TOURISM AND KARST AREAS

Formally/Formalmente “Pesquisas em Turismo e Paisagens Cársticas”

Scientific Journal of Brazilian Society of Speleology / Revista Científica da Sociedade Brasileira de Espeleologia

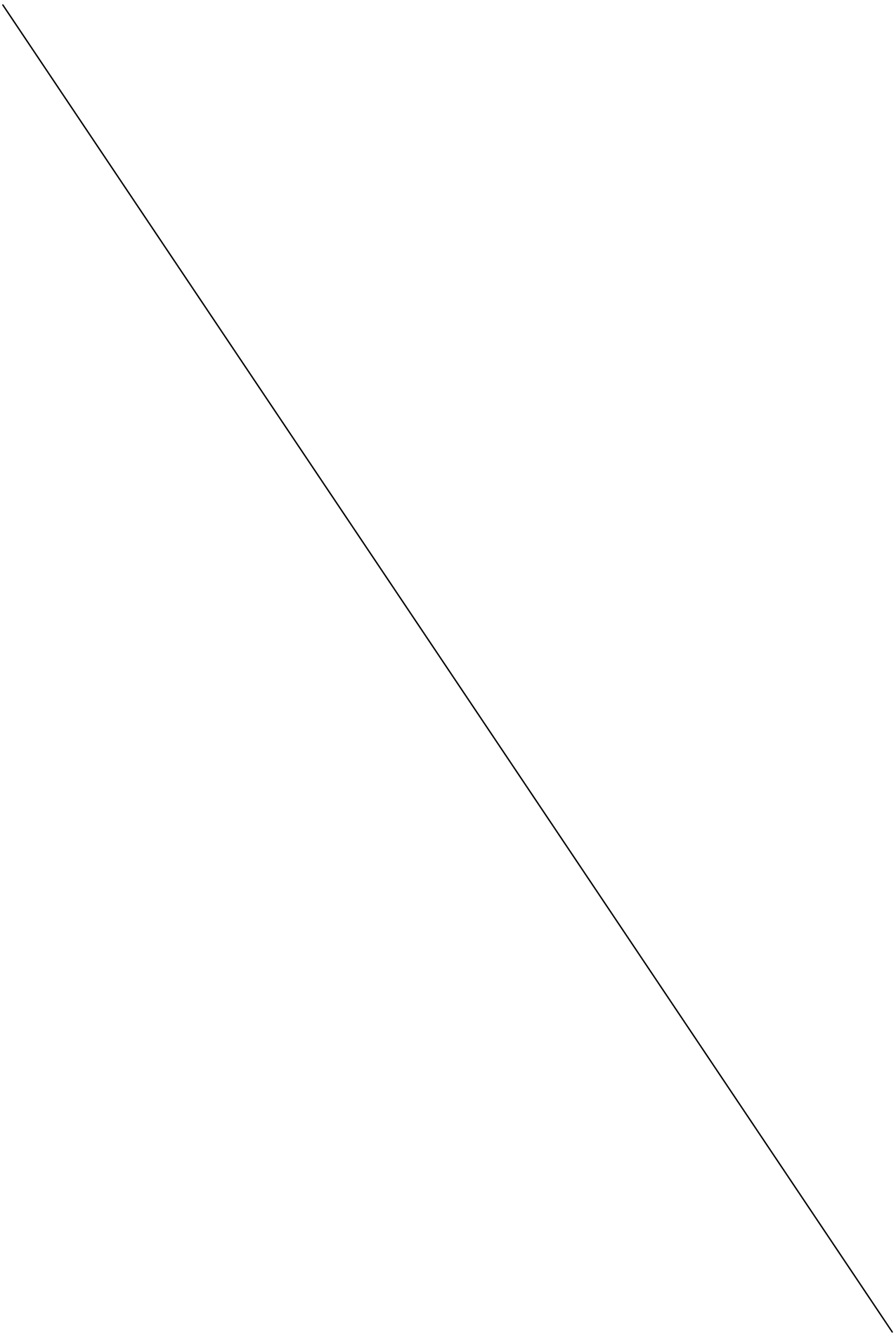
ISSN 1983-473X Vol. 4 Nº 1 2011

Phang Nga Bay, Thailand - photo/foto: Liz Price - see page/vide página: 28.

Original Articles/Artigos Originais

SPECIAL EDITION
Touristic use of water in karst areas

EDIÇÃO ESPECIAL
Uso turístico da água em áreas cársticas



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Gestão 2009-2011 (*Management 2009-2011*)

TOURISM AND KARST AREAS

(Formalmente/*Formally*: Pesquisas em Turismo e Paisagens Cársticas)

SUMÁRIO
(CONTENTS)

EDITORIAL

Em sua edição que abre o quarto ano de circulação de nossa revista, trazemos às comunidades científica e espeleológica uma série de mudanças que visam potencializar o nosso crescimento e ampliar a visibilidade dos artigos publicados.

Iniciamos este trabalho dentro da Sociedade Brasileira de Espeleologia em 2008. Na ocasião, um grupo de pesquisadores e espeleólogos, do Brasil e do Exterior, entendeu que existia espaço, primeiramente no âmbito nacional, para a criação de um periódico científico cuja especificidade tratasse das formas de uso sustentável das áreas cársticas e cavernas, tendo o turismo como principal vetor de desenvolvimento das atividades humanas.

Desde então, diversas adaptações foram sendo realizadas, como a alteração do nome do periódico, de *Pesquisas em Turismo e Paisagens Cársticas* (nome este que, oficialmente, ainda consta em seu ISSN) para *Turismo e Paisagens Cársticas*, e o reconhecimento em âmbito nacional por parte da academia e dos órgãos que avaliam a produção científica no Brasil, como a CAPES, por meio de seu índice Qualis.

Também recebemos os primeiros artigos de colegas estrangeiros neste período, oriundos da Malásia e de Portugal. Isto já nos despertou para um potencial de visibilidade mais ampla do periódico. Assim, tendo em vista que acreditamos neste potencial e que o manejo sustentável de áreas cársticas e cavernas é um tema de amplo interesse, passamos neste quarto volume para uma nova fase de nosso periódico, que passa a se chamar *Tourism and Karst Areas.* A mudança de nome é apenas o primeiro, de muitos passos a serem dados rumo à internacionalição e em busca de novos padrões de qualidade técnica, científica e editorial.

Para esta edição de inauguração da fase internacional da *Tourism and Karst Areas*, lançamos uma edição temática especial sobre o uso recreativo das águas em áreas cársticas. Sendo a água um recurso fundamental em tempos pretéritos para a evolução desta peculiar paisagem e, ao mesmo tempo, escasso nos dias atuais, julgamos o tema como estratégico para a questão do manejo sustentável do carste e das cavernas.

Nossa comissão editorial, nesta edição especial composta por Andrej Kranjc, Angel Fernández-Cortés, Emerson Galvani, Lívia Medeiros Cordeiro-Borghezan, Luiz Afonso Vaz de Figueiredo, Luiz Eduardo Panisset Travassos, Ricardo José Calembo Marra, Ricardo de Souza Martinelli e Rodrigo Lopes Ferreira, selecionou seis trabalhos que abordam, em diferentes escalas e aspectos, a relação entre o turismo e as águas em áreas cársticas e cavernas.

O artigo que abre esta edição é de autoria de Arrigo Cigna, tratando de um modo geral o desenvolvimento do turismo em cavernas com cursos d'água ativos, apresentando suas especificidades e propondo diretrizes gerais para seu manejo e conservação.

Os demais artigos apresentam resultados de pesquisas em diferentes níveis de detalhe com diversas possibilidades de uso das águas em áreas cársticas para o turismo. O segundo artigo, de Andrea B. Hall e Michael J. Day ressalta a importância da água como recurso para o ecoturismo em Porto Rico, descrevendo as principais atividades desenvolvidas em sua costa Norte e ressaltando a importância dos rios alogênicos neste contexto paisagístico. Em seguida, o terceiro artigo, de Liz Price, ilustra o potencial cênico e recreativo das paisagens cársticas na zona costeira da Tailândia, em uma particular forma de dolina, as hongs, da baía Phang Nga.

O quarto artigo é de autoria de Heros Augusto Santos Lobo, que apresenta os resultados de um monitoramento da temperatura da água do rio Roncador, e suas possíveis implicações na dinâmica atmosférica da caverna de Santana, no Brasil, e em seu manejo espeleoturístico. Os dois últimos artigos, apresentados apenas em português, abordam dois dos principais ícones turísticos do carste da Serra da Bodoquena, no Brasil. O quinto artigo, escrito por Maria de Fátima Bregolato Rubira de Assis, Maria de Fátima Lessa Bellé, Marina Brun Bucker, Mercedes Abid Mercante e Silvio Carlos Rodrigues, traz uma análise comparativa das transformações da paisagem na gruta do Lago Azul por meio de registros fotográficos a partir dos anos de 1980. Finalizando este número, Paulo Cesar Boggiani, Ana Cristina Trevelin, William Sallun Filho, Emiliano Castro de Oliveira e Luis Henrique Sapiensa Almeida, abordam o uso das tufas carbonáticas da Serra da Bodoquena para o turismo, com aspectos sobre a sua conservação e a perspectiva de criação de um Geoparque na região.

Desejamos a todos uma boa leitura, agradecendo, por fim, à todos aqueles que tornam a realização e publicação da *Tourism and Karst Areas* possível: autores, leitores e equipe editorial.

Heros A. S. Lobo
Editor Chefe

EDITORIAL

In this edition which opens the fourth volume of circulation of our journal, we bring to the scientific and speleologic communities a series of changes that allow the growth and the wide visibility of the published articles.

The edition of this journal was started in the Brazilian Society of Speleology in 2008. In that year, a group of researchers and speleologists from Brazil and other countries understood that the national scenario had space for a new scientific periodic, focused in the sustainable use of the karst areas and caves, having the tourism as the focus of the development of human activities.

Since that time, many adaptations was realized, as the alteration of the name of the journal, which was Pesquisas em Turismo e Paisagens Cársticas (Researches in Tourism and Karst Areas, in Portuguese, until now the official name registered in the ISSN) and was reduced to Turismo e Paisagens Cársticas (still in Portuguese in this first change), as well the recognition of the governmental agencies that endorse the scientific production in Brazil, with the insertion of the journal in the Qualis index.

We also received the first articles of stranger authors in this period, from Malaysia and Portugal. This fact made we think about the potential of the journal around the world. With this, considering that we believe in this potential and also that the sustainable management of karst areas and caves is a theme with worldwide interest, in this 4th volume we are starting a new phase of the journal, starting with its new name, ***Tourism and Karst Areas****. The official translation of the name is the first step, in a long way to the definitive internationalization and for the search of a better pattern of technical, scientific and editorial qualities.*

To this first English edition of ***Tourism and Karst Areas****, we launched a special thematic edition about the tourist use of the water in karst areas. Water is one of the main agents that govern the evolution of karst systems. In the other hand, is a strategic resource in the present days in karst areas, mainly for their sustainable tourist use.*

Our editorial staff, in this special edition composed by Andrej Kranjc, Angel Fernández-Cortés, Emerson Galvani, Lívia Medeiros Cordeiro-Borghezan, Luiz Afonso Vaz de Figueiredo, Luiz Eduardo Panisset Travassos, Ricardo José Calembo Marra, Ricardo de Souza Martinelli and Rodrigo Lopes Ferreira, selected six articles which address, in different scales and aspects, the relationship between the tourism and the water in karst areas and caves.

The first article of this number is written by Arrigo Cigna. The author treats in a general basis the development of tourism in active caves, presenting their specificities and proposing general guidelines to the cave management and conservation.

The other five articles show results of researches with a few possibilities of tourist use of karst waters. The second article, written by Andrea B. Hall and Michael J. Day, highlights the importance of water as a resource to the ecotourism in Porto Rico, describing the major activities of ecotourism developed in the karst of the north coast of the country and emphasizing the importance of the allogenic rivers in this context. In the sequence, Liz Price presents the scenic and recreational potential of the west coast of Thailand, in the Phang Nga Bay and its particular forms of dolines, the hongs.

The fourth article, of Heros Augusto Santos Lobo, presents the results of a water temperature monitoring in the Roncador river, cave of Santana, Brazil, and its possible implications in the atmospheric dynamics and tourist management. The two last articles, published only in Portuguese, were related to the main tourist icons of the Serra da Bodoquena karst area, in Brazil. The fifth article, written for Maria de Fátima Bregolato Rubira de Assis, Maria de Fátima Lessa Bellé, Marina Brun Bucker, Mercedes Abid Mercante and Silvio Carlos Rodrigues, brings a comparative analysis of the transformations of the landscape of the Lago Azul cave, using photographic records started in the 1980's. The last article, of Paulo Cesar Boggiani, Ana Cristina Trevelin, William Sallun Filho, Emiliano Castro de Oliveira and Luis Henrique Sapiensa Almeida, describes the tourist use of carbonatic tufa in the Serra da Bodoquena, including considerations about geoconservation and the creation of a geopark in the region.

We wish you all a good read, and finally, we want to thanks to all those that make the completion and publication of the ***Tourism and Karst Areas*** *feasible: authors, readers and editorial board.*

Heros A. S. Lobo
Editor-in-Chief

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Brazilian Society of Speleology / Sociedade Brasileira de Espeleologia (SBE)
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SHOW CAVE DEVELOPMENT WITH SPECIAL REFERENCES TO ACTIVE CAVES

DESENVOLVIMENTO DE CAVERNAS TURÍSTICAS COM ESPECIAL DESTAQUE ÀS CAVERNAS ATIVAS

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Abstract

The development of a wild cave into a show cave requires a careful study to evaluate the benefits and risks, by taking into account all pertinent factors such as the access, the synergy and possible conflict with other tourism related activities in the surrounding area, the availability of funds and many other related factors. The conversion should only take place if the results of the studies are positive. Some recently developed plastic materials have the advantage of a very long life, are easy to install and are relatively easy to modify. The development of an active wild cave, i.e. a cave with a watercourse, requires a typical approach, which is different with respect to fossil wild caves. Lampenflora is typical problem of show caves, because the light that is necessary for the visitors supplies enough energy to some plants, mainly algae and mosses, which may grow to the point of defacing and damaging seriously the cave itself. Sustainable development means that the environment meets the needs of the present without compromising the ability of future generations to meet their own needs. To this purpose the compliance with the Management Guidelines, recently adopted by the Union Internationale de Spéléologie, is instrumental for the protection of the cave environment.

Key-Words: energy balance; pathways; lighting; management guidelines.

Resumo

A transformação de uma caverna sem interferências em uma caverna turística requer um estudo cuidadoso para avaliar os benefícios e riscos desta transformação, levando em conta todos os fatores pertinentes ao processo, como a acessibilidade, sinergia e os possíveis conflitos com outras atividades turísticas correlatas em seu entorno, a disponibilidade de recursos e muitos outros fatores relacionados. A transformação deve ser realizada somente se os resultados destes estudos preliminares forem positivos. Sobre as estruturas de visitação, alguns materiais plásticos recentemente desenvolvidos têm a vantagem de apresentar maior vida útil, facilidade de instalação e manutenção relativamente simples. O desenvolvimento de uma caverna ativa em estado natural, por exemplo, uma caverna com um curso d'água em seu interior, requer um escopo específico, o qual é diferente em relação às cavernas fósseis em estado natural. Outro problema típico das cavernas turísticas é a geração de plantas e musgos em seu interior, porque a luz que é necessária para os turistas oferece um aporte energético que permite o seu pleno desenvolvimento, a ponto de causar danos ambientais na caverna. O desenvolvimento sustentável implica que o ambiente pode atender as necessidades do presente, sem comprometer a possibilidade das gerações futuras de prover suas próprias necessidades. Com este propósito, apresentam-se as Diretrizes de Manejo recentemente adotadas pela União Internacional de Espeleologia (UIS), como instrumento para a proteção do ambiente cavernícola.

***Palavras-Chave**: Balanço energético; roteiros de visitação; iluminação; Diretrizes de Gestão.*

1. INTRODUCTION

The fundamental principles for the development of a show cave are the protection of the environment, the safety of the visitors and profit. A process of optimisation among these aspects assures the best equilibrium and the reduction of the negative effects to a minimum level.

2. PROTECTION OF THE ENVIRONMENT

A cave is an environment with little contact with the exterior. Some years ago, Heaton (1986) reviewed the concept of energy levels as applied to caves. He classified caves into one of three categories: high-energy, moderate-energy, and low-energy levels. High-energy caves experience high-energy events on a regular basis. An example would be those caves that undergo periodic flooding. The strongest forces normally encountered by moderate-

energy caves are orders of magnitude lower than those associated with high-energy caves. The most significant forces may be running water, persistent wind, or even the activities of animals. Low-energy caves are again orders of magnitude smaller. Often in these caves the highest energy event may be a falling drop of water. According to this classification, high-energy passages will be minimally affected by tourist activities because such passages will be rearranged by rock fall or flooding within a year.

A river or a subterranean lake plays an important role in maintaining the natural equilibrium because they may absorb, more easily than rock, any further input of energy as it will be discussed later with more details.

In a show cave both the visitors and the electric lighting system release energy into the environment. A person who is walking will release nearly as much energy as a 200-watt bulb at a temperature of about 37°C. Therefore the total energy released by hundreds, or thousands, of visitors in a day is not negligible as an absolute amount. The heat released by the electric lighting system has the same order of magnitude (Cigna, 1993).

There are different ways to keep the additional energy input into the cave as low as possible. A limit of the number of visitors is given by the so called "visitors' capacity" which is defined as the maximum number of visitors acceptable in a time unit under defined conditions, which does not imply a permanent modification of a relevant parameter. Otherwise, instead of reducing the number of persons, the time they spend in the cave may be reduced. This result may be easily achieved when people enter the cave through one entrance and exit along another passage, instead of returning along the same pathway they entered the cave by.

Using high efficiency lamps can reduce the contribution of the electric lighting system. A further reduction can be obtained if the lamps are switched on only when visitors are in the vicinity.

Another perturbation of the cave environment is caused by the lint (hair, dry-flaking skin, dust from shoes and material from clothing) left by visitors. In caves visited by a large number of people the accumulation of lint becomes a real problem to be solved by careful removal. In fact it would cause deterioration of formations and reduce their pristine white beauty to a blackened mess.

Lint released into a cave might be reduced by means of air curtains at the entrance. Such a solution would “wash” people entering the cave and, at the same time, isolate the cave environment from the exterior since an air curtain acts as an invisible door and avoids airflow through it.

The protection of the environment of a show cave is fundamental, both from the point of view of avoiding any damage to a non-renewable patrimony, and the conservation of the source of income for the cave management. Therefore such a common interest may have an important role in the implementation of any action aiming to safeguard the cave environment.

Visitors also release carbon dioxide as a result of their breathing. Until a few years ago such carbon dioxide was considered a threat to the cave formations since it could have increased the water acidity and, consequently corrosion, instead of the deposition of new formations. Further accurate studies (Bourges et al, 1998) have shown that in many instances the carbon dioxide produced by natural processes (oxidisation of organic matter in the soil above a cave) may introduce, through the water percolating into the cave, amounts very much larger than the carbon dioxide released by visitors.

When the percolation water, with a relatively high concentration of carbon dioxide, reaches the cave environment it immediately releases part of this carbon dioxide, which is not in equilibrium with the carbon dioxide in the air. Therefore the chemical reaction moves towards the deposition of calcium carbonate and the formations continue to grow. In general, rather small caves with a high visitor flux, and without any input of natural carbon dioxide, might have formations corroded because the chemical reactions would be reversed when the carbon dioxide in the air dissolves into water, particularly when water vapour condenses on the cave walls.

Another form of environmental pollution may occur through the joint contribution of visitors and light. People may release cave spores or seeds of plants into the cave and they may grow in the vicinity of lamps if the light flux is high enough. The result is the so-called "lampenflora" i.e. green plants (generally algae, fern, moss) developing on cave walls or formations close to a light source. Such plants cover the surfaces with a greenish layer, which can become covered by the calcite deposit and no longer be removable. In fact lampenflora can be washed away by bleach or hydrogen peroxide if it is not covered by calcite. Special care must be taken to avoid any damage to the cave fauna.

The growth of lampenflora can be avoided by the employment of light sources with a very low emission of light that does not encourage the

chlorophyllian process and low light flux at the rock surface.

3. SAFETY OF THE VISITORS

As it has already been pointed out in the previous paragraphs the physical and chemical equilibriums of the environment should not be modified outside the range of the natural variations.

At the same time, any source of harm to the visitors must be avoided. This means that the pathways must be strong enough to withstand very high humidity and, sometimes, also floods. In the past, wooden structures were often used, but they had to be replaced frequently. Today, there are some self perceived “green” enthusiasts who want to still use wood because this material is natural. Nevertheless the rather short life of a wooden structure in the cave environment implies an additional cost, which is not justified. On the contrary the rotten wood provides large amounts of food modifying the equilibrium of the cave life. There is only one particular situation when wooden structures are to be preferred: and that is in the ice caves. In fact wood surface is less slippery than any other material and the low temperature avoids its decay.

Again the “green” enthusiasts have emphasised the criterion to use only structures, which can be easily decommissioned, once they are no longer needed. Such an argument is substantially wrong because, once it is no longer viable to operate a show cave, no one will spend any money to take any structure out of the cave even if they are relatively easy to decommission.

In the meantime, it is preferable to use a material that is compatible with the cave environment and will not release pollutants in the long run. At present, these materials are concrete, stainless steel and plastic.

Concrete in itself is economical but its use in a cave may become rather expensive when it must be carried along difficult passages where the use of mechanical aids is not allowed. However, any change in the future would make it difficult to disassemble the pathways and dispose of the waste.

Handrails made from stainless steel are also a convenient solution, particularly when they are also used as pipes to provide fresh water in different parts of the cave to wash the pathways. In fact, this higher cost of stainless steel is justified by a lack of any maintenance after many years of operation.

Recently plastic structures have been used in caves to build pathways. Presently the best material available on the market is a fiberglass reinforced plastic. Its key product features are that it is lightweight, corrosion resistant, non-conductive, low maintenance, slip resistant, fire retardant, etc. In addition this material has a high strength-to-weight ratio with one-third the weight of steel, allowing easy installation, with no heavy equipment, and less manpower. In fact simple tools easily work such materials and the different parts of the structure are assembled with stainless steel bolts. Another interesting advantage is the possibility of modifying any pathway very easily. On the other hand, other mixtures, e.g. of plastics and sawdust, must never be used because they are easily degraded by mould and their mechanical characteristics are quite poor.

An active cave is obviously subject to floods. Recently the climate changes have not really modified the annual amount of rainwater but its distribution is less uniform. For this reason periods of heavy precipitation are followed by relatively dry periods. Therefore since the size of the cave passages has not changed, the chance of important floods has increased and the water flow inside a cave might reach levels higher than in the past.

To avoid a collapse of the pathways, these structures must be designed in order to withstand not only a vertical charge due to the visitors but also a horizontal force due to an exceptional water flow. It is obvious that in general the tourists will not be allowed inside a cave during heavy storms with the risk of floods, nevertheless these floods should not damage the pathways seriously.

In any case it is possible that, sometimes, rocks displaced by the water flow may damage some parts of the pathways. The structure obtained with plastics, as reported before, are the most suitable to replace rather easily the damaged elements at low cost and in a short time, by reducing to a minimum the economical consequences.

4. PROFIT

Before starting any procedure to develop a wild cave into a show cave, a detailed study of the whole situation is required. Nearly twenty years ago, two great experts of cave management, Russell and Jeanne Gurnee (1981), wrote: "The successful development and operation of a tourist cave depends on a combination of factors, including:

1) Scientific investigation
2) Art
3) Technology
4) Management”

Scientific study is recommended at the beginning, as the first phase, in order to determine which hydrologic and geologic factors may have an influence on the development. Art is necessary both in determining the routeing of trails and selecting particular cave scenes to feature, and in lighting - which is in itself a combination of both art and the next factor, technology. The technology necessary to control water and other natural forces within the cave and to design suitable trails again combines with art to create a tasteful and agreeable cave tour. Management continues from the time the first plans are laid, through the developed or operational phase.

The four factors listed above apply both to the development of private caves and public or government lands. Often, because of limited financial resources of a private owner, one or more of these factors is not considered, and poor development and lack of financial success may result. Failure of a cave to succeed, either through the development phase or after, when the cave is open to the public, can lead to an unprotected area which has been advertised and known to the public that can be subsequently subject to vandalism.

In order to ensure that a cave has the highest chance of success as a tourist endeavour, a comprehensive study and evaluation should be made before any physical work is commenced. A cave study provides a "blueprint" which investors, technical people, workmen, exhibitors and administrators can follow to bring about a successful cave operation. The study plan is coordinated by management in order to develop a plan for the best display of the cave.

With a detailed study and cost prospectus, at the time the development is originally proposed, a cave can be successfully developed less expensively, more effectively and in less time.

Technological advances in the past fifty years in lighting, communications, transportation, marketing techniques and almost every phase of cave development, make it important to find the most efficient ways to complete the project. Every cave must be looked at from the position of the businessman, artist, engineer, speleologist and conservationist. The modification of a natural cave to permit easy visitation of the public requires all of these viewpoints. Balance among these views, through decisions made before beginning the venture, will assure a sound development.

