REVISTA DE
GESTÃO COSTEIRA
INTEGRADA

Journal of Integrated Coastal Zone Management

VOL. 14(2): June Junho 2014

http://www.aprh.pt/rgci/

Establishing, planning and managing protected areas in small islands

ISSN: 1646-8872

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ISSN 1646-8872

Esta revista está disponível em http://www.aprh.pt/rgci/pdf/rgci_14-2.pdf

Revista de Gestão Costeira Integrada

Journal of Integrated Coastal Zone Management

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Volume 14, Número 2 / Volume 14, Issue 2
Junho 2014 / June 2014

www.aprh.pt/rgci

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Journal of Integrated Coastal Zone Management
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GESTÃO COSTEIRA INTEGRADA
Journal of Integrated Coastal Zone Management

http://www.aprh.pt/rgci/pdf/rgci-528.pdf | DOI:10.5894/rgci528

Editorial

Establishing, planning and managing protected areas in small islands

"Coastal zone" means the coastal waters (including the land therein and thereunder) and the adjacent shorelands (including the waters therein and thereunder), strongly influenced by each and in proximity to the shorelines of the several coastal states, and includes islands, transitional and intertidal areas, salt marshes, wetlands and beaches (US Congress, 1972).

Small islands are defined as a land area with less than 10.000 km^2 with a population under 500.000 inhabitants (Beller et al., 2004) and they are *ipso facto* largely coastal entities (Saffache & Angelelli, 2010). These insular environments are known to be particularly sensitive to external pressures and climate change impacts (IPCC, 2001). Their remoteness, isolation, smallness, and closed systems, make terrestrial and coastal planning and management on small islands more challenging in scientific and technical terms (Calado et al., 2007, 2013). Therefore, island systems represent one of the challenges of our time: how to balance ecological integrity with economic development and collective quality of life (Baldacchino and Niles, 2011). In order to make effective and innovative scientific contributions for fostering a more sustainable development in small islands, the integrative approach of this thematic edition is in the interface of Ecosystem-Based Management (EBM), Land Planning (LP), Integrated Coastal Zone Management (ICZM) and Marine Spatial Planning (MSP).

Given the complexity of the issues involved, the aim of this volume is to provide a set of scientific contributions highlighting different methodological approaches and decision-support systems and thereby providing insight in different small islands geographical contexts. This thematic issue hopes to contribute to the improvement of the collective construction of theory and practice related to the integration of EBM, LP, ICZM and MSP approaches for fostering a more sustainable Development in these insular territories. A total of 12 peer-reviewed papers from Brazil (1), Portugal (7), Italy (1), United Kingdom (2) and United States of America (1), cover different subjects related to the above themes.

In the first paper "Small Islands Conservation and Protected Areas", the authors Helena Calado, Catarina Fonseca, Marta Vergílio, Ana C. Costa, Fabiana Moniz, Artur Gil and João Alveirinho Dias present a framework and overview on the management of protected areas in small islands.

The second paper entitled "Adaptation of macroalgal indexes to evaluate the ecological quality of coastal waters in oceanic islands with subtropical influence: the Azores" was written by Daniela Gabriel, Joana Micael, Manuela I. Parente and Ana C. Costa. In this study, four of the main indexes based on macroalgal abundance and composition were used to classify the coastal waters of the Azorean islands: the Greek EEI (Ecological Evaluation Index), the British RSL (Reduced Species List Rocky Shore Tool), the Spanish CFR (Quality of Rocky Bottoms Index) and the Portuguese MarMAT (Marine Macroalgae Assessment Tool). The metrics established in those tools were adapted to allow their application in this archipelago of subtropical influence. They concluded that all the applied indexes resulted in at least a "good" ecological status for the majority of the sampled sites.

The third article, "Assessing small island prioritization using species rarity: the tenebrionid beetles of Italy", was authored by Simone Fattorini and Leonardo Dapporto. The aim of this paper was to investigate conservation priorities of Italian small islands on the basis of tenebrionid species (*Coleoptera Tenebrionidae*) which are insects typically associated with coastal environments. They found that most of the studied islands have been recovered as having some conservation value, but the Tuscan Islands, Ustica, Pantelleria and the Pelagie Islands were found to have highest priority.

José Benedicto is the author of the fourth paper entitled "Identity and decision-making for sustainability in the context of small islands". This article focused on the analysis of how identity and sense of place identified on small islands can be an opportunity to inform local population about transition to sustainability. It constituted the opportunity to analyze how Flores Island (Azores, Portugal) community perceives local sustainability issues; what is the role that identity can play in the transition to sustainability; and what is the point of view from regional decision-makers, civil servant and key informants interviewed in the project.

In the fifth paper entitled "Concession in tourism services and partnerships in the Marine National Park of Fernando de Noronha, Brazil", the authors Deborah C. Estima, Maria A.M. Ventura, Andrea Rabinovici and Filomena M.C.P.F. Martins analyze the importance of partnerships and concessions in public use' support services at the Marine National Park of Fernando de Noronha (Brazil), in order to demonstrate the viability of sustainable management of tourism and funding in National Parks. This study is especially innovative because it deals with the first concession granted by the Brazilian government in an insular territory and shows initial results about the efficiency of that concession.

The sixth article written by Rose Queiroz, Maria Anunciação Ventura, José Ângelo Guerreiro and Regina Tristão da Cunha is entitled "Carrying capacity of hiking trails in Natura 2000 sites: a case study from North Atlantic Islands (Azores, Portugal)". This work 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: S. Miguel and Flores. It also aimed to evaluate the potential of TCC as a management tool for developing and planning a more sustainable tourism in these areas.

João Paulo Fernandes, Nuno Guiomar, Marco Freire and Artur Gil are the authors of the seventh research paper: "Applying an integrated landscape characterization and evaluation tool to small islands (Pico, Azores, Portugal)". This article illustrates the basic concepts in which Integrated Landscape Assessment (ILA) methodological approach is based, as well as its application to ecological and systematic conservation planning in small islands as the Pico Island (Azores Archipelago).

In the eighth research paper entitled "The Albufera Initiative for Biodiversity: a cost effective model for integrating science and volunteer participation in coastal protected area management", the authors Nick J. Riddiford, Jeroen A. Veraart, Inmaculada Férriz, Nick W. Owens, Laura Royo and Martin R. Honey put forward a multi-disciplinary field project, set up in 1989 at the Parc Natural de s'Albufera in Mallorca, Balearic Islands, Spain, as an example of a cost effective model for integrating science and volunteer participation in a coastal protected area. This paper also illustrates the added value of a long-term ecological knowledge base for decision making and capacity building in protected areas, in order to reduce environmental impacts from socio-economic development in surrounding coastal zones.

The article "Participative management of tourism in protected areas: Case-study from Lands of Priolo, São Miguel, Azores" is the ninth work of this thematic issue. It was written by Azucena de la Cruz, Rita Melo, Catarina Mourato, Raquel Ferreira, Joaquim Teodósio, Rui Botelho, Filipe Figueiredo, Ana Mendonça and Luis T. Costa. This paper presents the case-study of the application of the European Charter for Sustainable Tourism (ECST) in the "Lands of Priolo" (Eastern councils of S. Miguel Island, Azores, Portugal). The participatory planning process took place in 2011 and included a diagnosis, a strategy and an action plan (2012-2016) which are analyzed in this paper.

The tenth research paper, entitled "Basis for the geological heritage management in the Azores Archipelago (Portugal)" was authored by Eva Almeida Lima, João Carlos Nunes, Manuel Paulino Costa and Marisa Machado. This article describes how the geodiversity and geological heritage of the Azores archipelago is being inventoried, characterized, quantified, protected and promoted. Nowadays there have been identified and characterized 121 geosites distributed throughout the nine Azores islands and the surrounding seafloor. These geosites network ensure the representativeness of the Azorean geodiversity and reflects its geological and eruptive history with about 10 million years. Among the geosites, 57 were selected as priorities for the development of geoconservation strategies and implementation of promotion actions.

Paulo Antunes and Francisco Cota Rodrigues are the authors of the eleventh article of this thematic issue. Their work is entitled "Hydrogeochemistry assessment of volcanic lakes in the Flores Island Protected Areas (Azores, Portugal)". They identified three major processes that control the hydrogeochemical evolution of the lakes water in Flores Island (Azores, Portugal): (1) a marine sea salt input due to atmospheric transportation and deposition; (2) the hydrolysis of volcanic rock and; (3) a contribution of mineral water flowing through the rim of the crater. They concluded that aquatic systems have no direct interaction with seepage of magmatic fluids, a common process in Azores lakes. Therefore, according to their study, the highest decline in lake water quality is related to anthropogenic activities.

In the twelfth research paper entitled "Developing a Planning and Management System for Protected Areas on Small Islands (The Azores Archipelago, Portugal): the SMARTPARKS Project", Helena Calado, Marta Vergílio, Catarina Fonseca, Artur Gil, Fabiana Moniz, Susana Ferreira Silva, Miguel Moreira, Chiara Bragagnolo, Carlos Pereira da Silva and Margarida Pereira presented the SMARTPARKS Project, its rationale and main outcomes. Taking Pico Island Natural Park (Azores, Portugal) as its case study, the SMARTPARKS Project has adopted the ecosystem-based approach and the conciliation of conservation objectives with human needs and activities. Throughout its five tasks, several studies were developed and contributed to the functional analysis of each protected area constituting the Island Natural Park, in terms of their conservation and development values. This innovative application allows not only an integrated assessment of the protected areas but also a sustained monitoring.

This thematic issue represents a contribution towards a more sound knowledge on small islands' planning, management and sustainable development issues. It will be useful as a tool for local communities, researchers, technical officers, as well as for decision makers, stakeholders and environmental Non-Governmental Organizations, by supporting them for developing more effective and efficient science-based policies, in order to foster a more sustainable development in these insular territories.

In 2010, JICZM - Journal of Integrated Coastal Zone Management published a thematic issue on "Islands" (Volume 10, Number 3, 2010). Nevertheless, four years later, this new thematic edition on insular systems is completely focused on small islands conservation planning and management issues, therefore it doesn't pretend to cover all ranges of research subjects enclosed on "Island studies". As this will remain an open challenge, contributions on these broader subjects are most welcome, hoping that in a near future a new thematic issue gathering some of this collected expertise will be able to be published. Beyond this thematic issue, JICZM continues to welcome manuscripts approaching this theme. Its importance all around the world is undoubted and we believe that scientists need to claim their role as strategic stakeholders in socio-economic and environmental issues towards sustainability in small islands. Characterizing, assessing, monitoring and reporting are our crucial contribution in the protection of small islands communities and their natural resources.

Finally, we would like to take the opportunity of acknowledging all those who have contributed towards this thematic edition of JICZM - Journal of Integrated Coastal Zone Management. We warmly thank all authors who submitted their manuscripts for consideration of inclusion in this thematic volume. These 12 published research papers represent 70.6% of total submissions. The reviewing was a triple-blind process. We also thank the 46 reviewers (from Australia, Belgium, Brazil, Canada, Costa Rica, Finland, Greece, Iran, Israel, Italy, Japan, Portugal, Romania, Spain, Thailand, UK and USA) who have provided timely feedback to the authors, thereby helping the authors to improve their manuscripts.

REFERENCES

Baldacchino, G.; Niles, D. (2011) - *Island Futures: Conservation and Development across the Asia-Pacific Region*. 182p., Springer, Tokyo, Japan. DOI: 10.1007/978-4-431-53989-6

Beller W., D'Ayala P., Hein P. (2004) - *Sustainable development and environmental management of small islands*. UNESCO and the Parthenon Publishing Group 5, Paris. ISBN: 1-85070-267-5. Available online at http://www.cabdirect.org/abstracts/19911887938.html

Calado, H.; Braga, A.; Moniz, F.; Gil, A.; Vergílio, M. (2013) - Spatial planning and resource use in the Azores. *Mitigation and Adaptation Strategies for Global Change*, First Published on-line in November 2013. DOI: 10.1007/s11027-013-9519-2

Calado, H.; Quintela, A.; Porteiro, J. (2007) - Integrated Coastal Zone Management Strategies on Small Islands. *Journal of Coastal Research* (ISSN: 0749-0208), SI50:125-129, Australia. Available online at http://www.redmic.es/bibliografia/Docum_03049.pdf

Congress, U. S. (1972) - *Coastal Zone Management Act of 1972*. Public Law, 92-583. Available online at http://coastalmanagement.noaa.gov/czm/czm_act.html

IPCC (2001) - *Climate change 2001: impacts, adaptations and vulnerability*. Contribution of Working Group II to the Third Assessment Report. IPCC - Intergovernmental Panel on Climate Change, Geneva, Switzerland. Available online at: http://www.grida.no/publications/other/ipcc_tar/?src=/climate/ipcc_tar/wg2/index.htm

Saffache, P.; Angelelli, P. (2010) – Integrated coastal zone management in small islands: A comparative outline of some islands of the Lesser Antilles. *Revista de Gestão Costeira Integrada / Journal of Integrated Coastal Zone Management*, 10(3):255-279. DOI: 10.5894/rgci228

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Revista da Gestão Costeira Integrada 14(2):167-174 (2014)
Journal of Integrated Coastal Zone Management 14(2):167-174 (2014)

GESTÃO COSTEIRA INTEGRADA
Journal of Integrated Coastal Zone Management

http://www.aprh.pt/rgci/pdf/rgci-523_Calado.pdf | DOI:10.5894/rgci523

Small Islands Conservation and Protected Areas *

Áreas Protegidas e Conservação em Pequenos Territórios Insulares

H. Calado [@, 1], C. Fonseca [2], M. Vergílio [1], A. Costa [1], F. Moniz [1], A. Gil [3], J. A. Dias [4]

ABSTRACT

Islands may have a diversity of classifications, however, on this paper we address the constraints that include these territories in the category of small islands: size and population. To this particular balance and relation between population and availability of the territorial resource it sums the particular economic structures and the peculiar social constructions that shape islands communities and their relation with the surrounding environment.

The particular biogeography, the ecological specific features on islands and the fragile equilibrium they present stress the need for Conservation policies and strategies. Among the most effective tools used on Nature Conservation, protected areas and its management has become one of the most poplars. The aim of this paper is to give a framework and overview on the management of protected areas in small islands.

Keywords: Islands; Development; Nature; Management.

RESUMO

As Ilhas podem apresentar uma enorme diversidade de classificações, contudo, neste artigo, são abordadas as características que as incluem na categoria de Pequenos Territórios Insulares: tamanho e população. Ao balanço especifico entre população e disponibilidade do recurso território, somam se as particularidades das estruturas económicas e as peculiares construções socias que moldam as comunidades Ilhéus e a sua relação com o meio natural envolvente.

A biogeografia específica, as características ecológicas únicas e o frágil equilíbrio que apresentam, tornam mais premente a necessidade de politicas e estratégias de Conservação. Entre as ferramentas mais eficientes em Conservação da Natureza, as áreas protegidas e a sua gestão contam se entre as mais populares. O objetivo deste artigo é apresentar um enquadramento e visão geral da gestão de áreas protegidas em Pequenos Territórios Insulares.

Palavras Chave: *Ilhas; Desenvolvimento; Natureza; Gestão.*

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** Submission: 9 June 2014; Peer review: 9 June 2014; Reception of revised manuscript: 20 June 2014; Accepted: 24 June 2014; Available on-line: 25 June 2014*

1. INTRODUCTION

Small islands are defined as those with approximately 10.000 km² or less and approximately 500.000 or fewer residents (Beller *et al.,* 2004). Diversity of topics related to the islands is huge, making its simple mention incompatible with small texts as necessarily are papers in scientific journals (*e.g.,* Dias *et al.*, 2010). The complexity of the problems that they share demands for a more thematic approach. The option in this paper is to focus on Nature Conservation, namely Protected Areas.

The Convention on Biological Diversity (1992) emphasizes the importance of in-situ conservation, *i.e.*, *"the fundamental requirement for the conservation of biological diversity is the in-situ conservation of ecosystems and natural habitats and the maintenance and recovery of viable populations of species in their natural surroundings"* (UN, 1992). Protected areas are a fundamental tool of such conservation, contributing to the maintenance and recovery of ecosystems' reference conditions. In addition to their ecological value, protected areas have a large potential in cultural, recreational and economic terms. They protect landscapes and features which, at the local level, are often keystones to communities' culture and identity. Local communities and visitors may also explore the multiple opportunities for outdoor sports and other recreational activities in these areas, enjoying a closer contact with nature. These characteristics make protected areas relevant tourism destinations thus promoting local economy, creating employment and business opportunities (SCBD, 2008).

The International Union for Conservation of Nature defines protected area as *a "clearly defined geographical space, recognised, dedicated and managed, through legal or other effective means, to achieve the long term conservation of nature with associated ecosystem services and cultural values"* (Dudley, 2008). However, protected areas can be classified not only for the conservation of biological and ecological values but also for the protection of important geological, cultural and scenic features.

The role of protected areas in reaching sustainable development has been widely recognized by international and national organizations and currently there are more than 100.000 protected areas worldwide (IUCN, 2010). Nevertheless, these areas are insufficient to adequately shelter all ecosystems, habitats and species in need of protection (SCBD, 2004). One of the main difficulties is to ensure an effective management of these areas that can guarantee the achievement of the conservation objectives.

Challenges to planning and management of protected areas are numerous. Questions such as best configuration, priority objectives, required human and financial resources, evaluation of actions implemented, engagement of stakeholders, communication with local communities and conflicts' resolution are familiar problems to those dealing with the implementation and management of protected areas (Fonseca *et al.*, 2011). In addition, the lack of available information, biophysical changes and socio-economic pressures require adaptive approaches and solutions tailored to the needs of the ecological, geological, cultural and landscape heritages at stake.

Small islands' particular characteristics (namely their isolation, limited physical space and natural resources, closed systems, endemism, terrestrial/marine ecosystems linkages) add specific problems in terms of nature conservation. At the same time, economic and social development is a major concern in territories with small economies, seriously dependent on external markets, high transport costs and small populations (Hassan *et al.*, 2005). In this context, protected areas classification, planning and management is just as essential as demanding.

Currently, small islands are in the international spotlight with 2014 declared by the United Nations as the International Year of Small Island Developing States, trying to raise awareness on the unique value and challenges of these territories. Coinciding with this initiative, the International Day for Biological Diversity 2014 was dedicated to island biodiversity. Islands are considered biodiversity hotspots by harbouring a high number of endemic species in small areas (Hassan *et al.*, 2005; Deidun, 2010). Insular ecosystems are particularly vulnerable and in need of protection, however conservation measures may conflict with local communities' expectations and land uses thus requiring special attention in terms of planning and management (Fonseca *et al.*, 2011).

This article aims to provide a framework overview regarding management of specific natural values on islands ecosystems. The main focus will be protected areas in small islands, as they represent a global tool and solution for Nature Conservation.

2. ISLANDS: SMALL TERRITORIES, BIG CHALLENGES

Throughout the History small islands have been extremely relevant on civilization development and international trading organization. As known, first civilizations were fluvial (as Mesopotamia, dependent on the Tigre and Euphrates, and Ancient Egypt, subordinated to Nile) being relatively scarce the use of the marine environment. However, it was on those ancient times that, more or less sporadically, first steps were taken to establish trading with distant regions using the sea. However, intensive use of the sea for communication between far lands only emerged about five thousand years ago with the development of the Minoan civilization, on the island of Crete, on the Oriental Mediterranean. As usual, this was no coincidence. On its origin there were several factors, such as the island morphology, the scarcity of agricultural productive soils, the shaped accident littoral that enclosures several natural ports and the richness of marine resources that led to the development of fisheries, shipping architecture and navigation skills (*e.g.*, Braudel, 1998; Dias, 2004).

Being familiar with the sea and having acquired good navigation skills, it is not surprising that the Minoan civilization had rapidly became the first world thalassocracy (*thalassa* = sea; *kratia* = power), the first success civilization deeply dependent from the sea. On the first half of the second millennium they dominated the entire maritime trading on the Oriental Mediterranean Region, being the link between the other regional civilizations. They were succeeded by the Mycenaean on the second half of the second millennium b.C. (who also had Crete as base), by the Phoenicians, the

Ionians and the Dorians (already on the first half of the first millennium b.C). In fact, all the maritime trading and connection links between the different civilizations that were going to shape the entire Occidental History had its origins in that small island of Crete.

Due to their specific characteristics (namely the location on ocean context), small islands have always been connected, somehow, to civilization development. As an example, one can point out the importance of the islands of Madeira, Canary, Azores and Cape Verde on the Portuguese maritime expansion (and the Iberia in general) lead to what has been considered as the first globalization. Small Oceanic Islands served (and still serve today) has essential support points for the international maritime trading. However, in most cases, the habitable space available is scarce (they are mostly steep slopes and mountains) with poor undevelopable soils (mostly rock). Until the second half of the XX century, these small islands fulfilled their role as supporting spots for navigation and international trading. The population surplus allied to isolation and difficult living conditions (and often natural disasters) originated intense migration fluxes that disperse throughout the world, as verified in Madeira, Azores and Cape Verde. However, those same natural conditions that inhibited the development of great urban centres and promoted emigration also ended to protect small islands from environmental predatory actions. It's a reason to say that *clouds do have silver linings***.** Even with the consolidation of mass tourism, that seeks essentially sun and beach, small islands have remained, in general, relatively immune to negative environmental actions normally associated with that activity (extensive touristic resorts, deeply altered coastal ecosystems, etc)

The Industrial development consequences, the establishment of a global economy, the adoption of a highly consumptive model and the littoral allocation of societies and activities all around the world lead to the overcome of resilience limits on the larger part of our coastal ecosystems. On this highly worrying picture, some small islands still stand as environmental sanctuaries where often pristine ecosystems can be found.

Islands are particular territories, 'pieces' of land bounded by the sea and frequently isolated in relation to mainland, which can be perceived as self-contained systems. However they are strongly influenced by the surrounding ocean and atmosphere, and interaction processes may be established with adjacent islands and continental land areas (Cambers *et al.*, 2001). Islands characteristics turn these systems into natural laboratories for biogeography and ecology studies and other related disciplines (Whittaker & Fernández-Palacios, 2007). It was the analysis on the finches of the Galapagos Islands that pushed Darwin's theory of evolution a step further by linking origin with differences. Darwin carried other studies on island systems, namely geological works (Darwin, 1844) and studies on coral reefs found in the open sea and close to islands (Darwin, 1842).

The social, economic and political challenges posed by insular contexts have also been widely studied, particularly in what regards small islands territories (UNEP, 2013) Their isolation, small size and limited natural resources determine their socio-economic conditions, translated in small economies of limited diversification, constraints on transport and communication, small populations prone to outmigration and lack of qualified personnel (Hassan *et al.*, 2005; Baldacchino & Niles, 2011).

Within the context of sustainable development, the international community recognized the unique challenges of Small Islands Developing States (SIDS) at the UN Conference on Environment and Development (1992). Chapter 17 of Agenda 21 includes a programme area on the sustainable development of small islands, further developed by the Barbados Programme of Action (BPOA, 1994). This instrument highlights the special challenges and constraints that have resulted in major setbacks for the socio-economic development of those States and translates Agenda 21 into specific actions and measures (UN, 2010).

Currently, the United Nations Department of Economic and Social Affairs lists 51 SIDS, including territories as diverse as Cape Verde, Cuba, Singapore and East Timor (UNDESA, 2014). However, according to the Commission on Sustainable Development (CSD), SIDS share remoteness, susceptibility to natural disasters, few and reduced resources, small populations, dependence on international trade and vulnerability to global developments, lack of economies of scale, high transportation and communication costs, and costly public administration and infrastructure. They also share some of the most fragile and vulnerable resources on the planet – their sheer beauty, unmatched opportunities for recreation and tourism, unique and exceptional biodiversity and remarkable human cultures (Bush *et al.*, 2008; UNEP, 2014).

The economies of most small islands have a limited resource basis, resulting in an excessive dependence on international trade and higher vulnerability to external forces, such as economic liberalization and migration flows (Mimura *et al.*, 2007). On the other hand, their geographic remoteness and dispersion place them at a disadvantage economically, as they are isolated from markets, thus reducing competitiveness (UNDESA, 2014).

2.1. Human activities and environmental issues

Small islands represent some of the most vulnerable regions in the world in what concerns intensity and frequency of natural and environmental disasters, as well as their increasing impacts, with high economic, social and environmental consequences (UNDESA, 2014).The geographical framework of small islands, as well as their morphological and ecological characteristics, leads to a higher vulnerability to certain threats and phenomena such as climate variability and changes, proliferation of invasive exotic species, natural catastrophes and overexploitation of natural resources (Rietbergen *et al.*, 2008), coastal erosion and landward seawater intrusion (Vivero, 1995).

Considering the specificities of small islands, the Millennium Ecosystem Assessment (2005) highlights the following environmental problems:

- scarce and vulnerable water resources: fresh water sources are limited to surface reservoirs and groundwater aquifers, highly dependent on rainfall, varying with the geographic location and the climate

of the island. Its scarcity and increasing demand make these resources more vulnerable to sea level changes, problems of overpumping of ground water (and consequent salination) and contamination through leaching of soil residues, pesticides and fertilizers;
- sensitive species: high number of endemic species, species with low competitive ability, limited distribution and small populations, with lower adaptive capacity and consequent tendency to extinction phenomena;
- vulnerability to invasive species: invasive species may compete directly or indirectly with native species and alter ecological processes, faster and in a more pronounced way than in mainland territories, thus causing serious ecological and economic damage, with high social costs.

In addition to these issues, economic and social particularities create other pressures on the ecosystems. On most islands, especially small oceanic islands, fishing has always represented an essential source of animal protein and an important economic activity. The constant demand associated with new fishing techniques puts into question the sustainability of this activity and the maintenance of stocks, already threatened by natural hazards and pollution.

The conversion of forested areas into agriculture or construction areas may jeopardize the sustainability of island systems, considering the crucial role of forests as regulators of hydrological cycles. Moreover, forests provide relevant products, food, wood, animal products and important protection services against natural and anthropogenic hazards.

With limited resources, many small islands developed in external dependence on fossil fuels. This dependency entails not only economic problems but also issues of pollution, demand for space and unsustainability. However, islands usually have renewable energy resources. The challenge lies in reconciling the exploitation of these resources with conservation objectives.

Tourism constitutes an important economical sector often dominant in small islands economy. The remarkable natural and cultural assets found in small islands can be major attractions for tourists and protected areas offer unique opportunities for visitors (Tisdell & Wilson, 2012). Historic, architectural and archaeological features commonly found in protected areas enrich tourists' experiences while contributing to preserve and promote local traditions (Eagles *et al.*, 2002). The growing importance of nature tourism surely is a positive factor, with a huge potential for biodiversity conservation and to promote sustainable use of natural resources. However, tourism development must be carefully planned and managed to avoid the degradation and destruction of natural and cultural heritage.

Tourism as all other human activities such as agriculture, industry and construction, are a growing source of pollution all over the world. On small islands, the problem may be even more severe given the limited resources available for the treatment and disposal of waste and pollutants and the vulnerability of their ecosystems (Hassan *et al.*, 2005).

2.2. Coastal Zones

Islands are strongly influenced by the surrounding ocean and atmosphere and their large ratios of coastline lengths to land area determine highly coupled terrestrial and marine ecosystems. In such conditions the impacts of natural and anthropogenic changes can be immediately visible (Millennium Ecosystem Assessment, 2005).

Coastal zone includes the terrestrial surface as far as tides, waves or winds reach and have an influence, and that is under the direct influence of sea activity (Veloso-Gomes *et al.*, 2008). The Protocol on Integrated Coastal Zone Management in the Mediterranean reiterates this approach (2009): *"coastal zone means the geomorphologic area either side of the seashore in which the interaction between the marine and land parts occurs in the form of complex ecological and resource systems made up of biotic and abiotic components coexisting and interacting with human communities and relevant socioeconomic activities"*. Therefore, from an environmental impact perspective, small islands can be considered as being in its entirety coastal zones, and there is an immediate and direct impact of terrestrial socioeconomic activities on the marine environment (Pantin, 1994), as well as the opposite, as consequences of changes in the marine environment affect islands terrestrial territory.

Coastal zone in small islands is vital due to limited land availability and ocean exposure on all sides. It accommodates the majority of the population, supplies the majority of food and raw materials, it is a vital link for transportation, trade and communication with the outside world and it is a favourite destination for local people and tourists. It is therefore imperative to address unique coastal concerns of small islands, and to protect coastal environments while improving living standards within coastal communities (Calado *et al.*, 2011; Calado *et al.*, 2007).

The coastal vulnerability of island systems (particularly oceanic islands) results of the exposure of their extensive coastal areas to natural phenomena and dynamics, together with the inadequate infrastructures' development in the coastal zone, which may lead to serious problems of coastal erosion. In such conditions, the adverse effects of climate change and sea-level rise constitute high risks to the sustainable development of small islands (UNDESA, 2014). Climate change impacts will affect not only coastal communities but also important areas for conservation, considering the preponderance and relevance of coastal habitats on islands (Deidun, 2010).

Anthropological pressures are also a recognized threat to coastal and marine biodiversity, which has prompted intervention measures on behalf of environmental protection to ensure sustainability. Such measures try to restrict and prevent impacts of human and natural pressures on coastal and marine ecosystems and to assure a sustainable use of coastal and marine ecosystems. Coastal zone management plans and marine protected areas can play an important role in the conservation and sustainable use of such resources.

Natural resources, such as water, soil, air, shore systems and wildlife, can constitute important limits to the island' sustainable development depending on their level of exploitation, which can menace the ecosystem's functions.

Once destroyed these resources will hardly be restored due to the small capacity of these closed systems to recover (Goldsmith, 1991).

Islands systems represent one of the most pressing issues of our time: how to balance ecological integrity, economic development and collective wellbeing, illustrating the paradigm of sustainable development (Baldacchino & Niles, 2011). The main question is how to reconcile the need for space and resources for society and for conservation.

3. ISLANDS CONSERVATION: NEEDS AND TOOLS

Islands, and in particular oceanic islands, have been renowned for their extraordinary biota since Darwin studies and have, from then on, inspired scientists for the study of evolution, biogeography, ecology, and geology. In fact, ecology of island ecosystems is vastly different from that of mainland communities. Present-day islands' biotic assemblage's composition and functioning have been shaped by biogeographical, ecological and evolutionary processes dependent upon area, connectivity and isolation. Consequently they show particular patterns of colonization, adaptation, and speciation.

When islands emerge, ecological succession occurs as species that colonize the island by change events are prevented to leave due to isolation. High dispersal abilities are more likely to overcome distance which determines that plants, birds and certain insects are much more common on islands than poorly dispersing taxa like mammals. From the few new arrivals only some will be able to survive and establish populations. As a result, islands have fewer species than mainland habitats. Island populations are small, exhibit low genetic variability and are isolated from the predators and competitors that they initially evolved with. These new conditions provide opportunities to develop new strategies and adaptations. Different ecological pressures have dictated that some species become much more docile, may grow larger (island gigantism) or smaller (island dwarfism) Some of these unique adaptations are reflected in charismatic island species as Galapagos giant tortoise or komodo dragon. A high occurrence of endemism, where species are unique to a localized area, is also a consequence of this new environmental setting which acts upon the small genetic pool of the few successfully inbreeding colonizers thus resulting in the long run in a unique endemic species.

Oceanic islands, often rising from the deep ocean floor by volcanic activity, thus constitute favorable settings for speciation resulting in a remarkable high ratio of endemism when enough time has elapsed for selection processes to act upon first colonizers. Therefore age of the islands is an important factor to consider when addressing island biodiversity, also because older islands represent high probabilities for successful colonization by different organisms and a longer period for natural selection to take place. As result of their particular evolution processes, islands´ ecosystems contribute to biodiversity disproportionately to their land area. Although islands constitute 3% of the land surface of the world, one in six of the earth's known plant species occur on oceanic islands (Fisher, 2004) which comprise 30% of the world's biodiversity hotspots, representing 50% of marine tropical diversity with some unique and rare species (Myers *et al.,* 2000; Bellard *et al.,* 2014).

Island ecosystems are characterized by species scarcity, meaning fewer species per unit area than mainland, disharmonic assemblages as they tend to have a different balance of species compared to equivalent areas of mainland and this is enhanced with increasing isolation. These small populations, lower species numbers and simple ecosystem functioning represent increased vulnerability of islands biota both to natural disasters, such as hurricanes and earthquakes, and to human pressures like habitat destruction or pollution, due to their lower resilience when compared to mainland systems.

Island ecosystems have faced devastating effects of human colonization that has caused a high degree of extinction in the past and poses several severe threats in the present related to invasive species, climate change, natural and environmental disasters, land degradation and marine pollution.

Island conservation has become a vital international concern as islands display simple ecosystems, while providing natural laboratories to study evolution processes in action that can be extrapolated to larger ecosystems. Representing a microcosmos of the processes of threat and extinction in larger ecosystems, islands may also provide insights into effective management approaches.

3.1. Protected areas management

As already mentioned protected areas play a key role in the conservation of threatened natural and cultural heritages, especially if properly managed. However, protected areas management entails a difficult balance between different objectives. Although conservation is the underlying objective, the successful management of these areas cannot forget the funding requirements of conservation actions neither the need to ensure the sustainability and well-being of local communities. To protect the natural values while ensuring opportunities for socio-economic development can be even more complex in island systems, where space is extremely limited and natural resources cannot be separated from the human activities. In such exiguous territories the classification of protected areas and the restrictions imposed will, most likely, conflict with populations' expectations and land uses (both inside and near these areas). In effect, protected areas are not isolated from their surroundings and therefore those involved in the management of protected areas or in any way likely to be affected by management decisions should be included in the decision-making process (Alexander, 2008). According to the IUCN Guidelines for management planning of protected areas (Thomas & Middleton, 2003) the main benefits of involving stakeholders in management planning are: increased sense of ownership, greater public involvement in decision-making and closer links between conservation and development. This promotes communication that allows problems' identification and resolution (Gil *et al.*, 2011). Furthermore, local stakeholders may contribute in different ways to the management of protected areas through local knowledge and traditional expertise (Alexander, 2008).

In addition to participative mechanisms, protected areas management must have into consideration the different dynamics of the system, be prepared to accommodate (unforeseen) changes and deal with uncertainty. In the particular case of natural resources' management, uncertainty may arise from the following issues (Allen *et al.*, 2011; Williams, 2011):

i. Natural resources (ecosystems) are modified naturally over time through dynamic and not fully known processes;

ii. Environmental variation is only partially predictable and often uncontrollable, inducing stochastic processes (e.g. climate variability);

iii. The actual state of resources and systems is often unknown, in part because monitoring methodologies only allow partial observability (sampling variation);

iv. The results of management interventions are not always properly assessed and such actions may change the system state, directly or indirectly, deliberately or not.

Some authors argue that the most appropriate approach to deal with the complexity of socio-ecological systems and inherent uncertainty is an iterative process of decision making and learning, adjustable as change occur and its effects are understood (Allen *et al.*, 2011; Williams, 2011). Such process of adaptive management seeks to promote a proactive attitude and a continuous adaptation to new conditions and needs, only possible if supported by mechanisms for monitoring and evaluation.

All the challenges discussed warrant international attention and action on these matters. For example, in 2004 the Convention on Biological Diversity adopted a specific program of work on protected areas to support the establishment and maintenance of comprehensive, effectively managed and ecological representative national and regional systems of protected areas. One of the goals established by the program of work was the effective management of all protected areas, in particular through the development of management plans (SCBD, 2004).

The World Heritage Convention (1972) has developed also operational guidelines for the implementation of the Convention (revised in 2012) in which advocates appropriate management plans for the nominated properties which often coincide, at least partially, with protected areas.

At the European level, article 6 of Habitats Directive (1992) request Member States to establish the necessary conservation measures involving, if need be, appropriate management plans specifically designed for the sites of community importance. As Natura 2000, the resulting European network of nature protection areas, is implemented at a national level by Member States, management plans can be an essential tool for achieving the conservation goals.

A management plan is a tool to guide managers and other interested parties so that they might follow a logical decision-making process both today and in the future (Rowell, 2009). In the specific context of protected areas it can be understood as a working document that guides and facilitates the management of protected area resources, controls the uses of the area and promotes the development of necessary infrastructures (Thomas & Middleton, 2003).

The first management plans for protected areas were developed by scientists, presenting a solid characterization of the area but lacking similar quality in business and organizational aspects such as costs, resources and results (RSPB, 2009). However, as practitioners struggled with implementation increasing attention has been paid to these aspects. The International Union for Conservation of Nature, for example, has developed the Best Practice Protected Area Guidelines series which includes publications on management planning, economic values, financing, sustainable tourism and effectiveness evaluation.

Although these guidelines for management planning of protected areas are not specific for island systems they are as important in these territories. Standard land use planning instruments, based only on systems for the control and zoning of uses and activities, have failed to fully promote the active management and conservation of protected areas (and Natura 2000 sites). Protected areas demand the highest possible levels of strategy, planning and activity programming. They further require managers to proceed with the utmost transparency and rigor while sharing management responsibilities, looking for the optimal utilization of human, technical, technological and financial resources of each of the stakeholders (Gil *et al.*, 2011).

Strategic planning on important environmental areas demands a strong involvement from citizens or the ones that depend of these areas. Stakeholders must be involved in all stages of the process, namely in the definition of the protected area's mission, vision for the future and goals. This process can succeed in unifying most of the divergent interests of public and private stakeholders by involving them directly in plan's conception and development. Protected Areas management can be more cost-effective when resulting from participation and co-responsibility of relevant stakeholders, distributing specific management actions among stakeholders that can be incorporated into their own annual activities schedules.

CONCLUSION

Small Islands constitute a peculiar geographic entity. Diverse on their origins, locations and biophysical expressions they share common challenges and constraints. In general, oceanic islands are limited in space and isolated or remote. However, these conditions that limit their development patterns also dictate special biological and ecosystems features, with islands often being natural sanctuaries and presenting pristine conditions.

Natural resources, in general scarce, sensitive and vulnerable need special attention and management solutions in order to support islands development and to preserve good environmental conditions. Also, special attention must be paid to the unique living environments for some species worldwide.

All these challenges demand new debates and new strategic approaches to achieve sustainable development and environmental protection. While area-based management solutions like protected areas remain as the most efficient tool for this purpose their management needs to take into account the specificities of island territories. Instead of a conservation strategy focused only on species protection or areas/habitats management, a truly integrated approach must be adopted, contributing to the sustainable development of the protected area and, ultimately, of the entire island. The compatibility and integration of the protected areas management with the planning system of the island must also be guaranteed, reflecting the effects of the planning policies and territorial management actions.

Such management strategy depends heavily on community-based solutions, strong public participation and stakeholders commitment in management actions implementation.

ACKNOWLEDGMENTS

The authors would like to thank Fundação para a Ciência e Tecnologia (FCT) for funding the Project SMARTPARKS – Planning and Management System for Small Islands Protected Areas (PTDC/AAC-AMB/098786/2008).

The authors would like to thank Prof. António Frias Martins from CIBIO-Azores for his precious advices on islands environment.

REFERENCES

Alexander, M. (2008) - *Management planning for nature conservation: a theoretical basis and practical guide*. 426p., Springer, Dordrecht, The Netherlands. ISBN: 978-1402065811.

Allen, Craig R.; Fontaine, oseph J.; Pope, Kevin L.; Garmestani, Ahjond S. (2011) - Adaptive management for a turbulent future". *Journal of Environmental Management*, 92:1339-1345. DOI: 10.1016/j.jenvman.2010.11.019

Baldacchino, G & Niles, D. (eds.) (2011) - *Island Futures: Conservation and Development Across the Asia-Pacific Region*. 183p., Springer, Tokyo, Japan. ISBN: 978-4431539896.

Bellard, C.; Leclerc, C.; Courchamp, F. (2014) - Impact of sea level rise on the 10 insular biodiversity hotspots. *Global Ecology and Biogeography,* 23(2):203–212 DOI: 10.1111/geb.12093

Beller, W.; D'Ayala, P; Hein, P. (eds.). (2004) - *Sustainable Development and Environmental Management of Small Islands*. (Vol. 5) 419p., UNESCO and The Parthenon Publishing Group, Paris, France. Available on-line at http://pubs.iied.org/pdfs/7755IIED.pdf

BPOA (1994) - *Report of the global conference on the sustainable development of small island developing states*. Global Conference on the Sustainable Development of Small Island Developing States, United Nations General Assembly A/CONF.167/9. Available on-line at http://www.un.org/esa/dsd/dsd_aofw_sids/sids_pdfs/BPOA.pdf

Braudel, Fernand (1998) - *Les mémoires de la Méditerranée*. 399p., de Fallois, Paris, France. ISBN: 978-2877063043

Bush, T.; Purvis, M.; Barallon, L. (2008) - Leadership Development in Small Islands States. *In:* Lumby, J.; Crow, G.; Pashiardis, P. (eds.), *International Handbook on the Preparation and Development of School Leaders*. pp. 452-464, Taylor and Francis,UK. ISBN: 978-0805863871.

Calado, H.; Borges, P.; Phillips, M.; Ng, K.; Alves, F. (2011) - The Azores archipelago, Portugal: improved understanding of small island coastal hazards and mitigation measures. *Natural Hazards*, 58(1):427–444. DOI: 10.1007/s11069-010-9676-5

Calado, H.; Quintela A.; Porteiro, J. (2007) - Integrated Coastal Zone Management Strategies on Small Islands. *Journal of Coastal Research* (ISSN: 0749-0208), SI50:125-129, Gold Coast, Australia.

Cambers, G.; Mühlig-Hofmann, A.; Troost, D.G. (2001) - Inter-regional initiatives for sustainable small-island development. *Proceedings of the Global Conference on Oceans and Coasts at Rio + 10*. UNESCO, Paris. Available on-line at http://www.unesco.org/csi/smis/smisrio10.htm

Darwin, C. (1842) - *The structure and distribution of coral reefs*. 230p., Smith, Elder and Co., London, U.K. . Available online at http://books.google.pt/books?id=qLsQAAAAIAAJ&printsec=frontcover&dq=intitle:coral+intitle:reefs+inauthor:Darwin&hl=pt-PT&sa=X&ei=j-OYU6OPBNSu7Abs1oHgBQ&ved=0CB8Q6AEwAA#v=onepage&q&f=false

Darwin, C. (1844) - *Geological Observations on the Volcanic Islands, Visited During the Voyage of H.M.S. Beagle*. 175p., Smith, Elder and Co., London, U.K. Available online at https://archive.org/details/geologicalobser01darwgoog

Deidun, A. (2010) - Challenges to the Conservation of Biodiversity on Small Islands: the Case of the Maltese Islands. *International Journal of Arts and Sciences* (ISSN: 1944-6934), 3(8):175-187.

Dias, J.A. (2004) - *A Conquista do Planeta Azul: o início do reconhecimento do oceano e do mundo*. 47p., Universidade do Algarve, Faro, Portugal. Available on-line at http://w3.ualg.pt/~jdias/JAD/eb_CPAzul.html

Dias, J.A.; Carmo, J.A.; Polette, M. (2010) - Brief remarks on the islands and its management / Breves considerações sobre as ilhas e a sua gestão. *Revista de Gestão Costeira Integrada*, 10(3):243-253. DOI: 10.5894/rgci237

Eagles, Paul F.J.; McCool, Stephen F.; Haynes, Christopher D.A. (2002) - *Sustainable Tourism in Protected Areas: Guidelines for Planning and Management*. 183p., IUCN – The World Conservation Union, Gland, Switzerland / Cambridge, UK. ISBN: 2831706483. Available on-line at http://cmsdata.iucn.org/downloads/pag_008.pdf

European Union (2009) - Protocol on Integrated Coastal Zone Management in the Mediterranean. *Journal of the European Union*, L 34/19-34/28, 4.2.2009. Available on line at http://ec.europa.eu/world/agreements/downloadFile.do?fullText=yes&treatyTransId=12967

Fisher E. (2004) - Island ecosystems conservation and sustainable use: problems and challenges. *INSULA - the International Journal of Island Affairs*, Special Issue on Island Biodiversity, February, pp. 9–14.

Fonseca, C.; Calado, H.; Silva C.P.; Gil, A. (2011) - New approaches to environment conservation and sustainability in Small Islands: The Project SMARTPARKS. *Journal of Coastal Research* (ISSN: 0749-0208), SI64:1970-1974, Poland. Available online at http://www.ics2011.pl/artic/SP64_1970-1974_C. Fonseca.pdf

Gil A.; Calado H.; Costa L.T.; Bentz J.; Fonseca C.; Lobo A.; Vergílio M.; Benedicto J. (2011) - A Methodological Proposal for the Development of Natura 2000 Sites Management Plans. *Journal of Coastal Research* (ISSN: 0749-0208), SI64:1326-1330, Szczecin, Poland.

Goldsmith, F. (eds.) (1991) - *Monitoring for Conservation and Ecology*. 275p., Chapman & Hall, London, UK. ISBN: 978-0412356001.

Hassan, R.; Scholes, R.; Ash, N. (eds.) (2005) - *Ecosystems and Human Well-being: Current State and Trends*. Volume 1, 23p., Millennium Ecosystem Assessment, Island Press, Washington, D.C., U.S.A. ISBN: 1559632283. Available on-line at http://www.millenniumassessment.org/documents/document.766.aspx.pdf

IUCN WCPA (2010) - *50 Years of Working for Protected Areas - A brief history of IUCN World Commission on Protected Areas*. 23p., Gland, Switzerland. Available online at http://cmsdata.iucn.org/downloads/history_wcpa_15july_web_version_1.pdf

Mimura, N.; Nurse, L.; Mclean, R.; Agard, J.; Briguglio, L.; Lefale, P.; Payet, R.; Sem, G. (2007) - Small Islands. Climate Change 2007: Impacts, Adaptation and Vulnerability. *In:* M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden & C.E. Hanson, (eds.), *Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, pp.687−716, Cambridge University Press, Cambridge, U.K. Available online at http://www.ipcc.ch/pdf/assessment-report/ar4/wg2/ar4-wg2-chapter16.pdf

Myers, N.; Mittermeier, R.; Mittermeier, C.; da Fonseca, G.; Kent, J. (2000) - Biodiversity hotspots for conservation priorities. *Nature*, *403*(6772):853–858. DOI: 10.1038/35002501

Pantin, D. (1994) - *The Economics of Sustainable Development in Small Caribbean Islands*. University of the West Indies Press, Trinidad and Tobago. Available on line at http://gtuwi.tripod.com/chapter_2_-_the_economics_of_sustainable_development_in_small_caribbean_islands.htm

Rietbergen, S.; Hammond, T.; Sayehg, C.; Mooney, K. (2008) - *Island voices - island choices: developing strategies for living with rapid ecosystem change in small islands*. 40p., Ecosystem management series, 6th Ed. IUCN. *ISBN:* 978-2831710303. Available online at https://portals.iucn.org/library/efiles/edocs/CEM-006.pdf

Rowell, T. (2009) - Management planning guidance for protected sites in the UK: a comparison of decision-making processes in nine guides. *Journal for Nature Conservation*, 17(3):168-180. DOI: 10.1016/j.jnc.2009.03.002.

RSPB (2009) - *Generic Site Management Planning Format and Guidance Notes*. 170p., Sandy, Royal Society for the Protection of Birds (RSPB), London, UK.

SCBD (2004) - *Programme of Work on Protected Areas (CBD Programmes of Work)*. 31p., Secretariat of the Convention on Biological Diversity (SCBD), Montreal, QC, Canada. ISBN: 9292250264. Available online at https://www.cbd.int/doc/publications/pa-text-en.pdf

SCBD (2008) - *Protected Areas in Today's World: Their Values and Benefits for the Welfare of the Planet*. 96p., Secretariat of the Convention on Biological Diversity (SCBD), Montreal, QC, Canada. Available online at http://www.cbd.int/doc/publications/cbd-ts-36-en.pdf

Thomas, L.; Middleton, J. (2003) - *Guidelines for Management Planning of Protected Areas*. 79p., IUCN, Gland, Switzerland / Cambridge, UK. ISBN: 2831706734. Available online at https://portals.iucn.org/library/efiles/edocs/PAG-010.pdf

Tisdell, C.; Wilson, C. (2012) - *Nature-based Tourism and Conservation: New Economic Insights and Case Studies*. 520p., Edward Elgar Publishing Limited, UK / USA.

UN (1992) - *Convention on Biological Diversity*. *In: Treaty Collection*, United Nations (UN) Web site. Available on-line at https://treaties.un.org/doc/Treaties/1992/06/19920605%2008-44%20PM/Ch_XXVII_08p.pdf

UN (2010) - *Five-year review of the Mauritius Strategy for the Further Implementation of the Programme of Action for the Sustainable Development of Small Island Developing States*. Report of the Secretary-General [A/65/115], United Nations, General Assembly, New York, NY, U.S.A. Available online at http://www.un.org/en/ga/search/view_doc.asp?symbol=A/65/115.

UNDESA (2014) - Small Island Developing States. *In: Sustainable Development – Knowledge Platform*. Available online at http://sustainabledevelopment.un.org/index.php?menu=203

UNEP (2013) - *Identifying Emerging Issues from the Perspective of the Small Island Developing States*. 42p., Outcome of the UNEP-UNDESA Workshop on SIDS Emerging Issues, Cambridge, U.K. Available online at http://sustainabledevelopment.un.org/content/documents/1880sidsegm2.pdf

UNEP (2014) - *Small Islands. Regional Seas Programme*. UNEP - United Nations Environment Programme web site. Available online at http://www.unep.org/regionalseas/issues/smallislands/default.asp

Veloso-Gomes, F.; Barroco, A.; Pereira, A.; Reis, C.; Calado, H.; Ferreira, J.; Freitas, M; Biscoito, M. (2008) - Basis for a national strategy for integrated coastal zone management in Portugal. *Journal of Coastal Conservation*, 12(1):3-9. DOI 10.1007/s11852-008-0017-8.

Vivero, J. (1995) - Atlantic archipelagic regions: self-government and ocean management in the Azores, Madeira and Canary Islands. *Ocean & Coastal Management,* 27(1–2):47–71. DOI: 10.1016/0964-5691(95)00028-3.

Whittaker, R.; Fernández-Palacios, J. (2007) - *Island Biogeography: ecology, evolution, and conservation*. 416p., 2nd edition, Oxford University Press, New York. ISBN: 978-0198566120.

Williams, B. (2011) - Adaptive management of natural resources – framework and issues. *Journal of Environmental Management*, 92(5):1346-1353. DOI: 10.1016/j.jenvman.2010.10.041.

Revista da Gestão Costeira Integrada 14(2):175-184 (2014)
Journal of Integrated Coastal Zone Management 14(2):175-184 (2014)

ASSOCIAÇÃO PORTUGUESA DOS RECURSOS HÍDRICOS · UNIVALI · GESTÃO COSTEIRA INTEGRADA *Journal of Integrated Coastal Zone Management* · CIMA · Labomar

http://www.aprh.pt/rgci/pdf/rgci-465_Gabriel.pdf | DOI:10.5894/rgci465

Adaptation of macroalgal indexes to evaluate the ecological quality of coastal waters in oceanic islands with subtropical influence: the Azores (Portugal) *

Adaptação de índices de macroalgas para avaliação da qualidade ecológica de águas costeiras em ilhas oceânicas com influência sub-tropical: Açores (Portugal)

Daniela Gabriel [@, 1], Joana Micael [1], Manuela I. Parente [1], Ana C. Costa [1]

ABSTRACT

Due to their sedentary characteristic and the sensibility of certain *taxa* to excessive nutrients or toxic substances, the benthic macroalgal assemblage of a given locality reflects the effects of long-term exposure to pollution. For this reason, seaweeds have been used to assess the environmental condition of coastal communities.

Since the Water Framework Directive from the European Union (WFD/EU) was launched, several ecological indexes have been developed for ecological quality assessment and monitoring. Those indexes are based on different features that can be easily observed and combined into a single value, which in turn is translated to stakeholders as an ecological status.

In the present study, four of the main indexes based on macroalgal abundance and composition were used to classify the coastal waters of the Azorean islands: the Greek EEI (Ecological Evaluation Index), the British RSL (Reduced Species List Rocky Shore Tool), the Spanish CFR (Quality of Rocky Bottoms Index) and the Portuguese MarMAT (Marine Macroalgae Assessment Tool). The metrics established in those tools were adapted to allow their application in this archipelago of subtropical influence.

All the applied indexes resulted in at least a "GOOD" ecological status for the majority of the sampled sites. The differences in metrics and efficiencies of the indexes are discussed, with the most recent tools proving to be more precise and in accordance with other indicators. The increase of different sampling sites as well as the comparison with areas more impacted by human activities is still necessary to reinforce and validate the preliminary results presented here.

