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Scarabaeidae family (Coleoptera) as potential environmental quality bioindicator

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ABSTRACT

Insects are widely used as biological indicators of environmental quality in environmental monitoring studies, because they have certain aspects that help in the identification of environmental stress. The genus *Dichotomius,* from the family Scarabaeidae, has a wide occurrence in the Brazilian territory, being found in many Brazilian biomes, including in the Caatinga. The species *Dichotomius nisus* and *Dichotomius aff. Laevicollis* were recorded in the Catimbau National Park (PE), study area of this work, in environments of different conservation states. Through secondary data, the characteristics of these two species were analyzed considering certain criteria of ideal bioindicator. Both species demonstrated potential as a tool for indicating environmental quality, despite presenting different responses to a disturbance.

Keywords: Caatinga; scarabaeidae; biological indicator; environmental monitoring.

Família Scarabaeidae (coleoptera) como potencial bioindicador de qualidade ambiental

RESUMO

Os insetos são muito utilizados como indicadores biológicos de qualidade ambiental em estudos de monitoramento ambiental, visto que possuem certos aspectos que auxiliam na identificação de estresse ambiental. O gênero *Dichotomius*, da família Scarabaeidae, possui uma ocorrência ampla no território brasileiro, sendo encontrado em muitos biomas brasileiros, inclusive na Caatinga. As espécies *Dichotomius nisus* e *Dichotomius aff. Laevicollis* foram registradas no Parque Nacional do Catimbau (PE), área de estudo deste trabalho, em ambientes de diferentes estados de conservação. Por meio de dados secundários, foram analisadas as características dessas duas espécies levando-se em consideração certos critérios de bioindicador ideal. Ambas espécies demonstraram potencialidade como ferramenta de indicação de qualidade ambiental, apesar de apresentarem respostas distintas diante de uma perturbação.

Palavras-chave: Caatinga; scarabaeidae; indicador biológico; monitoramento ambiental.

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Introduction

Brazil has the largest biodiversity on the planet, with between 15 and 20% of the total, and is among the seventeen countries that are considered megadiverse, being the first in the world ranking. This biological diversity also manifests in the six biomes that it possesses (Amazon, Caatinga, Cerrado, Pampas, Atlantic Rainforest and Pantanal), which comprise ten phyto-ecological regions, thirty-one plant formations and many areas of pioneering formations, marine, river and lake action, besides the marine environment found in the coastal region of the country (Ganem 2011).

However, this natural wealth is threatened by the intense anthropogenic action practiced since many decades ago, putting at risk many species that are sometimes endemic to the region. Among many legal provisions that ensure the protection and conservation of biological diversity, it is worth mentioning Federal Law 9.985/2000, which establishes the National System of Conservation Units (SNUC). Conservation units - UC is an efficient conservation strategy *in situ*, when there is adequate management of the biological diversity that it shelters. The management of a UC should consist of actions guided by the management plan, in which it presents the survey of the most important aspects of the unit and its surroundings (environmental, socioeconomic, cultural and historical) (Brasil 2000).

Conciliating the need for the preservation of natural resource, genetic and natural landscapes with the need of use for certain purposes, such as the subsistence of traditional communities and scientific research, the law in question divides the UC into two groups: integral protection units and sustainable use units. The groups differ in terms of the level of interference granted, regulated by the law and the management plan of UC (Brasil 2000).

Although protected areas are not exempt from degradation of anthropogenic origin, an example is given by Veríssimo et al. (2011), which reports that in the Legal Amazon, in its protected areas, between 1998 and 2009, a percentage of 47.4% of total deforestation in the UC was verified, being observed to a greater extent in sustainable use units reaching 3.7% and with less intensity (2.1%) in the integral protection units.

Given this scenario, the monitoring of the preservation conditions is a fundamental step to management evaluation performed in the UC and for this it is important to know the environmental quality indicators in the place. One of the tools that can be used for this purpose is the use of bioindicator organisms, which will be the focus of this work.

Bioindicators of environmental quality

The interaction of living beings with their habitat leaves them susceptible to variations occurring in this environment, provoking positive or negative effects on these organisms. A study with entomofauna confirms this association, describing that the structure and abundance of insect communities oscillate with climatic, edaphic and environmental conditions (Lewinsohn et al., 2005). Due to this vital capacity of living beings responding to stimuli, in this external case, it can be used as indicators of environmental change (Neumann-Leitão & El-Deir 2009). Cordeiro et al. (2004) conceptualize bioindicators as organisms that are present or absent in a given area related to a certain environmental condition. Brown (1997, apud Wink et al., 2005) complements by stating that generally the change in abundance, diversity, and composition of a set of indicators measures environmental stress.

