

# Geotourism in caves of Santander (Colombia) as a novel strategy for the protection of natural and cultural heritage associated to underground ecosystems

## Abstract

In the department of Santander (Colombia) there is an extensive network of underground systems that has not been fully explored and is associated with highly fossiliferous mudstones and marine limestones of the Lower Cretaceous Rosablanca Formation, which is characterized by the development of valuable karstic systems showing a diverse richness of speleothems as well as fauna and flora. There is no doubt that this region has a karstic and biological richness, which, however, is ignored. Information regarding fauna and flora associated with these ecosystems is insufficient and limited. Similarly, local authorities responsible for environmental management strategies reported no environmental awareness in the community, or action plans oriented to conservation and use of these underground systems.

**Keywords:** Santander, geodiversity, caves, ecosystems, geotourism

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## Introduction

In recent years, tourism industry has become one of the main poles of development from various respects, especially economic source. It is such that most authorities believe that tourism will become dominant industry in near future and will have various socioeconomic effects.<sup>1</sup> Due to job creation and relatively rapid profiting characteristic, tourism is a proper ground for foreign investment and can accelerate tourism development, promote its economic criteria and bring out new ideas, technologies and markets.<sup>2</sup> The term “Geotourism” is said to be coined by the National Geographic Society (NGS) and is a relatively new concept in the tourism industry that has emerged as a rapidly growing form of tourism,<sup>3</sup> which is being adopted worldwide. According to Hose,<sup>4</sup> geotourism is fundamentally a geosite-based activity. Geotourism was first defined by Hose<sup>5</sup>. It has been defined as geological and geomorphological tourism<sup>6-7</sup> and as a form of nature tourism focused on geological sites<sup>8-9</sup> with emphasis on the “geological” element<sup>10</sup> and geo-interpretation.<sup>10,11</sup> In contrast, National Geographic<sup>12</sup> defines geotourism as “tourism that sustains or enhances the geographical character of a place—its environment, culture, aesthetics, heritage, and the well-being of its residents.” Geotourism, as a subcategory of tourism, is considered one of the new methods in providing tourism attraction<sup>13</sup> is a relatively new concept in tourism industry which has considerable growth in recent decade. Geotourism has a certain definition with geological tourism at its centre<sup>14</sup> and deals with the investigation of related forms and consequences to earth, geomorphologic and geological phenomena. According to Gates,<sup>15</sup> geotourism means “tourism in geological outlooks”. Geotourism, according to Dowling and Newsome,<sup>16</sup> deals with geology, geomorphology, natural outlooks and the forms of earth surface, layers with fossil, rocks and minerals with emphasis on the creating processes. Furthermore, it can be argued that geotourism is informed and responsible tourism in nature with the aim of looking at recognition of geological phenomena and processes and learning their formation and revolution.<sup>17</sup> According to the above definitions, geotourism is not only a new part of tourism market, it is a principal

guidance to help maintaining nature and sustainable development, which is compatible with the economic equilibrium, social condition and ecology and complements them. Subterranean systems are natural holes in the earth that may or may not be traversed by a water source, which are commonly called caves, caves and/or grottos depending on their size, shape and environmental conditions.<sup>18</sup> They are natural openings extending beyond the zone of light and large enough to permit the entry of man, which can occur in a wide variety of rock types because of widely differing geological processes (Figure 1). It ranges in size from single small rooms to interconnecting passages many miles long. The physical characteristics of the caves is that they are composed mainly of limestones that contain a large amount of calcium carbonate and are so soluble in water that, by favoring rain permeability, its components are diluted and form tens of thousands of years forming karst cavities. The scientific study of caves is called speleology. Caves are significant elements of geoheritage and they should therefore be included in any inventory of geosites in a given region, however, their assessment using general geosite assessment methods can be a difficult process and can present many weaknesses mainly because speleosites are very different from the other types of geosites.<sup>19</sup> Although the particular case of speleosites is not thoroughly analyzed in the geosite literature, there are however many studies regarding cave heritage and cave management.<sup>20-30</sup> The assessment of geomorphosites from karst regions is important in public awareness of the role of natural features in local development, drawing attention to the local authorities and to the general public regarding the role of geomorphological features in tourism development.<sup>31</sup> Geotourism also needs to be integrated into the entire natural profile of a valued protected area with geology becoming an essential component of existing scenic, botanical, and/or bird watching and other wildlife values and tourism oriented interests.<sup>10</sup> In the department of Santander there is a complex karstic system of approximately sixty-six (66) caverns associated with the Lower Cretaceous Rosablanca Formation, which consists of mudstones and marine limestones,<sup>32-34</sup> and is highly fossiliferous with an abundant fauna of ostracods, foraminifera,