Keywords: Water Framework Directive, Oceanic Islands, Ecological Quality Index, Macroalgae.

RESUMO

Devido à sua condição sedentária e à sensibilidade de certos taxa ao excesso de nutrientes ou a substâncias tóxicas, as macroalgas que ocorrem num determinado local espelham os efeitos da exposição de longa duração à poluição ou alterações de qualidade no meio. Por este motivo, as macroalgas têm sido utilizadas na avaliação das condições ambientais das comunidades costeiras, uma vez num local com impacto antropogénico, ocorre a diminuição ou desaparecimento de espécies mais sensíveis e um aumento de espécies ou abundância de macroalgas mais resistentes a ambientes poluídos.

A Directiva-Quadro da Água (DQA), estabelecida pela União Européia (2000/60/CE) para protecção das massas de águas, introduziu o conceito de "qualidade ecológica" para avaliação do estado dos ecossistemas aquáticos e do respectivo desvio relativo às condições de uma massa

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** Submission: 28 December 2013; Evaluation: 1 February 2014; Reception of revised manuscript: 3 May 2014; Accepted: 28 May 2014; Available on-line: 6 June 2014*

de água idêntica em condições pristinas. Desde o lançamento da DQA que diversos índices ecológicos com base em macroalgas têm sido propostos para a avaliação da qualidade ecológica e monitorização das águas costeiras e de transição. Estes índices têm por base diferentes factores de medição directa, e que são integrados num valor único, traduzível para o público em geral em termos de estado ecológico. Ao fornecer as condições e tendências do estado ecológico dos ecossistemas de maneira resumida, os índices podem auxiliar nos processos de decisão, planeamento e gestão.

No presente estudo, quatro dos principais índices ecológicos que utilizam a abundância e a composição das macroalgas foram empregados para classificar as águas costeiras de seis das nove ilhas Açorianas: o Índice Avaliação Ecológica (EEI, do inglês "Ecological Evaluation Index"), grego; o Índice de Lista de Espécies Reduzida (RSL, do inglês "Reduced Species List" Rocky Shore Tool), britânico; o Índice de Qualidade de Fundos Rochosos (CFR, do espanhol Índice de "Calidad de Fondos Rocosos"), espanhol; e o Índice de Avaliação de Macroalgas Marinhas (MarMAT, do inglês "Marine Macroalgae Assessment Tool"), portuguê. As métricas utilizadas nos índices escolhidos foram adaptadas para permitir a aplicação dos mesmos nos Açores, um arquipélago com uma flora marinha de forte componente de águas frias com elementos tropicais e subtropicais. Além disso, como estas ilhas apresentam uma zona entre-marés estreita devido à pequena amplitude de marés, e uma linha costeira de difícil acesso por terra, altamente exposta à ondulação, os índices foram adaptados para incluir dados da zona submersa.

Os valores obtidos variam conforme o índice utilizado, mas indicam que as águas costeiras dos Açores estão em "BOM" ou "EXCELENTE" estado ecológico. Este resultado vai ao encontro do esperado, visto que o arquipélago dos Açores se encontra isolado, no meio do Atlântico Norte, apresenta uma população de cerca de 250 mil habitantes, e não possui uma actividade industrial significativa, assemelhando-se a uma condição de referência, isto é, com reduzida interferência humana.

De maneira geral, os valores dos índices são muito semelhantes entre as ilhas, com tendência a divergirem menos quando se incluem dados de patamares submersos. Esta maior homogeneidade pode estar relacionada com o facto de se observar uma maior diversidade de habitats em mergulho e é um indicativo de que os índices são mais precisos se incluírem uma maior gama de profundidades de amostragem. Por outro lado, as leituras das zonas entre-marés estão dependentes das condições do mar, como a amplitude de maré e a altura das ondas, reforçando a necessidade de incluir os dados relativos à zona submersa.

As ilhas do Faial, São Jorge e Flores obtiveram a qualificação "EXCELENTE" nos quatro índices utilizados, enquanto o Corvo obteve excelente em três, a Graciosa em dois e o Pico apenas em um dos índices.

As diferenças nas métricas e na eficiência dos índices são discutidas, e os dados aqui apresentados reflectem a evolução dos índices ecológicos, sendo os mais recentes os de maior precisão e em acordo com outros indicadores. Este resultado está de acordo com o esperado uma vez que, a medida que são criados, os índices adaptam as métricas existentes e introduzem novos elementos aos índices anteriores. Os resultados indicam ser o MarMAT o índice mais apropriado ao presente estudo, sendo o mais coerente por não apresentar valores extremos e por incluir métricas que respondem a todas as exigências da DQA. O aumento da amostragem e respectiva replicação, bem como a comparação entre e com zonas mais sujeitas à actividade humana, serão necessários para reforçar e validar os resultados preliminares aqui apresentados.

Palavras-chave: *Directiva Quadro da Água, Ilhas Oceânicas, Índice de Qualidade Ecológica, Macroalgas.*

1. INTRODUCTION

Due to their sedentary condition, benthic macroalgae integrate the effects of long-term exposure to excessive nutrients and/or pollutants, resulting in a decrease or disappearance of more sensitive species or their substitution by more resistant or opportunistic *taxa*. For this reason, the study of macroalgal communities has been considered of great use for water quality monitoring (Marques *et al.*, 2009).

Macroalgae is largely used as bioindicators, especially in the shallow rocky bottom that represents most of the seafloor on the Azorean coastal zone. In this archipelago, as in other areas of the Atlantic (*e.g.* Bay of Biscay, Juanes *et al.*, 2008), the rocky bottom extends from the intertidal to the subtidal zone, displaying a mosaic of niches resulting from the colonization of different substrata (platforms, boulders, rockpools, crevices, etc.) by the most competitive representatives of the fauna and flora as a response to a combination of physical (tides, wave and light exposure, kind of substrate), chemical (salinity, nutrients) and biological factors (competition). These benthic habitats constitute an important part of the "coastal waters" as established by the Water Framework Directive (WFD), in the Hydrographic Region of the Azores (RH9).

Since the introduction of the "ecological quality status" (EQS) concept by the WFD (European Union (2000/60/CE)) as a concept to evaluate the status of aquatic ecosystems and their respective deviation from what would be found in pristine conditions, several ecological indexes have been created. In the case of transitional and coastal waters (up to one nautical mile), biological indexes have been proposed using macroalgal abundance and composition in evaluating and monitoring ecological conditions. Those indexes are used to illustrate and summarize the conditions and tendencies of the ecosystem ecological status, and which, when correctly applied, can help planning and decision processes. The most adequate indexes are the ones that combine various and easy to acquire features resulting in a single value that can be translated to the general public in terms of ecological status (Marques *et al.*, 2009).

Four of the main ecological indexes using macroalgae as bioindicator created for European coastal waters were tested in the Azores at six sampling sites located in different islands of the archipelago. The metrics of the different indexes were adapted according to the characteristics of the Azorean marine flora, *i.e.*, poorer than continental floras in terms of number of species (Titley & Neto, 2005) and of mixed nature with strong components of cold water floras with few tropical and subtropical elements (Neto 1997). Also taken into consideration were the different characteristics of the archipelago coastal lines that are difficultly accessed by land and highly exposed to waves.

The present work was developed to test the applicability of various ecological quality indexes using macroalgae as bioindicator in the Hydrographical Region of the Azores. The main objectives were: (1) to adapt for the Azores and to test in this archipelago previously existing ecological indexes created for other European coastal waters, and (2) to classify the coastal waters of six islands of the Azores using the adapted indexes.

2. MATERIAL AND METHODS

The Azorean archipelago, composed of nine volcanic islands and some islets, is located on the Mid-Atlantic Ridge (Figure 1), between the parallels 36º55' and 39º43' N and the meridians 24º46' and 31º16' W, and is one of the most isolated archipelagos on Earth (Borges & Gabriel, 2009). The archipelago coastal line extends to approximately 844 Km (Borges, 2003) and is composed of volcanic, mostly basal rocks (Forjaz, 1963) surrounded by very deep waters. The sandy beaches are rare but some beaches of medium-sized and small pebbles can also be found.

Located in the Northeast Atlantic, the archipelago is located in the warm temperate region, influenced by air masses with tropical, cold temperate and polar characteristics. The Gulf Stream acts on the climate, directly by the flux of warmer waters and indirectly as a barrier against the cold currents from the North (Fernandes, 1985).

The tides are semidiurnal with amplitudes lower than 2 m (Wallenstein *et al.*, 2008). The coastal line is highly exposed to the waves, with a few bays and harbors the sheltered exceptions (Neto, 1997). In the winter, the coast is subjected to violent sea storms (Neto, 1997). The seawater temperature presents a regular variation throughout the year, usually varying between 15 and 23ºC, with maximum amplitudes observed in the summer and minimum in the winter, although temperatures of 13,2º C in January and 29,4º C July have been registered (Lafon *et al.*, 2004).

The present work covers the coastal waters of six islands of the Azores, namely Flores and Corvo in the Western group, and Faial, Pico, São Jorge and Graciosa in the Central Group (Figure 1; Table 1). Sampling stations were selected on the basis of their proximity to the most significant population centers of the mentioned islands, therefore the mostly likely to be environmental disturbed. Collection campaigns were conducted during the summer, as this is the most environmental stable time of the year and the most favorable period for fieldwork on the Azorean coast.

Following the concept of reduced species list (Wells *et al.*, 2007), in each a list with the most significant species of a particular area acts as a surrogate to the full species list, a list of the most common algal species in the Azores, either in terms of occurrence throughout the year as throughout the archipelago, was produced. In the mentioned list, some species were grouped in higher *taxonomic* levels (*e.g.*, genera) or according to morphological similarity (*e.g.*, filamentous Phaeophyceae) as proposed by Neto *et al.* (2012), resulting in 37 selected *taxa*. This second reduction helped to avoid misidentifications during the surveys and reduced the time spent preserving samples in the field and specimen identification in the laboratory. The selection was done in a way that the final reduced list was in accordance with the natural proportion of green (Chlorophyta), brown (Phaeophyceae) and red algae (Rhodophyta) found in the

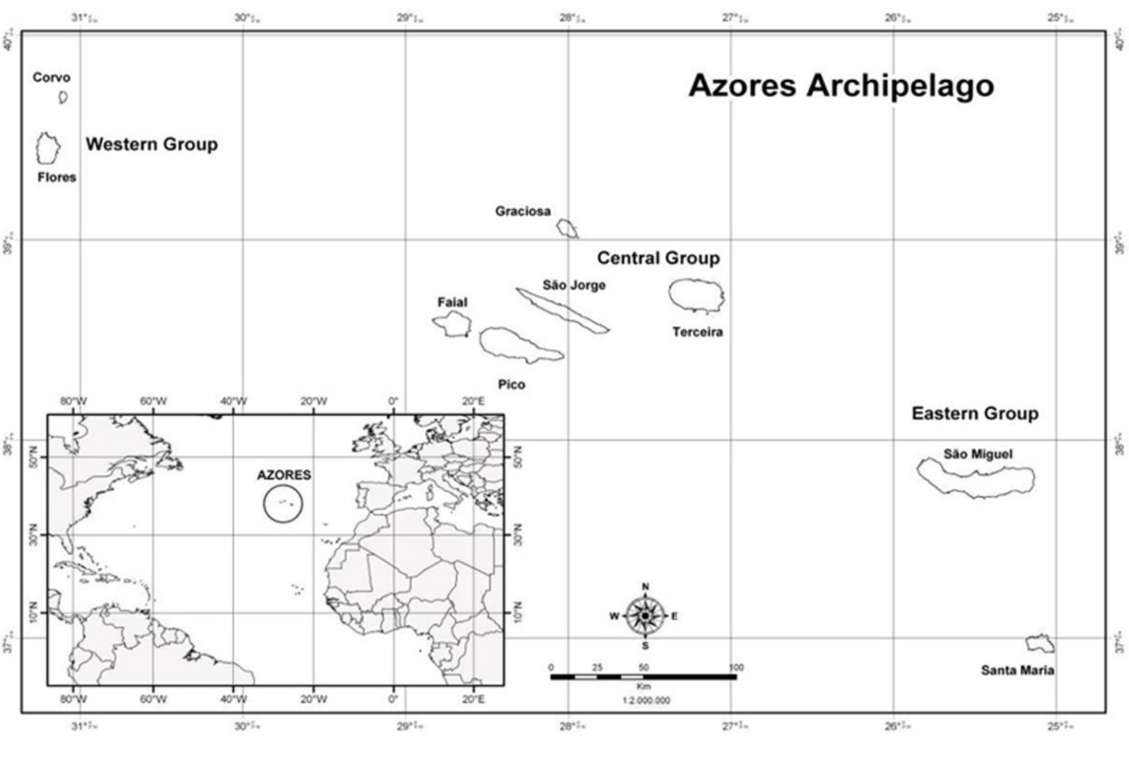

Figure 1. Geographic location of the Azores Archipelago in the North Atlantic (©Geography Section, University of Azores).
Figura 1. *Localização geográfica do Arquipélago dos Açores no Atlântico Norte (©Secção de Geografia, Universidade dos Açores).*

Table 1. Sampling station codes and coordinates.
Tabela 1. *Códigos e coordenadas dos pontos de amostragem.*

Island	Sampling Station Code	Coordinates
Pico	PIC	38°24'39" N, 028°16'24" W
Faial	FAI	38°35'48" N, 028°36'01" W
Flores	FLO	39°27'50" N, 031°07'57" W
Corvo	COR	39°40'58" N, 031°07'17" W
Graciosa	GRA	39°05'25" N, 028°00'19" W
São Jorge	SJO	38°41'24" N, 028°13'26" W

Azorean marine flora, *i.e.*, 51:62:261 (Parente 2010). This reduced list represented the basis for the selected indexes, to register the presence of the selected *taxa* and the cover of opportunistic species. The ecological status group (ESG) of each *taxon* was stipulated following the directions of Orfanidis *et al.* (2001). The macroalgae were classified as opportunists according to Wells *et al.* (2007) and Wallenstein (2011), and as invasive according to Parente (2010). This list, although reduced, was considered appropriate for the objectives of this study since Wallenstein (2011) did not observe significant differences between the use of complete and reduced species lists for the coastal classification of different islands of the Azores.

The shore description was also considered in the characterization of the studied communities since the physical nature of the substratum (*e.g.*, angle and size of the rocks) and the environmental conditions (*e.g.*, turbidity and sand scour) affect species richness and the occurrence of perennial or opportunistic *taxa* (Wells *et al.*, 2007) which in turn could interfere in the index result by inducing a wrong interpretation of such changes as a result of reduced water quality or anthropogenic influence (Ballesteros *et al.*, 2007). For that reason, these parameters were used to calibrate the indexes to the local natural conditions.

In the intertidal zone, transect readings were performed in the supralittoral, mediolittoral and infralittoral using a 25x25 cm quadrat, with 3 replicates per subdivision. In the subtidal zone, the readings were performed by scuba diving at selected depths (5, 15 and 25m), using a 50x50 cm quadrat (3 replicates per depth), following a transect of a maximum of 25 m long (depending of the sea bottom angle) and 1,5 m wide. The size of transects and quadrats, as well as the number of replicates, were chosen based on previous studies in such a way that the minimum sampling area was assured (Wallenstein *et al.*, 2009). The inclusion of subtidal readings, usually not considered in the ecological quality indexes, not only enabled the inclusion of a larger number of habitats, but also made possible to sample the sites to which there was no access from land or when the waves/tides were too high.

Besides the *in loco* identification of the presence/absence of macroalgae in the reduced species list, the coverage percentage of the invasive species was also registered in all readings. In the intertidal zone, the abundance of each macroalga was also registered using the DAFOR scale (Kent & Coker, 1992). Conspicuous algae, not included in the mentioned reduced list, were also registered.

Four ecological indexes were used in this study: the "Ecological Evaluation Index" (EEI; Orfanidis *et al.*, 2001), the "Reduced Species List" Rocky Shore Tool (RSL; Wells, 2008), Quality of Rocky Bottoms Index (CFR, from Spanish "Calidad de Fondos Rocosos"; Juanes *et al.*, 2008) and the "Marine Macroalgae Assessment Tool" (MarMAT; Neto *et al.*, 2012). The British (RSL) and the Portuguese (MarMAT) indexes were originally described for use in the intertidal zone and were also adapted in the present study to include subtidal species. On the other hand, the Spanish (CFR) and the Greek (EEI) indexes were applied only in the intertidal zone, because it was only possible to register the total algal coverage in this zone.

The "Ecological Quality Ratio" (EQR) was calculated to each index, resulting in a 0 to 1 scale, as defined by the WFD (2000/06/CE). EQR values close to 1 indicate pristine conditions while values close to 0 indicate high levels of disturbance, being translated to five classes of "Ecological Quality Status" (EQS): High, Good, Moderate, Poor and Bad.

3. RESULTS

A total of 43 *taxa* of macroalgae was observed, with Faial, the richest island in number of species, presenting 27 *taxa*. The number of red algae (Rhodophyta) was larger than the number of brown (Phaeophyceae) and green algae (Chlorophyta) in all water bodies studied, with a total of 26, 10 and 7 observed *taxa*, respectively (Figure 2). The coastal waters of Faial comprised the largest richness in Rhodophyta (14 *taxa*). The number of Phaeophyceae was largest in Graciosa, Pico and Flores (7 *taxa*). The largest number of Chlorophyta observed was 3 *taxa*, either in the islands of Pico and Faial. Pico presented the largest number of opportunist species (4 *taxa*), while the smallest number was observed in São Jorge and Graciosa, with 1 species in each.

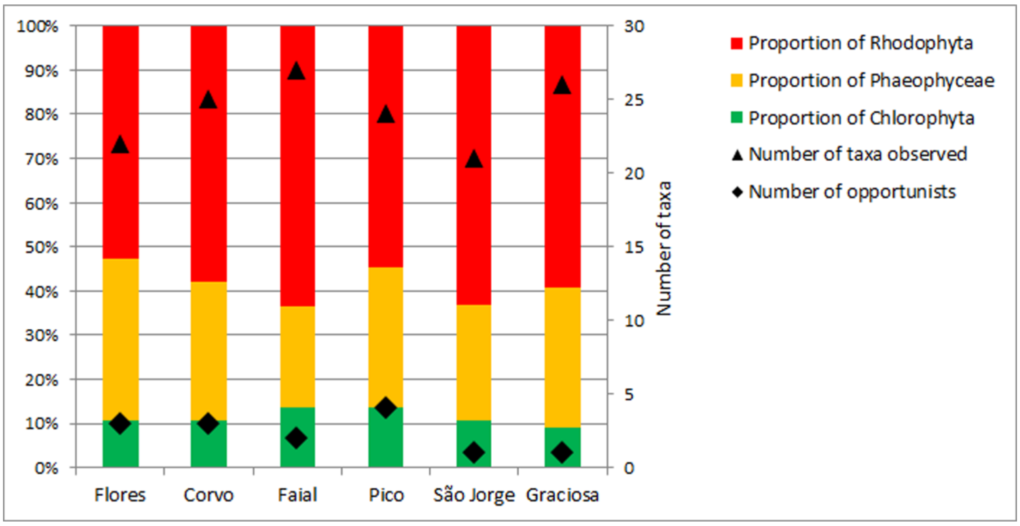

Figure 2. Species richness, proportions of Chlorophyta, Phaeophyceae and Rhodophyta and number of opportunistic algae in the respective water bodies.
Figura 2. *Riqueza específica, proporções de Clorófitas, Feofícias e Rodófitas e número de algas oportunistas nas respetivas massas de água.*

In general, the abundance of algal species was very variable among the water bodies, and composed of various rare and occasional occurring species. Nevertheless, the intertidal zone of São Jorge was dominated by articulated calcareous red algae that were also abundant in the intertidal zone of Flores and Faial. Among the frequently occurring algae, the following *taxa* stood out: crustose brown algae and calcareous red algae in Corvo; *Codium* spp. (Chlorophyta) and articulated calcareous red algae in Faial; crustose calcareous red algae and *Laurencia* spp. (Rhodophyta) in Pico; *Codium* spp. (Chlorophyta), *Hypnea* spp. (Rhodophyta) and crustose calcareous red algae in Graciosa.

The macroalgal communities were analyzed by multivariate ordination (nMDS) based on the presence of each *taxon* in the intertidal zone and in each sampled depth of the subtidal zone, for every island included in the present work. From the analysis of the species composition (qualitative data), five groups with similarity above 50% can be distinguished (Figure 3; see Table 1 for sampling sites codes). The group SJO_int/GRA_int is related with the algal community GRA_25m, which, together, forms the most dissimilar group. The group FAI_int/PIC_int/COR_int/PIC_int/FLO_int is composed of algal communities which, though somehow similar, present greater variability in their composition. The group COR_20m/COR_5m comprises all the subtidal communities observed in Corvo. At last, the largest group, SJO_25m/PIC_25m/GRA_15m/PIC_15m/FLO_5m/SJO_5m/GRA_5m/SJO_15m/FAI_25m/FLO_25m/ FAI_5m/FLO_15m/FAI_15m, suggests that there are very similar algal communities in SJO_5m and SJO_15m, as well as in FLO_15m and FLO_25m, and also in GRA_15m and PIC_15m, although the last pair is not as similar as the previous ones (Figure 3).

The application of the Ecological Evaluation Index (EEI) resulted in the maximum score of 10.00, meaning an Ecological Quality Ratio (EQR) of 1.0 for Flores and São Jorge. Therefore, these islands obtained "HIGH" Ecological Quality Status (EQS). On the other hand, Faial also achieved a very high score (0.92), with its water quality also classified as "HIGH". The coastal waters of Graciosa, Pico and Corvo reached a "GOOD" status classification.

The application of the Quality of Rocky Bottoms Index (CFR) indicates that the water bodies of São Jorge, Faial, Flores and Corvo represent maximum EQR values, meaning "HIGH" EQS. With high scores, close to upper limit of the "GOOD" status category, we can find Pico and Graciosa, with EQRs of 0.8 and 0.76, respectively.

Overall, the EQR values resulting from the application of the Reduced Species List Rocky Shore Tool (RSL) was very similar among the different islands, ranging from 0.80 in Pico to 0.88 in Corvo. Hence, all water bodies presented "HIGH" EQS, except for Pico, which is in the upper limit of the "GOOD" status category.

The application of the Marine Macroalgae Assessment Tool (MarMAT) resulted in the maximum ecological classification for all studied islands, *i.e.*, "HIGH" EQS. The EQR values showed very low variation among the different water bodies, with Faial the island with the highest value (0.94).

All results obtained by the application of the mentioned indexes can be observed in Table 2, along with the relevant data used in their calculation. In a more detailed analysis, it is possible to conclude that: (1) a larger number of opportunist *taxa* (4 species) was observed in Pico; (2) the largest coverage of opportunist algae (21.4%) was detected in Corvo; (3) the most predominant group of algae in the Rhodophyta

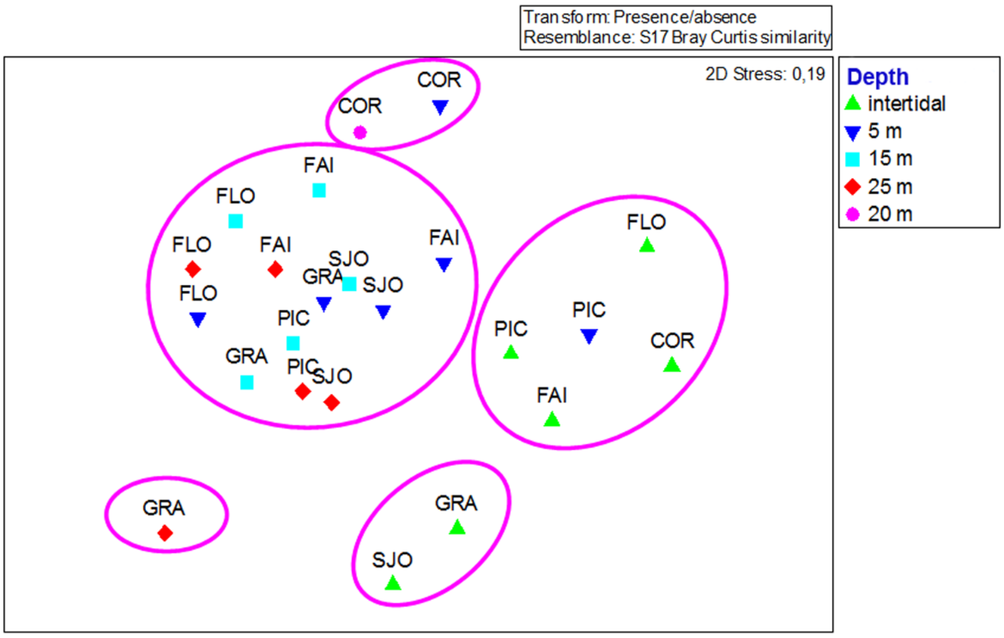

Figure 3. nMDS ordination of the algal communities from different islands (Bray-Curtis, on presence/absence matrix of species). Grouping of Cluster analysis with 50% similarity. See Table 1 for sampling stations codes.

Figura 3. *Ordenação nMDS das comunidades algais das diferentes ilhas (Bray-Curtis, sobre matrizes de presença/ausência de espécies). Agrupamentos da análise de Cluster a similaridade 50. Ver Tabela 1 para os códigos dos pontos de amostragem.*

with percentage of occurrence between 53% and 64%; (4) the water bodies of Faial and São Jorge presented very high Rhodophyta/Phaeophyceae ratio (R/P), with 2.8 and 2.4, respectively; (5) Flores, Faial and São Jorge achieved the "HIGH" status qualification in all indexes used, while Corvo reached "HIGH" status in 3 indexes, Graciosa in 2 and Pico in only one.

All calculated ERQ values are represented in Figure 4. It is noticeable that the indexes based only on intertidal data presented more variable values among islands.

4. DISCUSSION

In the present study, the total number of *taxa* observed did not vary considerably among the sampling sites, although the floristic composition was different between islands, especially in the intertidal zone. These contrasting results are probably due to the fact that the sampling sites selected for this study represent different morphological characteristics. Thus, as the intertidal and subtidal zones were considered as a sum of the different habitats, the total number of *taxa* was very similar between the islands. On the other hand, the species assemblages at the different subtidal depths of all the studied water bodies are more similar among them than the various intertidal assemblages. This result reflects the environmental instability in the intertidal zone and the greater diversity of sub-habitats in the subtidal of all the sampled sites. Wallenstein (2011), focusing only in the intertidal zone of the Azores, has already concluded that the number of species in that zone is as variable within islands as between different islands. This fact, resulting from a high variable environment, combined with the small number of sites sampled, makes it very difficult to interpret the geographic patterns of the species composition observed in the intertidal zone. The number of species per island registered by Wallenstein (2011) tended to increase with the number of sites sampled in each island, revealing a cumulative effect in the species richness as a result of increase in the sampling effort.

Species richness tended to decrease with depth down to 15 m, slightly increasing at 25 m depth. Corvo Island represented an exception, since the number of species observed was directly proportional to the increase of depth. This is probably due to its geographical orientation, which resulted in a greater exposure for the algal communities to cliff landslides and wave action, more protected in greater depths.

The dominant macroalgae of the intertidal zone were the crustose and articulated calcareous red algae, whose abundance reflects the presence of high-energy waves of those coasts. Other frequently occurring species were an encrusting species of *Codium* and various species of agarophyte turf-forming red algae, both habits reflecting adaptation to wave exposure (Wallenstein *et al.*, 2009). As expected, species richness was greater where highest water temperatures were

Table 2. Summary of the data used in the calculation of the ecological quality indexes, with their respective scores (EQR) and classifications (EQS) for each studied island. Indexes signaled with * were only applied in the intertidal zone. EQS in green are equivalent to "GOOD" status classification, and in blue to "HIGH" status.
Tabela 2. *Resumo dos dados utilizados no cálculo dos índices de qualidade ecológica, com respetivas pontuações (EQR) e qualificações (EQS) por massa de água estudada. Os índices assinalados com * foram calculados apenas para a zona entre-marés. Os EQS assinalados na cor verde equivalem à classificação "BOA", e em azul, à "EXCELENTE".*

	Flores	Corvo	Faial	Pico	São Jorge	Graciosa
Number of *taxa* observed	19	19	22	22	19	22
Number of opportunists	3	3	2	4	1	1
Number of ESG1 *taxa*	11	13	13	13	12	13
Number of ESG2 *taxa*	8	6	9	9	7	9
Coverage of opportunists	19%	21.4%	5.8%	14.2%	2.9%	5%
Shore description score	14	14	14	16	15	15
Proportion of Chlorophyta	11%	11%	14%	14%	11%	9%
Proportion of Rhodophyta	53%	58%	64%	55%	63%	59%
Proportion of opportunists	16%	16%	9%	18%	5%	5%
Rhodophyta/Phaeophyceae ratio	1.43	1.83	2.80	1.71	2.40	1.86
EEI *	1.00	0.80	0.92	0.70	1.00	0.73
RSL	0.81	0.88	0.84	0.80	0.86	0.84
CFR *	1.00	1.00	1.00	0.80	1.00	0.76
MarMAT	0.86	0.86	0.94	0.92	0.86	0.92

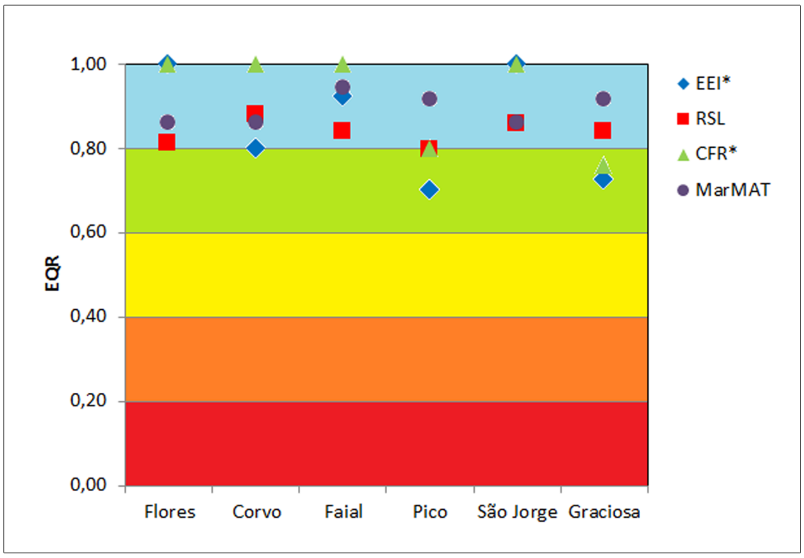

Figure 4. EQR (Ecological Quality Ratio) values calculated for the studied water bodies. The indexes marked with * were only calculated for the intertidal zone.
Figura 4. *Valores de EQR calculados para as diferentes massas de água estudadas. Os índices assinalados com * foram calculados apenas para a zona entre-marés.*

observed, but also in the islands of the Triangle, *i.e.*, Faial, Pico and São Jorge, probably as a result of the lower exposure to waves, since the sampling sites corresponded to more protected areas (Rusu & Soares, 2012) favoring the fixation and survival of a larger number of species.

In the Northern hemisphere, the proportion of Rhodophytes decreases with latitude, with 60 to 70% of red algae around 40º N and 30 to 40% in the Arctic (Santelices *et al.*, 2009). The present data decreased with latitude but revealed slightly lower values than what would be expected for the studied latitude. This might be due to the island effect on the number of species (Kier *et al.*, 2009) or to the fact that the species-rich group of filamentous red algae was not identified to species level. A slightly higher number of species in the islands of the Triangle (Faial, Pico and São Jorge) might be related to lower wave action and/or other biological factors not considered in the present work, such herbivory, mostly by fishes (Taylor & Schiel, 2010). The proportion of opportunistic algae observed here varied between 5 and 8%, which is in agreement with Wallenstein (2011), who determined that an average proportion of 0.10 (±0.06), with a maximum of 0.38, with 70% of all his sampling sites presenting 5 to 15% of opportunistic algae. In the mentioned study, the variability found between islands was too high to enable any conclusion concerning the difference between islands. However, the data of the present work indicates a tendency for lower proportion of opportunists in waters of better ecological conditions, even when this metric (proportion of opportunists) ((proportion is not included in the index used. From the three invasive species of macroalgae reported by Cardigos *et al.* (2006), only one was observed in the studied collection sites, the red alga *Asparagopsis armata*.

Wallestein (2011) registered an average ESG ratio of 1.4 (±0.6) in the Azores Archipelago, with 85% of the sampled areas with a value above 1.0, indicating a tendency of the communities to be dominated by late-succession species. The present data are in agreement with Wallenstein (2011), since 4 of the 6 studied water bodies obtained an ESG rate of 1.4.

The R/P (Rhodophyta/Phaeophyceae) ratio varies between 1.0 and 2.0 in temperate waters, and may reach 4.3 in tropical waters (Witman & Roy, 2009). In the present study, the calculated R/P ratio was between 1.4 and 2.8 for the different water bodies, reinforcing the suggestion of Titley & Neto (2005) that the algal communities of the Azores present characteristics of a temperate water flora, though also having tropical influences. Even though the R/P ratio is not considered to be a very precise biotic index (Marques *et al.*, 2009), this ratio has been used as an indicative in water quality classification, showing some separation between different water bodies conditions. As observed by Azzopardi & Schembri (2010) for the Mediterranean, the present results show that the water bodies grouping based on R/P ratio values reflects the same classification from the application of other biotic indexes. Therefore, the coastal waters of the islands classified as having a "GOOD" status by other indexes (Corvo, Pico and Graciosa) presented very similar R/P ratio values.

The islands of Faial, São Jorge and Flores achieved a "HIGH" EQS classification in the four indexes used, *i.e.*, EEI, RSL, CFR and MarMAT, while Corvo was classified as having a "HIGH" status in three, Graciosa in two and Pico in only one of the indexes. MarMAT application resulted in "HIGH" EQS for all water bodies, with Faial the one with the highest EQR value (0.94). The calculated EQR values vary according to the index used, but they all indicate that the Azorean coastal waters are in good or excellent condition. This result is in accordance with the expected, considering that the Archipelago of the Azores is isolated in the middle of the North Atlantic, with a population of only about 250 thousand inhabitants, and does not present any significant industrial activity, representing a close to reference condition state, *i.e.*, with reduced human interference and low anthropogenic pressure.

In general, the values resulting from the application of the different indexes are very similar among the islands, with the tendency to vary even less when subtidal data are included. This greater homogeneity may be related to the occurrence of the greater diversity of habitats observed in the subtidal zone, which might result in a more complete registration of the present species, contributing to a greater precision in the indexes' use. On the other hand, the intertidal surveys are dependent on the conditions of the sea, the tidal amplitude and the wave heights, reinforcing the need to include subtidal data. The greater instability of the intertidal habitats may also influence the results, and, once again, a larger replication if sampling sites per island would guarantee stronger data. In reality, the natural variation is the basis against which the effects of any anthropogenic change have to be contrasted to be detected and measured (Coleman, 2002) and that might be the less understood characteristic of marine ecosystems (Smayda 1984). This variation includes spatial and temporal components which are difficult to consider in the experimental planification and might determine the sampling scales (Coleman, 2002). Even when the sampling comprises a large range of natural variation, which is related to the sample size and replication (Skalski & McKenzie, 1982), the ability to statistically differentiate the impacted condition from the reference condition still depends on the size of the impact to be detected.

Additionally, in consequence of its geographic location near an amphidromic point in the North Atlantic, which determines small tide amplitudes, and because of its steep coastline, the area available for intertidal species fixation is very limited in the Azores. Therefore, besides the island factor that limits the available number of native species to be included in the indexes, the reduced intertidal area for algal fixation has also to be considered, reinforcing the need to include the subtidal zone in the coastal water classification for the WFD.

5. CONCLUSIONS

This preliminary work indicates that all coastal water bodies included here reaches the environmental goals established by the WFD and that most of them represent "HIGH" quality conditions.

The present data reflect the evolution of the ecological indexes, considering that, as they were created, the existing metrics were adapted and innovative ones were incorporated into new indexes, resulting in the fact that the most recent indexes seem to be more complete in terms of incorporated information. MarMAT revealed to be the most efficient index in the present study, since it seemed to be the most coherent by not presenting extreme EQR values. Moreover, this index included metrics that cover all the required features to be considered under the WFD, metrics for which data can be easily acquired by non-specialist personnel.

The inclusion of subtidal readings in the MarMAT index was justified by the small width of the intertidal zone in the Azores and by the great instability to which this zone is subjected to high wave action. These two factors limit the spatial availability and the environmental conditions for species colonization and succession that in turn might affect the results when the sampling is restricted to this zone, since there is greater variability, fewer species and greater abundance of opportunists. Therefore, by including subtidal data, these problems are compensated and the final result is more accurate for monitoring purposes.

Future work should increase spatial replication by increasing the number of sampling sites in each of the water bodies to guarantee representativeness and overcome interference of natural spatial variation of the biological elements used in the ecological status evaluation. Considering that the coastline different morphologies, the selection of future sampling sites should focus on coasts with different hydromorphological characteristics in every island. The validation of the adaptation of the different indexes used will depend on the comparison between some of these pristine sites and other strongly affected by human activities (*e.g.*, close to outfalls).

It should also be taken into consideration that, for its subtropical location, the Azorean macroalgae might suffer a significant effect of herbivory, especially by fishes (Taylor & Schiel, 2010). Therefore fishes could become a parameter to be included in coastal waters monitoring, since it probably is an important element contributing to the structure of the macroalgal community itself (Costa, 2003).

Finally, the results presented here indicate a good chance for the use of the MarMAT index adapted to the Azores (MarMAT-Az) for ecological evaluation and monitoring of the archipelago coastal waters under the application of the WFD or whenever the quality of the coastal environment is to be evaluated, such as in impact assessment studies. Additionally, the methodology followed here for the adaptation of the index for the studied region, is promising for the adaptation of this index for other geographical settings.

ACKNOWLEDGMENTS

The authors thank the support of Paula Aguiar, Cátia Pereira, Cláudia Hipólito, João Brum, Paulo Torres, Vitor Gonçalves, Agroleico Lda., and the skipper of "Alabote" and "Odisséia" vessels, for help with field work and/or data treatment. This work would not have been possible without funding from the Regional Direction of Land Management and Water Resources (DROTRH). The authors are also thankful to Leonel Pereira, Roberto Campos Villaca and the anonymous reviewer for their contributions in improving the manuscript.

REFERENCES

Azzopardi, M.; Schembri, P.J. (2010) - Assessment of the ecological status of Maltese coastal waters using the Rhodophyta/Phaeophyta Mean Ratio Index (R/P Rt. I.). *Rapport du Congrès de la Commission Internationale pour l'Exploration Scientifique de la Mer Méditerranée,* 39:718, Monaco. Available on-line at http://www.ciesm.org/online/archives/abstracts/index.htm

Ballesteros, E.; Torras, X.; Pinedo, S.; García, M.; Mangialajo, L.; Torres, M. (2007) - A new methodology based on littoral community cartography dominated by macroalgae for the implementation of the European Water Framework Directive. *Marine Pollution Bulletin*, 55(1-6):172-180. DOI: 10.1016/j.marpolbul.2006.08.038

Borges, P. (2003) - *Ambientes litorais nos grupos Central e Oriental do Arquipélago dos Açores, conteúdos e dinâmica de microescala*. 413p., PhD thesis, Universidade dos Açores, Portugal. *Unpublished*.

Borges, P.; Gabriel, R. (2009) - *Predicting extinctions on oceanic islands: arthropods and bryophytes / Estimar extinções em ilhas oceânicas: artrópodes e briófitos*. 80p., Grupo de Biodiversidade dos Açores, Angra do Heroísmo, Portugal. ISBN: 978-9728612511.

Cardigos, F.; Tempera, F.; Ávila, S.; Gonçalves, J.; Colaço, A.; Santos, R.S. (2006) - Non-indigenous marine species of the Azores. *Helgoland Marine Research*, 60(2):160-169. DOI: 10.1007/s10152-006-0034-7

Coleman, M. (2002) - Small-scale spatial variability in intertidal and subtidal turfing alga assemblages and the temporal generality of these patterns. *Journal of Experimental Marine Biology and Ecology*, 267(1):53-74. DOI: 10.1016/S0022-0981(01)00358-6

Costa, A.C. (2003) - *Diversidade de invertebrados das comunidades algais no subtidal de São Miguel e perturbação ambiental*. 196 p., PhD thesis, Universidade dos Açores, Portugal. *Unpublished*.

EC (2000) - Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a Framework for Community Action in the Field of Water Policy. *Official Journal of the European Communities,* 327(22/12/2000):1-73, Brussels, Belgium. Available on-line at http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:32000L0060

Fernandes, J. (1985) - *Terceira (Açores). Estudo geográfico.* 434 p., PhD thesis, Universidade dos Açores, Portugal. *Unpublished*.

Forjaz, V. (1963) - Resumo geológico das Ilhas dos Açores. *Atlântida* (ISSN: 1645-6815), 8(4–5):243–245. Instituto Açoriano de Cultura, Angra do Heroísmo, Terceira, Açores, Portugal.

Juanes, J.A.; Guinda, X.; Puente, A.; Revilla, J.A. (2008) - Macroalgae, a suitable indicator of the ecological status of coastal rocky communities in the NE Atlantic. *Ecological Indicators*, 8(4):351-359. DOI: 10.1016/j.ecolind.2007.04.005

Kent M.; Coker, P. (1992) - *Vegetation description and data analysis. A practical approach*. 363p., John Wiley and Sons, Chichester, England, U.K.. ISBN: 978-0471490937.

Kier, G.; Kreft, H.; Lee, T.M.; Jetz, W.; Ibisch, P.L.; Nowicki, C.; Mutke, J.; Barthlott, W. (2009) - A global assessment of endemism and speciesrichness across island and mainland regions. *Proceedings of the National Academy of Sciences of the United States of America,* 106(23):9322-9327. DOI: 10.1073/pnas.0810306106

Lafon, V.; Martins, A.; Figueiredo, M.; Melo Rodrigues, M.A.; Bashmachinikov, I.; Mendonça, A.; Macedo L.; Goulart, N. (2004) - Sea surface temperature distribution in the Azores region. Part I: AVHRR imagery and *in situ* data processing. *Arquipélago - Life and Marine Sciences*, 21A:1-18, Açores, Portugal. Available on-line at http://www.horta.uac.pt/intradop/images/stories/arquipelago/21a/1_Lafon_et_al_21A.pdf

Marques, J.C.; Salas, F.; Patricio, J.; Teixeira, H.; Neto, J.M. (2009) - *Ecological indicators for coastal and estuarine environmental assessment; a users' guide*. 208p., WIT Press, University of Coimbra, Portugal. ISBN: 978-1845642099.

Neto, A. (1997) - *Studies on algal communities of* São Miguel, *Azores*. 309 p., PhD thesis, Universidade dos Açores, Portugal. *Unpublished*.

Neto, J. M.; Gaspar, R.; Pereira, L.; Marques, J.C. (2012) - Marine Macroalgae Assessment Tool (MarMAT) for intertidal rocky shores. Quality assessment under the scope of the European Water Framework Directive. *Ecological Indicators*, 19:39-47. DOI: 10.1016/j.ecolind.2011.09.006

Orfanidis, S.; Panayotidis, P.; Stamatis, N. (2001) - Ecological evaluation of transitional and coastal waters: A marine benthic macrophytes-based model. *Mediterranean Marine Science* (ISSN: 1108-393X), 2(2):45-65, Hellinikon, Greece. Available on-line at http://www.medit-mar-sc.net/files/200812/14-1940245.pdf

Parente, M.I. (2010) - List of marine macroalgae (Rhodophyta, Chlorophyta and Phaeophyceae) *In*: Borges, P.A.V., Costa, A., Cunha, R., Gabriel, R., Gonçalves, V., Martins, A.F., Melo, I., Parente, M., Raposeiro, P., Rodrigues, P., Santos, R.S., Silva, L., Vieira, P.; Vieira, V. (eds.) *A list of the terrestrial and marine biota from the Azores*, 432 p., Princípia, Cascais, Portugal. ISBN: 978-989-8131-75-1.

Rusu, L.; Soares, C.G. (2012) - Wave energy assessments in the Azores islands. *Renewable Energy*, 45:183-196. DOI: 10.1016/j.renene.2012.02.027

Santelices, B.; Bolton, J.J.; Meneses, I. (2009) - Marine Algal Communities *In*: Witman, J.D. & Kaustuv, R. (eds.), *Marine Macroecology*, 440 p., University of Chicago Press. Chicago, IL, U.S.A. ISBN: 978-0226904122.

Skalski, J.; McKenzie, D. (1982) - A design for aquatic monitoring programs. *Journal of Environmental Management* (ISSN: 0301-4797), 14:237-251.

Smayda, T. (1984) - Variations and long-term changes in Narragansett Bay, a phytoplankton-based coastal marine ecosystem: relevance to field monitoring for pollution assessment *In*: White, H. (ed.) *Concepts in marine pollution measurements*, 757p., College Park: A Maryland Sea Grant Publication, University of Maryland, College Park, MD, U.S.A. ISBN: 978-0943676180.

Taylor, D.I; Schiel, D.R. (2010) - Algal populations controlled by fish herbivory across a wave exposure gradient on southern temperate shores. *Ecology*, 91:201-211. DOI: 10.1890/08-1512.1

Titley, I.; Neto, A.I. (2005) - The Marine Algal (Seaweed) Flora of the Azores: further additions and amendments. *Botanica Marina*, 48:248-255. DOI: 10.1515/BOT.2005.030

Wallenstein, F.M. (2011) - *Rocky Shore Macroalgae Communities of the Azores (Portugal) and the British Isles: a Comparison for the Development of Ecological Quality Assessment Tools*. 434p., PhD thesis, School of Life Sciences, Heriot-Watt University, Edinburgh, Scotland, U.K. *Unpublished*.

Wallenstein, F.M.; Neto, A.I.; Álvaro, N.V.; Tittley, I.; Azevedo, J.M.N. (2008) - *Guia para identificação de biótopos costeiros em ilhas oceânicas*, 92 p. Secretaria Regional do Ambiente e do Mar, Ponta Delgada, Portugal. ISBN: 978-9729988493.

Wallenstein, F.M.; Terra, M.R.; Pombo, J; Neto, A.I. (2009) - Macroalgal turfs in the Azores. *Marine Ecology*, 30(s1):113-117. DOI: 10.1111/j.1439-0485.2009.00311.x

Wells, E. (2008) - *Intertidal Coastal Waters Macroalgae – Rocky Shore Tool.* Tools paper prepared for the UK and Republic of Ireland. Water Framework Directive Marine Plants Task Team (MPTT/MAT01), 36p., Edinburgh, Scotland, U.K. *Unpublished*.

Wells, E.; Wilkinson, M.; Wood, P.; Scanlan, C. (2007) - The use of macroalgal species richness and composition on intertidal rocky seashores in the assessment of ecological quality under the European Water Framework Directive. *Marine Pollution Bulletin*, 55(1-6):151-161. DOI: 10.1016/j.marpolbul.2006.08.031

Witman, J.D.; Roy, K. (2009) - *Marine macroecology*. 440p., University Of Chicago Press, Chicago, IL, U.S.A. ISBN: 9780226904122.

Revista da Gestão Costeira Integrada 14(2):185-197 (2014)
Journal of Integrated Coastal Zone Management 14(2):185-197 (2014)

http://www.aprh.pt/rgci/pdf/rgci-467_Fattorini.pdf | DOI:10.5894/rgci467

Assessing small island prioritisation using species rarity: the tenebrionid beetles of Italy *

Avaliação de Prioridades de Conservação em pequenas ilhas, usando a raridade de espécies: os escaravelhos tenebriónidos de Itália **

Simone Fattorini [@, 1], Leonardo Dapporto [2]

ABSTRACT

We investigated conservation priorities of Italian small islands on the basis of tenebrionid species (Coleoptera Tenebrionidae) which are insects typically associated with coastal environments. Firstly, we estimated vulnerability of tenebrionid island communities in four different ways using their inter-island distribution, their overall rarity, their biogeographical characterization and the coastal perimeter of the occupied islands. Then, these four sets of vulnerability values were used to rank biotopes using the Biodiversity Conservation Concern index, BCC, which reflects the average rarity score of the species present in a site, and the Biodiversity Conservation Weight index, BCW, which reflects the sum of rarity scores of the same species assemblage. We found that most of the studied islands have been recovered as having some conservation value, but the Tuscan Islands, Ustica, Pantelleria and the Pelagie Islands were found to have highest priority.

Keywords: Conservation Planning; Insects; Island Biogeography; Italy; Mediterranean.

RESUMO

Neste artigo, a Investigação centra-se nas prioridades de Conservação em pequenas ilhas em Itália, com base em estudos de espécies Tenebrionidae (Coleoptera Tenebrionidae), insetos usualmente associados a ambientes costeiros. Em primeiro lugar, estimou se a vulnerabilidade das comunidades Tenebrionidae insulares de quatro formas diferentes: usando a sua distribuição inter-ilha; a sua raridade total; a caracterização biogeográfica; e o perímetro costeiro das ilhas ocupadas. Seguidamente, estas quatros conjuntos de dados de vulnerabilidade, foram usados para ordenar os biótopos de acordo com o Biodiversity Conservation Concern index, BCC, que reflete a raridade média das espécies presentes num sitio e o Biodiversity Conservation Weight index, BCW, que reflete a soma dos valores de raridade para algumas espécies da composição. Conclui-se que muitos estudos em pequenas ilhas são recuperados como tendo algum valor de conservação, mas as ilhas Tuscanas, Ustica, Pantelleria e Pelagie apresentam os mais altos valores de prioridade.

Palavras-Chave: *Planeamento e Conservação; Insetos; Biogeografia Insular; Itália; Mediterrâneo.*

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* *Submission: 30 December 2013; Evaluation: 5 February 2014; Reception of revised manuscript: 11 February 2014; Accepted: 13 February 2014; Available on-line: 19 February 2014*
** *Portuguese Title, Abstract and captions by Helena Calado on behalf of the Journal Editorial Board*

1. INTRODUCTION

The Mediterranean basin is occupied by almost 12,000 islands and islets (Arnold, 2008). Most of the Mediterranean islands have an area less than 3 km^2; only 162 Mediterranean islands are more than 10 km^2 large, 15 have an area over 500 km^2, and 9 present an area over 1000 km^2 (Morey & Martinez, 2000).

Because of the high "perimeter/area" ratio that characterizes small islands, their environmental diversity tends to be mostly represented by coastal ecosystems. Thus, although small islands occupy only a very small fraction of Earth surface, they may play an important role in conserving coastal ecosystems. Usually, the smaller the island, the higher the proportion of coastal valued and/or threatened ecosystems (Morey & Martinez, 2000). The total area of the Mediterranean islands is about 13% of the sea area, but they have a coastal length of 24,622 km, only 15% less than the mainland coastline.

In an attempt to achieve sustainability of Mediterranean coastal areas, fourteen Contracting Parties of the Barcelona Convention signed the Integrated Costal Zone Management Protocol in 2008, thus recognizing the need for management policies that are based on a holistic viewpoint of the functions that makeup the complex and dynamic nature of interactions in the coastal environment. This Protocol was then ratified by the European Union in 2010. In 2002, the European Parliament and the European Council also adopted a Recommendation on Integrated Coastal Zone Management which stressed the need to cover "the full cycle of information collection, planning, decision-making, management and monitoring of implementation" (http://ec.europa.eu/environment/iczm/home.htm).

As small islands are largely coastal entities of reduced surface, they are areas where the problems of sustainability are exacerbated (see, for example, Saffache & Angelelli, 2010, for a discussion on the Lesser Antilles case) and present therefore the need for a urgent rethinking about their management (Dias *et al.*, 2010). Coastal ecosystems in small islands can be threatened by a number of reasons, including pollution, coastal land occupation by tourist installations, concrete structures and networks of roads, population increase and increase in tourist pressure, resulting in a general landscape degradation and biodiversity loss (Morey & Martinez, 2000). Rising in sea level due to global warming is another important threat for coastal habitats of small islands (see Manne 2013 for a general discussion). With their environment more fragile and vulnerable than that of continental sites of similar areas, Mediterranean small islands should be therefore considered as valued threatened lands, needing special protection (Morey & Martinez, 2000). In terms of biodiversity, small islands host exclusive assortments of species, sometimes including endemic taxa, usually represented by small populations, which enhance their conservation value (Fattorini, 2006a; Whittaker & Fernández-Palacios 2007). Thus, for an integrated management of islands it is essential to know where biodiversity is concentrated and where it is most imperilled, in order to prioritise conservation actions and adopt the most urgent decisions.

