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Carrying capacity of hiking trails in Natura 2000 sites: a case study from North Atlantic Islands (Azores, Portugal) *

Capacidade de carga de trilhos pedestres inseridos em sítios da rede Natura 2000: um caso de estudo em ilhas do Atlântico Norte (Açores, Portugal)

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ABSTRACT

Tourism has registered a significant growth in the Azores representing already 15.2% of its regional Gross Domestic Product (GDP). Because an increase in the touristic activity may affect the quality of natural habitats, it is very important to evaluate the size of those impacts in order to take sustainable management measures. In this context, hiking trails are one of the most searched activities in the Azores in natural areas, and as such it is important to understand if they are under human pressure.

This study aimed to determine the Tourism Carrying Capacity (TCC) of hiking trails crossing Special Areas of Conservations (SAC) of Natura 2000, in two of the nine Azorean islands, São Miguel and Flores; it also aimed to evaluate the potential of TCC as a management tool for development and planning of a sustainable tourism, for those areas.

The Real Carrying Capacity (RCC) of the trails was determined by the Cifuentes' method, based on the Physical Carrying Capacity (PCC) modified by correction factors (social, precipitation, light and accessibility), selected according to the tourist activity and the conditions of the study area. The correction factor that negatively influenced the RCC the most, for all the trails, was the social factor followed by light. The minor RCC registered (118 visitors/day) was reported to the trail Lagoa do Fogo-Monte Escuro (São Miguel), while the greatest value (557 visitors/day) was calculated for the trail Ponta Delgada-Fajã Grande (Flores). In both trails correction factors social and light, were also the ones that most influenced the RCC. Even considering that the RCC has not yet been achieved in any of the studied trails, and that the Effective Carrying Capacity (ECC) has not been evaluated, it is relevant to keep monitoring those factors, since they are linked to the quality of the visit.

Even though with limitations, including the underlying method and its implementation, it is expected that the results of this study may contribute to improving the sustainable use of hiking trails in natural areas of the Azores. It is also recommended that we proceed with the determination of the tourism carrying capacity for all the hiking trails of the Azores, especially those located in protected areas, and also to carry out an assessment of ECC.

Keywords: Carrying capacity, hiking trails, sustainable management, Azores Islands.

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RESUMO

O turismo vem registando um aumento significativo nos Açores sendo actualmente responsável por 15,2% do seu Produto Interno Bruto (PIB) regional. Uma vez que um incremento neste sector poderá afectar a qualidade dos habitats naturais do arquipélago, revela-se muito pertinente avaliar a magnitude dessas alterações para se poder tomar decisões sustentadas de gestão. Neste contexto, os trilhos pedestres constituem uma das utilizações de espaços naturais com maior procura turística na região, pelo que se afigura importante avaliar se os sitios da Rede Natura que atravessam, estão sobre pressão antropogénica.

Este estudo pretendeu determinar a capacidade de carga turística de trilhos pedestres que atravessam Zonas Especiais de Conservação (ZEC) da Rede Natura 2000, em duas das 9 ilhas dos Açores, São Miguel e Flores, e avaliar o potencial da capacidade de carga turística como ferramenta de gestão no planeamento e desenvolvimento do turismo sustentável desses locais.

A Capacidade de Carga Real (CCR) dos trilhos foi determinada pelo método de Cifuentes, a partir da Capacidade de Carga Física (CCF), modificada por factores de correcção (social, precipitação, luminosidade e acessibilidade), selecionados em função da actividade turística e das condições das áreas em estudo. O factor de correcção que mais influenciou negativamente a capacidade de carga real de todos os trilhos foi o social, seguido da luminosidade. A menor CCR (118 visitas/dia) foi registada no trilho Lagoa do Fogo-Monte Escuro (São Miguel), e a maior no trilho Ponta Delgada-Fajã Grande (Flores) (557 visitas/dia). Em ambos os trilhos, foram também os factores de correcção social e luminosidade que mais influenciaram a CCR. Mesmo tendo em conta que a CCR não terá sido atingida, e ainda que não se tenha procedido à estimação da Capacidade de Carga Efectiva (CCE), será relevante que estudos futuros monitorizem aqueles factores, uma vez que estão muito ligados à qualidade da visita.

Embora com limitações, nomeadamente subjacentes ao método utilizado e à sua aplicação, espera-se que os resultados do presente estudo possam contribuir para melhorar a utilização sustentável dos trilhos pedestres em espaços naturais dos Açores. Recomenda-se também que se proceda à determinação da capacidade de carga turística de todos os trilhos pedestres dos Açores, sobretudo dos localizados em áreas protegidas, e também que se proceda à avaliação da CCE.

Palavras-chave: *Capacidade de carga, trilhos pedestres, desenvolvimento sustentável, Açores.*

1. INTRODUCTION

Outdoor recreation, including nature-based tourism, has long been recognized as an agent of ecological change in natural systems, with the potential to affect soil, vegetation, wildlife, and water quality (Monz *et al*., 2010). Nature-based tourism is growing at an annual cumulative rate of 7% (THR, 2006), as a response of people's desire to participate in tours aiming relaxation, discovery, learning and nature escapade, that is, getting away from the routine of life, and it is now becoming the main revenue for many countries (Alaeddinoglu & Can, 2011). The European countries are the largest tourist emitters, mainly Germany and the Netherlands (THR, 2006). As this kind of tourism increases, areas such as national parks and other protected areas will be placed under increasing pressure (Marzuki *et al*., 2011).