mollusks and echinoderms.<sup>35</sup> The Rosablanca Formation has a diverse richness of speleothems (zenithal, parietal and pavement) and fauna and flora, with geomorphological characteristics of slopes and steep escarpments, which visibly differentiate it from the adjacent formations. It differs from them, in addition, by its extensive valleys with relatively low topographies, high degree of dissolution and a

remarkable jointing in surface,<sup>36</sup> generating lapiaz (karren), sinkholes, uvalas, poljes, blind valleys, chasms, among others. The aim of this paper is to promote scientific research for which a geological scenery such as speleothems in Santander can be set up in a natural laboratory with the help of scientific advisory committee, academic institutions and, thus, covering the learning and research.

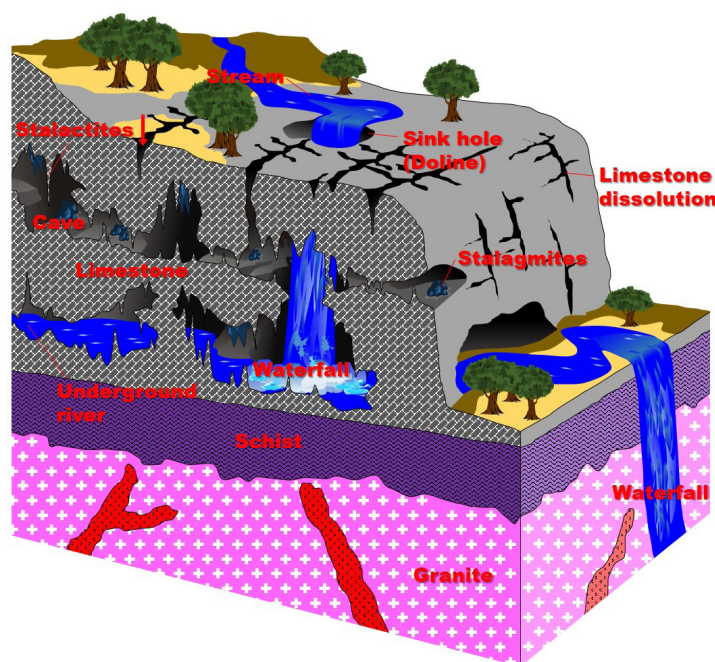


Figure 1 A typical karst ecosystem.

## Geological background

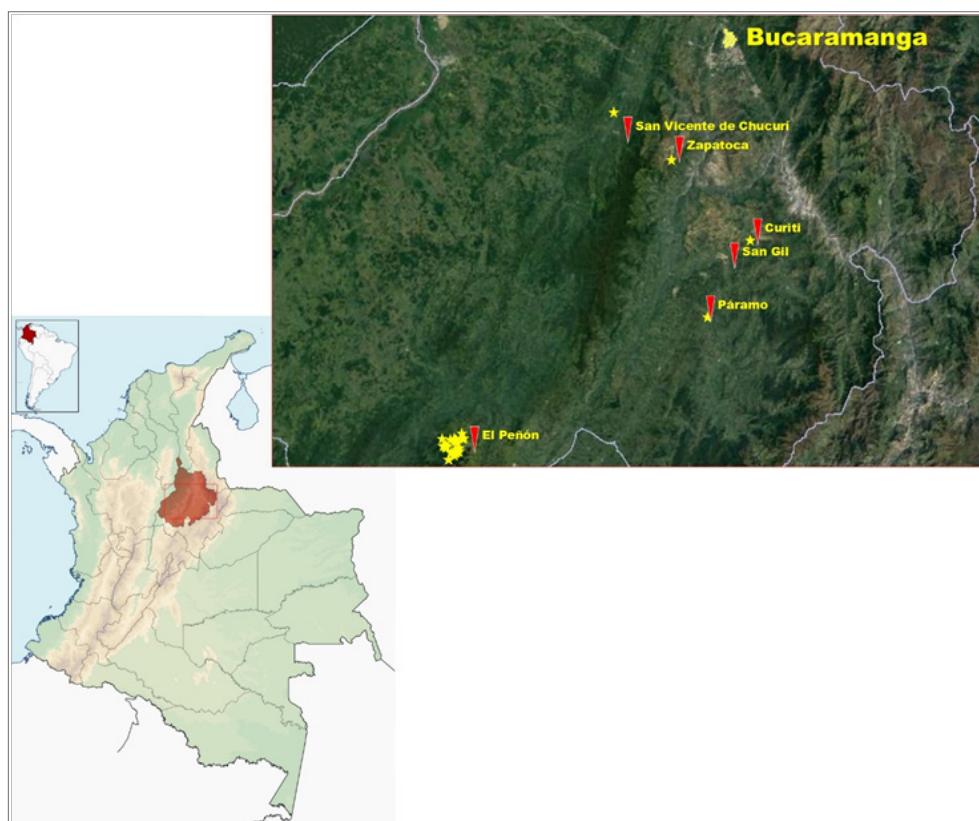
The Rosablanca Formation in the Magdalena Middle Valley overlaps concordantly Los Santos Formation and is in transitional contact with the overlying Paja and Ruitoque formations.<sup>32,36</sup> Different studies<sup>37–39</sup> have been carried out on this geological unit, particularly in relation to its stratigraphy and sedimentation environment. The Rosablanca Formation consists of dolomitic limestones and evaporitic limestones with few intercalations of rocks of terrigenous origin in the lower part.<sup>33</sup> The middle part includes biomicrites, marls and shales.<sup>39</sup> The upper part contains sandstones and biosparitic rudstones with large bivalves;<sup>37</sup> at the top, it contains abundant mollusks, oosparites, intrasparites with sandy spars, biosparitic grainstones and rudstones.<sup>36</sup> A great debate has arisen on its age of the Rosablanca Formation, which, however, can be considered as Lower Cretaceous.<sup>36</sup> The Province of Vélez in the Department of Santander, is the area with one of the largest developments of karstic environments in Colombia, and most are unknown and only has as reference the existing one in the municipality of La Paz, studied in good part by have the deepest gap in Colombia and the report of 56 cavities distributed in 5 municipalities of this province, of which some caves have been known, although not in an integrated manner and are developed on the calcareous rocks of the Rosablanca Formation, unit that according to its current structural characteristics, morphology, relief and climate, as well as morphodynamic processes, constitutes an active karstic system.<sup>40</sup>