The distribution of small islands in the western and eastern sectors of the Mediterranean Basin is uneven. In the Western Mediterranean there are some large islands (the Balearics, Corsica, Sardinia, Sicily) with relatively few small islands (usually associated with the largest ones), whereas in the Eastern Mediterranean there are few large islands but an extraordinary large number of small islands, especially in the Adriatic Sea (near the coast of the former Yugoslavia) and in the Aegean Sea. Placed in the centre of the Mediterranean, the Italian peninsula is at the interface between the Western and the Eastern sectors. Thus, some Italian small islands are placed in the Western Mediterranean, a few other in the Eastern Mediterranean. Moreover, Italian small islands vary greatly in their isolation (distance from the mainland and/or other islands) and geographical position with respect to major island systems and mainland areas which might act as source of species: for example, some islands are closer to the Sardinia-Corsican area and North African coasts than to the Italian peninsular ones. Thus, although not so numerous as those forming the Greek archipelagos, the Italian islands represent a biogeographically very heterogeneous assemblage of areas in most cases under strong human pressure.

Our knowledge of the biodiversity of Italian small islands varies considerably among islands and taxa, so only for the best investigated taxa (such as butterflies, Dennis *et al.*, 2008) and archipelagos (such as the Tuscan Islands or the circum-Sicilian islands. Fattorini, 2009a, 2010a) wide comparisons and cross-taxon biogeographical and conservation analyses are possible. Among the best sampled taxa for which there are a large number of well explored islands, the beetles belonging to the family Tenebrionidae are particularly interesting for the conservation of coastal ecosystems because they represent a conspicuous component of the beetle fauna inhabiting Mediterranean coastal ecosystems in terms of species richness, individual abundance and biomass (Fattorini, 2008a; Fattorini *et al.*, 2012a and references therein).

Taking advantage of a series of previous researches (Fattorini, 2006a, 2008a, 2009a,b, 2011a; Fattorini & Fowles, 2005) we were able to obtain virtually complete tenebrionid species lists for most of the Italian small islands and to use these data in the present paper to investigate conservation priorities. For this, we evaluated tenebrionid species vulnerability and used this information to identify the islands that host the most imperilled tenebrionid communities.

2. MATERIAL AND METHODS

We collected presence data on tenebrionid species for 57 Italian small islands (Figure 1). These data were obtained from literature sources (reviewed in Fattorini, 2008, plus data provided in Fattorini, 2009a,b, 2010a, 2011a,b) and personal new records.

Study islands varied greatly for their size and distance from the mainland. Island geographical characteristics are given in Table 1 whereas their conservation status is given in Table 2. Island area varied from 0.0000249 km^2 (a very small islet in the Tuscan Archipelago) to 223.5 km^2 (Elba Island) (mean ± SD: 12.185 ± 32.669). Distance to the mainland varied from 0 km (Mount Argentario, a fossil island currently connected to the mainland by three narrow strips of land) to

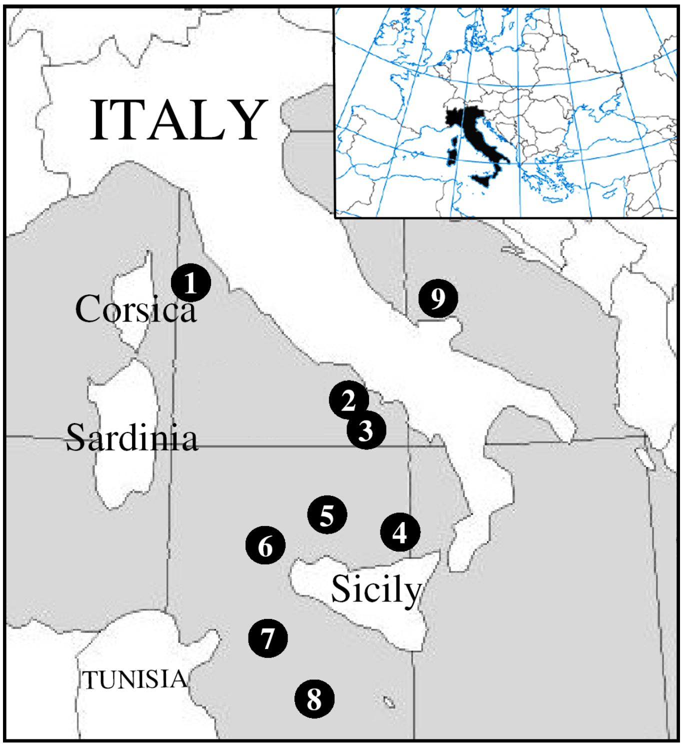

Figure 1. Location of studied Italian islands. 1: Tuscan Archipelago; 2: Pontine Islands; 3: Campane Islands, 4: Aeolian Islands; 5: Ustica Island; 6: Aegadian (Egadi) Islands; 7: Pantelleria Island; 8: Pelagian (Pelagie) Islands; 9: Tremiti Islands. The inset shows the position of Italy (in black) within the Mediterranean basin.
Figura 1. *Localização das ilhas italianas estudadas. 1 Arquipélago Toscano, 2. Ilhas Pontinas; 3: Ilhas Campânia, 4: Ilhas Eólias; Ilhas Ustica, 6: Ilhas Egadi, Ilhas Pantelleria, 8: Ilhas Pelagie, 9: Ilhas Tremiti. Assinalado a negro a posição de Itália na Bacia Mediterrânea.*

162 km (Linosa, close to North African coasts) (mean ± SD: 34.307 ± 29.886). Island maximum elevation, which may be considered an indirect measure of habitat diversity, varied from 0 m (for certain very small islands) to 1019 m (Elba island) (mean ± SD: 252.140 ± 290.918).

We considered presence data for 139 native tenebrionid species. Taxonomy followed Löbl & Smetana (2008). Cosmopolitan species, such as *Alphitophagus bifasciatus*, *Gnathocerus cornutus*, *Latheticus oryzae*, *Tribolium castaneum*, *Tribolium confusum*, *Tenebrio molitor*, *Tenebrio obscurus*, and *Alphitobius diaperinus*, which are associated with stored food, were not considered.

Islands were ranked on the basis of the vulnerability of their tenebrionid communities using the Biodiversity Conservation Concern (BCC) index (Fattorini, 2006b) and the Biodiversity Conservation Weight (BCW) index (Fattorini *et al.*, 2012b). In the BCC index, species occurring in a given area are classified into categories of endangerment and weighted by the respective vulnerability. The BCC index also combines the vulnerability of each species with total richness to obtain a measure of relative conservation.

$$\mathrm{BCC} = \frac{\sum_{i=1}^{L}(\alpha_i - \alpha_{\min})}{L(\alpha_{\max} - \alpha_{\min})}$$

The BCC is calculated as:
where L is the local (island) species richness, α_i is the weight assigned to the ith category of vulnerability, α_{min} is the minimum weight among all species; and α_{max} is maximum weight among all species. This formulation ensures the index ranges from 0 (all species belonging to the lower conservation category, α_l=1) to 1 (all species belonging to the highest endangerment category, α_{max}). The BCC index has been previously applied to identify priority areas or biotopes for butterflies in Mediterranean islands and European countries (Fattorini, 2006, 2009b; Dapporto & Dennis, 2008), fish in France (Bergerot *et al.*, 2008; Laffaille *et al.*, 2011; Maire *et al.*, 2013), tenebrionids, butterflies, birds and mammals in the Central Apennines (Fattorini, 2010b, c), and arthropods in Azorean forest fragments (Fattorini *et al.*, 2012b).

The BCC index is a 'relative measure', which means that it is not sensitive to species richness. This may be an advantage to compare species assemblages with different species richness, but poses some problems. For example, an assemblage with a single species, having this species α_{max}, would receive the same score as an assemblage with 10 species, all with α_{max}. Or worse, an assemblage with a single species with α_{max} has a higher score than an assemblage with 10 species, 9 with α_{max} and one with $\alpha_i < \alpha_{max}$. To overcome this problem, Fattorini *et al.* (2012b) introduced the BCW, which is calculated as follows:

$$\mathrm{BCW} = \frac{\sum_{i=1}^{L}(\alpha_i - \alpha_{\min})}{\sum_{i=1}^{S}(\alpha_i - \alpha_{\min})}$$

where S is the total species richness for all sites (all other symbols as for BCC, see above).

To express species vulnerability, we used four different approaches. In a first approach, we weighted species as an inverse function of their distribution. As the most widespread species occurred on 29 islands, species weights were calculated as the number of inhabited islands divided by 29. Using this weighting scheme in the BCC calculation, the most widespread species received an α-value of 1, whereas species occurring in only one island received an α-value of 29. The BCC calculated using this scheme will be referred to as BCC1.

In a second approach, we weighted species using the Kattan index (Kattan, 1992), which is based on species geographical distribution (wide/narrow distribution), habitat specificity (broad/restricted habitat specificity) and abundance (abundant/scarce population) and has been previously used to express species rarity in tenebrionid assemblages (Fattorini, 2008b, 2010b, c, 2013a, b). These

Table 1. Geographical characteristics of the Italian small islands.
Tabela 1. *Características geográficas das pequenas ilhas italianas*

Archipelago	Island	Latitude	Longitude	Area (km²)	Maximum elevation (m)	Perimeter (km)	Distance to the mainland (km)
Aegadian	Favignana	37°55'34"	12°19'16"	19.7	302	33	5.78
Aegadian	Levanzo	37°59'59"	12°20'04"	5.61	278	15	12.39
Aegadian	Marettimo	37°58'20"	12°03'20"	12.06	686	18	30.34
Aeolian	Alicudi	38°32'38"	14°21'12"	5.1	675	8	53.13
Aeolian	Basiluzzo	38°39'48"	15°06'50"	0.29	165	3.3	43.5
Aeolian	Bottaro	38°38'16"	15°06'37"	0.0073	21	0.44	42
Aeolian	Filicudi	38°34'17"	14°33'45"	9.49	774	14.5	45.3
Aeolian	Lipari	38°29'11"	14°56'3"	37.29	602	33	27.78
Aeolian	Lisca Bianca	38°38'22"	15°06'51"	0.0413	30	0.81	42
Aeolian	Panarea	38°38'14"	15°04'02"	3.34	421	8.5	42
Aeolian	Pietra del Bagno	38°28'29"	14°53'45"	0.0021	21	0.2	28
Aeolian	Salina	38°33'49"	14°50'16"	26.38	962	24	38.2
Aeolian	Scoglio Faraglione	38°34'46"	14°48'02"	0.0049	35	0.43	39
Aeolian	Stromboli	38°47'38"	15°12'40"	12.19	926	14.5	55.55
Aeolian	Strombolicchio	38°49'02"	15°15'07"	0.003	49	0.3	46.5
Aeolian	Vulcano	38°24'	14°58'	20.87	500	26.5	20.6
Campane	Capri	40°33'3.2"	14°14'33.36	10.4	585	17	5
Campane	Ischia	40°43'40"	13°54'40"	46.3	789	34	9.37
Campane	Vivara	40°44'37"	13°59'37"	0.3563	110	3	6.19
Pelagian	Lampedusa	35°30'56"	12°34'23"	20.2	133	26	120
Pelagian	Lampione	35°33'16"	12°19'59"	0.025	40	1.8	130
Pelagian	Linosa	35°52'	12°52'	5.34	195	11	162
Pontine	Palmarola	40°56'13"	12°51'29"	1.38	253	9	34
Pontine	Ponza	40°54'	12°58'	7.54	280	21	33
Pontine	Santo Stefano	40°47'22"	13°27'15"	0.32	84	2	47
Pontine	Ventotene	40°48'	13°26'	1.35	139	7	46
Pontine	Zannone	40°58'	13°3'	1.12	194	5	27.6
Tremiti	Caprara	42°08'08"	15°30'45"	0.45	53	4.7	24
Tremiti	Cretaccio	42°7'21.38"	15° 30' 0.14"	0.035	30	1.3	23.25
Tremiti	Pianosa	42°13'23"	15°45'2"	0.13	15	26	33.9
Tremiti	Scoglio Elefante	42°06'37.39"	15°29'32.89"	0.0004	20	0.3	22.2
Tremiti	San Domino	42°06'08"	15°29'17"	2.08	116	9.7	22.05
Tremiti	San Nicola	42°07'20"	15°30'36"	0.42	75	3.7	22.9
Tuscany	Mount Argentario	42°23'54"	11°08'34"	60.3	635	37	0
Tuscany	Capraia	43°03'0"	9°51'0"	19.5	447	19.3	27.07
Tuscany	Cerboli	42°51'30"	10°32'53"	0.050625	71	1.7	6.7
Tuscany	Elba	42°45'46"	10°14'22"	223.5	1019	147	9.32
Tuscany	Formica di Burano	42°22'49"	11°18'41"	0.0072	0	0.39	4.2
Tuscany	Formica di Grosseto	42°34'36"	10°53'0"	0.145	11	1	13.9
Tuscany	Giannutri	42°15'14"	11°06'13"	2.4	93	11	21.42
Tuscany	Giglio	42°21'00"	10°54'00"	21.2	498	28	26.2
Tuscany	Gorgona	43°25'45"	9°54'	2.2	255	5.5	33.46
Tuscany	La Scola	42°35'01.76"	10°06'22.72"	0.014	34	0.5	57
Tuscany	Montecristo	42°20'	10°18.30'	10.4	645	16	69.58
Tuscany	Pianosa (Tuscany)	42°35'	10°05'	10.3	30	1.3	42.35
Tuscany	Sparviero	42°47'49.3"	10°42'44.4"	0.01375	38	0.8	1.38
Tuscany (Elba)	Argentarola	42°25'6.7"	11°4'53"	0.012	43	0.46	11.6
Tuscany (Elba)	Gemini Fuori	42°43'02.53"	10°22'22.27"	0.01875	42	0.5	25.5
Tuscany (Elba)	Gemini Terra	42°43'06.78"	10°22'27.47"	0.01437	25	0.6	25.25
Tuscany (Elba)	Scoglio Remaiolo	42°42'35.35"	10°24'46.75"	0.001465	0	0.16	25.03
Tuscany (Elba)	Isolotto dei Topi	42°52'15"	10°25'24"	0.01375	34	0.4	9
Tuscany (Elba)	Isolotto Liscoli	42°44'39.69"	10°25'04.75"	0.0053	10	0.17	21.35
Tuscany (Elba)	Isolotto Ortano	42°47'24.80"	10°26'01.27"	0.012	22	0.48	16
Tuscany (Elba)	Scoglio Paolina	42°47'21.57"	10°13'52.59"	0.0025	13	0.2	26.5
Tuscany (Elba)	Scoglietto Portoferraio	42°49'17.42"	10°19'43.45"	0.0000249	20	0.44	18.32
Sicily	Pantelleria	36°47'27"	11°59'38"	86	591	51.5	70.85
Sicily	Ustica	38°43'	13°11'	8.6	238	16	53

Table 2. Protection status of studied islands.
Tabela 2. *Estatuto de proteção das ilhas em estudo.*

Archipelago	Island	Protection	Reference
Aegadian	Favignana	The island is Natura 2000 site ITA010004. The island is part of the Natura 2000 site ZPS ITA010027. The sea surrounding the island belongs to the "Area Marina Protetta delle Isole Egadi"	http://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=ITA010004; http://www.ampisoleegadi.it/; http://www.lasiciliainrete.it/NATURA/trapani/Riserva_isole_egadi/riserva_isole_egadi.htm; http://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=ITA010027
Aegadian	Levanzo	The island is Natura 2000 site ITA010004. The island is also part of the Natura2000 site ITA010027. The sea surrounding the island belongs to the "Area Marina Protetta delle Isole Egadi"	http://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=ITA010003; http://www.ampisoleegadi.it/; http://www.lasiciliainrete.it/NATURA/trapani/Riserva_isole_egadi/riserva_isole_egadi.htm; http://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=ITA010027
Aegadian	Marettimo	The island is Natura 2000 site ITA010002. The island is also part of the Natura 2000 site ITA010027. The sea surrounding the island belongs to the "Area Marina Protetta delle Isole Egadi"	http://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=ITA010002 http://www.ampisoleegadi.it/; http://www.lasiciliainrete.it/NATURA/trapani/Riserva_isole_egadi/riserva_isole_egadi.htm; http://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=ITA010027
Aeolian	Alicudi	About 75% of island is part of Natura 2000 site ITA030023 and ITA030044	http://natura2000.eea.europa.eu/natura2000/SDF.aspx?site=ITA030023
Aeolian	Basiluzzo	All island is part of the Natura 2000 site ZPS ITA030044	http://www.artasicilia.eu/old_site/web/natura2000/schede_natura_sicilia/CART_CTR10_PDF/577140.pdf
Aeolian	Bottaro	All island is part of the Natura 2000 site ZPS ITA030044	http://www.artasicilia.eu/old_site/web/natura2000/schede_natura_sicilia/CART_CTR10_PDF/577140.pdf
Aeolian	Filicudi	About 82% of island is part of Natura 2000 site ITA030023 and ITA030044	http://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=ITA030024
Aeolian	Lipari	About 67% of island is part of Natura 2000 site ITA030030 and ITA030044	http://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=ITA030030
Aeolian	Lisca Bianca	All island is part of the Natura 2000 site ZPS ITA030044	http://www.artasicilia.eu/old_site/web/natura2000/schede_natura_sicilia/CART_CTR10_PDF/577140.pdf
Aeolian	Panarea	About 78% of island is part of Natura 2000 site ITA030025. All island is also part of the Natura 2000 site ITA030044	http://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=ITA030025; http://www.artasicilia.eu/old_site/web/natura2000/schede_natura_sicilia/CART_CTR10_PDF/577140.pdf
Aeolian	Pietra del Bagno	All island is part of the Natura 2000 site ITA030044	http://www.portaledelleisoleolie.it/lipari_sud_sic_zps.pdf
Aeolian	Salina	Two SICs have been identified on the island: ITA030028 and ITA030029. Together, they cover about 72% of island surface. A marine SIC is ITA030041.	http://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=ITA030028; http://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=ITA030029
Aeolian	Scoglio Faraglione	None	
Aeolian	Stromboli	About 87% of island is part of Natura 2000 site ITA030026 and all the island is included in ITA030044	http://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=ITA030026
Aeolian	Strombolicchio	About 25% of island is part of Natura 2000 site ITA030026, and all the island is included in both ITA030026 and ITA030044. The island has been deigned as a Strict Nature Reserve	http://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=ITA030026
Aeolian	Vulcano	About 77% of island is part of Natura 2000 site ITA030027 and ITA030044	http://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=ITA030027
Campane	Capri	Two Natura 2000 sites have been identified on the island: IT8030038 and IT8030039. Together, they cover about 47% of island surface.	http://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=IT8030038; http://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=IT8030039
Campane	Ischia	The island includes four Natura 2000 sites: IT8030005, IT8030022 IT8030026, IT8030034. Altogether, they cover about 45% of the island's surface	http://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=IT8030005; http://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=IT8030026 http://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=IT8030034 http://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=IT8030022
Campane	Vivara	The island is Natura 2000 site IT8030012. It is also classified as "*Riserva Naturale Statale*"	http://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=IT8030012
Pelagian	Lampedusa	About 70% of island area is Natura 2000 site ITA040002. The island is also part of the Natura 2000 site ITA040013. A small fraction of the island's surface is protected as "Riserva naturale orientata Isola di Lampedusa"	http://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=ITA040002; http://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=ITA040013
Pelagian	Lampione	All island is part of Natura 2000 site ITA040002. The island is also part of the Natura 2000 site ITA040013. All island is part of "Riserva naturale orientata/integrale Isola di Linosa e Lampione"	http://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=ITA040002; http://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=ITA040013
Pelagian	Linosa	About 80% is part of Natura 2000 site ITA040001. All island is included in Natura 2000 site ITA040013. About 50% of the island is protected as "Riserva naturale orientata/integrale Isola di Linosa e Lampione"	http://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=ITA040001
Pontine	Palmarola	All island is included in Natura 2000 site IT6040020 All island is a strict nature reserve within the "Riserva naturale orientata/integrale Isola di Linosa e Lampione"	http://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=IT6040020
Pontine	Ponza	All island is included in Natura 2000 site IT6040019	http://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=IT6040019
Pontine	Santo Stefano	All island is included in Natura 2000 site IT6040020. The island is also part of the Riserva Naturale Statale denominata "Isole di Ventotene e S. Stefano"	http://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=IT6040020; http://www.comune.ventotene.lt.it/parchi_riserve.htm

Table 2. Continuação
Tabela 2. *Continuation*

Pontine	Ventotene	All island is included in Natura2000 site IT6040020. The island is also part of the Riserva Naturale Statale denominata "Isole di Ventotene e S. Stefano"	http://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=IT6040020; http://www.comune.ventotene.lt.it/parchi_riserve.htm
Pontine	Zannone	All island is included in Natura 2000 site IT6040020. The island is part of "Parco Nazionale del Circeo".	http://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=IT6040020; http://www.parcocirceo.it/ita_245_isola-di-zannone.html
Tremiti	Caprara	The island is part of Natura 2000 sites IT911011 and IT9110040. The island is part of "Parco Nazionale del Gargano"	http://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=IT9110011; http://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=IT9110040
Tremiti	Cretaccio	The island is part of Natura 2000 sites IT911011 and IT9110040. The island is part of "Parco Nazionale del Gargano"	http://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=IT9110011; http://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=IT9110040
Tremiti	Pianosa	The island is part of Natura 2000 sites IT911011 and IT9110040. The island is part of "Parco Nazionale del Gargano"	http://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=IT9110011; http://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=IT9110040
Tremiti	Scoglio Elefante	The islet is part of Natura 2000 sites IT911011 and IT9110040. The island is part of "Parco Nazionale del Gargano"	http://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=IT9110011; http://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=IT9110040
Tremiti	San Domino	The island is part of Natura 2000 sites IT911011 and IT9110040. The island is part of "Parco Nazionale del Gargano"	http://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=IT9110011; http://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=IT9110040
Tremiti	San Nicola	The island is part of Natura200 sites IT911011 and IT9110040. The island is part of Parco Nazionale del Gargano	http://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=IT9110011; http://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=IT9110040
Tuscany	Mount Argentario	The island is almost completely included in the Natura 2000 site IT51A0025.	http://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=IT51A0025
Tuscany	Capraia	The island is Natura 2000 site IT5160006. All island except the inhabited centre is Natura 2000 site IT5160007 and is part of the "Parco Nazionale dell'Arcipelago Toscano"	http://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=IT5160006; http://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=IT5160007
Tuscany	Cerboli	The island is part of Natura 2000 site IT5160011.	http://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=IT5160011
Tuscany	Elba	The island includes two Natura 2000 sites: IT5160102 and IT5160012. Together they cover about 51% of the island's area. The island is also included for about 50% of its surface in the "Parco Nazionale dell'Arcipelago Toscano"	http://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=IT5160102; http://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=IT5160102
Tuscany	Formica di Burano	The island is Natura 2000 site IT51A0035	http://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=IT51A0035
Tuscany	Formica di Grosseto	The island is Natura 2000 site IT51A0022.	http://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=IT51A0022
Tuscany	Giannutri	The island is completely included in the Natura 2000 site IT51A0024. It is included in the "Parco Nazionale dell'Arcipelago Toscano"	http://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=IT51A0024
Tuscany	Giglio	The island is almost completely included in the Natura 2000 site IT51A0023. Less than 50% of island's surface is included in the "Parco Nazionale dell'Arcipelago Toscano"	http://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=IT51A0023
Tuscany	Gorgona	Virtually all island is Natura 2000 site IT5160002 and is part of the "Parco Nazionale dell'Arcipelago Toscano"	http://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=IT5160002
Tuscany	La Scola	The island is Natura 2000 site IT5160013. It is also completely included in the "Parco Nazionale dell'Arcipelago Toscano"	http://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=IT5160013
Tuscany	Montecristo	The island is Natura 2000 site IT5160014. It is also completely included in the Parco Nazionale dell'Arcipelago Toscano.	http://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=IT5160014
Tuscany	Pianosa (Tuscany)	The island is Natura 2000 site IT5160013. It is also completely included in the "Parco Nazionale dell'Arcipelago Toscano"	http://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=IT5160013
Tuscany	Sparviero	The island is Natura 2000 site IT51A0035	http://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=IT51A0035
Tuscany(Elba)	Argentarola	The island is almost completely included in the Natura 2000 site IT51A0038.	http://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=IT51A0038
Tuscany(Elba)	Gemini Fuori	The islet is part of Natura 2000 site IT5160011. It is part of the "Parco Nazionale dell'Arcipelago Toscano"	http://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=IT5160011
Tuscany(Elba)	Gemini Terra	The islet is part of Natura 2000 site IT5160011. It is part of the "Parco Nazionale dell'Arcipelago Toscano"	http://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=IT5160011
Tuscany(Elba)	Scoglio Remaiolo	The islet is part of Natura 2000 site IT5160102.	http://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=IT5160102
Tuscany(Elba)	Isolotto dei Topi	The islet is part of Natura 2000 site IT5160011. It is part of the "Parco Nazionale dell'Arcipelago Toscano"	http://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=IT5160011
Tuscany(Elba)	Isolotto Liscoli	The islet is part of Natura 2000 site IT5160102.	http://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=IT5160102
Tuscany(Elba)	Isolotto Ortano	The islet is part of Natura 2000 site IT5160102. It is part of the "Parco Nazionale dell'Arcipelago Toscano"	http://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=IT5160102
Tuscany(Elba)	Scoglio Paolina	None	
Tuscany(Elba)	Scoglietto Portoferraio	The island is part of Natura 2000 site IT5160011. It is part of the "Parco Nazionale dell'Arcipelago Toscano"	http://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=IT5160011
Sicily	Pantelleria	About 76% of island is included into two Natura 2000 sites: ITA010019 and ITA010020. About 30% of island's area is protected as "Riserva naturale orientata Isola di Ustica"	http://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=ITA010019; http://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=ITA010020
Sicily	Ustica	About 40% of island is part of Natura 2000 site ITA020010. About 24% of island's area is protected as "Riserva naturale orientata Isola di Ustica"	http://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=ITA020010

three aspects were evaluated using information provided in Aliquò *et al.* (2006). Geographical distribution was evaluated with reference to the number of Italian administrative mainland regions from which each species is known. Species occurring in less than four regions (<20% of regions) were considered as geographically rare. Species associated with coastal habitats were considered as having restricted habitat specificity. Species reported as scarce by Aliquò *et al.* (2006) were considered as having scarce populations. Then, an eight-score scale was created that reflected different types of rarity and commonness, and each species was assigned to a score as follow: 1: species that are not rare; 2: scarce species (i.e. species rare for abundance); 3: species with narrow habitat specificity; 4: restricted species (i.e. species rare by range); 5: scarce species with narrow habitat specificity (i.e. species rare for both habitat specificity and abundance); 6: scarce and restricted species (i.e. species rare for both geographical range and abundance); 7: restricted species with narrow habitat specificity (i.e. species rare for both habitat specificity and geographical distribution); 8: restricted and scarce species with narrow habitat specificity (i.e. species rare for geographical distribution, habitat specificity and abundance). This weighting scheme assigns higher importance to geographical rarity which is appropriate for the purpose of our study because species with a narrow geographical distribution are more vulnerable at a global or regional level (*e.g.* endemics) (Kattan, 1992). Using this weighting scheme in the BCC calculation, species common for all rarity measures received an α-value of 1, whereas species rare for all three aspects received an α-value of 8. The BCC calculated using this scheme will be referred to as BCC2.

In a third approach, we strictly focused on the type of distribution shown by species. For this, we divided the species into the following categories: species endemic to single islands (SIE); species endemic to an archipelago (END); species occurring on one or more of the study islands, but not on the Italian mainland or major islands (Sardinia and Sicily), which is the case of species occurring on the African on Greek coasts (NIT); species occurring on the Italian mainland or major islands with highly fragmented distribution (FRG); species that are widespread on the Italian mainland (WID). For the calculation of the BCC index, the following arrangement of weights was used: SIE (α= 16), END (α= 8), NIT (α= 4), FRG (α= 2), WID (α= 1). In this case, weights followed a geometric series to take into account various sources of incertitude (see Fattorini, 2006a). In general, it is unlikely that species found only on islands will be later found also on mainland areas and endemics are obviously an important conservation target in island conservation; moreover, single island endemics are much more valued than species which occur on more than one island. A the other extreme, the assignment of a species to the FRG category may be problematic, because it is difficult to establish if a fragmented distribution reflects a true state of affairs or is due to the lack of knowledge, thus species with an assumed fragmented distribution have a score only slightly superior to that of widespread species. Finally, the intermediate weight assigned to the NIT category is due to the fact that species occurring on Italian islands, but not on other Italian areas, are of high conservation value from a national perspective, even if they may be largely distributed in other countries. This criterion is similar to the IUCN procedure for regional red list assessments (http://www.iucnredlist.org/documents/reg_guidelines_en.pdf). The BCC calculated using this scheme will be referred to as BCC3.

Finally, as a forth criterion, we calculated species rarity using the perimeter of the inhabited islands. In the BCC1 index, we calculated species rarity on the basis of the number of occupied islands. However, the islands included in our analysis have enormous differences in size, so a species living exclusively in a very small island should be considered much rarer than another living in a large island. To explore this form of rarity, we expressed species rarity as the inverse of the summed perimeter of the islands where the species lives. The rationale for using island's perimeter is due to the prevailing habitat type, i.e. coastal areas, whose extension should be more related with perimeter than area. Because this index is intimately related with the BCC1, but uses island perimeter instead of island number, we called it BCC1p.

The same rarity measures were used to calculate the respective BCW indices, which will be refereed to as BCW1, BCW2, BCW3, and BCW1p, respectively.

To investigate if the four BCC indices are influenced by island geography, we correlated their values with island area, elevation and distance to the closest mainland using a Pearson correlation coefficient. For each BCC index, we considered the islands included in the third quartile of the distribution of BCC values as priority islands. Then, we compared the various indices to assess the percentage of "priority islands" shared by two or more indices. Finally, we used ANOVAs to test if islands selected as priority islands by the four indices showed significant differences in their geographical characteristics, with LSD post hoc tests for pairwise comparisons. The same approach was used for the four BCW indices. Probability levels were set at 0.05 in all tests.

3. RESULTS

Values of BCC1, BCC2, BCC3, and BCC1p are given in Table 3. Values of BCC1 ranged from 0.004 to 0.827 (mean ± SE = 0.149 ± 0.019). Values of BCC2 ranged from 0.000 to 0.952 (mean ± SE = 0.369 ± 0.034), but only one island (Vivara) had a value of zero. Values of BCC3 ranged from 0.000 to 0.644 (mean ± SE = 0.149 ± 0.023), with nine islands having a value of zero. Values of BCC1p ranged from 0.0004 to 0.381 (mean ± SE = 0.020 ± 0.007).

Values of BCW1, BCW2, BCW3, and BCW1p are also given in Table 3. Values of BCW1 ranged from 0.000 to 0.161 (mean ± SE = 0.029 ± 0.005). Values of BCW2 ranged from 0.000 to 0.225 (mean ± SE = 0.047 ± 0.006), but only one island (Vivara) had values of zero. Values of BCW3 ranged from 0.000 to 0.210 (mean ± SE = 0.028 ± 0.005), with nine islands having a value of zero. Values of BCC1p ranged from 0.0002 to 0.3688 (mean ± SE = 0.0264 ± 0.007).

On average, BCC2 attained higher values than BCC1 (paired t-test, $t = 6.188$, $p<0.0001$) and BCC3 ($t = 14.333$, $p<0.0001$), whereas BCC1 and BCC3 did not show a significant difference in their average values ($t = 0.025$, $p = 0.980$). BCC1p showed lower values than BCC1 ($t = 2.299$, $p<0.0001$), BCC2 ($t = -10.799$, $p < 0.0001$), and BCC3 ($t = -5.967$, $p < 0.0001$).

Table 3. Values of Biodiversity Conservation Concern (BCC) and Biodiversity Conservation Weight (BCW) calculated for tenebrionid beetles using species rarity (BCC1, BCW1), vulnerability (BCC2, BCW2), biogeographical characterization (BCC3, BCW3), and perimeter of inhabited islands (BCC1p, BCW1p).
Tabela 3. *Valor de Interesse para Conservação da Biodiversidade (BBC) e de Peso para a Conservação da Biodiversidade (BCW) calculado para escaravelhos tenebrionídeos usando a raridade de espécies (BCC1, BCW1), vulnerabilidade (BCC2, BCW2) caracterização biogeográfica (BCC3, BCW3) e perímetro das ilhas habitadas (BCC1p, BCW1p).*

Archipelago	Island	BCC1	BCC2	BCC3	BCC1p	BCW1	BCW2	BCW3	BCW1p
Aegadian	Favignana	0.161	0.250	0.019	0.006	0.061	0.099	0.017	0.025
Aegadian	Levanzo	0.067	0.262	0.000	0.003	0.017	0.066	0.000	0.008
Aegadian	Marettimo	0.274	0.509	0.154	0.013	0.060	0.115	0.078	0.034
Aeolian	Alicudi	0.075	0.135	0.000	0.004	0.018	0.034	0.000	0.011
Aeolian	Basiluzzo	0.039	0.095	0.000	0.003	0.002	0.004	0.000	0.001
Aeolian	Bottaro	0.028	0.224	0.000	0.002	0.003	0.022	0.000	0.002
Aeolian	Filicudi	0.117	0.210	0.009	0.007	0.024	0.044	0.004	0.017
Aeolian	Lipari	0.130	0.272	0.008	0.005	0.057	0.123	0.008	0.025
Aeolian	Lisca Bianca	0.017	0.071	0.000	0.001	0.001	0.004	0.000	0.001
Aeolian	Panarea	0.112	0.266	0.006	0.008	0.034	0.082	0.004	0.027
Aeolian	Pietra del Bagno	0.004	0.095	0.000	0.000	0.000	0.004	0.000	0.000
Aeolian	Salina	0.095	0.232	0.006	0.004	0.031	0.078	0.004	0.015
Aeolian	Scoglio Faraglione	0.024	0.321	0.000	0.002	0.001	0.018	0.000	0.001
Aeolian	Stromboli	0.134	0.263	0.008	0.007	0.046	0.093	0.006	0.027
Aeolian	Strombolicchio	0.133	0.429	0.022	0.015	0.005	0.018	0.002	0.007
Aeolian	Vulcano	0.116	0.266	0.048	0.005	0.035	0.082	0.034	0.016
Campane	Capri	0.123	0.099	0.000	0.006	0.039	0.032	0.000	0.021
Campane	Ischia	0.162	0.200	0.031	0.006	0.033	0.042	0.015	0.015
Campane	Vivara	0.021	0.000	0.000	0.001	0.001	0.000	0.000	0.001
Pelagian	Lampedusa	0.420	0.571	0.238	0.016	0.161	0.225	0.210	0.074
Pelagian	Lampione	0.827	0.952	0.644	0.381	0.068	0.080	0.122	0.369
Pelagian	Linosa	0.365	0.519	0.084	0.026	0.095	0.139	0.050	0.081
Pontine	Palmarola	0.098	0.232	0.117	0.012	0.011	0.026	0.029	0.015
Pontine	Ponza	0.101	0.151	0.027	0.005	0.023	0.036	0.015	0.013
Pontine	Santo Stefano	0.127	0.127	0.104	0.018	0.016	0.016	0.029	0.026
Pontine	Ventotene	0.076	0.173	0.067	0.010	0.015	0.034	0.029	0.023
Pontine	Zannone	0.133	0.214	0.117	0.014	0.015	0.024	0.029	0.018
Tremiti	Caprara	0.085	0.243	0.027	0.017	0.012	0.034	0.008	0.027
Tremiti	Cretaccio	0.067	0.357	0.017	0.015	0.004	0.020	0.002	0.010
Tremiti	Pianosa	0.148	0.200	0.070	0.006	0.040	0.056	0.044	0.018
Tremiti	Scoglio Elefante	0.095	0.167	0.033	0.020	0.008	0.014	0.006	0.020
Tremiti	San Domino	0.105	0.253	0.021	0.019	0.019	0.046	0.008	0.039
Tremiti	San Nicola	0.089	0.187	0.021	0.018	0.016	0.034	0.008	0.038
Tuscany	Mount Argentario	0.264	0.088	0.036	0.007	0.047	0.016	0.015	0.014
Tuscany	Capraia	0.224	0.190	0.115	0.010	0.055	0.048	0.065	0.029
Tuscany	Cerboli	0.183	0.524	0.311	0.134	0.008	0.022	0.029	0.065
Tuscany	Elba	0.219	0.168	0.029	0.002	0.102	0.080	0.031	0.013
Tuscany	Formica di Burano	0.029	0.857	0.467	0.003	0.000	0.012	0.015	0.001
Tuscany	Formica di Grosseto	0.083	0.786	0.467	0.003	0.002	0.022	0.029	0.001
Tuscany	Giannutri	0.207	0.222	0.104	0.016	0.025	0.028	0.029	0.023
Tuscany	Giglio	0.233	0.272	0.098	0.006	0.067	0.080	0.065	0.021
Tuscany	Gorgona	0.268	0.222	0.222	0.041	0.033	0.028	0.063	0.060
Tuscany	La Scola	0.298	0.500	0.244	0.023	0.024	0.042	0.046	0.022
Tuscany	Montecristo	0.566	0.540	0.385	0.035	0.070	0.068	0.109	0.051
Tuscany	Pianosa (Tuscany)	0.091	0.175	0.007	0.020	0.011	0.022	0.002	0.029
Tuscany	Sparviero	0.183	0.524	0.311	0.134	0.008	0.022	0.029	0.065
Tuscany (Elba)	Argentarola	0.029	0.857	0.467	0.003	0.000	0.012	0.015	0.001
Tuscany (Elba)	Gemini Fuori	0.029	0.857	0.467	0.003	0.000	0.012	0.015	0.001

Table 3. Continuação
Tabela 3. *Continuation*

Tuscany (Elba)	Gemini Terra	0.093	0.524	0.311	0.003	0.004	0.022	0.029	0.001
Tuscany (Elba)	Scoglio Remaiolo	0.029	0.857	0.467	0.003	0.000	0.012	0.015	0.001
Tuscany (Elba)	Isolotto dei Topi	0.029	0.857	0.467	0.003	0.000	0.012	0.015	0.001
Tuscany (Elba)	Isolotto Liscoli	0.083	0.429	0.233	0.003	0.002	0.012	0.015	0.001
Tuscany (Elba)	Isolotto Ortano	0.029	0.857	0.467	0.003	0.000	0.012	0.015	0.001
Tuscany (Elba)	Scoglio Paolina	0.029	0.857	0.467	0.003	0.000	0.012	0.015	0.001
Tuscany (Elba)	Scoglietto Portoferraio	0.100	0.429	0.233	0.003	0.003	0.012	0.015	0.001
Sicily	Pantelleria	0.431	0.534	0.159	0.009	0.135	0.173	0.115	0.033
Sicily	Ustica	0.220	0.341	0.049	0.011	0.078	0.125	0.040	0.047

On average, BCW2 attained higher values than BCW1 ($t = 6.891$, $p<0.0001$) and BCW3 ($t = 4.183$, $p<0.0001$), whereas BCW1 and BCW3 did not show a significant difference in their average values ($t = 0.275$, $p=0.784$). BCW1p showed lower values than BCC2 ($t = -2.736$, $p=0.008$), but no significant difference was found for comparisons with BCW1 and BCW3 ($t = -0.369$, $p=0.713$, and $t = -0.258$, $p = 0.797$, respectively).

The four indices, BCC1, BCC2, BCC3, and BCC1p (Table 3), produced different island rankings which reflect the effect of the geographical characteristics of the islands on their faunal composition. The BCC1 index, which was calculated on the basis of species distribution across islands, was positively correlated with island distance to the mainland ($r = 0.639$, $p < 0.001$). This indicates that more remote islands have tenebrionid faunas composed by species occurring on few islands. By contrast, both the BCC2 index, which considered species rarity in terms of mainland distribution, habitat specialization and population abundance, and the BCC3 index, which considered species biogeography, were negatively correlated ($r = - 0.341$, $p = 0.009$ and $r = - 0.375$, $p = 0.004$, respectively) with island maximum elevation, which indicates that islands with higher maximum elevation (which can be considered a surrogate for habitat diversity) host tenebrionid faunas with a lower concentration of vulnerable and endemic species than environmentally less varied islands. Finally, BCC1p was positively correlated with island distance to the mainland ($r = 0.366$, $p = 0.005$).

The BCW1 index was significantly correlated with island perimeter ($r = 0.621$), area ($r = 0.536$), elevation ($r = 0.494$) and distance ($r = 0.554$) ($p < 0.0001$ in all cases). The BCW2 index was also significantly correlated with island perimeter ($r = 0.453$, $p < 0.0001$), area ($r = 0.342$, $p = 0.009$), elevation ($r = 0.442$, $p = 0.001$) and distance ($r = 0.588$, $p < 0.0001$). BCW3 and BCW1p were only correlated with distance ($r = 0.588$ and $r = 0.580$, respectively; $p < 0.0001$ in both cases).

To assess index congruence in identifying priority islands, we compared the islands included in the highest third quartile for each index. Within this quartile, 6 islands (Lampione, Montecristo, Lampedusa, Pantelleria, plus Cerboli and Sparviero at the boundary value of the quartile; 40%) were shared between BCC1 and BCC2; 6 islands (Lampione, Montecristo, La Scola, Cerboli and Sparviero, plus Lampedusa at the quartile boundary level; 40%) were shared between BCC1 and BCC3; and 14 islands (including Lampione, Montecristo, Cerboli, Sparviero; 87.5%) were shared between BCC2 and BCC3. Among the islands included in the BCC1p upper quartile, 10 (62.5%, including Lampione, Montecristo, Lampedusa, La Scola, Cerboli and Sparviero) were shared with BCC1; 5 (33.3%, including Lampione, Montecristo, Lampedusa, Cerboli and Sparviero) with BCC2, and 6 (40%, including Lampione, Montecristo, Lampedusa, La Scola, Cerboli and Sparviero) with BCC3.

Two islands (Lampione and Montecristo) were recovered as high priority islands by all four BCC indices, and two (Cerboli and Sparviero) were at the borderline of the selected cut-off value. Islands falling in the higher third quartile varied significantly among the four indices for their area (ANOVA $F = 2.831$, $p = 0.047$), perimeter ($F = 3.947$, $p = 0.013$), elevation ($F = 5.984$, $p = 0.001$), but not for distance ($F=0.703$, $p = 0.554$). LSD tests revealed significant ($p < 0.01$) differences between BCC1 and all other indices for area, elevation, and perimeter, whereas differences among the other indices were not significant..

As regards the BCW indices, 11 islands (78.5%) were shared in the highest third quartile between BCC1 and BCC2; 10 islands (71.4%) were shared between BCC1 and BCC3; and 9 islands (64.3%) were shared between BCC2 and BCC3. Among the islands included in the BCC1p upper quartile, 8 (57.1%) were shared with BCC1; 4 (28.6%) with BCC2, and 8 (57.1%) with BCC3. Overall, Lampedusa, Lampione, Linosa, Marettimo, Pantelleria, and Ustica were recovered by all four indices; Capraia, Elba, Giglio, and Montecristo, by three indices.

Islands falling in the higher third quartile did not vary significantly among the four indices for their area (ANOVA $F = 0.688$, $p = 0.563$), elevation ($F = 2.424$, $p = 0.076$), distance ($F = 0.022$, $p = 0.996$), or perimeter ($F = 1.113$, $p = 0.352$).

4. DISCUSSION

The four BCC and BCW indices used in this study produced different island prioritisations, which may be explained by the different species rarity measures used to calculate them and the effect of island geography on species composition. The BCC1 highlighted the conservation importance of very remote, although faunistically poor, islands, a result also supported by the BCW1 index. These remote islands host few species as a consequence of their distance from possible source areas, yet these species have a narrow distribution, occurring on one or few islands. Moreover, as indicated by results achieved using BCC1p and BCW1p indices, the faunas of these islands tend to be also characterised by species that are distributed on islands whose summed perimeter determines high rarity scores. This may appear surprising, because typically the most remote islands are those colonized by animal species with high dispersal power, which are also the most widely distributed among islands and which should have a total distribution with high perimeter. The fact that the most remote islands are usually colonised by widespread species is a common phenomenon and it is at the basis of the nested structure of most island faunas (Dennis *et al.* 2012; Ulrich *et al.* 2009). In the case of the tenebrionid beetles inhabiting the Italian small islands, two factors may have contributed to this unexpected pattern. First, tenebrionids tend to be sedentary animals, with low dispersal power, with most of the species found on small islands being flightless (Fattorini, 2002, 2008a, b, 2010a). This led to uncommon colonization events mostly favored by past land bridges and to repeated evolution of endemic forms (usually considered as subspecies), especially on the most isolated islands. Second, some of the most remote and highest priority islands are not exclusively sourced from the Italian peninsula and major islands but received several elements from the nearer North African mainland (Pantelleria, Linosa, Lampione and Lampedusa). Thus, these islands host several North African species that are absent from Italy and, hence, from all other islands. Interestingly, while BCC2 and BCC3 did not correlate with island distance, BCW2 and BCW3 were correlated with island isolation. This is consistent with the fact that endemic species, which have high conservation weights, tend to be more numerous on the most remote islands, thus increasing the BCW2 and BCW3 values for remote islands.

Another important result is the negative relationships of BCC2 and BCC3 with altitude, thus habitat diversity, which can be explained by the ecology of most of the tenebrionid species considered in this study. The BCC2 index included species' association with coastal environment as a factor of vulnerability in contrast with a broader habitat specificity. Although some low-elevation islands were occupied by forests before human exploitation (*e.g.* Lampedusa), in general, flat islands tend to be almost entirely occupied by coastal environments, and hence their faunal assemblages are mainly composed of tenebrionid species that were scored as rare for habitat because of their strict association with coastal environments. By contrast, islands with relatively higher elevations tend to be occupied also by non-coastal environments, such as the high Mediterranean maquis. The occurrence on these islands of tenebrionid species not strictly associated with coastal environments determines a decrease in the proportion of tenebrionids scored as rare for habitat in the BCC2 index, which led to a negative relationship between this index and island elevation.

The BCC3 index also had a negative correlation with island elevation. Because this index is based on a biogeographical categorization of species, this result implies that higher islands host species assemblages with a lower proportion of endemic species. This may be due to the fact that while endemic species are always a small number, a higher environmental diversity may promote the presence of many non-endemic species coming from the mainland. Because of the increase in the number of non-endemic species, endemics will represent a lower proportion of the tenebrionid faunas, thus leading to a decrease in the BCC3 index. Interestingly, BCW1 and BCW2 (constructed just to cope with potential over-indexing biases for poorest islands) were positively correlated with elevation. This indicates that the negative correlations found for BCC2 and BCC3 may be due to the fact that environmentally more diverse islands may even have as many or more rare species than the low-elevation islands, but because they also have many common species in certain habitats, the average rarity is lower.

The BCC2 and BCC3 results suggests that islands may be important not only for the presence of several endemic species, but also as ecological refugia for species associated with the particular coastal biotopes that have been deteriorated on more largely populated mainland areas. It should be also noted that BCC indices are not correlated with island area, whereas a positive correlation with island area was found for two BCW indices (BCW1 and BCW2). Lack of correlation with island area, however, is not a bias for the BCC index itself. For example, for the butterflies of the Italian islands the islands showing the highest BCC value were the largest in the sample (Dapporto & Dennis, 2008).

The islands prioritised by the various indices varied significantly in their geographical characteristics. In particular, the set of islands recovered by the BCC1 index had mean geographical characteristics different from those of all other three BCC indices. By contrast, the four BCW indices recovered similar island sets that were not significantly different in their mean values for the geographical characteristics used in this study.

Although the various indices gave different island prioritisations, most of the islands included in the third quartile for two or more of the three indices belong to the same two archipelagos, the Tuscan Islands and the Pelagie Islands (plus two very isolated islands, Pantelleria and Ustica, which do not belong to any archipelago). Except the Aegadian islands of Marettimo (prioritised by BCW1, BCW2, BCW3) and Favignana (prioritised by BCW1 and BCW2, respectively), no island belonging to the other Italian archipelagos (Aeolian, Campane, Pontine, and Tremiti) was prioritised by more than one index.

In spite of their low levels of endemism, the islands of Ustica and Pantelleria have been prioritised by one (Ustica) and two (Pantelleria) BCC indices, and by all BCW indices. Despite Ustica and Pantelleria emerged recently, suggesting that there was not sufficient time for higher endemicity levels to develop, these islands are located quite far from Sicily and mainland areas. This characteristic could have favoured some relatively fast morphological differentiation in some tenebrionid populations. Actually, one endemic taxon (*Opatrum validum marcuzzii*) is known from Ustica (out of 26 taxa; 3.8%) and two endemic taxa (*Heliopathes avarus donatellae* and *Probaticus cossyrensis*) from Pantelleria (out of 23; 8.7%). Only a fraction of the surface of these two islands is protected. The "Riserva naturale orientata Isola di Ustica" covers 204.36 hectares, i.e. 23.76% of Ustica's area, whereas the "Riserva naturale orientata Isola di Pantelleria" occupies an area of 2626.69 hectares, i.e. about 30% of the island's area. However, in both islands there is some habitat variability represented by presence of coastal areas, pine woods and maquis. Pantelleria in particular hosts a great mosaic of environmental variability including the Venere lake area, different woods around the Montagna Grande area and traditionally managed agricultural areas.

The Pelagie Islands are remote and very ancient islands. The island of Lampedusa (the largest amongst the Pelagie) shows a relatively rich tenebrionid fauna, including 28 taxa, 4 of which (*Erodius audouini destefanii*, *Pachychila dejeani doderoi*, *Alphasida puncticollis tirellii*, *Asida minima*; 14.3%) are endemic to this island. This island was included in the third quartile by both BCC1 and BCC2. Lampione, an islet of just 0.03 km^2, hosts six tenebrionid taxa, three of which (*Alphasida puncticollis moltonii*, *Tentyria* n. sp. and *Opatrum validum rottembergi*) are endemic to this island, and one (*Machlopsis doderoi*), endemic to the Pelagie Islands, occurs on Lampedusa and Lampione. Nineteen species are known from Linosa, with no exclusive endemic (although it is not clear if the *Tentyria* population of this island belongs to an African species or it is an endemic species), but *Stenosis brignonei* is endemic to Linosa and Lampedusa, and Linosa was included in the first quartile by the BCC1 index and the BCC1p index as well as by all BCW indices. The "Riserva naturale orientata Isola di Lampedusa" covers 369.68 hectares, i.e. about 15% of the island's area. The "Riserva naturale orientata/integrale Isola di Linosa e Lampione" (266.87 hectares) covers about 49.5% of Linosa (as an oriented nature reserve) and 100% of Lampione (as a strict nature reserve).

As a whole, Pantelleria and the Pelagie Islands host several species, more or less widely distributed in North Africa (especially Algeria and Tunisia), which occur in Europe only on these islands, like *Imatismus villosus* and *Pseudoseriscius griseovestis* on Linosa; *Pachychila crassicollis cossyrensis* and *Opatrum validum schlicki* on Pantelleria; *Pachychila tazmaltensis*, *Eutagenia aegyptiaca tunisea* and *Microtelus lethierryi* on Lampedusa; *Allophylax costatipennis costatipennis* on Lampedusa and Linosa; *Gonocephalum perplexum* on Lampedusa and Pantelleria. Thus, although Pantelleria and the Pelagie islands host few species, as expected because of their very small area and high isolation, their tenebrionid faunas are very peculiar, which leads to a high prioritisation.