Bioindicators have specificity for certain impacts, because several species are vulnerable to one type of pollutant and more resistant to others (Washington, 1984). Species with a higher tolerance to a given stressor factor are termed euripotent, and those that support less are estenopotent. As for ecological succession, they can be classified as opportunistic, which are species that predominante in disturbed areas, replacing natural species, and specialists are more environmentally sensitive (Neumann-Leitão & El-Deir 2009).

Studies with bioindicators can be done in a passive way, in which the species used inhabit the investigated site or active method, introducing species in a controlled way (Silva et al., 2000).

An important observation is made by Leitão-Neumann and El-Deir clarifying that the bioindication "is not limited to an analysis of the presence or absence of a species, its physiological vigor or the intensity of an environmental factor in relation to an organism only, but of the reaction of a biological system to an environmental change.".

Coleoptera as environmental bioindicator

The Insecta class has the highest diversity of species and greater abundance among other groups of the animal kingdom, whose representatives are distributed in all the habitats of the world. According to Loreau et al. (2002), this predominance indicates the importance of insects in the processes that regulate terrestrial ecosystems, mainly in the tropics.

Many insect groups are used as environmental bioindicators because they have a high diversity, functional importance, ecological fidelity, close relation with other species, rapid response to environmental fluctuations and ease of capture (Halffter & Favila 1993, García & Pardo 2004, Pearce & Venier 2006, Gardner et al., 2008).

Among these groups of insects, the order Coleoptera stands out for its numerous representatives, comprising 40% of the total number of insects. In the Neotropical region, 127 families were recorded, of which the Scarabaeidae family stands out for having great adaptive irradiation and for understanding approximately 25,000 species (Lawrence & Newton 1995 apud Costa et al. 2009). The most popular subfamily is Scarabaeinae which is taxonomically and functionally known, covering 12 tribes, 234 genera and 6,000 species (Hanski & Cambefort 1991 apud Costa et al. 2009).

The Scarabids can be divided according to their behaviors and habits, often peculiar, in groups called guilds. There are guilds related to food transport, classifying the species into paracoprids (conducting food into underground tunnels), telecoprids (producing food spheres for better allocation) and endocoprids (feeding and depositing their eggs in food); to the alimentary habit, being able to be coprifiers, necrophic or generalists; and to the temporal pattern of activity, grouping in diurnal, nocturnal, twilight and continuous activity (Silva et al., 2007, Holter et al. 2002). It is common to find coprophages in natural pastures, which play a key role in the biological control of the population of synanthropic flies and gastrointestinal nematodes, which develop in bovine manure, as well as in the recycling of nutrients (Marchiori 2000, Silva et al., 2011).

In many environmental monitoring studies is common to use scarabaeids as a biological indicator of environmental quality, because they constitute the following characteristics: they have established guilds, well-defined taxonomy for species, their sampling is easily accessible, high diversity in tropical forests and susceptible to the consequences of deforestation (Endres et al., 2007, Hernández 2003). However, coleoptera generally have two very peculiar morphological attributes, which have been associated with the success of their adaptation in arid and semi-arid regions. These attributes are the presence of elytra, which provide protection to the wings and body, and the location of the opening of the abdominal spiracles, found between the elytra and abdomen, thus avoiding water loss and developing the internal organs better (Lawrence & Britton 1991 apud Iannuzzi et al., 2008).

Many surveys of the species of the Scarabaeidae family were carried out in the Brazilian Northeast region (Endres et al., 2007, Hernández 2007, Costa et al., 2009, Barbosa et al., 2005, Liberal et al. 2011). In the Caatinga, there are some studies such as de Hernández et al. (2007) recorded 20 species in the Cariri region (PB); Medina & Lopes (2014) found 16 species with six new records in this biome in Milagres (BA) and; LIBERAL et al. (2011) cataloged 13 species in a National Park of Catimbau in Pernambuco. Only in Pernambuco 33 species were inventoried (Costa et al., 2009).