## History of speleology in Colombia

Colombia is characterized by a huge number of resources in karstic environments and underground ecosystems as the result of meteoric agents in combination with diagenetic processes and those geological structures developed through different orogenic processes along its geological history.<sup>36</sup> The history of speleology in our country dates back to the early 18<sup>th</sup> century, when Humboldt visited the Iconozo Bridge, the Grotto of Alfonza and the Cave of Los Ladrones, department of Tolima,<sup>41</sup> but the first explorations of the caves are attributed to Vélez,<sup>42</sup> who performed diverse archaeological explorations in the caves of Monquirá, department of Boyacá. Numerous works on caverns have been developed since then.<sup>36,43–57</sup> The first studies on fauna were made by Marinkelle and Gross.<sup>58</sup> At the beginning of the 70s the sporting interest for the caverns was born, with the development of numerous speleological expeditions,<sup>59</sup> with exploration and preliminary studies of twenty-four (24) caverns, contributing significantly to the mapping and inventory of caves in Colombia. Correal and Van der Hammen<sup>50</sup> conducted an archaeological study of Los Guacharos Cave in the department of Huila, reporting important findings about its use as a Paleolithic refuge. Between 1989 and 1990, the Colombian Speleological Expedition was carried out, conducting a survey of cave and caverns systems.<sup>60</sup> One of the most recent works of protection of the Colombian underground systems was carried out by the Alexander Von Humboldt Biological Resources Research Institute.<sup>54</sup> In Colombia, more than a hundred caves and

caverns have been recorded, many of which are geo-referenced, but very few have been studied in terms of their biota. The catalog of Colombian caves unifies the criteria of all disciplines related to speleology covering karst systems circumstantially fragile, that have exo and endokarstic morphologies, species of fauna and flora endemic, threatened and/or in danger of extinction, archaeological remains that have been looted without control and areas of tourist interest, managed without an adequate intervention.<sup>61</sup> The caves in our country are being regarded by the tourism sector as a potential resource for exploitation. In Colombia, the Eastern Cordillera is one of the most important regions in terms of the diversity of caves. They house a large amount of fauna, especially birds and bats that play an ecological role in the biological control of pests, dispersion and pollination of primary, secondary and agroecosystem forests.<sup>56</sup> The Province of Vélez (department of Santander) presents one of the main speleosites in Colombia, most of them still unknown, and according to their morphology, relief, climate and morphodynamic processes, they constitute an active karstic system.<sup>40</sup> Manco<sup>57</sup> performs the first analysis of the environmental impact caused by the misuse of caves in Manaure, Perijá Range, department of Cesar. In Santander, speleology dates back to 1851, when Father Romualdo Cuervos made an inspection of the Hoyo del Aire in Vélez.<sup>62</sup> Ancizar<sup>63</sup> refers in his pilgrimage of the Alpha to the cemeteries located in various

