SPECIES RICHNESS AND CONSERVATION OF CAVES IN THE URUCUIA RIVER SUB-BASIN, A TRIBUTARY OF THE SAN FRANCISCO RIVER: A CASE STUDY IN CAVES OF ARINOS, MINAS GERAIS, BRAZIL

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ABSTRACT

Inadequate land use and the overexploitation of natural resources are causing serious impacts on cave environments and therefore the proposal of conservation actions become necessary. The objective of the present study was to gather information on the invertebrate fauna of seven caves in the region of Arinos, in the northwest of Minas Gerais state, proposing priorities and conservation measures. A total of 374 species were registered, seven with troglomorphic traits. The expansion of agricultural practices and the pollution of water bodies are the most worrisome threats. The recovery of the cave surroundings and the awareness of nearby landowners are priority actions to be developed. The creation of reserves and corridors make up alternatives for the conservation of this important heritage.

Key words: invertebrates, endemism, conservation.

1. INTRODUCTION

Caves are natural subterranean cavities that shelter a wide diversity of animals, simply temporary visitors or residents (Culver & Pipan, 2009). Most cave animals include invertebrates, insects and arachnids, the most frequent and diverse groups (Romero, 2009).

Cave organisms can present different degrees of specialization to the subterranean environment, from those that use the caves as shelter to the ones that complete their entire life cycle in these environments. The species that are only found in caves (troglobites) are the main objective of studies due to their great evolutionary importance and vulnerability (Culver, 1982). These species frequently present morphological, physiological and behavioral characteristics that make them highly specialized to life in these environments (Culver & Wilkens, 2000). Furthermore, most of the troglobite species presents a high degree of endemism, being restricted to a single cave or a small group of caves; a fact that makes them vulnerable to severe alterations in their habitats (Culver et al., 2000).

Cave environments can have drainages that supply the surface and are used as shelter by various species with important ecological roles in the hypogean and epigean ecosystems. Bats, for instance, act in pollination and dispersion of seeds, conveying food resources to cave organisms in form of guano. Thus, caves are important for the maintenance of the ecosystems in which they are inserted (Elliott, 2000).

In spite of the recognized importance of cave habitats, they have been altered along the years by anthropic interventions. The main threats imposed to cave communities stem mainly from the inadequate use of the land for agricultural activities, expansion of cities, exploitation of surface and subterranean waters, and mining activities (Watson et al., 1997).

In 2005, Fundação Biodiversitas published the most recent atlas about the knowledge of the priority areas and actions for conservation of the biodiversity in Minas Gerais (Drummond et al., 2005). Among the areas, the region of Arinos in the northwest of the state was identified as a potential for conservation due to the inadequacy of data on the biota and threats, mainly due to agricultural expansion. Thus, the objective of the present study was to characterize the hypogen fauna of seven caves in the region, as well as to verify the impacts and threats to the caves and the cave fauna, aiding proposals for conservation action.

2. MATERIAL AND METHODS

The municipal district of Arinos, located in the northwest region of the State of Minas Gerais, possesses 19 caves registered in the database of the National Center of Cave Research and Conservation (CECAV) and the Brazilian Society of Speleology (SBE). Of these, seven had their invertebrate fauna sampled in July of 2010 (Figure 1). There are some caves with long extensions in the area, e.g., the Gruta Pé de Limão and the Lapa da Marcela, possessing linear development of 3,527.4 and 1,237.6 meters respectively (SBE, 2013).

The municipal district of Arinos is part of the coverage area and under direct influence of the Parque Nacional Grande Sertão Veredas, containing 5% of the total area of the park (IBAMA, 2003) (Figure 1). It is inserted in Rio Urucuia sub-basin, which includes the states of Minas Gerais and Goiás, being an important tributary of Rio São Francisco (Pereira et al., 2007). Farming represents the main economic activity in Arinos, responsible for about 36.5% of the municipal district Gross Domestic Product (Source: IBGE, 2010).

