, labeled (*i.e.* COUNTRY: Department, locality, coordinates, date, latitude and Collector), and deposited in entomological boxes. The beetles were curated and identified at the Instituto de Ecología, A.C. México, using taxonomic guides, genus revisions, catalogues (Vaurie 1958; Morón 1986; Edmonds 1994; Solís & Kohlmann 2002, 2004, 2013; Kohlmann & Solís 1997, 2001; Génier 2009; Ratcliffe & Cave 2006; Edmonds & Zidek 2010; Orozco 2012; Filippini et al. 2015, 2016; Ratcliffe 2019; Shaughney & Ratcliffe 2015) and comparison with collection reference material from the Museo de Historia Natural de El Salvador.

**Permits and sampling constraints.** Night collections in P-EI Bicentenario were performed in the escort of armed guards from the Cuerpo Municipal de Agentes Metropolitanos de Antigua Cuscatlán, processed by SalvaNATURA, due to the complex security conditions at the site. Likewise, park rangers in PN-EI Imposible escorted night samplings. Therefore, all sampling events were accommodated to the schedule of the security agents. Scarab beetles were collected under a scientific collection permit from the Ministerio de Medio Ambiente de El Salvador: MARN-AIMA-DEV-GSV-070-2018. The corresponding zoo-sanitary permit was obtained from the Ministerio de Agricultura y Ganadería de El Salvador for the shipment of the material to Mexico.

## **Data analysis**

**Comparison of species richness.** To determine if Scarabaeidae species richness was statistically different between the two study sites, confidence intervals (at 84%) of statistical expectations of species richness were contrasted. Payton et al. (2003) and MacGregor-Fors & Payton (2013) showed that an overlap of 84% in confidence intervals mimic the 0.05 tests, considered for significant differences when intervals do not overlap.

**Abundance.** Rank-abundance curve (Whittaker plot) were constructed to show the assemblage structure of Scarabaeidae at both sites. Whittaker plots are an informative method for graphically representing and comparing species' abundance from different assemblages (Whittaker 1965; Magurran 2004). To detect differences in the abundance of the two assemblages, the covariance (ANCOVA) between beetle abundance and the rank of each species at both sites were contrasted to determine how much of the total variation observed was due to regression between these two variables; study site (park) was used as a factor.

**Comparison of species composition.** The beta-Simpson species dissimilarity index ( $\beta$ Sim) was used to assess the turnover of species. The index differentiates the study sites by their richness value. It considers the number of "unique" species at the site with lower richness to determine the degree of dissimilarity in species composition between the two sites (Lennon et al. 2001). The index ranges from zero, where all species from the lower richness site are found at the higher richness site (lower dissimilarity), to one where no species from the lower richness site are found at the higher richness site (higher dissimilarity).

## **Results**

**General results and richness comparison.** The total abundance registered in both sites was 9725 beetles. They were distributed in five subfamilies, 16 tribes, 28 genera and 54 species (Table 1). The richness in PN-EI Impossible was higher (50 species) than in P-EI

Bicentenario (22 species) (Fig. 2). We registered three species for the first time in EI Salvador, 16 new local records in PN-EI Imposible and 22 in P-EI Bicentenario (Table 1).

**Abundance.** Eighty four per cent (n= 8127 individuals) of the total abundance registered (n= 9725), was recorded in PN-EI Imposible, while in P-EI Bicentenario 16 % (n= 1598) was registered (Table 1). Differences in assemblage structure were detected between the two sites (ANCOVA of rank-abundance curves  $F_{1,69} = 7.36$   $p < 0.01$ ) (Fig. 3).

**Functional groups.** The 28 genera and 54 species recorded were distributed into four functional groups (saprophagous-decomposers (animal matter), phytophagous-primary consumers, saprophytophagous-decomposers (plant matter), and predators-secondary consumers) and seven trophic guilds (coprophagous, necrophagous, rhizo-phyllaphagous, sapro-caulophagous, sapro-caulophagous, sapro-melophagous, and xylo-predators) (Tables 1).