caverns and makes a description of the Hoyo del Aire. The Hoyo del Aire geology has been characterized by Cuervo.<sup>62</sup> Le Doussal<sup>43</sup> cites the completion of explorations in La Hoyada Oscura Cavern, in the Páramo de Santurbán. Cabrera<sup>48</sup> carried out speleological studies in the El Yeso Cave (to the north of San Gil). Grose & Marinkelle<sup>64</sup> carry out a biospeleological study of La Macaregua Cave (San Gil). Acero et al.<sup>53</sup> perform a geological and speleological study in La Antigua, El Yeso, La Cueva and El Nitro caves. The first speleological report was carried out by the National Speleological Cadastre in the Don Juan Cave (Zapatoca). Its speleological resources represent a regional geological and biological record with an excellent preservation that can be declared as a Natural Reserve. Figure 2 illustrates the distribution of the main caves in Santander. The National University of Colombia published the book titled Caverns of Santander, Colombia: Field Guide, where they gathered the best speakers of Colombian speleology, so that the ordinary citizen and the academic can count on a reference of high quality and well documented.<sup>55</sup> Manco<sup>65</sup> socialized the historical development of the geospeleology in Colombia and studied the environmental impacts caused by the misuse of caves, where environmental impacts caused by the burning of garbage, mechanical cracking, breaking and graffiti in parietal and zenith speleothems, which have a notable impact on endemic species in the study area.



**Figure 2** Distribution of the main caves in Santander: (adapted and modified from Google Maps).



## Tourist advantage in caves of Santander

Recently, interest in practicing the exploration of underground ecosystems in Santander has increased. Our territory is the site of numerous and interesting karstic cavities that have developed because of the dissolution of limestones of the Rosablanca Formation. The efforts should focus on the organization of local communities, government actions, as well as the ecological impact, around the tourist use of the caves. Tourism in natural areas is an activity that, from a conservationist perspective, only leaves as a consequence the

deterioration of ecosystems, but the truth is that tourism does not only have negative consequences, but if not for this activity, many sites of great attractiveness already they would have been replaced by activities like cattle ranch or agriculture or human settlements. The tragedy of devastation of natural attractions by tourism is more related to an uncontrolled and massive activity of visitors who do not obtain guidance for access to underground ecosystems, nor on the responsibility for their actions within these. Figure 3 illustrates examples of the main underground ecosystems of Santander.



**Figure 3** Potential tourist attraction in the main underground ecosystems of Santander.

The underground ecosystems: The karstic formations constitute a characteristic topography of the subterranean ecosystems explored in the department of Santander over the years. The karst wealth of this region offers an ecotourism potential that, as suggested by various authors, can be used as a conservation tool to help the environment in which it takes place.<sup>66</sup> The exploration is carried out mainly by two types of visitors: (1) cavers for scientific or sporting purposes or both, although, however, can cause minor damage to the underground ecosystems by virtue of their physical, technical and intellectual preparation,<sup>67</sup> and (2) tourists for reasons of recreation or curiosity. Speleotourism is an activity that forms part of alternative tourism or nature, either in the modalities of ecotourism or adventure tourism, which in some cases is called speleism.<sup>68</sup> In Colombia, it is common to relate natural caves with myths and legends. The damages to these underground ecosystems are related to the extermination of bats, aquifer contamination and/or the obstruction of their orifices with fillers of garbage or other wastes. However, for speleotourism purposes, they are very interesting scenarios to see impressive

speleothems. The karstic systems represent natural laboratories that carry out important ecological functions such as: they are bodies of reserve and water drainages, refuge of endemic species, regulators of the climate, records of the climate for thousands of years, place of abundant fossils, minerals, and evidence of ancient cultures. To recognize more the important function of these subterranean ecosystems represents the base to promote their valuation and regulation by the national government for use and forms of access of their interiors. Unfortunately, it is an area where the community lives and that one of the gaps that we have. The problem for the conservation of these places is that there is no legal declaration to know who owns these underground ecosystems. In this case, it is necessary to ask for the legal permits and then do the procedure for the community to let us in.

Socio-environmental problems: In Santander, large amounts of money have been invested in tourism infrastructure projects, distributed in works of recovery of ecological trails, improvement and adaptation of parks, architectural designs, convention centers, theaters, etc.