Ecotourism is included in nature-based tourism, and it is understood as a strategy for conservation and a tool for economic development, meaning that its activities must take place in harmony with nature. Ecotourism development is being used in protected areas for supporting conservation and generating income. According to Sayan & Atik (2011) protected areas are becoming increasingly important in modern societies since they preserve natural resources and enhance the quality of life. The practice of ecotourism is an effective way to ensure sustainable development for nature reserves and represents one of the most environmentally-friendly alternatives for the economic development of protected areas (Li & Han, 2001), but it can also lead to the degradation of natural resources, when unplanned or poorly planned, especially if management is inadequate. Protection and development should occur simultaneously to ensure the conservation of natural resources and to maintain environmental services provided by protected areas (Maldonado & Montagnini, 2005).

Tourism often has the potential to contribute in a positive manner to local development but at the same time, its fast and sometimes uncontrolled growth, can be the major cause of environmental degradation and loss of local identity and traditional culture (Syamlal, 2008). Presently, the touristic use of protected areas (PA's), although sometimes generating resources to finance (partly or totally) conservation efforts, can also provoke environmental impacts that may damage natural values, if they are not properly managed. Thus, one of the main tasks of PA's managers is to assess, control and mitigate, the possible impacts caused by tourism activity. A common problem in natural areas is the concentration of visitors at a few attractive sites. At these points, the concentration of visitors is normally high and often exceeds the area's carrying capacity. Open access problems arise because of the difficulty of excluding visitors from sites and these lead to 'congestion' costs as visitation rates increase, and each additional user reduces the welfare of other users (*e.g*. beach facility tourism or 'wilderness' park tourism; Brown *et al*., 1997). The carrying capacity of an area includes several interrelated elements, and if one of them is exceeded, the balance among elements will be distorted.

From an ecological perspective, carrying capacity is understood as the maximum number of individuals of a given species that a given habitat can support, without being permanently damaged (Odum, 1989). The World Tourism Organization (WTO, 1993), however, proposed a definition of carrying capacity for tourism as "the maximum number of people that may visit a tourist destination at the same time, without causing destruction of the physical, economic, socio-cultural environment, and an unacceptable decrease in the quality of visitors' satisfaction". For Buckley (1999), the concept describes the number of visitors that produces no detectable, or at least no irreversible, ecological change to the ecosystems in an area. On the other hand,

carrying capacity refers to a certain threshold of people activity beyond which damage to the environment will occur (Williams & Lemckert, 2007). The concept is thus dynamic and fluid, neither fixed nor static, and can depend on the speed of change (Simon *et al.*, 2004). However, critics against establishing a numerical carrying capacity argue that it varies depending on the protected area objectives, upon tourism activities, and also because it does not provide a measurement of impacts (McCool & Lime, 2001).

The recent attempts to develop actual carrying capacities in terms of specific numbers of tourists or visitors raise significant questions for the decision-makers that establish policy strategies to tourism development (Saveriades, 2000). The aim of estimating tourism carrying capacity is thus to determine the upper desirable limits of development, i.e. the optimal use of tourism resources. But it also means making decisions about what ought to be done, what recreational opportunities should be provided, and how recreation use should be managed. There are several methods that enable the evaluation of the number of visitors to a PA such as Tourism Carrying Capacity (TCC; Cifuentes, 1992), which takes into account three levels of analysis: Physical Carrying Capacity (PCC), Real Carrying Capacity (RCC) and Effective Carrying Capacity (ECC), where PCC > RCC > ECC.

Other methods include Limits on Acceptable Changes (LAC; Stankey *et al.*, 1985), Visitor Experience and Resource Protection (VERP; US Department of the Interior, 1997), Tourism Optimization Management Model (TOMM; Manidis Roberts Consultants 1997), and Visitor Impact Management (VIM; Kuss *et al.*, 1990). Thus, it is important to evaluate the carrying capacity of PA´s to ensure that they can handle levels of visitation, which enable them to become economically self-sustainable (Cifuentes, 1992; Boo, 1993). It is necessary to define what are the possibilities and limitations of ecological destinations to preserve and not to destroy what visitors come to see.

Islands in general, have geographical, cultural, ecological and economic features that attract visitors, but the fragility and limitations of the destinations make the environment and communities more vulnerable to the pressures of tourism (Kokkranikal *et al.*, 2003). Then carrying capacity becomes one of the main techniques of tourism and recreation planning, and management. Destinations such as the Indo-Pacific Islands, with cheap and open access and weak capacity management, have experienced crowding, crime, pollution and price collapses (Buckley, 2002). But carrying capacity should be used to assist governance decisions based on desired conditions, not rigid numbers, and to encourage actions that reduce impact per visitor rather than simply the number of visitors. Determining how many people could use a given area before unacceptable impact sets in, is becoming critically important to many managers. In this view, studies of carrying capacity and control impacts of visitation are indispensable tools for tourism planning.

Despite the limitations associated to the carrying capacity concept, it has been described as an appropriate tool for management, as it enables the preservation of resources in PA´s. Increasing interest in these areas is focused on the existing natural attractions and covers the visiting of landscapes, the practicing of nature-based sports, among other outdoor activities. The management of PA´s that allows hiking activities can potentially conflict with conservation.

The main goal of this research was to assess the TCC of hiking trails crossing protected areas within Natura 2000 network, using six hiking trails, located in two of the nine islands, as case studies. It is also expected that the estimation of the tourism carrying capacity in these trails will provide stakeholders that explore or manage these trails, with useful data to prevent or minimize impacts that may occur when opening a trail to leisure or interpretative activities.