**Saprophagous-decomposers (animal matter)** (subfamily Scarabaeinae; n= 8462).

Represented by 12 genera and two trophic guilds: coprophagous (10 genera), necrophagous (one genus), copro-necrophagous (one genus). From the total number of specimens collected, 82% (n= 6937) was captured at PN-EI Imposible, whereas the remaining 18% (n= 1525) belong to P-EI Bicentenario. The dominant species at PN-EI Imposible were *Onthophagus landolti* Harold, 1880, *Uroxys deavilai* Delgado & Kohlmann, 2007 and *U. microocularis* Howden & Young, 1981; while *Onthophagus batesi* Howden & Cartwright, 1963, *O. belorhinus* (Bates, 1887) and *Dichotomius centralis* (Harold, 1869) were the dominant species at P-EI Bicentenario (Fig. 3).

**Phytophagous-primary consumers** (subfamilies Melolonthinae, Rutelinae, Dynastinae: Cyclocephalini; n= 1179). They include seven genera and one trophic guild: rhizo-phyllaphagous. We captured 1124 specimens (95 % of the abundance detected) belonging to this group at PN-EI Imposible. *Phyllophaga pruinosa* Blanchard, 1851 and *P. obsoleta*

(Blanchard, 1851) were the species with the highest relative abundance. The remaining 5 % (n=55 specimens) was obtained at P-EI Bicentenario. Here, *Cyclocephala lunulata* Burmeister, 1847 was the dominant species.

**Saprophytophagous**-decomposers (plant matter) (Dynastinae subfamilies: Dynastini, Oryctini, Phileurini and Cetoniinae; n= 65). Represented by eight genera and two trophic guilds: sapro-meliphages (six genera) and sapro-caulophages (two genera). At PN-EI Imposible, 72% of the observed abundance (n=47) was captured being *Hoplopyga liturata* (Olivier, 1789) the species with the highest relative abundance at this site. At P-EI Bicentenario, 28% (n=18) was obtained, being *Gymnetis ramulosa* Bates, 1872 the species with the highest relative abundance.

**Predators-secondary consumers** (Subfamily Dynastinae: Phileurini). Nineteen beetles belonging to two species (*Phileurus didymus* (Linnaeus, 1758) and *Phileurus valgus* (Olivier, 1789)) were captured. These were collected only at PN-EI Imposible.

**Comparison of species composition.** Species composition was similar at both sites ( $\beta_{\text{sim}}=0.16$ ; 84% similarity). This suggests that P-Bicentenario has lost a great fraction of its species rather than shifting its assemblage composition.

## Discussion

The scarab beetles are an important component in the ecosystems due to the processes they perform, which depend on their functional group and feeding habits (Deloya et al. 2007, Morón 2014). The relevance of saprophagous beetles (Scarabaeinae) as a model for ecological assessments (Halffter & Favila 1993; McGeoch et al. 2002; Spector 2006; Noriega et al. 2021) makes them one of the most studied taxa in the entire order Coleoptera (Philips 2011, Ramírez-Restrepo & Halffter 2016). In this study, we observed that the richness and abundance of saprophagous beetles were higher in PN-EI Imposible than in P-

El Bicentenario, suggesting that the degradation processes of animal wastes are carried out more effectively in the most conserved area (Batilani-Filho and Hernández 2017).

Coprophagous beetles were the most abundant species in PN-EI Imposible (*O. landolti*, *Uroxys microcularis* and *U. deavilai*) and in P-EI Bicentenario (*O. batesi*, *O. belorhinus*, and *Dichotomius centralis*), which suggests that the amount of vertebrate dung available in these parks is significant (Nichols et al. 2009). There is a direct relationship between the beetle abundance and the richness of mammal species (*i.e.* 104 mammal species at PN-EI Imposible, 41 at P-EI Bicentenario; SalvaNATURA 2008, 2012). However, to understand these patterns better, it is also necessary to consider other factors such as the vegetation cover of each site (Halffter & Arellano 2002). For instance, in El Salvador, Horgan (2008) found that the drop of richness, diversity and functional diversity in grassland areas close to forest patches is significant. In both parks, the necrophagous species with the highest abundance was *Coprophanæus corythus* (P-EI Bicentenario, n=93, PN-EI Imposible, n=56). The presence and abundance of this species, in addition to the sympatry with *C. boucardi* (Nevinson, 1891), could suggest that at P-EI Bicentenario there is a great availability of carcasses, which has been suggested as an indicator of a high degree of disturbance (Pablo-Cea et al. 2020).