All other islands selected by one or more indices belong to the Tuscan Archipelago. The Tuscan Archipelago is composed of seven main islands (Elba, Giglio, Capraia, Pianosa, Montecristo, Gorgona and Giannutri) and several islets located in the Tyrrhenian Sea, between Corsica and the Italian Peninsula. Main islands range from 2.2 km^2 (Gorgona) to 223.5 km^2 (Elba). The islands differ considerably in terms of their origin and geological features. The island of Gorgona is composed by both sedimentary and ophiolitic rocks. The island of Capraia is volcanic and originated about nine million years ago. The island of Montecristo is entirely granite, as is most of the Island of Giglio. The island of Elba shows a more composite origin, being granite in the western part (where Mount Capanne reaches 1018 m elevation), sedimentary and metamorphic in the central and eastern part (with gneiss and marble rocks) and alluvial (with clay, sandstone, and limestone soils) in the central plains. The island of Pianosa is composed of sedimentary rocks and shell formations. A total of 59 native taxa are known from these islands, 13 of which (22%) are endemic. Out of these 13 endemics, one (*Asida gestroi*) is classified as species, the others being represented by populations classified as subspecies. The percentage of endemic taxa (single island endemics and taxa endemic to the archipelago) varies considerably among the main islands, ranging from 5.88% (Elba, with two endemic taxa out of 34 taxa) to 55.56% (Montecristo, with 5 endemic taxa out of 9 taxa), whereas the islets have higher levels of endemism (67-100%) but with very few species (1-3 taxa). This is due to the fact that islets are colonised from adjacent islands by taxa that are endemic to the archipelago, but which are widespread within it. It has been suggested that for animals with low mobility (Fattorini, 2010a), islets tend to be colonized by adjacent islands more than by mainland areas, and this is probably the case of the islets surrounding the islands in the Tuscan Archipelago, such as the very small rocks around Elba island.

Levels of endemism can be explained by the paleogeographical history of this archipelago, with the islands which were isolated for longer showing higher levels of endemism (Fattorini, 2009a, b). Most endemics are associated with garrigue and maquis biotopes. Some taxa show an impressive cladogenesis, being represented with populations endemic to individual islands or to groups of a few islands, such as *Asida luigionii* (with two subspecies, *doriai* and *insularis*), the endemic *A. gestroi* (with the subspecies *gestroi*, *tyrrhena*, *capraiensis*, *lanzai*, and *gardinii*), and *Opatrum sculpturatum* (with the endemic subspecies *ilvense*, *urgonense*, *capraiense* and *igiliense*). The only endemic taxa likely associated with woodlands are *Colpotus strigosus oglasensis* and *Odocnemis ruffoi osellai*.

All islands of the Tuscan Archipelago are part of a National Park and most of their environmentally valuable areas are under strict protection. In particular all the entire island of Montecristo represents a biogenetic reserve established in 1971. Only two peoples live there, both nature reserve keepers. Visitors are highly restricted in yearly number and activities. Also on Gorgona and Pianosa access is regulated, but other islands were subject to high tourism pressures, notably Elba and Giglio. Despite the human population on the Tuscan Islands is relatively small and declining (*e.g.*, de Fabrizio, 2005), there have been important anthropic influences. Serious consequences have been produced by past growth of mass tourism (and partly also of the so-called ecotourism). This has resulted in the rapid degradation of the most fragile natural habitats especially before the establishment of the National Park. The effects have been especially serious on the coastal environments, which became more and more attractive to tourists just because of their increasing rarity. This is the case of the few and scattered sandy shores on Giglio, now completely obliterated by bathing establishments, or, of the small and very isolated beaches, constantly visited by tourists. The psammophilous species *Phaleria* spp. and *Trachyscelis aphodioides* are now considered to be extinct on this island as a result of the high anthropic pressure on the beaches. Increasing rarity of well-preserved places led to high pressure from tourists also on the Island of Giannutri. Although most of the footways on this island are currently forbidden, this is not known by most tourists, who reach the island by ferry-boats and concentrate in the few accessible places.

5. CONCLUSIONS

Most of the studied islands have been recovered as having some conservation value according to their tenebrionid faunas. No island was found to have a BCC value of zero with BCC1, only one with BCC2 and a few with BCC3. This fits with the high tendency for tenebrionids to have relict populations or to form endemic species and races resulting in virtually all the islands and islets to be considered of some conservation interest. Insular phenomena are know in many other organisms from Italian islands and this resulted in most islands being identified as Natura 2000 sites (see references reported in Table 2). Many islands are also part of National Parks or other types of protected areas at national or regional level. Therefore, virtually all islands are formally regarded as areas of conservation concerns. However, a formal recognition does not automatically imply that concrete measures for conservation are adopted. Because of limitation of funds and the need of urgent actions for the most "valuable" areas, prioritisation may help to allocate founds or enhance concrete conservation actions and appropriate integrated management policies in selected areas. The use of integrated management policies are extremely important in the context of the Italian small islands, because most of them are inhabited and/or used by people and it is necessary to avoid an opposition between economics and environmental sustainability. Results of our analyses of tenebrionid beetles indicate some islands as having highest priorities, which does not mean that other islands are of scarce interest. These include the islands belonging to the Tuscan Archipelago and some Sicilian Islands (Pelagie, Pantelleria and Ustica). Whereas the islands belonging to the Tuscan Archipelago are part of a National Park, Pantelleria, Ustica and the Pelagie Islands are both classified as natural reserves, not as a National park, and one of them (Lampedusa) is under severe anthropic pressure and social contrasts as it is a primary European entry point for migrants, mainly coming from Africa. More attention at national level should be paid in such situation.

ACKNOWLEDGMENTS

We would like to acknowledge P. Cardoso, P. Lo Cascio and G. Gardini for their suggestions and corrections.

REFERENCES

Aliquò, V.; Rastelli, M.; Rastelli, S.; Soldati, F. (2006) - *Coleotteri Tenebrionidi d'Italia*. CD-ROM. Museo Civico di Storia Naturale di Carmagnola, Carmagnola, Italy. ISBN: 8890120185.

Arnold, C. (2008) - *Mediterranean Islands*. 416p., Survival Books, London, U.K. ISBN: 978-0955648915.

Bergerot, B.; Lasne, E.; Vigneron, T.; Laffaille, P. (2008) - Prioritization of fish assemblages with a view to conservation and restoration on a large scale European basin the Loire (France). *Biodiversity and Conservation*, 17(9):2247-2262. DOI: 10.1007/s10531-008-9331-6.

Dapporto, L.; Dennis, R.L.H. (2008) - Island size is not the only consideration. Ranking priorities for the conservation of butterflies on Italian offshore islands. *Journal of Insect Conservation*, 12(3-4):237–249. DOI: 10.1007/s10841-008-9150-9.

De Fabrizio, E. (2005) - *Isola del Giglio. Il territorio, gli abitanti e la storia*. 272 p., Proloco dell'Isola del Giglio, Grosseto, Italy.

Dennis, R.L.H.; Dapporto, L.; Shreeve, T.G.; John, E.; Coutsis, J.G.; Kudrna, O.; Saarinen, K.; Ryrholm, N.; Williams, W. R. (2008) - Butterflies of European islands: the implications of the geography and ecology of rarity and endemicity for conservation. *Journal of Insect Conservation*, 12(3-4):205-236. DOI: 10.1007/s10841-008-9148-3.

Dennis, R.L.H.; Hardy, P.B.; Dapporto, L. (2012) - Nestedness in island faunas: novel insights into island biogeography through butterfly community profiles of colonization ability and migration capacity. *Journal of Biogeography*, 39(8):1412-1426. DOI: 10.1111/j.1365-2699.2012.02698.x.

Dias, J.A.; Carmo, J.A. do; Polette, M. (2010) - Breves considerações sobre as ilhas e a sua gestão. *Revista de Gestão Costeira Integrada / Journal of Integrated Coastal Zone Management,* 10(3):243-253. DOI: 10.5894/rgci237

Fattorini, S. (2002) - A comparison of relict versus dynamic models for tenebrionid beetles of Aegean Islands (Greece) (Coleoptera: Tenebrionidae). *Belgian Journal of Zoology*, 132(1):55-64. Available at: http://www.naturalsciences.be/institute/associations/rbzs_website/bjz/back/pdf/BJZ 132 (1)/Volume 132(1), pp. 55-64.pdf

Fattorini, S. (2006a) - Biogeography and conservation of endemic tenebrionid beetles (Coleoptera Tenebrionidae) on East Mediterranean islands. *Vie et Milieu,* 56:231-241. Available at: http://www.obs-banyuls.fr/Viemilieu/index.php/volume-56-2006/56-issue-3/563-article-4.html

Fattorini, S. (2006b) - A new method to identify important conservation areas applied to the butterflies of the Aegean Islands (Greece). *Animal Conservation*, 9(1):75-83. DOI: 10.1111/j.1469-1795.2005.00009.x.

Fattorini, S. (2008a) - Ecology and conservation of tenebrionid beetles in Mediterranean coastal areas. *In:* Fattorini, S. (ed.), *Insect Ecology and Conservation*, pp. 165-297. Research Signpost, Trivandrum, Kerala, India. ISBN: 978-8130802978.

Fattorini, S. (2008b) - A multidimensional characterization of rarity applied to the Aegean tenebrionid beetles (Coleoptera Tenebrionidae). *Journal of Insect Conservation*, 12(3-4):251-263. DOI: 10.1007/s10841-007-9080-y.

Fattorini, S. (2009a) - Both Recent and Pleistocene geography determines animal distributional patterns in the Tuscan Archipelago. *Journal of Zoology*, 277(4):291-301. DOI: 10.1111/j.1469-7998.2008.00540.x.

Fattorini, S. (2009b) - Faunal patterns in tenebrionids (Coleoptera: Tenebrionidae) on the Tuscan Islands: The dominance of paleogeography over recent geography. *European Journal of Entomology*, 106(3):415-423. DOI: 10.14411/eje.2009.053.

Fattorini, S. (2010a) – The influence of geographical and ecological factors on island beta diversity patterns. *Journal of Biogeography*, 37(6):1061-1070. DOI: 10.1111/j.1365-2699.2009.02252.x.

Fattorini, S. (2010b) - Use of insect rarity for biotope prioritisation: the tenebrionid beetles of the Central Apennines (Italy). *Journal of Insect Conservation*, 14(4):367–378. DOI: 10.1007/s10841-010-9266-6.

Fattorini, S. (2010c) - Biotope prioritisation in the Central Apennines (Italy): species rarity and cross-taxon congruence. *Biodiversity and Conservation*, 19(12):3413–3429. DOI: 10.1007/s10531-010-9903-0.

Fattorini, S. (2011a) - Biogeography of tenebrionid beetles (Coleoptera: Tenebrionidae) in the circum-Sicilian islands (Italy, Sicily): Multiple biogeographical patterns require multiple explanations. *European Journal of Entomology*, 108(4):659-672. DOI: 10.14411/eje.2011.084.

Fattorini, S. (2011b) – Influence of island geography, age and landscape on species composition in different animal groups. *Journal of Biogeography*, 38(7):1318-1329. DOI: 10.1111/j.1365-2699.2011.02486.x.

Fattorini, S. (2013a) – Species ecological preferences predict extinction risk in urban tenebrionid beetle guilds. *Animal Biology*, 63:93-106. DOI: 10.1163/15707563-00002396.

Fattorini, S. (2013b) - Relations between species rarity, vulnerability, and range contraction for a beetle group in a densely populated region within the Mediterranean biodiversity hotspot. *Conservation Biology*, 28(1):169-176. DOI: 10.1111/cobi.12157.

Fattorini, S.; Fowles, A. (2005) - A biogeographical analysis of the tenebrionid beetles (Coleoptera, Tenebrionidae) of the island of Thasos in the context of the Aegean Islands (Greece). *Journal of Natural History*, 39 (46), 3919–3949. DOI: 10.1080/00222930500533443.

Fattorini, S.; Santoro, R.; Maurizi, E.; Acosta, A.T.R.; Di Giulio, A. (2012a) - Environmental tuning of an insect ensemble: the tenebrionid beetles inhabiting a Mediterranean coastal dune zonation. *Comptes rendus Biologies*, 335(10-11):708-711. DOI: 10.1016/j.crvi.2012.09.009.

Fattorini, S.; Cardoso, P.; Rigal, F.; Borges, P.V.A. (2012b) - Use of Arthropod Rarity for Area Prioritisation: Insights from the Azorean Islands. *PLoS ONE*, 7(3):e33995. DOI: 10.1371/journal.pone.0033995.

Kattan, G. (1992) - Rarity and vulnerability: the birds of the Cordillera Central of Colombia. *Conservation Biology*, 6(1):64–70. DOI: 10.1046/j.1523-1739.1992.610064.x.

Laffaille, P.; Chantepie, S.; Lasne, E. (2011) - Assessing the conservation value of waterbodies: the example of the Loire floodplain (France). *Biodiversity and Conservation*, 20(11):2427–2444. DOI: 10.1007/s10531-011-9994-2.

Löbl, I.; Smetana, A. (eds) (2008) - *Catalogue of Palaearctic Coleoptera*. Vol. 5. *Tenebrionoidea*. 670p., Apollo Books, Stenstrup, Aamosen, Denmark. ISBN: 978-8788757699.

Maire, A.; Buisson, L.; Biau, S.; Canal, J.; Lafaille, P. (2013)- *A multi-faceted framework of diversity for prioritizing the conservation of fish assemblages. Ecological Indicators*, 34:450-459. DOI: 10.1016/j.ecolind.2013.06.009.

Manne, L. (2013) – Island species with nowhere to go. *In:* J. F. Brodie, E. Post & D. F. Doak (eds.), *Wildlife conservation in a changing climate*, pp. 226-244, The University of Chicago Press, Chicago, IL, U.S.A. ISBN: 978-0226074634.

Morey, M.; Martínez-Taberner, A. (2000) - Environmental conservancy strategies in the Mediterranean islands. *In:* Trabaud L. (ed.), *Life and Environment in the Mediterranean*, pp. 345–386, Wit-Press, Southampton, U.K. ISBN: 978-1853126802.

Saffache, P..; Angelelli, P. (2010) – Integrated Coastal Zone Management in small islands: A comparative outline of some islands of the Lesser Antilles. *Revista de Gestão Costeira Integrada / Journal of Integrated Coastal Zone Management* 10(3):255-279. DOI: 10.5894/rgci228

Ulrich, W.; Almeida, M.; Gotelli, N.J. (2009) - A consumer's guide to nestedness analysis. *Oikos*, 118(1):3-17. DOI: 10.1111/j.1600-0706.2008.17053.x.

Whittaker, R.J.; Fernández-Palacios, J.M. (2007) - *Island biogeography : ecology, evolution, and conservation*. 2nd edn., 416 p., Oxford University Press, Oxford & New York. ISBN: 978-0198566120.

Revista da Gestão Costeira Integrada 14(2):199-213 (2014)
Journal of Integrated Coastal Zone Management 14(2):199-213 (2014)

GESTÃO COSTEIRA INTEGRADA
Journal of Integrated Coastal Zone Management

http://www.aprh.pt/rgci/pdf/rgci-468_Benedicto.pdf | DOI:10.5894/rgci468

Identity and decision-making for sustainability in the context of small islands *

Identidade e tomada de decisão para a sustentabilidade no contexto de pequenas ilhas

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ABSTRACT

This article focuses on the analysis of how identity and sense of place identified on small islands can be an opportunity to inform local population about transition to sustainability. Small islands are considered to be vulnerable territories but they are good candidates to undertake an innovative and successful transition to sustainability, and to become models for larger territories. A participative scenario building and multi-criteria methodology has been developed to explore preferences for sustainable development in the context of a small island. The article is the opportunity to analyse how Flores Island (Azores, Portugal) community perceives local sustainability issues, what is the role that identity can play in the transition to sustainability, and what is the point of view from regional decision-makers, civil servant and key informants interviewed in the project. Sustainability research findings and islanders' preferences concern three points: (1) islanders' low expectations of change, (2) preference for greener development, and (3) the potential role of identity and public participation in the transition to sustainability. Locals have shown awareness about sustainability issues and they have demonstrated willingness to play an active role in decision-making processes. The contributions from the research participants are also an opportunity to inform the relationship between tourism and the sustainability of the island.

Keywords: Sense of place, Flores Island, Azores, multi-criteria appraisal, foresight scenario.

RESUMO

Este artigo analisa a identidade e o sentimento de pertença observados em ilhas pequenas como uma oportunidade para melhor informar a população local sobre os processos de transição para a sustentabilidade. As pequenas ilhas são consideradas territórios vulneráveis mas também são bons casos de estudo para testar e realizar transições inovadoras e bem-sucedidas para a sustentabilidade, e tornar-se assim modelos para áreas maiores. A metodologia participativa de construção de cenários e análise multi-critério foi desenvolvida com o objetivo de explorar as preferências dos intervenientes para o desenvolvimento sustentável no contexto de uma pequena ilha. Este trabalho visa descrever e analisar a forma como a população da Ilha das Flores (Arquipélago dos Açores, Portugal) interpreta as questões ligadas à sustentabilidade local e qual é o ponto de vista dos decisores, funcionários públicos e informadores-chave regionais que participaram no projecto. Este estudo visa também estabelecer qual é o papel que a identidade pode desempenhar na transição para a sustentabilidade. Os resultados da pesquisa centram-se em três pontos: (1) as baixas expectativas de mudança dos islenhos; (2) a preferência para um desenvolvimento mais "verde"; e (3) o papel potencial da identidade e da participação pública no processo da transição para a sustentabilidade. Os florentinos mostraram uma forte consciencialização relativamente às questões de sustentabilidade e demonstraram vontade em desempenhar um papel ativo nos processos de tomada de decisão. As contribuições dos participantes evidenciaram também a forte relação entre o turismo e a sustentabilidade da ilha.

Palavras Chave: *sentido de pertença, Ilha das Flores, Açores, análise multi-critério, cenários de futuro.*

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Submission: 31 December 2013; Evaluation: 5 February 2014; Reception of revised manuscript: 15 May 2014; Accepted: 21 May 2014; Available on-line: 30 may 2014

1. INTRODUCTION

Comparing with continental territories small islands seem to be insignificant spaces, but at least 10% of the world population lives on small islands (Baldacchino, 2007). This figure alone justifies the study of islands, but islands can also provide useful lessons on sustainability issues for larger territories (Depraetere, 2008) (sustainability concept is treated in Section 2.1); islands are indeed considered to be ideal places to undertake innovative strategies for sustainability (Depraetere, 2008; Kerr, 2005; Gagliardi, 2009). This article focuses on small islands independently of their remoteness. An island is considered to be small when its area is less than 10,000km^2 and it has fewer than 500,000 inhabitants (Beller *et al.*, 2004). As clearly defined geographic units surrounded by water, islands provide the opportunity to define the spaces they contain. Their size enables their integral study (Kelman & Lewis, 2005; Gagliardi, 2009), and wakes "the myth of total knowledgability" (Péron, 2004). Small islands illustrate the limits of our planet as "finite natural ecosystem" (Daly, 1991). The management of coastlines on small islands is especially crucial due to the importance for these areas in human development and the environmental and security concerns that such development can create, indeed, as Saffache & Angelelli observe small islands are "largely coastal entities" (2010).

Small islands' geographic specificities govern their societies and their economies (Rietbergen *et al.*, 2007). It is generally acknowledged that small islands suffer from structural constraints (Hache, 1998) and that they are associated to important economic and environmental vulnerabilities (Briguglio, 1995; Hache, 1998; UN, 1998a; UN General Assembly, 1988; Campling, 2006; Rietbergen *et al.*, 2007; Christofakis *et al.*, 2009; Fonseca *et al.*, 2011). Saffache & Angelelli (2010) identify three factors for vulnerability in the Lesser Antilles: small size, insularity and remoteness, and susceptibility to natural disasters. It is reasonable to consider that (in different degrees) these factors also influence other islands. Considering an extended literature review Campling (2006) proposes a list of economic and environmental vulnerabilities identified for small islands developing states (SIDS) (Table 1).

Table 1. Economic and environmental vulnerability in SIDS(adapted from Campling, 2006).
Tabela 1. *Vulnerabilidades económicas e ambientais nos SIDS (adaptado de Campling, 2006).*

SIDS economic vulnerability	SIDS environmental vulnerability
Small domestic market	Climate change/ sea level rise
Limited resources	Volatile biodiversity
Open to international trade	Limited land/urbanization
Vulnerable to external shocks	Natural resource depletion
Location/transport costs	Water/sanitation
Political sovereignty	Natural environmental disasters

The vulnerabilities pointed-out by Campling (2006) are directly related to their small size that limits economic growth and the availability of productive and natural areas. This increases the conflicts over their use and decreases their resilience over negative economic and environmental impacts (small domestic market, limited resources, volatile biodiversity, limited land/urbanization, natural resource depletion and availability of water and the consequent sanitary problems). The small size is also reason for their small population and consequent limited internal demand and production capacity, handicapping potential economies of scale, but also a higher relative dependency on the exterior and a poor degree of competition, increasing economic vulnerability. As well, due to their small population and economy, islands suffer from having limited political influence. Isolation increases also the dependency towards transport (location/transport costs) and it limits the alternatives to transport goods and people. Moreover because of their small economies islands do not have capacity to influence prices (open to international trade and vulnerable to external shocks). As well, small island states are especially sensible to climate change and natural environmental disasters (Briguglio, 1995; Pelling & Uitto, 2001; Kelman, 2010).

In what concerns socio-cultural characteristics, communities in small remote islands are deeply influenced by isolation and remoteness (Kotlok, 2005; Pitt, 1980). The dwellers of these islands are affected by the combination of small size and isolation but they also appear to be good candidates to undertake successful transitions to sustainability and they can benefit greatly from this transition (even though this pathway is not exempt of challenges). Small islands can surmount their "intrinsic handicaps" by deciding adapted strategies (Encontre, 1999), thus economic and environmental vulnerabilities should not be seen as fatalities (Armstrong *et al.*, 1998; Armstrong & Read, 2002; 2003). The challenge is then to define from a local and Regional (unless specified region refers in this article to an administrative division of a country) perspective the strategies better adapted for each island case.

The present research explores the case of a small island (Flores Island, Azores, Portugal) (Figure 1) informing, from local and Regional perspectives, the transitions to sustainability. This article reflects upon the role that identity, and islanders' relation to the place, plays or can play, in decision-making for sustainability in small islands. The purpose of the present research was originally to explore the preferences for sustainable development in a small island. Identity was not initially considered as a theme of the research but the contributions from the research participants led to study the relation between identity and small islands and how it can play a role in the transition to sustainability. The novel methodology developed in the context of the research, 'Participative foresight scenario mapping' (this methodology, developed in Section 4: 'Methodology: Participative foresight scenario mapping', is an adaptation of multi-criteria mapping (Stirling, 1997)), was the opportunity to inform the potential pathways that a small island can undertake to build the preferred future, but it was also the opportunity to inform the potential role played by identity in the transition to sustainability in small islands. The research was not an inquiry to the population but it was the opportunity to explore in depth the preferences of a representative share of the local population. The article follows a conventional structure of literature review (Section 2) where the themes of identity, sustainability and decision making in the context of small islands are going to be treated. The case study area is presented in Section 3. Sections 4 and 5 define respectively the methodology developed and used in the research and fieldwork and data analysis. Section 6 develops the research findings concerning the low expectation of change for the island of Flores (Section 6.1), the local and Regional preference for greener development for the island (Section 6.2) and the potential role of identity and public participation in the transition to sustainability (Section 6.3). Finally Section 7 concludes the article.

2. LITERATURE REVIEW

2.1. Islands, conceptual image of the world and identity

Institutional reflection on sustainable development began in the 1980s with reports from the International Union for Conservation of Nature and the United Nations (IUCN *et al.*, 1980; World Commission on Environment and Development, 1987). The definition given by the World Commission on Environment and Development (WCED) in *Our Common Future*, "development that meets the needs of the present without compromising the ability of future generations to meet their own needs", constitutes a benchmark reference. This definition clearly states the requirement of assuring continuity without handicapping the present generation; it also advocates development that ensures that future generations can enjoy the possibility of satisfying their needs. But sustainable development is a controversial term (Jabareen, 2004; Counsell and Haughton, 2006; Krueger & Gibbs, 2007; UN, 2010). The concept enables "possible interpretations" (Haughton, 1999) that difficult decision-making. One example of this is the debate around the preference for weak or strong sustainable development precepts. Agyeman *et al.* (2002) define weak sustainability as a situation where natural capital can be replaced by manufactured capital as long as the former is equal in value. On the other hand, strong sustainable development does not propose trade-offs between natural assets and economy (or at least limitations to these trades-offs) (Daly & Farley, 2004). One consequence of this is that optimal decision making requires a deep knowledge of the available natural capital. Small scales can be the opportunity to have a reasonable grasp

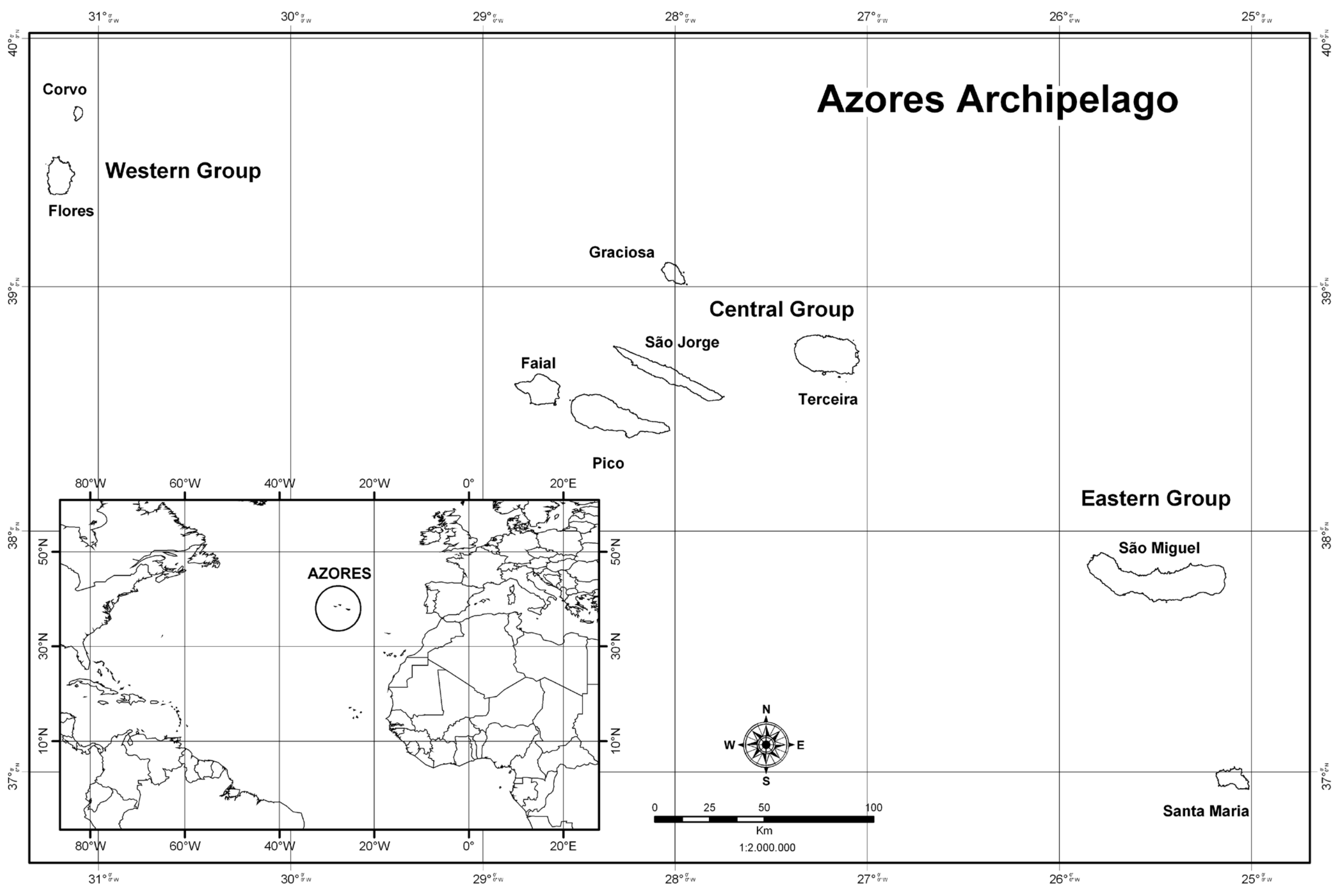

Figure 1. The Azores Archipelago and Flores Island (source: University of the Azores' Geographic Information and Land Planning Research Centre (2010)).
Figura 1. *Os Açores e a Ilha das Flores (fonte: Centro de Informação Geográfica e Planeamento Territorial da Universidade dos Açores).*

of the entire territory (and therefore a good understanding of the available natural capital), and to involve a wide range of stakeholders in manageable processes (see the role of local authorities in Local Agenda 21, conf. Section 2.2). In this context working on small islands allows this closeness and it is also the opportunity to develop holistic approaches for sustainability in manageable scales.

Islands' territories act as closed systems (Calado *et al.*, 2007) and their maritime boundaries are a constant reminder that Earth itself is a finite space with limited resources. Applying Boulding's analogy of "spaceship earth" the image of the 'spaceship island' can be used to illustrate their potential usefulness as models for sustainability; as Boulding (1993, originally published in 1966) states: "we can only find out about a closed system if we participate in it". Islanders' lives in "aquaria" (Putz, 2004) support the idea that islanders have the experience of living in confined territories. Therefore, even though small islands are not totally closed systems, islanders' isolation can be inspiring examples for other places (for example in the case of decision-making for sustainability). As Putz expresses on the Maine archipelago (US) and islands in general:

"there is still in the Maine archipelago, and on islands elsewhere, an intact vision of the world which differs from that of others and which offers not merely diversity and its advantages, but a sensibility about the world that the world could use, since citizens everywhere are coming to realize that the earth itself is an island. In this sense, mainlanders are the pre-Copernicans, and islanders are the most sophisticated, modern and up-to-date. Islanders know about islandness and all of us should have some of this imprinted on our consciousness" (Putz, 2004).

Remoteness and isolation have influenced remote islands' ecology explaining the existence of important rates of natural endemism (Chapuis *et al.*, 1994; Quammen, 1997, Francisco-Ortega *et al.*, 2000; Dumont *et al.*, 2010) but over the centuries isolation has also influenced local communities (Pitt, 1980; Kotlok, 2005). Islanders' identity, forged by centuries of "geographical separation", is considered central in these societies (Pitt, 1980). For Péron (2004) islanders' identity is characterised by a sense of "pride in being different". Erickson & Roberts define identity as: "the qualities which make an individual, or place capable of being specified or singled out, which make it unique and separate" (1997). For Bonaiuto *et al.* (2002) the study of the relation of place and identity is crucial in sustainability because specific pro-environmental attitudes are defined by the place directly concerned: "pro-environmental attitudes, just as other psychological processes, should be conceived as place-situated phenomena and therefore should be studied taking into account and dealing more directly with the places or situations they refer to or are embedded in". Place identity concept should be differentiated from place attachment concept. Place attachment is defined as "the affective link that people establish with specific settings, where they tend to remain and where they feel comfortable and safe" (Hernández *et al.*, 2007, p310), Morgan (2010) defines it as the "experience of a long-term affective bond to a particular geographic area and the meaning attributed to that bond". Place identity is defined as a process by which people describe themselves in relation to a specific place (Hernández *et al.*, 2007); therefore this concept involves the relevance of the physical environment in the definition of individuals' identity. Moreover, for Erickson & Roberts (1997) place identity is an element of individual and collective self-identity.

Islands have a special attraction in western culture. They are often associated with the image of heaven/Eden/paradise or utopia (Ward, 1993; Connel, 2003; Kotlok, 2005). But this idyllic image is not necessarily shared by islanders themselves (Ward, 1993; Cambers, 2006). However this attractiveness is probably one of their main strengths that should be treasured (Baldacchino & Pleijel, 2010). Aware of this attractiveness, islanders can build 'intentional ideals' where individuals construct "intentional communities" from an initial situation (Miller, 2009), this should be understood as the situation in the moment when the community decides to undertake the construction of their intentional ideals. Whereas the world's economy is defined by movement and globalisation, islands have been defined as the "quintessential physical place" (Péron, 2004); in other words, for Péron, islands are the most obvious examples of clearly defined geographical units. Stratford (2008) also supports this vision: "in an age of hyper-mobility, islands provide spatial and temporal limits, and foster strong sense of identity". This strong sense of identity is translated into self-awareness. Islands provide "possible sources of identification and belonging within wider contexts of life" (Olwig, 2007) while creating a "sense of a place closer to the natural world and to neighbours" (Conkling, 2007). This idea is also shared by Soulimant who observes that island societies are characterised by a "feeling of belonging, a strong identity and the will of distancing itself from the others" (2011). Hernández *et al.* acknowledge that islands, like cities, "represent strong, stable and comprehensive environments" (2007). Depraetere (2008) proposes that islanders are characterized by having a "strong sense of place". This signifies that islands have a strong identity which is felt by islanders and visitors. This feeling is consequence of the combination of natural and cultural characteristics. Islanders' strong sense of place can be used as a "mobilising principle" against global dysfunctions and to plan opposition against unwanted situations (Hay, 2006). In a similar vein Uzzel *et al.* (2002) showed that communities with strong place identity are more willing to support environmental attitudes and behaviour, therefore they should be more incline to undertake transitions towards sustainability. Therefore place identity in islands should be an opportunity to implement sustainable behaviours among local population; islanders' relation to the place should not be a threat but an opportunity in these processes.

The Small Islands Voice participative project, aiming at informing sustainability on islands (the initiative was supported by the UNESCO and it involved 15 island states and territories) allowed Cambers (2006) to observe that islanders are aware of local issues and the importance of adapting their economic development to islands' limited resources (the following section develops the role of public participation in the transition to sustainability). This can be explained because resources are limited in small islands (Briguglio, 1995; Campling, 2006), and the effect of human activity on the local environment is more visible (Depraetere, 2008). But this predisposition to pro-environmental attitudes might not be directly translated into pro-environmental behaviours (Kollmuss & Agyeman, 2002). However, considering islands' economic and environmental vulnerabilities already treated in the introduction (Campling, 2006), islanders' situation should benefit greatly from adapting sustainable ways of life. But the outcomes of decision-making and the process themselves might be challenged by islanders' aversion to change.

2.2. Requirements for decision-making in the context of islands

Participation in decision-making for sustainability is a pre-condition for policies' effective implementation (Agenda 21 Chapter 28.2a, 1992; Agyeman & Angus, 2002; Stiglitz *et al.*, 2009). Principle 10 of the Rio Declaration clearly states this idea: "environmental issues are best handled with the participation of all concerned citizens". Participative processes are undertaken all over the world to reach these goals (e.g. LA21). Local and Regional authorities are seen as the better positioned to lead decision-making for sustainability due to greater flexibility and awareness of local issues and challenges (Haughton & Naylor, 2008). Even though national scale is also crucial in decision making for sustainability (e.g. National Sustainable Development Strategies), the local scale is an opportunity to be closer to sustainability issues at stake as well as the answer(s) to these problems (Fidélis & Moreno Pires, 2009). Local Agenda 21 (UN, 1992) is a clear example of institutional support for initiatives to promote local participation in the resolution of sustainability issues. Another example of local participation is sustainable regeneration. Haughton (1998) describes sustainable (economic) regeneration as a long-term process, actively involving local population and combining economic, social and environmental concerns in a balanced way; such regeneration can be intended to address an unsustainable or vulnerable situation. Moreover the involvement and the acceptance of local population are considered to be relevant for the successful conservation of protected areas. Wells & McShane (2004) acknowledge: "among the key issues, there is now a broad consensus that most protected areas will have limited future prospects without the cooperation and support of local populations".

Therefore general public participation and acceptance is not exclusive to small islands but their characteristics seem to magnify these requirements. Kotlok's indications of the Cape Verde case are illustrative of these needs, that might not be island specific but that seem to be exacerbated in islands: "the island's development can only be conceived by local stakeholders who consider themselves the only individuals able to know their needs in what concerns development" (2005). Considering small islands' specific features, Péron proposes for each island an "appropriate socio-cultural plan" (2004) that respects each island's individuality and history and that is "human in character" (2004). In Péron's opinion, by respecting islands' myths and imaginaries, these locally sound plans are preserving the island's identity. She also proposes that development plans should be aware of local environment and island's reduced scale in order to "exploit it in a more complex and intricate way" (Péron, 2004). Therefore islands' spaces should influence in depth decision-making processes (being inclusive of local characteristics and identity) and the outcomes (developing genuine policies respectful of local culture and environment). But Stratford (2008) warns about the existence of barriers to the implementation of policies for sustainability in islands: decision-makers very often prioritize other objective such as economic development goals, sacrificing island's unique characteristics. The following section will present the case study area to provide information to understand its current situation and why it was a good case study area to implement foresight scenario mapping methodology (conf. Sections 4 and 5).

3. CASE STUDY: FLORES ISLAND (AZORES, PORTUGAL)

The Azores are a Portuguese autonomous Region composed of nine islands (Figure 1). The total population was of 246,102 residents in 2011, for a population density of 106.4 inh./km^2. In what concerns the overall sustainability of the archipelago, the ecological deficit estimated for the entire archipelago was of -1,65 ha*hab^{-1} in 2002 (SRAM, 2006). Although the image given to the exterior is that of a homogeneous Region, the reality is that each island is influenced differently by conditioning factors and each island might benefit from different opportunities (SRAM, 2006). Therefore adequate policies and projects for sustainability should be studied at the Regional and at an island level to preserve the Regional cohesion but also to develop policies coherent with each individual island.

Flores Island has an area of 141.7km^2 and is situated in the Azores' westerly point (39º31´28´´N, 31º07´27´´W). Its decreasing population consisted of 3,792 *florentinos* in 2011, this year the recorded population density was of 26.9inha./km^2, the second lowest in the archipelago. Flores hosts two councils: Santa Cruz and Lajes das Flores (2,288 and 1,503 inhabitants in 2011, respectively). The combination of its relatively recent settlement (15th century) and its uncouth geo-morphology has allowed the conservation of important patches of endemic habitats. Moreover, Flores and Corvo Islands are the two most remote islands in the Archipelago, and they are in the periphery of this European outermost Region. Following Taglioni's (2011) classification of islands Flores can be considered to be in a situation of hyper-insularity. The island was declared a UNESCO Biosphere Reserve in 2009; in addition to this, 32% of the territory is classified as Natura 2000 sites (Azores Government, 2013); therefore even if these declarations are not necessarily translated into good environmental practices they witness of the recognition of the natural value of the island. Its economy is mostly dependent on the tertiary sector; extensive agriculture (cattle farming) and fisheries are complementary activities for additional revenues. In the Azores the employment is actually mostly supported by the tertiary sector (62.2% of the total jobs), the secondary sector employs 25.4% of the population and the primary sector 12.4% of the jobs (this information is not disaggregated for each island) (SREA, 2005). In what concerns energy production and renewable energies, Flores Island is currently of the Azorean islands with the highest proportion of electricity produced from renewable sources. Tourism is seen as a possible support of the island's economy in the future (Azores Government, 2007). From 1995 to 2011 the number of registered tourists grew from 2095 to 7426 (SREA, 2014) and the number of registered hotels and rural houses increased from two in 1995 to 16 in 2013. Even though these numbers are lower than what can be found in other touristic islands this growth might have had environmental and socio-economic impact. The tourist in the Azores values especially the landscape, nature and the quietness; the typical tourist to the archipelago corresponds to the image of the responsible tourist (which classification includes: ecotourism, alternative tourism, sustainable tourism and soft tourism) (SREA, 2007).

Although Flores is home of important protected areas, testifying of its environmental value and political will to preserve the natural habitat, there are actions to be undertaken in order to improve local sustainability and to increase local resilience. The dashboard of sustainability calculated for Flores Island in the context of the *PReDSA* report concluded that the island was overall (combination of economic, social and environmental scores) in a reasonable situation (SRAM, 2006), but action can be undertaken to increase these scores. Due to the island's double isolation (in the archipelago and within it), its reduced size and population, and the recent nomination of UNESCO Biosphere Reserve, Flores was considered to be a relevant case study area to undertake this novel research which methodology is presented in the following section.

4. METHODOLOGY: PARTICIPATIVE FORESIGHT SCENARIO MAPPING

Participative foresight scenario mapping methodology proposes a participative approach to develop and appraise with multiple criteria a series of potential future scenarios, in the present case study for Flores Island in 2030. The aim of the process was to explore in depth potential scenarios for sustainability in a small island, it was not set as an inquiry to the population and the results do not have statistical significance. The process is divided into two main phases (Figure 2): i) scenario development; and ii) scenario multi-criteria appraisal. The vision development phase comprises a two step process of semi-structured scoping interviews with decision-makers and key informants, followed by focus groups with lay citizens. The appraisal phase involved the decision-makers and key informants in the multi-criteria analysis of the foresight scenarios previously developed and *PReDSA* scenarios (*Hotelândia*, *Lactogenia*, *Ecotopia*, *Sociopolis* and *Infocracia*).

In the context of the research two foresight scenarios were created in two steps (the scenarios are developed in Section 5). Initial contributions from decision-makers and key informants (gathered in semi-structured scoping interviews) were combined to develop two draft future scenarios. The interviewees were asked about how they expect the island of Flores could be in 2030 and how they would like it to be, and which the main challenges to reach this vision

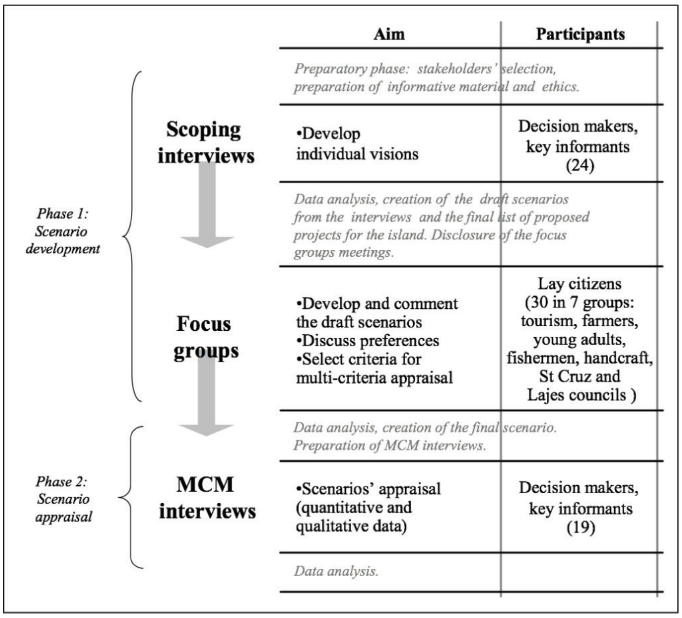

Figure 2. Participative foresight scenario mapping methodology.
Figura 2. *Metodologia participativa para a criação e avaliação multi-critério de cenários de desenvolvimento futuro.*

were. They were then asked to develop their points of view for the following themes: tourism, nature conservation, agriculture, forestry, fishery, industry and trade, information technologies, energy and education. In addition to this they had the opportunity to comment on the utility of Regional policies for the island.

In the second step of the scenario development phase these alternative visions were the opportunity to develop preferences in focus groups that involved local lay citizens (second step in the scenario development phase). This way the focus groups participants could comment about the draft scenarios and provide local insights into the visions. Seven focus groups were the opportunity to convene 30 lay citizens (see Figure 2). The two main contributions from participants were the comments made about the draft scenarios and the selection of the economic, social and environmental criteria later used in the multi-criteria interviews (Phase 2 of the methodology). The final versions of the scenarios (made of contributions from the scoping and the focus groups) were appraised later in the multi-criteria appraisal phase.

Multi-criteria analysis (MCA) processes have been valued for their ability to support decision-making by facilitating the comparison of different options or perspectives, in spite of their potential inherent multi-dimensionality (Martinez-Alier *et al.*, 1998). MCA have been used to assess projects and policies that have economic, social and environmental impacts (Gamper & Turcanu, 2007). The fact that MCA methods are multidimensional tools makes them particularly appropriate for dealing with sustainability issues. Multi-criteria mapping (MCM) (Stirling, 1997; Stirling & Mayer, 2000; Davies, 2006; McDowall & Eames, 2007) has been adapted for the present study to appraise the different scenarios in Flores Island. MCM aims at providing a more open and transparent mean for environmental appraisal. MCM was first used to assess the perceived risks and benefits associated with genetically modified, conventional, mixed and organic agricultural systems (Stirling & Mayer, 2000). More recently, this appraisal methodology has been used in the field of hydrogen and energy futures (McDowall & Eames, 2007) and in a transnational appraisal of obesity policy options to tackle obesity (Stirling *et al.*, 2007). The deliberative mapping project (Burgess *et al.*, 2007) embedded the MCM method into a larger participative process involving lay and specialized stakeholders.

The MCM approach enables a more complete appraisal and produces a more detailed picture of the different alternatives existing in the field of study (Stirling & Mayer, 2000). Stirling (1997) identified the main challenges related to environmental appraisal exercises which are: the difficulty to predict the future and to understand natural and social phenomena; the existence of multiple points of view on the matter at stake; and different alternatives to reach the same goal increase the complexity of the decision-making. The MCM approach is realistic as it does not consist of an optimisation of a variable but the appraisal of different criteria for different options/scenarios (Stirling, 1997). MCM-Analysis software (Stirling & Champion, 2009) is used to produce graphs, also called *maps* (see Figure 3). The assessment method is relevant to support decision-making as it makes visible the convergence or divergence in the opinions and the identification of potential sources of uncertainty and risk. MCM has been used in cases where participants, mainly specialists, had technical knowledge on the subject in question, which is usually a very specific issue. In Deliberative Mapping participant lay stakeholders had been instructed about the subject in discussion (Burgess *et al.*, 2007).

One of the challenges of the present research was to understand the process when a varied sample of key informants and decision-makers are using this appraisal method for the assessment of multiple characteristics (criteria) of holistic development scenarios. In the present case the level of specialisation in different fields differs substantially from one interviewee to another; this specificity was related to the role of expertness in the assessment of holistic visions. The Participative foresight scenario mapping methodology was developed to facilitate a discussion of perspectives for Flores' sustainable futures.

5. FIELD WORK AND DATA ANALYSIS

Fieldwork took place in the second semester of 2009. It involved 26 Regional and local decision-makers and key informants in the scoping and the multi-criteria interviews (10 were Regional and 16 were *florentinos*) (see Table 2), and 30 local lay citizens in seven focus groups (fishermen, young adults, tourism, handcraft, farmers, Santa Cruz das Flores and Lajes das Flores, see Figure 2).

Following the method presented in the previous section, two holistic non-technical foresight scenarios, Balanced and Standard Development Scenarios (BDS and SDS respectively) (Table 3), were developed for Flores Island. The MCM interviews consisted of the appraisal of BDS and SDS scenarios alongside five institutional scenarios to bring more substance and additional perspectives to the exercise (*Lactogenia*, *Hotelândia*, *Ecotopia*, *Sociopolis* and *Infocracia*) (SRAM, 2006), the summary of these scenarios is also presented in Table 3. The interviewees had to use at least 15 economic, social and environmental criteria (see Table 4) pre-selected by lay citizens in the focus groups. In the MCM interview the stakeholders were invited to give a pessimistic and an optimistic score to each scenario for each criterion, the difference between the lower (pessimistic) and the higher (optimistic) scores informs about the existence of uncertainty. This process involves the production of quantitative data presented in graphs such as Figure 3 which combines the data from the totality of the interviewees (additional graphs can be created following other characteristics of the interviewees, for instance: age, profession, location, gender).

6. FINDINGS

Contributions from the research participants reflect a low expectation of change for Flores (conf. Section 6.1). In addition to this sense of continuity the research participants identified BDS and *Ecotopia* as the preferred scenarios (see Figure 3, these scenarios have the highest overall optimistic and pessimistic scores). This shows a preference for greener development in opposition to more intensive and potentially aggressive models of development for the local environmental (SDS, *Hotelândia* and *Lactogenia*), and it implies the acknowledgement of the limits to growth imposed by the island (conf. Section 6.2). Some contributions informed on the role that identity, the concepts of Utopia and heaven, and public participation can play in these processes (conf. Section 6.3).

6.1. Foresight scenarios and low expectations of change

When asked how they envisioned the future of the island in 2030 research participants tended to say that the island was not going to experiment important changes. The main reasons given to this were the combination of three factors: the emigration of young generations, the low ambition of the remaining population and a certain aversion to change. The Regional specialist of rural tourism interviewed clearly stated this idea: "*the most competent emigrate. There is little capacity to understand the island's value and in consequence to innovate in profitable fields*" and "*changes are related with culture. And islands with a small population are very conservative, exactly because of this. They* [locals] *do not trust change*". Another participant, a member of an association, augured "*stagnation*" in the main sectors of activity: agriculture, fishery, trade and industry. One participant to a focus group declared that the population was indeed "*static*". Other factors that influence the low perspective of change were also identified. One factor was the existence of path-dependency: "*investments have been made and it is impossible to change them*" (local entrepreneurship support services). The other factor is directly related to the low potential of development of local industry (this sector is considered to be the only vehicle for deep change): "*about industry I do not see actually a lot of options"* (local museum representative) and "*I do not see great possibility for development* [in industry]. *Handicraft is an area that will always be complementary*" (Regional representative of local development association).

Table 2. Decision-makers civil servants and key informants interviewed.
Tabela 2. *Decisores, funcionários públicos e informadores-chave entrevistados no projeto.*

Int.	Area of activity	Position	Civil servant/ independent	Flores/ Azores/ Portugal
1	Tourism	Representative of service	Civil servant	Azores
2	Entrepreneurship	Representative of service	Civil servant	Azores
3	Air and sea transport	Representative of service	Civil servant	Azores
4	Environment	President	Independent (NGO)	Azores
5	Entrepreneurship	Service employee	Civil servant	Azores
6	Environment	Representative of service	Civil servant	Azores
7	University (geography and economy)	Head of department	Independent (academic)	Azores
8	Agriculture	Representative of service	Civil servant	Azores
9	Culture	Library representative	Civil servant	Flores
10	Tourism	Guest house manager	Independent	Flores
11	Tourism	Restaurant manager	Independent	Flores
12 and 13	Environment (education)	Service employees	Civil servant	Flores
14	Local representative	St Cruz representative	Civil servant	Flores
15	Local representative	Lajes representative	Civil servant	Flores
16	Entrepreneurship	Local director of service	Civil servant	Flores
17	Youth association	Association representative	Independent (assoc.)	Flores
18	Environment	Service employee	Civil servant	Flores
19	Culture	Museum representative	Civil servant	Flores
20	Economy	Freelance consultant	Independent	Flores
21	Entrepreneurship	Association representative	Independent (assoc.)	Azores
22	Fishermens association	Association representative	Independent (assoc.)	Flores
23	Island association	Association member	Independent (assoc.)	Flores
24	Environment	Association managing director	Independent (NGO)	Portugal
25	Agriculture	Local director of service	Civil servant	Flores
26	Infrastructures and land transport	Local director of service	Civil servant	Flores

Table 3. BDS and SDS and institutional scenarios (summary).
Tabela 3. *BDS, SDS e cenários institucionais (resumo).*

Scenarios		Description
Standard development scenario (SDS)		Scenario of development through public investment in infrastructure, enabling a more intensive primary sector that will permit to export some agricultural products (bovine meat, milk and milk derivative products) and a more standardized tourism model (capitalising on the island's opportunities but not specifying a minimum environmental impact). Increase in economic activity (public and private) and employment.
Balanced development scenario (BDS)		Scenario of the development through high environmental quality standards and valuing local patrimony associated with nature and living on the island. Careful investments are fundamental, as well as infrastructure aiming at valuing the island, prioritizing local population and thinking in tourism. They would also specify a minimum environmental impact, as well as conservation, improving and valuing the ecosystem services and reduction of external dependence.
Institutional scenarios	*Hotelândia*	Based on tourism development and four driving areas: regional quality products, natural patrimony quality, cultural patrimony differentiation and air and sea transports.
	Lactogenia	Based on the excellence of farming development and four driving areas: regional quality products, farming potential, subsidies and EU policies.
	Ecotopia	Based on the protection and natural patrimony value and four driving areas: geothermic resources, natural patrimony quality, pressure on natural resources and geologic and tectonic risks.
	Sociopolis	Based on the development of social cohesion with youth population, EU subsidies and education as driving areas.
	Infocracia	Based on betting on information society and four driving areas: geostrategic position, youth population, Azorean Diaspora and outermost region's characteristics.

Table 4. Criteria used in the MCM interviews.
Tabela 4. *Critérios utilizados nas entrevistas MCM.*

Economy	Society	Environment
Agricultural sustainability (19)	Employment creation (19)	Waste management (19)
Fisheries management and its sustainability (19)	Lifestyle and health (19)	Sustainability territory resources and ground use (19)
Wealth creation (19)	Healthcare services (19)	Biodiversity (19)
Tourism typology and profitability (19)	Cultural life and culture (14)	Appropriate water use (19)
Energy management (11)	Educational system (14)	Air contamination produced on the island (19)
Enterprise activity health (2)	Demographic evolution (10)	Landscape (1)
Sustainability and adaptation of the transport system (9)	Population reintegration (1)	Population involvement (1)
Government incentives (1)	Social exclusion (1)	Marine area protection (1)
Handicraft development (1)		

In brackets the number of times each criterion was used.
The criteria used only one time were proposed by the interviewees in the MCM interviews.