Natura 2000 is a European Union (EU) network established by two Directives: (1) the Habitats Directive (Council Directive 92/43/EEC of 21 May 1992), dedicated to manage the conservation of natural habitats and of wild fauna and flora inside Special Areas of Conservation, (SAC's); (2) the Birds Directive that aims the conservation of wild birds (Council Directive 2009/147/EC (the codified version of Council Directive 79/409/EEC as amended) inside Special Protection Areas (SPA's). Natura 2000 network represents around 18% of the EU's terrestrial territory, and its basic principle is the compatibility of human activities with places of natural importance for conservation.

2. METHODOLOGY

2.1. Study area

Located in the North Atlantic Ocean, along the mid-Atlantic ridge, the Portuguese Azores archipelago consists of 9 islands and several islets of volcanic origin, geographically spread into three groups, between latitudes 37–40ºN and longitudes 25–31ºW. The archipelago is distant about 1,500 km west from Lisbon and 3,900 km east from the east coast of North America, and has a land surface of 2,333 km^2 (Pena & Cabral, 1997; Instituto Hidrográfico, 1981) (Figure 1). The Azores, along with Madeira, Selvagens, Canaries, and Cape Verde, belongs to the Macaronesia Region, a world biodiversity hotspot that represents 0.3% of the EU territory. The Azorean most important resources are its landscape, endemic flora and fauna, mild climate and friendly people. The archipelago is becoming famous for its natural values, as well as its tourism opportunities at sea and land, both of which are closely related.

In the Azores, SPA's and SAC's cover 16% of the territory (IGEO, 2009), being instrumental for nature conservation. As these areas are crossed by trails, now used for hiking in ecotourism related activities, it is important to understand how is the relation between each hiking trail and its carrying capacity, in order to evaluate if there is a pressure over the area, with adverse consequences for natural resources.

Our study was conducted on hiking trails located on SAC's within the frame of Natura 2000, at two of the 9 Azorean islands: São Miguel (SM), the largest island, with an area of 744.55 km^2, in the eastern group, and Flores (FL), one of the smallest, with 141.02 km^2, in the western group. São Miguel, the so-called "Green Island" because of its exuberant vegetation, is the largest and most populated island of the archipelago, has the highest touristic flow, and 7% of its land is integrated in Natura 2000 network. On the contrary Flores has 31% of its land covered by Natura 2000 network, but lower touristic flow and population density.