Phytophagous beetles have been considered a good indicator group (Morón 2014), and a key element for forest conservation (Deloya & Martínez-Cortés 2010). In this study, we observed that the richness and abundance of this functional group of beetles were higher in PN-EI Imposible than in P-EI Bicentenario. The most abundant species in PN-EI Imposible (*Phyllophaga pruinosa*, *P. obsoleta*) and in P-EI Bicentenario (*Cyclocephala lunulata*) are rhizo-phytophagous beetles (Morón 1986, Ratcliffe & Cave 2006). The abundance of phytophagous beetles is associated to the availability of plant resources having a greater vegetation cover at PN-EI Imposible than at P-EI Bicentenario (SalvaNATURA 2008, 2012). This factor has been suggested as a key determinant of beetle diversity, even more than the

availability of food resources itself (Halffter & Arellano 2002). P-EI Bicentenario is immersed in a complex matrix of abandoned and active coffee growing areas. García-Atencia et al. (2015) suggest that a matrix surrounded by crops benefits the reproductive success of phytophagous beetle species. Therefore, this park meets at least in part a requirement to safeguard a good richness and abundance of species of this functional group. However, an important aspect to consider is the location of P-EI Bicentenario, which is almost completely surrounded by the urban area of San Salvador. The low richness and abundance of phytophagous (and saprophytophagous) beetles could be also explained by light pollution effect. In cities, artificial light increases the halo of attraction for insects, causing insects from nearby areas to be intercepted by predators when flying, killing them and consequently affecting local populations (Eisenbeis & Andreas 2009; Camacho 2015). Currently, the human communities living within the area are requesting the implementation of public lighting within the park (DCL 2021), an aspect that would be an advance for their safety, but which must be carefully evaluated and implemented to ensure the least possible impact on the biodiversity of the area.

Delgado-Castillo and Deloya (1990) suggested that the diversity of saprophytophagous beetles is related to the conservation status of the forests. In this study, we observed that the richness and abundance of saprophytophagous beetles were higher in PN-EI Imposible than in P-EI Bicentenario. The most abundant species in PN-EI Imposible (*Hoplopyga liturata*) and in P-EI Bicentenario (*Gymnetis ramulosa*) are sapro-melliphagous beetles (Shaughney & Ratcliffe 2015; Ratcliffe 2019). The higher abundance of saprophytophagous beetles suggests that plant matter degradation is greater in PN-EI Imposible compared to P-EI Bicentenario; also indicates that the availability of soil organic matter and decaying wood is higher in EI Imposible (Delgado-Castillo & Deloya 1990; Deloya & Martínez-Cortés 2010; Pardo-Lorcano et al. 2011; Márquez et al. 2013). To further explore the causes of low richness and abundance in P-EI Bicentenario, we suggest that future studies must evaluate

aspects related to park management (e.g. rate of timber extraction in any state of decay or the rate of reforestation with native or non-native trees in the area). Unfortunately, those aspects were not evaluated in this study; however, families inhabiting at P-EI Bicentenario collect firewood for survival (Pablo-Cea et al. 2022). This fact certainly influences negatively the richness of saprophytophagous beetles. Assessing aspects like these would help to understand the effect of habitat transformation on beetle diversity. Therefore, controlling them would benefit the conservation of beetles of this functional group in P-EI Bicentenario.

Deloya (2006) proposed the predators' functional group that feed on other insects to include beetles of the Tribe Phileurini. This behaviour has long been identified, but for which little documented evidence for this tribe exists (McCleve 2007, Ratcliffe & Cave 2009). In the present study, two species of the genus *Phileurus* were captured (*P. dydymus* and *P. valgus*). They are present only at PN-EI Imposible, which means the absence of this functional group in P-EI Bicentenario; and consequently, the absence of the processes carried out by these beetles (e.g. control of insect populations). Ratcliffe & Cave (2006) mention that *P. dydymus* is found in relatively undisturbed areas, whereas *P. valgus* is a species more tolerant to habitat perturbation. The biology of the genus and of the functional group, in general, is poorly known (Ratcliffe & Cave 2006) for instance there is scant information on larval stage, life history and larval development (Ratcliffe & Cave 2009, 2015); so more work is needed to assess its relationship with the forest conservation status.