Therefore it seems that the opinion is that the island tends to immobility or at least low expectations of change. This point of view echo the conception of islands as places where change does not happen as fast as in other territories (Péron, 2004; Stratford, 2008). The contributions from the case study inform that the combined effect of depopulation (emigration of younger generations), the geographic factors that condition socio-economic development, pathway dependency, and a cultural rejection to change seem to limit the prospects of innovative decision-making and entrepreneurship that could invigorate the local socio-economic structures in Flores Island.

6.2. Preferences for greener development

The focus group participants and the participants to the multi-criteria interviews identified BDS (conf. Table 3 and Figure 2) as the most preferable scenario for the island. For instance participants to the focus groups stated clearly their preferences: "*it* [BDS] *makes the island more natural and nowadays this is what it is valued*", "*between these two scenarios* [SDS and BDS] *I clearly prefer the second* [BDS]. *The one that is more sustainable*" or "*Scenario 2* [BDS] *is much better than scenario 1* [SDS]. *In everything*". The decision-makers and key informants also advocated clearly, and almost unanimously, for BDS. For instance the civil servant representative of the local museum labelled it as the "*ideal*" scenario; a local restaurant manager thought that the scenario was "*More adequate* […] *considering the size of the island and the existing conditioning factors*". The local freelance economist observed that BDS: "*corresponds to the idealized scenario for Flores Island*". The Regional entrepreneurship support services representative opined that: "[BDS] *files down some of SDS problems, some of its ridges.*" Another example is the statement made by one member of the ecology centre team: "*I think that this scenario* [BDS] *is the most positive for the island in 2030*".

BDS also scored better than the other scenarios in the quantitative multi-criteria appraisal (see Figure 3). It is interesting to observe that *Ecotopia* scenario was overall the scenario that got the second best score. Even though institutional scenarios were not considered to be realistic, the fact that *Ecotopia* got high scores is consequent with the preference for BDS and it reinforces it. Therefore, even if uncertainty (length of the bars) is elevated, it is clear that quantitative appraisal is congruent with the qualitative preferences for BDS. The preference for such scenarios reflects a genuine awareness of sustainability requirements, and the benefits that such model of development could generate in a small island. These contributions reinforce Cambers' (2006) observations about islanders' awareness of sustainability issues. Depraetere's statement provides an explanation about this proneness to acknowledge the issues derived from unsustainable practices on island: "Due to the strong sense of place that they engender, islands are the ideal spaces to experience the pernicious and dysfunctional chasm between these two separate ecos [economy and ecology]. Islands magnify the schizophrenic practices of these two types of 'development'" (2008).

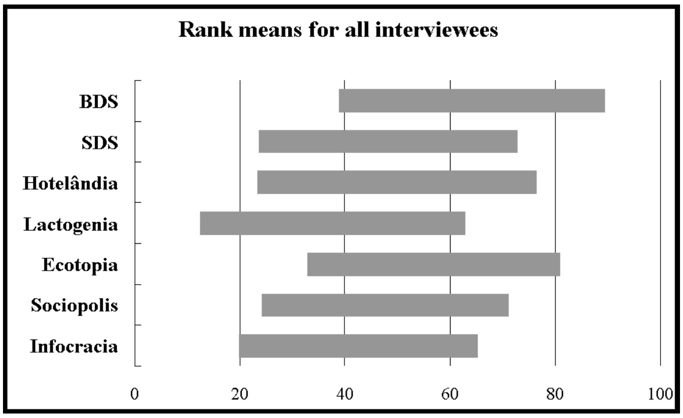

Figure 3. Quantitative appraisal of the scenarios.
Figura 3. *Análise quantitativa dos cenários.*

6.3. The potential role of identity and public participation in the transition to sustainability

In previous sections islands have been described as territories that have developed their own strong identity (Pitt, 1980; Stratford, 2008) and they are prone to be aware of the issues that can challenge local sustainability (Cambers, 2006). In the case of Flores, the research participants often described the island as a heaven (or a potential heaven) on Earth and they associated this image with the local environment (Table 5). One participant to the focus groups affirmed that: "*I would like that this* [Flores] *was a paradise; it has all the conditions for that*". These contributions reveal the value given to local natural environment and the local quality of life. They also reflect that the persons involved in the project are aware of the potential the existent natural environment has in the sustainable development of the island and the relation between tourism and nature conservation.

Tourism appears to be one way of valuing and taking advantage of the island's characteristics, and it is often associated with the local environment (conf. Table 5). The indications on tourism reflect that locals should promote the island's unique identity, for instance taking advantage of the isolation: "*the last sunset in Europe… it must yield a profit.* […] *Remoteness as identity. I think that it is very important, even to give an image of limited accessibility.* […] *To appeal the sense of adventure*" (Regional representative of nature conservation association). Moreover it was acknowledged that visitors would value local efforts to implement sustainable development practices for instance about the use of renewable sources of energy: "*it is an added value for all the people that visit it, for the tourist who says: 'look, on this island they produce 50% of clean energy!'*" (local Council representative). It is also relevant to observe that local preferences correspond to the preferences that the visitors to the Azores have for landscape, nature and the quietness (conf. Section 3). But it was also noticeable that an individual island in an archipelago has difficulties to differentiate itself from the other islands in the archipelago. Some comments

Table 5. References linking nature, the concepts of heaven and 'green utopias' and tourism to Flores.
Tabela 5. *Referências que relacionam a natureza, o conceito de paraíso e "utopia verde", e o turismo para a Ilha das Flores.*

"The natural heaven." (Representative of an entrepreneurship association)
"Quality, life and quietness". (Representative of regional agriculture secretary)
"*Heaven in the westerly point of Europe.*" (Local representative)
"*Nature. Atlantic ocean.*" (Local representative)
""*The island" – copy/paste of Aldous Huxley's concept. "Agritourism": combine traditional agriculture with tourism.*" (Local guest house manager)
"*Nature conservation is good for us and it is good for tourism.*" (Participant to farmers focus group)
"*Preserved nature, sustainable tourism.*" (Local freelance consultant)
"Wild. Nature tourism." (Regional representative of the environment secretary)
"*In what concerns the economy, main activities: senior tourism and nature tourism.*" (University professor)
"*Nature. Rural tourism. Renewable energy (wind, tidal, solar). Waste management system with reutilization.*" (Local library representative)
"*Tourism more developed. Increase nature conservation.*" (Local representative of the environment secretary)
"Local environment is sustainable only if there is equilibrium between the primary sector, tourism sector and the environment." (Participant to young adults focus group)

pointed out at the need to define a differentiated identity or trade-mark, and therefore identified it more clearly from the other islands: "*each island* […] *should find its own trademark and identity*" (local freelance consultant) or "*Flores should develop a trademark, a unique identity*" (nature conservation association). These ideas were directly linked to tourism and traditional handcraft: the challenge is how to increase the island's uniqueness and attractiveness.

But this differentiation and the transition to sustainability can be challenging, some research participants informed that one way of overcoming these difficulties is to involve the community in the project. In small islands public participation is relevant in order to develop policies that propose "appropriate socio-cultural plans" (Péron, 2004, conf. Section 2.2). In the present project this pre-requisite was directly related with Flores' future sustainability: it will only be possible if the local community is actively involved in this process. The local restaurant manager clearly stated this point: "*if in 2030 the population is involved, even if instead of 4000 people we are 2000* […] *I think that Flores will be sustainable*", and the Regional representative of natural areas conservation also stressed these requirements: "*involving locals, and not only, people related to the different fields, try to understand… the different ways of thinking and try to reach a consensus on which is the best goal to reach*". But a local freelance consultant observed that individuals do not participate in decision-making process: "*they* [*florentinos*] *do not have this tradition, public participation is very low*". The contributions from the interviewed local restaurant manager helps to understand this low level of public participation: "*Maybe due to isolation, because of broken promises, they* [*florentinos*] *do not trust the system. And finally they become indifferent*". Therefore further efforts should be undertaken to achieve greater participation and effectiveness in decision-making processes. Moreover, in the case of small islands in an archipelago effective local decision-making is required to avoid uninformed decision-making from external decision-making centres. The Regional rural tourism specialist clearly stated these points: "*they* [*florentinos*] *rely on external decisions and normally external decisions are not thought because…* […] *non-locals* [decision-makers] *hardly know the island*". This produces a negative dynamic of disenchantment and finally indifference among local population, leading the community to a negative spiral that reduces the potential for participation in decision-making but also entrepreneurship and innovation.

Whereas it was observed that there is a lack of participation in decision-making and distrust towards existing decision-making processes, it was also noticeable that the aspiration of island communities is to play a steering role in the decisions that concern their future. The main argument was that only locals know correctly the island. For instance a member of the local fishers' organisation stated clearly that local fishers are the only able to define conservation areas: "*It will not be the scientists* [to decide optimal areas for maritime conservation] *because they do not know anything about local fisheries, we do know*". The representative of the local library also stated clearly the same idea: "*it is the people that live on the island that know better what the island needs*". This willingness to be taken in consideration and to play an active role can be understood as a desire to value and protect local identity and the elements that constitute it. But it seems that confidence in the decision-makers should be renewed in order to increase the active involvement of the lay population in decision-making.

7. CONCLUSION

The literature review has shown that insular communities suffer from economic and environmental vulnerabilities that challenge their development, however islands are also considered to be relevant case study areas to undertake projects for sustainability. Independently of the methodological contributions, the present project has brought light into some of the elements that constitute the identity of Flores Island. These elements were directly related to the value given to local environment. But it can be argued that this preference for BDS, and *Ecotopia* scenario can also be explained by a will to avoid changes which corresponds to the low expectation of change identified in the research. Green development, as proposed in this scenario, might have been seen by the participants as a way to guarantee the continuity of the existing way of life and it can be used as an argument to prevent deeper social and economic changes. But this preference for greener options is however an opportunity to foster sustainable behaviours among the concerned population.

Small territories face rapid depletion of their natural resources; the consequence of this is a fast materialisation of the negative side effect of unsustainable growth observable by the local population. Therefore islanders are potentially the first beneficiaries of efficient and sustainable use of the available land and, as observed by Péron (2004), adapted plans should be decisive in this process. Moreover the participation of the local community is essential to inform these policies in order to produce the "appropriate socio-cultural plan(s)" (Péron, 2004) adapted to each individual island and accepted by the local population. The case study as shown that local and Regional participants value positively Flores Island environment and that nature is usually used to identify and characterize the island. Moreover, islanders' predisposition to understand and be aware of the threats associated to unsustainable practices should be a factor of success in these participative processes and in adapting "pro-environmental behaviours" (Kollmuss and Agyeman, 2002). Independently of the utility for sustainable land management, the international declaration of protected areas (e.g. UNESCO Biosphere Reserves or Natura 2000 sites) can work as a lever to foster local environmental practices in Flores Island. On the one hand they can help to reinforce the value that locals give to the environment and the image they have of their own island. On the other hand they can help to potentiate nature tourism sector, which is often seen as a key sector in the economy of small islands (McElroy, 2006). Tourism in Flores can play a relevant role in wealth creation and the preservation of the elements that constitute the local identity, which in this research was often related with the local natural environment. Therefore in Flores tourism seems to be an opportunity rather than a threat for local sustainability, but it is relevant to question if the current growth of the sector can modify this situation.

ACKNOWLEDGMENTS

I would like to thank the four anonymous referees and the editorial board that have made constructive comments on the article. I would also like to thank Brunel University that funded this PhD research, Professor Susan Buckingham, Professor Malcolm Eames, the members of the Centre for Human Geography in Brunel University, all the research participants, Dr Artur Gil and Dra Sandra Hervías Parejo.

REFERENCES

Agyeman, J.; Angus, B. (2002) - The role of civic environmentalism in the pursuit of sustainable communities. *Journal of Environmental Planning and Management*, 46(3):345-363. DOI: 10.1080/0964056032000096901

Agyeman, J.; Bullard, R.; Evans, B. (2002) - Exploring the nexus: bringing together sustainability, environmental justice and equity. *Space and policy*, 6(1):77-90. DOI: 10.1080/13562570220137907

Armstrong, H. W.; De Kervenoael, R.J.; Li, X.; Read, R. (1998) - A comparison of the Economic Performance of Different Micro-states, and Between Micro-states and Larger Countries. *World Development*, 26(4):639-656. DOI: 10.1016/S0305-750X(98)00006-0

Armstrong, H. W.; Read, R. (2002) - The phantom of liberty? Economic growth and the vulnerability of small states. *Journal of International Development*, 14(3):435–458. DOI: 10.1002/jid.886

Armstrong, H. W.; Read, R. (2003) - The determinants of economic growth in small states. *The Round Table*, 92(368):99-124. DOI: 10.1080/750456745

Azores, Regional Government (2007) - *Plano de Ordenamento Turístico da Região Autónoma dos Açores (POTRAA). Decreto Legislativo Regional n.º 38/2008/A.* Available on-line at http://www.dre.pt/pdf1sdip/2008/08/15400/0541405451.PDF

Azores, Regional Government (2013) - *Arquipélago dos Açores, Rede Natura 2000*. Available on-line at http://redenatura2000.azores.gov.pt/web01/

Baldacchino, G. (2007) - *A World of Islands: An Island Studies Reader.* 640p., Island Studies Press, Prince Edward Island, Canada. ISBN: 978-99932-86-10-3

Baldacchino, G.; Pleijel, C. (2010) - European islands, development and the cohesion policy: a case study of Kökar, Aland Islands. *Island Studies Journal* (ISSN 1715-2593), 5(1):89-110, Institute of Island Studies, University of Prince Edward Island, Canada. Available at: http://www.islandstudies.ca/journal

Beller, W.; D'Ayala, P.; Hein, P. (2004) - *Sustainable Development and Environmental Management of Small Islands. (Vol. 5)* 419pp., UNESCO and The Parthenon Publishing Group, Paris, France. Available on-line at http://portal.unesco.org/es/ev.php-URL_ID=12824&URL_DO=DO_TOPIC&URL_SECTION=201.html

Bonaiuto, M.; Carrus, G.; Martorella, H.; Nonnes, M. (2002) - Local identity processes and environmental attitudes in land use changes: the case of natural protected areas. *Journal of Economic Psychology*, 23(5):631-653. DOI: http://dx.doi.org/10.1016/S0167-4870(02)00121-6

Boulding, K.E. (1966) - The economics of the coming spaceship earth. *In*: Daly, H.E. and Townsend, K.N. (Eds.), *Valuing the Earth. Economics, Ecology, Ethics*, pp.297-310, The MIT press, London, England. ISBN: 0262540681. Available on-line at https://notendur.hi.is/bdavids/UAU101/Readings/BOULDING.pdf

Briguglio, L. (1995) - Small island developing states and their economic vulnerabilities. *World Development*, 23(9):1615-1632. DOI: 0305-750X(95)00065/8

Burgess, J.; Stirling, A.; Clark, J.; Davies, G.; Eames, M.; Mayer, M.; Staley, K.; Williamson, S. (2007) - Deliberative mapping: a novel analytic-deliberative methodology to support contested science-policy decisions. *Public Understanding of Science*, 16(3):299-322. DOI: 10.1177/0963662507077510

Calado, H.; Quintela, A.; Porteiro, J. (2007) - Integrated Coastal Zone Management Strategies on Small Islands. *Journal of Coastal Research* (ISSN 0749.0208), SI50:125-12. Available on-line at http://www.redmic.es/bibliografia/Docum_03049.pdf

Cambers, G. (2006) - Islanders' perspectives on sustainable living. *Island Studies Journal* (ISSN 1715-2593), 1(1):125-142, Institute of Island Studies, University of Prince Edward Island, Canada. Available at: http://www.islandstudies.ca/journal

Campling, L. (2006) - A Critical Political Economy of the Small Island Developing States Concept: South-South Cooperation for Island Citizens?. *Journal of Developing Societies*, 22(3):235-285. DOI: 10.1177/0169796X06068031

Chapuis, J.L.; Boussès, P.; Barnaud, G. (1994) - Alien mammals, impact and management in the French subantartic islands. *Biological Conservation*, 67(2):97-104. DOI: 10.1016/0006-3207(94)90353-0

Christofakis, M.; Mergos, G.; Papadaskalopoulos, A. (2009) - Sustainable and Balanced Development of Insular Space: the case of Greece. *Sustainable Development*, 17(6):365-377. DOI: 10.1002/sd.396

Conkling, P. (2007) - On islanders and islandness. *The geographical Review*, 97(2):191-201. DOI: 10.1111/j.1931-0846.2007.tb00398.x

Connel, J. (2003) - Island dreaming: the contemplation of Polynesian paradise. *Journal of Historical Geography*, 29(4):554-581. DOI: 10.1006/jhge.2002.0461

Counsell, D.; Haughton, G. (2006) - Sustainable Development in regional planning: the search for new tools and renewed legitimacy. *Geoforum*, 37(6):921-931. DOI: 10.1016/j.geoforum.2006.02.001

Daly, H.E. (1991) - Towards an environmental macroeconomics. *Land Economics*, 67(2):255-259. DOI: 10.2307/3146415

Daly, H.E. and Farley, J.C. (2004) Ecological economics: principles and applications. Island Press, Washington, USA. ISBN: 1559633123

Davies, G. (2006) - Mapping deliberation: calculation, articulation and intervention in the politics of organ transplantation. *Economy and Society*, 35(2):232-258. DOI: 10.1080/03085140600635722

Depraetere, C. (2008) - The challenge of Nissology: A global outlook on the world archipelago. Part II: the global and scientific vocation of Nissology. *Island Studies Journal* (ISSN 1715-2593), 3(1):17-36, Institute of Island Studies, University of Prince Edward Island, Canada. Available at: http://www.islandstudies.ca/journal

Dumont, Y.; Russell, J.C.; Lecomte, V.; Le Corre, M. (2010) - Conservation of endangered endemic seabirds within a multi-predator context: the Barau's petrel in Réunion Island. *Nature Resource Modeling*, 23(3):381-436. DOI: 10.1111/j.1939-7445.2010.00068.x

Encontre, P. (1999) - The vulnerability and resilience of small island developing states in the context of globalisation. *Natural Resources Forum*, 23(3):261-270. DOI: 10.1111/j.1477-8947.1999.tb00914.x

Erickson, B.; Roberts, M. (1997) - Marketing local identity. *Journal of Urban Design*, 2(1):35-59. DOI: 10.1080/13574809708724395

Fidélis, T.; Moreno Pires, S. (2009) - Surrender or resistance to the implementation of Local Agenda 21 in Portugal: the challenges of local governance for sustainable development. *Journal of Environmental Planning and Management*, 52(4):497-518. DOI: 10.1080/09640560902868363

Fonseca, C., Calado, H., Pereira da Silva, C.; Gil, A. (2011) - New approaches to environment conservation and sustainability in Small Islands: The Project SMARTPARKS. *Journal of Coastal Research*, SI64:1970-1974

Francisco-Ortega, F.; Santos-Guerra, A.; Kim, S.-C.; Crawford, D. J. (2000) - Plant genetic diversity in the Canary Islands: a conservation perspective. *American Journal of Botany* (ISSN: 1537-2197), 87(7):909-919, St Louis, USA. Available at: http://www.amjbot.org/content/87/7/909.long

Gagliardi, P. (2009) - Organizations as Designed Islands. *Island Studies Journal* (ISSN 1715-2593), 4(1):43-52, Institute of Island Studies, University of Prince Edward Island, Canada. Available at: http://www.islandstudies.ca/journal

Gamper, C.D.; Turcanu, C. (2007) - On the governmental use of multi-criteria Análisis. *Ecological Economics*, 62(2):298-307. DOI: 10.1016/j.ecolecon.2007.01.010

Hache, J.D. (1998) - Towards a Political Approach to the Island Question. *In*: G. Baldacchino & R. Greenwood (eds), *Competing Strategies of Socio-Economic Development for Small Islands: Volume 2: Proceedings – An Island Living: Patterns of Autonomy and Dependence in the Small Islands of the North Atlantic*, pp. 31-68, Charlottetown, Institute of Island Studies, Prince Edward Island, Canada. ISBN: 0919013236

Haughton, G. (1998) - Principles and practice of community economic development. *Regional Studies*, 32(9):872-877. DOI: 10.1080/00343409850118022

Haughton, G. (1999) - Environmental justice and the sustainable city. *Journal of Planning Education and Research*, 18(3):233-243. DOI: 10.1177/0739456X9901800305

Haughton, G.; Naylor, R. (2008) - Reflexive local and regional economic development and international policy transfer. *Local Economy*, 23(2):167-178. DOI: 10.1080/02690940801976240

Hay, P. (2006) - A Phenomenology of Islands. *Island Studies Journal* (ISSN 1715-2593), 1(1):19-42, Institute of Island Studies, University of Prince Edward Island, Canada. Available at: http://www.islandstudies.ca/journal

Hernández, B.; Hidalgo, M.C.; Salazar-Laplace, M.E.; Hess, S. (2007) - Place attachment and place identity in natives and non-natives. *Journal of Environmental Psychology*, 27(4):310-319. DOI: 10.1016/j.jenvp.2007.06.003

International Union for Conservation of Nature and Natural Resources (IUCN), UNEP and WWF (1980) - *World Conservation Strategy, Living Resource Conservation for Sustainable Development*. Gland, Switzerland. http://www.a21italy.it/medias/688-wcs-004.pdf

Jabareen, Y. (2004) - A knowledge map for describing variegated and conflict domains of sustainable development. *Journal of Environmental Planning and Management*, 47(4):623-642. DOI: 10.1080/0964056042000243267

Kelman, I.; Lewis. J. (2005) - Ecology and Vulnerability: Islands and Sustainable Risk Management. *International Journal of Island Affairs*, 14(2):4-12 Available at: http://www.ilankelman.org/articles1/kelmanlewis2005.pdf

Kelman, I. (2007) - Sustainable Livelihoods from Natural Heritage on Islands. *Island Studies Journal* (ISSN 1715-2593), 2(1):101-114, Institute of Island Studies, University of Prince Edward Island, Canada. Available at: http://www.islandstudies.ca/journal

Kerr, S.A. (2005) - What is small island sustainable development about?. *Ocean and Coastal Management*, 48(7-8):503-524. DOI: 10.1016/j.ocecoaman.2005.03.010

Kollmuss, A.; Agyeman, J. (2002) - Mind the gap: why do people act environmentally and what are the barriers to pro-environmental behaviour. *Environmental Education research*, 8(3):239-260. DOI: 10.1080/13504620220145401

Kotlok, N. (2005) - Emigration et insularisme au Cap-Vert. *In:* http://halshs.archives-ouvertes.fr/halshs-00610193/en/

Krueger, R.; Gibbs, D. (2007) - Introduction: Problematizing the Politics of Sustainability. *In:* Krueger, R. and Gibbs, D. (eds.), *The Sustainable Development* Paradox. Urban Political Economy in the United States and Europe. pp.1-12, Guildford Press, New York. ISBN: 1593854986.

Martinez-Alier, J.; Munda, G.; O'Neil, J. (1998) - Weak comparability of values as a foundation for ecological economics. *Ecological Economics*, 26(3):277-286. DOI: http://dx.doi.org/10.1016/S0921-8009(97)00120-1

McDowall, W.; Eames, M. (2007) - Towards a Sustainable Hydrogen Economy: A Multi-criteria Mapping of the UK-SHEC Hydrogen Futures. *International Journal of Hydrogen Energy*, 32(18):4611-4626. DOI: 10.1016/j.ijhydene.2007.06.020

McElroy, J.L. (2006) - Small island tourist economies across the life cycle. *Asia Pacific Viewpoint*, 47(1):61-77. DOI: 10.1111/j.1467-8373.2006.00303.x

Miller, D. (2009) - Where is the Why if the What is in How? The Issue of Intent in Unintentional Ideal Communities. *Journal of Cultural Research*, 13(1):29-52. DOI: 10.1080/14797580802674811

Morgan, P. (2010) - Towards a developmental theory of place attachment. *Journal of Environmental Psychology*, 30(1):11-22. DOI: 10.1016/j.jenvp.2009.07.001

Olwig, K.F. (2007) - Islands as places of being and belonging. *The Geographical Review*, 97(2):260-273. DOI: 10.1111/j.1931-0846.2007.tb00402.x

Pelling, M.; Uitto, J.I. (2001) - Small islands developing states: natural disaster vulnerability and global change. *Environmental Hazards*, 3(2):49-62. DOI: 10.3763/ehaz.2001.0306

Péron, F. (2004) - The contemporary lure of the island. *Tijdschrift voor Economische en Sociale Geografie*, 95(3):326-339. DOI: 10.1111/j.1467-9663.2004.00311.x

Pitt, D. (1980) - Sociology, Islands and Boundaries. *World Development*, 8(12):1051-1059. DOI: 10.1016/0305-750X(80)90093-5

Putz, G. (2004) - On Islanders. *In:* P. Conkling & D. D.Platt (eds.), *Holding ground. The best of Island Journal 1984-2004*, pp.28-31, Island Institute, Rockland, Canada. ISBN: 0942719344. Available at: http://www.islandinstitute.org/publications/Holding-Ground/12250/

Quammen, D. (1997) - Islands as biological communities. *In:* P. Conkling & D. D.Platt (eds.), *Holding ground. The best of Island Journal 1984-2004*, pp.196-199, Island Institute, Rockland, Canada. ISBN: 0942719344. Available at: http://www.islandinstitute.org/publications/Holding-Ground/12250/

Rietbergen, S., Hammond, T., Sayegh, C., Hesselink F. and Mooney K. (2007) - *Island voices – island choices: Developing strategies for living with rapid ecosystem change in small islands*. IUCN, Gland, Switzerland. ISBN: 2831710308. Available at: www.iucn.org/dbtw-wpd/edocs/CEM-006.pdf

Saffache, P.; Angelelli, P. (2010) - Integrated Coastal Zone Management in small islands: A comparative outline of some islands of the Lesser Antilles. *Revista de Gestão Costeira / Journal of Integrated Coastal Zone Management,* 10(3):255-279. DOI: 10.5894/rgci228

Soulimant, N. (2011) - *Faire face au changement et réinventer des îles*. 478p., Phd thesis, Université de La Rochelle, Institut du Littoral et de l'Environnement LIENS - Equipe AGÎLE, La Rochelle, France. Available at: http://tel.archives-ouvertes.fr/tel-00750862/

SRAM - Secretaria Regional do Ambiente e do Mar (2006) - PReDSA: Perspectivas para a sustentabilidade na Região Autónoma dos Açores, Contributo para a elaboração de um plano regional de desenvolvimento sustentável. SRAM, Azores, Portugal. ISBN: 9729992525

SREA - Serviço Regional de Estatística dos Açores (2007) - *Estudo sobre os Turistas que visitam os Açores. 2005-2006*. RAA, Azores, Portugal. Available at: http://estatistica.azores.gov.pt/upl/%7B0495a21a-2be6-4194-a769-7fea70f594fa%7D.pdf

Stiglitz, J.E., Sen, A. and Fitoussi, J.-P. (2009) - *Report by the Commission on the Measurement of Economic Performance and Social Progress*. Available at: http://www.stiglitz-sen-fitoussi.fr/documents/rapport_anglais.pdf

Stirling, A. (1997) - Multi-criteria Mapping, Mitigating the problems of environmental valuation? *In:* J. Foster, J., *Valuing Nature?: Economics, Ethics and Environment*, pp.186-210, Routledge, London, England. ISBN: 0415129788.

Stirling, A.; Mayer, S. (2000) - Precautionary Approaches to the Appraisal of Risk: a case study of a GM crop. *International Journal of Occupational and Environmental Health*, 6(4):296-311. DOI: 10.1179/oeh.2000.6.4.296

Stirling, A.; Lobstein, T.; Millstone, E. (2007) - Methodology for obtaining stakeholder assessments of obesity policy options in the PorGrow project. *Obesity Review*, 8(2):17-27. DOI: 10.1111/j.1467-789X.2007.00355.x

Stirling, A.; Champion, T. (2009) - *MCM Analysis Manual*. Version 2.3 (draft). Available at: http://www.multicriteria-mapping.org/

Stratford, E. (2008) - Islandness and struggles over development: A Tasmanian case study. *Political Geography*, 27(2):160-175. DOI: 10.1016/j.polgeo.2007.07.007

Taglioni, F. (2006) - Les petits espaces insulaires face à la variabilité de leur insularité et de leur statut politique. *Annales de Géographie*, 115(652):664-687. DOI: 10.3917/ag.652.0664

Taglioni, F. (2011) - Insularity, political status and small insular spaces. *Shima: The International Journal of Research into Island Cultures* (ISSN: 1834-6057), 5(2):45-67, Southern Cross University, Australia. Available at: http://hal.archives-ouvertes.fr/docs/00/68/60/53/PDF/f._Taglioni_Shima_v5n2_45-67.pdf

UN General Assembly (1988) - *A/RES/43/189, 83rd plenary meeting, 20 December 1988*. Available at: http://www.un.org/documents/ga/res/43/a43r189.htm

UN (1992) - *Agenda 21, Earth Summit – The United Nations Program of Action from Rio, Chapter 3, Section III, Paragraph 23.2*. Available at: http://www.un.org/esa/dsd/agenda21/res_agenda21_23.shtml

UN (1998) - *Freshwater resources in small island developing States*. Available at http://islands.unep.ch/dd98-7a3.htm

UN (2010) - *Sustainable Development: From Brundtland to Rio 2012. Background paper*. United Nations Headquarters, New York, U.S.A. Available at: http://www.un.org/wcm/webdav/site/climatechange/shared/gsp/docs/GSP1-6_Background%20on%20Sustainable%20Devt.pdf

Uzzell, D.; Pol, E.; Badenas, D. (2002) - Place identification, social cohesion, and environmental sustainability. *Environment and Behavior*, 34(1):26-53. DOI: 10.1177/0013916502034001003

Ward, G. (1993) - South Pacific Island Futures: Paradise, Prosperity, or Pauperism? *The Contemporary Pacific* (ISSN: 1043-898X), 5(1):1-21. University of Hawai'i Press, US. Available at: http://scholarspace.manoa.hawaii.edu/handle/10125/12882

Wells, M.P.; McShane, T.O. (2004) - Integrating protected areas management with local needs and aspirations. *Ambio*, 33(8):513-519. DOI: 10.1579/0044-7447-33.8.513

World Commission on Environment and Development (1987) - *Our Common Future*. Oxford University Press, Oxford, U.K. http://www.un-documents.net/wced-ocf.htm

Revista da Gestão Costeira Integrada 14(2):215-232 (2014)
Journal of Integrated Coastal Zone Management 14(2):215-232 (2014)

GESTÃO COSTEIRA INTEGRADA
Journal of Integrated Coastal Zone Management

http://www.aprh.pt/rgci/pdf/rgci-469_Estima.pdf | DOI:10.5894/rgci469

Concession in tourism services and partnerships in the Marine National Park of Fernando de Noronha, Brazil *

Concessão de serviços turísticos e parcerias no Parque Nacional Marinho de Fernando de Noronha, Brasil

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ABSTRACT

Protected areas are created with the aim of promoting environmental protection and preserving biodiversity, thus responding to the growing need to maintain the sustainability of the planet. In Brazil, the increase in the number of protected areas is evident, namely in the case of Parks, where tourism is one of several activities compatible with the management of such areas. However, simply establishing protected areas doesn't necessarily ensure their efficiency, and therefore public-private partnerships arise. In this work, we analyze the importance of partnerships and concessions in public use support services at the Marine National Park of Fernando de Noronha, in order to demonstrate the viability of sustainable management of tourism and funding in National Parks. To understand how such partnerships and concessions actually work and what their importance to the sustainability of tourism is, we conducted interviews and made *in loco* observations during 2012 and 2013. We found that the concession of services that involve supporting the public use of the park enabled great improvements in the infrastructure and in tourist services provided in the protected area, and created jobs for the local community. We were, however, unable to examine the environmental impacts of the concession because specific reports were not made available. We also found that there is a solid network of organizations, government and businesses that work together in planning, implementing, managing and supervising tourism in the Park, bringing positive results to the sustainability of this activity. This network is possible through signed agreements and above all due to the existence and operation of the protected area's Advisory Council. This study is therefore innovative, for it deals with the first concession granted by the Brazilian government in an insular territory and shows initial results about the efficiency of that concession. We hope it will induce new research that culminates in the validation of this management model for tourism in protected areas, through the preservation and valorization of the environment and responsible use.

Keywords: tourism; sustainability; partnerships; concession; protected areas; Fernando de Noronha.

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** Submission: 31 December 2013; Evaluation: 3 February 2014; Reception of revised manuscript: 21 April 2014; Accepted: 23 April 2014; Available on-line: 14 May 2014*

RESUMO

As áreas protegidas são criadas com a finalidade de promover a conservação da biodiversidade e a proteção do ambiente, face à necessidade crescente de manter a sustentabilidade do planeta. No Brasil é notório o aumento do número destas áreas, nomeadamente os Parques, onde o turismo é uma das atividades compatíveis com a gestão destes espaços. Contudo, a criação destas áreas por si só não garante a sua eficácia, fazendo surgir parcerias público-privadas. Neste trabalho, analisa-se a importância das parcerias e concessões de serviços de apoio ao uso público no Parque Nacional Marinho de Fernando de Noronha, de forma a demonstrar possibilidades de gestão sustentável do turismo e financiamentos em Parques Nacionais. Para isso foram realizadas entrevistas e observações in loco, em 2012 - 2013, cujo objetivo foi verificar como ocorre a concessão e as parcerias na prática e sua importância para a sustentabilidade do turismo. Observa-se que a concessão dos serviços de apoio ao uso público no Parque possibilitou grandes melhorias relacionadas com as infraestruturas e serviços turísticos prestados na área protegida, como também com a geração de emprego aos moradores locais. Contudo, não foi possível averiguar os impactos ambientais decorrentes dessa concessão, devido a não disponibilização de relatórios específicos. Verifica-se também que existe uma rede de relações coesa formada por organizações, governo e empresas que trabalham em conjunto no planeamento, implementação, gestão e monitorização do turismo no Parque, culminando em resultados positivos para a sustentabilidade desta atividade. Essa rede é possível através de acordos firmados e sobretudo pela existência e funcionamento do Conselho Consultivo da área protegida. Dessa forma, este estudo possui carácter inovador, sendo a primeira concessão realizada pelo governo brasileiro em território insular, trazendo resultados iniciais sobre a efetividade dessa concessão. Espera-se que seja indutora de novas investigações que culminem para a validação deste modelo de gestão do turismo em áreas protegidas, através da preservação e valorização do ambiente e de usos responsáveis.

Palavras-chave: *turismo; sustentabilidade; parcerias; concessão; áreas protegidas; Fernando de Noronha.*

1. INTRODUCTION

The Marine National Park of Fernando de Noronha (PARNAMAR FEN) is located in the Fernando de Noronha (FEN) Archipelago, Brazil, and is classified as a full protection area, with tourism being one of the activities allowed (Portaria Nº 57, de 26 Julho de 2010). The "Fernando de Noronha" island is the only inhabited island in the archipelago, with a population of 2.630. This number doubles if one considers the floating population (transient workers and researchers) (IBGE, 2013). The Park was established in 1988 and covers 70% of the island, amounting to an area of 112,7 Km^2 (Decreto nº 96.693, de 14 de Setembro de 1988)

Indeed, in FEN, tourism is a high priority and strategic sector to achieve the sustainable development of the islands, where natural heritage is understood to be the main asset in the promotion of tourism. Because it is also the island's main business, virtually all inhabitants have some kind of connection with tourism, either directly or indirectly: tour guides, lodging owners and staff, restaurants, scuba diving companies, etc.

The PARNAMAR FEN shows great potential to promote tourism as a factor of sustainability, but public use policies have had, from the onset, a restricting role. In 2010, a concession agreement was reached with a private company, EcoNoronha, regarding support services for public use, in an effort to improve the situation and allow a responsible and sustainable use of the protected area.

Our study aims at analyzing the importance of partnerships and concessions in public use support services in the PARNAMAR FEN, in order to demonstrate possibilities in sustainable management of tourism and funding in National Parks. We resorted to interviews and *in loco* observation, in an effort to understand how such partnerships and concessions actually work and what their importance to the sustainability of tourism is. We try to understand this new reality in the PARNAMAR FEN with the intention of contributing to the future validation of a viable model for the management of tourism in insular protected areas.

The importance of such a study has to do with the innovative character of its subject-matter, for we deal with the first concession granted by the Brazilian government in an insular territory. Therefore, we look to better comprehend and discuss the efficiency of concessions of public use support services, recognizing that such realities are possible when considering the management of tourism in protected areas, which are directly affected by social and political contexts. We seek to discuss the specificities of this model in the particular case of the PARNAMAR FEN. We hope our analysis will encourage more research and above all new concessions and partnerships for the promotion of sustainable tourism, enabling the management of protected areas through the preservation and valorization of the environment.

2. NATIONAL PARKS AND TOURISM

Protected areas are considered to be one of the most effective tools in promoting the preservation and conservation of the environment as well as sustainable development. Protected areas have been changing and adapting through the years, due to new developments and needs. Yet they remain key in maintaining the valuable services provided by nature and its ecosystems, thus assisting social interests (Cases, 2012; MMA, 2010; Wyman *et al.*, 2011).

In Brazil, the government passed law no. 9.985, in 2000, that establishes the National System of Nature Conservation Units (SNUC). This law lays down the criteria and directives for the creation, implementation and management of protected areas, which are designated as "conservation units". These areas divided into two main categories: Sustainable Use Units (direct use) and Full Protection Units (indirect use), with the National Park (PARNA) belonging to the latter. The main goal of a PARNA is the preservation of natural ecosystems, while allowing for scientific research as well as for environmental education activities, recreation and sustainable tourism (MMA, 2006).

National Parks (PARNAs) belong to the public domain, and private property that would fall within its borders is expropriated upon creation by federal decree. They must have an Advisory Council comprising representatives of government agencies and of organizations from civil society, presided by the entity responsible for its administration which, in the case of all parks in Brazil is ICMBio. Highlights from the Council's responsibilities include: the preparation of internal statutes; overseeing the preparation, implementation and revision of the Management Plan; trying to reconcile the interests of all stakeholders; and pursuing the integration of the protected area with the remaining areas and surroundings (MMA, 2006).

According to Gohn (2000) and Burkowski & Varajão (2010), these Councils should have an inter-institutional nature and serve as mediators in the state/society relation, effectively decentralizing public management. Grau (2004) considers that decentralization and democratization need to be associated for the protected area to work.

The SNUC establishes that protected areas have five years after their onset to come up with a Management Plan, which must address all management activities, such as environmental protection and conservation measures, scientific research, promotion and integration of the protected area in the social and economic life of the local community, and public use management (MMA, 2006). Especially in protected areas of the Park category, the Management Plan must ensure the preservation and maintenance of the Park's biodiversity; the protection and valorization of natural resources used for subsistence by traditional populations in the surroundings of the parks, whilst promoting their social and economic integration; environmental education and sustainable tourism (Santos, 2011).

The Brazilian Institute for the Environment and Natural Resources – IBAMA (2007), explains that a Management Plan is a dynamic project that uses ecological planning techniques to establish zones and guidelines that make managing the protected area possible, according to its goals. Until the Management Plan is prepared, all activities in the protected area "*must be of a kind that safeguards the integrity of the resources the unit is supposed to protect, ensuring that traditional populations that might inhabit the area have all the conditions and means necessary to satisfy their material, social and cultural needs*" (MMA, 2006).

According to the Ministry of the Environment – MMA (2014), in August 2013 Brazil had 1.783 protected areas, of which 69 are national parks (one of them being the PARNAMAR FEN) distributed over seven biomes. Santos (2011) asserts that few of the National Parks have a Management Plan and/or are open to visitation. The same thing is true regarding the existence of Advisory Councils in these areas. Some of the parks are not open to public visitation because they lack investment in facilities and staff, or because they do not include tourism in their Management and Public Use Plans.

Scientific research, environmental education and tourism are amongst the few activities that are allowed inside National Parks in Brazil. Research is essential in protected areas for it feeds back into the whole process of managing such spaces, providing important indicators for an efficient management and for the preparation of management plans. Environmental education focuses on educational activities, raising the awareness of the local community and visitors to environmental matters, being thus a tool to minimize conflicts that might arise upon the implementation and management of a protected area. Finally tourism, an activity with great potential in a protected area, uses pristine nature as a major attraction (Gorini *et al.*, 2006; MMA, 2006).

In spite of there being several sectors of tourism, in this paper we do not aim at discussing or differentiating existing definitions, but rather at emphasizing the importance of sustainability in this activity. Therefore, the sectors used by the authors quoted throughout this paper will focus on a kind of tourism that seeks contact with nature in a sustainable way, mainly in protected areas.

Leisure in direct contact with nature, specifically in protected areas, is increasingly valued globally, because it is an activity with great potential to assist in the conservation of these spaces, together with environmental education. Ecotourism is considered an activity that promotes environmental conservation and the involvement of the community that lives in and/or around protected areas (Santos, 2010b; Araújo *et al.*, 2011; Zeller, 2012; Wyman *et al.*, 2011).

However, to plan and develop ecotourism, people are needed who are qualified and aware of the necessity to preserve the environment, as well as who are committed to advance the cause of sustainability, given that these are interdependent. Planning must consider strategies that benefit local communities, promote social equity and ensure participative mechanisms. It is important to consider the thoughts of locals and tourists in order to achieve responsible planning for the activity. One has to consider the quality, quantity and diversity of services, as well as the creation of jobs that involve the local community (Araújo *et al.*, 2011; Barreto, 2003) and eventual environmental impacts (Wyman *et al.*, 2011).

Tourism is frequently the main driving force behind the economy of small islands, and this calls for the sustainable use of resources and for coherent conservation policies that ensure an adequate exploration of such vulnerable territories (Carvalho *et al.*, 2009; Moniz, 2006). In small insular territories, tourism is considered one of the few opportunities for economic diversification, but this requires adequate and continuous planning and management, because the excessive pressure exerted over fragile ecosystems would endanger its viability (Lima, 2008).

Islands have great environmental value and their management is delicate and complex, involving several environmental protection statutes, such as protected marine areas. Because of use pressures, such as tourism, insular coastal management becomes even more complex, requiring the resolution of problems and conflicts. Many islands considered to be natural sanctuaries have become commercial products in the tourism market. Tourism boosts the economy of these insular territories, but also exerts great pressure on ecosystems, sometimes even exceeding the limits of sustainability. In an effort to safeguard their natural values, some islands have been adopting restrictive measures such as limiting the number of visitors (Dias *et al.*, 2010; Mohr *et al.*, 2009).

Protected areas, namely the PARNAs, can use tourism in an orderly and sustainable way, garnering benefits for the management of such areas. For that to be the case, tourism has to be managed, overseen, controlled and have adequate infrastructures that have minimal impact in the environment. Yet, one of the greatest constraints of public use of Parks is the scarcity of financial resources managers have at their disposal to promote such measures (Pasquali, 2006; Wyman *et al.*, 2011). This is a very pertinent matter if Brazil is to achieve efficiency and efficacy in its Parks. It is possible for the system to generate revenue from tourism and educational activities when these areas are strategically inserted in local and/or regional development plans. In this context, it is important that Park managers know and analyze the principal instruments of public policies that concern protected areas, so that they are capable of combining management with the measures and strategies implemented in any one locality (Cases**,** 2012; Wyman *et al.*, 2011).

Another challenge is the realization of participative management through an inclusive process that entails human and financial resources, besides the involvement and training of the different stakeholders. This involvement is essential to avoid and/or minimize conflict between stakeholders and the manager of the protected area should play the part of mediator (Cases**,** 2012).

Santos *et al.* (2011) stress that regarding PARNAs, there is not enough information concerning their implementation, maintenance and management, namely information having to do with social, economic and environmental issues. To carry out these measures, some Parks in Brazil have been making concessions and/or outsourcing to private enterprises, as in the case of the Iguaçu and Tijuca National Parks.

3. CONCESSIONS AND THE MANAGEMENT OF TOURISM IN NATIONAL PARKS

New paradigms, such as sustainable development and leisure in the midst of nature, value the services provided by natural unspoiled environments and bring visitors from all over the world to protected areas. That attraction works not only with tourists that value the preservation of the environment, but also with investors that are interested in using those natural resources in a sustainable way (Terborgh *et al.*, 2002; Santos, 2010a). Small islands exert a special attraction, mainly due to conditions associated with insular geography and environmental vulnerabilities that create singular economic practices (Moniz, 2006).

In protected areas, public visitation, including tourism, must be subject to norms and restrictions established in the Management Plan, as well as in the Public Use Programs of the area, ensuring that visitation takes place in a sustainable way, compatible with the preservation of the environment (Santos, 2010ba, 2011). This program must therefore be an integral part of the full planning of the protected area, allowing for an increased efficiency of its management (Takahashi, 2004).

Santos (2011) notes that the Management Plan is one of the main tools to achieve the sustainability of tourism in protected areas and that the planning and development of tourism by companies and public agencies in that area has to take into account the plan's restrictions. Moniz (2006) emphasizes that for small insular destinations to develop according to the principles of sustainability, they must use new instruments and information that evaluate the impacts of local policies and the fulfilment of sustainability goals in tourism activities, and allow for preventive and corrective measures. On that note, Kinker (2002) stresses that because several external factors interfere directly with tourism, its sustainability can only be assessed in a certain moment.

According to Fennell (2008), the balance of the tourism industry depends on the existence of positive relations between local communities and protected areas. Politics are the driving force responsible for the balance of the social, environmental and economic sectors, enabling the adequate and effective planning of tourism. The most important thing in different management models is that they must promote and value cooperation amongst different stakeholders, providing real benefits for the local community and for the environment.

In an effort to regulate visitation to protected areas, the MMA of Brazil has published, in 2006, the document "Guidelines for Visitation in Conservation Units" with directions and principles for this activity: it must take place in a democratic way; the planning and management have to respect the preservation character of the area; needs to promote the social and economic development of adjacent populations; adequate infrastructure must be in place and the provision of quality services must be ensured. In 2008, the same Ministry, in collaboration with the Ministry of Tourism (MTur), has created the "Program of Tourism in Parks" that aims to promote responsible tourism that takes into account the conservation of biodiversity, sociocultural diversity and traditional knowledge. This program was based on studies carried out by the "Action Plan for the Organization and Promotion of Tourism in National Parks", which laid down priorities for 25 National Parks, including the PARNAMAR FEN (MMA, 2006, 2008).

In spite of showing great potential for ecotourism, many Brazilian National Parks are unprepared for public use. Some even have management plans, but these are inadequate or impractical. This happens mostly because they do not focus on the management of public use and although visitor profile studies exist, there is no expertise to use the results for the improvement of plans that would maintain the conservation character of the areas. Visitation principles must first be established and only then public use planning can take place with effective results for environmental protection in these areas (Galante *et al.*, 2002; Dourojeanni & Pádua, 2001; Zeller, 2012).

Santos *et al.* (2011) argue that the promotion of tourism in the PARNAs has to involve the local population and give due attention to regional specificities, enabling visitors to enjoy the natural and cultural resources of the protected area and thus support the development of local communities and respect for the environment. Ecotourism will only come to be if there is a network of actors that will have it conceived and implemented. Designated *tourism trade*, this network brings together public authorities, private enterprise, Non-Governmental Organizations (NGOs), local populations and consumers/tourists. On this note, the guidelines of the SNUC (MMA, 2006) emphasize the importance of the support and cooperation that NGOs, private organizations and individuals can bring to the promotion of research, ecotourism, management, maintenance, education and awareness-raising in protected areas.

According to Santos (2010a), in a study conducted in 2009, from 57 surveyed PARNAs, 25 (43,86%) have no management plan and from these, 22 (68, 75%) are incomplete. The same study found that 25 Parks (43,86%) have active councils, 23 (40,36%) have no council at all and 9 (15,78%) have councils that are not active. Regarding public use support infrastructures, the study found that 11 Parks have some kind of infrastructure, but not all are open to visitation. These are: Serra da Capivara; Brasília; Foz do Iguaçu; Ubajara; Serra do Cipó; Serra dos Órgãos; Tijuca; Aparados da Serra; Serra Geral; Itatiaia; and Fenando de Noronha.

The planning and execution of policies and strategies regarding ecotourism in protected areas will involve several actors of different areas and therefore overlapping of responsibilities and interests may occur, be it at a the level of government, state, municipalities, populations or entities concerned with environmental preservation (Coelho *et al.*, 2000). This cooperation has to exist between the private, public and NGOs sectors to ensure that the norms of management plans for the protected areas are always respected (Araújo *et al.*, 2011). It's in this context of trying to reconcile the interests of several stakeholders that public-private partnerships materialize (Burkowski & Varajão, 2010; Wyman *et al.*, 2011).

Rocktaeschel (2006) states that the outsourcing/concession of visitation support services in protected areas is aimed at requalifying the use patterns of such areas, thus enabling the fulfillment of their environmental protection goals and fomenting the responsible use of heritage through visitation. He stresses that the implementation and improvement of visitation support infrastructures is a great alternative when these areas have insufficient financial resources. We are told concessions can be: of all explored activities or services in one single concession; by activity or service type; individual, by activity or service; and pulverized or individual. Wyman *et al.* (2011) exemplify concessions like the inclusion of fees that concessionary companies pay to render services inside the protected areas (souvenir stores, restaurants, trails, hotels), providing the know-how required to innovate and respond to the visitors' demands.

Zeller (2012) and Santos (2010a) argue that concessions to private companies are a viable possibility in the management of the public use of Parks, but stress that in that case protected areas must be attractive enough for companies to be interested in concession calls. That's why partnerships are so important to the sustainability of tourism in the PARNAs. As Santos *et al.* (2011) state, it is a continuous effort to obtain sustainable results in the long run.

To the MMA (MMA, 2010), the concession of services in National Parks tries to adequate use patterns in these areas to the federal rules and norms for the preservation of the environment, whilst reinforcing the importance of heritage as a touristic attraction that brings benefits such as: the improvement of heritage preservation conditions; better exploitation of the visitation potential; reduction in public expenses; increase in government funds; creation of distinguished conditions for environmental education and research. This way, the concession allows private investments in visitor service, promotes environmental conservation and, through the ICMBio, enables more actions to protect and manage the protected area.

Because of that, MMA of Brazil (2006) sees the adoption of concessions, permits and authorizations for the provision of quality services and infrastructures to visitors as a possible alternative. However they remark the need for continuous and rigorous evaluation of these services and infrastructures, as well as for a program to supervise the environmental impacts of activities, amongst other guidelines.

In Brazil, there are no specific laws regarding concessions in protected areas. General legislation that regulates concessions in all Federal Public Services is used instead, namely (Santos, 2010a): Law nº.6.019/74; Federal Constitution of 1988; Law nº 8.666/93; Law nº 8.987/95; Law nº 9.074/95; Law nº 9.941/97; Law nº 9.985/2000; Decree nº 4.340/02; Decree nº 5.758/06; Normative Ruling nº 02/2009; Normative Ruling nº01/2010; Ordinance nº 117 of 12 of March of 2010, published in the DOU of 15 of March of 2010.

To finance procedures in the PARNAS, concessions have to take into account information arising from economic viability studies, comprising different scenarios for the operation of services and considering visitor flux and the protected area's capacity. For concessions to have positive results, the planning of activities must follow some principles, namely: care for all users; constancy in service provision; provision of adequate services; fair prices; and treat the public well. In this scenery, providers of support services at the PARNAs are seen as important actors in the promotion of sustainable tourism that is in accordance with nature conservation (MMA, 2008; Roocktaeschel, 2006).

An example of concession of public use in protected areas in Brazil is the Iguaçu Falls National Park, which in 2010 welcomed 1.2 million tourists. With a total area of 185.262,2 ha, it was the first protected area in the country to be nominated Natural World Heritage Site by UNESCO in 1986. The "Cataratas do Iguaçu S.A." company was established in 1998 and won the public tender called by IBAMA to manage the public use of the Park through a concession. More than ten years after the start of operations in the Park, this company is considered by the Brazilian government to be a model of management of public use to be followed by other protected areas. This model of involvement and participation of private endeavor through concession was a pioneering initiative of the Government and was only possible because the Park presented the right conditions, such as a consistent management plan, with several revisions; economic viability due to the number of visitors; land issues worked out; and good infrastructure outside the protected area (Gorini *et al.*, 2006; Roocktaeschel, 2006). This company has also won the concession for public use support services in the Tijuca National park, in 2012, in the city of Rio de Janeiro (Portaria Nº 442, de 5 de dezembro de 2012).

