

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).

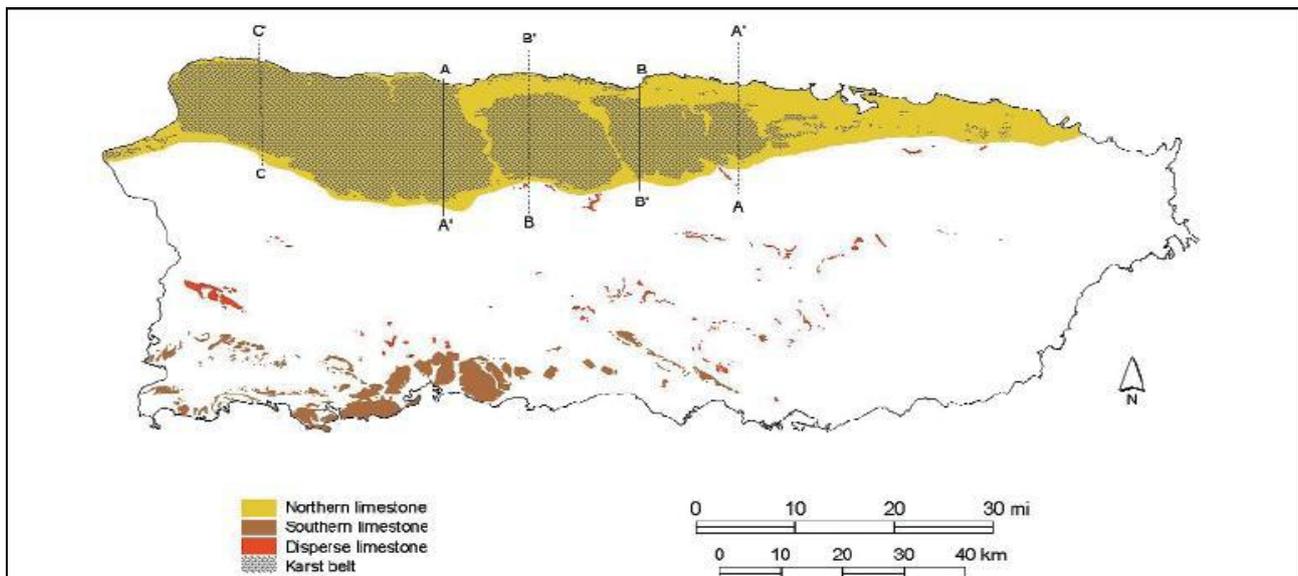


Figure 1: Distribution of karst in Puerto Rico. Source: Monroe (1976) in Lugo et al. (2001)

Six distinct limestone formations are recognized in northern Puerto Rico: in ascending order, the San Sebastián Formation, the Lares Limestone, the Cibão 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). *Mogotes* 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 exsurgences 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.

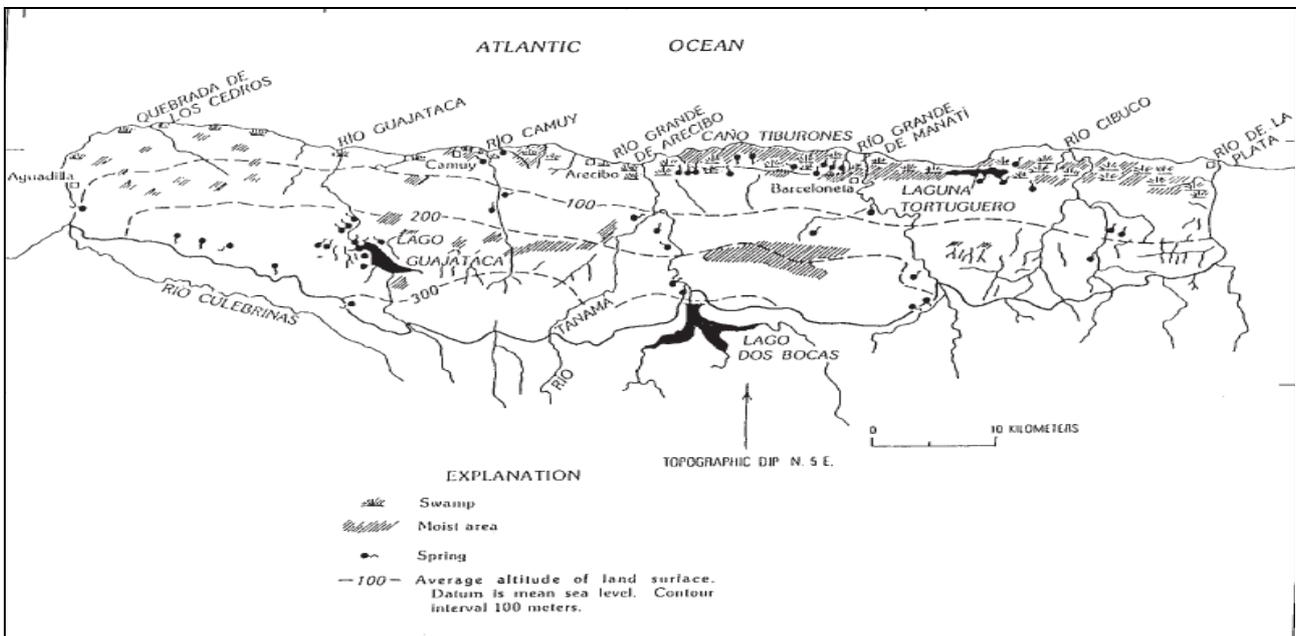


Figure 2: The northern karst belt. Source: Giusti (1976) in Lugo et al. (2001)

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)

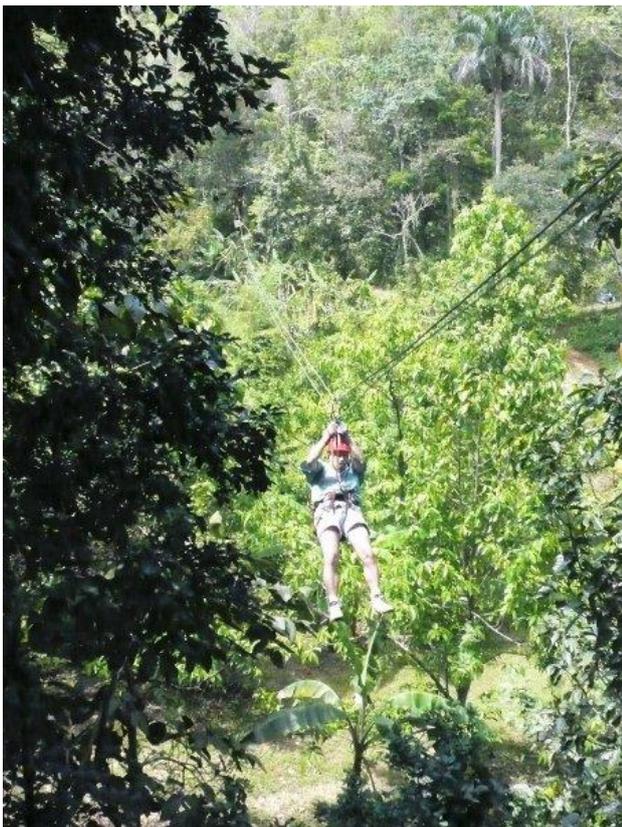


Figure 8: Zip-lining over the Río Tanamá.
Source: Andrea Hall (2009)

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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