Speleological associations, which bring together those caves being considered for tourism, can be of great service not only to the group developing a cave, but also in preserving the cave as nearly as possible to its natural state". It would be really rather difficult to have a better description of the procedure to adopt for the development of a tourist cave.

In addition to an Environmental Impact Assessment, the procedures suggested in the planning phase commonly include those that can quantify certain parameters (topographical, social and economic) used to predict tourist flows. Some of these methodological procedures, well known and successfully applied in the geographic-economic field, tend not to be employed in the development of show caves because of some lack of knowledge.

The rather widespread feeling among speleologists, and people in general, that a cave is "lost" to science when it is developed as a tourist attraction, is not at all supported by the important scientific results obtained from many show caves. Sometimes the borderline between use and abuse may be difficult to define; nevertheless a careful development continuously monitored may be the most efficient way to protect a cave.

It is evident that the economy of a region around a show-cave-to-be can be radically modified by the cave development. Therefore strenuous opposition to any tourist visitation appears to be rather unfair towards the local people, particularly when a suitable compromise between strict conservation and a sound development can be found. But in any case, as it was previously reported, a cave development cannot be accepted if it is not supported by appropriate preliminary research.

A recent evaluation of the number of show cave visitors all around the world (Cigna & Burri, 2000), based on data obtained for about 20% of all show caves, estimate a global number of more than 150 million visitors per year. By assuming a budget per person as reported in Table 1 the total amount of money spent to visit the show caves is around 3 billion US $ (2008). The number of the local people directly involved in the show cave business (management and local services) can be estimated to be up to several hundred per cave, i.e. some hundreds of thousands of individuals in the world.

By taking into account that there are several hundred other people working indirectly to each person directly connected with a show cave (Forti & Cigna, 1989), a gross global figure of about 100 million people receive income from the show cave business. Therefore, it can be roughly assumed that for each tourist visiting a show cave there is about one other person directly or indirectly connected who is earning income from the visit.

In addition to show caves, the existence of karst parks, which include a cave within their boundaries, must also be considered. As reported by Halliday (1981) the number of visitors to the top three karst national parks in USA (Mammoth Cave, Carlsbad Caverns and Wind Cave) amounted to about 2,500,000 tourists each year. Therefore karst parks give a further increase to the number of people involved in the whole "karst" business.

Table 1 - Rough estimation of the annual direct and local budget of a show cave per each visitor (in US $, 2008).

Source	US$
Direct income	6.5
Other local income:	
Souvenirs & snacks	2.0
Meals	6.5
Transportation	2.5
Travel agency	2.5
TOTAL	20.0

There are many other human activities that involve a larger number of people; nevertheless the figures reported above are not negligible, and give an indication of the role that show caves play in the global economy.

The "destination life cycle" term was first mentioned in Butler's model (1980). Such a concept led to the development of a model very useful to describe the stages of evolution of a tourist attraction (Swarbrooke, 1999) as reported in Fig. 1.

Once the critical range of elements of capacity is reached, i.e. the level of stagnation, there are four possibilities of evolution. If the management does not act, the evolution may be comprised between decline and stabilisation according to other factors independent from the management itself. If a whole set of socioeconomic factors is negative a decline will start. On the other hand, if such a set is not negative there is a chance that stagnation last for a longer time without a decline.

But, if the management is more careful and diligent, then it can take some initiatives. Such initiatives may be simple actions, which could be just enough able to counteract the stagnation and start again a further growth of the number of visitors. If, on the contrary, such initiatives are much more effective, a true rejuvenation can be obtained and the growth of the number of visitors could be the sign of a new era in the life of the cave. Such a change is typical of the development of a new attractive to be developed either inside the cave (new pathway, lighting, "son et lumière", etc.) or outside (park area, tourist attractions, etc.).

5. THE MANAGEMENT OF SHOW CAVES

In 1997 the IUCN World Commission on Protected Areas issued a booklet (Watson et al., 1997) with guidelines for cave and karst protection, taking care of caves in general, i.e. wild caves. The principia included in this publication provided a good basis but it was deemed necessary to have guidelines directed particularly to show caves

The concept of establishing guidelines to be used as general parameters for good show cave management, originated during informal discussions between members of the International Show Caves Association at the time of the inaugural meeting of ISCA in Genga, Italy, in November 1990. These discussions continued over time and were first drafted for consideration at an ISCA meeting held on 17th September 2004 during the 30th Anniversary of the opening of Frasassi Cave, in Italy, to the public (Cigna, 2005).

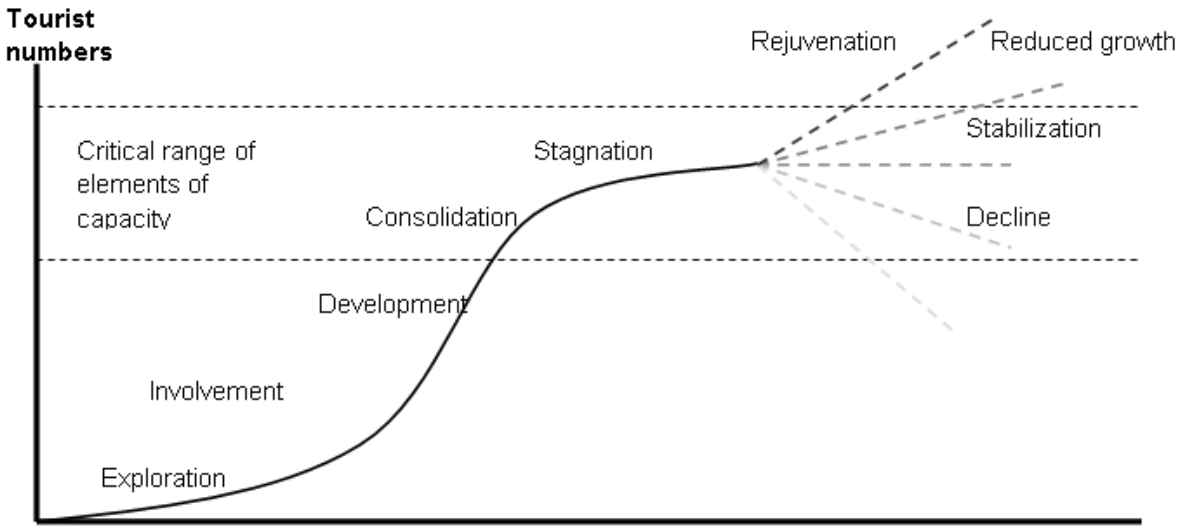

Fig. 1 - Tourist area cycle of evolution (Swarbrooke, 1999)

The idea of creating guidelines, received strong recommendations from the UIS Department of Protection and Management at the 14th International Congress of Speleology held in Kalamos, Greece, in August 2005 (Cigna, 2008).

These management guidelines are the result of wide cooperation between the International Show Caves Association (ISCA), the Union Internationale de Spéléologie (UIS) and the International Union for Conservation of Nature and Natural Resources (IUCN). The intention was to create commonly accepted guidelines that all show caves managers can work towards, taking into account both the protection of the environment and socio-economical constraints. Many recommendations and suggestions have been received in the course of nearly twenty years, and therefore the document reported here can be considered as the result of an active cooperation among specialists involved in this matter (Cigna, 2009; 2010). Since the General Assembly of ISCA in Liptovsky Mikulas, Slovakia, October 2010, has not approved such guidelines for reasons outside the scientific domain, they are now issued as a UIS document.

UIS Management Guidelines for Show Cave

1 DEVELOPMENT OF A WILD CAVE INTO A SHOW CAVE

The development of a show cave can be seen as a positive financial benefit to not only itself, but also the area surrounding the cave. The pursuit of these anticipated benefits can sometimes cause pressure to be applied to hasten the development of the cave.

Before a proposal to develop a wild cave into a show cave becomes a physical project, it is necessary to carry out a careful and detailed study to evaluate the benefits and risks, by taking into account all pertinent factors such as the access, the synergy and possible conflict with other tourism related activities in the surrounding area, the availability of funds and many other related factors. The conversion should only take place if the results of the studies are positive. A wild cave that is developed into a show cave, and is subsequently abandoned, will inevitably become unprotected and be subject to vandalism in a very short time. A well managed show cave assures the protection of the cave itself, is a source of income for the local economy and also may contribute to a number of scientific researches.

1-1 A careful study of the suitability of the cave for development, taking into account all factors influencing it, must be carried out, and must be carefully evaluated, before physical development work commences.

2 ACCESS AND PATHWAYS WITHIN THE CAVE

In many caves it has been found to be desirable to provide an easier access into the cave for visitors through a tunnel, or a new entrance, excavated into the cave. Such an artificial entrance could change the air circulation in the cave causing a disruption of the ecosystem. To avoid this, an air lock should be installed in any new entrance into a cave. On the other hand it must be mentioned that in some very exceptional cases a change in the air circulation could revitalize the growth of formations. A decision not to install an air lock must be only taken after a special study.

2-1 Any new access into a cave must be fitted with an efficient air lock system, such as a double set of doors, to avoid creating changes in the air circulation within the cave.

Caves are natural databases, wherein an incredible amount of information about the characteristics of the environment, and the climate of the cave, are stored. Therefore any intervention in the cave must be carried out with great care to avoid the destruction of these natural databases.

2-2 As much as possible, any development work carried out inside a cave should avoid disturbing the structure, the deposits, and the formations of the cave.

When a wild cave is developed into a show cave, pathways and other features must be installed. This invariably requires materials to be brought into the cave. These materials should have the least possible impact on both the aesthetics of the cave and its underground environment. Concrete is generally the closest substance to the rock that the cave is formed in, but once concrete is cast it is extremely expensive and difficult to modify or decommission. Stainless steel has the distinct advantage that it lasts for a long time and requires little, to no, maintenance but it is expensive and requires special techniques to assemble and install. Some recently developed plastic materials have the advantage of a very long life, are easy to install and are relatively easy to modify.

2-3 Only materials that are compatible with the cave, and have the least impact on the cave, should be used in a cave. Cement, concrete, stainless steel and

plastics that do not emit volatile organic chemical are examples of such materials.

The environment of a cave is usually isolated from the outside and therefore the introduction of energy from the outside will change the equilibrium balance of the cave. Such changes can be caused by the release of heat from the lighting system and the visitors and also by the decay of organic material brought into the cave, which introduces other substances into the food chain of the cave ecosystem. In ice caves, the environmental characteristics are compatible with wood, which is frequently used for the construction of pathways, as it is not slippery.

3 LIGHTING

The energy balance of a cave should not be modified beyond its natural variations. Electric lighting releases both light and heat inside the cave. Therefore high efficiency lamps are preferred. Discharge lamps are efficient, as most of the energy is transformed into light, but only cold cathode lamps can be frequently switched on and off without inconvenience. Light-emitting diode (LED) lighting is also very promising. As far as possible, the electric network of a cave should be divided into zones to enable only the parts that visitors are in to be lit. Where possible a non-interruptible power supply should be provided to avoid problems for the visitors in the event of a failure of an external power supply. Local code requirements may be applicable and these may permit battery lamps or a network of LEDs or similar devices.

3-1 Electric lighting should be provided in safe, well-balanced networks. The power supply should preferably be non-interruptible. Adequate emergency lighting should be available in the event of a power outage.

Lampenflora is a fairly common consequence of the introduction of an artificial light supply into a cave. Many kinds of algae, and other superior plants, may develop as a result of the introduction of artificial light. An important method to avoid the growth of green plant life is to use lamps that do not release a light spectrum that can be absorbed by chlorophyll.

3-2 Lighting should have an emission spectrum with the lowest contribution to the absorption spectrum of chlorophyll (around 440 nm and around 650 nm) to minimize lampenflora.

Another way to prevent the growth of lampenflora is the reduction of the energy reaching any surface where the plants may live. The safe distance between the lamp and the cave surface depends on the intensity of the lamp. As a rough indication, a distance of one meter should be safe. Special care should also be paid to avoid heating the formations and any rock paintings that may exist.

3-3 Lighting sources should be installed at a distance from any component of the cave to prevent the growth of lampenflora and damaging the formations and any rock paintings.

The lighting system should be installed in such a way that only the portions of the cave occupied by visitors are switched on, leaving the lighting in the portions of the cave that are not occupied switched off. This is important from the aspects of reducing the heating of the cave environment and preventing the growth of lampenflora, as well as decreasing the amount of energy required and its financial cost.

3-4 Lighting should be installed to illuminate only the portions of the cave that are occupied by visitors.

The lighting system should be installed in such a way that only the portions of the cave occupied by visitors are switched on, leaving the lighting in the portions of the cave that are not occupied switched off. This is important from the aspects of reducing the heating of the cave environment and preventing the growth of lampenflora, as well as decreasing the amount of energy required and its financial cost.

4 FREQUENCY OF VISITS AND NUMBER OF VISITORS

The energy balance of a cave environment can be modified by the release of heat by visitors. A human being, moving in a cave, releases about 150 watts – approximately the same as a good incandescent lamp. Consequently, there is also a limit on the number of visitors that can be brought into a cave without causing an irreversible effect on the climate of the cave.

4-1 A cave visitor capacity, per a defined time period, should be determined and this capacity should not be exceeded. Visitor capacity is defined as the number of visitors to a given cave over a given time period, which does not permanently change the environmental parameters beyond their natural fluctuation range. A continuous tour, utilizing an entrance and another exit, can reduce the time that visitors spend

in a cave, compared to the use of a single entrance/exit.

In addition to the normal tours for visitors, many show caves have special activities, sometimes called "adventure tours", where visitors are provided with speleological equipment for use in wild sections of the cave. If such a practice is not properly planned, it may cause serious damage to the cave.

4-2 When visits to wild parts of a cave are arranged, they must be carefully planned. In addition to providing the participants with the necessary speleological safety equipment, the visitors must always be guided by a guide with good experience in wild caves. The pathway, where visitors are to travel along, must be clearly defined, for example with red and white tape, and the visitors should not be allowed to walk beyond this pathway. Special care must be taken to avoid any damage to the cave environment, and the parts beyond the pathway must be maintained in a clean condition.

5 PRESERVATION OF THE SURFACE ECOSYSTEM WHEN DEVELOPING BUILDINGS, PARKING, REMOVAL OF SURFACE VEGETATION AND WASTE RECOVERY

It is important that the siting of the above ground facilities, such as the buildings, parking and waste recovery, be well planned. There is a natural tendency to try and place these development features as close as possible to the cave entrance. Sometimes these features are built over the cave itself, or relevant parts of it. The hydrogeology above the cave must not be modified by any intervention such as the watertight surface of a parking area. Any change in the rainwater seepage into a cave can have a negative influence on the cave and the growth of its formations. Care should be exercised also when making any change to the land above the cave, including the removal of the vegetation and disturbance of the soils above the bedrock.

5-1 Any siting of buildings, parking areas, and any other intervention directly above the cave, must be avoided in order to keep the natural seepage of rainwater from the surface in its original condition.

6 MONITORING

After the environmental impact evaluation of the development, including any other study of the cave environment, it is necessary to monitor the relevant parameters to ensure that there is no deviation outside acceptable limits. Show caves should maintain a monitoring network of the cave environment to ensure that it remains within acceptable limits.

6-1 Monitoring of the cave climate should be undertaken. The air temperature, carbon dioxide, humidity, radon (if its concentration is close to or above the level prescribed by the law) and water temperature (if applicable) should be monitored. Airflow in and out of the cave could also be monitored.

When selecting scientists to undertake studies in a cave, it is very important that only scientists who have good experience with cave environments be engaged for cave related matters. Many, otherwise competent scientists, may not be fully aware of cave environments. If incorrect advice is given to the cave management, then this could result in endangerment of the cave environment. Cave science is a highly specialized field.

6-2 Specialized cave scientists should be consulted when there is a situation that warrants research in a cave.

7 CAVE MANAGERS

The managers of a show cave must never forget that the cave itself is "the golden goose" and that it must be preserved with great care. It is necessary that persons involved in the management of a show cave receive a suitable education, not only in the economic management of a show cave, but also about the environmental issues concerning the protection of the environment at large.

7-1 Cave managers should be competent in both the management of the economics of the show cave and its environmental protection.

8 TRAINING OF THE GUIDES

The guides in a show cave have a very important role, as they are the "connection" between the cave and the visitor. Unfortunately, in many instances the guides have not been trained properly and, not withstanding that they are doing their best, the overall result will not be very good. It is very important that the guides receive proper instructions about the environmental aspects of the cave as well as dealing with the public. It is important that

guides are skilled in tactfully avoiding entering into discussions, which can have a detrimental effect on the overall tour. The guides are the guardians of the cave and they must be ready to stop any misbehaviour by the visitors, which could endanger the cave environment.

8-1 Cave guides should be trained to correctly inform the visitors about the cave and its environment.

6. CONCLUSION

Following the cycle of Fig. 1, after the "stagnation" step there are four possible evolutions: decline, stabilization, reduced growth and rejuvenation. The first one, i.e. decline is the consequence of an outside factor (crisis, decrease of interest, etc.), which is not counterbalanced by any action of the cave management. The stabilization may happen if the influence of the outside factors is not too strong. The reduced growth may develop if the outside factors are minimal or, at least, the cave management adopts some actions to add some improvement if the cave development.

The most interesting case is the rejuvenation, i.e. an important addition of new sources of interest for the potential visitors. Such a result may be achieved both inside the cave, after an important change of its structures (new passages developed for visitors, new lighting system, etc.) or the development of other source of interest outside the cave (natural park, monuments, tourist attractions, etc.). Examples of such interventions in France are reported by Gauchon & Biot (2010).

Obviously the last case is the most effective and should always be taken into account by a cave manager in order to keep alive the tourists' interest into the cave and its environment. In conclusion the whole show cave "industry" must be constantly and carefully changing to adapt to the shifts that are brought to us all by our rapidly changing world. There are challenges that we must all rise up and meet.

Finally, the UIS Management Guidelines for Show Cave, reported above, are a strong recommendation to be adopted by show cave managers in order to assure the protection of the cave environment, the safety of the visitors as well a sustainable development, which means that the environment meets the needs of the present without compromising the ability of future generations to meet their own needs.

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Fluxo editorial:
Recebido em: 11.01.2011
Corrigido em: 18.03.2011
Aprovado em: 19.04.2011

TOURISM AND KARST AREAS
(*formally*/formalmente: Pesquisas em Turismo e Paisagens Cársticas)
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WATER AS A FOCUS OF ECOTOURISM IN THE KARST OF NORTHERN PUERTO RICO

A ÁGUA COMO RECURSO ECOTURÍSTICO NO CARSTE DO NORTE DE PORTO RICO

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Abstract

Karst landscapes are fundamentally characterized by underground drainage systems that ultimately create many of the landforms that make karst unique, and which generally result in a scarcity of surface water. Where surface water does exist in karst, it represents an important resource for wildlife and human populations, particularly in the burgeoning realms of recreation and tourism. On the highly urbanized Caribbean island of Puerto Rico, karst landscape covers approximately one-third of the land area, especially adjacent to the north coast, and much of the island's nature-oriented tourism is focused here because it is the least fragmented remaining habitat. The northern karst region is traversed by several major allogenic rivers which effectively dissect the karst into distinct karst blocks with little surface drainage and virtually all water underground. The rivers themselves are a primary focus of ecotourism in the karst belt because they provide accessibility and represent a resource for transportation, entertainment and education, and they are used by individuals and tour operators to maximize their use and enjoyment of the karst landscape. Ecotourism activities focused on the rivers include caving, water sports, canyoneering, climbing, hiking, zip-lining and bird-watching. Without water, levels of ecotourism within the karst would be considerably reduced, so water, although limited, provides a critical recreational and economic resource in the karst landscape.

Key-Words: Puerto Rico, Caribbean, karst, water, ecotourism.

Resumo

As paisagens cársticas são fundamentalmente caracterizadas por sistemas de drenagem subterrânea, que originam muitas formas de relevo que as tornam únicas, e que geralmente resultam na escassez da água em superfície. Quando a água está presente na superfície das paisagens cársticas, ela representa uma importante fonte de recursos para a vida selvagem e as populações humanas, particularmente para as atividades de recreação e turismo. Em Porto rico, uma ilha densamente urbanizada do Caribe, as paisagens cársticas correspondem a aproximadamente um terço do território, especialmente no trecho adjacente à costa Norte. Muitas das atividades de turismo de natureza na ilha são desenvolvidas nesta região, por se caracterizar como um habitat menos fragmentado. O carste do Norte de Porto Rico é atravessado por grandes rios de recarga alogênica, que efetivamente dissecam o relevo cárstico em distintos trechos com pequena drenagem superficial e, eventualmente, grandes aquíferos subterrâneos. Estes rios são os focos primários do ecoturismo na região do carste, dado que são de fácil acesso e representam também um recurso estratégico para o transporte, entretenimento e educação. Os rios são utilizados por pessoas e operadores turísticos, de modo a maximizar seu uso e buscar o melhor aproveitamento da paisagem cárstica. As atividades ecoturísticas desenvolvidas nestes rios incluem espeleoturismo, esportes aquáticos, canionismo, escaladas, montanhismo, arborismo e visualização de aves. Sem as águas, o desenvolvimento do ecoturismo nesta região cárstica seria reduzido. Assim, a água, embora seja um recurso limitado no carste, possibilita um fator recreacional e econômico crítico nesta região.

***Palavras-Chave**: Porto Rico; Caribe; Carste; Água; Ecoturismo.*

1. INTRODUCTION

Water in karst

Water is fundamental to the development of karst because of its central role in the carbonate dissolution process (Ford; Williams 2007). Paradoxically, surface water is often scarce in karst landscapes because the drainage is predominantly underground via a spectrum of voids ranging from microscopic pores to large conduits. Although much of the underground flow eventually reappears at the surface as springs, these are typically located around karst peripheries and, for this reason, water is a particularly critical resource within the interior of

karst areas, and sites where it is present at the surface represent important foci both for wildlife and for human activities.

Historically, human activities in karst areas have centered on accessible surface water sources, although advances in drilling and pumping technology have rendered wells increasingly efficient and reliable, such that more than 25% of the World's population now obtains its water from karst aquifers (Ford; Williams 2007). Water continues to play a critical role in human use of karst areas, particularly in the burgeoning realms of recreation and tourism. Karst landscapes provide significant venues for ecotourism (e.g. Bundschuh et al. 2007) and the scarce water sources within karst can play a major role in promoting recreational and tourism opportunities (Scott et al. 2004). Few studies have examined this topic in detail, and a particularly striking example is presented here.

Karst in Puerto Rico

Puerto Rico consists of three physiographic regions: a volcanic central mountainous area (the Cordillera Central) of late Jurassic to Eocene age, a marginal Tertiary karst belt and a discontinuous coastal plain (Monroe 1976, Troester 1992, Troester et al. 1987). Carbonate deposition began in the early Cretaceous period but peaked in the early Tertiary period, with deposition of the limestones beginning and ending earlier in the south than the north. After active volcanism and tectonism ceased, extensive middle Oligocene to Pliocene limestones and terrigenous sediments were deposited over the older rocks, particularly along the northern flanks of the mountains, forming the northern karst belt (Monroe 1976).

There are marked climatic differences between the northern and southern portions of Puerto Rico, with the north being characterized by a moist, humid climate while the south is much drier (Lugo et al. 2001). Different climates lead to different rates of karstification and different (more/less developed) features, with the north having better developed karst with more distinctive karst landforms, such as cockpits and towers.

Karst covers between 28% (Lugo et al. 2001) and 34% of Puerto Rico (Monroe 1976) and is most extensive in the northern karst belt, which is the best documented (Monroe 1976, Troester 1992, Lugo et al. 2001). The northern karst belt extends about 70km east-west parallel to the northern coast west of San Juan, with a maximum width of about 22 km south of Arecibo. The karst belt encompasses approximately 1,600 km² or about 20% of the land area of Puerto Rico (Giusti 1978), and accounts for about 90% of the karst in Puerto Rico, with the residual 10% in the south and in scattered outcrops in the Cordillera Central (Figure 1).