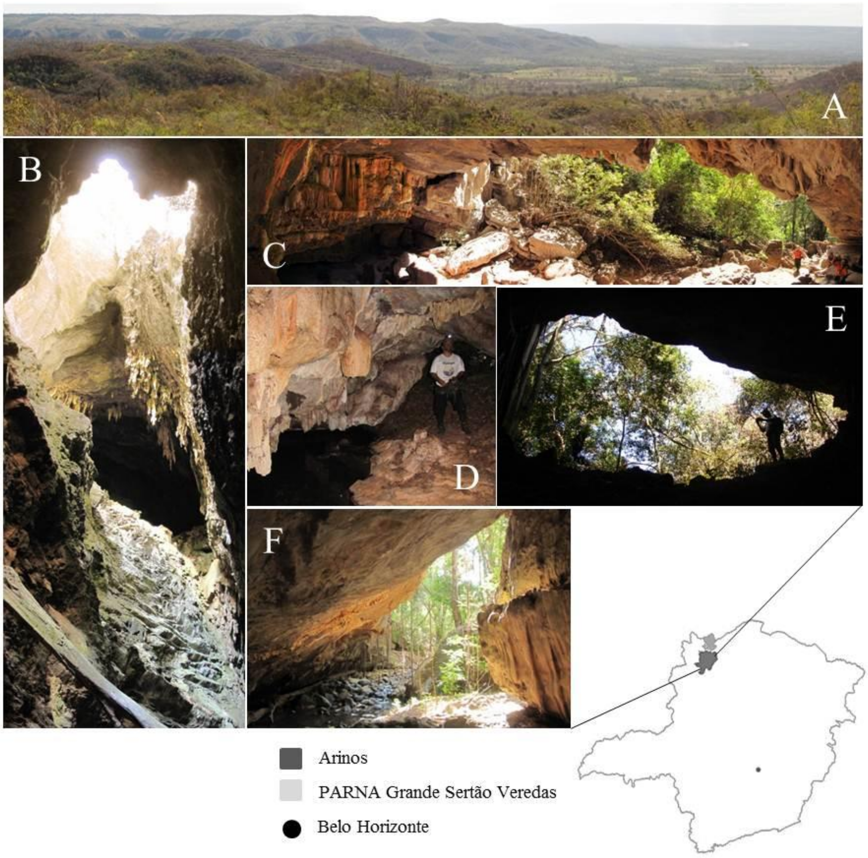

Figure 1 - Map of the State of Minas Gerais highlighting the limits of the municipality of Arinos in the northwestern State. The image also highlights the limits of the Parque Nacional Grande Sertão Veredas, with 5% of its area being included in the city limits of Arinos. Arinos Region (A), the entrance area of Lapa da Marcela (B) entrance area of Lapa da Capa (C), interior of Lapa do Salobo Lapa (D), entrance area of Lapa da Suindara (E) and entrance area of the Lapa do Taquaril (F).

The invertebrate collections were conducted through active searches, prioritizing organic deposits (plant deposits, carcasses, guano, etc.) and micro-habitats (under stones, humid soil, openings, speleothems, etc.). The specimens were collected with the aid of tweezers, brushes and hand nets (with water body presence) and stored 70% alcohol in glass vials. The collection team was always the same, being composed of biologists with experience in speleology and manual collection of invertebrates in caves, as recommended by Weinstein & Slaney (1995).

As well as in several other works, the organisms were identified at the best accessible and separate taxonomic level into morphospecies (Souza-Silva et al., 2011a, Oliver & Beattie, 1996; Derraik et al., 2002; Ward & Stanley, 2004; Derraik et al., 2010). The specimens were deposited in the subterranean invertebrate collection of Lavras (ISLA), at the Federal University of Lavras (UFLA).

The determination of potentially troglobite species was carried out through the identification of characteristics such as the reduction of the pigmentation, reduction of the ocular structures and elongation of appendages, which can vary among the groups (Culver & Wilkens, 2000).

The Mantel test was used to test the relationship of the geographical distance between the caves and the faunistic similarity (Manly, 1986; Mantel, 1967). Non-metric multidimensional scaling (nMDS) analysis, based on the Jaccard index, was used to visualize groups of caves according to the composition of the fauna. Later, a one-way

ANOSIM was conducted to test the significance of the separation of the groups (Clarke, 1993).

Information on impacts and threats to the caves of the region was obtained, characterizing the impacts in the interior and in the cave surroundings (~250m, CONAMA 347/2004), as well as the potential threats. The impacts and threats were characterized qualitatively (presence or absence), concomitantly to the collections of invertebrates, and by satellite images (Google Earth). The information was crossed-referenced with the biological data (total richness and of troglomorphic species) of the caves, as an aid in conservation action proposals.

3. RESULTS

Biological aspects

A total of 374 species were recorded (average richness 79±29 species per cave), distributed in 39 taxa and at least 99 families (Table 1). The taxa with higher richness were Coleoptera (87 spp.), Staphylinidae being the most representative group (28.7% species), followed by Diptera (74 spp.), Chironomidae being more representative of the group (27% species) (Table 1). The Lapa do Camilo was the cave with the highest species richness (115 spp.), followed by Lapa da Capa (113 spp.) and the Lapa da Marcela (94 spp.) (Table 2).