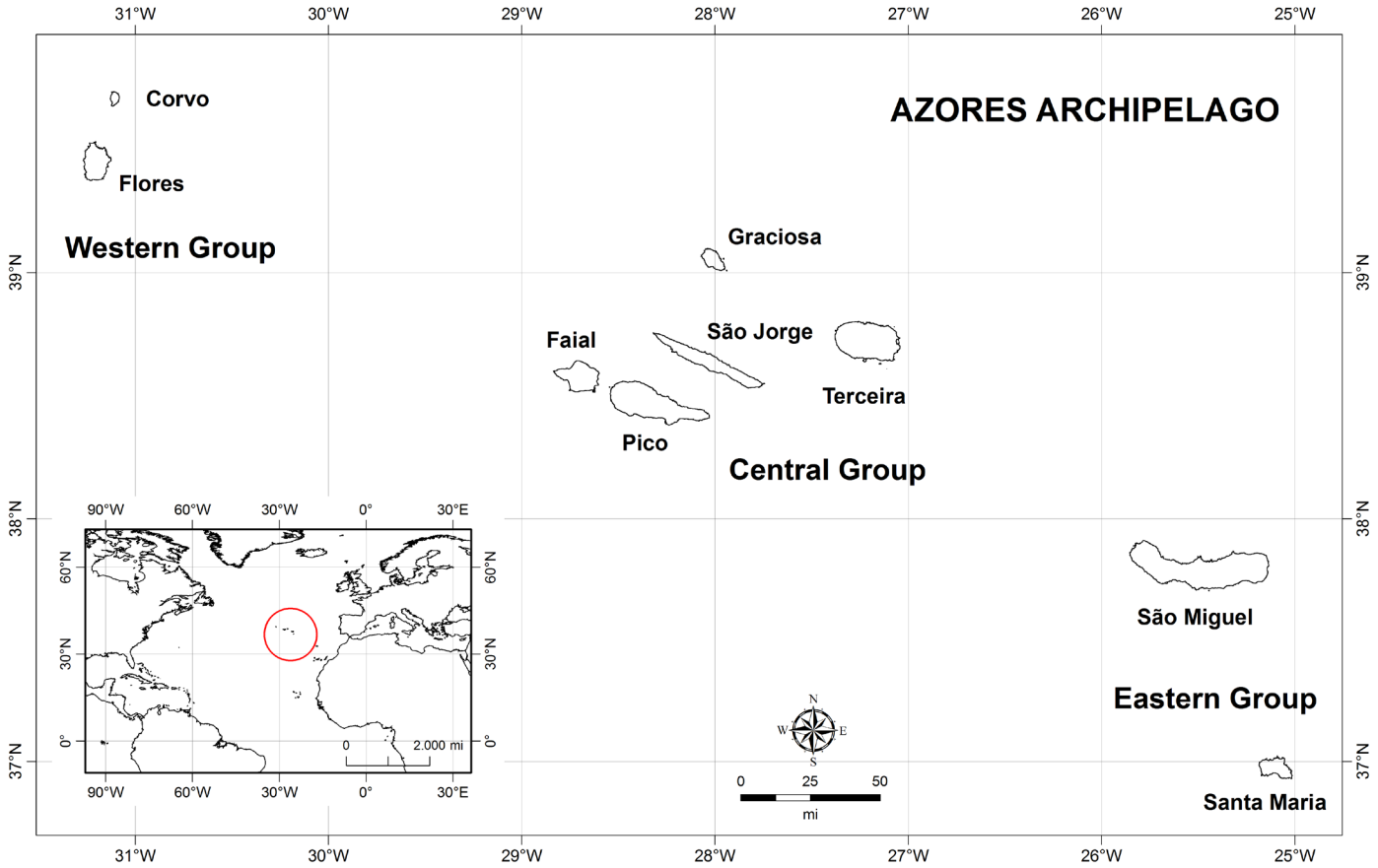

Figure 1. Location and composition of the Azores archipelago. Source: Section of Management and Environmental Planning, University of the Azores.
Figura 1. *Localização e composição do Arquipélago dos Açores. Fonte: Secção de Gestão e Planeamento Ambiental, Universidade dos Açores.*

The surveys were done at the following SAC's: Lagoa do Fogo Nature Reserve (SM), Morro Alto (FL) and Costa Nordeste (FL). These areas are now included in the recently created Island Natural Parks (INP's), in the category of "protected areas for management of natural resources" (Legislative Regional Decree nº15/2007/A).

The nine islands of the Azores Archipelago account for 69 official hiking trails, some of which are temporarily closed mostly due to landslides related to heavy rains. Unofficial trails also exist and are currently being used by tourists. In São Miguel Island (SM) there are 31 official trails while Flores Island (FL) has only four. All official trails have informative panels (length, difficulty, duration) and directional marks, and the majority are linear. Trail classification, identification, marking, maintenance, supervision and promotion, are responsibility of the Azorean Government. In both islands, all the trails that crossed, or were totally within the mentioned PA´s, were sampled, including the trails used by hikers that are not recognized for the local authorities, but may eventually become official trails in a near future.

A total of 6 hiking trails were investigated in the two islands, three per island. In São Miguel, the trails were sampled at Lagoa do Fogo Nature Reserve (Legislative Regional Decree nº 152/74), once it is among the most important conservation area of the island, presenting geological, biological and landscape values of high touristic relevance. In Flores, three trails were investigated within two PA´s: Morro Alto (two official trails) and Costa Nordeste (one unofficial trail). Morro Alto Reserve is the largest wetland in a high elevation in the Azores, and also the best preserved. Costa Nordeste is dominated by extensive and high coastal cliffs. General characteristics of the trails under investigation are summarized in Table 1.

Sampling

The Azorean protected areas are open, and thus there is no control on the number of visitors or gated input/output points, making it difficult to estimate the real number of tourists. A GPS was used to determine geographical position, altitude and length of the trails. All the trails selected are mainly for hiker use, although motorized vehicles and bikes may also be present in some of them. Fieldwork was performed in the summer of 2009 and 2011. For each hiking trail, an inventory of landscape characteristics and natural resources was generated, including information regarding the trail's geographical location (georeferenced), biota (birds and vegetation), state of conservation, accessibility and safety. It was decided, due to time and resource constraints and in order to provide an efficient and easy evaluation of the trails, that sampling points would be at intervals of 500 meters.

Table 1. Characteristics of the hiking trails sampled during the research.
Tabela 1. *Informações sobre os percursos pedestres amostrados neste estudo.*

Hiking Trails	Acronyms	Distance (m)	Altitude (m)			Protected Area
			Minimum	Mean	Maximum	
São Miguel						
Praia-Lagoa do Fogo	PRC2SMI	6000	246	424	559	Lagoa do Fogo
Pico da Barrosa-Ribeira das 3 Voltas	PRPBRV	8000	246	481	900	Lagoa do Fogo
Lagoa do Fogo- Monte Escuro	PRLFL	6000	580	633	752	Lagoa do Fogo
Flores						
Ponta Delgada-Fajã Grande	PR1FLO	12000	120	271	374	Costa Nordeste
Poça do Bacalhau	PR3FLO	7000	54	527	629	Morro Alto
Cedros-Ponta Ruiva	PRCPR	3500	238	266	315	Costa Nordeste

Methods

Physical, real, and effective carrying capacity were assessed by Cifuentes' methodology (Cifuentes, 1992), adapted according to specific bio-physical peculiarities and characteristics of the area, as suggested by the IUCN (Ceballos-Lascuráin, 1996). The logic of the method is based on site-specific factors, which reduce the level and quality of visitation, and consider the limiting factors of the areas.

Physical Carrying Capacity (PCC)

PCC is defined as the maximum number of users that can physically fit into, or onto, a specific area.

$$PCC = A \times \frac{U}{a} \times Rf \quad (1)$$

Where: A = available area for public use (trail distance)

$\frac{U}{a}$ = Area required per user to walk comfortably (1 visitor per m²)

Rf = Rotation factor (number of visits/day)

In order to measure PCC, the following assumptions were done:

- Rf = Open period ÷ Average time of visit
- Since there are no entrance gates in the PA´s studied, the daily hours of sunshine (daylight) were defined as a parameter, as hiking is done during daylight [average daylight of the summer months (June to September)]: 11.29h in SM and 11.24h in FL. The average time of visit is the average time required to go across the hiking trail.