Several other examples exist around the world of protected areas that are granted as concessions to improve the efficiency of their management and revenue generating tools: Kakadu National Park (Australia); Yosemite National

Park and Grand Teton National Park (United States); Galapagos National Park e Yasuní National Park (Ecuador); Tambopata National Reserve (Peru); Arrayanes National Park e Nahuel Huapi National Park (Argentina); South African National Parks e Kruger National Park (Africa do Sul). According to their specificities, each of these protected areas and contracting terms present a different set of benefits and conflicts. Normally, when problems appear they have to do with the lack of regulation and supervision of the concession by environmental agencies (Gorini *et al.*, 2006; Wyman *et al.*, 2011).

An example of efficient management of tourism in protected areas is the Great Barrier Reef Marine Park/Green Island National Park. It was thanks to the Management Plan, supported by rigorous laws and environmental guidelines, together with supervision, monitoring and cooperative management between the Park's staff and tour operators, that the protected area has been overcoming conflicts and attaining the balance of marine and coastal ecosystems. This is an example of cooperative management that seeks to deal with impacts and ensure sustainable tourism in the Park (Zeppel, 2011).

Indeed, concessions in tourism management are not only an opportunity, but also a challenge. The process of establishing a concession in support services for tourism in protected areas stands on four pillars: 1) a consistent political and judicial context suitable to the local realities to ensure a basis for the contracting of the concession; 2) studies that demonstrate the financial viability of the concession; 3) a prospectus with a clear and objective description of the best practices for the concession, with the opportunities, limitations and management procedures; and 4) be clear about the environmental, social and economic responsibilities regarding the protected area and its surroundings. And since these are protected areas, concession contracts must consider the need for environmentally friendly practices which minimize impacts through the use of indicators such as: monitoring plans; development of adequate infrastructure; use of alternative energy; waste management; and risk analysis (Wyman *et al.*, 2011).

4. THE ISLAND OF FERNANDO DE NORONHA – MARINE NATIONAL PARK AND TOURISM

The island of FEN is the only inhabited island in the archipelago and has a total area of 17,017 km^2. It is located in the Atlantic Ocean, in the Brazilian Continental Platform, 350 km away from the city of Natal, Rio Grande do Norte, and 545 km away from the city of Recife, Pernambuco. Volcanic in origin, it is approximately 10 km long with a maximum width of 3,5 km. The perimeter is about 60 km. The highest point in the island is the "Morro do Pico", 321 m high (Figure 1) (IBAMA, 1990; Mitraud, 2001).

According to the Brazilian Institute of Geography and Statistics (IBGE, 2013), the population of the island in 2010 was 2.630, with this number doubling if we add the floating population (transient workers and researchers). With a tropical climate, the island is home to the only oceanic mangrove in the Southern Atlantic, located at the PARNAMAR FEN. The coast is indented with cliffs and residual Atlantic Forest, and the island is regarded as refuge and nursery to many marine species.

Because of the geographic isolation peculiar to oceanic islands, FEN has been on the route of the great voyages to the South Atlantic, having been settled by the Dutch and the French. In 1737, under the jurisdiction of the State of Pernambuco, Brazil, construction started on a village, a military outpost and a correctional colony. When, in 1938, there was the need for a political prison, the island came under the jurisdiction of the Union, Federal Government of Brazil. During the Second World War, in 1942, the military occupied the archipelago and the Federal Territory of Fernando de Noronha was established. The military were in charge for 45 years, until the transition from military to civil government. The first civil governor of the archipelago was

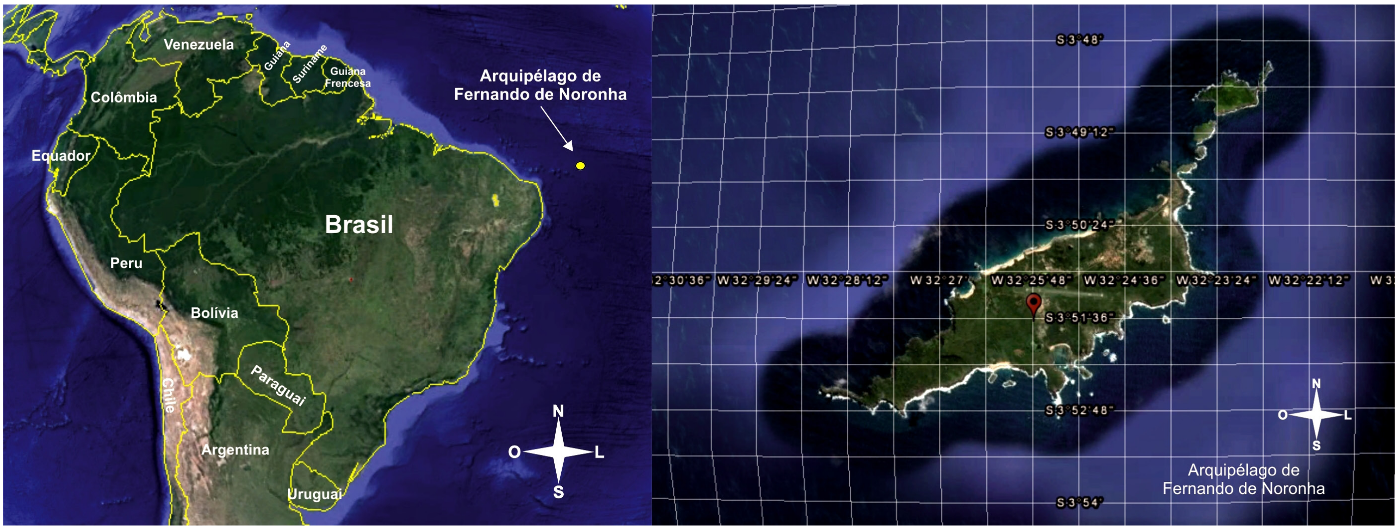

Figure 1. Fernando de Noronha location on a map.

appointed in 1987. The two protected areas, Environmental Protection Area (APA) and PARNAMAR FEN, were created in this period and mark the beginning of a greater openness to tourism in the island (Souza & Vieira Filho, 2011).

As a consequence of the way humans occupied the island through the years, several impacts were caused due to the disorderly and predatory use of the natural resources of the island. Indiscriminate logging and the introduction of plant and animal species are examples of such impacts, with some later becoming aggressive invaders. Because the archipelago stands as feeding and breeding grounds for marine fauna, it has to be protected against the predatory actions of residents and the ever increasing number of tourists (Mitraud, 2001; Mohr *et al.*, 2009). The growing urbanization and tourist flow in the island, combined with morphological features, might accelerate problems that have to do with coastal erosion, which through the years have already become apparent in soil degradation and land movements (Castro, 2010).

Before the two protected areas were established, the Brazilian Institute for Forestry Development (IBDF) was in charge of protecting the archipelago, describing it as a "high priority area for conservation" in a document concerning the "World Conservation Strategy", prepared in 1980 by the International Union for the Conservation of Nature (IUCN). In 1986, the gradual increase in unplanned uses of the island, as well as the investments in inadequate infrastructure, gave rise to the "Comitê Pro-Parque Nacional Marinho de Fernando de Noronha", which advanced several actions to demonstrate the need to preserve the island through the establishment of the National Marine Park (IBAMA, 1990; Mitraud, 2001).

The PARNAMAR of FEN was, then, created in 1988 with the purpose of protecting the terrestrial and marine ecosystems of the archipelago. Comprising a total area of 112,7 km^2, it covers 70% of the archipelago (Figure 2) and harbors the only mangrove forest in the south Atlantic, as well as many marine species that use it as feeding and breeding grounds. The Park is ranked in the "full protection" category, meaning it is intended to "*protect representative samples of terrestrial and marine ecosystems of the archipelago that ensure the preservation of its fauna, flora and other natural resources, providing opportunities for controlled visitation, education and scientific research and contributing to the protection of sites and structures of historical and cultural interest that might exist in the area*" (Decreto nº 96.693, de 14 de Setembro de 1988; MMA, 2008).

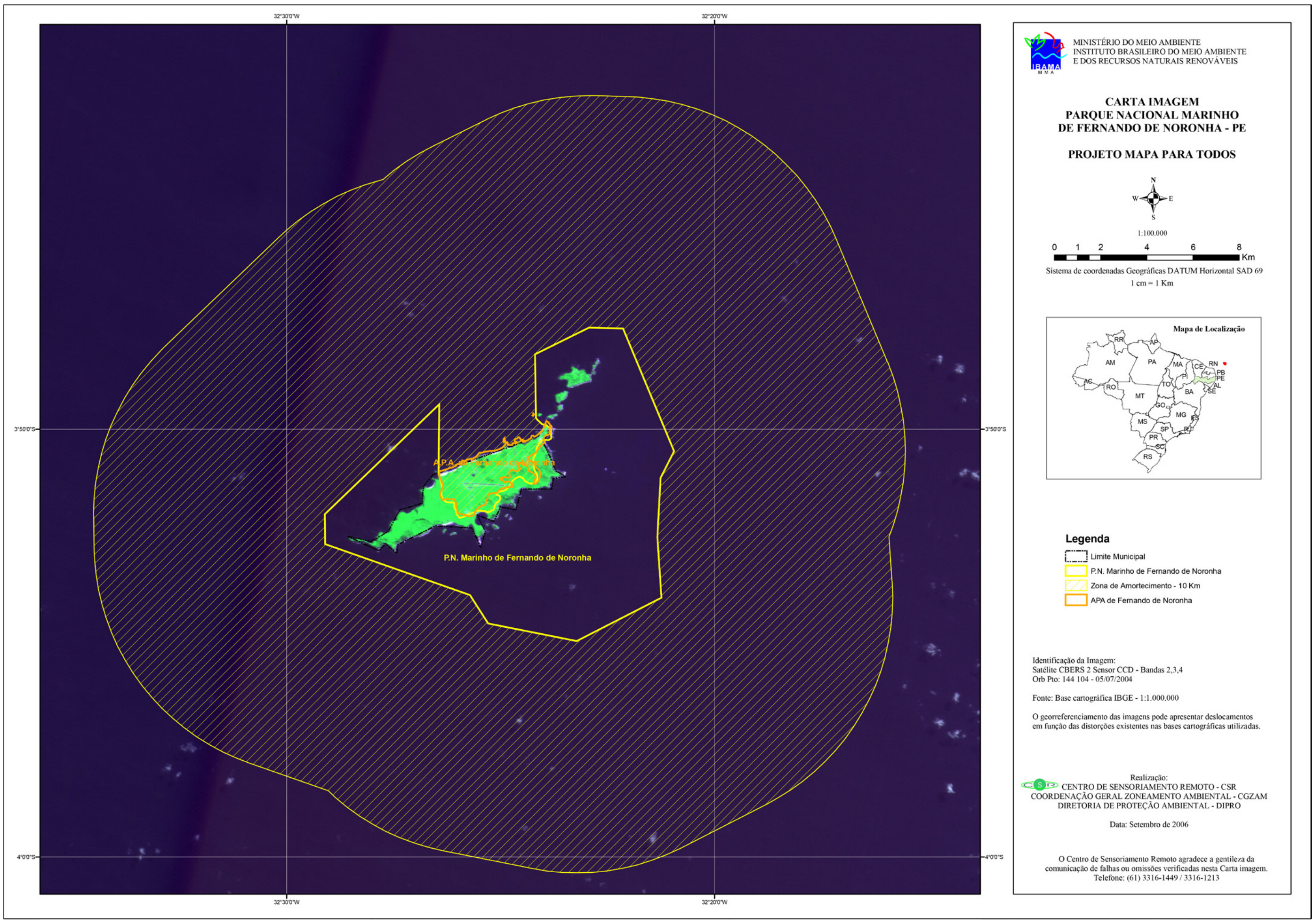

Figure 2. Map of the PARNAMAR of Fernando de Noronha (Fonte: MMA, 2001).

Management of the Park is carried out by the Chico Mendes Institute for the Conservation of Biodiversity (ICMBio), bound to the MMA, which has the mission of protecting the Brazilian natural heritage as well as promoting socio-environmental development (Decreto nº 96.693, de 14 de Setembro de 1988; Carvalho, 1999; MMA, 2001, 2005). The Managing Council of the Park has a consultive and joint nature and includes representatives from the following institutions: the PARNAMAR of FEN; the APA of FEN; the Executive Management of IBAMA in Pernambuco; The Administration from the State District of FEN; the District Council of FEN; the Department of Science, Technology and Environment of the State of Pernambuco; the Federal University of Pernambuco; the Aeronautics Detachment of Fernando de Noronha of the Second Regional Aerial Command; the Popular Assembly of FEN; the "Golfinho Rotador" Center; the "Pró-Tamar" Foundation; the local Tour Guides Association; the local Scuba Diving Companies Association; and the local Tourist Boats Association.

Observing the legal requirements for the management of the protected area, in 1990 the Management Plan of the Park was prepared, with tourism activity addressed in the Public Use Program (IBAMA, 1990). Between 1997 and 1999, the IBAMA and WWF-Brasil signed an agreement to carry out the project entitled "Recreative Uses Development in the Marine National Park of Fernando de Noronha" which sought to plan and implement the recreative use of the Park, reconciling recreative visitation with the protection of terrestrial and marine ecosystems, improving visitation support infrastructures to offer a safe and comfortable environment to visitors, thus consolidating the protected area. The results and conclusions of this project highlight the importance of Park managers as those in charge of ensuring the implementation and sustainability of the elements proposed in the recreative use system, maximizing recreative benefits and thus guaranteeing the protection of the environment. As happens with most Brazilian Parks, after having management plan and infrastructure the PARNAMAR of FEN saw neither new investments nor adequate management mechanisms to fulfill the purpose of its establishment (MMA, 2008).

The establishment of both protected areas brought greater visibility to the island as a tourist destination with great natural attractions and scenic beauty. Shortly thereafter the first lodgings appeared. The system of family lodgings was introduced, transforming the homes of locals into lodging facilities, and tourism ventures such as restaurants, diving schools and rent-a-car began to appear.

Because of its natural and historical potential, in 2001 FEN was recognized as being of outstanding importance for the preservation of the world's natural and historical heritage by the United Nations Educational, Scientific and Cultural Organization – UNESCO (MMA, 2005; ADM&TEC, 2000). To keep this distinction, continuous supervision of tourism is essential. This entails understanding, planning and monitoring the impacts of such activities so that sustainable development is achieved.

In 2009 a study was carried out to evaluate the feelings of the local community towards the social and cultural changes brought along by tourism activities that started in the Park after the end of military government in the archipelago. It was found that most people (72,5%) considered the progress of tourism in the island to be great, with 83,3% saying it brings more benefits than problems. However, some 16,7% refer problems that are due to increased tourism, such as: water shortages, increased living costs, increased numbers of inhabitants, lodgings and vehicles, less security, amongst others. There is the perception that, through the years, improvements were made in the infrastructure and in working conditions, but the increased number of inhabitants became a major problem that sometimes results in tensions between locals and temporary residents (floating population) regarding the use of the natural resources of the island and the restrictions imposed by environmental legislation (Souza & Vieira Filho, 2011).

Currently, in 2013, tourism is the main economic activity and the island is considered one of the best sustainable tourism destinations in Brazil. As in other Brazilian islands (Ilhabela, Ilha do Mel, Ilha Grande), tourism in FEN has the status of protected area, regarded as a paradisiacal destination with visible ecological appeal (Prado, 2003). The main activities tourists partake in are: trails, scuba diving whale watching, and participation in the activities carried out by the environmental NGOs. But, in spite of this potential and status, some factors hamper the development of tourism in the island: distance to mainland; limited infrastructures; environmental preservation tax (staying in the island and access to the Park); high price of tourism trade (flight, accommodation); restrictions to land use and occupation, amongst others (Souza & Vieira Filho, 2011). Besides these limitations, the availability of water, energy and adequate waste management are real issues that make one wonder about the real levels of sustainability (environmental, social and economic) in the island (Cleto, 2013).

Other research conducted in 2013 shows that these problems remain and that the use and occupation of the island are in increasingly unsustainable. It also reveals that the publicized image of the island highlights natural beauty while ignoring the reality of most inhabitants in which "paradise" is close to collapse. The research goes on to stress that during the preparation of the "Study on Peak Capacity and Sustainability Indicators in the Environmental Protection Area of Fernando de Noronha" the MMA had already alerted for the need of improvements in occupation patters, ecosystem exploration and emissions in the area. We are told that since the PARNAMAR of FEN was established the economy has been evermore centered on tourism, with locals giving up their quality of live to offer better conditions to tourists. The depletion of the natural attributes of the island would therefore entail the loss of the main source of income for locals, *i.e.* tourism. This dependency on tourism is the main challenge in attaining sustainability (Cleto, 2013).

Although sustainability remains to be achieved in FEN, the kind of tourism and the services that it offers already seek direct contact with nature and the valorization of natural and cultural heritage. Services are mostly provided by locals, with small lodging facilities and trained tourist guides. In order to keep the impact of tourism low, the island authorities control the flow of tourists through the payment of an environmental fee (R$ 48,20 / € 15 per day), quantifying and identifying each visitor to the island (airport and seaport). Visitor entrances are limited to 246 per day, according to the Administration's norms.

Because the Park has full protection status, living in the area of the PARNAMAR of FEN is forbidden by federal law. The singular natural attributes of the Park make for diverse visitation possibilities, such as walking trails, boat trips, scuba diving, bathing areas, geologic landscapes, historical sites, and others. Apart from leisure activities, environmental education and scientific research also take place and must be authorized and supervised by the ICMBio (MMA, 2001, 2005). In 2013 there were in the area of the Park 5 beaches, 14 walking trails and 3 Information and Control Posts.

Operating hours are also in place: the park can be visited daily from 08:00 to 18:30, with the exception of "Baía dos Golfinhos" and "Praia do Leão" which can be accessed outside operating hours under the supervision of "Tamar" and "Golfinho Rotador" staff, so that visitors can experience the conservation activities of these organizations. Besides established visiting hours, there are other rules that have to be observed when visiting the Park. For example, when visiting the natural pool of "Praia da Atalaia", tourists must be accompanied by a local guide certified by the ICMBio and can only stay in the water for 30 minutes, with no sunscreen, to avoid disturbing the marine environment.

In the beginning there was little visitor infrastructure or supervision, as was the case with most Brazilian protected areas. Signaling could only be seen in tourist maps and some signboards and there were no access gates or collection of admission fees. The increased number of visitors together with the physical features of the Park brought about more impacts and conflicts. To assess and change this situation, in 1995 the "Ecotourism Program for the Archipelago" was launched. But only in 1997 has the IBAMA signed an agreement (nº 006/97) with the *World Wide Fund for Nature* (WWF) to bring order to public visitation in the Park, in the process creating subprograms for recreation and leisure, education and environmental education, as predicted in the Management Plan (Mitraud, 2001).

In July 2010, the MMA decreed the insertion of the following studies in the area's Management Plan until there latter is reviewed: "Recreative Use of the Park"; "Study on Peak Capacity and Operationalization of Activities in Nautical Tourism"; "Executive Project for the Adjustment/ Recovery of Trails; "Readjustment Project for the Visitor Center and Expography Project for the Visitor Center" (Portaria Nº 57, de 26 Julho de 2010). In 2011, the MMA has further established norms and procedures for the registration and authorization of the exercise commercial activities regarding visitor tours in the Park's area (Portaria Nº 12, de 23 de Fevereiro de 2011). These measures, combined with Brazilian laws on the preservation of the environment, have been assisting in the planning, development and supervision of public use in the PARNAMAR of FEN.

Because there was the need to implement infrastructure, management and supervision of public use and the ICMBio lacked human and financial resources, in 2010 a bidding process was started for a concession contract to provide support services for the public visitation and collection of admission fees in the Park (Decreto nº 96.693, de 14 de Setembro de 1988; IBAMA, 1990; MMA, 2008).

5. METHOD

In order to attain our objectives, we sought to identify all stakeholders that were active in the Park's area and learn about their *modus operandi* (Table 1), especially if they were involved in the planning, implementation, management and supervision of tourism and provided services and/or tourist attractions in the area, with environmental protection in mind. Because in this study we try to analyze concessions and partnerships in the management of tourism in the Park, data were collected through individual interviews with representatives of six institutions/companies, forming a population of six respondents: the PARNAMAR of FEN (ICMBio – Federal Government); EcoNoronha (concessionary); environmental NGOs; and the island's Administration (State Government of Pernambuco).

Table 1. Stakeholders network in the PARNAMAR of Fernando de Noronha.

STAKEHOLDER		ROLE
ICMBio/ PARNAMAR of FEN		Manage the protected area, in particular, supervise the concessionary company.
FEN Administration	Environment	Preserve the island's environment
	Ecotourism	Plan, implement and monitor sustainable tourism in the island.
EcoNoronha		Fulfill the actions laid down in the concession contract for the public use of the Park.
"Tamar" NGO		Preserve sea turtles.
"Golfinho Rotador" NGO		Preserve spinning dolphins.
Private Companies (*Tourism trade*)		Use the Park's area for tourism services (scuba diving, boat trips, pedestrian trails).
Local community		Enjoy the Park.
Tourists		Get to know and enjoy the Park.

The choice of population for our research took into account time and financial constraints. We therefore suggest that a wider study is conducted that involves tourist operators, residents and tourists in Fernando de Noronha, in an effort to embrace all stakeholders that might be affected in a positive and/or negative way by the concession. This would provide a complete analysis of this model of public use management in protected areas.

Two data groups were used: primary data, based on six semi-structured interviews and *in loco* observations (participant); and secondary data, involving information about the concession process and the management of tourism in the Park. Empirical research was carried out by means of semi-structured interviews with the legal representatives of institutions (PARNAMAR/ICMBio; Administration/ Management of Ecotourism and Management of the Environment), organizations (the "Tamar" and the "Golfinho Rotador" ENGOs) and the concessionary (EcoNoronha). The respondents were informed of the purpose and relevance of our study and permitted that their statements be recorded, with each interview running for about one hour. Interviews were digitally recorded and later transcribed in full for analysis. Respondent's phrases were indexed according to topic for analysis and interpretation. The following topics were addressed: the mission of the institution; general description of their role in the island; the progress and sustainability of tourism; the balance between tourism activities and environmental preservation; the management of the Park; the concession of public use services in the Park; and partnerships concerning tourism in the Park.

We also examined the minutes of some meetings of the Park's Advisory Council and made *in loco* observations during the months of January, February and December of 2012. Furthermore we followed activities in November of 2013. This amounted to a total of 17 days of field work. We employed a qualitative approach, useful in the understanding of social issues because there is direct contact between the researcher and his object of study. This research is classified as a case study and elaborates on the respondent's perceptions of the tourism management model of the PARNAMAR FEN, resorting to content analysis and descriptive exploratory study (OMT, 2005; Gil, 2008; Vergara, 2010).

6. RESULTS

6.1. Concession of tourism services in the PARNAMAR of FEN

The PARNAMAR of FEN was part of a group of Brazilian National Parks surveyed by the MMA (2008) for investments through concessions of tourism services, and in 2010 a concession contract was signed with EcoNoronha. In order to improve visit quality and diversify recreational attractions, the MMA recommends that Parks plan and implement recreational activities and reconcile tourism with the protection of marine and terrestrial ecosystems, while improving the infrastructure of the protected area.

According to the norms established in the call notice nº 01/2010, process nº 02070.001685/2010-49, of the ICMBio (MMA, 2010), only one company answered the concession call, EcoNoronha, a company of the Cataratas do Iguaçu S.A. group. It satisfied all legal requirements and won the concession. The call notice includes: basic project; model letter of accreditation; model declaration– minor; model declaration of compliance with the provisions of Art. 10 of Law nº 4.358/2002; model declaration of inspection; model declaration of independent proposal; and contract draft (Table 2). The concession period is 15 years, and may be extended for another 5 years.

From the beginning of the concession to the time of our research, 2013, the company has already carried out improvement works in public visitation support services, such as: renovation and creation of information and control posts (PICs) for visitor support; establishment of convenience stores with diners an equipment rental; conservation actions (reduction of environmental impacts and restoration of vegetation); implementation and maintenance of recycle bins; use of sustainable technologies; adequate treatment for solid and liquid waste; harvest and use of rainwater; implementation of appropriate infrastructure for disabled people; hiring and training of local staff; creation of a webpage with information concerning the Park and its norms.

Respecting the deadlines and the values specified in the concession contract, in September 2012 the collection of individual admission fees started (Brazilians pay R$ 75,00 / € 23,00 and foreigners R$ 150,00 / € 46,00). Tourists are then entitled to access all public visitation areas, including walking trails and beaches for 10 consecutive days. The following people are exempted from paying fees: Brazilian citizens over 60 years old; children under 11 years old; legal inhabitants of the island; public servants working in the island; and researchers cleared by the ICMBio. Guided tours, scuba diving, boat trips and other such services are provided in the Park by personnel cleared by ICMBio (tour guides and registered companies).

According to the authorities of the State District of FEN, in 2012 the island was visited by 62.960 tourists. We were unable to learn the number of visitors to the Park for the same year, but according to data provided by ICMBio, in the following year (2013) the Park received 61.580 visitors. Of these, 54.885 paid the entrance fee and 6.695 were covered by exemption norms. The concession contract establishes that the company must transfer to ICMBio 14,6% of the value of each admission. Based on the study of economic viability for the concession, in 15 years ICMBio will receive an estimated seven million, eight hundred and eighty four thousand Brazilian "reais" (R$ 7.884.000,00 / € 2.454.927,00).

To better understand how the concession of support services for public visitation in the Park works, we sought the opinion of the general manager of EcoNoronha in the island, discussing the process of implementing and managing the Park as well as the importance of partnerships and sustainability for tourism in the protected area (Table 3).

To validate the performance of EcoNoronha in the Park, we surveyed the perceptions of the legal representatives of the PARNAMAR, of the "Tamar" and "Golfinho Rotador" NGOs, of the Management of Ecotourism and of the Management of the Environment from the

Table 2. Concession liabilities besides the contents of the Basic Project.

LIABILITIES OF CONCESSIONARY (EcoNoronha)
Cannot carry the brand of the concessionary in products to be sold in the Park. Can only be displayed in facilities inside the protected area, upon permission of ICMBio;
Collect and dispose of waste by-products of daily operations, in suitable conditions;
Be responsible for the training of contracted staff, according to operation rules and general knowledge of the Park;
Implement an efficient radio communications system in the Park for supervision and control of visitation services;
All logos, illustrations, pictures and any other visual programming material concerning the Park must first be submitted and approved by ICMBio;
Allow and facilitate free access of ICMBio staff and authorized personnel to the protected area, as well as to the counting and control systems for monitoring purposes;
Promote the modernization, replacement, improvement and expansion of technology, equipment and facilities during the concession period;
Carry out, every 3 months, a satisfaction survey with visitors to the Park, proposing research methods and ensuring that at least 35% of monthly visitors are interviewed.
Produce monthly and yearly reports for ICMBio about visitor flux (number of visitors, number of exemptions, granted amenities and collected amount);
Make available for the general public information emanating from ICMBio;
Start collecting entrance fees within 90 days from signing the contract.
Provide information and explanations when required by ICMBio and report all occurrences concerning the fulfillment of the contract;
Pay for the concession in time, until the fifth day of each month;
Replace any worker who is deemed inconvenient to the order or norms of the concession;
Be liable for the damage and disappearance of material goods and malfunctions caused to the grantor or third parties by the staff, because of negligence or willful misconduct in the execution of the contract, according to Law nº 8.666/93;
Immediately rectify any damage to goods under the concessionary's responsibility, when prompted by ICMBio.
Provide services in accordance with the contract, *i.e.*, with staff that is trained, has good educational and moral level and is correctly habilitated.
Ensure that workers abide rigorously by the legislation of environmental protection.
Whenever requested, prepare and submit to ICMBio reports on construction work to be carried out;
Abide by the Safety and Occupational Medicine Standards, Laws nº 8.666/93 and 8.987/95, the Brazilian Civil Code, the Technical Norms of the ABNT, environmental legislation and other pertinent laws and regulations.
At the end of the contract, return to ICMBio the rented property in perfect use conditions, with the equipment in good condition and in accordance with the goods inventory.
LIABILITIES OF THE GRANTOR (ICMBio)
Must interrupt or change the operation of visitor activities when the safety of visitors to the Park is compromised;
Approve in advance all replacement, construction or improvement projects. Likewise, approve beforehand the Environmental Control Plan of civil construction works;
Supervise and police the fulfillment of the concession and of all activities stipulated in the contract, having the power to halt, refuse, and impose the replacement or destruction of any service that is not in agreement with the contract;
Appoint a delegate or commission to supervise the execution of services and activities specified in the contract;
Demand the immediate suspension or replacement of a company worker who is problematic for supervision and policing reasons;
Whenever deemed necessary, inspect and challenge services or activities carried out according to contract.

Table 3. Perceptions of the manager of EcoNoronha about the concession process and tourism in the Park.

SUBJECT		MANAGER'S PERCEPTIONS ON THE MATTER
Motives to bid for concession		We already had the know-how from the Iguaçu National Park (Brazil) concession, specifically in services, infrastructure and public use management in National Parks.
Objectives of concession		The concession contratct is about providing support services for public visitation of the PARNAMAR of FEN, where there is a business plan to be executed. This business plan is in accordance with the Park's Management Plan.
Concession obligations – Operation of the company in the Park		Provision of support services to visitors: build adequate infrastructure (walking trails, visitor centers, diners, toilets, etc.), provide quality services, track and help tourists and local guides in the trails, etc. The contract also covers the collection of admission fees to the Park.
Constraints to operations in the Park		One of the biggest challenges of operating in the Park has to do with its insular nature and the obstacles imposed by insularity, like having to do all transport by sea in precarious conditions. This was more evident during the infrastructure building process, but goes on even now in the visitor management phase. The qualifications of staff members are also an issue, but this is being addressed with training.
How the company interacts with:	PARNAMAR of FEN– ICMBio	This is a relationship between the concessionary company and the entity responsible for that concession. We are bound to comply with the obligations established in the concession contract. This is a great partnership because of the common interests, *i.e.*, to provide quality support services to visitors and maintain the appeal of the Park to tourists while preserving the environment. EcoNoronha are not a full member of the Park's Management Council but take part in meetings as observers, asking questions and contributing to the best possible management of public use.
	NGOs	Our main partnerships are with the "Tamar" and "Golfinho Rotador" NGOs, because they work directly in the Park's area. EcoNoronha support some of these NGOs' initiatives because these are some of the main tourist attractions in the protected areas.
	The island's Administration	The relationship is good and we cooperate in several matters, especially in the promotion of FEN as a tourist destination in Brazil and abroad. For this effort we also partner with the Company of Tourism of Pernambuco (EMPETUR), which are responsible for managing tourism in the State of Pernambuco and work to increase tourist flow and improve visitation quality in the island.
	Local community	One of our priorities when starting operations in the island was to establish a good relationship with the local community. This is reflected in how many of the company's staff are locals (98%). We also prefer local suppliers and so promote the island's economy. We value cultural heritage and support some events and projects undertaken by the community.
	Local tourism businesses	Tourism businesses and EcoNoronha are the link between tourists and the Park. EcoNoronha pay continuous attention to the demands of tourists that visit the Park and use the services and facilities of the company, thus ensuring quality standards that comply with the concession's requirements.
How the management of public use works		Currently there are no conflicts, either with tourists or locals. The local community understands how important tourism is for the island given that many residents work with tourists. This facilitates synergies and friendly relations. Because the Park is already consolidated (25 years), initial conflicts that appear when a full protection area is established have already been surpassed.
Public-private partnerships in the management of tourism in the Park		There are public-private partnerships in the management of tourism: all companies that provide tourist services in the protected area have signed agreements with the ICMBio. All services in the Park are provided by third-parties, while the environment agency (ICMBio) is responsible for setting rules and supervision.
Contribution of EcoNoronha to the Park		EcoNoronha are responsible for a major breakthrough in the PARNAMAR of FEN due to the improved infrastructure for visitors, bringing the reception of tourists in the island to an all new level. The Park now is equipped with all necessary infrastructures to allow for a proper visitation, always in compliance with environmental norms and sustainability parameters laid down in the Management Plan.
Future developments		There are several possibilities of development in the Park's area, like new services to be added to public visitation. However, many environmental restrictions complicate this process in a full protection area.
Balance between tourism activities and the preservation of the environment in the Park		The main point of the concession is the balance between tourism activities and the preservation of the environment in the PARNAMAR of FEN. And so, the concession rests on three interconnected pillars: environmental concern; quality public visitation; and accessibility that is compatible with a protected area.

island's Administration, since they all cooperate to ensure the environment is preserved in the protected area. Our intention was to identify the benefits, advantages and conflicts that arise from the concession of tourism services to EcoNoronha, thus allowing for a deeper analysis of the concession.

According to the Manager of the PARNAMAR of FEN, EcoNoronha have previous experience from the concession of support services to public use in the Iguaçu National Park that facilitates operations in line with the norms of the concession and brings about more advantages than disadvantages. Being a private company means operations are easier and more agile, contributing to an increased cooperation with the protected area. This partnership allows the government to act in an organized, lawful and agile way. He says that in spite of the admission fee being mandatory, visitors are very satisfied with the quality of services and infrastructure and this way the protected area collects funds directly (14,7% ICMBIO, 15,3% EcoNoronha and 70% investments in PARNAMAR). But there are disadvantages too, he warns: some people don't understand the purpose of the concession, and believe the Park was privatized. Because of this, it is important for the PARNAMAR to provide more information about the concession, making it easier for people to understand the role of the Park in the concession process.

The legal representative of the "Golfinho Rotador" NGO, considers that earlier the PARNAMAR had no conditions to manage the public use of the protected area in an adequate way and that the concession improved that management, providing the Park with the infrastructure needed for quality visitation in compliance with environmental norms. However, she recalls that at the onset of operations, all service providers that were already active in the area had to be organized, and this originated conflicts in the local community. The conflicts were due to the fear that EcoNoronha would curb the activity of tourist operators in the protected area. The question has however been settled, since the need for registration was only a control measure by the Park's manager. The company hired many locals (98% of staff), but this can become a serious question because some locals went from being self-employed to being employees, thus changing the dynamics of the local economy. As for a partnership between EcoNoronha and the NGO, she tells us there are no signed agreements, but that the company contributes to the research activities and environmental education carried out by the organization.

To the legal representative of the "Tamar" NGO, despite the commercial interests of EcoNoronha, the company improved the Park greatly through the provision of excellent quality services. Indeed he states that the company is responsible for a small revolution in the island, whether regarding infrastructure, whether regarding the provision of quality services and also the regulation of the labor market. He explains that the improvements in the infrastructure and services of the Park will naturally force tourism operators to improve as well. This has already happened with lodgings and, because of EcoNoronha, is now happening with tourist services. Nonetheless, locals still need to be trained. Regarding their relationship with the grantor, we are informed that there is a healthy cooperation, mainly because the environmental NGO monitors several beaches in the Park but also because of activities that they carry out together. There is, however, one catch, he says, that has to do with the souvenir business. "Tamar" is a self-supporting organization that relies on the sales their shops make throughout the country, besides other kinds of assistance and funding. EcoNoronha also have very profitable souvenir shops in the island and are consequently competition for the NGO. Despite this, he stresses the importance of EcoNoronha for the Park and for the island as a whole, and specifically for the partnership with "Tamar".

The manager of Ecotourism in the Administration of FEN, admits that EcoNoronha came to add value, in the sense that their purpose is to offer quality infrastructures and tourist services that are in compliance with the Park's norms. The manager of Environment in the Administration of FEN, agrees that the concession brought benefits to the island. She recalls that before the concession the relationship of the Administration with the Park was difficult, especially concerning tourism management, because the protected area had no funds to invest in the infrastructures, services and supervision needed for adequate visitation. When EcoNoronha started operations in the island there was some conflict, but in time they succeeded in establishing a good relationship with everyone. Finally, he declares that tourism is now more expensive in the island, but at least visitors can expect great value for their money.

Considering the need to improve the process of concessions for visitation support services in protected areas in Brazil, the MMA (Portaria Nº 442, de 5 de dezembro de 2012) introduced in December 2012 a Workgroup for the Evaluation of Concessions, with the aim of evaluating existing concessions, namely the PARNAMAR of FEN. Although this evaluation by the Workgroup already took place, it is yet to be made available (March 2014) to the Park's chief. As of now the results cannot be examined.

However, before the Workgroup was established, in August 2012 there were controversial situations concerning the concession, as was the case of the construction of an Information and Control Post at the Southeast Beach. According to the concession notice, all construction works must first be approved by ICMBio. As it happened, some locals didn't like the project and claimed its visual impact was severe and changed the beach landscape. This situation was solved by removing the physical structure of the Post, with EcoNoronha having to start the project over to get a new approval of ICMBio, this time with the assent of residents. This case illustrates the kind of solvable conflicting situations that may occur in concessions in protected areas.

Another controversial situation concerning the concession was the apprehension the local population felt towards the admission fees in the Park. It was claimed this measure would interfere with tourist flow in the island and affect local income, since tourism is the main source of income for locals. Notwithstanding the importance of the objections, tourist flow actually increased after the concession (2010 = 61.114 tourists / 2012 = 62.960 tourists), thus demonstrating the importance and viability of the concession in the protected area, concerning the availability of public use services and infrastructure.

Besides the Workgroup created by the MMA, the PARNAMAR of FEN established a monitoring committee for the concession contract which monitors all items in the Basic Project periodically and makes them available in annual reports. In this case, ICMBio are responsible for monitoring the environmental, social and economic impacts (positive and negative) stemming from the concession in the Park. EcoNoronha only have to comply with all the norms laid down in the concession contract, with environmental preservation being determinant. We stress we had no access to these reports during our research period. We learned a questionnaire has already been prepared for visitors to the Park, as envisaged in the concession contract, to assess visitor satisfaction with the services and infrastructure offered by EcoNoronha in the Park. However, it is yet to be distributed.

We come then to the conclusion that, despite being recent, the concession is significantly improving the PARNAMAR area of FEN. Even with all the hindrances associated with the insular context, the provision of services is stable and efficient, offering quality infrastructures and services that observe environmental norms. Although the introduction of yet another environmental fee remains a controversial issue in FEN, the amount that is charged is more affordable than the one practiced by the island's Administration (R$ 392,83 / € 119,00 for 10 consecutive days). As it is, EcoNoronha establish partnerships and consolidate a participatory concession model in National Parks.

6.2. Partnerships in the management of tourism in the PARNAMAR of FEN

We identified the organizations, institutions and companies that are active in the area of the PARNAMAR of FEN (Table 1). We started with a global survey and then proceeded to analyze whatever activities they carry out that are linked to sustainable tourism. This initial analysis revealed the existence of a network made up of actors from the public and private sectors. Despite their collaborative work, some actors have a broader scope of action concerning the planning, implementation, management and supervision of tourism. These are the PARNAMAR/ICMBio; the "Tamar" and "Golfinho Rotador" NGOs; the island's Administration; and EcoNoronha. These actors form a network and although each one has its specific goals, they try to work together when it comes to the sustainability of tourism and the preservation of ecosystems in the Park. These partnerships are established through signed agreements and answer the need for collective efforts, seeing that all parties have common interests in the protected area.

The mission of the "Tamar" NGO is to research, preserve and handle sea turtles, with funds coming mainly from Petrobras and with the support of ICMBio. This NGO started working in FEN in 1984, *i.e.* before the Park was created. This is one of their most important bases, offering excellent conditions for conservation works on the biology and behavior of sea turtles in their natural environment. Taking advantage of the fact that the island has a considerable influx of tourists throughout the year (approximately 60.000 visitors per year), this NGO promotes awareness-raising and environmental education activities, mainly at the Visitor Center. In this center tourists find souvenir shops, diners and information desks that offer services to the community and visitors alike. Through this NGO tourists can also take part in the tagging of turtles and watch them lay their eggs during spawning season. These activities garnered international acclaim as a successful marine conservation experience, serving as a model for other countries, especially when it comes to the involvement of the local population.

The "Golfinho Rotador Center" started activities in the island in 1990, with the mission of doing research on spinner dolphins in the archipelago in order to find strategies for the preservation of this species' natural behavior. Funded mainly by Petrobras and with the support of ICMBio, it promotes an environmental education program and tries to provide subsidies for sustainable local development. Specifically, this NGO's aims are: to raise the awareness of locals and train them in environment preservation; subsidize the island's sustainability; improve the quality of ecotourism services; study the natural history of dolphins; research the interaction of dolphins with nautical tourism; propose measures for the conservation of this species; propose and take part in actions that aim to preserve the environment in FEN. To achieve this, they run research programs and environmental education programs. Local students are the target of the environmental education program and take part in lectures, workshops and field trips. Professional courses in ecotourism are also available. The other program is aimed at tourists, who are briefed at "Mirante dos Golfinhos". Additionally, there are open lectures at Tamar's Visitor Center.

Despite there being other ENGOs in the island, these two are the most relevant when it comes to tourist activities and environmental preservation in the Park, using environmental education, guide training, cultural valorization, lectures, participatory tourism programs, etc. These organizations were active in the area and striving to protect the environment since before the Park was established and now their activities proceed in partnership with ICMBio and EcoNoronha. Because some activities, like Dolphin Watching and Turtle Spawning, are carried out outside opening hours, there is an agreement between the Park/ICMBio, EcoNoronha and the NGOs to enable the area being used at those times. This entails changes to the logistics of company staff to ensure facilities are open and activities are supervised.

Apparently, the role of the island's Administration is sometimes mistaken for that of EcoNoronha or of the protected area themselves. The Administration is responsible for planning, implementing laws, fomenting and supervising tourism in the island as a whole with strong investments in marketing campaigns to promote FEN as a destination. It is also responsible for providing the island with infrastructures, promoting services, controlling tourist flow, marketing the destination, amongst other actions that directly affect the sustainability of tourism in the island. Among Administration sectors in FEN we find the Coordination Office for the Environment and Ecotourism, with a manager for the Environment and another one for Ecotourism.

The main element of this network is the ICMBio, which has the principal role in the management of the PARNAMAR of FEN. Despite the island's Administration being the local representatives of Government, the Park is autonomous regarding management because it is a Federal protected area. As executor of the SNUC's resolutions, the ICMBio proposes, implements, manages, protects, inspects and supervises the Park. It also fosters and carries out research, protection, preservation and biodiversity conservation programs and acts as environmental police for the protection of the Park. They are also responsible for the supervision of outsourced services, run by EcoNoronha, as well as by other tourism companies active in the protected area. The Park has a headman and the management model comprises an Advisory Council, established in 2001, consisting of public and private entities and of civil society organizations, thus legitimating local participatory management.

Looking into the minutes from the Advisory Council's meetings, it is possible to see how this management takes place and how partnerships between stakeholders are established regarding the planning, implementation, management and supervision of tourism. During the Council's meetings, which take place every two months, stakeholders discuss, opine and suggest ideas for the Park, some regarding tourism activity. The results can be verified in terms of research, laws, supervision, infrastructure, services, education, promotion, etc. The Advisory Council can therefore be seen as a formal connection between stakeholders, where all matters regarding management are discussed and solutions suggested to avoid or minimize disputes over interests in the protected area. We should stress that despite the fact that our study looks into some stakeholders with greater depth, all of them are represented in the Council, thus validating a local participatory management.

Our results may come to show that the head of the protected area is competent in its management, as are the partners that make up this network and try to promote sustainability in tourism, validating a viable management model for public use in National Parks that can be implemented. But again we stress the importance of a broader study that covers all stakeholders and of the supervision of all activities linked to the environmental component of the concession's sustainability.

FINAL REMARKS

Many Brazilian PARNAs face difficulties intrinsic to their status and lack management plans or appropriate funding. Despite being located in one the country's principal tourist destinations, the PARNAMAR of FEN also experienced constraints that hindered its management. Our analysis of the way the concession of services in the Park works and of how partnerships are established for its management allowed for new insights into a viable model for the management of tourism and funding of protected areas in islands.

We found that the management model of public use in the PARNAMAR of FEN is based on the concession of support services for that use, with public-private partnerships and signed agreements. This model comprises several stakeholders that have a preponderant role in the planning, implementation, management and supervision of tourism in the Park. Despite different interests, stakeholders in the network manage to work in synergy and obtain results at the levels of research, laws, supervision, infrastructure, services, education, promotion, marketing, etc. There is a cohesive network of relationships between stakeholders that, in addition to individual actions, enables joint efforts for the improvement of the sustainability of tourism in the PARNAMAR of FEN.

Our data show that EcoNoronha played a crucial role in turning tourism into a tool for the growth of the local economy, using infrastructures and services to generate revenue in the area of the Park. Besides that, the company also collects admission fees that represent direct and bureaucracy-free funds for the protected area and streamline its management.

As it is, the network is promoting the sustainability of tourism in the Park in the sense that it tries to involve everyone, fostering dialogue and the sharing of knowledge. It also advances the economic growth of tourism and the competitiveness of the island as a whole, whilst ensuring that practices remain responsible and balanced in the long run for the sake of environmental preservation. There is also an effort to improve the qualifications of the resorts and of those involved in tourism activities, combined with the development of environment-friendly products and services that consolidate the destination and satisfy visitors.

All parties try to optimize the use of resources and enhance environmental efficiency, promoting good practices in the Park. The involvement of the local community in the protected area is also patent, with most inhabitants working directly or indirectly with tourists and therefore profiting from the Park, while consolidating its participatory management model. Nonetheless, because it is an ongoing process, constant supervision is required.

Given that during our research we had no access to the results of the MMA's Workgroup and of the technical reports, we were unable to verify the data concerning compliance and supervision of the components of sustainability (environmental, social and economic) in the Park. Therefore, regarding the concession, we cannot yet assert that this is an appropriate model to be replicated in other insular contexts.

Despite the positive results for the sustainability of tourism in the Park, it is not yet possible to know if these three elements are balanced, making it necessary to verify if the indicators used by the MMA and ICMBio are adequate for local characteristics and observe the parameters of environmental preservation. Moreover, there should be a broader and uninterrupted study that includes the local community, tourist operators and visitors.

For the network to proceed with its efforts towards the sustainability of tourism in the Park, this management model must be integrated into the policies and programs of sustainable development of the island and become an inducing factor for such development. The effective management of the PARNAMAR of FEN requires strategies, plans and resources and the valorization of the area by the local community. However, it is important to strengthen the management possibilities for tourism in the protected area by all stakeholders and ensure constant supervision of activities through adequate and measurable indicators.

Finally, we can conclude that for concessions to be implemented in protected areas, namely in National Parks, there needs to be legislation that is both solid and in line with local characteristics, especially when dealing with insular contexts. The bidding process also needs to be transparent ant judicious and include all legal matters concerning the environment. Moreover, it is important for the success of the concession that the Park be consolidated, with management plan and operating Council. It is also essential for the Park to have a manager who is capable of planning and thoroughly supervising the entire concession process, while establishing partnerships with all stakeholders and ensuring participatory management with positive results. Our study demonstrates the importance and viability of a model for the concession of public use support services in a marine protected area, clarifying the employed procedures and the opinions of some actors in the process and providing a basis for future research that will lead to the legitimation of a model to be applied in other insular contexts.

AKNOWLEDGMENTS

We would like to thank: the Administration of the Island of FN for their invaluable support during our research; the PARNAMAR of FN/ICMBio, EcoNoronha and the ENGOs. This research was possible thanks to a doctoral grant awarded be the "Fundo Regional de Ciência – FRC" (Governo dos Açores) M3.1.2/f/042/2011.

REFERENCES

Araújo, L.R.R.; Freitas, D.M.A.; Braghini, C.R. (2011) – Ecoturismo como alternativa para o desenvolvimento sustentável da Área de Proteção Ambiental do Morro do Urubu – Aracaju (SE). *Revista Brasileira de Ecoturismo* (ISSN 1983-9391), 4(2):228-249. São Paulo, Brasil. Available at http://www.sbecotur.org.br/rbecotur/seer/index.php/ecoturismo/article/view/115/83

Barreto, M. (2003) – O imprescindível aporte das ciências sociais para o planejamento e a compreensão do turismo. *Horizontes Antropológicos* (ISSN 0104-7183), 9(20):15-29. Porto Alegre, RS, Brasil. Available at http://www.scielo.br/pdf/ha/v9n20/v9n20a01.pdf

Burkowski, R; Varajão, G.F.D.C. (2010) – Sustentabilidade da Visitação Pública em Unidades De Conservação: um estudo de caso do Plano de Negócios do Parque Estadual Do Itacolomi-MG. *Caderno de Geografia* (ISSN 2318-2962), 20(34):22-43. PUC–Minas, Brasil. Available at http://periodicos.pucminas.br/index.php/geografia/article/view/1663/1770

Carvalho, L.F.A. (1999) – *Impactos do Turismo no Arquipélago de Fernando de Noronha: um estudo no caminho do desenvolvimento sustentável*. 126p., Monografia de Licenciatura em Turismo, Universidade de São Paulo, Escola de Comunicações e Artes, Departamento de Relações Públicas, Propaganda e Turismo. São Paulo, SP, Brasil. *Unpublished*

Carvalho, M.L.; Rodrigues, A.N.; Roque, S.; Centeio, G.; Furtado, A.J.; Santana, P. e Alfama, V. (2009) – *Plano de Gestão – Parque Natural do Fogo*. 323p., Ministério do Ambiente, Desenvolvimento Rural e Recursos Marinhos, Cabo Verde. Available at http://portaldoconhecimento.gov.cv/handle/10961/1889

Cases, Maria Olatz (2012) – *Gestão de Unidades de Conservação: compartilhando uma experiência de capacitação*. 396p., WWF-Brasil, Brasília, DF, Brasil. ISBN 978-8586440496. Available at http://www.ipe.org.br/livrogestaoUC.pdf

Castro, J.W.A. (2010) – Ilhas oceânicas da Trindade e Fernando de Noronha, Brasil: Uma visão da Geologia Ambiental. *Revista da Gestão Costeira Integrada*, 10(3):303-319. DOI: 10.5894/rgci170

Cleto, A.W. (2013) – *De cemitério de ideias a embrião de sementes. Uma experiência sobre a mobilização social em Fernando de Noronha*. 192p., Dissertação de Mestrado, Universidade de Brasília, Brasília, Brasil. Available at http://repositorio.unb.br/handle/10482/14295

Coelho, M.C.N.; Lopes, L.T.; Fenzl, N. (org.). (2000) – *Estado e políticas públicas na Amazônia. Gestão de recursos naturais*. 290p., Editora Cejup, PA, Brasil. ISBN: 978-8533804319.

Dias, J.A.; Carmo, J.A.; Polette, M. (2010) – Breves considerações sobre as ilhas e a sua gestão / Brief remarks on the islands and its management. *Revista da Gestão Costeira Integrada / Journal of Integrated Coastal Zone Management* 10(3):243-253. DOI: 10.5894/rgci237

Dourojeanni, M.J.; Pádua, M.T.J. (2001) - *Biodiversidade: a hora decisiva*. 307p Curitiba: Editora: UFPR. ISBN: 978-8573350753.

Feitosa, M.; Gómes, C. (2013) - Aplicação do Tourism Ecological Footprint Method para avaliação dos Impactos Ambientais do Turismo em Ilhas: um estudo em Fernando de Noronha. *Revista Brasileira de Pesquisa em Turismo, 7*(2):220-238. DOI: 10.7784/rbtur.v7i2.509

Fennell, D. (2008) – *Ecotourism*. 282p., 3rd ed., Routledge, London. ISBN: 9780415429313.

Galante, M.L.V.; Beserra, M.M.L.; Menezes, E.O. (2002) – *Roteiro metodológico de planejamento de parques nacionais, reservas biológicas e estações ecológicas*. 135p., Ministério do Meio Ambiente (MMA), Brasília, DF, Brasil. Available at http://www.icmbio.gov.br/portal/images/stories/imgs-unidades-coservacao/roteiroparna.pdf

Gil, A.C. (2008) – *Métodos e técnicas de pesquisa social*. 200p., 6ªed., Editora Atlas, São Paulo, SP, Brasil. ISBN: 978-8522451425

Gohn, M.G.M. (2000) – O Papel dos Conselhos Gestores na Gestão Urbana. *In:* Ana Clara Torres Ribeiro (compil.), *Repensando a Experiência Urbana na América Latina: questões, conceitos e valores*. pp. 175-201, Consejo Latinoamericano de Ciencias Sociales (CLACSO), Buenos Aires, Argentina. ISBN: 9509231525. Available at http://bibliotecavirtual.clacso.org.ar/clacso/gt/20100930063218/torres2.pdf

Gorini, A.P.F.; Mendes, E.F.; Carvalho, D.M.P (2006) – Concessão de serviços e atrativos turísticos em áreas naturais protegidas: o caso do Parque Nacional do Iguaçu. *BNDES Setorial* (ISSN 1414-9230), 24:171-209, Rio de Janeiro, RJ, Brasil. Available at http://www.bndes.gov.br/SiteBNDES/export/sites/default/bndes_pt/Galerias/Arquivos/conhecimento/bnset/set2406.pdf

Grau, N.C. (2004) – La democratización de la administración pública: Los mitos a vencer. *In:* L. C. B. Pereira, N. C. Grau, L. Garnier, O. Y. Oszlak & A. Przeworski (eds.), *Política* *y gestión pública*. 43-90p., Centro Latinoamericano de Administracion para el Desarrollo Humano (CLAD), Buenos Aires, Argentina. ISBN: 9505576102.