Table 1 - List of taxa, families and number of species of each family registered in the caves of Arinos, northwestern Minas Gerais, in 2010. NI: not identified.

Taxa	Families
Acari	Laelapidae (4), Macrochelidae(2), Macronissidae (2), Ameroseiidae (1), Anystidae (1), Cheiletidae (1), Erythraeidae (1), Opilioacaridae (1), Rhagidiidae (1), Teneriffidae (1), Veigaiidae (1)
Amblypygi	Phrynidae (1)
Annelida	NI
Araneae	Ctenidae (4), Araneidae (3), Theridiidae (3), Pholcidae (2), Salticidae (2), Deinopidae (1), Oonopidae (1), Psauridae (1), Scytodidae (1), Segestriidae (1), Sicariidae (1), Symphytognathidae (1), Theridiosomatidae (1), Trechaleidae (1), Actinopodidae (1)
Blattodea	Blattellidae (2), Blattidae (1)
Coleoptera	Staphylinidae (25), Carabidae (15), Tenebrionidae (9), Elmidae (3), Dryopidae (2), Gyrinidae (2), Pselaphidae (2), Bostrichidae (1), Cholevidae (1), Curculionidae (1), Dermestidae (1), Histeridae (1), Hydrophilidae (1), Ptylodactilidae (1)
Collembola	NI
Crustacea	NI
Diptera	Chironomidae (20), Tipulidae (12), Drosophilidae (6), Psychodidae (5), Ceratopogonidae (4), Phoridae (4), Sciaridae (3), Cecidomyiidae (2), Simuliidae (2), Anthomyzidae (1), Culicidae (1), Dixidae (1), Dolichopodidae (1), Keroplatidae (1), Milichiidae (1), Muscidae (1), Tabanidae (1)
Ephemeroptera	Euthyplociidae (1), Leptophlebidae (1)

Gastropoda	NI
Hemiptera	Veliidae (4), Belostomatidae (3), Ploiariidae (3), Notonectidae (2), Reduviidae (2), Cydnidae (1), Gelastocoridae (1), Gerridae (1), Hebridae (1)
Homoptera	Cicadellidae (2), Cixiidae (2)
Hymenoptera	Braconidae (1), Formicidae (10), Mutillidae (1)
Isopoda	Armadilidae (1), Platyarthridae (1), Porcelionidae (1), Styloniscidae (1)
Isoptera	Termitidae (2)
Lepidoptera	Hesperiidae (1), Noctuidae (4), Pyralidae (1), Tineidae (8)
Megaloptera	Corydalidae (1)
Neuroptera	Myrmeleontidae (1)
Odonata	Coenagrionidae (1), Libellulidae (1), Protoneuridae (1)
Opiliones	Gonyleptidae (3), Scadabiidae (1)
Orthoptera	Phalangopsidae (2)
Ostracoda	NI
Palpigradi	Eukoeneniidae (1)
Platyhelminthes	Temnocephalidae (1)
Plecoptera	Perlidae (1)
Polydesmida	Polidesmoidea (1)
Polyxenida	Polyxenidae (1)
Pseudoscorpiones	Chernetidae (1), Chthoniidae (2), Garypidae (1)
Psocoptera	Lepidopsocidae (1), Psyllipsocidae (4), Ptyloneuridae (2)
Spirobolida	Rhinocricidae (1)
Spirostreptida	Pseudonannolenidae (1)
Trichoptera	Leptoceridae (1), Hydropsichidae (1)
Turbellaria	NI

Table 2 - Caves studied in the municipality of Arinos and their geographic coordinates (UTM) (X, Y, Z) (Datum SAD 69), sampled area (SA - meters), total species richness (S) and troglomorphic species (TS).

Caves	X	Y	Z	SA	S	TS
Camilo	353310	8240506	23L	120	115	2
Capa	357713	8236358	23L	480	113	0
Marcela	354261	8240358	23L	400	94	0
Suindara	354162	8240098	23L	160	55	0
Salobo	369279	8287176	23L	40	50	2
Taquaril	369401	8295327	23L	150	78	1
Velho Juca	354106	8240266	23L	70	46	2

Seven species with troglomorphic traits were recorded, each species being restricted to a single cave, thus endemic (Table 3). Troglomorphic species include Isopoda (two species), Hirudinea, Collembola, Polydesmida, Polyxenida and Turbellaria (one species each) (Table 3). These species occurred in two regions: the first comprising the Lapa do Taquaril and Salobo and the second comprising the Lapa do Camilo and Velho Juca (Figure 2).