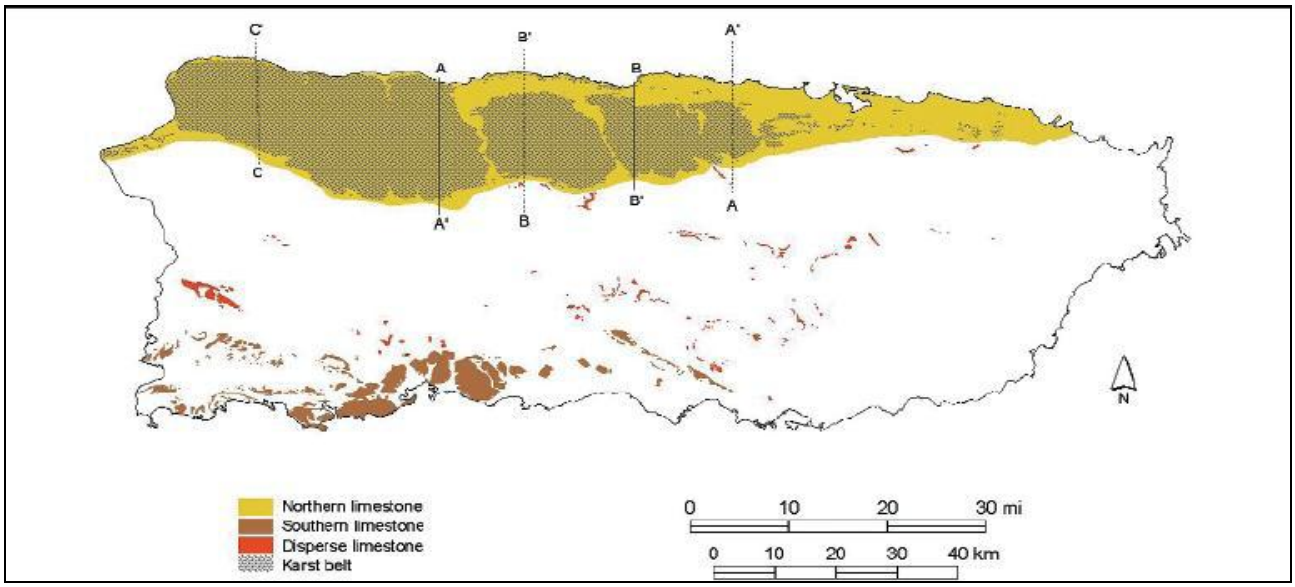

Figure 1: Distribution of karst in Puerto Rico. Source: Monroe (1976) in Lugo *et al.* (2001)

Six distinct limestone formations are recognized in northern Puerto Rico: in ascending order, the San Sebastián Formation, the Lares Limestone, the Cibäo Formation, the Aguada Limestone, the Aymamón Limestone and the Camuy Formation (Giusti 1978). The northern karst belt includes extensive areas of dry valleys and sinkholes, together with more dramatic landforms

such as cockpits and *mogotes*. Cockpits are deep, often steep-sided depressions separated by broadly conical residual hills (Monroe 1976, Day 2004, Day; Chenoweth 2004). *Mogotes*, isolated residual hills surrounded by a relatively flat alluviated plain, are a type of tower karst, with the hills having a rounded or conical shape, rather than the classical vertical tower shape of other tower karst areas (Day 1978, Day; Tang 2004). *Mogote*s occur particularly along the northern edge of the northern karst belt, and they are perhaps the most distinctive and obvious landforms of the northern karst (Lugo et al. 2001). There are also numerous cave systems (Miller 2009).

The limestone belt is traversed by several major perennial rivers whose headwaters rise in the volcanic and mountainous terrain to the south and which flow north through the limestones to the north coast (Figure 2). The largest of these are the Río Grande de Arecibo and the Río Grande de Manatí, both of which cut across the karst belt via surface alluviated valleys. Smaller rivers, such as the Río Encantado and the Río Tanamá traverse the karst belt via discontinuous cave systems and deep, narrow canyons. The north-flowing river valleys (the Río Camuy, Río Guajataca, Río Grande de Manatí, Río Grande de Arecibo, Río Encantado, Río Tanamá, Río de la Plata and Río Cibuco) largely follow structural (fault) lines and effectively dissect the northern karst belt into distinct karst blocks, mostly forested, that have little surface drainage, with virtually all flow underground (Giusti 1978, Lugo et al. 2001). Valley systems are an important component of tropical karst landscapes (Day 2002) and those in Puerto Rico are particularly significant.

Throughout the Caribbean, human activities have had widespread adverse impacts on karst landscapes (Day 1993, 2010) which are predicted to increase (Day; Chenoweth 2009). In this context, the northern karst belt of Puerto Rico has an interesting history of colonial agricultural expansion and contraction, followed by depopulation and then urban and industrial encroachment (Pico 1974, Lugo et al. 2001). Recently it has been regarded as one of the World's most endangered karst areas (Tronvig; Belson 1999) and it has been a focus of karst conservation efforts on the island (Day; Kueny 1998, Mujica-Ortiz; Day 2001). Paradoxically, although the karst is under extreme human pressure, it still represents the least fragmented natural habitat in Puerto Rico, making its use, conservation and management all the more critical (Lugo *et al.* 2001).

By surface area, water occupies less than 5% of the northern karst belt, with virtually all of that being in the form of the through-flowing allogenic rivers (Figure 2). Water is also exposed where sections of major cave systems, such as those of the Río Camuy and Río Tanamá, have been uncovered by collapse of cave roof sections (Gurnee; Gurnee 1974, Lugo et al. 2001). Additionally, surface water is present at springs, particularly where groundwater exsurges peripheral to the main body of the karst but also locally within the karst blocks. Water is also present in many caves, particularly those at lower elevations and peripheral to the main drainage systems.

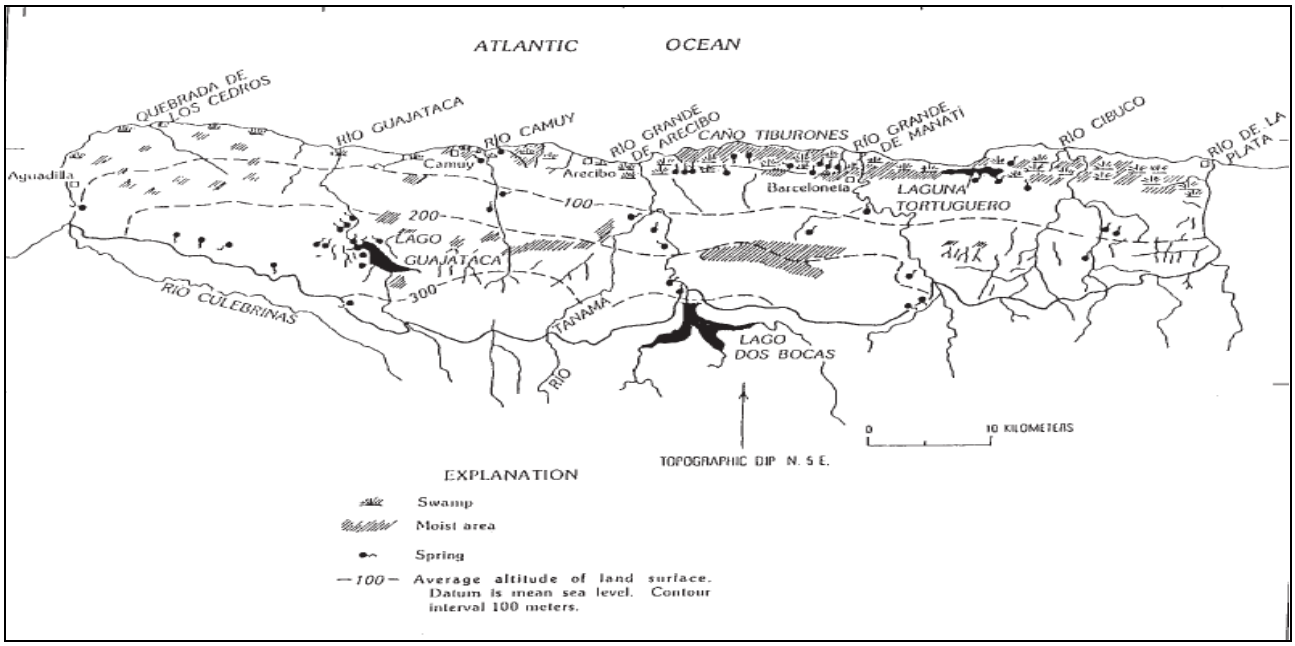

Figure 2: The northern karst belt. Source: Giusti (1976) in Lugo *et al.* (2001)

Ecotourism in Puerto Rico

The definition of ecotourism is complex, multiple definitions exist, and the term has varied meanings to different people and to various organizations. Although there are a plethora of definitions available to choose from, most definitions include certain criteria. Fennel (2001), for example, suggests that ecotourism is a type of specialty travel that is nature-oriented, promotes conservation, protects local culture, benefits the local population, and promotes education.

Activities conducted under the title of ecotourism are varied and can take place in many different environments. Examples include such "low-impact" activities as hiking, cycling, rafting, bird-watching and astronomical observation. Others are limited to specific landscapes and thus are more 'specialized': caving and SCUBA diving are examples. In karst landscapes both general and specialized ecotourism occur and tourism is becoming an important aspect of human use of karst areas, with attendant impacts (Huppert *et al*. 1993, Day 2010). The Caribbean karst, including that in Puerto Rico, appeals to tourists because of its natural environment and unique topography. These assets create unique visitor experiences. The karst also contains diverse and endemic plant and animal populations, and provides a wide variety of outdoor activities while supporting biological, ecological and geomorphological diversity (Lugo et al. 2001).

Increasingly aware of sustainability issues, Puerto Rico has recently turned to ecotourism and sustainable development in an effort to conserve and protect its natural resources (Frederique 2004). With a land area of 13,790 km² and a population of nearly 4 million people (CIA 2010), Puerto Rico has a population density of more than 430.5 people per km², second in the Caribbean only to Barbados (Scarpaci; Portela 2009). Sustainable development and ecotourism have become particularly important national issues precisely because of the island's small size and high population density. Well-planned sustainable tourism development should lead not to the deterioration of natural areas but to their conservation (Page; Dowling 2002).

Although surface water is uncommon in many karst areas, in other landscapes water is an important component of mainstream tourism and ecotourism alike (Jennings 2006, Crase; O'Keefe 2011). Water provides opportunities for a wide range of activities that are not feasible on land (Jennings 2006), and is also a magnet for wildlife, for whose existence it is critical (Sinclair et al. 2006).

2. METHODOLOGY

Ecotourism activities in the northern Puerto Rican karst were investigated through literature reviews and field research during 2009 (Hall 2010). A preliminary analysis of tourism and ecotourism websites was first conducted in order to discern what types of activities are offered in the karst. Ten adventure tour companies that operate extensively within the karst were identified and three that appeared to have particular affinity with the northern karst were contacted. Subsequently, appointments were made to participate in selected ecotourism activities in the karst landscape, and the companies themselves became a primary source of information. The three companies were selected because they represent the size spectrum and scale of tourism operations in the Puerto Rican karst. They also offer a wide range of ecotourism activities that appear to typify those offered within the karst landscape, and they were available during fieldwork. Participant observation, surveys and interviews were the primary research methods employed. Further details of the research methodology are provided by Hall (2010).

3. RESULTS

Water as an ecotourism focus

Numerous ecotourism activities take place in the karst landscape, and virtually all of these are related to or focus primarily or exclusively on the water. Overall, it is estimated that about 40% of ecotourism in Puerto Rico takes place within the karst (Hall 2010), and 85% of the ecotourism activity within the karst itself is water-centered.

Water, particularly as represented by the rivers and the river valleys, plays three pivotal and intersecting roles within the northern karst. First, it provides access and a means of transportation, facilitating entry into the karst and passage through it. Major roads across the karst follow the major valleys, and many minor roads follow courses of dry valleys. More significantly, the rivers and valleys represent the route ways via which ecotourists enter and traverse the karst, on foot, on horse or via the rivers themselves by tube, canoe, kayak or swimming (Figure 3).

Second, water within the karst provides a fundamental source of entertainment, providing the essential medium for enjoyable activities such as swimming, diving, body-rafting (Figure 4), tubing, canoeing and kayaking. Drinking the river water is inadvisable, but some ecotourists imbibe and seek out spring water, and valley-side waterfalls,

particularly those that are spring-fed, offer opportunities to wash off any riverine debris.

Figure 3: Tourists using river as form of transportation/entertainment in the karst. Source: Andrea Hall (2009)

Figure 4: Body-rafting down the Río Tanamá. Source: Andrea Hall (2009)

Third, water plays a significant educational role within the karst, particularly since water is the fundamental agent in karst landscape development and cave formation. Surface rivers, unroofed caves, cave streams (Figure 5) and springs all provide opportunities for educational activities within ecotourism, focusing on hydrology, geomorphology and biogeography. Through the medium of water, ecotourists learn about karst and cave development, aquatic biology and other aspects of karst science. Water also represents an important tool for communicating information about potential degradation of the karst, focusing, for example, on the potential for water contamination and rapid transfer of pollutants. Additionally, the surface water is an important 'magnet' for wildlife, and thus serves as a major focus for wildlife viewing and tracking, particularly bird-watching, which is one of the primary ecotourism activities (Raffaele 1989).

Many of the ecotourism activities within the karst use the water in multiple and complementary ways, combining access, entertainment and education in numerous and diverse ways. In itself, water in the rivers and springs represents a dramatic scenic element within the karst, and thus plays multifaceted roles, which may be exemplified by brief discussion of some specific ecotourism activities.

Hiking is a basic component of much of the karst-based ecotourism, either as the primary activity or as a means to other ends, such as climbing, caving or bird-watching. Many hiking trails enter the karst via valleys, and most organized hikes begin and/or terminate at the rivers, particularly providing post-hiking swimming opportunities. In some locations, trails cross the rivers via fords or bridges, adding a different or additional dimension to hikes (Figure 6).

Figure 5: Entrance of river cave on Río Tanamá. Source: Andrea Hall (2009)

Figure 6: Hammock bridge over Río Tanamá. Source: Andrea Hall (2009)

Climbing and rappelling are more specialized ecotourism activities within the karst, and often take place adjacent to the rivers where valley-side cliffs provide suitable and accessible locations.

Canyoneering, in which participants navigate along the narrower river valleys through combinations of hiking, free-climbing, swimming and body rafting, center on the rivers by necessity (Figure 7). Zip-lining, descending using gravity by means of a pulley running down a fixed, inclined cable line, is not restricted to river valleys but is often located there because of the local relief available between the valley edges and the river bed, which provides for significant elevations, swift transgress and impressive views (Figure 8).

Figure 7: Canyoneering, Río Tanamá.
Source: Andrea Hall (2009)

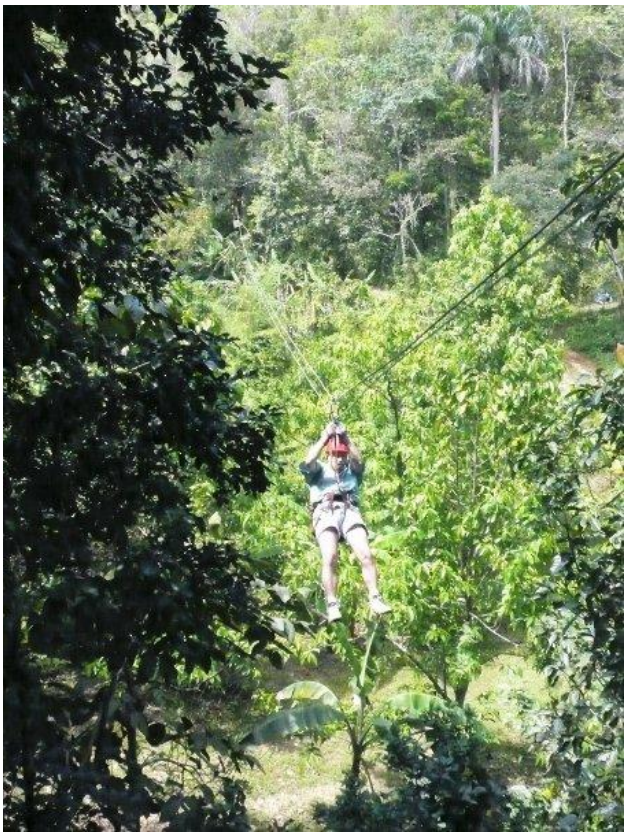

Figure 8: Zip-lining over the Río Tanamá.
Source: Andrea Hall (2009)

Caving is, of course, an ecotourism activity that is inextricably linked to karst, and particularly to the role of water in karst. While caving does not necessarily involve intimate interaction with water, most caving tours do involve water, either in the caves themselves or at the surface before or afterwards.

Ecotourism activities in the karst are variable in terms of their specificity towards the karst (Hall 2010). Some, such as caving, are karst-specific, while others are less intimately focused on the karst itself. Nevertheless, water remains a critical focus, as documented above.

Although all the rivers provide potential ecotourism sites, the Río Tanamá is seemingly the most important river for ecotourism in the karst of Puerto Rico. The reasons for this are not entirely clear, but revolve around scenic considerations, accessibility, its size, and proximity to other attractions. Although water pollution is problematic throughout the karst (Hunter and Arbona 1995), the lower Río Tanamá has a relatively unspoiled character, with relatively low levels of apparent water contamination. The Río Tanamá Valley is also very scenic, with steep valley sides, canyons, waterfalls and sections where the river passes through short caves. The downstream section of the Río Tanamá is readily accessible, giving access to natural areas with well developed trails and other facilities. The Río Tanamá is also close to the Arecibo Observatory, which is another major tourism focus within the karst (Hall 2010).

4. CONCLUSION

Even though surface water is limited in occurrence in the northern karst of Puerto Rico, it plays a pivotal role in influencing ecotourism in the karst, which is itself a major tourism focus. In particular, the rivers which traverse the karst provide transportation, entertainment, and educational opportunities, which are used by individuals and tour operators to maximize their use and enjoyment of the karst. The rivers provide access and a means of transportation to and through the karst landscape. Water in the karst landscape also provides a fundamental source of entertainment, as many of the activities available are related to the water resources. Ecotourism activities within the karst, such as caving, water sports, canyoneering, climbing, hiking, zip-lining and bird-watching are strongly linked to the rivers and to other water sources. The rivers provide a significant educational role, particularly due to water's fundamental role in the development and formation of karst landforms.

Water plays a critical role in human use of karst areas, particularly in recreation and tourism. Karst landscapes provide significant venues for ecotourism and the scarce water sources within karst play a major role in promoting recreational activities and tourism opportunities. Without water, levels of ecotourism within the karst would be considerably reduced, so water, although limited, provides a critical recreational and economic resource in the karst landscape.

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Fluxo editorial:
Recebido em: 07.12.2010
Aprovado em: 30.04.2011

TOURISM AND KARST AREAS
(*formally*/formalmente: Pesquisas em Turismo e Paisagens Cársticas)
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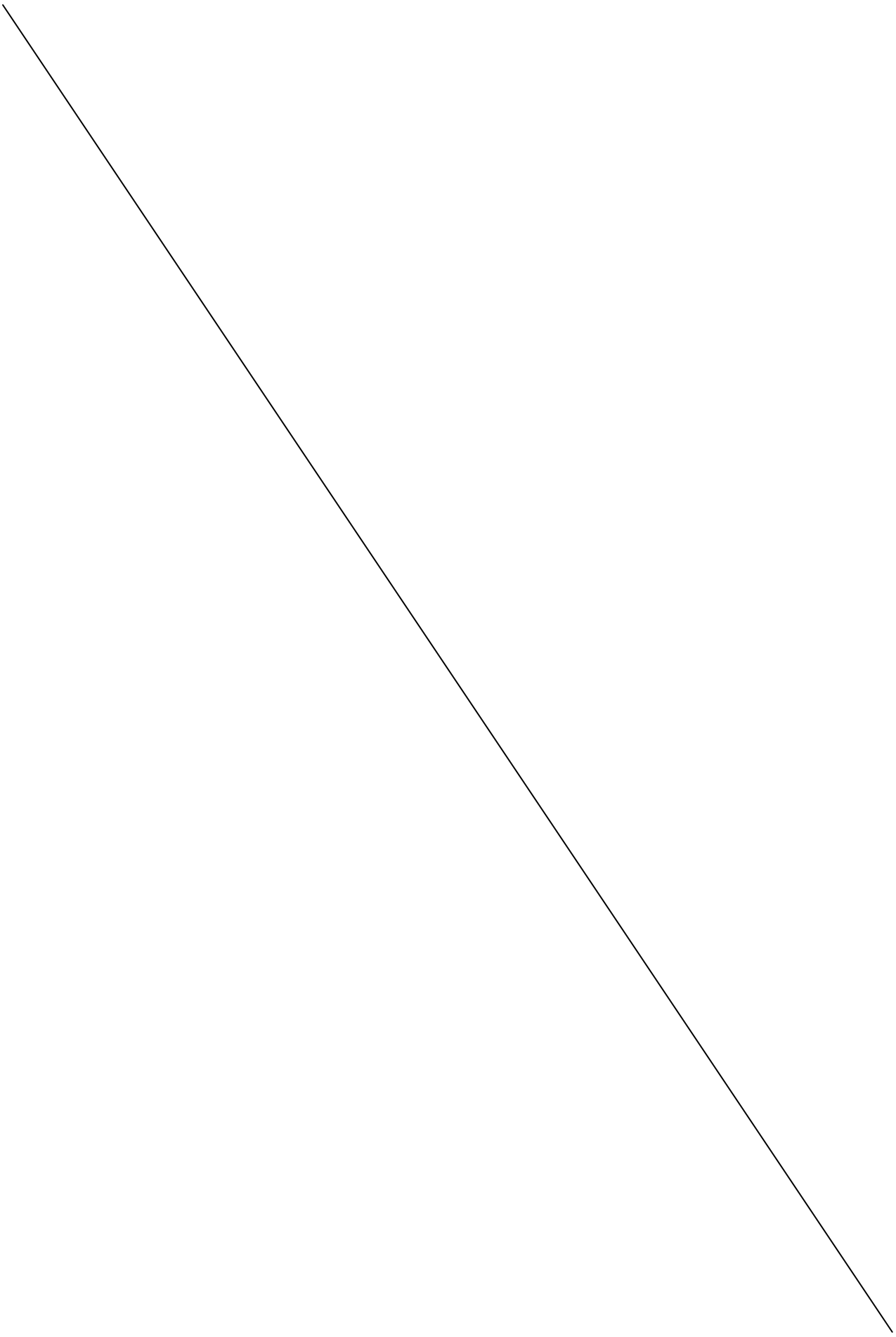

HONGS OF PHANG NGA BAY, THAILAND

HONGS DA BAÍA PHANG NGA, TAILÂNDIA

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Abstract

Hongs are dolines within fengcong karst that are invaded by the sea. They are surrounded by steep walls and sheer cliffs, and are only accessible through sea-level caves within the tidal zone. The isolated limestone islands of Phang Nga Bay in Thailand rise steeply from the sea and are often forest covered, and contain scenic hong lagoons. They are a very popular place for tourism. Kayaking into the hongs is a lucrative operation for tour companies. Visitors are attracted by the beautiful landscape and the chance to explore dark caves by kayak and to see the hidden gardens inside the hongs.

Key-Words: hong, doline, marine karst, tidal cave, Thailand, Southeast Asia.

Resumo

Hongs são dolinas do carste de fengcong que são invadidas pelo mar. Elas são circundadas por paredes íngremes e penhascos, e são acessíveis somente por cavernas ao nível do mar, na zona das marés. As ilhas calcáreas isoladas da baía de Phang Nga são muito elevadas em relação ao nível do mar e muitas vezes são cobertas por florestas, além de abrigarem lagoas cênicas nas hongs. Elas são um lugar muito popular para o turismo. Passeios de caiaque nas hongs são uma opção lucrativa de passeio para as operadoras de turismo. Os visitantes são atraídos pela beleza da paisagem, bem como pela chance de explorar cavernas afóticas em um caiaque e observar os jardins ocultos das hongs.

***Palavras-Chave**: Hong; Dolina; Carste costeiro; Cavernas de marés; Tailândia; Sudoeste asiático*.

1. INTRODUCTION

Phang Nga Bay or Ao Phang Nga lies south of the province of Phang Nga in the Isthmus of Kra in south Thailand. The Isthmus of Kra is a narrow landbridge that connects the Malay peninsula to Thailand. The Thai peninsula has the Andaman Sea to the west, and the Gulf of Thailand to the east. Phang Nga Bay is located in the Andaman Sea and is surrounded on three sides by the resort towns of Phuket, Phang Nga and Krabi.

The west coast of the southern Thai peninsula has numerous limestone islands. These islands extend southwards down the Thai coast and as far as the Langkawi islands in northwest Malaysia. Limestone is also found on the mainland, occurring as karst towers in Phang Nga, Phuket, Krabi, Trang and Satun provinces, and across the Malay border into Perlis and Kedah.

Phang Nga Bay is a large karst area that has been flooded by the sea, leaving the karst plain fully submerged, and resulting in islands that rise dramatically from the sea. It is a stunning landscape. The islands generally have sheer cliffs and rugged profiles, and can be compared to the famous World Heritage site of Ha Long Bay in Vietnam. [photo 01]

Photo 1: General view of limestone towers in Phang Nga Bay

The limestone of the Phang Nga area dates to the Permo-Carboniferous period. The walls of the cliffs show solution notches, formed when the sea level was higher. Dissolution and wave action shaped the cliffs. There are clusters of steep sided hills typical of fengcong karst, as well as individual single towers. Some of the towers have fossil caves with entrances high up in the cliffs. There are younger sea-level caves as well as drowned caves which are now below sea level.

Many of these islands contain hongs. Hong is a Thai word meaning room. Hongs are basically large dolines that are open to the sky and are surrounded by steep limestone cliffs and contain tidal lagoons. The hongs can only be reached through the caves, unless one wants to climb up and over the sheer limestone walls. Access through the caves depends on the tides. During high tide the entrance and possibly the whole cave will be underwater, but as the tide lowers, a way through the cave is revealed. Many of the caves have low entrances which are close to the water level, and have deep water throughout. This means that access through the cave is limited to short periods of maybe an hour or so around the low tides. Some caves have high ceilings inside and are well decorated with stalagmites and stalactites, and some even have colonies of bats and swiftlets. These creatures must use other dry entrances and not the tidally submerged ones. [photo 02]

Photo 2: Kayaks entering sea cave

The sea-level caves may pre-date the hongs, or may have been formed as a result of them. The hongs, which can be more than 300 m in diameter, may have originally had a roof.