The Family Scarabaeidae has high ecological fidelity; therefore, showing specific environmental characteristics (Morón 1997, 2014). In PN-EI Imposible, the abundant species are typical of closed vegetation areas (e.g. *U. deavilai*, *U. microcularis*, *Canthon femoralis* (Chevrolat, 1834), *Phyllophaga pruinosa*) (Rivera-Cervantes & Halffter 1999; Delgado & Kolhmann 2007; Solís & Kolhmann 2013; Morón 2018). However, *Onthopagus landolti*, the dominant species, has a wide range of ecological tolerance and feeding plasticity

(Avendaño-Mendoza et al. 2005; Reyes-Novelo et al. 2007; Andresen 2008; Basto-Estrella et al. 2012), which could indicate an advanced state of transition at the site, coming from a past of disturbance, towards a more natural state. At P-El Bicentenario, *O. batesi* and *Dichotumius centralis*, two of the most abundant species, are typical of open vegetation areas and possess high environmental tolerance (Kohlmann & Solís 1997; Howden & Young 1981; Kohlmann & Solís 2001; Montes de Oca 2001; Horgan 2008). Their higher abundance could indicate that the site still retains many characteristics of an open area and not of a forest. In other hand, *O. belorhinus*, the other abundant species in the park, is associated with closed vegetation areas in El Salvador (Pablo-Cea et al. 2020). Its abundance at the site, together with the presence of other species typical of closed vegetation areas, less abundant in the park (e.g. *C. boucardi*, *C. corythus*, *Phanaeus pacificus* Moctezuma & Halffter, 2021) could indicate that the ecological restoration process in P-El Bicentenario is beginning and in the future, if the conservation efforts carried out in the park continue, even more species associated with less disturbed states could be found at the park.

Since the origin of the Natural Protected Areas System of El Salvador, the importance of PN-El Imposible to protect biodiversity has been widely recognized (Komar 2002; Álvarez & Komar 2003; USAID 2010, Medrano & Hernández 2017). Fortunately, beetles are no exception (Pablo-Cea et al. 2020). However, the absence of many species in the P-Bicentenario reflected in the species richness values, and the  $\beta_{sim}$  suggest that significant loss of Scarabaeidae species in the least conserved sites of the country is happening. This loss of species highlights the importance of conducting biological surveys in alleged less important areas for conservation in order to implement strategies for their management and protection. Because only giving priority to specific patches of forest in the territory is neglecting the protection of less charismatic sites. Therefore, causing the loss of habitat suitable to disturbance tolerant species but which perform an equally important function for the ecosystems (Nichols et al. 2008). In countries like El Salvador that have gone through

severe economic and social problem, any patch of forest, including heavily degraded ones, are important for safeguarding species. The work of institutions such as SalvaNATURA (the organization that co-manages P-EI Bicentenario) and the Ministerio de Medio Ambiente y Recursos Naturales de El Salvador is key to protect biodiversity.

In El Salvador, the absence of research using standardized methodologies to estimate the abundance of animal groups continues to limit the re-evaluation of Komar's (2002) proposal. Certainly, functional groups of the Family Scarabaeidae reflect the conservation status of PN-EI Imposible and P-EI Bicentenario, demonstrating the applicability that this approach has as a monitoring tool for conservation in this country. Scarabaeidae, and specially the Subfamily Scarabaeinae is taxonomically well studied, at least at the regional level. The methodologies to capture them are relatively simple, rapid, easily repeatable, and require relatively few personnel to be performed. All these are indispensable requirements for a good indicator group (Moreno et al. 2007). Clearly the use and popularity of the Subfamily Scarabaeinae as a model group (Favila and Halffter 1993) has eclipsed the use of other subfamilies in this sense. Nonetheless it is important to note that the whole family has useful characteristics to be applied in this type of studies (Morón 2014), hencefore more related research is needed in this sense to clear this up.

The cost-benefit ratio of using a single indicator group is better than collecting data from many groups. Because the last implies a more intensive sampling effort, causing the taxonomic and financial aspects to be a constraint (Bladt et al. 2008), which is a considerable limitation in a country like El Salvador where financial issues are one of the main causes for stopping biodiversity studies (Komar 2002). Based on the possible advantages, here we propose to use functional groups of the Family Scarabaeidae to assess the forests condition in the Salvadoran territory as an option for identifying priority areas for conservation and management. Unfortunately, a limiting factor to this proposal is the

violence in El Salvador, which makes rarely sampled areas inaccessible. This is a harsh problem especially in the eastern zone of the country (Pablo-Cea, personal observation).