Table 3 - List of troglomorphic species recorded in the studied caves.

Species	Camilo Cave	Salobo Cave	Taquaril Cave	Velho Juca Cave
Hirudinea sp.	-	X	-	-
Collembola sp.	X	-	-	-
Trichorhina sp.	X	-	-	-
Styloniscidae sp.	-	-	-	X
Oniscodesmidae sp.	-	-	-	X
Polyxenidae sp.	-	-	X	-
Turbellaria sp.	-	X	-	-

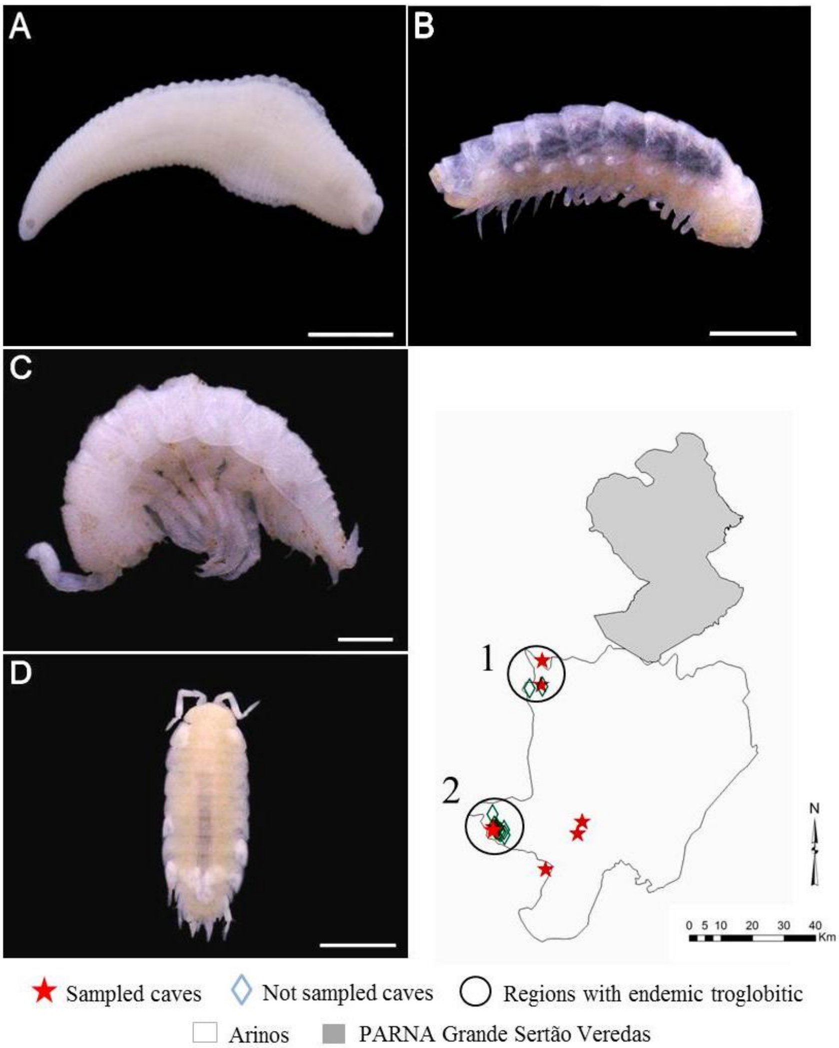

Figure 2 - Regions of endemism and species with some troglomorphic traits recorded in the region of Arinos. (1) Region of the Lapa do Taquaril and Salobo: (A) and Hirudinea sp (B) Polyxenida sp. (2) Region Lapa do Camilo and Velho Juca: (C) Styloniscidae sp. and *Trichorhina* sp. Scale bars for A and D correspond to 1 mm, in B to 500 µm and C to 200 µm.

The Mantel test showed that the faunal composition of the caves have no relation to the geographical distance between them. The non-metric multidimensional scaling (NMDS) analysis indicated the separation of caves into two groups (Figure 3).

The first group consists of the caves of Lapa da Marcela, Capa, Camilo and Taquaril, all with rivers contributing allochthonous material, and the second by Lapa Velho Juca, Suindara and Salobo, the first two being dry caves and the latter has drainage exiting the cave, so it does not perform the input of allochthonous materials (Figure 3). The separation was confirmed by one-way ANOSIM (R: 0.83, p: 0.03).