IBAMA (1990) – *Plano de Manejo do Parque Nacional Marinho de Fernando de Noronha*. 253p., IBAMA - Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis, Fundação Pró-Natureza (PRONATURA). Brasília, DF, Brasil. Available at http://www.icmbio.gov.br/portal/images/stories/biodiversidade/_PARNA_MARINHA_DE_FERNANDO_DE_NORONHA.pdf

IBAMA (2007) – *Efetividade de gestão das unidades de conservação federais do Brasil*. 96p., Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis (IBAMA), Brasília, DF, Brasil. Available at http://www.mma.gov.br/estruturas/pda/_arquivos/prj_mc_061_pub_liv_002_uc.pdf

IBGE (2013). – Fernando de Noronha. *In:* portal internet *Cidades@*, Instituto Brasileiro de Geografia e Estatística (IBGE), Brasília, DF, Brasil http://www.cidades.ibge.gov.br/xtras/perfil.php?lang=&codmun=260545

Kinker, S.M.S. (2002) – *Ecoturismo e conservação da natureza em parques nacionais*. 224p., Ed. Papirus, Campinas, SP, ISBN: 8530806662.

Lima, L.H.A. (2008) – *Áreas Protegidas e/ou Zonas de Desenvolvimento Turístico em Cabo Verde? O caso da Boa Vista*. 133p., Tese de Doutoramento, Universidade de Aveiro, Aveiro, Portugal. Available at http://ria.ua.pt/bitstream/10773/558/1/2008001391.pdf

Mitraud, Sylvia F. (coord.) (2001) – *Uso Recreativo no Parque Nacional Marinho de Fernando de Noronha: um exemplo de planejamento e implementação*. 96p., WWF-Brasil, Brasília. DF, Brasil. Available at http://arquivo.rosana.unesp.br/docentes/fernando/ECO II/MITRAUD. Uso recreativo do PN Marinho de Fern. Noronha - Vol8 - WWF.pdf

MMA (2001) – *Fernando de Noronha Archipelago / Rocas Atoll Tropical Insular Complex. Nomination for inclusion as an UNESCO World Heritage Natural Site*. 144p., Ministério do Meio Ambiente (MMA), Brasília, DF, Brasil. Available at http://whc.unesco.org/uploads/nominations/1000rev.pdf

MMA (2005) – *Plano de Manejo da APA Fernando de Noronha – Rocas – São Pedro e São Paulo (Resumo Executivo)*. 53p., Ministério do Meio Ambiente (MMA), Brasília, DF, Brasil. Available at http://www.icmbio.gov.br/portal/images/stories/imgs-unidades-coservacao/Resumo Executivo_f.pdf

MMA (2006) – *Diretrizes para Visitação em Unidades de Conservação*. 61p., Ministério do Meio Ambiente (MMA), Brasília, DF, Brasil. ISBN: 85-7738-021-1. Available at http://www.mma.gov.br/estruturas/ascom_boletins/_arquivos/livro.pdf

MMA (2008) – *Programa de Turismo nos Parques*. 42p., Ministério do Meio Ambiente (MMA) e Ministério do Turismo (MTur), Brasília, DF, Brasil. Available at http://www.mma.gov.br/estruturas/sbf2008_dap/_publicacao/149_publicacao16122010111448.pdf

MMA (2014) – *Tabela consolidada das Unidades de Conservação*. *In:* Cadastro Nacional de Unidades de Conservação (CNUC), portal internet do Ministério do Meio Ambiente (MMA), Brasília, DF, Brasil. http://www.mma.gov.br/images/arquivos/areas_protegidas/cadastro_uc/UCs%20consolidadas%20esfera%20de%20gestao%204.pdf

Mohr, L.V.; Castro, J.W.A.; Costa, P.M.S.; Alves, R.J.V. (2009) – *Ilhas Oceânicas brasileiras: da pesquisa ao manejo* – volume II. 502p., Secretaria de Biodiversidade e Florestas, Ministério do Meio Ambiente (MMA), Brasília, DF, Brasil. ISBN: 978-8577380763

Moniz, A.I.D.S.A. (2006) – *A sustentabilidade do turismo em ilhas de pequena dimensão: O caso dos Açores*. Dissertação de Doutoramento, Universidade dos Açores, Portugal. Available at https://repositorio.uac.pt/bitstream/10400.3/208/1/DEG_Doutor_Ana_Isabel_Moniz.pdf

OMT (2005) – *Introdução à metodologia da pesquisa em turismo*. 287p., Organização Mundal de Turismo (OMT), Ed. Roca, São Paulo, SP, Brasil. ISBN: 857241570X.

Pasquali, R. (2006) – *Parcerias público-privadas na gestão de serviços turísticos em parques nacionais: possibilidades para o Parque Nacional da Chapada dos Guimarães – MT*. 93p., Dissertação, Universidade do Vale do Itajaí, Itajaí, SC, Brasil. Available at http://www6.univali.br/tede/tde_busca/arquivo.php?codArquivo=505

Prado, R.M. (2003) – As espécies exóticas somos nós: reflexão a propósito do ecoturismo na Ilha Grande. *Horizontes Antropológicos*, 9(20):205-224. DOI: 10.1590/S0104-71832003000200011.

Rocktaeschel, B.M.M.M. (2006) – *Terceirização em áreas protegidas - Estímulo ao ecoturismo no Brasil*. 134p., SENAC São Paulo, SP, Brasil. ISBN: 8573594756

Santos, A.A. (2010a) – *Concessão ou Terceirização de Serviços Turísticos em Parques Nacionais Brasileiros: Incentivo ao aumento de receitas*. 223p., Dissertação de Doutorado, Universidade Federal de Lavras, MG, Brasil. Available at http://www.bibliotecaflorestal.ufv.br/bitstream/handle/123456789/4048/Tese_Anderson-Alves-Santos.pdf?sequence=1

Santos, A.A.; Rezende, J.L.P.; Borges, L.A.C.; Borém, R.A.T. (2011) – Cadeia de serviços turísticos: possibilidade de inclusão social nos parques nacionais brasileiros. *Revista Brasileira de Ecoturismo* (ISSN 1983-9391), 4(1):208-227, São Paulo, SP, Brasil. Available at http://www.sbecotur.org.br/rbecotur/seer/index.php/ecoturismo/article/view/125

Santos, A.M. (2010b) – O ecoturismo, uso público e o Parque Nacional do Iguaçú. *Fórum Ambiental da Alta Paulista* (ISSN 1980-0827), 4(3):229-242, Associação Amigos da Natureza da Alta Paulista, Tupã, SP, Brasil. Available at http://www.amigosdanatureza.org.br/publicacoes/index.php/forum_ambiental/article/view/82/85

Santos. A.A. (2011) – Parques Nacionais Brasileiros: relação entre Planos de Manejo e a atividade ecoturística. *Revista Brasileira de Ecoturismo* (ISSN: 1983-9391), 4(1):141-162, São Paulo, SP, Brasil. Available at http://www.sbecotur.org.br/rbecotur/seer/index.php/ecoturismo/article/view/122/68

Souza, G.M.R.; Vieira Filho, N.Q. (2011) – Impactos socioculturais do turismo em comunidades insulares: um estudo de caso no arquipélago de Fernando de Noronha-PE. *Revista Acadêmica do Observatório de*

Inovação do Turismo (ISSN 1980-6965). 6(4):1-18, Rio de Janeiro, RJ, Brasil. Available at http://www.spell.org.br/documentos/ver/8046/impactos-socioculturais-do-turismo-em-comunidades-insulares--um-estudo-de-caso-no-arquipelago-de-fernando-de-noronha-pe/i/pt-br

Terborgh, J.; Spergel, B.; Guapyassu, M. (2002) – *Tornando os parques eficientes: estratégias para a conservação da natureza nos trópicos*. 518p., Ed.UFPR/Fundação o Boticário, Curitiba, PR, Brasil. ISBN: 8573351071.

Vergara, S.C. (2010) – *Projetos e relatórios de pesquisa em administração*. 96p., 4ª ed., ed. Atlas, São Paulo, SP, Brasil. ISBN: 8522460132.

Wyman, M.; Barborak, J.R.; Inamdar, N.; Stein, T. (2011) – Best Practices for Tourism Concessions in Protected Areas: A Review of the Field. *Forests,* 2(4):913-928. DOI: 10.3390/f2040913.

Zeller, R.H. (2012) – Planejamento da visitação pública em oito parques nacionais brasileiros: oportunidades para ajustes. *Revista Nordestina de Ecoturismo*, 5(2):6-18. DOI: 10.6008%2FESS1983-8344.2012.002.0001.

Zeppel, H. (2011) – Managing Tourism on Green Island, Great Barrier Reef Marine Park: Conservation, Commerce and Compromises. *In:* Jack Carlsen & Richard Butler (eds.), *Island Tourism – Sustainable perspectives*, pp.38-53, Cabi, U.K. ISBN: 978-1845936792.

Legislação referida:

Decreto nº 96.693, de 14 de Setembro de 1988. Cria o Parque Nacional Marinho de Fernando de Noronha e dá outras providências. Publicado no Diário Oficial da União de 15.9.1988. Available at http://www.planalto.gov.br/ccivil_03/decreto/1980-1989/D96693.htm

Edital de Concorrência Nº 01/2010, Processo Nº 02070.001684/2010-49. 99p., Publicado no Diário Oficial da União de 15.3.2010. Available at http://www.icmbio.gov.br/portal/images/stories/licitacoes/2010/52.Edital%20de%20CC%20N%C2%BA%2001.2010%20Ingressos%20%20FERNANDO%20DE%20NORONHA%20final.pdf

Lei nº 9.985, de 18 de julho de 2000. Cria o Sistema Nacional de Unidades de Conservação da Natureza. Publicado no Diário Oficial da União de 19.7.2000. Available at http://www.planalto.gov.br/ccivil_03/leis/l9985.htm

Portaria Nº 12, de 23 de Fevereiro de 2011. Estabelece normas e procedimentos para o cadastramento e a autorização para exercício da atividade comercial de condução de visitantes no Parque Nacional Marinho de Fernando de Noronha. Publicado no Diário Oficial da União de 1.3.2011. Available at http://www.jusbrasil.com.br/diarios/25094178/pg-66-secao-1-diario-oficial-da-uniao-dou-de-01-03-2011

Portaria Nº 442, de 5 de dezembro de 2012. Institui o Grupo de Trabalho de Avaliação de Concessões e dá outras providências. Publicado no Diário Oficial da União de 6.12.2012. Available at http://www.icmbio.gov.br/intranet/download/arquivos/cdoc/biblioteca/resenha/2012/dezembro/Res2012-12-06DOUICMBio.pdf

Portaria Nº 57, de 26 Julho de 2010. Incorpora ao Plano de Manejo do Parque Nacional Marinho de Fernando de Noronha/PE os estudos referidos. Publicado no Diário Oficial da União de 27.7.2010. Available at http://pesquisa.in.gov.br/imprensa/jsp/visualiza/index.jsp?jornal=1&pagina=60&data=27/07/2010

Revista da Gestão Costeira Integrada 14(2):233-242 (2014)
Journal of Integrated Coastal Zone Management 14(2):233-242 (2014)

GESTÃO COSTEIRA INTEGRADA
Journal of Integrated Coastal Zone Management

http://www.aprh.pt/rgci/pdf/rgci-471_Queiroz.pdf | DOI:10.5894/rgci471

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)

Rose Emília Queiroz [1], Maria Anunciação Ventura [1], José Angelo Guerreiro [2], Regina Tristão da Cunha [@, 1]

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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* *Submission: 31 December 2013; Evaluation: 11 February 2014; Reception of revised manuscript: 4 April 2014; Accepted: 23 April 2014; Available on-line: 13 May 2014*

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.

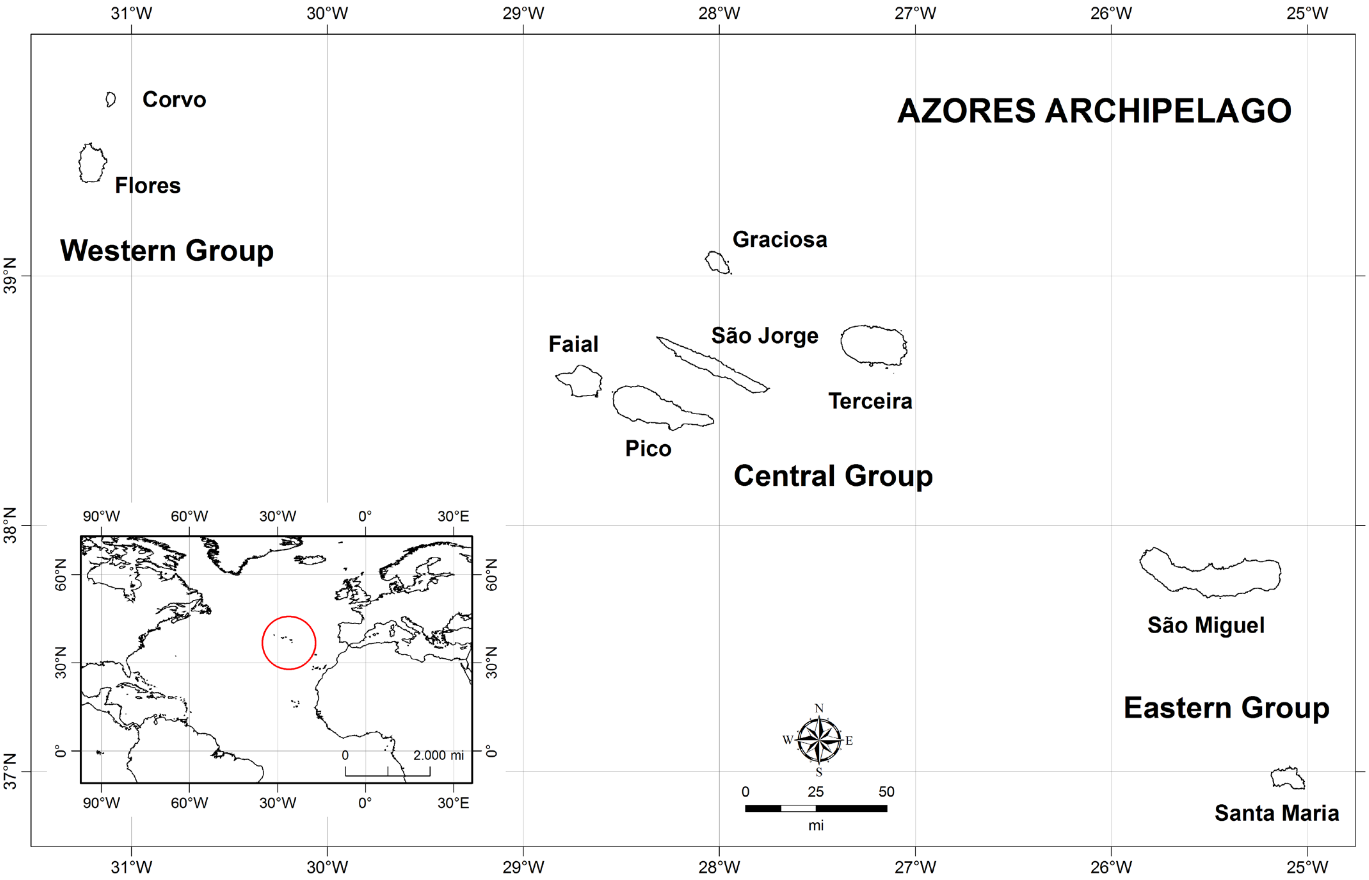

Figure 1. Location and composition of the Azores archipelago. Source: Section of Management and Environmental Planning, University of the Azores.
Figura 1. *Localização e composição do Arquipélago dos Açores. Fonte: Secção de Gestão e Planeamento Ambiental, Universidade dos Açores.*

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.

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

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).

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

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:

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

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.*

		Correction factors ()				
Hiking Trails	**Distance (m)**	Social	Precipitation	Daylight	Accessibility	**RCC (visits/day)**
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.

ACKNOWLEDGEMENTS

This study is part of the FCT financed project PTDC/AAC-AMB/104714/2008 (Operational Competitiveness Program COMPETE) and was also supported by a PhD scholar awarded to Rose Emília by DRCTC (Azorean Government) M3.1.2/F/011/2008. We greatly appreciate the assistance provided by Roberto Resendes from the Biology Department, University of the Azores, and by Pablo Escudero Aznar (Eurodisseia Program).

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.

Revista da Gestão Costeira Integrada 14(2):243-266 (2014)
Journal of Integrated Coastal Zone Management 14(2):243-266 (2014)

GESTÃO COSTEIRA INTEGRADA
Journal of Integrated Coastal Zone Management

http://www.aprh.pt/rgci/pdf/rgci-473_Fernandes.pdf | DOI:10.5894/rgci473

Applying an integrated landscape characterization and evaluation tool to small islands (Pico, Azores, Portugal) *

Aplicação de uma caracterização integrada da paisagem e de uma ferramenta de avaliação a pequenas ilhas (Pico, Açores, Portugal)

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ABSTRACT

Each landscape is determined and can be characterised by two types of environmental factors: stable biophysical characteristics and manageable land use patterns. The consideration of both these characterisation domains allows the definition of a homogeneous system of reference (the stable characteristics) with which every possible land use pattern can be compared through the use of common evaluation algorithms. The Integrated Landscape Assessment (ILA) concept builds a framework for data retrieval and evaluation processing that maximizes the following advantages: through the use of a stable reference system, it allows the comparative simulation of different land use scenarios, as well as the permanent availability of the same reference system, independently from the intensity of land use changes throughout the years. It also allows the use of different evaluation algorithms according to different evaluation contexts or paradigms, without having to repeat or adapt the characterisation process.

The present paper illustrates the basic concepts on which ILA is based and developed as well as its application to ecological planning and systematic conservation planning in the Pico Island (Azores Archipelago).

Keywords: Systematic conservation planning, integrated landscape assessment, GIS, Macaronesia.

RESUMO

Cada território é determinado e pode ser caracterizado por dois tipos de factores ambientais: características biofísicas estáveis e padrões de uso do solo susceptíveis de gestão. A consideração destes dois domínios de caracterização permite a definição de um sistema de referência homogéneo (as características estáveis), relativamente ao qual cada possível padrão de ocupação do solo pode ser comparado através do uso de algoritmos de avaliação comuns. O conceito de Análise Integrada da Paisagem (ILA) corresponde a um quadro de referenciação de dados de caracterização e avaliação e de realização de procedimentos de avaliação. Com o recurso ao ILA e através do uso de um sistema de referência espacial estável, é possível a simulação comparativa de diferentes cenários de ocupação do território, bem como a permanente disponibilidade do mesmo sistema de referência, independentemente das variações mais ou menos intensas dos padrões de ocupação do território ao longo dos anos. Permite também o uso de diferentes algoritmos de avaliação de acordo com diferentes contextos ou paradigmas de avaliação, sem ter de repetir ou de adaptar o processo de caracterização territorial.

O presente artigo ilustra os conceitos em que o ILA se baseia e desenvolve, bem como a sua aplicação ao planeamento ecológico e ao planeamento sistemático de conservação da natureza na ilha do Pico (Arquipélago dos Açores).

Palavras Chave: *Planeamento sistemático de conservação, avaliação integrada da paisagem, GIS, Macaronésia.*

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** Submission: 31 December 2013; Evaluation: 4 February 2014; Reception of revised manuscript: 22 March 2014; Accepted: 6 April 2014; Available on-line: 10 April 2014*

1. INTRODUCTION

Small islands are *ipso facto* largely coastal entities (Saffache & Angelelli, 2010). They constitute a particular example of integration through space and time of multiple natural, social and economic functions. This integration is materialized in a set of land use systems and social structures adapted to the particular natural constraints and resources framed by the available technologies. Each structure tries to find the best conjunctural solution to the feasibility equation, balancing labor and other investments with the different products and alternative sources, in order to maximize the desired landscape functions.

Nevertheless, in the case of the North Atlantic Archipelagos of Canaries, Madeira and Azores, this integration is only several hundred years old and interrelates two completely different evolutionary processes. On one side the natural island ecosystems that evolved undisturbed for millennia, determining, because of their isolation, particular geo-morpho-climatology, and bio-, anemo- and hydro-choric processes, singular communities with unique character, particular patterns of biodiversity and high degree of endemism (Borges *et al.*, 2000; Duarte *et al.*, 2008; Borges & Hortal, 2009; Bastos *et al.*, 2012). On the other side, human communities arrived to these islands in the last millennia or few hundred years, and quickly introduced their particular land uses, cultures and imported plants and animals, replacing or destroying many habitats and species and facilitating the invasion by alien species (Martins, 1993; Silva & Tavares, 1997; Yanes *et al.*, 1997; de Nascimento *et al.*, 2009; Silveira & Dentinho, 2010; Triantis *et al.*, 2010; Fernández-Palacios *et al.*, 2011; Connor *et al.*, 2012).

These manifold interactions generated very diverse landscape functions and processes that integrate the way the landscape respond to the human needs and factors of disturbance, as well as the way in which it ensures the functions corresponding to the needs of all other components of the island ecosystem. These interactions built a complex multifunctional system whose management poses particular challenges, given the need to ensure a sustainable development of the human communities, and simultaneously ensuring, not only the preservation of the existing ecological values, but also the recovery and eventual restoration of threatened or locally destroyed ones.

To these challenges one must still consider the foreseeable disturbances associated with climate change (Fonseca *et al.*, 2006; Robertson *et al.* 2011), as well as by urban and infra-structural development (often associated with tourism), that destroy or drastically change varied areas of habitat, mainly along the coast, but also frequently, in areas with a particular scenic character or morphologic particularities.

These two factors of threat must be considered with particular attention, their possible consequences in small islands almost ecologically isolated with exception of human carried propagules, which can determine, in a short term, a dramatic change in the island ecology. These issues and problems have to be faced taking into consideration that in humanized insular environments, the identification of values and threats as well as its valuation and the definition of management objects and targets in what regards nature conservation, have to take into consideration criteria and perspectives (as well as systems of values) different (to say the least) of those adopted in mainland systems.

Another critical issue is the unique character of each island implying the need to adopt for each one individually adapted planning and management (Wong *et al.*, 2005). Therefore, in these unique and differently but normally strongly humanized environments, it is crucial the availability of characterization and evaluation frameworks able to characterize the existing land resources and processes, as well as the way they are affected or allocated at any moment and land use context. Simultaneously, such a characterization and evaluation framework must be able to allow the development of land use scenarios and the evaluation of their consequences in terms of the sustainability of the ecological values and functions of each island.

In order to be able to fulfil these tasks, the ILA (Integrated Landscape Ecological Analysis) (Fernandes *et al.*, 2006) model has been developed. ILA is a framework for environmental characterization and evaluation. Its objectives are to build a coherent characterization and evaluation framework for landscape ecological studies, and to allow, within this framework, all types of expert knowledge or models to be operated on a coherent working background.

The ILA model is based on the following basic ideas:

- Each landscape is determined and can be characterized by two types of environmental factors:
  - Stable biophysical characteristics and related functions and processes;
  - Manageable land use patterns and related functions and processes.
- The consideration of the above mentioned levels of characterization allows the definition of a homogeneous system of reference (the stable characteristics) to which every possible land use pattern can be compared through the use of common modelling and evaluation algorithms.

ILA is, consequently, a framework for data and processes characterization and evaluation, where the only requirement is the availability of a stable geographical reference base that can be qualified with the same set of indicators or descriptors as the system to be evaluated.

This implies that every geographical land use, habitat or ecological structural arrangement can be described by a set of indicators or other evaluation tools, susceptible of being applied, at the same time, to a given stable geographical or ecological reference system. in order to determine the variation of these indicators or evaluation descriptors. As a result, for each type of case study, a particular geometry and representation scale, as well as a set of elements and functions to be represented, must be identified according to the definition of the research targets. In order, for example, to be able to simulate different sets of management criteria, eventually different representation geometries will have to be simultaneously considered and included in the research objectives.

The main methodological advantage of ILA is the fact that, on the basis of its concept, are geometrical and functional descriptions of the landscape and a conceptual framework where given processes or characteristics can be analysed, simulated or evaluated in a consistent and coherent way, allowing, namely, the combination and application of both economic and ecological models. It allows also the combination of different working scales through the aggregation of scale-compatible units or objects in higher hierarchical units. These processes can be entirely developed in the frame of common geographic information systems and geostatistical frameworks.

2. BUILDING AN INFORMATION FRAMEWORK FOR SYSTEMATIC CONSERVATION PLANNING IN AN ISLAND CONTEXT

2.1. Conceptual framework

Landscape characterization in the frame of planning and management processes considers the need to differentiate the different domains or information layers which, when integrated, build the representation of the character of a landscape at a given moment (Fernandes, 1993).

This approach presents, nevertheless, important constraints, because it doesn't integrate the processes and interactions that occur in the different layers and between them. Additionally it does not take into consideration the time dimension and the evolutionary processes intrinsic to the nature of the landscape itself. It is therefore necessary to complement and develop this characterization model, in order to include these processes, as well as making it able to represent and operate the temporal evolution processes.

Such characterization model has to consider in its basic assumptions, that one must distinguish between the layer of the stable resources and the layer(s) of the resource allocation, according to different uses (human or natural) or planning alternatives and scenarios (Fernandes, 2000a). This distinction derives from the fact that the stable resources and structural processes correspond to the intrinsic framework of each landscape, including, not only the availability of resources, but also temporal factors like release rates (*e.g.* natural geological weathering and nutrient or soil elements release rate). This resource layer interacts with the circumstantial layers by conditioning their characteristics and dynamic patterns as well as the levels of resource availability.

It is based on these concepts and perspectives, and on the consideration that different disturbances determine distinct hierarchical types of influences and perturbations on the different landscape elements, that the Integrated Landscape Assessment approach (ILA) was developed (Fernandes, 2000b). As a consequence, the ILA model includes at least two conceptual working layers:

- A circumstantial layer corresponding to the present conjunctural state of the landscape depicting the present factors of resource allocation.
- A stable potential layer depicting the stable characteristics of each site and allowing the identification of use constraints or potentials (*e.g.* available resources, their availability rates or spatial process paths and patterns).

These two layers correspond, conceptually, to the resource baseline and its evolution trend and to a given land use situation (present or planning scenario of resource allocation) allowing the evaluation of the resulting evolution trends, in the classical sense of impact evaluation (Figure 1).

Each layer will display the structural arrangement of landscape units and associated ecotopes. As a result we obtain an information system where every geographical land use or habitat can be described by a set of indicators or other evaluation tools, that can be applied both to the present landscape as well as to the stable reference geographical or ecological system, in order to determine the variation of these indicators or evaluations descriptors (Fernandes *et al.*, 2006).

With such an instrument it is consequently possible to evaluate the reversibility or irreversibility of given disturbances, and the positive or negative sustainability of each land use in each landscape unit. We can also identify the nature (resource or disturbance) of landscape corridors or other connectivity paths, the effective degree of complementarity between land units and the real variation on the degree of fragmentation (Fernandes, 2000a, 2000b).

When analysing nature conservation issues, this approach of a sinecological character, must be complemented by an autoecological characterisation of target species, groups of species and habitats. This characterisation will include, for example, the habitat demands for these species and can be associated with the optimum curves for each species or groups of species or habitats, allowing the identification of the degree of fulfilment of the ecological optimum by the prevailing condition in each land unit. Such information or models will allow, for example, the evaluation of the degree of stress that a given target species is supporting in its present habitat (*e.g.* due to habitat reduction, fragmentation or loss of habitat complementarity) and, therefore, the evaluation of its resilience relative to external disturbance such as land use changes or natural environmental oscillations.

The use of the ILA model at structural and functional levels allows the use of a large variety of tools like:

- Comparison of landscape metrics (Leitão & Ahern, 2002; Kelly *et al.*, 2011) between the reference and the circumstantial characterisation layers;
- Qualitative evaluation of the stable or circumstantial character of landscape elements (like matrix, patches or corridors) or characteristics (like fragmentation, connectivity or complementarity) (*e.g.* Watts & Handley, 2010; Martín-Martín *et al.*, 2013);
- Landscape or habitat connectivity or connectedness modelling as well as target animal movements, using for example percolation or cost-distance models (Richard & Armstrong, 2010; Etherington & Holland, 2013);
- Evaluation of management scenarios according to different sets of valuation criteria (Fernandes, 2000a; Castellazzi *et al.*, 2010; Bryan *et al.*, 2011).

2.2. Application to the universe of small islands

The development of characterization models able to support ecosystem-based management processes in small

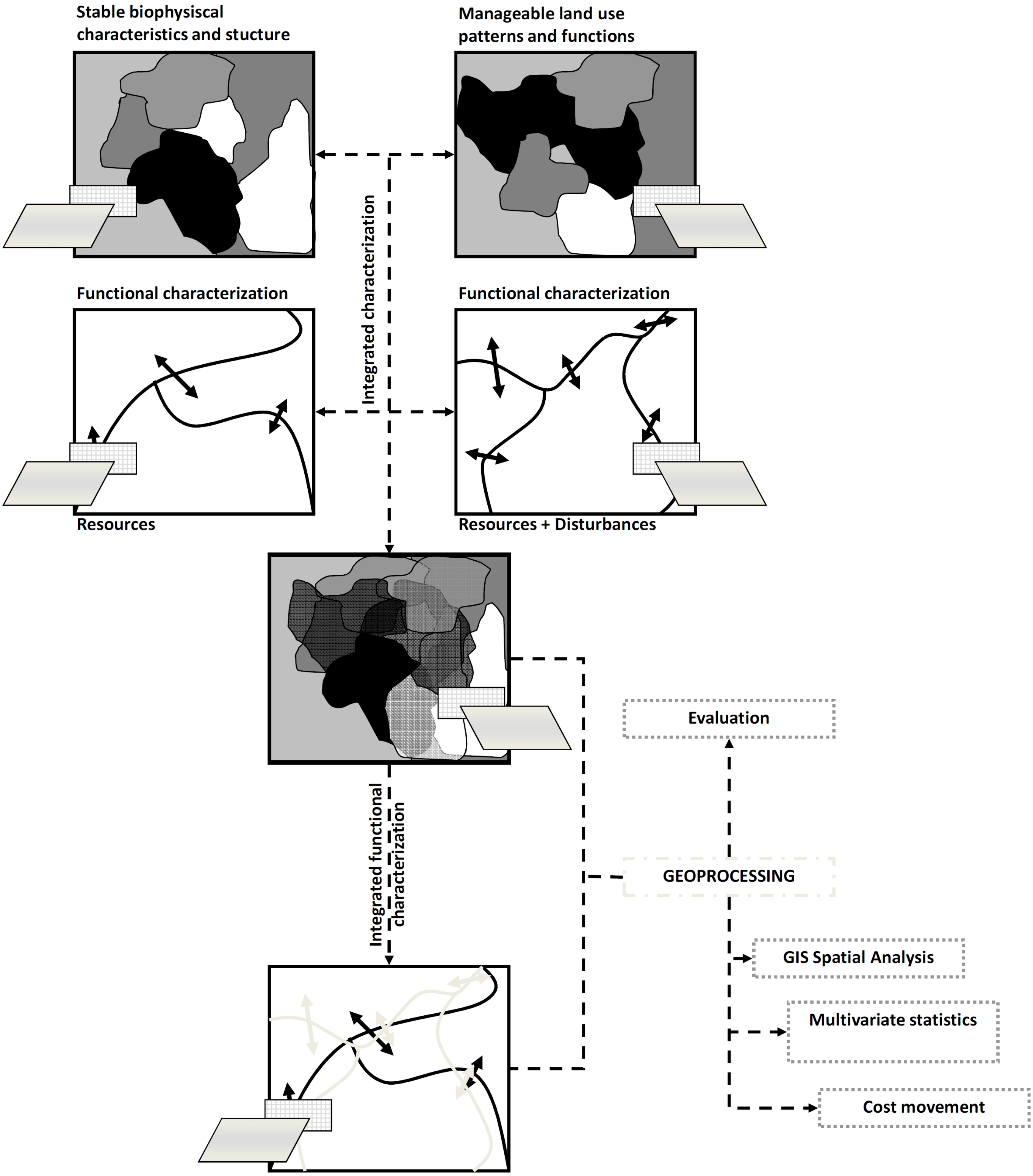

Figure 1. General structure of the ILA model (Fernandes *et al.*, 2006).
Figura 1. *Estrutura geral do modelo ILA (Fernandes et al., 2006).*

islands face several difficulties related, not only, with data availability, but also with the particularities of small islands environments. The main differences between small islands and mainland ecosystems are, as already referred, the fact that, while in continental systems the pedologic and bioclimatic factors are dominant, determining the ecological zoning, in islands systems, these factors appear conditioned in particular ways, due to the restricted geographic space of each island, what makes particularly complex the development of a reference model for these systems.

Let's consider several works conducted in different Atlantic islands (Diniz & Matos, 1986; Cruz, 1994; Diniz & Matos, 1999; Capelo, 2004; del-Arco *et al.*, 2006, 2009). One can verify that the master lines of the ecological zoning in these islands are primarily referred to morphological factors (slope position, local morphology and aspect) that will influence the critical climatic factors (water and temperature) in terms of direct exposure or shelter, in terms of altitudinal zoning or in the exposure to the different types of winds with different moisture content (influencing rainfall and evapotranspiration), as well as to the indirect precipitation associated with the formation of stable cloud belts at given altitudes.

Only marginally, and detectable at detailed scales, are the influence of the soil and other forms of substrate noticeable. The main types of such features in the case of the Santiago Island (Cape Verde) are water courses and drainage lines, open valleys, beaches, arid areas and wetlands (Diniz & Matos, 1986). In the case of El Hierro (Canaries), there are important areas of not zonal vegetation associated with particular geological occurrences, rocky substrates, areas subject to salt influence and sandy subtracts (del-Arco *et al.*, 2006). Finally, in Madeira there are important areas of non zonal vegetation associated with riparian areas, rocky substrates, salinity gradient influence and sandy subtract (Cruz, 1994). It is important to stress that all considered Atlantic islands are of a volcanic origin that doesn't allow a wide variation of soil types, geochemistry and related ecological characteristics.

These examples, although not exhaustive and systematic, illustrate quite well, what must be the main guidelines for the construction of a biophysical system of reference for insular environments. Thus, these lines will have to integrate the main determinant ecological (phytogeographic) factors as well as local factors that determine differences in the distribution of plant communities (Stephenson, 1990; Huston, 1999; Wright *et al.*, 2003; Zelený *et al.*, 2010; Bui, 2013; Costa *et al.*, 2013; Dorman *et al.*, 2013; Laliberté *et al.*, 2013; Moeslund *et al.*, 2013).

All these factors (resources) must be considered in their present (and not potential) form, because the purpose of these characterization approach is that it must express the present reality of the resources and not their hypothetical evolution in a much longer time frame than that of the planning and management process. This approach correspond consequently, in its essence, to the conceptual matrix developed by Diniz & Matos (1986) that allowed them to perform, for the entire Archipelagos of Cape Verde and São Tomé e Príncipe and also vast areas in Angola (Diniz & Matos, 1998), a ample set of evaluation procedures for planning and management of agriculture, but that can directly be also used for nature conservation and other purposes (*e.g.* Cienciala *et al.*, 2013).

ILA is of particular utility in this context, because it allows the consistent consideration, comparison and evaluation of the same geographical object in different forms (*e.g.* land use or natural habitats spatial allocation) or according to different evaluation criteria (*e.g.* naturalness or adaptation to given target species or habitats). This consistency derives, as stated, from the definition of an independent object of reference (*e.g.* ecological reference units) that can be characterized with the same set of indicators as all scenarios or land use alternatives, and support evaluation algorithms adapted to the different selected evaluation criteria.

Critical for the development of all the algorithms based in target habitat or target species criteria, is the availability of detailed data on the autoecology of these particular species or the synecology of these habitats. An example of such databases is, for the Azores archipelago, the Azorean Biodiversity Portal (Borges *et al.*, 2010).

Particularly important is the determination of criteria for the definition of minimal viable populations (Shaffer, 1981; Gilpin & Soulé, 1986; Flather *et al.*, 2011) and the identification of critical factors affecting these criteria, such as, among others, habitat area, fragmentation, patchiness, edge/core relation, (*e.g.* Saunders *et al.*, 1991; Lamberson *et al.*, 1994; Tscharntke *et al.*, 2002; Borges & Hortal, 2009; Weigelt & Kreft, 2013).

The second set of data includes the interaction between land uses and natural values, and implies the creation of a detailed database on each type of patch, in which, at least the associated natural values, are identified together with the historical and present factors determining their characteristics and conditioning the existence of these values. Of particular importance is the clear identification of the native or alien nature of these values, and, in the last case, their positive or negative feedbacks over time for autochthon values.

The third set of data is critical for the future conduction of the management processes. This is mainly due to the fact that it must bring together economic and ecological factors within their social context.

Thus, the first question to assess when developing planning and management instruments, is the way in which the different stakeholders (*e.g.* farmers) make their management decisions. This is of the utmost importance for example in the frame of conservation planning and policy-making to search and identify the factors that potentiate a positive involvement instead of the classical limitation (prohibition) approach of many conservation policies. There are domains where it is possible to find a replacement for former damaging practices or other types of trade-offs. The example of the development in the Azores islands of a leisure "industry" around whale watching and diving that built an alternative to the former activity of whale hunting is a particular good example of this process.

But at the level of much of the stakeholders (farmers and fishermen) the alternative is not so easy, because of the difficulty in identifying and developing non-commodity outputs that compensate certain restrictions derived from the needs for a systematic conservation and ecosystem-based management. This is exactly the level where the ability to evaluate and simulate alternative management approaches using a single integrated tool, will be able, not only to define policies, but also to allow the involvement of all stakeholders in the definition of these alternatives, and particularly in their implementation. This involvement is potentiated by the availability of comprehensive information and results of modeling (including their basic assumptions).

This is achieved, not only trough the characteristics of the ILA framework as a basis for this modeling process, but also because it builds a very malleable and maneuverable instrument to display and discuss the different scenarios and criteria. One can, therefore, implement multifunctional management systems, integrating all factors in a clearly defined geographical framework. The only way to ensure the sustainability of the processes of sound and assumed governance, involves strong and reliable forms of contracting and accounting, ensuring a comprehensive clarification of all the responsibilities involved, the assumptions and criteria on which the policies and decisions are based, and the robustness and soundness of the accountability processes (Gil *et al.*, 2011a, 2011b).

In an island environment, with strictly limited resources, consensual management approaches are of critical importance. As a consequence, the ability to sample all information in a coherent framework where all evaluation procedures can be lead in a reproducible way with a comprehensive reference system, allows an active involvement of all stakeholders in the development of the best solutions for each site and moment and the permanent reevaluation of these solutions.

2.3. Building the characterization system

As previously stated when describing the ILA model, the first step for its implementation is the characterization of the reference layer. This layer must be defined in such a way that it represents, with the best possible detail, the stable biophysical characteristics of the area. Therefore, its quality, accuracy and volume of integrated information depend from the available information and its quality and detail.

The geographical object that will build the basic structure of this layer can be designated as "ecological reference unit" (ERU) in the sense that it integrates all determinant stable ecological factors occurring in the study area. As previously stated, these factors correspond basically to the following list:

- Main determinant ecological (phytogeographic) factors:
    - Bioclimatology (generally related to elevation and slope aspect);
    - Macro-relief, conditioning slope exposition but also the predominant dynamic processes such as landslides, valley breezes, Foehn effects, hydrologic retention, evapotranspiration and indirect precipitation (fog or clouds);
    - Substrate, determining, between many other factors, nutrients, water availability and thermal balances;
- Local factors:
    - Micro-relief;
    - Soils and substrates;
    - Water availability;
    - Chemical constraint factors (*e.g.* nutrients, salts, toxicity).

Its selection derives from the fact that the ERUs are primarily focused on areal characteristics and express mainly ecological factors determinant of the development of vegetation and the differentiation of vegetation communities.

Particular relevant factors for the fauna and that are independent from the present vegetation, must also be taken into consideration (*e.g.* cliffs, presence of water, rockiness). Associated with this layer of geographical elements, other layers must be built, characterizing the dynamic processes occurring in that area: among others, hydrology, macro- and micro-climatology, erosion and sedimentation patterns.

Of particular importance is the need to ensure that all these characterization layers and databases have common descriptors as it would be the case if applied to the present landscape. Only in this way can they be compared, and evaluation procedures conducted, using this reference layer as the reference for all evaluation processes. Vegetation proved to be a very adequate "common language" to fulfill this function.

In effect it showed to be useful, in most circumstances, to include in the data describing each ERU, whenever possible, the most probable vegetation communities susceptible of naturally occurring in these units. The reason for this usefulness derives from the fact that many valuation variables are easily applied to vegetation communities (and equivalent land uses), allowing a wider set of evaluation procedures and modeling possibilities.

The second domain of characterization is the present land use, where it is critical to adopt a classification system able to represent the land uses classes, and their main characteristics such as density or structural diversity. To this purpose, it is necessary to proceed the biotope or land use cartography in such a way as to ensure an adequate inventory of their nature, value(s), stress factors, conflicts, disturbances or other particular factors affecting the characteristics or functions of the site and its use or vegetation (Ichter *et al.* 2014).

Also noteworthy in this cartographic and data sampling process, is the need to identify and map all particular elements with ecological, socio-cultural or other significance, in order to have a complete sampling, not only of the macro habitat structure, but also from microhabitats and particular elements of special cultural significance.

3. APPLICATION IN THE PICO ISLAND (AZORES)

3.1. Study area

The Azores is an isolated North Atlantic archipelago (Figure 2a), formed by nine main islands and several small islets and seamounts located along the Mid-Atlantic Ridge (Feraud *et al.*, 1980), approximately between the coordinates 37° to 40° N latitude and 25° to 31° W longitude and distributed from West-Northwest (WNW) to East-Southeast (ESE). Over 1600 km from Portuguese mainland (and 1900 km from Newfoundland), the Azorean islands (Figure 2b) extend for about 615 km and are divided into three groups:

the western group (Flores and Corvo); the central group (Faial, Pico, S. Jorge, Terceira and Graciosa); and the eastern group (S. Miguel and S. Maria, plus the Formigas islets). All islands are volcanic of recent origin, having arisen along ocean-floor fracture zones where the North American, Eurasian, and African tectonic plates meet at a triple-junction (Ferreira, 2005; Azevedo & Ferreira, 2006 Calado *et al.*, 2013). According to Azevedo & Ferreira (2006) the western group is situated entirely on the North American Plate and the other two groups are within a transition zone named Azorean micro-plate between the Eurasian and African Plates.

The Azores are the youngest archipelago in the Macaronesian region (Fernández-Palacios *et al.*, 2011). The oldest rocks in the archipelago are found on Santa Maria Island (8.12 Myr B.P.) while Pico is the youngest island of the archipelago (0.25 Myr B.P.) (Abdel-Monem *et al.* 1975; Feraud *et al.* 1980; Azevedo *et al.*, 1991; Nunes 1999; Azevedo & Ferreira, 2006).

This study was conducted in the Pico Island (Figure 2c) which is the second largest island of the archipelago with 447.74 km^2. Presents an oval shape, elongated in the E-W direction, trending along ca.42 km long and ca.15.2 km wide (maximum values) (Cancela d'Abreu *et al.*, 2005).

3.2. Building the resource information layer

The sources of information for Pico are very diversified but have important limitations in critical variables like soil and vegetation maps, as well as deficiencies in their cartographic quality.

3.2.1. Biophysical Information

Geology

The Island of Pico, through its morphology, expresses remarkably the effects of volcano-tectonic structures that are in its origin (Nunes, 1999; Madeira & Silveira, 2003; Cruz *et al.*, 2006; França *et al.*, 2006; Dias *et al.*, 2007). Three different areas can be distinguished on the island (Madeira, 1998; Nunes, 1999; Madeira & Silveira, 2003; França *et al.*, 2006; Dias *et al.*, 2007): the older volcano (Topo volcano), a central type shield volcano located in the middle-south of the island, is composed of ankaramitic and basaltic lava flows and is partially dismantled by landslides, displaced by faulting and covered by younger volcanism; an intermediate volcanostratigraphic unit, which comprises several alignments of basaltic spatter cones and related lava flows along WNW-ESE fault; and finally the youngest unit of the island is the Madalena Volcanic Complex, which can be structurally divided into two sub-units, the East fissural zone which is composed of several alignments of cinder and

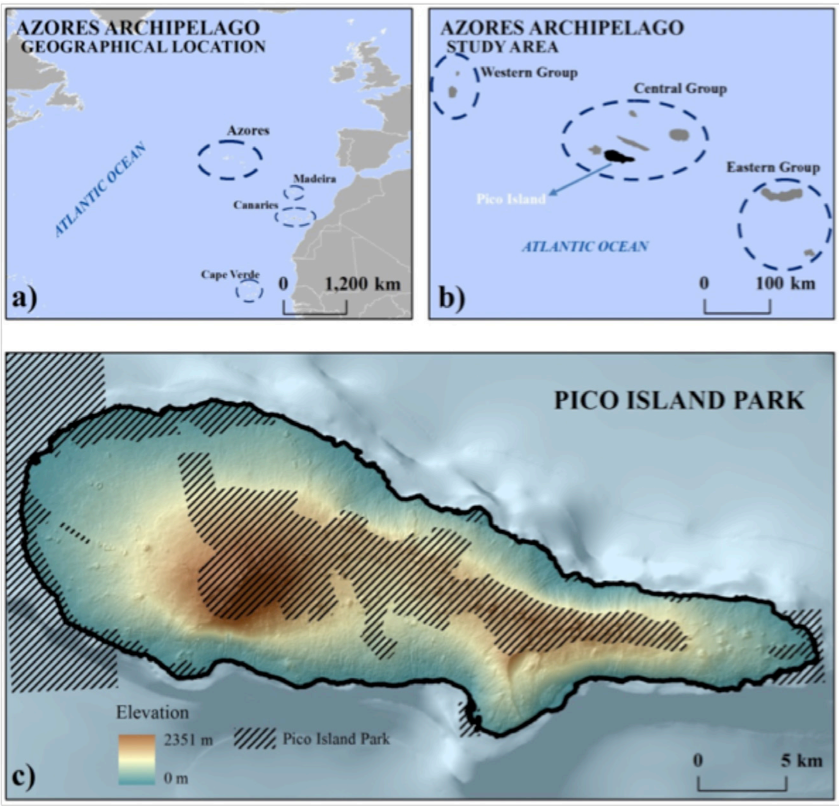

Figure 2. Study area.
Figura 2. *Área de Estudo.*

spatter cones and related lava flows, and the strato-volcano of Pico displaying a pit crater on its summit and straddling the fissural structure at its western end. Over these three units one can observe recent volcanic occurrences (1562-64, 1718 and 1720), that correspond to the different "Mistérios" formations.

Soils

Soils are generally young andisols, developed from pyroclastic materials under humid and mesic conditions (Pinheiro *et al.*, 1998; Auxtero & Madeira, 2009). Soils differ essentially on the P sorption and adsorption capacity (Auxtero *et al.*, 2007) due to the presence of colloidal constituents which have been observed in soils with andic properties (Madeira *et al.*, 2007). Given that a soil map of the Pico Island was unavailable, the Soil Quality Map (Pinheiro *et al.*, 1987) was used, presenting a classification (I to VII) of the soils suitability for agriculture and forestry, together with the indication of particular limiting factors like risk of erosion or drenching.

The analysis of the map allows us to observe the absence of soils belonging to class I and II (arable soil apt for permanent use) and only limited areas of classes III, IV and III+IV (arable soils with occasional use). Analyzing the soil maps and related data, it is possible to verify the extreme poverty of the soils of the Pico Island (only 2.2% are arable soil without limitations), and the overwhelming percentage of soils with extreme limitations and only aptitude for natural pastures or forest or that should be preserved as natural reserve because they cannot sustain any economical use (56.6 %). Considering the subclasses displaying soil limitations, it is possible to verify that 64 % present limitations for the good development of roots and 27% present erosion risks. These results show an island with a very limited potential for agriculture and only a limited potential for pasture. Due to all these limitations, the large majority of the island should be preferably reserved for natural vegetation (aggregation of classes VI and VII and their combinations).

Digital Elevation Model and derived information

The data on altimetry was used to build a Digital Elevation Model through the Topo to Raster module (ArcGIS 10™) which is based on the algorithm developed by Hutchinson (1989). This approach uses an iterative finite difference interpolation technique and it is a discretized version of thin plate splines (Wahba, 1990). Slopes were computed according to the Horn's method (Horn, 1981) and hydrologic analysis followed the eight-direction flow model (D8), presented by Jenson & Domingue (1988). The characterization of the drainage system is of critical importance for management, in particular when considering that this are the paths followed by contamination and also the watersheds that ensure the existence and evolution of lakes, ponds, wetlands and mires, as well as their possible contamination or eutrophication. Therefore, each hydrological basin that showed to be endorheic was identified as a potential area for flow accumulation, information that was later compared with the soil quality map in order to identify the wet or flooded soils, which were than combined with the previous map, in order to assess its correction. It also allowed the identification of other areas with interest in terms of preservation, improvement and restoration of wetlands and habitats associated with wet or (temporarily or permanently) drenched soils. Pico volcano is the highest altitude in the Azores (2351 m), and slopes range from 0 to 61.45º.

Climate

We used data from the CIELO model to characterize the main climatic elements (Azevedo *et al.*, 1998, 1999a, 1999b). The climate of the island is temperate oceanic with low annual temperature amplitudes, a regular rainfall distribution along the year and high relative humidity. Rainfall varies strongly with altitude from 1000 - 1900 on the lower 100m, to more than 4000 mm above 700 m. The geographical distribution of the rainfall shows a small deviation to the North. Despite its regular distribution during the year, still has some monthly variation, with maximum values in January-February and a minimum in July. Its monthly distribution shows that the winter months are the ones with the most rainfall. The indirect precipitation associated with fog and clouds is very important particularly between 180 and 700 m. There is also snowfall mainly above 2000m. Moisture is also an important characteristic averaging around 80% along the year. It tends to augment with altitude, and presents a clear influence from the morphology, which can be associated with fog and mainly with the stationary clouds between 180 and 700 m. The temperature amplitude is very small, varying in Madalena from around 13ºC-14ºC in January and February to 22ºC-23ºC in July and August, for an average year temperature of 17,4ºC. The winds blow predominantly from SW.

Flora and vegetation

From a chorological perspective, the Azores archipelago is included in the Macaronesian region (Fernández-Palacios & Andersson, 2000; Vanderpoorten *et al.*, 2007) which includes very characteristic vegetation structures with a high number of endemic *taxa* (superior to the expected for insular regions with their characteristics). It is also relevant because this is an area of refuge of wet subtropical vegetation formation *(Laurisilvae*) that built the Mediterranean basin vegetation during the Tethyan-Tertiary period (Sjögren, 2000; Dias 2001; Vargas, 2007; Rodríguez-Sánchez & Arroyo, 2008; de Nascimento *et al.*, 2009; Rodríguez-Sánchez *et al.*, 2009; Schirone *et al.*, 2010; Fernández-Palacios *et al.*, 2011; Nogué *et al.*, 2013). This fact, according to some authors (*e.g.* Sjögren, 2000), is proved by the existence of remnants of the *Laurisilvae* (like the presence of *Laurus azorica* in some areas of the littoral of Morocco and in the SW of Portugal mainland (Monchique mountain).

In Azores, 947 vascular plant species are registered, from which only 7.2 % are endemic *taxa* (Borges *et al.*, 2010). However, a large number correspond to exotic species resulting from accidental or voluntary introduction after the colonization of the islands. Since the settlement in the 15th century, vegetation has changed significantly essentially for cereal crops, pasture and forestry, being currently affected by the invasive behavior demonstrated by some of the introduced species (Furtado, 1984; Martins, 1993; Silva &

Tavares, 1997; Silva & Smith, 2006; Lourenço *et al.*, 2011; Schaefer *et al.*, 2011; Costa *et al.*, 2012; Gil *et al.*, 2013).