Another minor draw back is the lack of accurate identification tools designed explicitly for El Salvador; hence, in upcoming years, works dealing with the local taxonomic limitations must be carried out.

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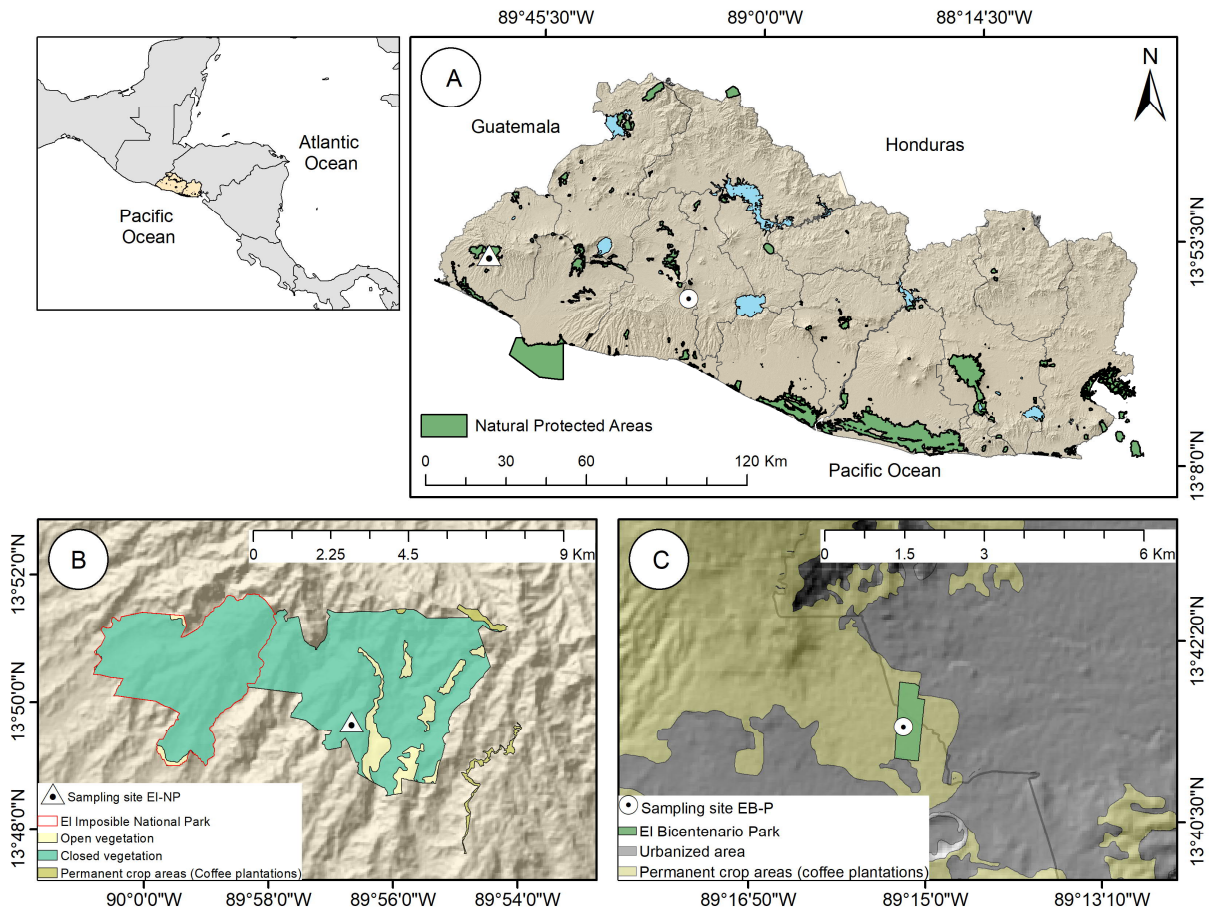
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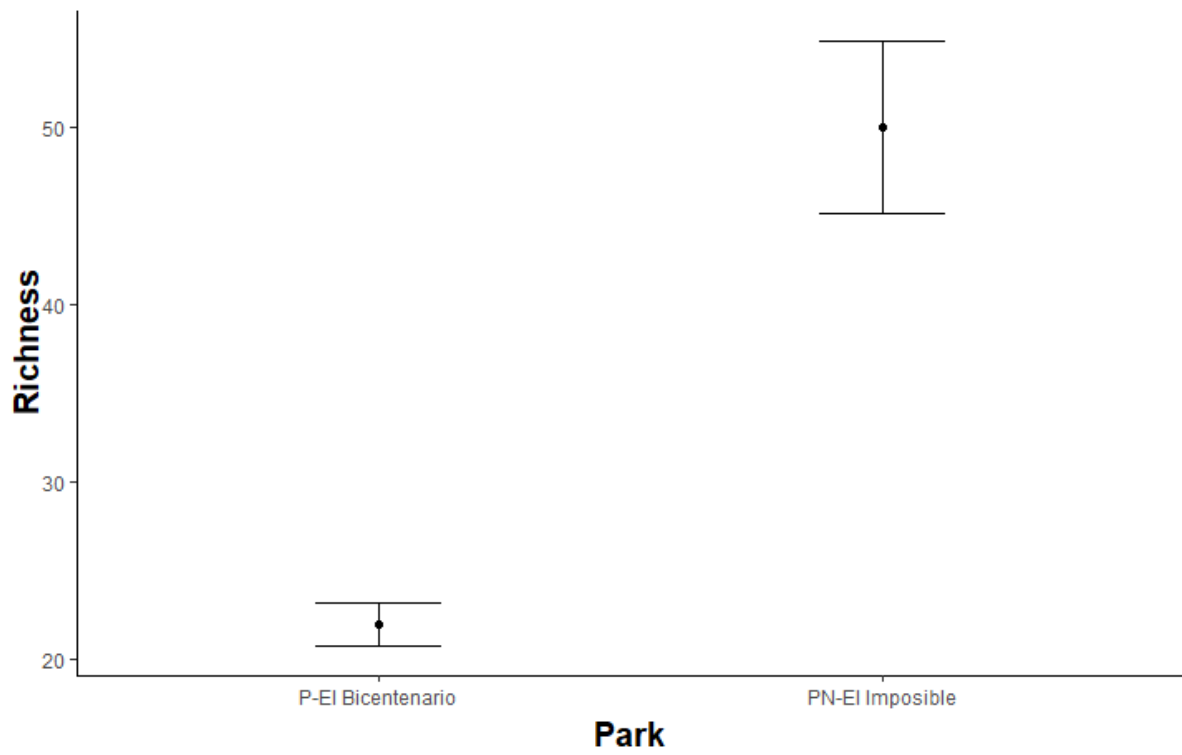