Today they are open to the sky, admitting sunlight which allows the growth of flora. This presents a beautiful area akin to a hidden garden. Mangroves are found at sea level, and small forests may be found if there is sufficient dry land. Plants are able to grow on the sheer walls, especially cycads which can be seen high up on the walls. cycads are the oldest group of seed-bearing plants and have undergone relatively very little change over the last three hundred million years or so, earning them the euphemism of "living fossils". There may be endemic species of palms and figs. [photo 03]

Photo 3: Mangroves are commonly found inside hongs

The fruiting tress such as figs provide seasonal food for many species of birds and primates. Long-tailed macaques feed on fruit and insects, as well as crabs and crustacea at water level. [photo 04] Dusky langurs, or leaf monkeys are vegetarian and can survive on the plants inside the hong. Even gibbons may be found on the larger karst islands where there is continuous forest cover big enough to support their dietary needs. At water level, monitor lizards, snakes and other reptiles may be seen. Birds are common inhabitants.

Photo 4: Dusky langur (also known as leaf monkey, spectacled langur, or spectacled leaf monkey) (Trachypithecus obscurus) can be seen inside the hongs

Local people have known about these caves for a long time and have collected birds' nests from within the caves. Fisherman also go to the hongs. But the vast majority of visitors are tourists. South Thailand has been a popular tourist destination for decades, and for the last 20 years, sea kayaking into the hongs has been a lucrative operation for tour companies. Flotillas of canoes go to the hongs each day.

Visitors are attracted by the beautiful landscape and the chance to explore dark caves by kayak, or even a long swim, and to see the hidden gardens inside the hongs.

2. TOURISM IN PHANG NGA

Flying into the international airports of Phuket or Krabi you can get a good view of the limestone islands dotted around the coastline. This area of southern Thailand is heavily visited by tourists all year round. There are renowned tourist sights such as James Bond Island, or Ko Phing Kan, which was made famous when the area was used for filming "The Man with the Golden Gun".

Apart from boat trips and recreational diving, sea canoeing is very popular in the Krabi and Phuket areas. There are many accessible islands to explore in the Phang Nga bay area, which has sheltered waters. The area is part of National Marine Parks and there are strict controls on tour groups. This helps to protect the islands and caves. One negative aspect of the visitors is the feeding of the sea eagles from the boats. The birds are fed with scraps of chicken, and this routine is upsetting their natural diet as well as making them reliant on free hand-outs.

Phuket is the main base for sea canoe trips. These range from day trips to seven day tours. On the day trips, a large boat takes the tourists to the island, and from there they paddle single or double kayaks into the hongs. [photo 05]

Ko Hong or Hong Island is one of the most visited islands. In the centre is a hidden lagoon. After a low entrance the cave roof rises, revealing some stalagmites and stalactites on the dry banks. Then the roof suddenly lowers and the walls close in leaving a gap not much larger than a kayak. The canoeists have to lie flat to get through. This tunnel leads out into a hong. The sheer limestone walls rise more than 100 m, and are capped with green vegetation. The grey and white cliffs are streaked with red, orange and black striations, created by algae and lichens. Green pandanus and other palms and shrubs cling to the precipitous walls. There are mangroves at water level.

Photo 5: Karst tower of Ko Hong

Ko Panak is a larger island off the Phuket coast. It has at least nine hong lakes, four of which are each more than 100 m across and are used for tourism. Mangrove Cave, Tham Pa Chai Len, is a dark cave leading to a hong with mangroves, which is used by fishermen. Diamond Cave, Tham Phet, is just south of Mangrove Cave, and named from a nice flowstone inside the dark cave. The 70 m long cave leads to one hong, then an arch passes to another hong. Bat Cave, Tham Khang Khao, on the west side of the island is 150 m long and dark, and houses colonies of insect bats which seem oblivious of the kayaking tourists. The cave leads to a very large hong, 120 m across. Troops of crab-eating Long Tailed macaques inhabit the hong. The fourth cave is Oyster Cave, Tham Man Hoi, 50 m long and leading to a small hong. [photo 06]

Photo 6: Paddling through the cave into a hong

Further north in Phang Nga Bay, Tham Lod is a tunnel cave that small tourist boats pass through. Nearby, the sea caves of Ko Thalu are popular with visitors in kayaks, but no hongs are known. To the

east, Ko Kudu Yai has three small hongs but it is not known if there is access to them though sea level caves.

With the constant flow of tourists in the area, there are many more sea-level caves and smaller hongs that have been found by local kayak companies. [photo 07]

Photo 7: Karst towers in close proximity and provide a stunning landscape

There are also mainland caves used for kayak tours. On the east side of Phang Nga bay is Krabi province, and 40 km north of Krabi town is Ao Luk. From here tourists are taken to Than Bokkhorani National Park. The main attraction of this park is its waterfalls and flora, but there are also ancient caves, petroglyphs, cave tunnels and mangroves. The canoe tours start at Bo Tho Pier, paddling down the river to Tham Lot Nua (Lot Tai) a 90 m long cave tunnel in a small hill. The southern entrance is 30 m wide and the northern is 15 m. The roof is about 8 m high and there are some nice hanging stal. Daylight penetrates the whole cave. Dusky langur monkeys are commonly seen. [photo 08]

Photo 8: Tham Lot Nua

Tham Phi Hua To is famous for its ancient petroglyphs. The cave is upstream from Tham Lot Nua and only accessible by boat. Concrete steps lead up to the cave entrance, the steps were built in 2525, i.e. 1982 on the Gregorian calendar. Tham Phi Hua To is also identified as Tham Hua Kalok, and is known as Big Headed Monster Cave. A big headed ghost reputedly lived in the cave. There are three entrances and the cave is basically two large chambers, each about 30 m across. [photo 09] The 'monster' can be seen on one of the walls. It is a petroglyph, one of several ancient paintings which can be found on the walls. They have been dated at 2000-3000 years old. There are various pictures portraying animals such as fish, dugong, shark and crocodile. In human form there are people, a shaman, and an alien with a triangular head. There are paintings of hands, one of which had six fingers. The paintings are red and black in colour, the red from tree bark and the black from squid ink. The cave chambers go through the hill and are lit by daylight. The back entrance gives a good view over the mangroves to the coast, with lots of limestone hills jutting up. There are lots of shells littering the floor of the cave, once eaten by ancient man.

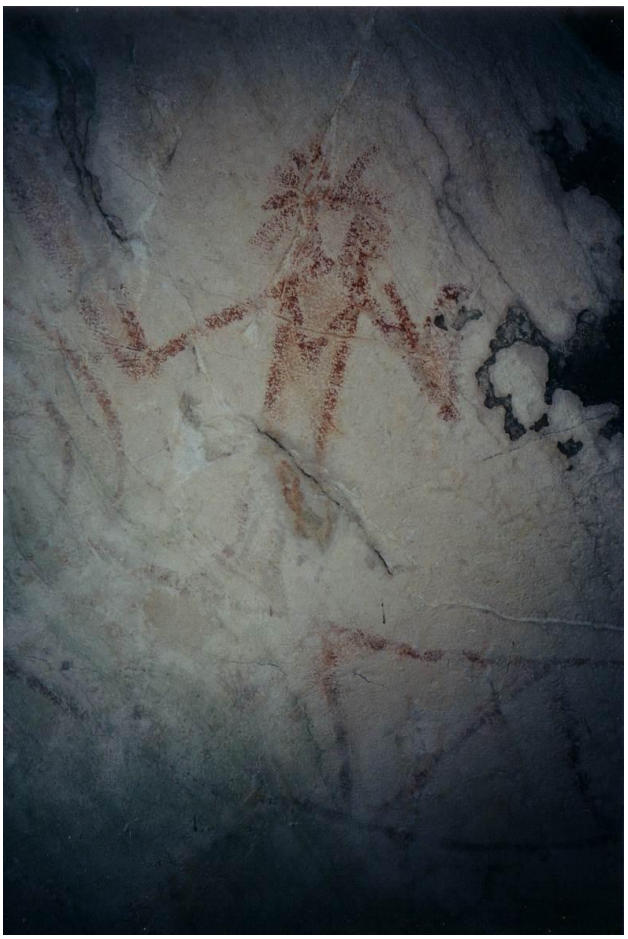

Photo 9: Petroglyph in Tham Phi Hua

Going upstream from Bo Tho Pier leads to Tham Lod. This is dark, due to a bend which prevented daylight from penetrating. It emerges in a

beautiful hong, circular and surrounded by high cliffs. There are cycads clinging to the sheer cliffs, and oyster shells on the lower walls.

Near the town of Krabi is the very popular beach area at Ao Nang. This includes Rai Ley Bay and Phra Nang Bay. Although part of the mainland, this small peninsula is only accessible by boat from Ao Nang. The area has become a mecca for rock climbers, with hundreds of people climbing every day. There is one lagoon accessible from Rai Ley beach, but instead of entering by sea cave, visitors have to climb up the hill and then down to the lagoon, which is called Sa Phra Nang or Holy Princess Pool.

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Fluxo editorial:
Recebido em: 05.01.2011
Aprovado em: 18.02.2011

TOURISM AND KARST AREAS
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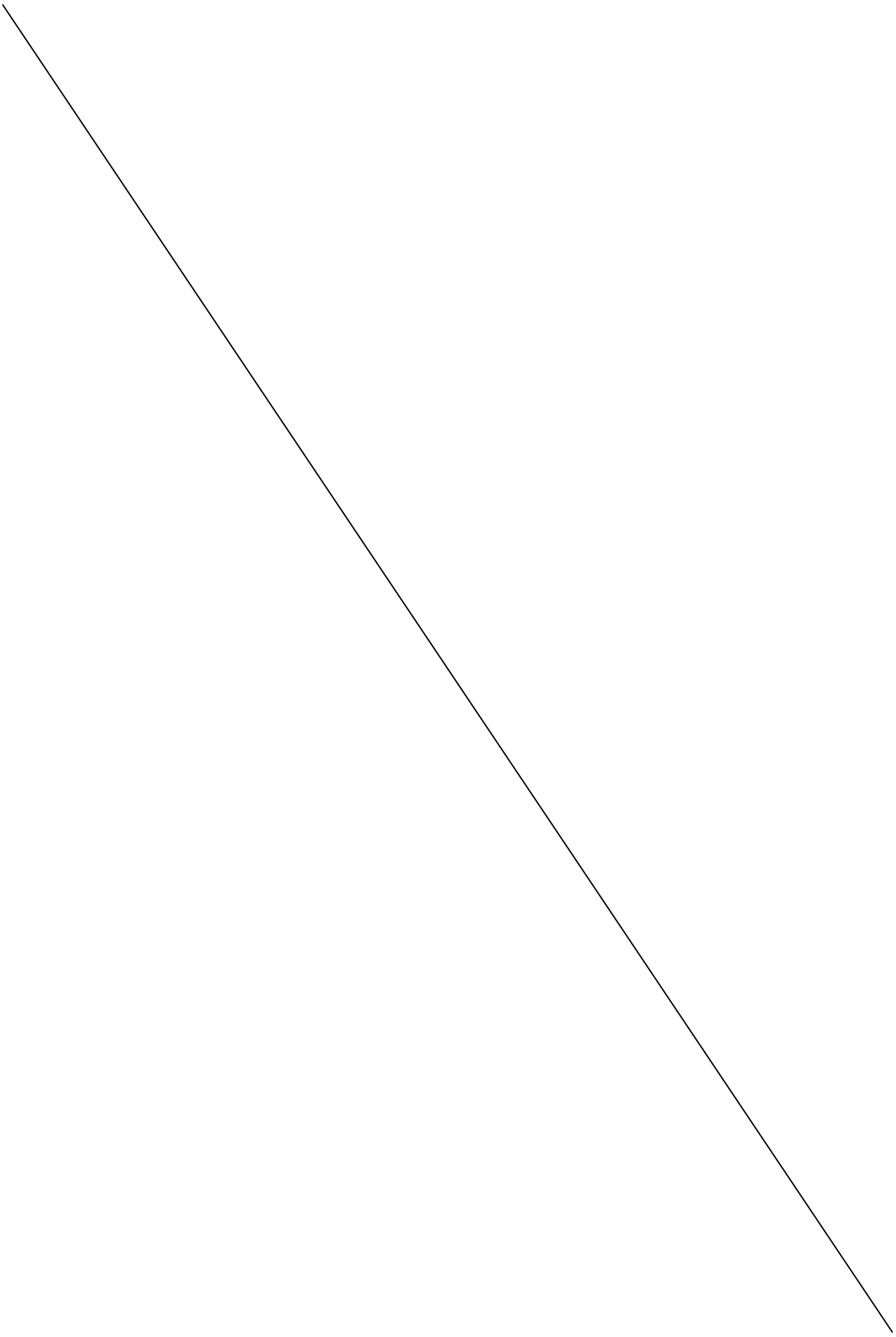

MONITORING OF WATER TEMPERATURE OF THE RONCADOR RIVER: CONTRIBUTION TO SPELEOCLIMATE ANALYSIS AND TOURIST MANAGEMENT OF THE CAVE OF SANTANA (IPORANGA, BRAZIL)

MONITORAMENTO DA TEMPERATURA DA ÁGUA NO RIO RONCADOR: CONTRIBUIÇÃO À ANÁLISE ESPELEOCLIMÁTICA E AO MANEJO TURÍSTICO DA CAVERNA DE SANTANA (IPORANGA-SP, BRASIL)

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Abstract

The monitoring of cave environments for tourist management is necessary for the establishment of limitations in visitation, thus promoting the preservation of caves. With this in mind, the water temperature of the Roncador river was monitored in the cave of Santana, along with that of the atmosphere, in order to verify their participation in the atmospheric system of the cave and possible impacts of tourism to be considered during management decisions. The results show that for a large portion of the river gallery, at distances greater than 300m from the resurgence, the air temperature is governed by the temperature of water. This has made it possible to establish conclusions identifying the dynamics of atmospheric circulation, the dispersion of the impacts of visitation, and the capacity of the Roncador river to maintain the stationary state of the atmosphere in the gallery of the river in the cave of Santana.

Key-Words: Environmental monitoring; Energy flow; Cave management; Speleotourism; microclimate.

Resumo

O monitoramento dos ambientes cavernícolas para fins de manejo turístico deve ser realizado em uma base ampla, de forma a considerar todas as possibilidades e limitações para o seu uso. Nesse sentido, realizou-se um monitoramento da temperatura da água do rio Roncador, em conjunto com o monitoramento de variáveis atmosféricas, na caverna de Santana, com o intuito de verificar sua participação no sistema atmosférico da cavidade e possíveis interferências no manejo turístico. Os resultados demonstraram que grande parte da galeria do rio, em trechos em distância superior a 300 m de sua ressurgência, possuem a temperatura do ar governada pela temperatura da água. Com isso, foi possível estabelecer conclusões que dão suporte para a dinâmica de circulação atmosférica, a dispersão de impactos de visitação e a capacidade do rio Roncador na manutenção do estado estacionário da atmosfera na galeria do rio na caverna de Santana.

***Palavras-Chave**: Monitoramento Ambiental; Níveis de Circulação de Energia; Manejo de Cavernas; Espeleoturismo; Microclima.*

1. INTRODUCTION

The management of caves for tourist purposes requires a wide array of environmental studies in an attempt to preserve the subterranean environment and make its use sustainable.

From a practical point of view, speleoclimatic parameters are among the most important for the management of caves because they have proved to have a relation of cause and effect, with environmental alterations due to visitation can be identified, whether they are transitory or permanent, direct or indirect (CIGNA; FORTI, 1988; LOBO, 2008; ROCHA, 2010).

The presence of bodies of water inside caves also exercises a decisive role in tourist management, since they objects of considerable attraction for tourism (LOBO, 2007); moreover, they play a role as vectors in the dispersion of impacts (HEATON, 1986; PULIDO-BOSCH et al., 1997), and they influence the relative and absolute humidity of the air (DUBLYANSKY; DUBLYANSKY, 1998; BUECHER, 1999; CARRASCO et al., 2002), as well as the temperature, with the size of the effect depending on the size of this body of water. In

extreme cases, the temperature of the water can even make a direct contribution to condensation corrosion at higher temperatures (SARBU; LASCU, 1997) or, at greatly reduced temperatures, participate in the formation of speleothems of ice (PFLITSCH et al., 2006; PIASECKI et al., 2006).

The present paper presents partial results of research monitoring the speleoclimate in the cave of Santana, located in Iporanga city, Brazil, focusing of the temperature of the water of the Roncador river. This river has already been the focus of earlier studies which have emphasized its role in the evolution and dynamics of the local karst (KARMANN, 1994), as well as the sources of recharge and hydrological connections within the system (AYUB, 2007). Here, the monitoring of the temperature of the water was focused on the identification of its possible correlation with the temperature of the air, serving as a basis for the understanding of the physics of the thermal system of the cavity and its atmospheric resilience in relation to the impact of visitation.

2. MATERIALS AND METHODS

This study was conducted in the cave of Santana, which is partially located within the bounds of the State Touristic Park of the Upper Ribeira River (PETAR) in the municipality of Iporanga in the southwestern part of the state of São Paulo. The cave is located in a limestone massif, more than 200m below the surface. At present, some 7.2km have been mapped, and hundreds of meters are left to be explored. The traditional visitation circuit encompasses some 460m of galleries in three of the six levels, close to the resurgence of the Roncador river. The total vertical variation is 54m, with the resurgence located at an altitude of 250m above sea level.

The cave of Santana, in a subtropical zone, is surrounded by dense Atlantic Coastal Rain Forest, with rains concentrated between December and February, an annual average of 1,500mm of rain, and daily accumulations of up to 300mm (GUTJHAR; TARIFA, 1993).

The lower gallery of the cave of Santana is traversed by the Roncador river; the main swallet is located in the Pérolas cave. Recharge here is mainly allogenic, although autogenic recharge is also quite active, as can be seen in periods of intense rain, when segments of the upper galleries suffer partial flooding (Figure 2).

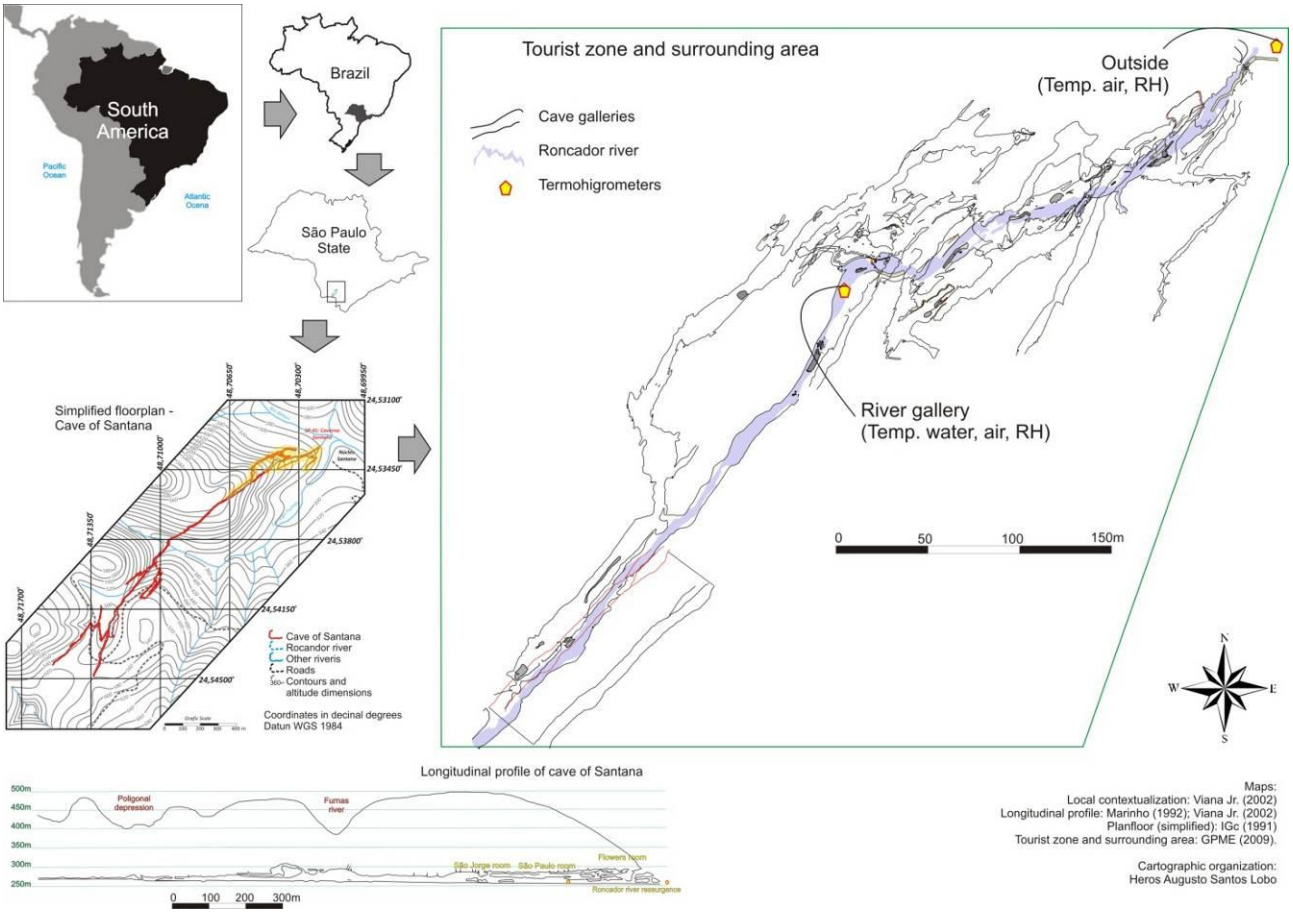

Figure 1 – Location of cave of Santana and points of data collection

Figure 2 – Variation in water level in cave of Santana: a) normal level of the Roncador river, with the paths for visitation clearly evident (historic photo from 2007, when the cave still had a gate); b) raised water level, with the river covering the paths; c) normal level of water in the Meeting Room, with rimstone dams apparently totally fossilized; d) rimstone dams filled with water, showing active autogenic flow in the upper gallery

The choice of the cave of Santana for the realization of this study was due to its importance in the regional and national context of ecotourism and speleotourism. The cave receives an average of 20,000 visits per year, with peaks of over 30,000. The carrying capacity at present is limited to 117 visits per day, as established by Lobo (2008), although recent studies by Lobo et al. (2011) suggest the feasibility of an increase to 297.

The monitoring of atmospheric parameters and the temperature of the water was conducted with Testo instruments (series 175 and 177). Only the data about temperature and relative humidity of the external station and a single point in the river gallery some 300m from the entrance of the cave are presented here for the comparison of the temperature of the water (Figure 1). The accuracy of the instruments is 0.2 °C for air temperature, and 0.1 °C for that of water, as well as 2% for relative humidity. The precision of the temperatures presented here is 0.1 °C and 0.1% for the relative humidity of the air. The sensors were installed against the walls of the cave, which may alter the results somewhat in relation to the integration of the readings with the underground atmosphere of the specific passage. However, preliminary studies in the cave of Santana have shown that for the scale of accuracy of the sensors, this difference is not detectable. Monitoring was carried out for a continuous period of a year, although instrument failures left certain gaps in the data. Collections were made every 30 minutes, for a total of 48 readings per day. The river station was monitored continuously from April 1 to December 11, 2009, but at this time the flooding of the gallery of the river interrupted the functioning of the thermohygrometer. During the period of effective monitoring, the cave continued to receive regular tourist visitation from Tuesday to Sunday, from 9 am to 5 pm.

The first set of analyses involves descriptive statistics. These provide averages of central tendency (medium, mode, and average) and variability (height, standard deviation, and variance) for each daily, monthly, and annual series. This procedure made it possible to determine the

simplification necessary to conclude the other statistical analyses.

The mode was used as the main measurement of central tendency for the analysis because the daily series involved great repetition and the standard pattern of variability could be identified for each of the parameters.

The use of the mode is also justified, as pointed out by Gerardi; Silva (1981), because it is efficient for the graphic presentation of data. The average, on the other hand, was used to present the disadvantages of asymmetric series (GERARDI; SILVA, 1981), such as was found for the external monitoring points.

Statistics were used for the analysis of speleoclimatic parameters (e.g. MANGIN, 1984; LAROCQUE et al., 1998; MANGIN et al., 1999; FERRARI; KARMANN, 2008), as well as for speleoclimatology (e.g. CALAFORRA et al., 2003; FERNÁNDEZ-CORTÉS et al., 2006). The statistical analyses of temporal series are initiated with a moving average. In addition to the graphs with the moving averages, the revelation of greater discrepancies in the original series, led to the plotting of the residuals.

Analyses were also made using three temporal functions: autocorrelation, spectral density, and cross correlations. Autocorrelation quantifies the relation of linear dependence for successive values in an interval of time. The spectral density corresponds to a transformation of the domain of time to that of frequency using a Fourier transformation of the function of autocorrelation. Cross correlation verifies the independence of two series of variables, showing whether they are equal to or distinct from each other.

3. RESULTS AND DISCUSSION

3.1. Temperature and relative humidity of air

The results from the monitoring of the temperature and relative humidity of the air outside the cave are presented in Figure 3.