The genus Dichotomius, from the Coprini tribe, is recorded in many works in several regions of Brazil (Costa et al., 2009, Hernández 2007, Ender et al., 2011, Marchiori 2000, Otavo et al., Rodrigues et al. 2013, Silva et al. 2007, Vieira & Silva 2012), showing a wide distribution in the Brazilian territory in different habitats, being identified, besides the caatinga, in Atlantic Forest, open tree savanna and in pastures. They are generally well represented in the collected samples, standing out in abundance in relation to the other groups. According to Silva et al. (2011) this genus has about 161 species that occur in the Americas.

Degradation of the Caatinga

The Caatinga biome has an area of 844,453 Km^2, which covers all the states of the northeast region and a northern part of the state of Minas Gerais (IBGE 2004). Being an exclusive biome of Brazil, there are many endemic species of the region, however, there are few protected areas and a high rate of deforestation, about 54% of its total extent (IBGE 2012). This is due to two facts: in previous years, there were few studies about its flora and fauna, erroneously considered as a biome poor in species diversity and low degree of endemism, giving little attention to its conservation (Silva et al.); and is also attributed to being a populated area with low human development indexes, whose inhabitants seek their source of subsistence in the environment, mainly exploiting energy and edaphic resources, the latter through agricultural activities (Hauff 2010).

In 2009, there were 24 UC of federal management constituted by the Caatinga vegetation (IBGE 2010), being the third biome with the least protected areas, corresponding to

1.3% of the total protected federal protected areas, behind the Pantanal and the Pampa. Although being protected areas, deforestation is observed as revealed by a study by Trebbi et al. (2011), which reported that in seven years, 94,715 hectares were deforested in the interior of forty four sustainable use consevation units present in the Caatinga, representing about 1.8% of the place designated for conservation.

In view of the exposed critical scenario of the Caatinga, it was proposed in this work to identify potential bioindicators of environmental preservation through native species of Scarabaeidae in a conservation unit in the caatinga.

Materials and Methods

The existing conservation unit in the Caatinga selected for this study was the Catimbau National Park (Catimbau PARNA) located between the geographical coordinates 8° 24' 00" and 8° 36' 35" of South Latitude and 37° 09' 30" and 37° 14' 40" of West Longitude. The PARNA covers three municipalities of Pernambuco, Buíque, Tupanatinga and Ibimirim, resulting in an area of 62,300 ha, located in a transition zone between the Sertão and Agreste of the state (Carvalho Neto & Santos 2012, Farias 2009). It is considered the second archaeological park in the country, which was converted into an Integral Protection Unit (Rufino et al., 2008) by means of the Decree of December 13, 2002. One of the reasons why the Catimbau PARNA was created is the scenic beauty of the place, made up of large rocky walls with rock engravings found particularly in the existing caves, which total about two thousand (Carvalho Neto & Santos 2012).

The predominant climate, according to Köppen, is BSh'w (warm and dry), with an average annual temperature of 26°C and average rainfall of 600 mm, presenting more intense rains from April to June (SUDENE 1990) . Its vegetation is predominantly shrub, typical of the Caatinga, possessing both primary and secondary forest areas, with presence of Cerrado species, rupestrian fields, Atlantic Forest and restinga (IBAMA 2007, Carvalho Neto & Santos 2012). In the middle of this common vegetation of the Caatinga, there is differentiated vegetation bacause it is located in separately in some points that receive greater precipitation, called "brejo de altitude" (Tabarelli & Santos 2004).

The creation of protected areas in the Caatinga ratifies the commitment of the state government to promote its protection, especially the areas considered of biological importance "high" and "very high", which are priority for the conservation of the Caatinga biodiversity (SOARES et al., 2016). The PARNA of Catimbau is recognized for being a site that contains important endemisms, being relevant in the biological aspect and priority for the conservation of the Caatinga biodiversity (Geise et al., 2010, Vital et al. 2008).

The present study of propositional character sought initially to identify the species found in the PARNA of Catimbau in the scientific literature, with the objective of associating them with the different degrees of conservation of the UC. From works describing the common escarabids in PARNA, two species (*Dichotomius nisus* and Dichotomius aff. Laevicollis) were identified as potential bioindicators of environmental quality. In these works, surveys were carried out in different habitats and one of them is related to the precipitation factor (Liberal et al., 2011, Schiffer 2005). Other studies were used to obtain more information on the species chosen and their habitats. The criteria used to choose the ideal biological indicator for this work were: (a) to be taxonomically well defined, (b) easily recognizable by non-specialists, (C) present a wide geographical distribution, (d) be abundant, (e) (E) have low genetic and ecological variability, (f) preferably have a large size, (g) have low mobility and a long life cycle, (h) have well-known ecological characteristics and (i) Laboratory ".