However, it does not really have an adequate infrastructure, there is no planning on the part of the tour operators, with the absence of trained native guides and quality services, there is a lack of basic services, signaling, security or first aid for geotourism. On the other hand, there is no social inclusion or geo-education. Due to the lack of awareness, there is no waste collection services, in this way the inhabitants around underground ecosystems deposit garbage in improvised landfills, which aesthetically leaves much to be desired for those who visit our territory. Generally, the caverns have been altered from their natural state, with the progressive deterioration of the internal galleries due to graffiti and scratches on the crust of the internal walls, and the looting of stalactites and stalagmites, which causes irreversible damage to their ecological and scenic conditions, as a consequence of the lack of regulation policies. Regarding its cultural use, celebrations or rituals are no longer celebrated inside the caverns, but important findings have been made that show that these were used by the pre-Hispanic settlers to carry out the collective burials.<sup>69</sup> Informal tourism has not followed the basic principles that, together with reason and the desire to act ethically, allow sustainable development, which is reflected in the indiscriminate disposal of garbage inside and outside the caverns, such as cigarette packs, beverage containers, photographic film wraps or remains of provisions, and campfires scattered around the caverns. The latter is an aspect to consider as the surrounding vegetation can be very vulnerable to forest fires. These considerations are of great importance, since caverns represent both an attraction for geotourism and part of the geological heritage of Santander, with a large amount of underground aquifers, habitat of species, and important ecological functions and environmental services.

**Benefits for local communities:** Local communities around karstic formations in the department of Santander must ensure greater social and economic benefits of tourism. However, they should be organized legally by a committee of tourism with management capacity before various instances and the participation of native guides as volunteers in the provision of speleotourism services. On the other hand, it is important to link the students of schools as volunteers in the maintenance of tourist areas, such as trails, roads, interior and exterior of caverns, parks, etc. However, it is important for the development of the geotourism the governmental support in the tasks of maintenance and adaptation of infrastructure.

**Public investment:** In Santander, different actors of the sector must intervene (direct and indirect), who will manage the provision of infrastructure and public services necessary for the enjoyment of the rich natural and cultural heritage of our region, the offer of private services (lodging, food, transportation, native guides, direct and indirect as banking, telephony, services cleaning, shops, crafts, recreational services, etc.) and the implementation of the legal and planning framework that supports the development of the activity in the destination. On the other hand, geotourism should promote environmental education as a fundamental tool to promote the relationship of human society with its environment, in order to provide current and future generations with a more just, equitable and sustainable personal and collective development. In this way, you can consider that you have a product ready to launch it on the market and turn it into an offer. In Colombia, tourism projects have generated attitudes of apathy, lack of sense of territorial relevance, commitment and credibility in the local communities towards the governmental entities. Local communities feel that private interest is often privileged, rather than collective, which generates distrust and requires greater efforts of supervision and vigilance among them. It is important to have the participation of experts in speleology, who must document the state of the caverns, the cataloging of speleothems, the

layout of suggested routes for the transit of visitors and identification of species of fauna and flora existing inside and of the vegetation of its surroundings. It is advisable to avoid fixed lighting installations and the use of guardrails inside the caverns, which can generate a strong environmental impact. Therefore, it is necessary that both guides and visitors use special lamps during the tour. The training of native guides is fundamental to educate and properly guide visitors. The installation of location, descriptive and interpretive signage is of great importance as an educational tool to guide geotourism. It is also important to link Santander's private sector, government institutions and local communities. The local communities do not have regulatory policies regarding the care and respect that must be had towards the caverns and the infrastructure that has been generated for the development of geotourism. In this way, if their natural and cultural heritage is not guarded by the inhabitants of the region, they will be very vulnerable, as a consequence of the lack of territorial relevance and regulatory policies. However, if there are no monitoring mechanisms, the regulations established by the local communities will not be effective.<sup>70</sup>

## Geoconservation of speleosomes

According to Murphy and Chamberlain,<sup>71</sup> caves are important as they preserve archaeological and palaeoenvironmental data otherwise lost from the land surface, however, the fragile nature and limited extent of cave deposits is often not appreciated by non-specialists. Sporting cavers are viewed as damaging to the cave interior deposits, however, they have added greatly to our knowledge of the archaeological record contained in the caves, valuing the underground environment and taking steps to preserve the cave interior deposits. Therefore, any geoconservation strategy that deals with caves must involve the caving community. Although numerous of caverns have been identified in Colombia, these important ecosystems are not regulated or monitored by the State or assisted by corporations and environmental entities, despite the wealth of fauna they contain and the tourism and sports possibilities they offer. The caverns of Colombia represent a hidden paradise, being little-known and very threatened ecosystems. The caverns in Colombia constitute a spectacular and extensive karstic system, represented by labyrinths of passages of dry caves, that later were crossed by subterranean rivers, forming combined underground passages. The caves and the system of underground rivers developed on beds of limestones of the Lower Cretaceous, particularly in the Rosablanca Formation. The caves are part of the cultural and religious life of local communities and lead to the unique harmony between nature and culture; the cave system and its contiguous wooded gorge is a site of cultural and natural heritage that requires active geoconservation.<sup>72</sup> Caves are exploited, some for touristic purposes, others as way path for evacuation of black waters and sewages that trigger the destruction of its biotic elements and consequently inducing a great harm to the equilibrium of the ecosystem.<sup>36</sup> A very important aspect to consider is the level of integrity and conservation of speleosomes, especially due to the high fragility and vulnerability of speleothems in the karstic context. Speleosomes with a high degree of conservation represent practically those in which access has been restricted immediately after the discovery (Los Guacharos Cavern is the only one in Colombia that is legally protected as a National Natural Park). Access restriction is currently the most efficient way to protect these speleosomes. Speleosomes that have been moderately impacted by anthropic action are caves that have had some protection due to a restriction of access at a given time and control of visits or by means of tourism organized. Los Guacharos Cavern is quite frequented by tourists from all over the world since it is one of the national caverns of reference. It has benefited from such protection immediately after