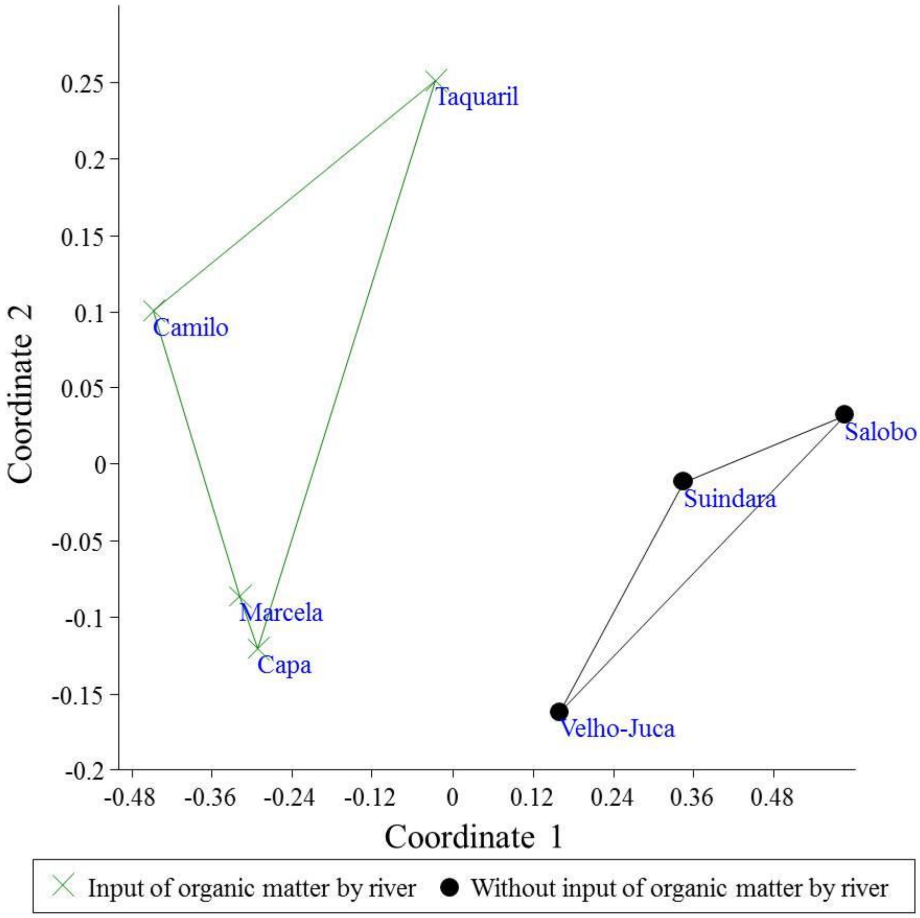

Figure 3 - Non-metric multidimensional scaling analysis (NMDS) based on Jaccard similarity index for the studied caves in the municipality of Arinos (Stress: 0.08).

Impacts and threats

The principal impacts recorded in the surroundings of the caves comprised vegetation removal, to create trails or for use as firewood or converted into pasture and crops (Table 4, Figure 4). The inner portions of the caves were well preserved, only trampling and some graffiti having been observed in the Lapa do Salobo (Table 4). The Lapa da Capa was the only cave that did not show any visible impacts.

The principal potential impacts to the caves studied include exploitation and water resource pollution (Table 5).