Real Carrying Capacity (RCC)

RCC is the maximum allowable number of users to the hiking trails, once the correction factors (*Cf*) derived from the particular characteristics of the site have been applied to the PCC. For the calculation of RCC, PCC was modified by a series of correction factors, such as social (*Cf* soc), precipitation (*Cf* pre), daylight (*Cf* lig) and accessibility (*Cf* acc).

$$RCC = PCC \times (Cf1 \times Cf2 \times \ldots - Cfn) \quad (2)$$

Where: Cf = correction factor

To measure RCC, the following assumptions must be done: the correction factors are obtained by considering the environment, biophysical and social factors. These factors are closely linked to the specific conditions and characteristics of each site or activity. *Cf* is expressed as follows:

$$Cf = 1 - [\frac{Ml}{Mt}] \quad (3)$$

Where: $M1$ = limiting magnitude of variable
Mt = total magnitude of variable

The correction factors

These factors are calculated after fieldwork and are selected based on tourism activities and local conditions of the study area. As a result of the correction factors, values near 0 indicate a limiting factor in the carrying capacity of the trail, while those close to 1 show no limitation. The factors used to calculate RCC are:

- *Cf* soc - it refers to the quality of visitation, and the distance required between groups to avoid crowding. To

this factor we consider groups of 15 people and a distance of 250m between groups. Regarding the group size, we calculated the carrying capacity for the hiking trails, with a maximum of 15 members per group, according to the directions proposed for ecotourism by The International Ecotourism Society (TIES, 2006) and WWF-Brazil (2003).The distance required per group was calculated through the sum of the distances between groups and the space occupied by each group. Also, the number of groups (NG) that can be simultaneously in the path is generated by the expression:

$$NG = (\text{Site total(trail)} \div \text{distance required by each group}) \quad (4)$$

To calculate the Csoc, we first obtain the number of people (P):

$$P = NG \times \text{Number of people per group} \quad (5)$$

Moreover, the limiting magnitude (Ml) presented by the site was calculated:

$$Ml = Mt - P \quad (6)$$

- Daylight: Light intensity has an impact on carrying capacity as well.
- Precipitation: Rain often occurs on the islands affecting tourists' sightseeing. Hence, it can be taken as a limiting factor. Characteristics related to RCC are the annual average of the number of days in which rainfall is ≥ 0.1 mm, and daylight period.

To study the variations and trends in climate it is important to have long series of data. Thus, climate series are generally used to classify a region's climate and to make decisions for a wide variety of purposes involving agriculture and natural vegetation management, tourism, transportation and research in many environmental fields. In this study, we used Climate series (1971-2000) of the annual average precipitation during summer season (June to September). Data on daylight and precipitation were obtained from the Institute of Meteorology, IP Portugal.

- Accessibility: it is related to the degree of difficulty presented by the hiking path, according to slope range and soil type. The sum of meters that theoretically may result in difficulty of access for some hikers was considered as an additional correction factor.

Effective Carrying Capacity (ECC)

ECC is the maximum number of visitors that a trail can sustain, given the management capacity (MC) available, and adjusting the RCC to the correction factors. Thus, it takes into consideration the infrastructures related to the trails, facilities and equipment, staff (number and qualifications), funding, among others, providing the number of visitants.

Results and Discussion

Effective Carrying Capacity (ECC) was not possible to calculate due to the absence of infrastructures related to the trails that would provide the number of visitants. Although it was possible to determine the related correction factors for the Azorean trails, it was impossible to evaluate the MC given the lack of data concerning variables, such as infrastructures, facilities, etc. Thus, the RCC should be considered with care, given the lack of this important indicator for the calculation of TCC.

The trail Ponta Delgada-Fajã Grande (FL) had the largest PCC (44 960 visits/day), because of its relatively easy access and total length. On the contrary, Cedros-Ponta Ruiva (FL) trail, in spite of its easy access, had the lowest PCC (13 113 visits/day), because of its shortest length (Table 2).

After applying the corresponding correction factors to PCC, the Real Carrying Capacity (RCC) was calculated for each hiking trail (Table 3). In the present study, the social correction factor (soc) had the greatest influence on the overall RCC, as it was the most limiting factor (0.057) for all the hiking trails, which led to consider a reduction on the number of visits per day. The same trend was found for the trails located in the protected area of La Tigra National

Table 2. Physical Carrying Capacity and rotation factors (number of visits/day)
Tabela 2. *Cálculo da Capacidade de Carga Física (CCF) e factores de rotação (número de visitas/dia)*

Hiking Trails	Distance (m)	**Rf -** rotation factors	**PCC** (visits/day)
São Miguel			
Praia-Lagoa do Fogo	6000	2.82	16935
Pico da Barrosa-Ribeira das 3 Voltas	8000	2.82	22580
Lagoa do Fogo- Monte Escuro	6000	2.26	13548
Flores			
Ponta Delgada-Fajã Grande	12000	3.75	44960
Poça do Bacalhau	7000	2.81	19670
Cedros-Ponta Ruiva	3500	3.75	13113

Park, Honduras (Maldonado & Montagnini, 2005). soc is also determined by the quality with which visitors can enjoy the attractions in the whole journey and that relates to the difficulty of managing large groups. In some cases, visitors must walk back over the same path covered previously to return to the starting point. This creates a space limitation for visitors due to the probability of encountering other tourist groups on the return.