The highest maximum temperatures during the period were registered in the months of September (31.2 °C) and November (32.1 °C). On the other hand, the minimum temperatures were registered in June (9.7 °C) and August (9.5 °C). These absolute values cannot be seen in Figure 3, which provides only the moving averages. The month which was the hottest during the period monitored was November, while July and August were the coldest.

Measures of central tendency of the external temperature series revealed an annual average of 19.9 °C, with a mode of 17.9 °C and a median of 19.9 °C. For the relative humidity, the central tendency and dispersion reflected in the mode and median, as well as the maximum, were 99.9%, while the average was 98.9% and the low 60.2%. The variation over the year was a spread of 23.4 °C for temperature and 39.7%.for humidity.

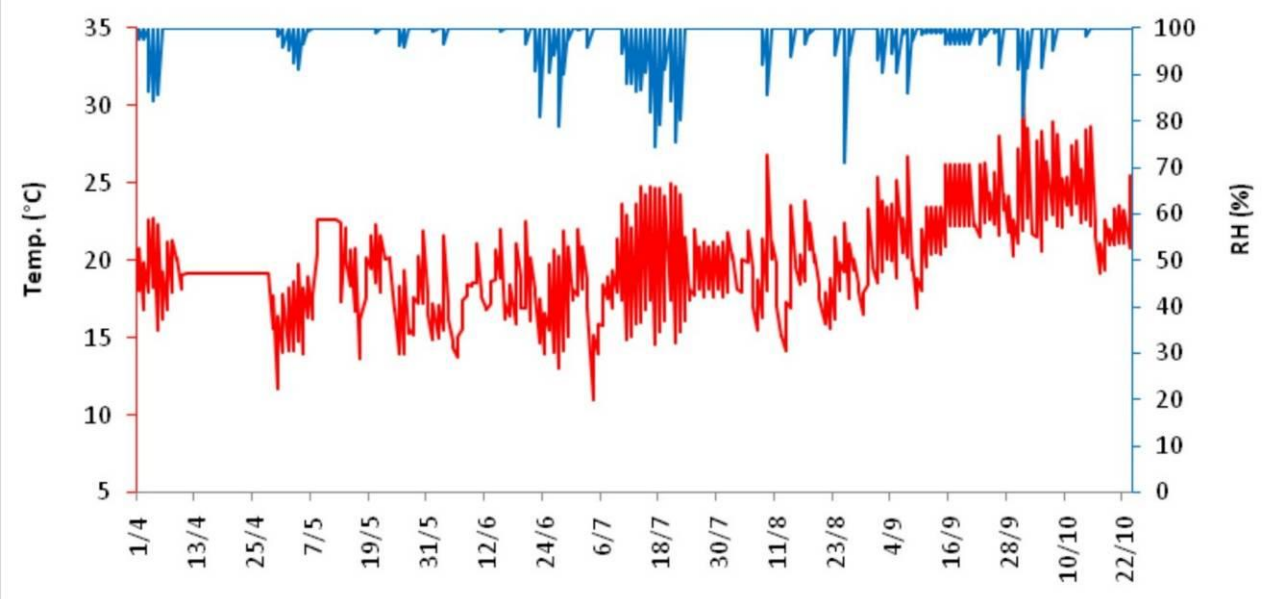

Figure 3 – Smoothed series based on moving averages of temperature (red) and relative humidity of air (blue) for the external monitoring station for the period from April 1 to December 11, 2009.

The various gaps in the original series make a global statistical analysis of the data via temporal series impossible; consequently, the analyses here are limited to the longest uninterrupted period of the original series, from July 1 to December 13, 2009, a total of 166 days, which includes part of the winter and part of the summer. In this series, autocorrelation and spectral density were calculated, as presented in Figures 4 and 5 for air temperature.

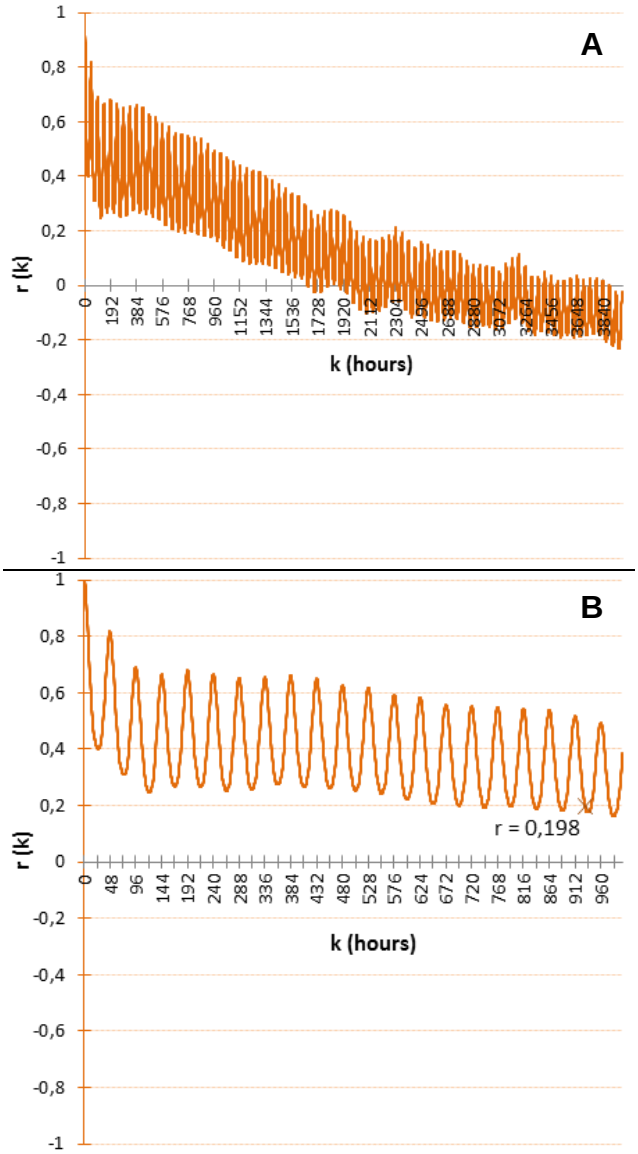

Figure 4 – Autocorrelation function for entire series (A) and in detail for the first 500 hours (20,8 days) (B) in external station.

Autocorrelation was used to study the series of 3984h (166 days). The variation shows a cyclic periodicity of 24 hours, as can be seen in Figure 4A; details can be seen in Figure 4B. The memory effect of the system is approximately 930h (38.75 days), when the *r* index reaches a value of 0.198. In general, the autocorrelation function shows a decrease over time, a pattern that is repeated for the other series analyzed by other monitoring stations.

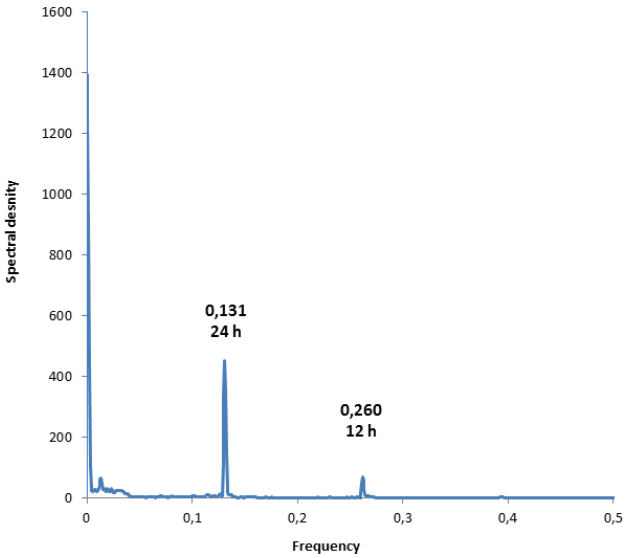

Figure 5 – Spectral density of series selected at external monitoring station

Spectral density shows peaks at 24h and 12h, which is coherent with the atmospheric dynamics and the results of autocorrelation. However, the high spectral density is close to zero, with the existence of periodic phenomena which extend beyond the time period analyzed.

For the monitoring station near the point of collection of data in the river, Figure 6 shows the averages of dispersion and central tendency for the entire series for the air temperature. The relative humidity of the air at this point was constant throughout the monitoring period, with a value of 99.9%, showing the saturation of the air.

The minimal temperature fell to 17.3 °C at 9am on June 4, 2009, at this monitoring station, although the temperature here had been close to this for hours (17.4 °C between 5:30am and 8:30am). At the other extreme, the high registered was 20.2 °C at 6:30pm on July 4; this same temperature was registered at other monitoring stations in the same cave. Except for this single elevated value, the maximum registered was 19.3 °C. The daily thermal variation was normally less than 1 °C. Visual analysis of the graph suggests that the air temperature at this station is correlated with that of the outside air in relation to the minimum.

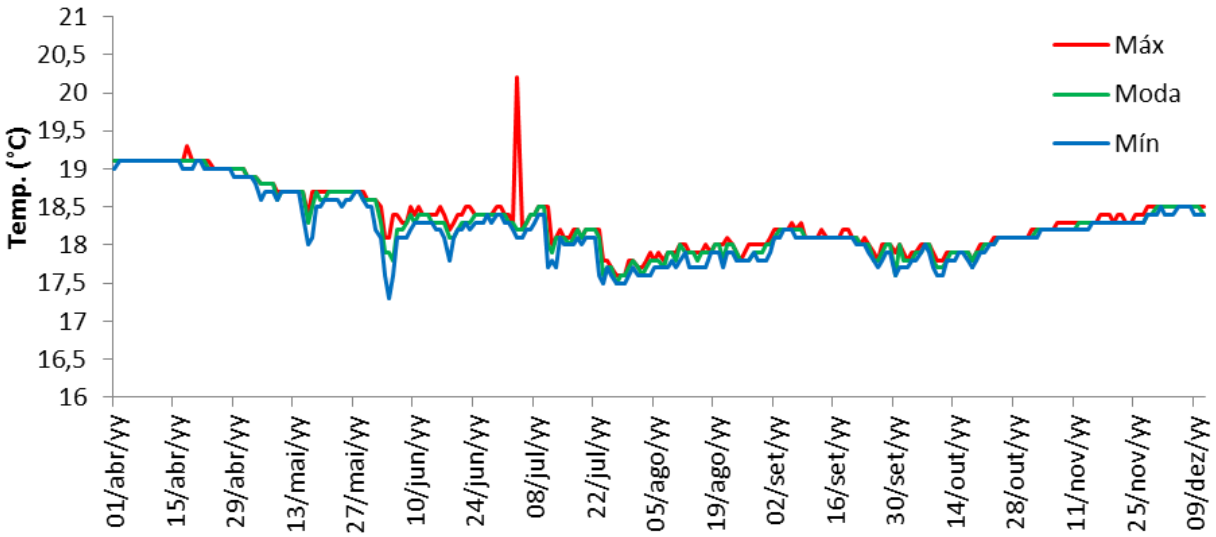

Figure 6 – Simplified series of air temperature at station in gallery of river, with measures of dispersion (maximum and minimum) and central tendency (mode) for the period from April 1 2009 to March 31, 2010.

An analysis of the entire temperature series for the air at this station reveals an annual average of 18.28 °C, a mode of 18,1 °C and a median of 18,2 °C. The annual temperature variation was 2.9 °C, if the extreme of 20.2 °C is included in the analysis, but only 2 °C if it is ignored. Any variation in humidity was observed at this station, with all the measures of central tendency being equal to 99.9% throughout the period monitored.

The smoothing of the data involved the adoption of the moving average; the graph of the respective residuals is presented in Figure 7.

The smoothed series does not reveal any large differences in relation to the original series of data (Figure 7A), suggesting the lack of anthropic influence at this point in the cave. The only exception deviating from the general behavior of the temperature at this point occurred on July 4, reflecting an event of unknown origin also revealed in Figure 6 and the residuals observed in Figure 7B.

The results of the autocorrelation and spectral density functions for the temperature of the air in the gallery of the river are presented in Figure 8.

The analysis of the data was applied to a series of 6120h (255 days). The autocorrelation function (Figure 8A) shows a slow decrease, revealing reduced atmospheric dynamics at this point. The memory effect was found after 2266h (94,41 days), when *r* was equal to 0,2. On the other hand, the spectral density (Figure 8B) shows that the cut-off frequency was very low at this point, so that only the visualization of a single 24h cycle of low spectral density was possible.

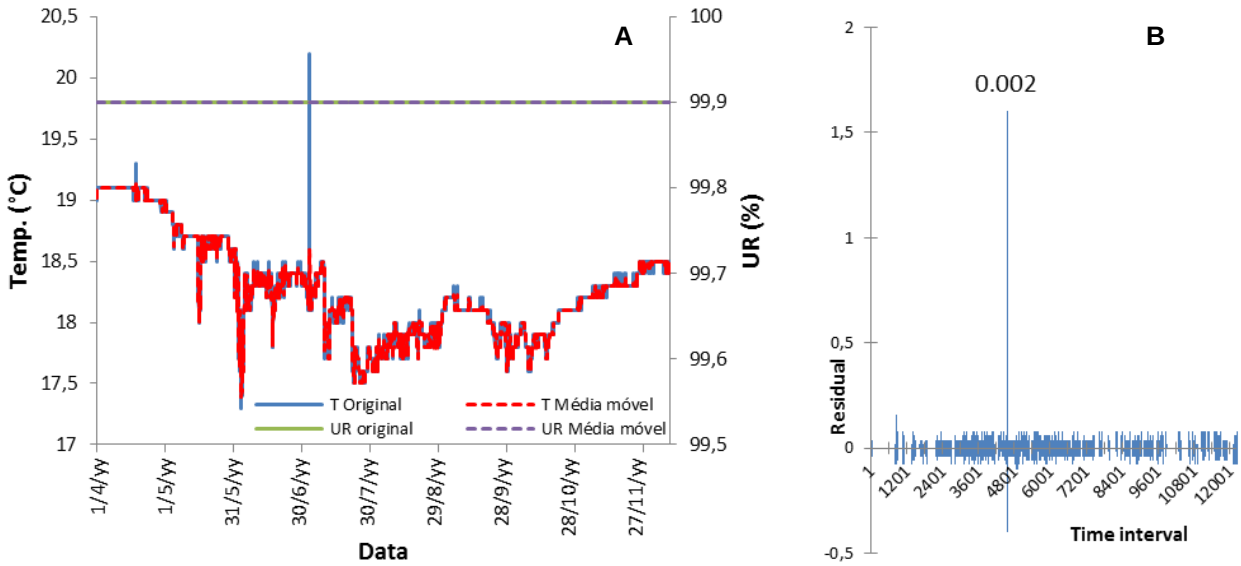

Figure 7 – Original series for temperature (T) and relative humidity (RH), showing moving averages (A) and the graphs of the respective residuals from smoothing x moving average (B) measured at the station in the gallery of the river for the period from April 1 to December 11, 2009.

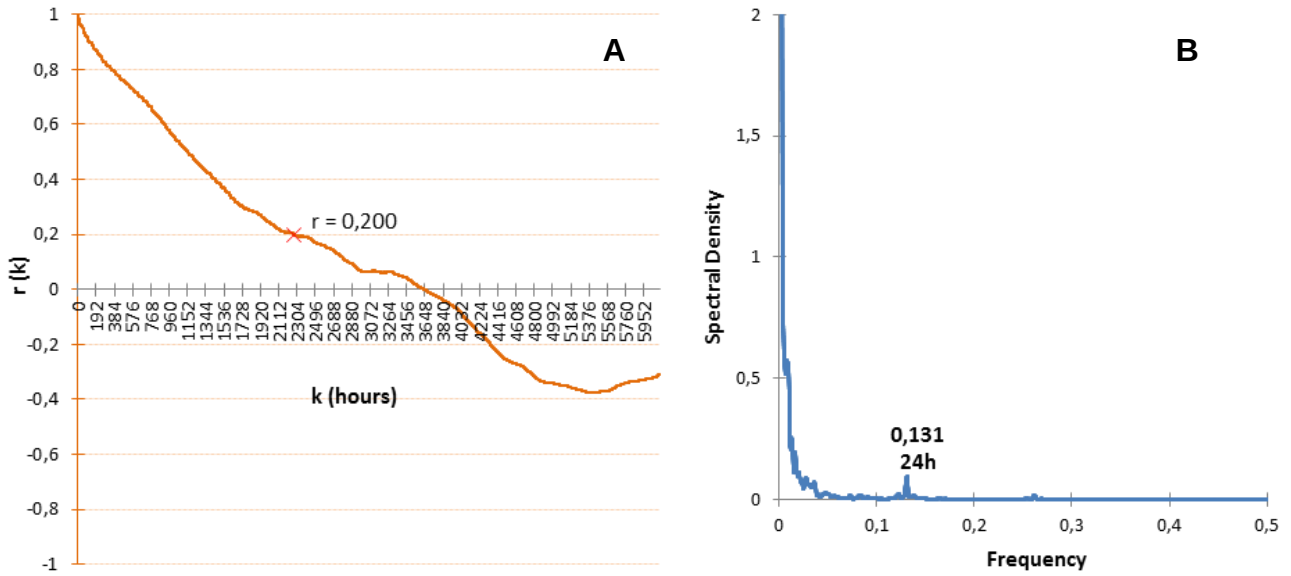

Figure 8 – Functions of autocorrelation (A) and spectral density (B) for the series of air temperature at the station in the gallery of the river.

3.2. Water temperature

The results of the monitoring of the temperature of the water with the measures of dispersion and central tendency of the series collected are presented in Figure 9.

The temperature of the water was coldest on July 27, with a temperature of 17,1 °C between 5:00h and 15:30h. On the other hand, the maximum was registered in November, reaching 19,3 °C between 16h on November 28 and 4h on the 29th. For most of the days monitored, the variation in daily temperature was zero. The only unusual value was registered for July 27, when this variation reached 0.8 °C. On a daily scale, the high, low and mode were the same. Table 1 presents the descriptive statistics for water temperature on a monthly scale.

Although the annual series was incomplete and rainfall was not measured, the increase of the temperature of the water during November and December, as well as the decrease in the months of June through August are in agreement with historical rainfall data for the region, with summer (December to February) registering the most rain and winter (July to August) the least (GUTJHAR; TARIFA, 1993). In July, the daily temperature variation was the greatest, 0.8 °C, which gave rise to a sudden increase in the temperature of the water on July 22. In the same month, a daily variation of 0.6 °C was also found, as well as other lesser variations in the range of 0.1 °C to 0.2 °C on 18 other days of the month; hence, July was the month with the greatest variation in temperature of the Roncador river.

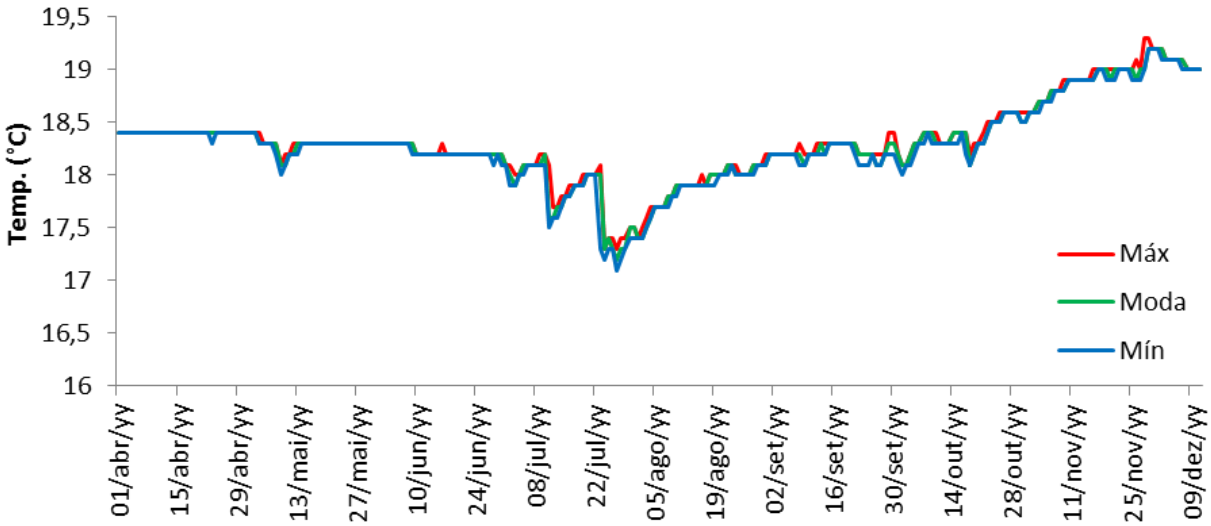

Figure 9 – Simplified series of water temperature at station in the river gallery, with measures of dispersion (maximum and minimum) and central tendency (mode) for the period from April 1 to December 11, 2009.

Table 1 – Measures of dispersion and central tendency for the water temperature on a monthly scale.

Measure	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Maximum (°C)	18,40	18,40	18,30	18,20	18,20	18,40	18,60	19,30	19,20
Average (°C)	18,40	18,29	18,23	17,79	17,88	18,22	18,37	18,91	19,07
Mode (°C)	18,40	18,30	18,20	18,00	17,90	18,20	18,30	18,90	19,10
Minimum (°C)	18,30	18,00	18,10	17,10	17,40	18,10	18,00	18,60	18,90
Daily variation (°C)	0,10	0,10	0,10	0,80	0,10	0,20	0,20	0,30	0,10
Standard deviation	0,005	0,066	0,048	0,304	0,191	0,063	0,150	0,154	0,075

On the other hand, on a broader time scale, the temperature variation during the entire period of 8 months and 11 days was minimal, showing the great thermal stability of the water. The variation during the entire period was 2.2 °C, with an average of 18,29 °C and a mode and median of 18,3 °C.

The temperature series for the water was also analyzed by statistical techniques for temporal series. Figure 10 shows the results for the moving average and the autocorrelation function.

For the analysis of the temperature of the water, a series of 6120h (255 days) was adopted. The smoothing of the series did not generate any major variation in relation to the original data collected (Figure 10A). Even for those days of greatest variation in temperature in July, the residuals generated did not surpass 0.1 °C, showing that the variation was gradual and slow. The autocorrelation function (Figure 10B) supports the conclusion of a system with low dynamics of exchange, especially in comparison with the dynamics of the gallery of the river; the memory effect was 1851h (77,12 days). On the other hand, the dynamics of the water was greater than that of the air at this point in the cave, as shown by the autocorrelation function of air temperature presented in Figure 8A.

Based on the data collected, an attempt was made to identify the existence of a relationship between the variation of the temperature of the water and that of the air in an attempt to verify the role of water as a vector in the dispersion of atmospheric impacts. For this purpose, the results of correlation tests were crossed with those of the temperature series (Figure 11).

The temperature of the air at the point monitored in the gallery of the river had a low correlation with that outside the cave, with a total lag of 435h (Fig. 11A). This values differs from that at other points monitored in the gallery of the river, and even in one of the upper galleries (LOBO et al., 2009), where the lags differed between 1 and 4 hours. On the other hand, Figure 11B shows the high correlation between the temperatures of the water and air at this point in the gallery of the river, with an index of 0.422 in the zero interval.

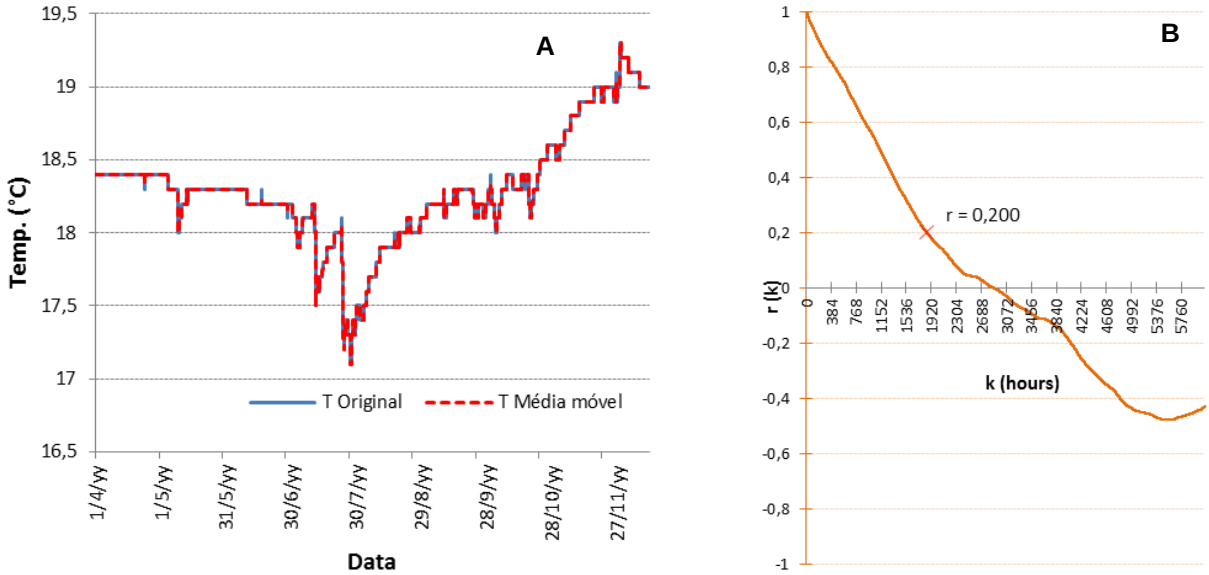

Figure 10 –original temperature series for the water and the moving average (A) and respective autocorrelation function (B) for the period from April 1 to December 11, 2009.