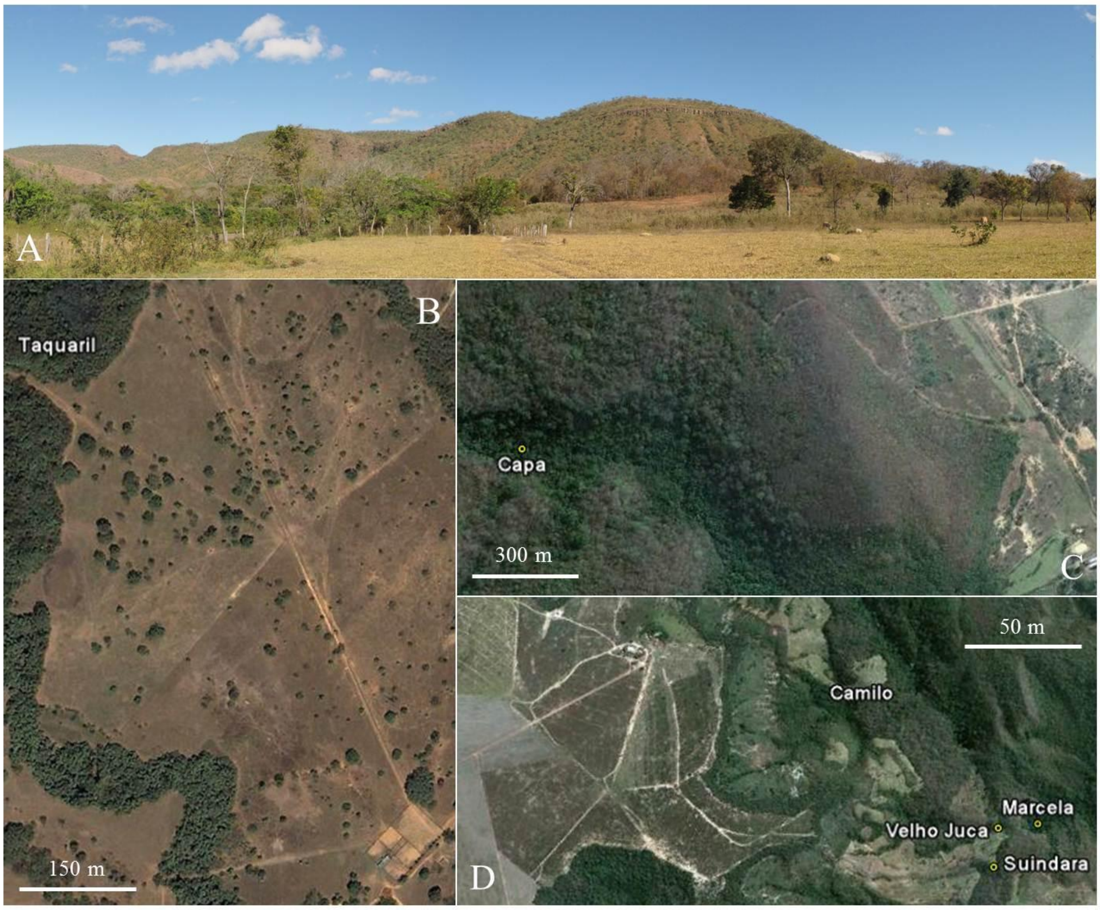

Figure 4 - Some impacts and threats in the surrounding of the caves studied in Arinos. (A) Lapa do Salobo and (B) Lapa do Taquaril showing the conversion of native forest to pasture. (C) Lapa da Capa without visible impacts, but with agricultural activities at a distance of approximately one kilometer. (D) Lapa do Camilo, Marcela, Suindara and Velho Juca showing the conversion of native forests into agricultural areas. Images A, B and C: Google Earth (2008).

Table 4 - List of actual impacts in the surroundings (~ 250m) and inside the caves studied in the city of Arinos.

	Real impacts on the surrounding (~250m)						Real impacts within	
Caves	**Trail**	**Deforestation**	**Livestock**	**Garbage**	**Siltation**	**Area burned**	**Trampling**	**Graffiti**
Camilo	X	X	-	-	-	-	-	-
Capa	-	-	-	-	-	-	-	-
Marcela	-	X	X	-	-	X	-	-
Suindara	X	X	-	-	X	-	-	-
Salobo	X	X	-	X	-	-	X	X
Taquaril	-	-	-	X	-	-	-	-
Velho Juca	X	X	-	-	X	-	-	-

Table 5 - List of potential impacts in the surroundings (~ 250m) and inside the caves studied in the city of Arinos.

	Potencial impacts on the surrounding (~250m)			Potencial impacts within	
Caves	**Pollution of stream**	**Exploitation of water resources**	**Deforestation**	**Pollution of stream**	**Exploitation of water resources**
Camilo	X	-	-	X	-
Capa	-	-	-	-	-
Marcela	X	X	X	X	X
Suindara	-	-	-	-	-
Salobo	X	X	-	X	X
Taquaril	X	X	-	X	X
Velho Juca	-	-	-	-	-

4. DISCUSSION

Biological aspects

The present study revealed high species richness for the caves of the area. This high richness is confirmed when compared with caves of other regions of Brazil that on average presented 50±20 species (Bento, 2011; Bernardi et al., 2012; Cordeiro, 2008; Ferreira, 2004; Ferreira & Horta, 2001; Ferreira et al., 2009; Ferreira et al., 2010; Santana et al., 2010; Souza, 2012; Souza-Silva & Ferreira, 2009; Souza-Silva et al., 2011b,c; Zampaulo, 2010; Zeppelini Filho et al., 2003; Fundação Estadual do Estado de São Paulo, 2010a,b,c,d).