The analyzed data were plotted in tables, in the form of values on a scale of 1 to 3, according to their agreement with given parameter, which in turn were pre-established weights for each one, according to the level of relevance in the efficiency of bioindication. The establishment of weights was the result of a consensus among the authors of this study, because there is no basis for this type of evaluation. The results obtained aided in the discussion and conclusion of the study.

Results and Discussion

The evaluation of the species *Dichotomius nisus* and *Dichotomius aff. Laevicollis* based on the parameters suggested by Johnson et al. (1993) resulted in the following values (Table 1):

Table1. Evaluation of selected species from the parameters of ideal bioindicator defined by Johnson et al. (1993).

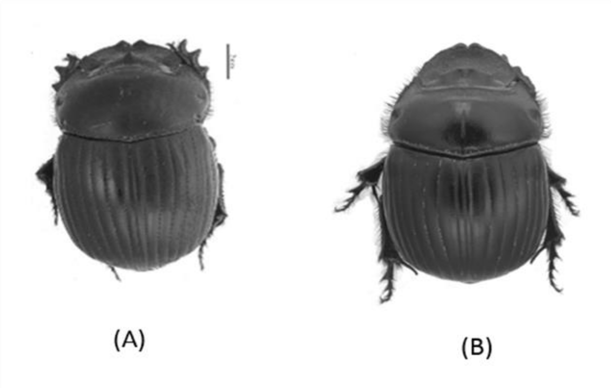
Parameters evaluated and their respective weights	Species: *Dichotomius aff. laevicollis* DA	R	Dichotomius nisus DA	R	Average
Taxonomically well defined (3)	1	3	3	9	6
Easily recognizable by non-specialist (1)	1	1	1	1	1
Present broad geographical distribution (1)	2	2	3	3	2,5
Be abundant (2)	2	4	2	4	4
To have low genetic variability (2)	-	-	-	-	-
To have low ecological variability (2)	1	2	3	6	4
Preferably have a large size (1)	1	1	1	1	1
To have long lifecycle (2)	1	2	1	2	2
Display low mobility (2)	1	2	1	2	2
To have well-known ecological characteristics (3)	2	6	2	6	6
Have possibility of use in laboratory studies (1)	3	3	3	3	3

DA: Degree of agreement
R: Result

Analyzing by the average, it is observed that one of the significant points for its potential as a biological indicator is its taxonomy, which had the value 6 as a result. However, for Vieira & Silva (2012), the species *Dichotomius aff. Laevicollis* (Felsche 1901) urgently needs a taxonomic revision, since it is part of a complex group of species called the sericeus group. As for the *Dichotomius nisus* (Olivier 1789), no objection was found in the literature regarding its taxonomy.

One of the weak point that the species presented is their recognition by a layman in the area, since the Scarabaeidae have numerous representatives and the distinction between the species are variations in their morphological characters not known and little expressive to the views of a nonspecialist. This fact can be verified in Figure 1 (Vieira & Silva 2012).

Figure 1: Scarabaeidae (A) *Dichotomius* aff.*laevicollis* (B) *Dichotomius nisus*



Source: Vieira & Silva, 2012

It was considered a mean agreement with respect to the parameters geographical distribution and abundance, which the latter is one of the Strong point due to the high weight conferred to it. The occurrence of *Dichotomius aff. Laevicollis* was verified in abundance in the Atlantic Forest, the Caatinga and the transition zone between these two biomes in the northeastern region of Brazil (Pernambuco and Bahia) (Liberal et al., 2011, Vieira & Silva 2012).

Its incidence in restinga in southeastern Brazil (Espírito Santo) was also recorded (Vieira et al., 2008). It is important to note that this species was found only in relatively conserved areas, meaning that its abundance and distribution may be compromised by the degradation of these regions. This sensitivity to the degradation conferred on the species shows its potential as a bioindicator for less anthropogenic areas.