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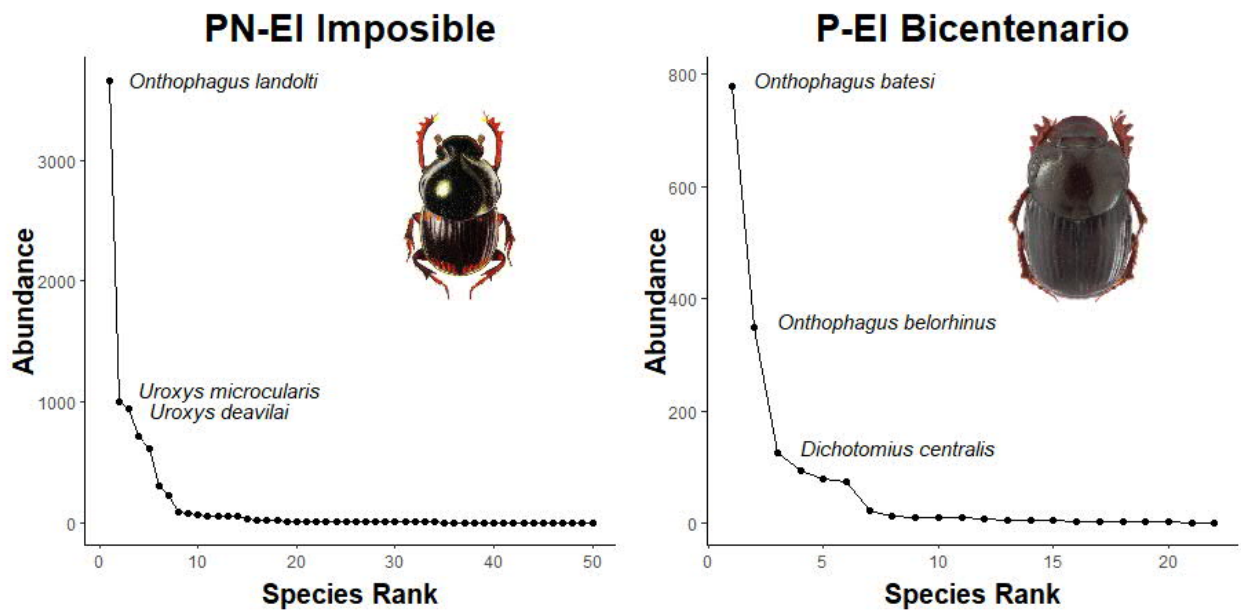
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**Fig. 1.** A) Map of El Salvador showing the location of the study sites (Triangle: PN-EI Imposible; Circle: P-EI Bicentenario). B) Map of PN-EI Imposible. C) Map of P-EI Bicentenario.