The Brazilian region that has a highest prominence regarding cave species richness is the Cordisburgo municipal district region. Souza (2012), in a study conducted at 17 caves, registered an average richness of 80 (±47.8) species. Among the caves studied by Souza (2012), stand out Gruta Morena, with a richness of 238 species. Thus, the caves of the Arinos region together with the region of Cordisburgo can be considered prominent regions in the country regarding cave species diversity.

The high richness found occurs probably due to the river presence within the caves. Rivers import organic matter that can be used as habitats and food resources by several species. The rivers can also transport invertebrates from the external environment that colonize and eventually establish themselves in the caves, using the organic matter as shelter and food (Souza-Silva et al., 2012), increasing the richness and the number of individuals associated to the caves.

Although none of the studied caves presents high troglobitic species richness, it is important to note the endemism found. None of those species appeared in more than one cave. The endemism is commonly registered for troglobites (Culver & Wilkens, 2000; Culver & Pipan, 2009), a fact that worsens the fragility of those species facing alterations in their habitats. As such, the four caves of the region that shelter these species should, as a priority, be included in conservation plans (Figure 5).

The separation of the caves as to species composition was influenced by the presence of rivers contributing allochthonous organic materials to the interior of the caves. The presence of rivers can cause disturbances (e.g. flooding) that select the same species that will come to colonize the cave, although they may be distant (Simões, 2013). A fact that corroborates this idea is that the proximity did not influence the species composition. For instance, the Lapa do Taquaril presented higher similarity with the Lapa da Marcela, about 57 km away, than with the Lapa do Salobo, about 8 km away.

Threats to cave fauna

The main threat to cave fauna observed was the removal of outside vegetation. The loss of vegetation surrounding the caves can lead to extinction of locally endemic species (Reboleira *et al.*, 2011). Furthermore, there are para-epigean species, those living in the interface between the epigean and hypogean environments (Prous et al. 2004). The removal of vegetation surrounding may decrease the resource input to the environment and change the habitat of these species, for example, by changing the temperature and humidity of the local.

The exploitation and pollution of water bodies is a potential threat to the caves studied, because the main regional economic source is farming activity (Source: IBGE, 2010). The impacts of this type of activity can lead to severe changes in the environment and cave fauna. An example of species affected by this type of impact is the mollusk *Antrobia culveri* Hubricht (1971), residing in the Tumbling Creek cave, Missouri, USA. Agricultural practices are affecting water quality, likely causing a population decline of this species (Neill et al., 2004). The exploitation of water resources can lower the water level and cause loss of habitat. For example, the decline of the water level has caused losses in the community of species that depend on this habitat in southwestern Australia (Eberhard & Davies, 2011).

Actions for conservation

Given the observed threats, the main emergency recommendations for conservation of the studied caves and of their fauna would be the recovery of the cave surroundings that present some type of vegetation removal. Furthermore, the realization of awareness programs (especially for the landowners in cave surroundings) dealing with the appropriate use of the land and the hydric resources is fundamental, so that pollution and overexploitation of the water bodies does not take place.

It is important point out that karstic terrain and caves are among the most vulnerable environments on the planet. Characteristics such the hydrology and geomorphology, make the karst an environment interlinked between different regions (Ford & Williams, 2007). As such, disturbances can result from impacts and alterations occurred at a considerable distance requiring conservation actions at the local and regional levels in order to have effective protection and management of these environments (Watson et al., 1997).

The proximity of the Arinos region to the limits of PARNA Grande Sertão Veredas makes the region a place of extreme importance, since this area acts as a buffer zone for the Park. In 2005, the “Atlas de Áreas Prioritárias para a Conservação em Minas Gerais”, released by the Fundação Biodiversitas, proposed the creation of a corridor between the region of Arinos and PARNA Grande Sertão Veredas (Drummond et al., 2005).

A possible alternative for conservation of the caves (and of their fauna) would be the creation of a sustainable use unit, which mainly incorporates the caves that shelter endemic troglobite species. The conservation unit category that would most be framed in the region of Arinos would be that Area of Relevant Ecological Interest (Área de Relevante Interesse Ecológico - ARIE). In general, an ARIE is an area of small extension, with little or no human occupation, with unique characteristics or with rare specimens of the biota, that seeks harmonize land use with conservation goals (Source: SNUC, Lei 9985/2000).