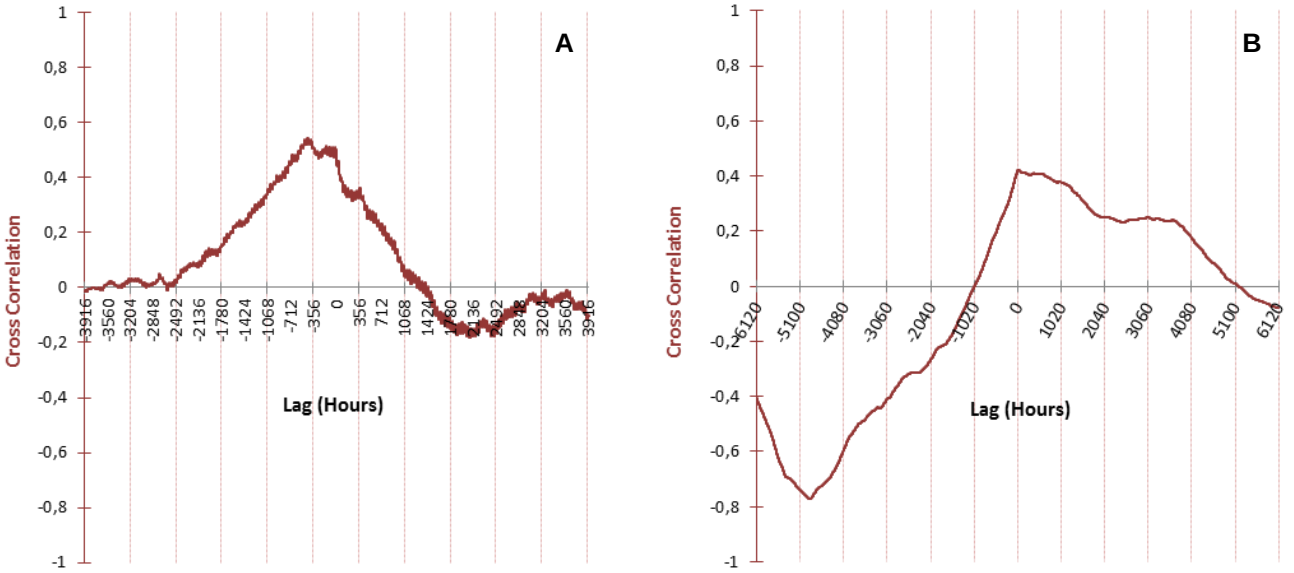

Figure 11 – Cross correlations between external air temperature and that at the collection point in the gallery of the river (A) and between that of the air in the gallery of the river and that of the water (B)

The time it takes for the water of the Roncador river to traverse the distance from the swallet to the region of the ressurgence varies from 44 to 51h 20min (AYUB, 2007). With this, the water suffers little influence from the external temperature, an influence limited to specific points and the limited variation mentioned in Table 1. The water thus takes on the thermal characteristics of the rock, which, in the long run, governs the thermal system of caves (FREITAS; SCHMEKAL, 2003; LUETSCHER; JEANNIN, 2004). This is especially true in the case of confined underground aquifers, such as is the case of the Pérolas-Santana system, which for much of the trajectory is a freatic system without any contact with the underground atmosphere. On the other hand, the low correlation between the air temperatures outside and inside the cave at this point reveals a limited gas exchange, which may be caused either by the rise of masses of warmer air to the upper galleries or by the gradual difference in air density generated by the differences in temperature and relative humidity, which causes a certain atmospheric isolation along part of the gallery of the river, and which may indeed extend for the entire trajectory after this point.

These results show the importance of water temperature in the maintenance of the stationary state of the thermal system of the cave of Santana after this stretch of the river gallery, where a buffer effect on temperature is introduced These results corroborate those of Pflitsch; Piasecki (2003), who affirm that the water is much more influential in thermal alterations than are air currents, since the water has a greater capacity for the retention of heat.

As a result of this behavior, it seems that hypothesis that the impacts generated by visitation of the downstream gallery of the river and that of the upper galleries should not be extended to the deeper regions of the cave. This hypothesis is in agreement with what is known about the movement of masses of air as a function of the direction of water flow (CIGNA, 1967) or even variation in the depth of bodies of water, which show an effect of air movement resembling a piston (PULIDO-BOSCH et al., 1997).

The effect of the water temperature on the dynamics of the circulation of energy in the cave of Santana is clear. In caves with active rivers, the courses of the water are the main determinants in the energy balance (see article by Arrigo Cigna in this volume of the journal). In the cave of Santana, the data presented show the influence of water in the energy balance for a large part of the cave, which complements with details the results of the studies of Lobo; Zago (2007) on the energy flow in a cave from the perspective of the analysis of Heaton (1986). This influence decreases in importance in the regions close to the resurgence and in the upper galleries, where the energy balance is strongly influenced by air currents.

4. CONCLUSIONS

Based on this study in the cave of Santana, it is possible to conclude that:

- The temperature of the water exerts an influence on the temperature of the air in the gallery of the river up to 300m from the resurgence.
- Given the dynamics of the Roncador river and the physical shape of the galleries of the cave of Santana, these results can be extended to the

gallery of the river upstream from the monitoring station.

- Based on the mechanism of thermal regulation linking the water in the Roncador river and the atmosphere of the cave, the impacts from visitation to downstream areas and in the upper galleries are not the same as those observed for this point and upstream from it.
- Therefore, monitoring the temperature of the water has proved to be an efficient tool for speleotourist management, making it possible to establish a limit for sustainability in the face of impacts from touristic visitation. Its use can contribute to the establishment of hydrothermal zones inside a cave with distinct patterns of variation in temperature and relative humidity. Moreover, the patterns of water temperature identified may also contribute to the classification of the levels of energy circulation in a cave, thus serving as an important indicator for speleological management and of dispersion and/or accumulation of the impacts of visitation.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the suggestions of prof. Emerson Galvani (FFLCH/USP), which have contributed to an improvement in the original manuscript, and also prof. Linda Gentry El-Dash (Unicamp) for the translation of the final text.

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Fluxo editorial:
Recebido em: 04.03.2011
Corrigido em: 19.04.2011
Aprovado em: 23.05.2011

TOURISM AND KARST AREAS
(*formally*/formalmente: Pesquisas em Turismo e Paisagens Cársticas)
Brazilian Society of Speleology / Sociedade Brasileira de Espeleologia (SBE)
www.cavernas.org.br/turismo.asp

O REGISTRO FOTOGRÁFICO APLICADO EM ESTUDOS AMBIENTAIS NA GRUTA DO LAGO AZUL EM BONITO/MS: RETROSPECTIVA DE DUAS DÉCADAS – 1989 A 2010

THE PHOTOGRAPHIC RECORD APPLIED IN ENVIRONMENTAL STUDIES AT THE GRUTA DO LAGO AZUL IN BONITO/MS: RETROSPECTIVE OF TWO DECADES - FROM 1989 TO 2010

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Resumo

Este artigo pretende mostrar o uso da fotografia como recurso para o registro da paisagem, a fim de documentar as transformações ocorridas durante um determinado período. As fotografias são da Gruta do Lago Azul, município de Bonito/MS, importante atração turística da Serra da Bodoquena. A região foi escolhida para demonstrar a importância do uso de imagens para registros como forma de comparação e demonstração da evolução da consciência ambiental no local. Dessa forma, por intermédio da visitação à Gruta do Lago Azul, foram feitas fotografias do local que, comparadas com outras fotografias retiradas no final da década dos anos de 1980, nos permitiu uma análise comparativa da paisagem em seus aspectos geográficos, humanos e culturais.

Key-Words: imagem fotográfica; turismo ecológico; preservação ambiental.

Abstract

This paper aims to show the use of photography as a means to record the landscape in order to document the changes occurring during a given period. Photographs are from the Gruta do Lago Azul, Municipality of Bonito/MS, is the main natural tourist attraction in the Serra da Bodoquena. The region was chosen to demonstrate the importance of using images for records as a means of comparison and demonstration of the evolution of environmental awareness at the site. Thus, through the visitation to the Gruta do Lago Azul photographs were taken of the site, which compared with other photographs taken in the late 1980s, allowed us a comparative analysis of the landscape, in its geographic features, human and cultural rights.

***Palavras-Chave**: Photographic image; ecological tourism; environmental preservation*.

1. INTRODUÇÃO

O presente artigo é resultado de uma atividade da disciplina Prática de Campo, do curso de Mestrado em Meio Ambiente e Desenvolvimento Regional da Universidade Uniderp Anhanguera, em parceria com a Universidade Federal de Uberlândia-MG, realizada na região da Serra da Bodoquena-MS. Entre os vários locais visitados, foi escolhida para o estudo a Gruta do Lago Azul, localizada no município de Bonito/MS, um dos principais pontos turísticos da região.

A imagem fotográfica da gruta é usada pela mídia como atrativo turístico do município por ter sido uma das primeiras formas de divulgação do turismo em Bonito. O primeiro *folder*, elaborado em 1989, traz na folha de rosto sua imagem, como mostrado na figura 1.

Por ter sido uma das primeiras formas de divulgação pela mídia, hoje pode ser usada como um exemplo para avaliar a melhoria decorrente da regulamentação do processo de visitação da Gruta e as mudanças da consciência ambiental. Segundo Boni e Moreschi (2007, p. 138): "A fotografia é uma forma de obter registro que serve como fonte documental". Portanto, o registro fotográfico foi escolhido como uma forma apropriada para documentar a evolução de cuidados ambientais no referido ponto turístico.

Há trabalhos científicos que apresentam imagens do local, tais como Boggiani (2007, 2008) e Sabino (2003), acompanhadas de explicações

detalhadas sobre as características geológicas e geográficas, fundamentais para qualquer estudo, inclusive para aqueles em sítios espeleológicos pela raridade de patrimônios tombados em nosso país.

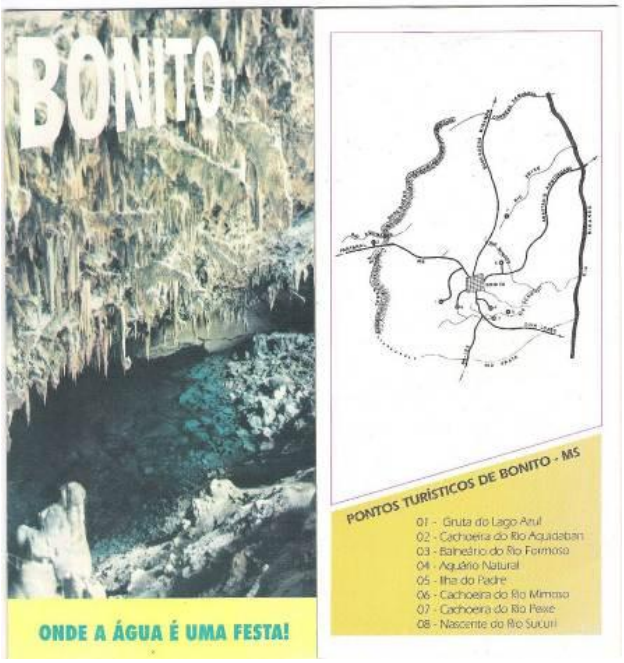

Figura 1: imagem digitalizada do primeiro *folder* dos atrativos turísticos de Bonito/MS (1989).

A visita ao local, acompanhada das explicações de professores e guias especializados, proporcionou aos participantes a possibilidade de registros das características do lugar observado, visando à coleta de dados para estudos ambientais, envolvendo tópicos geográficos e geológicos, biológicos, ecológicos e sociais.

Diante da relevância da Gruta do Lago Azul como patrimônio histórico, destacamos a necessidade e a importância dos registros fotográficos datados dos últimos vinte anos para avaliar a possibilidade da associação da prática do ecoturismo aos cuidados e respeito aos recursos naturais. Segundo Rouillé (2009, apud SANTOS, 2009, p. 2): "Na realidade a fotografia é, ao mesmo tempo e sempre, ciência e arte, registro e enunciado, índice e ícone, referência e composição, aqui e lá, atual e virtual, documento e expressão, função e sensação".

Como se observa na figura 2, o uso do recurso fotográfico possibilita ao pesquisador o registro de fósseis para estudo científico no piso do lago subterrâneo da Gruta do Lago Azul sem a necessidade de tocar ou remover o objeto de estudo.

Na atualidade, na qual o avanço das tecnologias digitais promove importante melhoria na precisão e detalhamento na produção de imagens, o recurso da fotografia torna possível o registro e o estudo científico de determinada realidade existente, sem necessidade de alterá-la, especialmente em ambientes sensíveis à ação antrópica.

Figura 2: Imagem do piso do lago subterrâneo da Gruta do Lago Azul, com ossadas desarticuladas de mamíferos fósseis do Pleistoceno (fotografia Ismael Escote). Fonte: Artigo "Gruta do Lago Azul, Bonito, MS – Onde a luz do sol se torna azul" (BOGGIANI, 2008).

2. ÁREA DE ESTUDO

A Gruta do Lago Azul é um dos mais importantes atrativos turísticos do estado de Mato Grosso do Sul. O nome se deve ao lago subterrâneo cujas águas adquirem a cor azul por conta da incidência dos raios solares.

> *A formação geológica do Planalto da Bodoquena explica parte da plasticidade das surgências. Estudos mostram que o subsolo do planalto é formado por rochas calcárias puras, originadas há 550 milhões de anos. A pureza e a antiguidade das rochas tornam as águas límpidas (BOGGIANI, 1999). O calcário dissolvido na água absorve e decanta as poucas impurezas restantes, tornando a água mais cristalina ainda. Em alguns locais, a visibilidade debaixo da água chega a 60 m, uma das águas mais transparentes do mundo*. (SABINO; ANDRADE, 2002 apud SABINO; ANDRADE, 2003, p.2).

A Gruta do Lago Azul, importante atrativo turístico, revelada na figura 3, insere-se no contexto geológico da Serra da Bodoquena, onde são identificados dois compartimentos geomorfológicos principais: o Planalto da Bodoquena e a Depressão do Rio Miranda. Em ambos:

> [...] *a paisagem é influenciada pela presença das rochas carbonáticas do Grupo Corumbá, com inúmeras cavernas, dolinas e demais feições típicas de relevo cárstico. Nesse contexto a Gruta do Lago Azul situa-se*

na Depressão do Rio Miranda em dolomitos do Grupo Corumbá (Formação Bocaina), em domínio de planícies cársticas com morros residuais. (SALLUN FILHO; KARMANN, 2007 apud BOGGIANI, 2008, p. 4).

Figura 3: Aspecto do lago subterrâneo ao fundo da Gruta do Lago Azul (Bonito/MS) que adquire a cor azul sob incidência dos raios solares. Fonte: Artigo "Gruta do Lago Azul, Bonito, MS – Onde a luz do sol se torna azul" (BOGGIANI, 2008). Foto J Sabino.

Boggiani (2008), em uma breve retrospectiva histórica, esclarece que o início da visitação turística ao local se deu em 1970. No mesmo ano foram feitos estudos para utilização da água, porém a idéia não prosperou. Em 1978 foi encaminhada pelo Secretário de Estado proposta de tombamento das Grutas do Lago Azul e Nossa Senhora Aparecida, cujo processo foi aprovado pelo IPHAN - Instituto de Patrimônio Histórico e Artístico Nacional.

Em abril de 1982, ambas foram adquiridas pelo governo do estado de Mato Grosso do Sul. Em 1984, sob a coordenação do arquiteto Clayton Ferreira Lino foram realizados, por uma equipe multidisciplinar, levantamentos topográficos do local e apresentado um plano de manejo turístico da região. Foi então construído um caminhamento no interior da Gruta do Lago Azul com blocos calcários, para facilitar a visitação turística. (BOGGIANI, 2008).

A gruta está localizada entre os córregos Anhumas e Taquaral, a uma distância de 19 km da cidade de Bonito que, por sua vez, fica a 280km da capital de Mato Grosso do Sul, Campo Grande.

Além da paisagem subterrânea, a gruta tem importância científica porque, em 1992, a Expedição Franco-Brasileira de Espeleomergulho, coordenada pelo francês Mathias Rossello e por Augusto Auler, hidrogeólogo membro do Grupo Bambuí de Minas Gerais, encontrou fósseis de um bicho-preguiça gigante do período pleistoceno (10 mil a 1,6 milhões de anos), de um tigre dente-de-sabre e de um servídeo (ancestral do veado ou corsa), segundo o periódico "Brasilturis Jornal" publicado na época. Também foram encontrados, além dos fósseis de mamíferos pleistocênicos, minerais raros e crustáceos endêmicos.

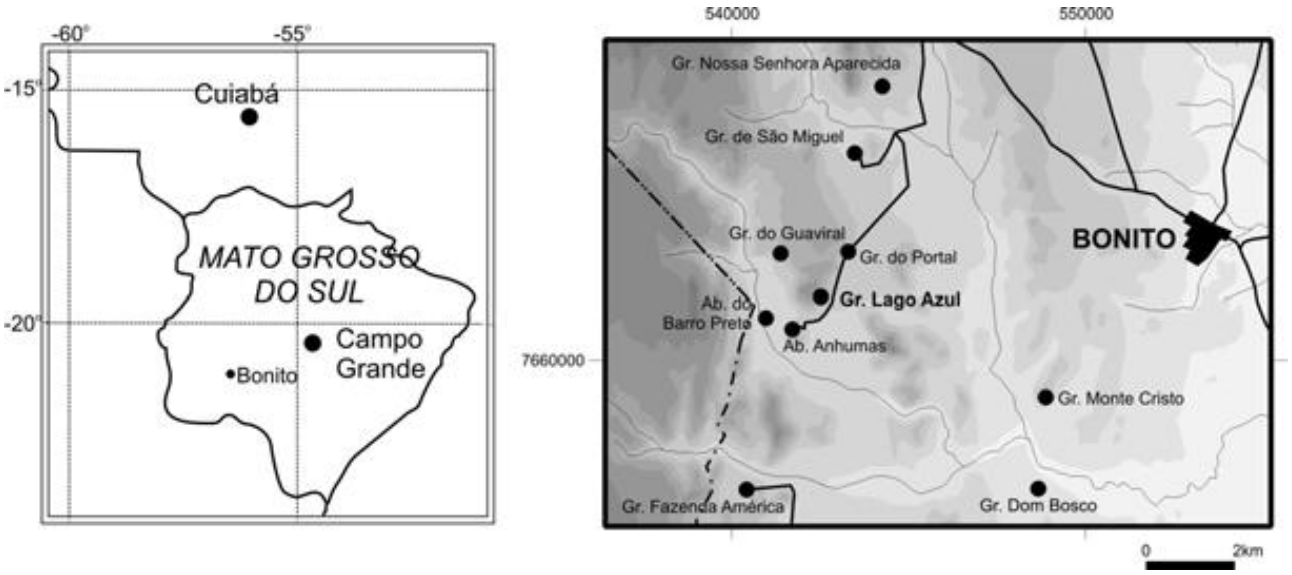

Figura 4: Localização e acesso à Gruta do Lago Azul.
Fonte: Artigo "Gruta do Lago Azul, Bonito, MS – Onde a luz do sol se torna azul" (BOGGIANI, 2008).

A Gruta do Lago Azul é composta de um grande salão principal de 224m NW-SE por 184m NE-SW, e 150 metros de desnível que, em sua maior parte, encontra-se submerso. Na entrada, há o Salão do Lago, com 143m de extensão e 50m de desnível, com piso rico em espeleotemas e teto com estalactites esparsas. A entrada circular tem aproximadamente 40m de diâmetro, permitindo entrada de luz até o lago. Próximo ao nível do lago encontra-se a Salão do Quartinho, com 10m de

comprimento. Tem-se ainda um salão lateral – Salão Superior –, no extremo oeste da caverna, adornado com estalactites, estalagmites e espeleotemas, estes também presentes no Salão dos Corais. (BOGGIANI, 2008.). Os espeleotemas têm crescimento bastante lento, qual seja, cerca de um milímetro por ano. Como revelam as variações climáticas do local, são amparados por proteção legal contra qualquer depredação.

A Gruta do Lago Azul e a Gruta Nossa Senhora foram tombadas pelo Instituto de Patrimônio Histórico e Artístico Nacional – IPHAN, em 13/10/1978, gozando de proteção também do IBAMA. Em 11/6/2001, foi criado pelo governo do estado de Mato Grosso do Sul, na área das cavernas, o Monumento Natural da Gruta do Lago Azul, uma unidade de conservação estadual, porém ainda não demarcada. (BOGGIANI, 2007). Em virtude da falta de estrutura, tão somente a Gruta do Lago Azul está autorizada a receber turistas. A visitação é administrada pela Prefeitura do município de Bonito.

A constituição da Gruta do Lago Azul apresenta um salão principal, com piso inclinado, e um lago subterrâneo ao fundo, com 50 metros de profundidade e outros salões secundários. Contém uma entrada circular com 40 metros de diâmetro, o que possibilita a entrada de luz natural. Em razão da incidência dos raios solares no lago, mais precisamente nos meses de setembro a fevereiro, as águas adquirem uma coloração azul intensa, o que motivou a denominação dada à gruta. (BOGGIANI, 2007).

A visitação à Gruta ocorre com acompanhamento de guias credenciados, em número limitado de turistas, a fim de minimizar os impactos ambientais provocados ao local. Para tanto, foi realizado um estudo da capacidade de carga de visitação turística coordenada pelo professor Paulo Cesar Boggiani no período de 26/6/1999 a 29/09/2000. Houve o monitoramento da temperatura e da umidade da caverna, interna e externamente, sem que fosse necessária a interrupção da visitação turística.

Segundo consta do Estudo de Impacto Ambiental e Relatório de Impacto Ambiental (EIA-RIMA, 2007) da Gruta, o equilíbrio da temperatura depende da quantidade de energia recebida/perdida. A transferência de energia pode se dar: por condução – meio direto (aquecimento do solo); por convecção – pela movimentação do ar no interior da caverna; por radiação – luz solar. Quanto maior a abertura da caverna, maior a troca de energia entre os ambientes subterrâneo e superficial. As cavernas, pelo fluxo relativamente baixo de energia, são consideradas ambientes fechados, ressalvando-se aquelas que apresentam rios subterrâneos ou as que sofrem inundações periódicas.

O monitoramento da temperatura e umidade permite determinar a capacidade de carga real (CCR) por intermédio do Método de Cifuentes. Ainda segundo o EIA-RIMA (2007), os dados confirmaram que, devido à grande dimensão e abertura para o meio externo, a Gruta do Lago Azul não sofre influência da visitação no que se refere à variação da temperatura e umidade. Ressalta-se, porém, que a identificação da influência da visitação foi dificultada pelo fato de ela coincidir com o horário em que naturalmente a atmosfera da caverna sofre aumento da temperatura ocasionado pela variação da temperatura externa. (EIA-RIMA, 2007).

O caminhamento percorrido no interior da Gruta foi construído em 1984, com blocos de calcário rejuntados com argamassa e não há corrimão de apoio. A aparência rudimentar é proposital para não provocar impacto na paisagem interna da caverna. Os visitantes, acompanhados de um guia, descem em grupos de quinze. A visitação é feita no período diurno e leva em torno de uma hora e meia. O percurso é o mesmo tanto na subida como na descida. Permanecem simultaneamente no interior da caverna no máximo três grupos que fazem quatro paradas durante o período da descida, quando então são fornecidas informações sobre essa atração turística. A última parada fica a dez metros acima do nível do lago, não sendo permitido chegar até ele.

Segundo o EIA-RIMA (2007) da Gruta do Lago Azul (em fase de análise pelo CECAVI-IBAMA), a Lei Municipal 689/1995 tornou obrigatória a visitação dos passeios somente com acompanhamento do guia de turismo, sendo até hoje as grutas de Bonito as únicas no Brasil com este nível de exigência.

O acesso à gruta é feito percorrendo uma mata que, segundo o EIA-RIMA (2007), pode ser utilizada como fonte de informação nas visitações turísticas. Já na área sobre a gruta, a diversidade e a densidade foram muito baixas quando comparadas com a área de acesso.

Constatou-se que o local já sofreu ação do fogo com destruição da vegetação original. Possivelmente o fogo e outras atividades anteriormente desenvolvidas na área causaram o empobrecimento da vegetação e a diminuição da cobertura vegetal. Daí a necessidade de recuperação da vegetação pela possibilidade de degradação irreversível no interior da caverna, uma vez que a quantidade de vegetação pode influenciar na

infiltração de água para o interior. Também importante seria o aumento das áreas protegidas no entorno da gruta para diminuir o efeito de borda causado por atividades agrícolas.

O estudo do professor Boggiani (2008) ressalta a importância de um caminhamento fixo para a visitação de cavernas, favorecendo o cálculo de sua capacidade de carga, a proteção contra o pisoteamento de certos espaços da fauna, bem como evitam-se locais com risco de contágio de doenças. Foi sugerido um novo caminho e também a criação de um museu para possibilitar ao visitante a compreensão de toda a evolução da "paisagem cultural" da caverna da Serra da Bodoquena.

3. METODOLOGIA

A imagem fotográfica da Gruta do Lago Azul é utilizada como atrativo turístico do município de Bonito/MS. Por ter sido uma das primeiras formas de divulgação, hoje pode ser usada como recurso para avaliar a melhoria decorrente da regulamentação do processo de visitação da Gruta e as mudanças de consciência ambiental. Representa o marco inicial do turismo na região da Serra de Bodoquena.