**Fig. 2.** Species richness in each study area ± Confidence Intervals (84%). PN-EI Imposible (50± 4.85); P-EI Bicentenario (22±1.22).



**Fig. 3.** Rank-abundance curve (Whittaker plots) of the Family Scarabaeidae in both sites. Images; left: *O. landolti* (modified from Kohlmann & Solís 2001); right: *O. batesi* (modified from Capello & Halffter 2019).

**Table 1.** Species of Coleoptera Scarabaeidae in two protected areas in El Salvador, Central America (expressed in abundance; PNEI: PN-EI Imposible; PEB: P-EI Bicentenario). <sup>1</sup>: first record in El Salvador; <sup>2</sup>: first record in PN-EI Imposible. TG: Trophic Guild; C: Coprophagous; N: Necrophagous; R-P: Rhizo-Phyllophagous; S-M: Sapro-Melliphagous; S-C: Sapro-Caulophagous; X-L: Xilo-Predator.

Species	TG	PNEI	PEB	Total
<b>Saprophagous-decomposers (animal matter)</b>				
Subfamily Scarabaeinae				
Tribe Ateuchini				
<i>Ateuchus rodriguezii</i> (Preudhomme de Borre, 1886)	C	1	0	1
<i>Uroxys deavilai</i> Delgado & Kohlmann, 2007	C	946	0	946
<i>Uroxys microcularis</i> Howden & Young, 1981	C	1002	0	1002
Tribe Coprini				
<i>Canthidium pseudopuncticolle</i> Solís & Kohlmann 2004	C	71	0	71
<i>Copris costaricensis</i> Gahan, 1894	C	87	3	90
<i>Copris lugubris</i> Boheman, 1858	C	5	0	5
<i>Dichotomius annae</i> Kohlmann & Solís, 1997	C	0	12	12
<i>Dichotomius centralis</i> (Harold, 1869)	C	59	125	184
<i>Dichotomius yucatanus</i> (Bates, 1887)	C	57	78	135
Tribe Deltocilini				
<i>Canthon cyanellus sallei</i> Harold, 1863	C	4	0	4
<i>Canthon femoralis</i> (Chevrolat, 1834)	C	610	0	610
<i>Deltocilium sublaeve</i> Bates 1887	C/N	4	0	4
Tribe Oniticellini				
<i>Eurysternus magnus</i> Laporte, 1840	C	1	0	1
Tribe Onthophagini				
<i>Onthophagus batesi</i> Howden & Cartwright, 1963	C	1	780	781
<i>Onthophagus belorhinus</i> (Bates, 1887) <sup>2</sup>	C	306	350	656
<i>Onthophagus championi</i> Bates, 1887	C	1	0	1
<i>Onthophagus landolti</i> Harold, 1880	C	3654	0	3654
<i>Onthophagus marginicollis</i> Harold, 1880	C	0	8	8
Tribe Phanaeini				
<i>Coprophanaeus boucardi</i> (Nevinson, 1891)	N	0	74	74
<i>Coprophanaeus corythus</i> (Harold, 1863)	N	56	93	149
<i>Phanaeus eximius</i> Bates, 1887	C	6	0	6
<i>Phanaeus pacificus</i> Moctezuma & Halffter, 2021	C	62	2	64