The creation of a conservation unit could be linked to the National Action Plan for the Conservation of Speleological Heritage in Karstic Areas in the São Francisco River Basin, because Arinos is part of the region covered by this plan (Cavalcanti et al., 2012). Therefore, the previously proposed corridor creation could connect the area of the park with the area where the caves of Arinos are inserted, mainly the regions of endemism (Figure 5).

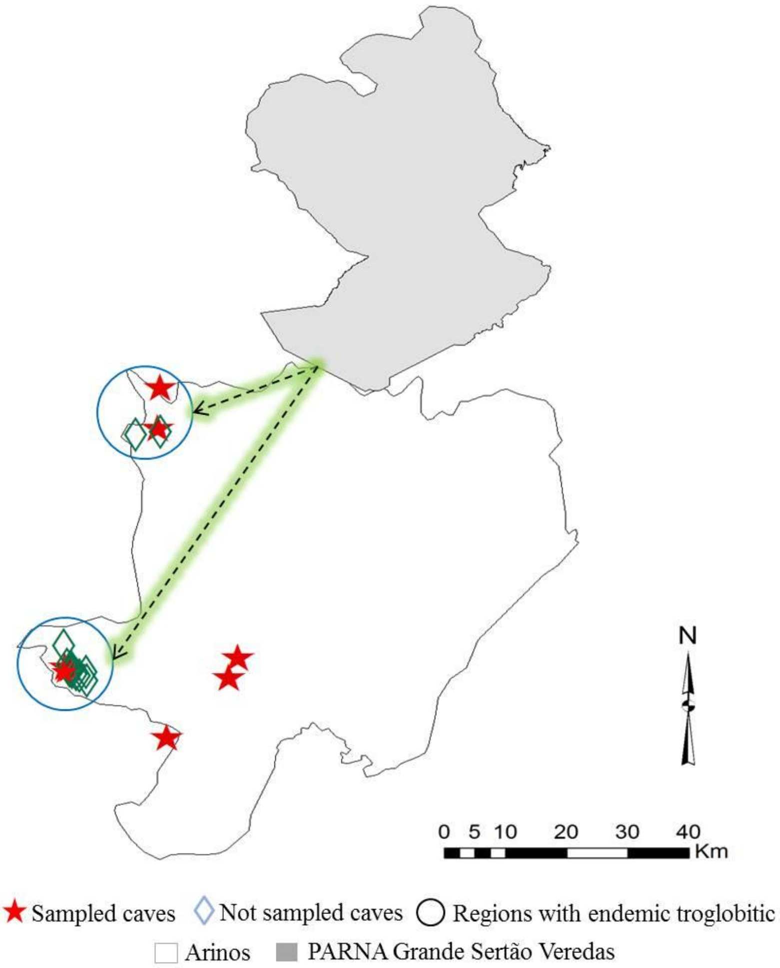

Figure 5 - Geographic limits of the municipality of Arinos, northwest of Minas Gerais, and the Parque Nacional Grande Sertão Veredas. The figure shows the location of all caves currently registed to Arinos, especially those covered in this study and for regions with endemic troglobite species. Arrows indicate possible directions of a future ecological corridor between the park and the caves region of Arinos.

5. CONCLUSIONS

The caves of the municipal district of Arinos present high species richness, mainly due to the presence of rivers that frequently carry large amounts of organic matter to the interior of the caves, supplying food and shelter for countless species. All of the troglomorphic species were endemic to a single cave, therefore being priority habitats for conservation.

The biota of several Arinos caves remains unknown. Thus, more biological inventories are necessary to obtain a more complete diagnosis of the cave fauna. Furthermore, the east region of the municipal district still does not have cave registrations, surveys to confirm the existence or not of caves in this area being necessary.

The expansion of agricultural practices in the area is the most worrisome threat for the cave fauna. This type of land use, besides the conversion of forests into pastures, can pollute water courses with pesticides and pollutants resulting from the raising of livestock and agricultural practices, causing serious disturbances to the cave populations.

An important step for the conservation of the caves of the region would be the investment in the environmental education of the population, mainly rural, as to the appropriate use of the land and hydric resources, and their importance for the cave fauna maintenance. The creation of reserves and ecological corridors in themselves, are not enough for conservation, but they make up a first step for the construction of regional conservation strategies (Margules & Pressey, 2000). The creation of reserves for protection of biodiversity and natural resources is an important step, but one that should consider economic, social and ecological aspects, so that it has the fundamental support of the society.

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