its discovery in 1953 and then organized for tourism. Finally, there are some speleosites strongly impacted by anthropic action due to the exploitation of limestone or water (in El Peñón, where until now around 65 cavities have been studied and are under a mining title, although it is estimated that there are more than 300 caverns there, and in Mesa de Los Santos), storage of debris (Hipocampo Cavern and others easily accessible), vandalism (El Nitro, El Yeso and La Vaca caves), and looting (Borboso, La Antigua and La Vaca caves). In El Peñón, recent discoveries were already notified to the mayor of this municipality and the Colombian Geological Service to perform their studies, although their exact locations are confidential, taking into account that several karstic systems in Santander have been looted. Underground ecosystems have been little investigated in Santander in relation to inventory and composition of species of fauna, flora, microorganisms that inhabit them, fulfilling functions (nutrient cycles, trophism, evolutionary relationships) and their conservation status. The main problems for their management are mainly related to the sensitivity of some of the species that exist there, the intervention of the caves with temporary or permanent artificial lighting.<sup>18</sup> Manco<sup>57</sup> reveals how the misuse of caverns in Santander due to anthropic activity has generated various impacts that disturb and alter the endokarstic system of these natural cavities. Activities such as mining, disposal of garbage, bonfires, dumping of sewage, indiscriminate tourism, destruction of speleothems and pictograms, graffiti on walls and ceilings, looting of archaeological material and little legislation for their protection have severely affected the caverns (Figure 4). For example, La Vaca, Los Carracos, El Molino and El Hoyo del Aire caves have suffered a progressive deterioration due to indiscriminate and poorly planned tourism. Therefore, these speleosites should not be entered massively, although this does not mean to stop visiting them. Other cases are associated with the irrational exploitation of limestones, which causes great deterioration in the karst areas. According to Muñoz-Saba et al.,<sup>18</sup> other direct impacts on the fauna are caused by alterations in the energy sources

that enter the caves, particularly in the guano of bats and birds. The ignorance of these underground ecosystems brings therefore the inadequate use, deterioration and local extinction of the fauna. In Colombia there are no policies that regulate their use, valuation and conservation. However, researchers from the Universidad Nacional de Colombia, the Research Institute of Biological Resources Alexander von Humboldt, the Colombian Speleological Association, the Speleological Federation of Latin America and the Caribbean and the Moisés Bertoni Foundation, produced a guide for its conservation from the exploration of caverns in Santander to differentiate the geomorphology both external and internal, identify the karstic landscapes to establish the presence of caverns and to know the karstic geology. The underground ecosystems in Santander have great biodiversity, with species of animals that, apparently, there is no record in the world and freshwater sources also unknown and that are protected between rocks. The Macaregua (Curití) and La Alsacia (Zapatoca) caves are the only ones in the country to receive the declaration of priority sites, for the preservation of national bats. Apart from the bats, there are also other mammals as the black-eared shag (*Didelphis marsupialis*) or weasel, birds as the guácharo (*Steatornis caripensis*) that only lives in caverns and travels up to a hundred kilometers to eat palm seeds, among other forest plants, amphibians as the sea toad (*Rhinella marina*) and fish as the *Trichomycterus sketi* (small cave catfish). There is also a great diversity of arthropods (insects, arachnids, crustaceans and myriapods). The approximately 175 caverns identified in Santander are unprotected and are not considered for environmental protection, despite being unique, fragile ecosystems with a variety of endemic fauna. Taking into account the environmental situation of the department of Santander and the role played by the caves in the recovery and conservation of the biological communities, it is evident that the protagonists of these natural processes of recovery are bats.<sup>73</sup> Figure 4 illustrates activities on geo-education, formulation of regulation policies and social inclusion that can be developed along with geotourism.