For all the trails analyzed, values of around 1 for the correction factor "precipitation" (prec) suggest that it did not affect RCC. During the summer, prec had the lowest PCC, as would be expected. However, the daylight correction factor (day) influenced the RCC of the trails. This may be a consequence of the fog conditions frequently observed on the areas surrounding the hiking trails, as it may block visibility. The accessibility correction factor (acc) in turn, did not affect much the results of RCC, probably because acc is closely related to differences of trail surfaces regarding occurring soil, and in the Azores the surface is similar in the majority of the trails. However, this factor is subjective because it has as reference the personal perceptions and the sensitivity of the researchers and planners. The correction factors precipitation, daylight and accessibility are intrinsically related, as they influence the flow of people, and the impact the trails will suffer. Similar results were found for the Termessos National Park, Turkey, where the visitation to the park and the use level of the trails therein depend upon the season, weather, and trail conditions (Sayan & Atik, 2011).

In practice, for the majority of the areas there is a risk of saturation or carrying capacity overload particularly in the peak seasons (Sayan & Atik, 2011). Since the vast majority of visitors come to the Azores during the summer, they most certainly are not willing to go hiking under heavy rain, thus we only considered the days of lower precipitation for analysis. Nevertheless, as in the Azores heavy rain and fog can occur throughout the year affecting tourists' sightseeing, it should be considered as a limiting factor.

The Lagoa do Fogo-Monte Escuro trail (SM) had the lowest RCC, as a consequence of the correction factors referring to the social and daylight variables. These two factors reduced the RCC considerably, in comparison to the Ponta Delgada-Fajã Grande trail (FL) that had the highest RCC, as it was the least affected by the same correction factors (Table 3); also this latter hiking trail had lower slope gradients and was easier to walk than the first one, therefore it yielded the highest RCC of all the hiking trails.

All hiking trails are located inland, with the exception of the Ponta Delgada-Fajã Grande trail (FL) that develops along the shoreline. As tourism pressures over coastal areas are increasing, the results provided by this trail may be of considerable value for coastal management. This may be emphasised by the fact that most of the studies on Tourism Carrying Capacity on coastal areas address beaches (*e.g.* Zacarias, 2013)

Most certainly, the real carrying capacity of the trails has not yet been attained in either of the studied protected areas (Table 3). However, as the number of visitors tends to increase in the Azores (SREA, 2013) the probability of approaching the carrying capacity limits may also increase.

Although not always consensual, the carrying capacity assessment remains one of the most useful and applied techniques (Zacarias *et al.*, 2011) for tourism and recreation planning, and management, especially if combined with other management tools. These tools may include changing periodically the visiting sites, to allow their recovery or even to adapt visits to season characteristics.

The carrying capacity should facilitate the process of continuous monitoring of tourism by adjustment to plans as needed, and to ensure that tourism development is carried out within the context of the optimum overall capacity level, thus ensuring its sustainability (Saveriades, 2000). Furthermore, the carrying capacity can only be examined in a case-by-case situation because it is sensitive to many variables (*e.g.* location, type of tourist activity, speed of tourism growth, temporal dimension of technical developments; Simon *et al.*, 2004).

Table 3. Real Carrying Capacity (RCC) and correction factors, calculated for the hiking trails.
Tabela 3. *Resultados do cálculo da Capacidade de Carga Real (CCR) e factores de correcção para os trilhos.*

Hiking Trails	Distance (m)	Correction factors ()				RCC (visits/day)
		Social	Precipitation	Daylight	Accessibility	
São Miguel						
Praia-Lagoa do Fogo	6000	0.057	0.950	0.252	0.767	176
Pico da Barrosa-Ribeira das 3 Voltas	8000	0.057	0.950	0.252	0.844	258
Lagoa do Fogo- Monte Escuro	6000	0.057	0.950	0.252	0.642	118
Flores						
Ponta Delgada-Fajã Grande	12000	0.057	0.945	0.270	0.858	557
Poça do Bacalhau	7000	0.057	0.945	0.270	0.686	195
Cedros-Ponta Ruiva	3500	0.057	0.945	0.270	0.671	127

In Europe, there are many entrances and roads that cross national parks and PA´s allowing the entrance of both visitors and people who live or work in these areas, along with the traffic (Beunen *et al*., 2008). Determining the number of users is an important factor to evaluate an area's carrying capacity, as it can assist the implementation of strategies to help maintain the population and the potential impacts on its surrounding environment (Williams & Lemckert, 2007). Control can be exerted through various methods such as entry restrictions, reducing the number of facilities, pricing, and by enforcing behavioural guidelines (Kokkranikal *et al*., 2003).

The protected areas in the Azores are open access and there is no control on the number of visitors or a gateway of input/output, making it difficult to assess the real impact concerning the tourists' visits to these areas. Brown *et al*. (1997), when comparing two economies highly dependent on tourism, the Maldives Islands and Nepal, demonstrate that from an economic perspective the open access to a great deal of resources which attract tourists to scenic areas, prevents the capturing of significant parts of the potential revenue locally.

As ECC was not evaluated, RCC should not be considered as the existent Tourist Carrying Capacity of each trail, but only an approach to it and an important indicator of its tendency.

CONCLUSIONS

Mostly in vulnerable habitats, the establishment of the area's touristic carrying capacity may prevent potential anthropogenic impacts over hiking trails, and help decision-makers. With the increase of tourism flow in the Azores, the probability of increasing environmental hazards is also growing and sustainable approaches should be promoted. In this view, it is recommended to establish visitors' centres, gateways and handrails, at least in those trails located in sensitive areas, allowing the counting of visitors and providing information on the trails, as well as guidance and monitoring along them, in order to prevent major impacts from tourist activity.