Para a realização do presente artigo, foram pesquisados outros artigos científicos sobre a Gruta do Lago Azul, o EIA-RIMA (2007) do Monumento Natural da Gruta do Lago Azul Bonito/MS, artigos sobre turismo na região de Bonito e estudos sobre o uso de fotografia. O registro fotográfico, pela sua veracidade de comunicação, foi escolhido como a melhor forma para documentar a evolução de cuidados ambientais naquele ponto turístico.

Na visitação à Gruta do Lago Azul, realizada no dia 25 de junho de 2010, dentro da Prática de Campo foram tiradas pelos alunos algumas fotos digitais que possibilitaram comparações com registros fotográficos tradicionais, constantes de acervo pessoal de uma das pesquisadoras, datado de julho de 1989.

Na primeira etapa do trabalho, para o embasamento teórico, foram consultados artigos científicos essenciais à compreensão do tema, haja vista que o registro fotográfico da imagem não se explica por si só, assim, a contextualização se faz necessária. Um estudo em fontes primárias e secundárias sobre ecoturismo, preservação ambiental, uso de imagens fotográficas e história da região da Serra de Bodoquena–MS foi realizado para melhor análise das fotografias – segunda etapa do trabalho. Em um terceiro momento, foi idealizada e realizada a construção do artigo com vistas a revelar a importância desse recurso em trabalhos científicos.

A proposta de apresentar imagens fotográficas em dois espaços temporais para análise interpretativa permitiu a percepção na mudança da paisagem decorrente da observância à legislação ambiental.

As fotos do ano de 1989 foram tiradas com uma câmera Yashica analógica, de uso doméstico (modelo da época) e que utilizava filme Kodak. Na atualidade as fotografias foram tiradas em câmeras digitais, apresentando notável qualidade de imagem. Foram também coletadas imagens produzidas em artigos científicos e *folders* turísticos.

4. RESULTADOS E DISCUSSÃO

As fotos escolhidas e transformadas em objeto de análise se referem a dois momentos, a saber, 1989 e 2010, os quais registram a visitação na Gruta do Lago Azul. No decorrer desse período, inúmeras discussões foram feitas acerca da preservação da natureza e da necessidade da educação ambiental para que a prática do turismo ecológico não contribua para a degradação do meio ambiente.

O acesso à Gruta há vinte anos se dava de forma bem mais agressiva ao meio ambiente. Era permitido aos turistas chegarem com seus veículos até a grade de proteção da entrada. Atualmente foi construída uma base de apoio – recepção – em uma distância planejada para possibilitar a recuperação e proteção da biodiversidade do entorno da gruta, como já mencionado. Como mostram as figuras 5, 6, 7 e 8 há necessidade de percorrer uma trilha dentro da mata até a grade de proteção. Na recepção são fornecidos os equipamentos de proteção e orientações aos visitadores, como apresenta a sequência de figuras:

Figura 5: caminhamento de acesso entre a recepção e a gruta.Fonte: BUCKER, Marina (2010).

Figura 6: caminhamento de acesso entre a recepção e a gruta. Fonte: BUCKER, Marina (2010).

Figura 7: grade de proteção ao acesso à gruta. Fonte: BUCKER, Marina (2010).

Figura 8: entrada da Gruta do Lago Azul. Fonte: BUCKER, Marina (2010).

O caminhamento nos salões da Gruta também sofreu mudanças significativas. As pessoas que aparecem nas imagens do ano de 1989, adultos e crianças são objetos de comparação e servem de parâmetro para análise quanto às modificações ocorridas na regulamentação da visitação com vistas à preservação do patrimônio (figura 9).

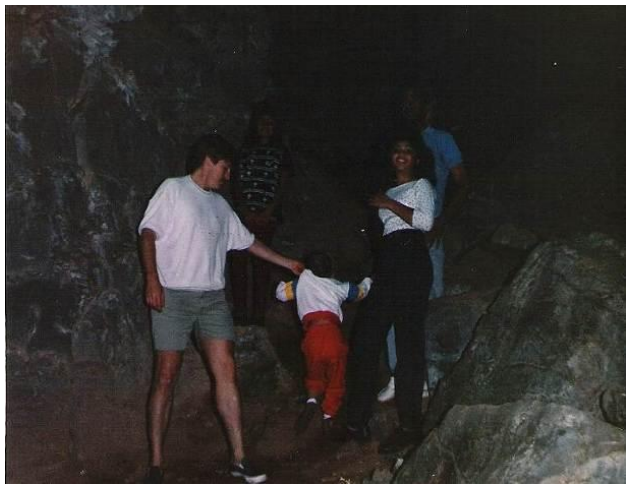

Figura 9: presença de uma criança menor de 05 anos. Fonte: BELLÉ, Fátima (1989).

Nesse acervo, observa-se que, no ano de 1989, o acesso de visitadores se dava sem nenhum equipamento de segurança, nem calçados apropriados. Era permitido o acesso de crianças sem qualquer restrição etária. Na atualidade, não se permite a entrada de menores de 05 anos na Gruta do Lago Azul.

O turismo na cidade de Bonito intensificou-se nos anos de 1990 e tornou-se um dos principais destinos do estado de Mato Grosso do Sul. Dessa maneira, a preocupação com a alteração da paisagem pela ação do homem fez com que o número de visitações, a limitação da quantidade de pessoas por grupo e a presença obrigatória de guia turístico para orientações e esclarecimentos fossem obrigatórias, evitando acidentes tais como da figura 10 a seguir, que registra uma estalagmite quebrada.

Figura 10: imagem da estalagmite quebrada na Gruta do lago Azul. Fonte: BELLÉ, Fátima (2010).

Nesse sentido, a educação ambiental se faz necessária no intuito de valorizar as áreas naturais da região, bem como para evidenciar à população a importância de preservar o meio ambiente, partindo do pressuposto de que os recursos naturais são

esgotáveis. Dentro desse processo, a documentação, por meio do registro fotográfico, da agressão à natureza provocada pela ação antrópica é um instrumento que pode ser usado de forma a sensibilizar a população com vistas à sustentabilidade do planeta. Segundo Sabino e Andrade (2003):

> *A atividade turística, quando mal conduzida, pode afetar negativamente os componentes sensíveis do ambiente (e.g., Bratton, 1985; Garber & Burger, 1995; Cole, 1997). Para a prática correta do ecoturismo, devem ser estabelecidos protocolos de visitação que visam minimizar o conflito entre recreação e conservação da natureza (Cole, 1993), preparando o visitante para compreender e respeitar as características dos ambientes* (Niefer & Silva, 1999; Mitraud, 2001; Sabino & Andrade, 2002).

O acesso ao Lago Azul foi modificado, como se observa nos registros fotográficos. A descida, em 1989, se dava pela lateral direita e era permitido chegar até o lago (figura 11). Na atualidade, a descida é feita pela esquerda (figura 12) e os visitantes são proibidos de atingir as proximidades do lago.

Figura 11: caminhamento de acesso ao lago da gruta. Fonte: BELLÉ, Fátima (1989).

Ao retomar a imagem de 21 anos atrás (figura 11), percebe-se que não havia a presença de grupos organizados com controle de visitação. Também não se observa a presença do guia no grupo e nem a utilização de equipamentos de segurança, como capacetes. A figura 12, registro feito durante a aula de prática de campo, permite observar os alunos do curso usam capacete branco, estão acompanhados do guia, fazendo a visitação dentro dos padrões de segurança estabelecidos.

Figura 12: caminhamento de acesso ao lago da gruta. Fonte: PAIVA, Izabela (2010).

Ao retomar a imagem de 21 anos atrás (figura 11), percebe-se que não havia a presença de grupos organizados com controle de visitação. Também não se observa a presença do guia no grupo e nem a utilização de equipamentos de segurança, como capacetes. A figura 12, registro feito durante a aula de prática de campo, permite observar os alunos do curso usam capacete branco, estão acompanhados do guia, fazendo a visitação dentro dos padrões de segurança estabelecidos.

Considerando que a fotografia pode representar a realidade presa na imagem, como objeto de estudo pode se transformar em instrumento capaz de, mediante as informações percebidas, possibilitar a análise, comparação e avaliação das paisagens. Os registros abaixo nos permitem comparar a alteração na vegetação da entrada da gruta. Todos os registros foram feitos na estação do inverno – mês de julho – sendo que as fotos, figuras 13, 14 e 15 são de julho de 1989 e as figuras 16 e 17 são registros do ano de 2010.

Os registros fotográficos de paisagem, em um primeiro momento, prendem a atenção pela beleza cênica neles refletida. Como se observa, algumas medidas de proteção foram tomadas para evitar que o pisoteamento destruísse a vegetação. Por isso, reforçamos a necessidade de um conhecimento pré-existente da realidade representada na imagem, elemento indispensável para análise interpretativa do que se vê. A comparação entre as imagens permite constatar que a prática do turismo, dentro de um aparato legal – normas e legislação – somado à educação ambiental, protege a natureza.

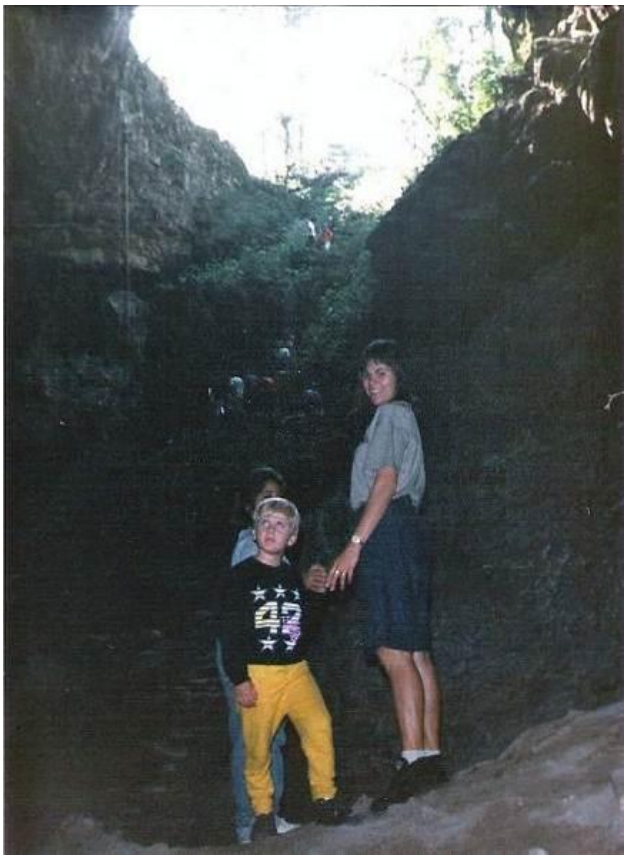

Figura 13: foto da entrada da Gruta.
Fonte: BELLE, Fátima (1989)

Figura 14: foto do caminhamento dentro da gruta.
Fonte: BELLE, Fátima (1989)

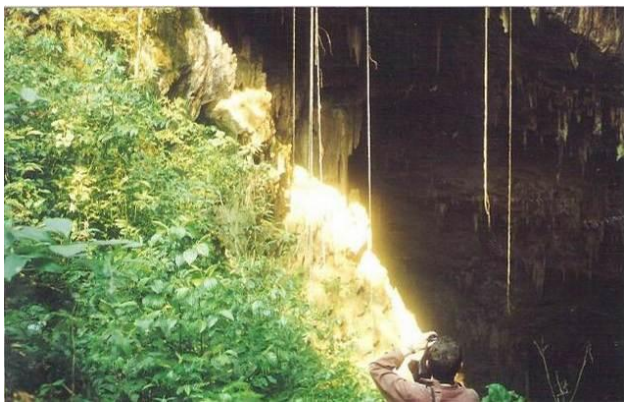

Figura 15: imagem lateral da entrada da gruta.
Fonte: BELLINCANTA, Joel (1989).

Figura 16: imagem da entrada da gruta.
Fonte: GOMES, Suellem (2010).

Figura 17: Imagem da lateral direita da Gruta do Lago Azul. Fonte: GOMES, Suellem (2010).

5. CONSIDERAÇÕES FINAIS

O uso da fotografia, como material de resgate, suporte de análise, documento ou como objeto de estudos, permitiu constatar as transformações ocorridas na visitação da Gruta do Lago Azul, principalmente com relação ao respeito e preservação do meio ambiente. A proposta contributiva deste artigo foi buscar revelar que o registro fotográfico é um recurso excelente como metodologia adequada de pesquisa e análise comparativa das transformações ocorridas na paisagem num determinado espaço de tempo.

Os resultados demonstraram que as imagens não se prestam tão somente à contemplação, mas também para despertar no observador a consciência

ambiental, envolvimento, preocupação com a degradação, enfim, desejo de preservação.

Constatou-se que a utilização de imagens fotográficas é mais uma ferramenta de resgate, suporte de análise, documento, ou ainda, como objeto de estudo, pretende explicar ou demonstrar as alterações sofridas na natureza, quando o turismo ecológico não respeita o meio ambiente. Nesse sentido, a intenção desse artigo foi demonstrar que, por intermédio do uso de imagens fotográficas, um recurso bastante significativo e pouco explorado em educação ambiental, pode se desenvolver um trabalho de consciência ambiental. Mediante as imagens fotográficas é possível constatar que o turismo ecológico deve ser realizado sem, contudo, deixar de respeitar a natureza.

A análise de imagens fotográficas da Gruta do Lago Azul possibilitou verificar que, com normas de segurança e com estudos científicos para avaliar a capacidade de carga da gruta, torna-se possível a prática do turismo e o trabalho para o desenvolvimento de uma consciência ambiental.

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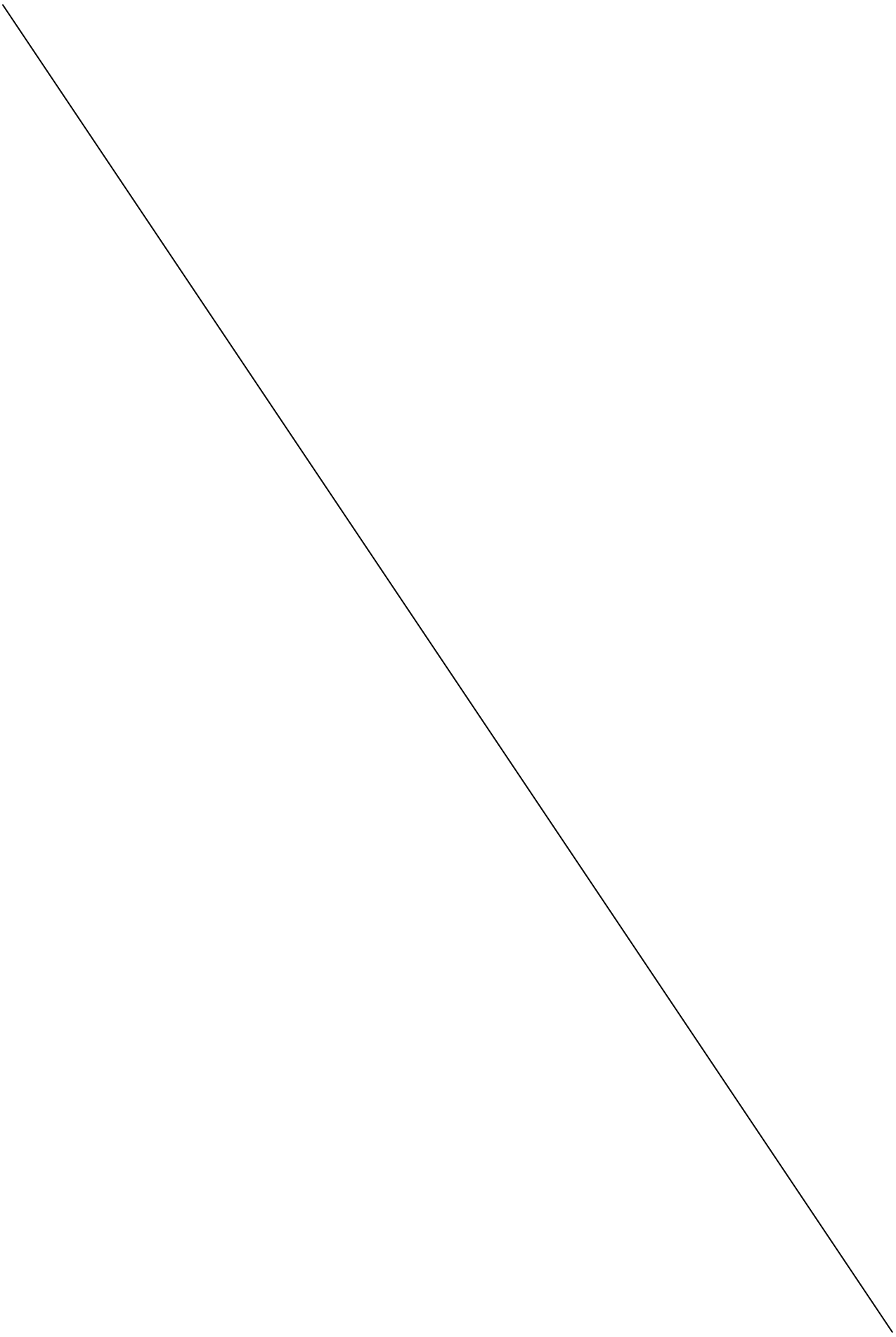
Fluxo editorial:
Recebido em: 10.02.2011
Corrigido em: 23.05.2011
Aprovado em: 09.06.2011

TOURISM AND KARST AREAS
(*formally*/formalmente: Pesquisas em Turismo e Paisagens Cársticas)
Brazilian Society of Speleology / Sociedade Brasileira de Espeleologia (SBE)
www.cavernas.org.br/turismo.asp



TURISMO E CONSERVAÇÃO DE TUFAS ATIVAS DA SERRA DA BODOQUENA, MATO GROSSO DO SUL

TOURISM AND CONSERVATION OF ACTIVE TUFAS OF THE BODOQUENA PLATEAU, MATO GROSSO DO SUL STATE

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Resumo

A atividade turística da Serra da Bodoquena (Estado de Mato Grosso do Sul) é caracterizada por empreendimentos turísticos privados em suas nascentes e ao longo dos principais rios, como os rios Formoso e Mimoso, além de suas cavernas, com destaque para a Gruta do Lago Azul e o Abismo Anhumas. Os rios da Serra da Bodoquena são de grande valor paisagístico, devido a limpidez das águas e pelo contínuo crescimento de tufas calcárias (tufas ativas), que são sedimentos e rochas carbonáticas que se desenvolvem pela precipitação de carbonato de cálcio associada à atividade biológica, motivo pelo qual dependem da qualidade das águas. No presente trabalho, é feita uma análise da atividade turística nos atrativos com tufas e seu grau de conservação frente aos preceitos do geoturismo, levando-se em consideração a proposição de um geoparque na região, nos moldes propostos pela UNESCO.

Palavras-Chave: tufa, Serra da Bodoquena, Mato Grosso do Sul, turismo, geoturismo, geoparque.

Abstract

This paper presents a panorama of touristic activities in the Bodoquena Plateau (State of Mato Grosso do Sul). The attractions involves springs and both the Formoso and Mimoso rivers, as well as caves, especially those of Lago Azul and the Anhumas pit. The great beauty of the rivers of the area is due largely to the quality of the water, which is clear and blue, and the widespread active limestone tufas formed by the constant accumulation of precipitated calcium carbonate, in association with biological activity. An analysis is made here of tourist activity in sites where this tufa is found, for the creation of a geopark in the region candidate to a Global Geopark Network assisted by UNESCO.

Key-Words: *Tufa; Bodoquena Plateau; Mato Grosso do Sul State; Tourism; Geotourism; Geopark.*

Introdução

A Serra da Bodoquena constitui feição de relevo de destaque no sudoeste do Estado de Mato Grosso do Sul, com direção Norte-Sul, e às margens da planície do Pantanal (figura1). Trata-se de um planalto escarpado a oeste, no limite com o Pantanal do Nabilique, com suas drenagens correndo para leste, no sentido do Rio Miranda, cortando maciço calcário contínuo, com aproximadamente 400 km de comprimento e 30 a 40 km de largura.

A atividade turística na Serra da Bodoquena concentra-se ainda na região de Bonito, que recebeu em 2010 o total de 276 164 visitas em seus atrativos, segundo dados da Prefeitura Municipal de Bonito, e tem, como principal atrativo, os rios de extrema transparência e grande valor cênico no contexto de paisagem cárstica, onde se realiza atividades de mergulho, flutuação, rafting em trechos dos rios com cachoeiras e represas de tufas ativas.

O carste da Serra da Bodoquena é caracterizado por salões e condutos submersos e nascentes e rios com ampla formação de tufas calcárias que continuam em crescimento, na forma de cachoeiras e represas naturais ao longo das drenagens (figura 2).

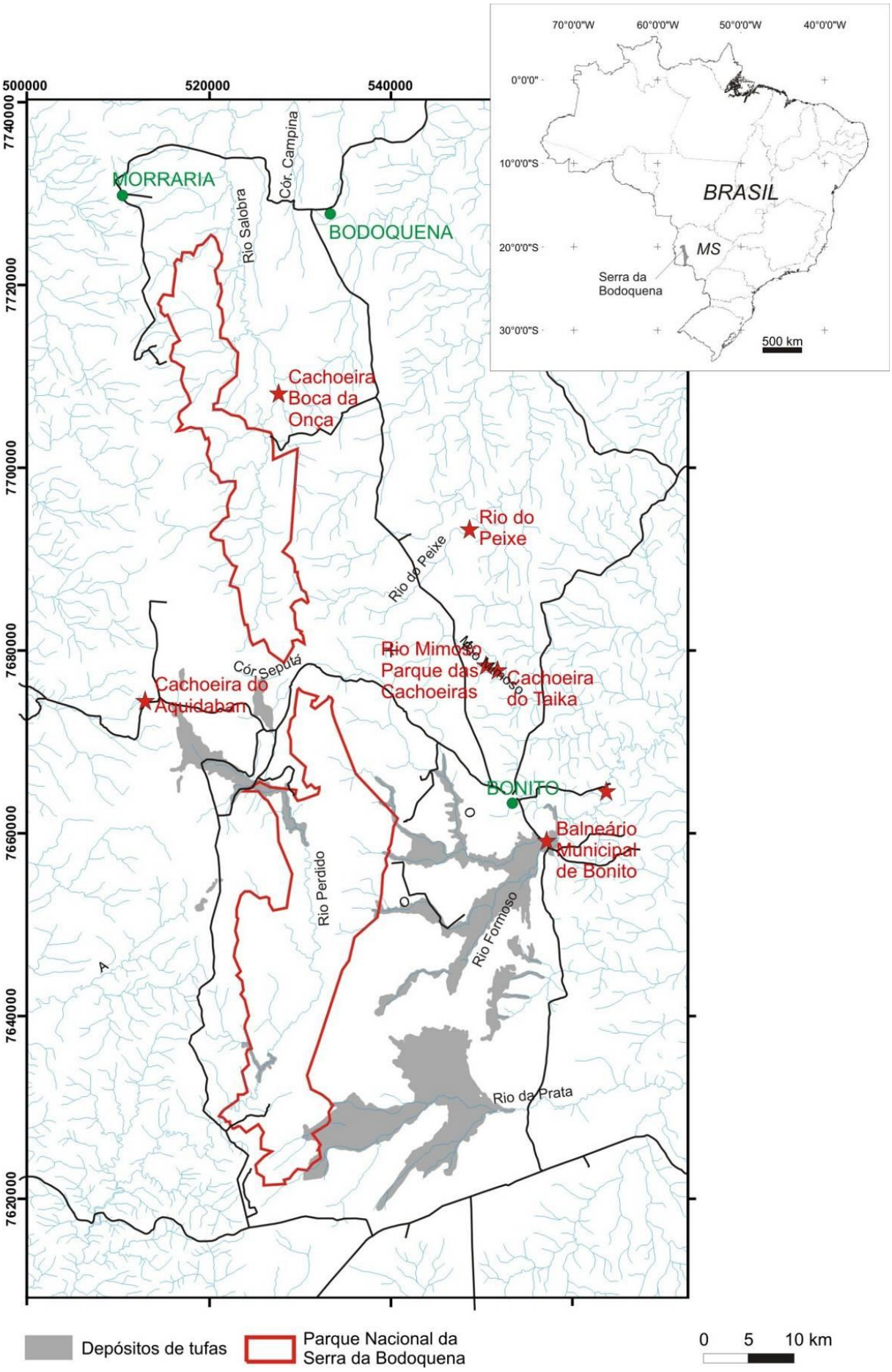

Figura 1 – Localização da Serra da Bodoquena e das principais localidades com atividades turísticas em tufas.

Figura 2 – Cachoeira de tufa ativa no Rio Formoso, Serra da Bodoquena.

As tufas são depósitos carbonáticos fluviais frágeis e facilmente erodidos e quebrados. Por se encontrarem em formação, são dependentes das condições físico-químicas e biológicas de suas águas, cuja descaracterização pode causar danos irreversíveis às tufas e consequente comprometimento da atividade turística.