Figure 4 Problems and solutions on the use of caverns in Santander.

## Working with local communities

It is important to develop strategic alliances with local communities for the conservation of the natural and cultural heritage associated with the caves, in such a way that social inclusion is ensured in the provision of sustainable geotourism services without destroying the caves. According to Castellanos-Morales et al.,<sup>74</sup> karstic and biological richness in the municipality of La Paz is ignored, which was evidenced by the absence of this knowledge in the local communities, who mostly recognized the existence of only El Molino and El Indio caves. On the other hand, information regarding fauna and flora associated with these ecosystems is insufficient and limited. Manco<sup>57</sup> has developed a training work with local communities, especially to the owners of the properties indicating the importance of these ecosystems, taking into account that they are the ones that allow entry to these sites. However, it is very important to perform talks in schools and the community in general. Tourism in Santander has traditionally been managed by entrepreneurs who have developed profitable businesses with capital and knowledge about the tourism market. However, local communities have historically been isolated from the benefits of these activities, becoming only spectators. According to Demarest and Barrientos,<sup>75</sup> the social exclusion of local communities contributes to the destruction of underground ecosystems, since these can be involved in illicit activities in search of economic income. However, the lack of human and financial resources of the institutions in charge of managing the natural and cultural heritage makes it necessary to develop alternative models that involve local communities in their conservation.<sup>76</sup> Therefore, the implementation of a co-management model that takes advantage of geotourism as a conservation tool combined with other productive activities is a viable option for its conservation. On the other hand, it is necessary to develop scientific studies aimed at the integral knowledge of underground ecosystems to support both cavern conservation policies and educational programs.

## Recreational, aesthetic and scientific value of underground ecosystems

Caves have traditionally been used in several ways by thousands of years and only recently recognized their recreational, aesthetic and scientific value. However, this has not prevented their degradation and it is suggested that the carrying capacity of a cave should be effectively zero.<sup>77</sup> The scientific value of speleothems is determined firstly by their intrinsic and functional values.<sup>19</sup> Other important aspects also contributing to their scientific value are considered by several authors.<sup>23,25,78–79</sup> Speleothems also provide important information about natural phenomena, such as climate change, tectonic, seismic or volcanic activity.<sup>19,80–83</sup> The exploitation of caves for tourism purposes in face of the need for protection and conservation of underground ecosystems is still a matter of debate that involves a series of different factors and variables.<sup>23,25,78–79,84–85</sup> The degradation of caves can be attributed to the physical alteration of natural passages, installation of lighting, pathways, platforms and associated infrastructure.<sup>77</sup> Once caves have been entered a process of deterioration begins, and the result is a place retaining little aesthetic value and interest. Caves allow a large number of tourists to know these underground ecosystems and understand their specific need for conservation and protection.<sup>24</sup> The opening of a cave for tourism will depend on its accessibility, which exercises control over the number of tourists.<sup>86</sup> Therefore, the carrying capacity of tourists is the most important factor

in the decision to open a cave for tourism.<sup>25,85</sup> However, speleologists consider that a cave is “lost” once opened for tourism.<sup>79</sup> Cave fauna is impacted by alteration of hydrology, temperatures, lighting conditions, and carbon dioxide levels, and, therefore, resulting invasive plants, desiccation of cave formations, and localized sedimentation highlight the need for effective ongoing monitoring of the cave atmosphere, water quality, and particulate deposition.<sup>77</sup> Speleothems are very useful for recreational purposes with a minimally modified environment (no artificial lighting system) where visitors have an experience close to caving and speleology.

**Internal threats:** The collection of minerals from speleothems, the excavation of sediments and archaeological remains and scientific works, are internal threats, which have the potential to affect subterranean ecosystems and their inhabitants added to not understanding the underground ecosystems, lack of planning, infrastructure and bad practices.

**Aesthetics and science:** The observation of speleothems is one of the most exciting experiences in underground ecosystems and is very important in the reconstruction of their evolutionary history. Therefore, its destruction is like erasing evidence of the geological history of our planet.

**Waste disposal:** The tourism in caves of intensive use generally produce problems by the indiscriminate waste disposal, which besides being unsightly contributes to the contamination of underground ecosystems. Therefore, to guarantee its use in the present and its permanence in the future, it is essential to perform an environmental education process with regular cleaning.