Apart from reliable environmental monitoring plans and an effective analysis of the carrying capacity of trails, other approaches could be tested in order to avoid disturbance over protected areas: (i) to increase environmental knowledge and awareness about local natural resources; (ii) to work on conditions to limit accessibility in selected places; (iii) to build economic incentives to correct specific deficiencies (e.g. subsidies, eco-taxes); (iv) to manage the presence and to control the tourists on each site; and (v) to invest on environmental conservation and restoration of the areas. The physical limitations (state of conservation, soil, topography and infrastructures) of the trails should be taken into consideration when planning any expansion of the visitation levels, or the addition of official trails, in order to maintain environmental quality, visitor's safety, and the quality of visitation.

In this study, the ECC was not determined due to the absence of physical and human resources on the sampled trails. As the conditions of infrastructures and equipments available at each hiking trail are very important for the quality of the use, it is recommended to calculate the Effective Carrying Capacity (ECC) in a near future for a complete assessment of the tourism carrying capacity of the trails. Given the results of this analysis, and taking into consideration its limitations, it can be said that the current hiking trails' capacity has weak points as a result of the scarcity of physical resources (equipments and infrastructures) and human resources (staff), which do not allow an optimal performance of activities in the areas under study.

This research represents the first approach to establish tourism carrying capacity in trails belonging to protected areas of the Azores Natura 2000 network. It is important to assess the real current visitation levels of the hiking trails, not only to understand their meaning but also to decide upon future increases in visitation. The results provided by this approach may also contribute to coastal management, as it was highlighted by the hiking trail located along the shoreline.

It seems clear that there is a need for further multidisciplinary approaches over hiking trails, not only for those under analysis but also for the remaining hiking trails of the Azores, and the future planned.

Finally, it could be interesting to extend the assessment of tourism carrying capacity through time, to have a multi-year evaluation, along with multidisciplinary studies. The pursuit of carrying capacity studies should be encouraged as a way to guarantee the sustainability of the hiking trails in the Azorean protected areas, and a better quality in the experience of the visitors.

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REFERENCES

Alaeddinoglu, F.; Can, A.S. (2011) – Identification and classification of nature-based tourism resources - western Lake Van basin, Turkey. *Procedia Social and Behavioral Sciences*, 19:198–207. doi: 10.1016/j.sbspro.2011.05.124

Beunen, R.; Regnerus, H.D.; Jaarsma, C.F. (2008) – Gateways as a means of visitor management in national parks and protected areas. *Tourism Management*, 29(1):138-145. doi: 10.1016/j.tourman.2007.03.017

Boo, E. (1993) – Ecotourism planning for protected areas. *In:* K. Lindberg & D. E. Hawkins (eds.), *Ecotourism: A Guide for Planners and Managers*, pp. 15-31, The Ecotourism Society, North Bennington, Washington, DC, USA. ISBN: 0963633104

Brown, R.K.; Turner, K.; Hameed, H.; Beteman, I. (1997) – Environmental carrying capacity and tourism development in the Maldives and Nepal. *Environmental Conservation*, 24(4):316-325. doi: 10.1017/S0376892997000428

Buckley, R. (1999) – An ecological perspective on carrying capacity. *Annals of Tourism Research*, 26(3):705-708. doi: 10.1016/S0160-7383(99)00011-0

Buckley, R. (2002) – Surf Tourism and Sustainable Development in Indo-Pacific Islands. II. Recreational Capacity Management and Case Study. *Journal of Sustainable Tourism*, 10(5):425-442. doi: 10.1080/09669580208667177

Ceballos-Lascuráin, H. (1996) – *Tourism, Ecotourism and Protected Areas: the state of nature-based tourism around the world and guidelines for its development.* 315p., World Conservation Union (IUCN), Gland, Switzerland. ISBN: 2831706483

Cifuentes, M. (1992) – *Determinación de la Capacidad de Carga Turística en Áreas Protegidas*. 28p., Centro Agronómico Tropical de Investigación y Enseñanza (CATIE), Turrialba, Costa Rica. ISBN: 9977571295 Available at http://books.google.com.br/books?id=ICoOAQAAIAAJ&printsec=frontcover&hl=pt-BR&source=gbs_ge_summary_r&cad=0 - v=onepage&q&f=false

Governo dos Açores (s/d) – *Natura 2000 data available to the public***.** Internet site of Governo dos Açores, Ponta Delgada, Açores, Portugal. Available at http://www.azores.gov.pt/Portal/en/entidades/srrn-dra/noticias/Natura+2000+data+available+to+the+public.htm

Instituto Hidrográfico (1981) – *Roteiro do Arquipélago dos Açores*. Instituto Hidrográfico, Lisboa, Portugal.

Kokkranikal, J.; McLellan, R.; Baum, T. (2003) – Island Tourism and Sustainability: A Case Study of the Lakshadweep Islands. *Journal of Sustainable Tourism*, 11(5):426-447. doi: 10.1080/09669580308667214

Kuss, F.R.; Graefe, A.R.; Vaske, J.J. (1990) – *Visitor impact management.* 105p., National Parks and Conservation Association, Washington, D.C., USA. ISBN: 0940091313.

Li, W.; Han, N. (2001) – Ecotourism management in China's nature reserves. *Ambio*, 30(1):62-63. doi: 10.1579/0044-7447-30.1.62

Maldonado, E.; Montagnini, F. (2005) – Carrying Capacity of La Tigra National Park, Honduras. *Journal of Sustainable Forestry*, 19(4):29-48. doi**:** 10.1300/J091v19n04_03

Manidis Roberts Consultants (1997) – *Developing a Tourism Optimisation Management Model (TOMM), a model to monitor and manage tourism on Kangaroo Island* [Final Report]. South Australian Tourism Commission, Adelaide, SA, Australia. *Unpublished*.