No presente trabalho é apresentado um panorama da atividade turística em rios com tufas ativas e discutido o enquadramento dessa atividade entre os princípios do geoturismo, modalidade do ecoturismo que tem o uso do Patrimônio Geológico como benefício da comunidade local. Essa discussão se faz necessária, assim como proposta de conservação desse patrimônio, diante do processo de criação do Geoparque Bodoquena – Pantanal.

Atividades turísticas em tufas na Serra da Bodoquena (Mato Grosso do Sul)

O turismo em Bonito teve origem incipiente no início da década de 1980 e tinha, como principal atrativo, a Gruta do Lago Azul, que chama atenção devido ao lago subterrâneo que adquire a cor azul intensa, com a incidência dos raios solares. De forma secundária, era visitada também a Gruta Nossa Sra. Aparecida, ambas de forma precária e sem nenhuma infra-estrutura. Juntamente com as grutas, outro local visitado era a Ilha do Padre, na porção média do Rio Formoso, único naquela época com uma precária estrutura para receber turistas, restrito a visitantes da própria região.

A primeira agência de turismo, criada por volta de 1990, de nome Happakany Tour Viagens e Turismo, tinha por objetivo organizar as descidas de bote inflável através das barragens de tufas ao longo do Rio Formoso, atividade iniciada pelo mesmo grupo que já realizava, de forma pioneira no Brasil, as atividades de *rafting* no Rio Paraibuna no Estado do Rio de Janeiro. Dava-se início, assim, à estruturação do turismo em Bonito, o qual teve como importante marco o primeiro curso de formação de guias de turismo, realizado entre dezembro de 1992 e abril de 1993 e depois com a instituição do Conselho Municipal de Turismo de Bonito (COMTUR – Bonito) em 1995 (Barbosa e Zamboni, 2000; Boggiani 2001).

Apesar da presença de grutas com valor cênico excepcional, como a Gruta do Lago Azul e o Abismo Anhumas, pode-se afirmar que são os rios e nascentes, com águas extremamente límpidas, associados à diversidade e arranjo da biota, que proporcionam à região o pleno desenvolvimento do turismo de natureza (Boggiani & Clemente 1999, Oliveira 2009).

Os balneários e atrativos com cachoeiras de tufas são os mais procurados e com maior número de visitação. São também os visitados repetidamente, devido à balneabilidade, principalmente por parte do turista do próprio Estado de Mato Grosso do Sul, ainda mais por ser uma região sem acesso direto a praias.

Os empreendimentos turísticos concentram-se ainda no Município de Bonito, com capacidade hoteleira para por volta de 5.000 hóspedes. Nesse município, no percurso do Rio Formoso, existem quatro empreendimentos com licença ambiental, na forma de balneário (Balneário Municipal Rio Formoso, Balneário do Sol, Balneário do Gordo e Praia da Figueira), dois com atividade de flutuação e mergulho livre (Parque Ecológico Rio Formoso e Bonito Aventura) e três operadoras de mergulho autônomo que oferecem atividades de mergulho em diferentes trechos do rio.

A atividade de maior fluxo turístico tem sido ainda a de *rafting*, oferecida por sete operadoras com uso de botes infláveis (com capacidade para até 10 pessoas cada) e duas que com uso de boias individuais (atividade conhecida como "boia-cross").

O local de embarque nos botes no Rio Formoso depende da operadora, já o desembarque é o mesmo para todas, efetuado na localidade conhecida como Ilha do Padre, onde foi criada a unidade de conservação estadual Monumento Natural do Rio Formoso (Decreto Estadual MS 11.453-03, de 23 de outubro de 2003), porém ainda não estruturada como tal.

O percurso realizado com os botes infláveis ao longo do Rio Formosos é de aproximadamente 3 km, com transposição de cinco barragens naturais.

Além da descida de bote, outro atrativo muito procurado é o Balneário Municipal Rio Formoso que contou, em 2010, com 12.617 visitantes. Nessa contagem, não foi contabilizado o número de visitantes residentes em Bonito, para os quais não é cobrado ingresso e, por isso, sem controle numérico de visitas.

Tabela 1 – Número de visitantes em atrativos turísticos com tufas calcárias em Bonito (Mato Grosso do Sul) em 2010.

Atividades Turísticas em Tufas no Rio Formoso, em 2010	**Total de Visitas**
Flutuação e Mergulho Livre (Aquário Natural, Bonito Aventura, Parque Ecológico Rio Formoso, Bike e Cavalgada no Rio Sucuri)	16.714
Balneários (Balneário Municipal Rio Formoso, Praia da Figueira, Balneário do Sol, Ilha do Padre, Balneário Ilha Bonita)	35.954
Boia Cross (Boia Cross Cabanas e Boia Cross Eco Adventure)	10.421
Passeios de Bote (Iberê, Bonito Scuba, Karajá, Natura, MM Expedições, Hotel Fazenda Cachoeira, Bonitur e Keda d'Água)	41.608
Mergulhos Autonomos (Caimãn, Bonito Scuba e Dive Bonito)	994
Total de visitas nos atrativos com tufas	105.691
Total de visitas em Bonito	276 164

Fonte: Dados da Secretaria Municipal de Desenvolvimento Agrário, da Produção, da Indústria, do Comércio e do Turismo de Bonito (MS).

Além do Rio Formoso, também em Bonito o Rio Mimoso tem empreendimentos turísticos de grande procura turística. Nesse rio, o turismo teve início na propriedade do Sr. Taika, onde se encontra a Cachoeira do Taika, uma das maiores da região. Atualmente os turistas percorrem duas trilhas, uma de cada lado do rio, nos atrativos conhecidos como Parque das Cachoeiras (margem direita) e Estância Mimosa Ecoturismo (margem esquerda) – figura 3. Onde, segundo a Secretaria Municipal de Turismo, Indústria e Comércio de Bonito/MS, em 2010 esses dois atrativos turísticos receberam 22.684 turistas. Mais ao Norte, o Rio do Peixe, com as mesmas características de tufas, também tem atrativo turístico, na Fazenda Água Viva, chamado "Cachoeiras do Rio do Peixe", estruturado no início da década de 1990, o qual contou, em 2010, com 11.033 turistas.

Ainda no Município de Bonito, no seu extremo oeste, existe uma grande concentração de tufas na única drenagem que corre para oeste, através da escarpa da Serra da Bodoquena, no sentido do Pantanal. Essa concentração ocorre no Rio Aquidaban, que possui mais de 11 cachoeiras, sendo a maior com aproximadamente 120 m de altura (figura 4), onde já se realizou atividades turísticas no período entre 1995 a 2003, mas atualmente a propriedade rural dedica-se exclusivamente a pecuária.

Figura 3 – Conjunto de represas de tufas no Rio Mimoso, Estância Mimosa.

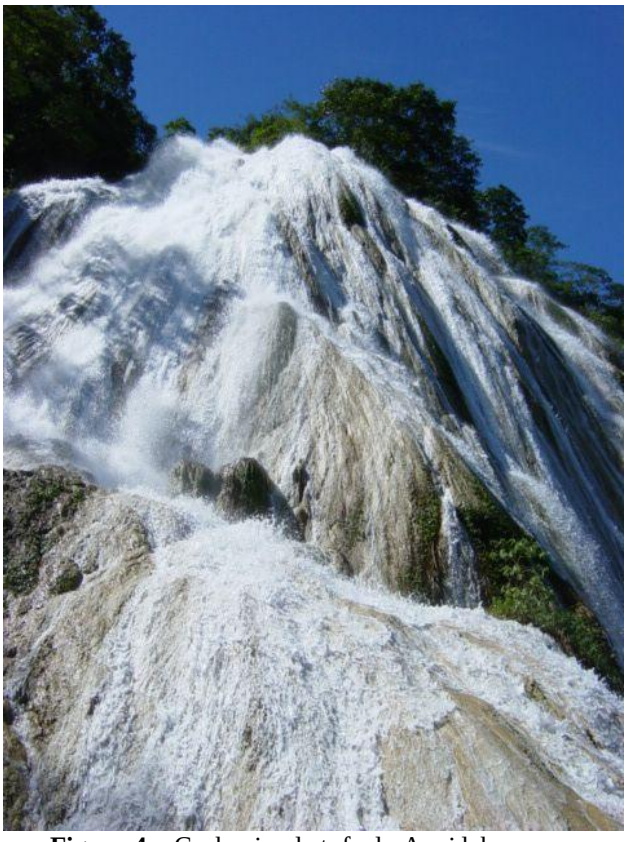

Figura 4 – Cachoeira de tufa do Aquidaban, com aproximadamente 120 m de altura, em rio de mesmo nome, na borda oeste da Serra da Bodoquena.

Fora do Município de Bonito, existe ao Norte, no Município de Bodoquena, o atrativo Boca da Onça Ecotur, que possui a maior cachoeira do Mato

Grosso do Sul, com 156 m de altura, em escarpa originada pelo entalhamento do Rio Salobra, na forma de garganta no maciço calcário central da Serra da Bodoquena, onde se desenvolve a prática de rapel a partir de plataforma artificial, montada para que a descida com corda seja realizada em vão livre, sem contato direto com as tufas, que recobrem os paredões.

Ainda em Bodoquena, existe o Rio Betione, com potencial turístico, porém com empreendimentos que se encontram atualmente fechados, inclusive um balneário municipal, além de drenagens menores, como o Córrego Campina, com inúmeras barragens e cachoeiras de tufas, porém com alturas inferiores a um metro. Ao Sul, no Município de Jardim, tem-se o Balneário Municipal de Jardim no Rio da Prata, outro rio com grande potencial turístico que conta com o atrativo turístico Recanto Ecológico Rio da Prata.

Somados os números de visitas dos atrativos relacionados chega-se ao total de 170 mil visitas por ano. Com base apenas na observação visual, pode-se dizer que a atividade, até o momento, não tem causado danos significativos às tufas, o que é resultado dos cuidados na infra-estrutura de visitação e orientação por parte dos guias que acompanham a visitação, principalmente para se evitar o pisoteio.

Se considerarmos a área de distribuição das tufas e as concentrações, principalmente do Rio Formoso e seu afluente Formosinho, e Rios Mimoso, Perdido e Salobra, Aquidaban e Betione, pode-se afirmar que as Tufas da Serra da Bodoquena constituem um dos maiores conjuntos de tufas das Américas e sem dúvida se encontra entre as maiores do mundo, perdendo apenas para o de Plitvice na Croácia e o de Jiuzhaigou, na China, ambos declarados Patrimônio da Humanidade pela UNESCO.

Demais ocorrências de tufas no mundo ocorrem na forma de depósitos isolados e relativamente menores, como as cachoeiras de tufas de Gordale Scar (Norte de Yorkshire – Inglaterra), ou barragens que não ultrapassam um metro de altura ao longo de pequenas drenagens (Ford & Pedley 1996). Levantamento realizado por Pentecost (1995), na Europa demonstra a existência de 320 depósitos carbonáticos, entre esses 227 de tufas e 93 de águas termais sendo, que entre as 227 tufas, apenas 156 ativas. Entre os depósitos termais, destaca-se o do Yellowstone National Park (EUA), considerado uma entre as maiores ocorrências de travertinos ativos do mundo e também os depósitos de travertino da Itália, na região de Roma e da Toscana, de importância histórica devido a ampla utilização em construções da época do Império Romano.

Outra área turística em fontes termais com precipitação carbonática (travertinos) são os depósitos de Pamukkale, na Turquia (Herrero & Escavy. 2010).

No Brasil existem outras ocorrências de tufas ativas, ainda com relativamente baixa atividade turística, em rios da Serra das Araras (Estado de Mato Grosso) e no Estado de São Paulo, na Serra do André Lopes (Sallun Filho et al. 2011), no interior do Parque Estadual Caverna do Diabo e APA Quilombos do Médio Ribeira, criados em 2008 com o desmembramento do Parque Estadual de Jacupiranga.

Evolução das Tufas da Serra da Bodoquena e sua conservação

Não existe ainda nenhum projeto constante e de longo prazo de monitoramento do grau de preservação das Tufas da Serra da Bodoquena, além da observação visual, a qual possibilita constatar que as tufas, no geral, encontram-se em bom estado de conservação, com pontuais locais de degradação física apenas.

Estudos específicos foram realizados para se verificar o impacto negativo da descida dos botes infláveis sobre as represas de tufas do rio Formoso o que, aparentemente, não tem causado degradação.

A maior ameaça à conservação das tufas é o intenso turvamento das águas em função dos desmatamentos e falta de manejo adequado dos solos para as atividades de pecuária e agricultura. No passado, outra ameaça era o lançamento de esgoto da cidade de Bonito no rio Formoso. Havia uma pequena estação de tratamento, mas essa tratava apenas 10% das residências. Atualmente, todas as residências e hotéis de Bonito têm recolhimento e tratamento total de seus efluentes.

Não foi encontrado, na bibliografia disponível, relação dos principais parâmetros das águas que poderiam ser selecionados para estabelecimento de monitoramentos ambientais com o objetivo de preservação das tufas. Horvatinčič et al. (2006), em estudo sobre a poluição das águas e sedimentos dos lagos de Plitvice (Croácia), cita a conclusão do trabalho de Srdoč et al. (1985) que, ao medirem o carbono orgânico dissolvido na água desses lagos, constaram que o aumento do C orgânico pode alterar ou mesmo interromper o processo de precipitação de tufa.

O estudo de Horvatinčič et al. (2006) teve como objetivo principal investigar até que ponto o aumento da eutrofização, na forma de intenso crescimento vegetal em alguns lagos do Plitvice Lakes National Park, seria natural ou antrópico, através da análise de elementos traços, nutrientes e carbono orgânico dissolvido das águas e sedimentos e concluíram, em função de não constarem nenhum valor anômalo de elementos traços, que o fenômeno seria natural. A análise das águas foi realizada sazonalmente durante dois anos em 15 pontos, com medição *in situ* da temperatura, pH, condutividade, oxigênio dissolvidos e coleta de amostras para análise de elementos traços (B, Al, Cr, Mn, Fe, Ni, Cu, Zn, Cd, Ba, Pb, P) e ânions (SO_4^{2-}, Cl^-, F^-, $NO3^-$, NO_2^-, HPO_4^{2-}), além da análise de testemunhos de sedimentos (40 cm de profundidade) de cinco localidades diferentes.

Na localidade de Jiuzhaigou na China, com cachoeiras de tufa de 70 metros de altura, a poluição das águas já vem sendo apontada como problema, principalmente devido ao fato do regime hidrológico vir a ser um sistema interligado de lagos barrados, o que implica em maior retenção das águas, de forma semelhante ao que ocorre no Rio Formoso em Bonito. Pentecost (2010) aponta que a preocupação maior seria com a poluição por fosfato, oriundo dos fertilizantes, este composto seria ligado ao carbonato e agiria como um inibidor das superfícies de crescimento, por reduzir a nucleação carbonática. O autor cita exemplos de onde isso já vem ocorrendo, como pequenos depósitos no Reino Unido e França.

Estudos desenvolvidos na Europa Mediterrânea, citados por Pedley (2009), têm demonstrado que teria ocorrido maior razão de crescimento de tufas entre 7.300 e 6.800 anos e por volta de 4.600 anos atrás. O segundo pulso de maior crescimento relativo teria ocorrido após a última glaciação e concomitante ao *optimum climático* atlântico, depois do qual teria ocorrido declínio abrupto de desenvolvimento das tufas, marcado por períodos menos úmidos seguidos por mudanças na vegetação, o que também teria acontecido na Espanha por volta de 2.700 anos atrás (Taylor et al. 1998).

No estudo de Pedley (2009) fica demonstrado que existem discrepâncias nas idades dos eventos de maior ou menor formação de tufas na Europa, o que seria reflexo de variações regionais ou de atitudes, às quais o clima encontra-se relacionado, mas é possível traçar um quadro geral, para a Europa Mediterrânea, que do início ao meio do Holoceno (entre 10.000 a 5.000 anos) teria ocorrido um máximo de formação de tufas com o declínio na formação dessas entre 4.000 e 2.000 anos antes do presente. Os períodos de maior formação de tufas seriam coincidentes aos intervalos úmidos e quentes entre as glaciações e também aos com maiores níveis de CO_2 na atmosfera (Griffiths & Pedley 1995).

Muitas podem ser as razões para explicar o constatado declínio na formação das tufas da Europa, mas entre elas a principal pode ter sido a diminuição no volume das descargas dos rios e ai a discussão é se essa diminuição seria natural ou causada pelo Homem (Goudie et al. 1993, Smith et al. 2004). Mudanças na composição química também são consideradas, uma vez que diminuição no conteúdo de carbonato nos solos, desmatamento e consequente diminuição do aporte de nutrientes influenciam no crescimento das tufas.

Apesar de no trabalho de Pedley (2009) não se comprovar a ação antrópica como responsável para o declínio da formação de tufas na Europa, após 2 700 anos antes do presente, é um alerta para demonstrar a fragilidade desses depósitos, e que os mesmo podem ter o desenvolvimento comprometido com modificações nas drenagens.

Para as tufas da Serra da Bodoquena, com base em síntese das datações disponíveis, Sallun Filho et al. (2009) interpreta que as tufas teriam início de formação desde cerca de 6.500 anos cal. antes do presente com decréscimo por volta de 2.700 anos cal. Em tempos mais antigos do que 2.700 anos antes do presente, interpreta-se que provavelmente teria ocorrido um período de maior umidade, quando o crescimento de tufas teria sido maior, dada a grande extensão dos depósitos atuais e antigos frente ao atual quadro de distribuição da drenagem.

Esse aparente declínio na formação das tufas da Serra da Bodoquena, por volta de 2.700 anos atrás, não pode ser associado à interferência humana, uma vez que os registros arqueológicos na Serra da Bodoquena são escassos e não foram encontradas evidências de alteração antrópica da drenagem naquele intervalo de tempo.

Os exemplos acima reforçam a importância da manutenção das condições de drenagem para preservação das tufas, o que poder ser colocado como fator de preocupação a possibilidade de mudanças no volume das águas, ao menos de alguns rios, como o Rio Mimoso. Nesse rio, foi relatado que ao final de 2007 e início de 2008 ele ficou totalmente seco durante meses de estiagem, tendo inclusive levado ao fechamento temporário de atrativos turísticos.

Fora as possibilidades de alteração das Tufas da Serra da Bodoquena por poluição das águas superficiais, tufas na forma de barragem podem ser

quebradas por falta de cuidado no pisoteio, como já ocorreu no Balneário Municipal de Bonito, e vem se discutindo a possibilidade de desgaste das mesmas em função das frequentes descidas de botes (*rafting*), mas no geral, como abordado adiante, os conjuntos de tufas, seja na forma de cachoeiras ou de barragens, encontram-se em bom estado de conservação, além de excepcional conjunto totalmente preservado ao longo do Rio Perdido, no interior do Parque Nacional da Serra da Bodoquena, onde não há ainda nenhum tipo de visitação turística.

Nota-se, face ao exposto, que a maior degradação das tufas encontra-se em função dos desmatamentos, principalmente de matas ciliares (ripárias), porém em áreas específicas e ainda relativamente restritas e que, no geral, não há evidências claras na degradação das tufas.

Proposta de uso geoturístico das tufas da Serra da Bodoquena

O potencial geoturístico das Tufas da Serra da Bodoquena ainda é pouco utilizado e esse deverá ser aprimorado com vistas às intenções de implantação de um geoparque na região.

A definição de geoturismo assemelha-se a de ecoturismo o qual, segundo as Diretrizes para um Política Nacional de Ecoturismo de 1994 é definido como "segmento da atividade turística que utiliza, de forma sustentável, o Patrimônio Natural e Cultural, incentiva sua conservação e busca a formação de uma consciência ambientalista através da interpretação do ambiente, promovendo o bem-estar das populações envolvidas". Essa definição segue a da Sociedade Internacional de Ecoturismo, segundo a qual ecoturismo é a visita responsável a áreas naturais conservando o ambiente e melhorando o bem estar das populações locais.

As definições acima de ecoturismo são semelhantes a de geoturismo o qual, segundo revisão de Brilha (2005), diferem apenas quanto a maior ênfase no uso dos aspectos geológicos dos destinos turísticos, porém são enfáticas quanto ao fim social e o bem estar das comunidades que residem nas localidades turísticas.

Além da visitação e desenvolvimento de projetos educacionais, a atividade geoturística inclui o incentivo à comercialização de artesanato feito geralmente com rochas e minerais da própria localidade. Nesse aspecto, o uso das tufas para esse fim não é recomendado, uma vez que implicaria em procedimentos de depredação. Nas tufas são encontrados com relativa frequência fósseis de plantas na forma de moldes, com reprodução perfeita e delicada principalmente de folhas. De acordo com a legislação brasileira, não é possível comercializar fósseis, por outro lado, a confecção de réplicas possibilita a reprodução desses fósseis, com uso de resina ou gesso, o que pode vir a ser excelente fonte de renda e emprego.

Os atrativos turísticos em tufas calcárias, na Serra da Bodoquena, são em sua grande maioria empreendimentos privados, com exceção apenas dos balneários municipais de Bonito e Jardim. No de Bonito, a população residente tem acesso gratuito, mas os demais atrativos não apresentam nenhuma forma de visitação com objetivo social, como abertura em determinados dias para escolas ou determinadas faixas sociais, como pessoas de baixa renda, terceira idade, portadores de necessidades especiais ou algo do gênero, muito menos projetos educacionais, o que demonstra estarem longe de serem definidos como atividade geoturística, ou mesmo ecoturismo, uma vez que não vêm proporcionando claros benefícios à comunidade local e são raros os projetos educacionais. Não há placas, painéis ou folhetos explicativos sobre a gênese e importância das tufas, apenas alguns Guias de Turismo se preocupam em passar essas informações.

Diante do exposto acima, se há a intenção de implantar um geoparque na região, essa questão terá que ser analisada levando em consideração principalmente o estabelecimento de visitações públicas, ao menos nas concentrações de tufas no Rio Perdido, no interior do Parque Nacional da Serra da Bodoquena, o que deve ser analisado em seu plano de manejo. Outra possibilidade é a reabertura do Balneário Municipal de Bodoquena e de alguns atrativos ao longo do Rio Betione, onde algumas estruturas já existem, na forma de pequenos campings, medidas essas que poderiam ser incrementadas através do geoparque, que tem como um dos objetivos ampliar a atividade turística ao longo da Serra da Bodoquena, ainda muito concentrada em Bonito.

Na parte média a baixa do Rio Salobra, foi analisada a implantação de turismo para benefício do Assentamento Canaã, localizado na sua margem, por parte da ONG ambientalista ECOA, porém o grau de degradação de suas margens, principalmente devido aos desmatamentos, tornou essa parte do rio muito degradada, o que inviabilizava, naquela época, por volta de 1995, o desenvolvimento desse projeto.

Apesar das tufas na forma de cachoeiras e barragens serem as mais procuradas para atividade turística, outro tipo de tufa de ocorrência significativa na Serra da Bodoquena é na forma de grãos finos a médios inconsolidados (pulverulenta)

que constituem depósitos antigos, minerados para uso como corretivos de solo e para ração animal. Esses depósitos, apesar de não terem interesse direto ao turismo, após a lavra originam-se espaços na forma de lagos artificiais, alguns utilizados como balneário, como é o caso do atrativo já citado "Praia da Figueira", que reproduz o ambiente de formação das tufas lacustres, com formação e sedimentação de lama calcária biogênica no fundo, coberta por concentrações de algas do gênero *Chara*.

Determinadas áreas de ocorrência de tufas antigas ricas em fósseis vegetais, em regiões já degradas e distantes das de tufas em formação, poderiam também vir a ser objeto de projetos educacionais com atividade de coleta de fósseis, desde que devidamente orientadas por profissionais capacitados e as coletadas destinadas a coleções paleontológicas ou uso didático, desde que respeitada a legislação a respeito.

Conclusões e Recomendações

Apesar de não existir ainda na Serra da Bodoquena como um todo e nem em Bonito, onde se concentra o turismo em atrativos com tufas, efetivo e contínuo monitoramento das tufas, não há evidências conclusivas de degradação das mesmas, restrita apenas a destruições localizadas, sem comprometimento dos conjuntos maiores de tufas.

Medidas tomadas nos principais atrativos, como construção de plataformas e pontes de madeira, e orientação aos turistas, por parte dos guias, o que efetivamente evita o pisoteio, tem se mostrado eficaz na proteção.

Para o futuro, considera-se necessário estabelecer pontos chaves para monitoramentos das águas fluviais com objetivos específicos para proteção das tufas, uma vez que essas propostas para a região tem priorizado a fauna aquática ou qualidade das águas apenas, e não as tufas calcárias que continuam em processo de formação.

Para o estabelecimento da atividade geoturística na região, durante a implantação do geoparque proposto (Geoparque Bodoquena – Pantanal) será necessário implantar recursos geoturísticos, na forma de placas e folhetos educativos, com informações a respeito da geologia e paleontologia das tufas e explicações sobre o processo de formação, ainda pouco divulgado entre os turistas.

Projetos educacionais, com envolvimento de alunos das escolas da região e de outras localidades, serão também necessários, uma vez que o desconhecimento sobre essas formações é grande ainda entre as populações locais, apesar do contato frequente com as tufas em suas atividades de lazer.

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Fluxo editorial:
Recebido em: 08.02.2011
Aprovado em: 13.07.2011

TOURISM AND KARST AREAS
(*formally*/formalmente: Pesquisas em Turismo e Paisagens Cársticas)
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