The *Dichotomius nisus* species obtained a high agreement in the criterion of geographic distribution, because it is widely distributed in Brazil in several biomes and ecosystems such as Atlantic Forest, Pantanal, Restinga and Amazon (Schiffler et al., 2003, Flechtmann et al. Al. 2010, Schiffler 2005). However, these biomes confer closed environments, which are unfavorable conditions for this species, resulting in low abundance (Medina & Lopes 2014). As you can see, the abundance index is relative, also seen in the species D.aff. Laevicollis, due to environmental conditions, being high in open areas, pasture and agriculture (Rodrigues et al., 2013, Schiffler et al., 2003, Silva et al., 2007). There is also record in the Caatinga, in its open areas and also in "brejos de altitude" (Endres et al., 2007, Liberal et al., 2011, Vieira & Silva 2012).

There are few studies on the genetic analyzes of the escarabeids. There is no data on intraspecific variability of the species in question. However, the ecological variability of the species *Dichotomius nisus* is high because it is well adapted to the different types of ecosystems mentioned above.

Despite the disagreement of the parameter size of the species, this item was considered relatively insignificant since microorganisms can be used for this purpose. From the identification key developed by Vieira & Silva (2012) of the species collected from Scarabaeidae in the National Forest of Contendas do Sincorá (BA), an estimation of the size of the species studied was done, being around 15 millimeters.

According to Borror & Delong (1988), the life cycle of beetles varies greatly, from four generations a year to a generation in several years. In general they are short, and under favorable conditions multiply quickly, thus compensating for this disadvantage.

Similar punctuation of the item evaluated previously, due to the discordance of the same, is seen in this criterion of mobility. Like all arthropods, species have articulated appendages, and the escarabeídeos have tarsal claws to aid in their locomotion (Silva et al., 2011).

One of the major concepts acquired by the species studied was the knowledge of their ecological characteristics, although each one had a degree of average agreement. Liberal et al. (2011) classify the species *Dichotomius aff. Laevicollis* as copropic of paracoprism type, but Medina & Lopes (2014) disagree considering the species as a generalist organism. Vieira & Silva (2012) have categorized as copro-necrophagous, because of the baits used (human faeces and bovine carcasses) to capture sampling. In this same work it was verified that the species has nocturnal habit.

Regarding ecological succession, the species is considered specialist, since it lives in a narrow range of environmental conditions, being little tolerant to changes. Unlike this species, *Dichotomius nisus* is a generalist being for supporting environmental modifications and dominating areas previously inhabited by less resistant species (specialist), resulting in low equitability. They are therefore more adapted to degraded and anthropogenic areas, being found most frequently in pasture areas, which may be associated to the continuous supply of resources (Liberal et al., 2011). The resources are attractive because of their food habit, being classified as paracoprism, whose behavior avoids the exposure in high temperatures of the day, characterizing nocturnal species (Liberal et al., 2011, Hernández 2007). However, Silva et al. (2007) identify as generalist, preferentially coprophages, because the baits are human faeces and putrefactive beef. They are species that have good adaptation to dry environments, as opposed to *Dichotomius aff. Laevicollis* (Vieira & Silva 2012), and that for Liberal et al. (2011) the seasonal variation is a relevant factor in determining species diversity, abundance and richness.

The great majority of the research has this possibility of use in laboratory studies, mainly those carried out with insects. Samples are sorted and separated in morpho-species, and later they are fixed with the help of pins in entomological box (Barbosa 2008).

Conclusions

In view of the above, it can be concluded that the species *Dichotomius aff. Laevicollis* and *Dichotomius nisus*, although they do not possess all the desirable attributes to be a perfect bioindicator, according to the parameters established by Johnson et al., have such potentiality because their reactions to anthropogenic disturbance are considerably known and described in the literature.

Although the species presented different behaviors in relation to the environmental degradation (*Dichotomius aff. Laevicollis* susceptible to disturbance and *Dichotomius nisus* having greater adaptability to the anthropic areas) converge in their results of the reading of their behaviors before a negative environmental impact.

As there are few studies in Brazil on bioindicators, it is understandable to have rare initiatives for the use of biologically indicated species in environmental monitoring projects. However, attention should be paid to this highly efficient tool in detecting areas that need more attention from the public authorities in the matter of nature conservation, since they gradually increase the areas of deforestation and loss of biodiversity. Initially, they can be used in conservation units as a way of controlling any type of degradation, especially in conservation units of sustainable use.

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