Marzuki, A.; Hussin, A.A.; Mohamed, B.; Othman, A.G.; Som, A.P.M. (2011) – Assessment of nature-based tourism in South kelantan, Malaysia. *Tourismos: an international multidisciplinary journal of tourism* (ISSN: 1790-8418), 6(1):281-295. Available at http://www.chios.aegean.gr/tourism/VOLUME_6_No1_art16.pdf

McCool, S.F.; Lime, D.W. (2001) – Tourism carrying capacity: tempting fantasy or useful reality. *Journal of Sustainable Tourism*, 9(5):372-388. doi: 10.1080/09669580108667409

Monz, C.A.; Marion, J.L.; Goonan, K.A.; Manning, R.E.; Wimpey, J.; Carr, C. (2010) – Assessment and monitoring of recreation impacts and resource conditions on mountain summits: examples from the Northern Forest, USA. *Mountain Research and Development*, 30(4):332–343. doi: 10.1659/MRD-JOURNAL-D-09-00078.1

Odum, E. (1989) – *Ecology and Our Endangered Life Support Systems*. 283p., Sinauer Associates, Sinauer, Stanford, CT, USA. ISBN: 0878936531

Pena, A.; Cabral, J. (1997) – *Roteiros da Natureza. Região Autónoma dos Açores*. 147p., Temas e Debates, Lisboa, Portugal.

Saveriades, A. (2000) – Establishing the social carrying capacity for tourism resorts of east coast of Republic of Cyprus. *Tourism Management*, 21(2):147-156. doi: 10.1016/S0261-5177(99)00044-8

Sayan, M.S.; Atik, M.S. (2011) – Recreation carrying capacity estimates for protected areas: a study of Termessos National Park. *Ekoloji* 20(78):66-74. doi: 10.5053/ekoloji.2011.7811

Simon, F.J.G.; Narangajavana, Y.; Marques, D.P. (2004) – Carrying capacity in the tourism industry: a case study of Hengistbury Head. *Tourism Management*, 25(2):275–283. doi: 10.1016/S0261-5177(03)00089-X

SREA (s/d) – *Hóspedes, Dormidas e Estada Média.* Internet site of SREA - Secretaria Regional de Estatística dos Açores, Ponta Delgada, Açores, Portugal. http://estatistica.azores.gov.pt:81/ReportServer/Pages/ReportViewer.aspx?%2fTurismo%2fHospedes+Dormidas+e+Estada+-Media&rs:Command=Render

Stankey, G.H.; Cole, D.N.; Lucas, R.C.; Petersen, M.E.; Frissell, S.S. (1985) – *The Limits of Acceptable Change (LAC) system for wilderness planning*. 37p. [General Technical Report INT-176 – USDA]. Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT, USA.

Syamlal, G.S. (2008) – Carrying Capacity Study of Coastal Tourism in Kumarakom, Kerala. *Journal Ekonomi Bisnis* (ISSN : 0853-862X), 13(1): 15p., Gunadarma University, Jakarta, Indonesia. Available at http://ejournal.gunadarma.ac.id/index.php/ekbis/article/view/317/257

THR (2006) – *Turismo de natureza: 10 produtos estratégicos para o desenvolvimento do turismo em Portugal.* 60p. THR – Asesores en Turismo Hotelería y Recreación, S. A.. Turismo de Portugal, Lisboa

TIES (2006) – *Global Ecotourism Fact Sheet.* TIES – The International Ecotourism Society, Washington, DC, U.S.A. Available at http://www.ecotourism.org/atf/cf/%7B82a87c8d-0b56-4149-8b0ac4aaccd1cd38%7D/TIES%GLOBAL%ECOTOURISM%FACT%20SHEET.PDF (accessed January 2011)

US Department of the Interior (1997) – *The Visitor Experience and Resource Protection (VERP) Framework. A Handbook for Planners and Managers.* 103p., Service Center, National Park Service, Denver, CO, USA.

Williams, P.; Lemckert, C. (2007) – Beach Carrying Capacity: Has it been exceeded on the Gold Coast? *Journal of Coastal Research* (ISSN 0749.0208), SI50 (ICS2007 Proceedings):21-24. Available at http://www.griffith.edu.au/__data/assets/pdf_file/0003/313347/Beach_Usage.pdf

WTO (1993) – *Sustainable Tourism Development: Guide for Local Planners.* 166p. WTO - World Tourism Organization, Madrid, Spain. ISNB: 9284400384

WWF Brasil (2003) – *Manual de Ecoturismo de Base Comunitária – ferramentas para um planejamento responsável*. 470p., WWF – World Wildlife Fund Brasil, Brasília, DF, Brasil. ISBN: 85-86440-12-4

Zacarias, D.A., 2013. Avaliação da capacidade de carga turística para gestão de praias em Moçambique: o caso da Praia do Tofo. *Revista da Gestão Costeira Integrada (Journal of Integrated Coastal Zone Management),* 13(2):205-214. DOI: 10.5894/rgci345.

Zacarias, D.A.; Williams, A.T.; Newton, A. (2011) – Recreation carrying capacity estimations to support beach management at Praia de Faro, Portugal. *Applied Geography*, 31(3):1075-1081. doi: 10.1016/j.apgeog.2011.01.020.