<i>Phanaeus wagneri</i> Harold, 1863	C	3	0	3
Tribe Sisyphini				
<i>Sisyphus mexicanus</i> Harold, 1863	C	1	0	1
<b>Phytophagous-primary consumers</b>				
Subfamily Melolonthinae				
Tribe Diplotaxini				
<i>Diplotaxis angustula</i> Moser, 1918 <sup>2</sup>	R-P	17	0	17
<i>Diplotaxis mistura</i> Vaurie, 1960 <sup>2</sup>	R-P	20	0	20
Tribe Melolonthini				
<i>Chlaenobia tumulosa</i> (Bates, 1888) <sup>2</sup>	R-P	7	2	9
<i>Phyllophaga (Phytalus) pruinosa</i> Blanchard, 1851 <sup>1,2</sup>	R-P	717	0	717
<i>Phyllophaga (Ph.) obsoleta</i> (Blanchard, 1851) <sup>2</sup>	R-P	221	5	226
<i>Phyllophaga (Ph.) grupo lineata</i>	R-P	12	0	12
<i>Phyllophaga (Ph.) grupo pentaphylla</i>	R-P	12	5	17
<i>Phyllophaga (Phyllophaga) sp.</i>	R-P	13	9	22
Subfamily Rutelinae				
Tribe Anomalini				
<i>Anomala pincelada</i> Filippini et al. 2015 <sup>2</sup>	R-P	54	11	65
<i>Anomala robiginosa</i> Filippini et al. 2015 <sup>2</sup>	R-P	4	0	4
<i>Anomala</i> sp1	R-P	2	0	2
<i>Callistethus multiplicatus</i> Filippini et al. 2015 <sup>1,2</sup>	R-P	25	0	25
Subfamilia Dynastinae				
Tribe Cyclocephalini				
<i>Aspidolea singularis</i> Bates, 1888	R-P	5	2	7
<i>Cyclocephala deceptor</i> (Casey 1915)	R-P	2	0	2
<i>Cyclocephala lunulata</i> Burmeister, 1847	R-P	12	21	33
<i>Cyclocephala mafaffa</i> Burmeister, 1847	R-P	1	0	1
<b>Saprophytophagous-decomposers (plant matter)</b>				
Subfamily Dynastinae				
Tribe Dynastini				
<i>Megasoma elephas</i> (Fabricius, 1775)	S-M	1	0	1
Tribe Oryctini				
<i>Strategus aloeus</i> (Linnaeus, 1758)	S-C	2	1	3
<i>Strategus jugurtha</i> Burmeister, 1847	S-C	6	2	8
Tribe Pentodontini				

<i>Tomarus sallaei</i> (Bates, 1888)	S-C	2	0	2
Subfamily Cetoniinae				
Tribe Cetoniini				
<i>Cotinis mutabilis</i> Gory & Percheron, 1883	S-M	0	5	5
<i>Euphoria avita</i> Janson, 1881 <sup>2</sup>	S-M	2	0	2
<i>Euphoria iridescens</i> (Schaum, 1841) <sup>1,2</sup>	S-M	7	0	7
<i>Euphoria pulchella</i> (Gory & Percheron, 1833) <sup>2</sup>	S-M	2	0	2
<i>Euphoria yucateca</i> Bates, 1889 <sup>2</sup>	S-M	2	0	2
Tribe Gymnetini				
<i>Argyripa lansbergei</i> (Sallé, 1857) <sup>2</sup>	S-M	1	0	1
<i>Gymnetis ramulosa</i> Bates, 1872 <sup>2</sup>	S-M	1	9	10
<i>Hoplopyga liturata</i> (Olivier, 1789) <sup>2</sup>	S-M	21	1	22
<b>Predators-secondary consumers</b>				
Subfamilia Dynastinae				
Tribe Phileurini				
<i>Phileurus didymus</i> (Linnaeus, 1758)	X-L	10	0	10
<i>Phileurus valgus</i> (Olivier, 1789)	X-L	9	0	9
<b>Total</b>		<b>8127</b>	<b>1598</b>	<b>9725</b>