**Flora and fauna:** Caves provide a unique habitat for a variety of fauna and flora forms that are very susceptible to anthropic activity. Bats are the most obvious way of life found in subterranean ecosystems. However, they are endangered and therefore they should be protected by law. It is evident that the protagonists of these natural processes of recovery are bats, and in particular those of frugivorous habit.<sup>73</sup> Its influence on ecological interactions, such as pollination and dispersion of multiple species or the consumption of harmful insects has been widely recognized.<sup>87</sup>

**Archaeological and palaeontological sites:** Because its climatic conditions are constant, underground ecosystems are excellent sites for the preservation of buried sediments, artefacts and faunal remains.<sup>88</sup> The excavation and study of these sites reveal numerous evidences of the ancestral indigenous cultures that inhabited the department of Santander as well as skeletal remains of its recent geological history. Scientists from the Universidad Nacional de Colombia and the Humboldt Institute found in underground systems of the province of Vélez, vertebrae, long bones, jaws and teeth of large herbivorous and carnivorous mammals of probably of the Plio-Pleistocene age, which would be the first fossil cemetery recorded in a Colombian cavern. However, excavation is a destructive process that removes the information, and, therefore, anyone who discovers remains should not disturb them, and should seek the advice of an expert immediately.

**Photography:** The photography of caves plays a very important role in their conservation as it can increase awareness of their majestic beauty and demonstrate how they can be affected. However, taking pictures should be restricted or forbidden, taking into account several reasons, including that the flashlight disturbs bats.

**Artificial aids:** In the past, it was common practice to place artificial aids in caves,<sup>89</sup> but over time these were phased out. However, in recent years bolts and anchors have proliferated in the Santander caves and caverns, which can be very unsightly and even dangerous, since an excessive number can weaken the rock.

**Carrying capacity:** The deterioration of a cave is directly related to the number and type of visitors it receives, a process that can be accelerated unless they are more aware of the impact of their activities, which can be supported by adequate supervision. In Santander, there are no studies of the carrying capacity, to establish the number of tourists that can enter each of the underground cavities, and local communities are not able to meet the demand of tourists or of properly orienting the visitor interested in the karst systems of the area. Therefore, it is very important to understand the tourist carrying capacity as a dynamic tool, not just to limit, but also to improve the tourist visitation.<sup>90</sup>

**Restrictions on access:** Restrictions and controls are necessary because of the fragility of many karst features and to ensure that public safety requirements are met.<sup>91</sup> The caves must have specific access requirements, ranging from asking the owner to the need to obtain a guide. In Santander, those who live around caves refer to these as sacred places where stories, myths and legends are held over time because they are presumed to have played an important role in the religious magical conception of Los Guanes culture, who used them as cemeteries for the Caciques and probably as places of worship and meditation as evidenced by some archaeological pieces found.

**Geoeducation strategy for cave conservation:** We consider that the most effective way to ensure the long-term cave conservation is through geoeducation, providing visitors with a combination of understanding, attitudes and abilities that they will need as a reminder to those who are more regularly engaged with caving activities.

**External threats:** It is likely that the most important threat to the biodiversity of underground ecosystems comes not from human activities within them, but from activities outside these systems, which includes contamination of aquifers, deforestation and destruction of underground systems for mining purposes.<sup>92</sup>

**Statutory protection:** Caves should require legal protection by being notified as a place of scientific interest or as a national nature reserve.

## Conclusion

In Santander, hundreds of caves can be considered as representative speleosomes due to their exceptional values, standing out for their spatial development, richness and diversity of speleothems, underground streams and lakes and paleontological or archaeological remains. The state of the art in relation to the development of studies of karstic systems has generated a strong impact in the scientific community because they represent a very useful tool for scientists of all the areas that are interested in the subject of the underground ecosystems. Speleology of the underground systems in Santander will contribute to design and establish policies of environmental conservation and sustainable management of these systems extremely sensitive to anthropic action that can lead to their disappearance. However, it is very important to continue working on the integral management of speleosomes, the legislation to ensure their adequate geoconservation,

and the use of speleosomes for diffusion, interpretation and geoeducation. The relevance and aesthetic and scenic value of speleosomes can turn it into a tourist resource important enough to become one of the main attractions of Santander to experience, learn and enjoy its natural and cultural heritage. Geotourism has emerged as a strategy for sustainable tourism promotion based on the scientific, natural, cultural, recreational and didactic interest of our territory, providing new development and employment opportunities for local communities, generating a range of economic benefits. It is necessary to make partnerships linked to educational institutions, tour companies, hotels and restaurants, non-governmental organizations, companies of unique goods and so forth, together with the development of a master plan including the preservation and the administration of speleosomes. It is important to contemplate activities such as, training of native guides, training workshops and organization for the inhabitants, environmental education for visitors on ecological functions of the caves, possible damages that tourism can cause and precautions to avoid accidents, construction of external and internal trails, signaling implementation, contingency plan in case of emergencies, monitoring and cargo control.

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## Conflict of interest

The author declares that there is no conflict of interest.

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