The Pico Island, from a phytocenotic perspective presents, in the context of the Azores archipelago, the highest plant diversity, due to its altitude (2345 m) and the small human population of the island, determining a relative low disturbance intensity. Its main vegetation types are the following (C.S. Cruz, 2013 *pers. comm.*):

- In the coastal area communities with *Euphorbia azorica, Crithmum maritimum, Juncus acutus, Festuca petreae, Cynodon dactylon, Plantago coronopus, Lotus subbiflorus. Solidago sempervirens, Campanula vidalii, Daucus carota* subsp. *maritimus, Spergularia azorica, Polypogon monspeliensis, Frankenia pulverulenta,* etc. can be found;
- In the lower altitudes up to 600-700m, forest or bush formations dominated by *Myrica faya, Erica azorica, Laurus azorica, Frangula azorica, Ilex perado* subsp. *azorica, Viburnum tinus* subsp. *subcordatum, Picconia azorica, Myrsine africana, Rubus ulmifolius, Hedera helix* subsp. *canariensis, Smilax divaricata* can be found;
- At altitudes between 500 and 1800m, forests of *Laurus azorica. Juniperus brevifolia, Frangula azorica, Daphne laureola, Euphorbia stygiana, Prunus lusitanica* subsp. *azorica, Rubus hochstetterotum, Hedera helix* subsp. *canariensis, Vaccinium cylindraceum* occur;
- Above 1700m, predominate shrub lands with *Calluna vulgaris, Daboecia azorica* and *Thymus caespititius*;
- In the water courses one can find essentially *Laurus azorica,* and *Hedera helix* subsp. *canariensis.*

3.2.2. The land use information

An updated GIS-based map is essential to aid environmental planning of future land cover of the case-study area (Santos & Gomes de Oliveira, 2013). The information on the land use of the Pico Island used was the Land Use Map (2008) produced by the University of Azores (Figure 3, Moreira, 2013).

The main features that can be observed are the very limited urban occupation, restricted almost only to the heads of the municipalities (Madalena, Lajes do Pico and São Roque) and the rest of the area is almost only occupied by pasture, natural vegetation (mainly *Erica azorica* and *Myrica*

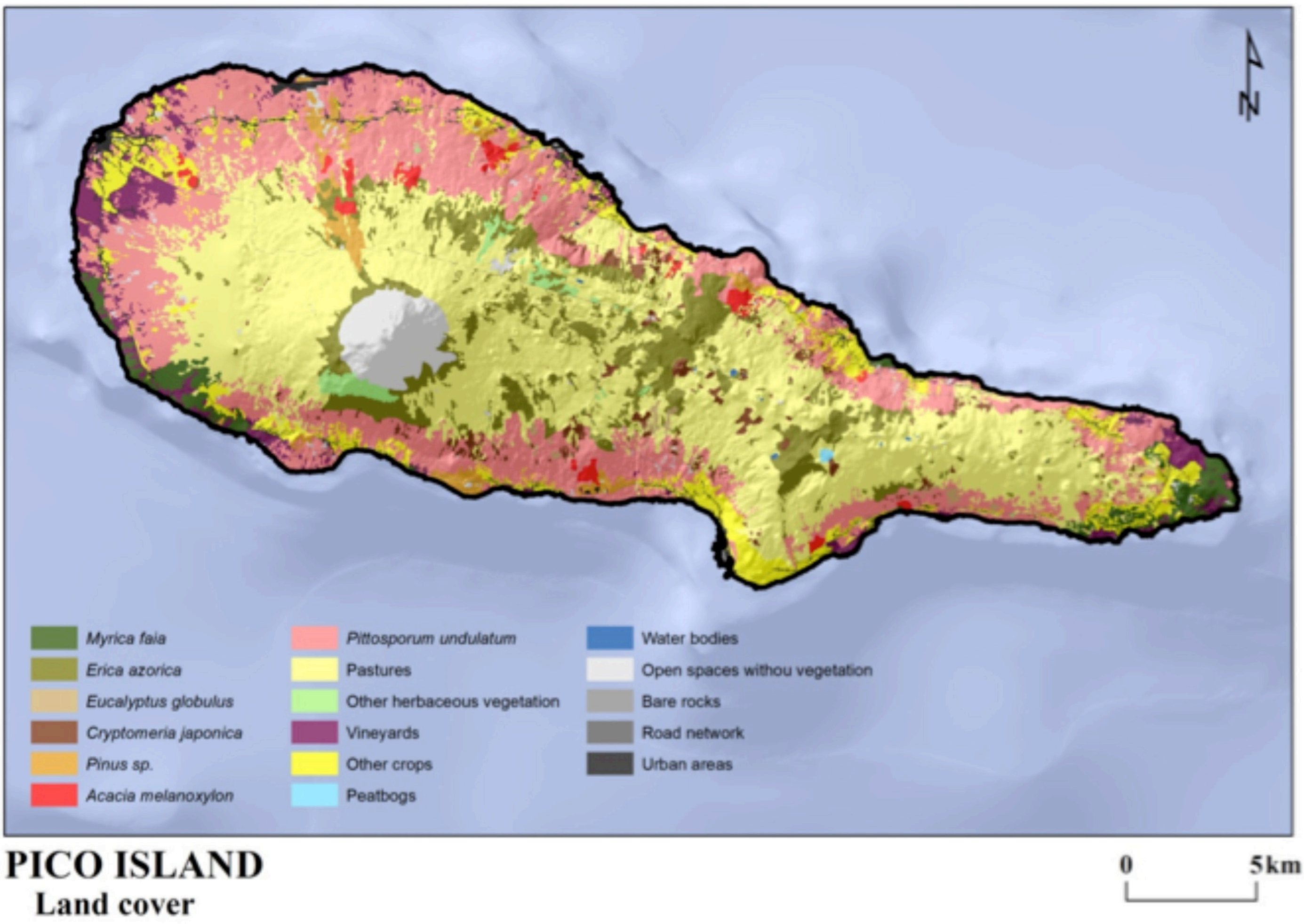

Figure 3. Land use map (2008) of Pico Island (Moreira, 2013) **.**
Figura 3. *Carta de Ocupação do solo (2008) da Ilha do Pico (Moreira, 2013).*

faya) and invading alien vegetation (mainly *Pittosporum undulatum)*, as well as areas of traditional vineyards that build the World Heritage cultural *Landscape of the Pico Island Vineyard Culture*. Most of the island presents low levels of disturbance and use intensity, except along the peripheral littoral road, with the development of 2nd residence houses and some touristic infra-structures.

The land use map uses a very limited legend mainly focused in economic activities and providing poor information on natural formations, leading, inclusively, to some misinterpretation or even errors. One example is the classification of most of the Pico Mountain as "naked soil". The class "other herbaceous and bush vegetation" is also very general and imprecise. This lack of precision derives from the fact that these maps have been mainly produced through orthophotomaps photo-interpretation and have a working scale that doesn't allow more detailed classifications. This situation limits its ability to display elements occupying small areas or situations of combined uses. For example, there are large areas classified as *Pittosporum undulatum* woodland that still have important percentages of occupation by *Myrica faya*, and present a different significance for example, for the identification of priority management areas (in this case for the control of invasive species and the recovery of the "Faial Forest").

When comparing the agricultural use (predominantly pasture) with the soil quality map, it is possible to verify that a large percentage of the agricultural activities are located in soils with none or almost no potential for that kind of land use. Further analysis on the scarce agricultural resources of the island, stresses the need for a very careful management of the apparent areas of conflict (areas with extreme limitations and potential only for natural vegetation occupied with pastures). This can be acceptable, even in areas of high erosion risks, if the pastures and mainly the grazing intensity, is managed in the sense of the protection of the soil, and the development of a more diverse mosaic with, for example, the inclusion (or restoration) of natural thickets in the most endangered or fragile areas.

Nevertheless, the areas more susceptible to erosion are mainly located around the Pico Mountain, where there are only marginal fringes of pasture and in a large area in the eastern half of the island, in areas with a limited agricultural potential (mainly only natural pasture). This is not a critical situation, because well managed livestock grazing, together with the adequate management of the pasture vegetation, can be very effective in preventing erosion (Ammer *et al.* 1986).

3.2.3. The reference information layer - Ecological reference units (ERU)

As stated above, any characterization and evaluation process needs to have a stable comprehensive reference system, to which any item can be compared and any evaluation can be referred. In the case of geographic and land use systems, the concept of land unit (Zonneveld, 1989) is used referred to the stable biophysical variables (like geology, soil, climate, morphology, position) and expressed in different ways, namely using the natural vegetation corresponding to these stable ecological characteristics.

It was therefore in this context, that the ecological reference units (ERU) were defined, considering the geological zoning of the island, the morphology, the soil potential productivity (Pico Island Soil Quality Map), the climate zoning (considering rainfall, moisture, prevailing winds, indirect precipitation associated to cloud belts), morphology, internal drainage areas and respective watersheds as well as gully-similar water courses. 87 ERU were identified (Figure 4) and their main characteristics listed in Table 2 (see Appendix 1). The selection of the thresholds for variables like rainfall, moisture, prevailing winds or elevation was made considering their importance in the occurrence of distinct types of natural vegetation (interpreted from Dias, 2001; Dias *et al.*, 2005).

These ERU build the main referential for the modeling and evaluation procedures. They try to reflect, in the best way possible, according to the available biophysical data, the main ecological characteristics occurring in the island. Their boundaries must be considered as having low precision, due to the fact that, for the definition of some boundaries, climatic isolines where used as a result of the absence, for example, of natural vegetation map, that would show more correct boundaries. Micro-habitats like small volcanic craters, wet soils, small mires, rocky areas are not necessarily represented for the same reason: low availability and poor reliability of the available information.

Given the fact that these units where built based on the combination of the above mentioned factors, expressing the classic concept of land unit first proposed by Zonneveld (1989), there is permanently the possibility, given the availability of better information, of correcting the ERU map, without invalidating the analytical process and the way the scenarios are built.

The analysis of the characteristics of the different ERU apparently points to a very diversified ecology, although, when analyzing with more detail the variation of these characteristics it is possible to conclude that generally, we have a altitudinal differentiation due to climatic variability, some variation between the northern and southern sides due to the prevailing winds and some variability associated with the geological substrata and the presence of drenched soils originating wetlands, lakes and mires.

In this context, we cannot speak of a high internal or diversity (the geology is homogeneous and the morphology relatively regular), but there is an important micro-structural diversity associated with small resource patches that, together with the altitudinal zoning, contribute to a relative high potential biodiversity.

3.3. The use of ILA in the valuation and evaluation processes

The process of valuation is critical for the scenario building and assessment procedures. Therefore, it is crucial to clarify the criteria adopted to attribute values to the different data and objects.

The context of the present study is the development of systematic conservation planning and ecosystem-based management practices in the context of small islands, ensuring the existence of open systems of governance

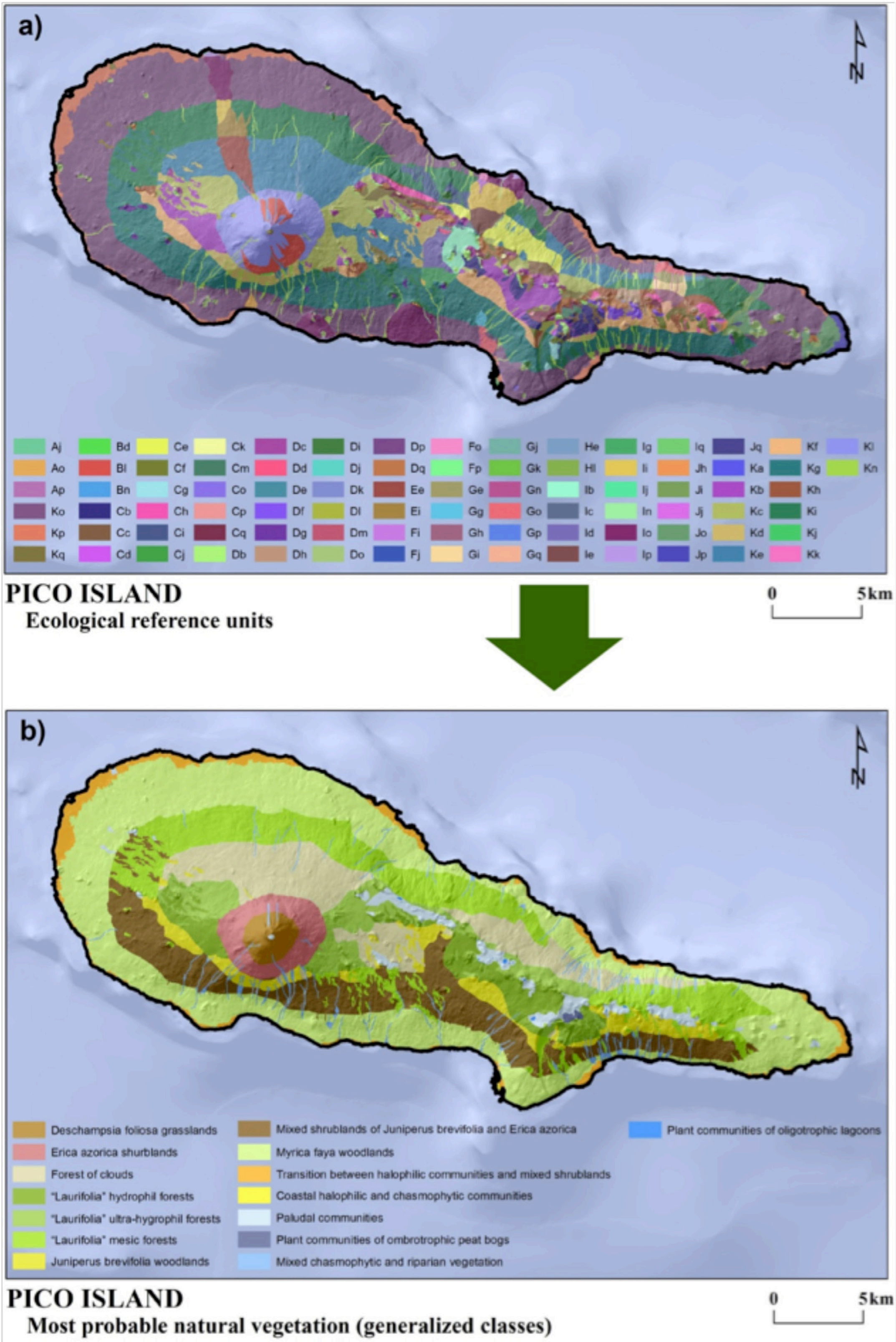

Figure 4. Ecological reference units a), and most probable natural vegetation (generalized classes from Table 2 included in Appendix 1) b).

Figure 4. *Unidades ecológicas de referência a), e vegetação natural associada mais provável (classes generalizadas a partir da Tabela 2 incluída no Apêndice 1) b).*

involving an effective participation of all stakeholders. Consequently, there are two main valuation criteria to be simultaneously considered:

- Present and potential conservation value, representing the interest for the preservation and promotion of nature, natural functionality and biodiversity value;
- Societal value, including current potential economic and welfare value.

These evaluation procedures (Figures 5 and 6) were conducted, in the case of the conservation and nature protection value, considering the following estimated qualitative characteristics of each land unit (union of land use and ERU): rarity of the vegetation communities, biodiversity (intrinsic and structural), unique character of the vegetation communities, resilience, degree of threat, and naturalness.

The estimation of the relative economic value of the present land use was performed based on a qualitative combination of the average economic value of each type of land use, corrected according to soil quality and added to the socio-cultural value perceived by the islanders. This perception is still focused in the predominant value of pasture land (main income source and additionally wine producing areas. Urban expansion for 2nd housing, although growing in importance, is still marginal in terms of income source.

Both these criteria (land productivity and subjective perception by the islanders) are not absolute as the simple consideration of the figures illustrates, showing how large are the areas occupied by pasture that have no adequate soil productivity for that land, use and that can even be degraded through erosion if the pasture management and the grazing intensity are not adequately preformed. So, considering the present land use as corresponding directly to high values when these land uses have an important economic significance, is clearly inappropriate, although it must always be taken into account that it still builds the base of subsistence for an important number of families and of the global economy of the island, and expresses the perception based on which the islanders base their benefit expectations.

In this sense, the consideration of the value of the agricultural areas or areas of potential expansion, must take into account a factor of devaluation corresponding to the situations where land productivity is too low, or the risks of land degradation associated with incorrectly managed grazing, high. Obviously, if these risks are avoided by an adequate use, an immediate revaluation of the parcel must occur.

Another example of how the context must be taken into account when attributing a value to a certain parcel for a given land use, is the case of real estate (for second housing or tourism). The first factor that must be taken into account and that is already considered in the PROTA - Regional Territorial Plan (DROTRH, 2008), are the costs of building infrastructures (namely water supply and wastewater disposal and treatment) which must be incorporated in the parcel cost, in order to avoid socialization of the cost and privatization of profits. Other important factors are, for example, the way in which a certain construction affects landscape and aesthetical values, devaluating neighbor or even far away parcels, or adding value to these parcels, situation where compensation should be in order. This process of reevaluation is of particular importance on an island with a particularly high touristic potential, based mainly in its landscape aesthetical value. Therefore, the

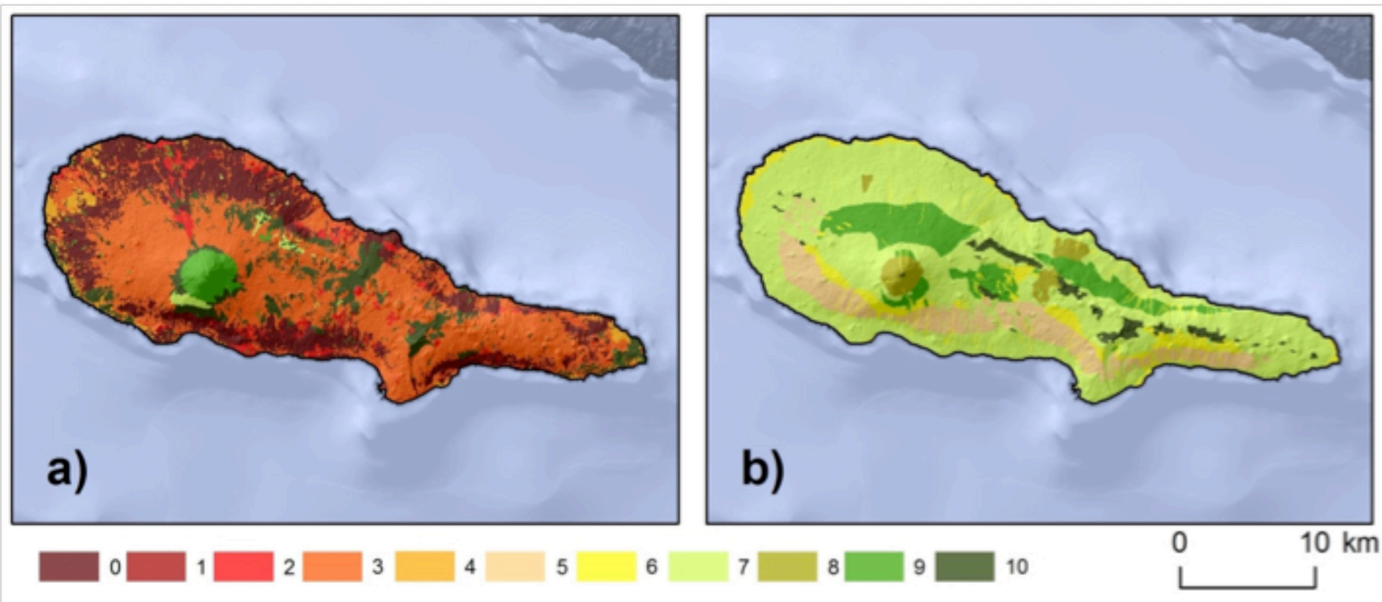

Figure 5. Qualitative estimation of the present conservation value of the present land use a), and qualitative estimation of the present conservation of the natural vegetation susceptible of occurring in the absence of disturbances b) (10 max).

Figura 5. *Estimativa qualitativa do valor de conservação do quadro actual de ocupação do solo a), e estimativa qualitativa do valor de conservação da vegetação natural susceptível de ocorrer na ausência de perturbações b) (10 max).*

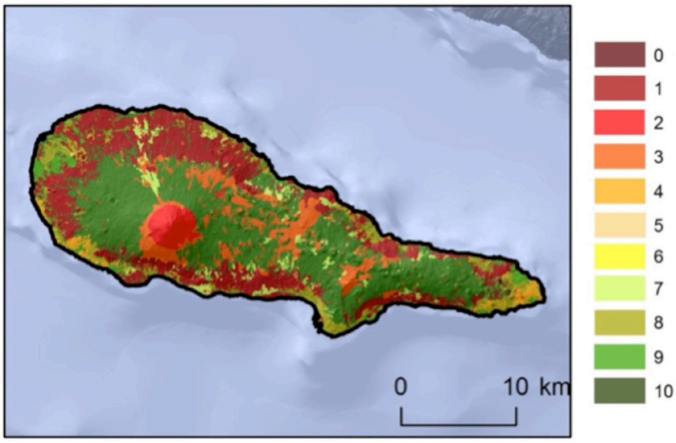

Figure 6. Qualitative estimation of the relative economic value of the present land use (10 max). Due to lack of precise information, the potential value of the coastal areas for second housing and touristic development is not included.

Figura 6. *Estimativa qualitativa do valor económico relativo do quadro actual de ocupação do solo (10 max). Devido à carência de informação mais detalhada, o valor potencial das zonas costeiras para habitação secundária e desenvolvimento turístico não foi incluído.*

global touristic development of the island, depends of an adequate management of that landscape. Given that this management is performed by others than the touristic operators, the way the entire landscape is managed must be integrated, and all land managers (mainly farmers) must be brought together and compensated for this integrated and concerted management. This process should not be solely understood as a conservation management in the sense of preserving the present landscape as it is, but that must also take into account all added value resulting from the recovery of degraded areas, areas infested by invasive alien plant species and especially, recovery of the natural vegetation.

The ERU also allow a comparison between the reference situation and the present situation allowing the identification (within the limits of the valuation criteria) of areas of value gains or losses. Figure 7 illustrates the degree of loss of Conservation Value and Protection Value, computed by associating the conservation value with the degree of threat of each formation.

It is clear to observe that the areas without value losses (negative values) correspond to natural vegetation, while areas with positive values correspond to areas strongly infested or with a completely alloctonous vegetation.

It is important to stress that the valuation of the present land use is subject to divergence in criteria. For example, the biodiversity of the *Pittosporum undulatum* areas should be considered null or very low or, should it be taken into consideration that these *Pittosporum undulatum* communities still include an important number of native species (*e.g. Myrica faya*)? This second criteria is important, in the sense that it must be taken into consideration, because the eradication of *Pittosporum undulatum* must not correspond to the total destruction of the infested areas covered by this species, but solely to the removal of the alien species and the promotion of the remaining native ones.

The valuation of the conservation value poses still other types of problems, as is the case when the present conjunctural value of one type of vegetation formation, can correspond to situations with different levels of degradation or proximity to the natural conditions. For example, some areas of *Erica azorica* can correspond to pioneer or initial stages of a re-naturalization succession, whereas in other areas, it corresponds to the natural community of that particular area. Therefore, the simple fact of having an area with *Erica azorica* cannot be equally valued, but must take into consideration different levels of value: it is a natural plant community, but on one site one must support its evolution and eventual replacement by another community, while on the other site this is the target community.

Another problem when considering the valuation of conservation variables is their conservation status. There are different forms of classification of conservation value:

- Belonging to the Natura 2000 Network, where the quality and boundaries result from the present values existing in that area;
- Belonging to any of the conservation figures included in the Natural Park, where the boundaries were defined with nature conservation political considerations, that do not correspond necessarily with existing potential values (nevertheless one must take into account that all Natura 2000 areas are integrated in the Natural Park, what does not invalidate the different criteria for boundary definition and value assessment).
- A third type of conservation area could be eventually added, corresponding to areas fulfilling the NATURE 2000 criteria, but occupying small areas that didn't allow it's classification at the European level, but could be implemented at the island level.

While the first case (and third hypothetical case) represents an existing value and an obligation to preserve and promote it, the second case does not correspond necessarily to high value areas or represent all potential value areas. It constitutes primarily an administrative instrument aimed at the protection and promotion of conservation values.

In this context, the value associated with the conservation status must be primarily based in the existence of the value, and take into consideration the eventuality that many micro- or meso-structures or objects, do not fulfill the scale conditions of the Natura 2000 classification and are not included, without losing their conservation status of objects corresponding to the Natura 2000 value criteria (third type of areas).

The administrative status (belonging to a protected area) is presently more relevant when valuing a parcel for a given use, due to the very strong use restrictions associated with this protected status, assuming more a societal and economical character than an ecological one.

Another criterion for valuing the conservation aspects is the use of the ERU. The ERU try to portray, as best as the available information allows, the existing and potential resources, allowing an evaluation, for example, of aspects like the naturalness of a given vegetation community (if it corresponds to the ecological characteristics of that site

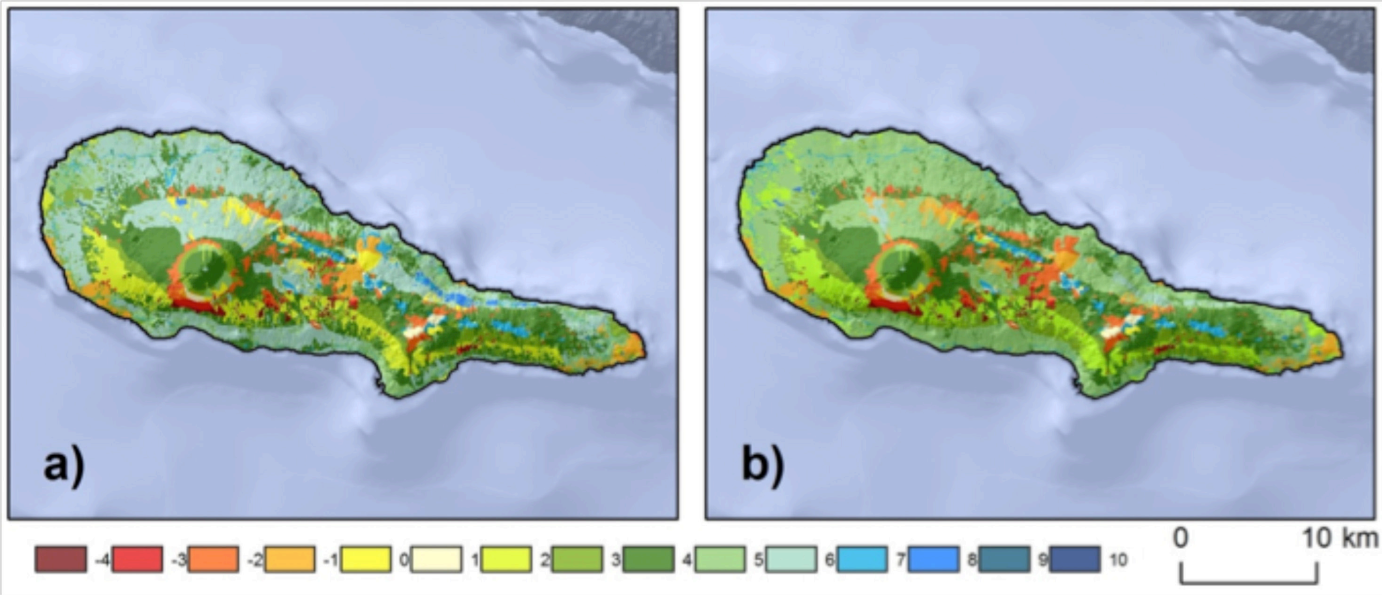

Figure 7. Difference in the conservation value (considering rarity, biodiversity, unique character and naturalness) a); and difference in the protection value (considering the conservation value and the degree of threat) b) between the reference situation and the present land use.
Figura 7. *Diferenças do valor de conservação (considerando a raridade, biodiversidade, carácter único e naturalidade a) e diferenças do valor de protecção (considerando o valor de conservação e o grau de ameaça) b) entre a situação de referência e o quadro actual de ocupação do solo.*

or if it results from any type of disturbance) or its stability according to the deviation degree between the present ecological situation and the situation corresponding to the local stable resources. This last condition is, for example, very significant on the valuation of existing conservation values because it gives an indication on their viability and probable evolution.

The question of being able to identify the viability of an existing value is critical for any conservation policy, because it allows the distinction between values with little maintenance needs (only protection from eventual disturbances), and values whose existence depend on given disturbances, implying the need to evaluate if it is better to invest in that disturbance of a certain value, or invest in the restoration of that value on an adequate site with the adequate resources.

It was therefore in this context, that the valuing process conducted in the scenarios developed in the frame of this research was based on the ILA approach, where there is a clear distinction between what corresponds to the stable resource layer of characterization and what are the conjunctural layers (present land use and management scenarios).

Similar criteria where used to evaluate both layers, when considering, for example, the plant cover (*e.g.* structural and floristic diversity, rarity of the vegetation communities, naturalness of the formation and resilience), the soil resources (soil agricultural aptitude and risk factors), geology and dynamic processes (runoff, erosion, etc.). This allows the development of the same evaluation procedures to different management scenarios and their comparison in relation to the resources layer (the ERU).

One last remark concerning the valuation process is the development of methods and instruments for a systematic conservation planning and ecosystem-based management in a context of efficient governance. Therefore, the attribution of values has always taken into account this combination of targets, implying that every scenario or evaluation procedure must be soundly explained in terms of the valuing criteria and evaluation perspective applied in that particular case. Also of particular importance is the need to ensure that the process of definition of the valuation criteria is as integrated as possible.

3.4. The use of the ILA framework in scenario building and evaluation

This integration is a *sine qua non* condition for governance, in the sense that it is precisely at this level of attribution of value that the different actors and stakeholders must actively participate. In the context of an island where the value attributed to an object can derive from familiar or social factors established centuries ago and strongly preserved by the isolation (or insularity) assuming a character that outside that context is difficult to understand, this effective involvement is of primary importance.

From the knowledge and consideration of these values, and their integration in the different evaluation and simulation models, depends strongly the success of any systematic conservation planning, aiming at an ecosystem based management integrated in the sustainable development of the island and the quality of living of their inhabitants. As an illustration of the way this process can be conducted, two scenarios were tested, corresponding to the following value factors (Table 1).

In a way to implement systematic conservation planning techniques we used CLUZ (Conservation Land-Use Zoning,

Table 1. Scenarios considered in the modeling and evaluation processes.
Tabela 1. *Cenários considerados nos processos de modelação e avaliação.*

Scenario	Value factors
1 - Identifying management strategies: investment in restoration, preserving areas of economic significance	Maximization of potential natural formations, conservation value and preservation of the economic value of the main economic activities
2 - Identifying management strategies: investment in restoration, preserving areas of economic significance, considering the different soil aptitudes and the need to safeguard given habitats	Maximization of potential natural formations, conservation value and preservation of the economic value of the main economic activities, introducing a factor of correction of the economic value associated with soil quality and promoting the conservation value of areas associated with wetlands

Smith, 2004) and Marxan (Ball *et al.,* 2009) softwares. In addition to other capabilities, CLUZ is an ArcView GIS interface which acts as a link for the Marxan conservation planning software, and it was in that sense that it was used is this study. Marxan was originally conceived to solve a specific problem referred to as “the minimum set problem”, in order to get some minimum representation of biodiversity resources for the lowest possible cost (Possingham *el al.*, 2006). Marxan uses the simulated annealing algorithm, which is a local search algorithm (meta-heuristic) for global optimization problems (Henderson *et al.*, 2003). The spatial optimization process built into Marxan, selects an optimal network of conservation sites that achieves conservation goals, minimizing a set of costs, by estimating, for each planning unit, the external design constraints and thus avoiding costly planning units (Lagrabrielle *et al.*, 2010). For this study, planning units consist of a regular mesh of hexagons, making it easier to combine several types of cost values and better suited for the identification of planning units. The hexagons have an area of 5 ha, which is a spatial resolution that adapts well with the conservation features and cost data used.

The portfolio of costs combines three different costs:

- Combined planning unit cost: It is assigned to each planning unit a cost value, based on its area, financial value, the opportunity cost of it being protected (*e.g.* lost income from farming) or any other relevant factor. Marxan calculates the combined cost of all the planning units in the portfolio.
- Boundary cost: Measures the amount of edge that the planning units in a portfolio share with unprotected units. Thus, a portfolio containing one connected patch of units will have a lower boundary cost than a number of scattered, unconnected units. The length of edge is multiplied by the “boundary length modifier” constant, which is a user-defined number. Increasing the BLM increases the cost of having a fragmented portfolio.
- Species penalty factor (or target penalty cost): It calculates whether the target for each conservation feature is met by a portfolio and includes a cost for any target that has not been met.

Two scenarios were considered. In the first scenario we considered the investment in restoration, preserving areas of economic significance. The scenario was developed considering that the cost corresponded to the conceptual distance between the present vegetation and ecological conditions, and the conditions susceptible of occurring when that area has suffered no disturbances. This cost tries to express the effort needed to achieve the restoration of that vegetation and ecosystems.

As target, two different types of areas were considered: for these areas with low economic value the target was defined as being the difference between the protection value of the ERU and the conservation value of that particular use. For the land uses with a high social value the target considered was the conservation value calculated for that use. The result illustrates a clear differentiation between two types of areas: those clearly targeted as conservation management areas and those where the present land use is considered as having priority over the restoration of the natural vegetation.

Analyzing these results, the relevance of the protection of agricultural areas and the maintenance of the already identified existing values is clear, but they also point to the importance of managing (recover) the areas presently occupied by invasive species and forestation with alien species. This scenario points, therefore, to two types of target management areas: areas already with high conservation value and areas with a land cover of no or with negative ecological value, aiming at the restoration on these areas of the corresponding natural vegetation. Nevertheless, the fact that the target value for the areas with predominant economic value was maintained high, implied that, very important habitats (particularly habitats associated with wetlands) were not included in the target management areas.

In terms of building a management plan, this is not necessarily negative, because these areas are already identified as target areas and because they demand a particular type of management that, although not incompatible with grazing and pastures, implies particular attention to the prevention of the eutrophication of the sink areas, eventually compromising the potential vegetation communities.

In the second scenario we considered the investment in restoration, preserving areas of economic significance considering the different soil aptitudes and the need to safeguard given habitats. This essay was carried out integrating a correction of the societal cost through the consideration of the soil aptitude. This was achieved considering that the agricultural areas (pasture, vineyards and other cultures) presented an higher cost if they occupied soils of high quality and a lower one if they occupied soils of low quality, with the exception of the vineyards due to their particularity (cultural landscape of intense work, creating the conditions for vine growth in low quality soils - *World Heritage of the Pico Vineyards*). The cost for the target habitats corresponded to their Protection Value, while as target the Conservation Value was still the selected criteria.

The results allow us to observe that the main targets resulting from this scenario correspond to the recovery of the *Laurisilvae* forest and the protection of the wet areas. Again, as already stressed, the valuation of the different types of potential natural vegetation is subjective and can, if altered, lead to somewhat different results. For example, we can clearly observe that the lower value attributed to the scrubland mosaic of *Erica azorica* and *Juniperus brevifolia* compared with the high value for *Laurisilvae* clearly determined the higher importance attributed to the northern side of the Mountain and the Achada Plateau.

Combining these two scenarios different target management areas (Figure 8) were obtained with the following characteristics and management targets:

- Protection of the Pico Mountain, the existing formations of *Myrica faya* and *Erica azorica* (scenario 1);
- Protection and/or recovery of the cloud forest and the different wet lands, expanded to all drenched areas (scenario 2);
- Wetlands and protection and/or recovery of *Erica azorica* communities located in the slope deposits of the Pico Mountain (maximum priority for scenarios 1 and 2 combined);
- As a complementary proprietary management area we must consider the recovery of the areas infested by *Pittosporum undulatum*;
- The coastal escarpments are also included due to their particular character and sensitivity.

These examples illustrate the way this approach can define management targets and areas for the ensemble of the island based on the integrated landscape characterization system, and using existing and tested methods for the evaluation of areas with more priority for conservation management (like the Marxan approach). These results can be still developed, complementing the Target Management Areas with habitats occupying small patches, where particular values (not only floristic) can occur, and demand, therefore, a multifaceted targeted management approach. These patches are associated with small volcanic formation, wet areas, springs, lakes, deposits and particular geological characteristics.

4. CONCLUSIONS

The use of the ILA framework, by allowing the possibility of comparison between the present situation values and constraints, with a stable reference situation, corresponding to the existing stable natural resources, illustrates clearly the management challenges faced in Pico or any other small island.

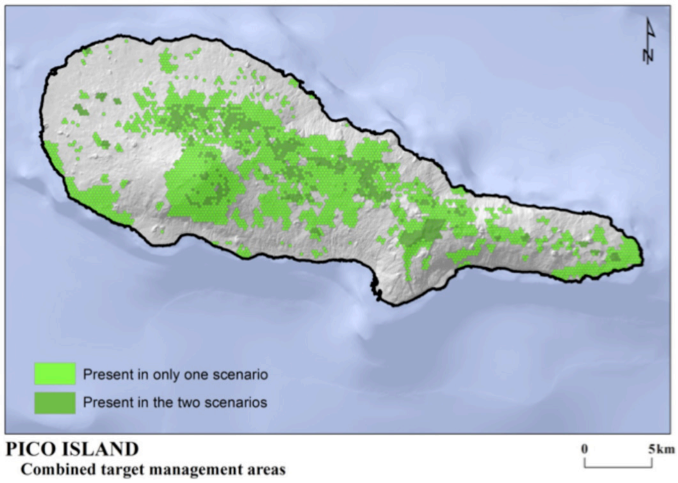

Figure 8. Combined target management areas resulting from scenarios 1 and 2.
Figura 8. *Áreas de gestão prioritárias de acordo com os resultados dos cenários 1 e 2.*

The scarcity of resources (economical and biogenetical) imposes that the attribution of values must be done according to a multi-dimensional and multi-criteria approach. This is the only way to enable comparative evaluations and decision making within a sound ecosystem-based management aimed at a systematic conservation in the frame of an efficient and functional territorial governance. It also illustrates the need for methodological approaches able to display and evaluate management scenarios in order to fulfill the conditions that Davoudi *et al.* (2008) consider necessary "to describe, analyze and evaluate territorial governance actions":

- Context: to describe the general structural conditions, features and dynamics of the territory. Describing the favorable territorial preconditions for defining and implementing territorial governance actions (institutional thickness, innovative milieu, territorial capital, etc.);
- Policies: to describe the institutional frameworks of territorial policies, instruments and procedures for governance (i.e. the "governing" of governance);
- Territorial governance actions, defined as the experiences, projects, programs, etc., that need or stimulate a territorial governance approach: to evaluate governance processes and results, at different levels, considering both process criteria and results criteria, and their interaction (does a good process always correspond to a good result?).

Obviously, the presented approach is not the only system of characterization and diagnosis (there were no economic, social and cultural data incorporated and considered in the presented essay with the exception of land use). Nevertheless, the methodological framework proved to be a powerful consolidated tool in the evaluation of strengths, weaknesses, opportunities and threats of the biophysical systems and the land use systems, in regard to the natural resources and constraints, and mainly in depicting and justifying these values. These last characteristic is critical for the full involvement of all stakeholders in the governance process.

ACKNOWLEDGMENTS

This project was developed in the frame of the SMARTPARKS project funded by the Fundação de Ciências e Tecnologia (Portugal) (project PTDC/AAC-AMB/098786/2008). This research paper was partially developed on the behalf of a Post-Doctoral Research Project (M3.1.7/F/005/2011) lead by A. Gil and supported by the FRC - Regional Fund for Science (Azorean Regional Government).

REFERENCES

Abdel-Monem, A.; Fernandez, L.A.; Boon, G.A. (1975) – K-Ar ages from the eastern Azores group (Santa Maria, S. Miguel and the Formigas Islands). *Lithos*, 8:247-254. DOI: 10.1016/0024-4937(75)90008-0

Ammer, U.; Pröbstl, U.; Mössmer, E.-M. (1986) – Erosion auf Almen. Ein Beitrag zu aktuellen Fragen des Bodenschutzes. *Forstwissenschaftliches Centralblatt*, 105(1):48-59. DOI: 10.1007/BF02741696

Auxtero, E.; Madeira, M. (2009) – Phosphorus desorbability in soils with andic properties from the Azores, Portugal. *Revista de Ciências Agrárias* (ISSN 0871-018X), 32(1):423-433, Lisboa, Portugal. Avalilable at http://www.scielo.oces.mctes.pt/pdf/rca/v32n1/v32n1a37.pdf

Auxtero, E.; Madeira, M.; Sousa, E. (2007) – Predicting the degree of P saturation of selected Andisols from the Azores (Portugal) by the acidified ammonium oxalate and the Mehlich 3 methods. *Revista de Ciências Agrárias* (ISSN 0871-018X), 30(2): 314-325, Lisboa, Portugal. Avalilable at http://www.scielo.oces.mctes.pt/pdf/rca/v30n2/v30n2a23.pdf

Azevedo, J.M.M.; Ferreira, M.R.P. (2006) – The volcanotectonic evolution of Flores Island, Azores (Portugal). *Journal of Volcanology and Geothermal Research*, 156:90-102. DOI: 10.1016/j.jvolgeores.2006.03.011

Azevedo, J.M.M.; Ferreira, M.P.; Martins, J.A. (1991) – The emergent volcanism of Flores Island, Azores, (Portugal). *Arquipélago* (ISSN 0870-6581), 9:37-46, Ponta Delgada, Portugal. Available at http://www.horta.uac.pt/intradop/images/stories/arquipelago/9/Cap5_AZEVEDO-JMM.pdf

Azevedo, E.B.; Pereira, L.S.; Itier, B. (1998) – Modelling the local climate in islands environments. Orographic clouds cover. *In*: Schemenauer, R.S.; Bridgman, H. (eds.), *First International Conference on Fog and Fog Collection*, pp.433-443. IDRC, Ottawa. ISBN: 0968388701.

Azevedo, E.B.; Pereira, L.S.; Itier, B. (1999a) – Simulation of local climate in islands environments using a GIS integrated model. *In*: Musy, A.; Pereira, L.S.; Fritsch, M. (eds.), *Emerging technologies for sustainable land use and water management*. PPUR, Lausanne. ISBN: 2880744385.

Azevedo, E.B.; Pereira, L.S.; Itier, B. (1999b) – Modelling the local climate in islands environments: water balance applications. *Agricultural Water Management*, 40(2-3):393-403. DOI: 10.1016/S0378-3774(99)00012-8

Ball, I.R.; Possingham, H.P.; Watts, M. (2009) – Marxan and relatives: software for spatial conservation prioritization. *In*: Moilanen, A.; Wilson, K.A.; Possingham, H.P. (eds.), *Spatial conservation prioritization: Quantitative methods and computational tools*, pp.185-195, Oxford University Press, Oxford, U.K. ISBN: 0199547777.

Bastos, R.; Santos, M.; Ramos, J.A.; Vicente, J.; Guerra, C.; Alonso, J.; Honrado, J.; Ceia, R.S.; Timoteo, S.; Cabral, J.A. (2012) – Testing a novel spatially-explicit dynamic modelling approach in the scope of the laurel forest management for the endangered Azores bullfinch (Pyrrhula murina) conservation. *Biological Conservation*, 147(1):243-254. DOI: 10.1016/j.biocon.2012.01.009

Borges, P.A.V.; Gabriel, R.; Arroz, A.; Costa, A.; Cunha, R.; Silva, L.; Mendonça, E.; Martins, A.F.; Reis, F.; Cardoso, P. (2010) – The Azorean Biodiversity Portal: an internet database for regional biodiversity outreach. *Systematics and Biodiversity*, 8(4):423-434. DOI: 10.1080/14772000.2010.514306

Borges, P.A.; Hortal, J. (2009) – Time, area and isolation: factors driving the diversification of Azorean arthropods. *Journal of Biogeography*, 36(1):178-191. DOI: 10.1111/j.1365-2699.2008.01980.x

Borges, P.A.; Serrano, A.R.; Quartau, J.A. (2000) – Ranking the Azorean natural forest reserves for conservation using their endemic arthropods. *Journal of Insect Conservation*, 4(2):129-147. DOI: 10.1023/A:1009629012205

Bryan, B.A.; Crossman, N.D.; King, D.; Meyer, W.S. (2011) – Landscape futures analysis: Assessing the impacts of environmental targets under alternative spatial policy options and future scenarios. *Environmental Modelling & Software*, 26(1):83-91. DOI: 10.1016/j.envsoft.2010.03.034

Bui, E.N. (2013) – Soil salinity: A neglected factor in plant ecology and biogeography. *Journal of Arid Environments*, 92:14-25. DOI: 10.1016/j.jaridenv.2012.12.014

Calado, H.; Braga, A.; Moniz, F.; Gil, A.; Vergílio, M. (2013) – Spatial planning and resource use in the Azores. *Mitigation and Adaptation Strategies for Global Change*, Published Online in November 2013. DOI: 10.1007/s11027-013-9519-2

Cancela d'Abreu, A.; Moreira, J.M.; Oliveira, M.R. (Coord.) (2005) – *Livro das paisagens dos Açores: contributos para a identificação e caracterização das paisagens dos Açores*. SRAM/DROTRH, Ponta Delgada. ISBN: 989-2000056.

Capelo, J. (Ed.) (2004) – A paisagem vegetal da Ilha da Madeira. *Quercetea* (ISSN 0874-5250), 6:3-200, Lisboa, Portugal.

Castellazzi, M.S.; Matthews, J.; Angevin, F.; Sausse, C.; Wood, G.A.; Burgess, P.J.; Brown, I.; Conrad, K.F.; Perry, J.N. (2010) – Simulation scenarios of spatio-temporal arrangement of crops at the landscape scale. *Environmental Modelling & Software*, 25(12):1881-1889. DOI: 10.1016/j.envsoft.2010.04.006

Cienciala, E.; Centeio, A.; Blazek, P.; Soares, M.C.G.; Russ, R. (2013) – Estimation of stem and tree level biomass models for Prosopis juliflora/pallid applicable to multi-stemmed tree species. *Trees*, 27(4):1061-1070. DOI: 10.1007/s00468-013-0857-1

Connor, S.E.; van Leeuwen, J.F.N.; Rittenour, T.M.; van der Knaap, W.O.; Ammann, B.; Björck, S. (2012) – The ecological impact of oceanic island colonization – a palaeoecological perspective from the Azores. *Journal of Biogeography*, 39(6):1007-1023. DOI: 10.1111/j.1365-2699.2011.02671.x

Costa, H.; Aranda, S.C.; Lourenco, P.; Medeiros, V.; Azevedo, E.B.; Silva, L. (2012) – Predicting successful replacement of forest invaders by native species using species distribution models: The case of Pittosporum undulatum and Morella faya in the Azores. *Forest Ecology and Management*, 279:90-96. DOI: 10.1016/j.foreco.2012.05.022

Costa, H.; Bettencourt, M.J.; Silva, C.M.N.; Teodósio, J.; Gil, A.; Silva, L. (2013) – Invasive alien plants in the Azorean protected areas: invasion status and mitigation actions. *In*: Foxcroft, L.C.; Richardson, D.M.; Pyšek, P.; Genovesi, P. (eds.), *Plant invasions in protected areas*, pp.375-394, Springer, Dordrecht, Germany. DOI: 10.1007/978-94-007-7750-7_17

Cruz, C.S. (1994) – Considerações relativas à zonagem fitoecológica do Arquipélago da Madeira. *In*: Pinto-Gomes, C. (ed.), *Actas do I Colóquio Internacional de Ecologia da Vegetação*, pp.91-113, Universidade de Évora, Évora, Portugal.

Cruz, J.V.; Antunes, P.; Amaral, C.; França, Z.; Nunes, J.C. (2006) – Volcanic lakes of the Azores archipelago (Portugal): Geological setting and geochemical characterization. *Journal of Volcanology and Geothermal Research*, 156(1-2):135-157. DOI: 10.1016/j.jvolgeores.2006.03.008

Davoudi, S.; Evans, N.; Governa, F.; Santangelo, M. (2008) – Territorial governance in the making. Approaches, methodologies, practices. *Boletín de la A.G.E.* (ISSN 0212-9426), 46:33-52, Madrid, Spain. Available at http://dialnet.unirioja.es/descarga/articulo/2686504/1.pdf

de Nascimento, L.; Willis, K.J.; Fernández-Palacios, J.M.; Criado, C.; Whittaker, R.J. (2009) – The long-term ecology of the lost forests of La Laguna, Tenerife (Canary Islands). *Journal of Biogeography*, 36(3):499-514. DOI: 10.1111/j.1365-2699.2008.02012.x

del-Arco, M.J.; Wildpret, W.; Pérez-de-Paz, P.L.; Rodríguez-Delgado, O.; Acebes, J.R.; García-Gallo, A.; Martín, V.E.; Reyes-Betancourt, J.A.; Salas, M.; Bermejo, J.A.; González, R.; Cabrera, M.V.; García, S. (2006) – *Mapa de vegetación de Canarias*. Grafcan Ediciones, Santa Cruz de Tenerife, Spain. ISBN: 8461138112

del-Arco, M.J.; Rodríguez-Delgado, O.; Acebes, J.R.; García-Gallo, A.; Pérez-de-Paz, P.L.; González-Mancebo, J.M.; González-González, R.; Garzón-Machado, V. (2009) – Bioclimatology and climatophilous vegetation of Gomera (Canary Islands). *Annales Botanici Fennici* (ISSN 0003-3847), 46:161-191, Helsinki, Finland. Available at http://www.sekj.org/PDF/anb46-free/anb46-161.pdf

Dias, E. (2001) – *Ecologia e classificação da vegetação natural dos Açores*. Cadernos *de Botânica* 3, Angra do Heroísmo. http://www.angra.uac.pt/GEVA/WEBGEVA/Publicacoes/phd/PhD.htm

Dias, E.; Mendes, C.; Melo, C.; Pereira, D.; Elias, R. (2005) – Azores central islands vegetation and flora field guide. *Quercetea* (ISSN 0874-5250), 7:123-173, Lisboa, Portugal.

Dias, N.A.; Matias, L.; Lourenço, N.; Madeira, J.; Carrilho, F.; Gaspar, J.L. (2007) – Crustal seismic velocity structure near Faial and Pico Islands (AZORES), from local earthquake tomography. *Tectonophysics*, 445(3-4):301-317. DOI: 10.1016/j.tecto.2007.09.001

Diniz, A.C.; Matos, G.C. (1986) – Carta da zonagem agro-ecológica e da vegetação de Cabo Verde. I Ilha de Santiago. *Garcia de Orta. Série de Botânica* (ISSN 0379-9506), 8(1-2):39-82, Lisboa, Portugal.

Diniz, A.C.; Matos, G.C. (1999) – Carta da zonagem agro-ecológica e da vegetação de Cabo Verde. X Ilha de Santo Antão. *Garcia de Orta. Série de Botânica* (ISSN 0379-9506), 14(2):1:34, Lisboa, Portugal.

Diniz, A.C.; Matos, G.C. (1998) – *Zonagem agro-ecológica de Angola (estudo cobrindo 200000 km^2 do território)*. Instituto de Cooperação Portuguesa, Lisboa. ISSN: 0379-9506

Dorman, M.; Svoray, T.; Perevolotsky, A. (2013) – Homogenization in forest performance across an environmental gradient - The interplay between rainfall and topographic aspect. *Forest Ecology and Management*, 310:256-266. DOI: 10.1016/j.foreco.2013.08.026

DROTRH (2008) – *PROTA: Plano Regional de Ordenamento do Território da Região Autónoma dos Açores*. Direcção Regional de Ordenamento do Território e dos Recursos Hídricos, Secretaria Regional do Ambiente e do Mar, Governo Regional do Açores. Ponta Delgada.

Duarte, M.C.; Rego, F.; Romeiras, M.M.; Moreira, I. (2008) – Plant species richness in the Cape Verde Islands – Eco-geographical determinants. *Biodiversity & Conservation*, 17(3):453-466. DOI: 10.1007/s10531-007-9226-y

Etherington, T.R.; Holland, E.P. (2013) – Least-cost path length versus accumulated-cost as connectivity measures. *Landscape Ecology*, 28(7):1223-1229. DOI: 10.1007/s10980-013-9880-2

Feraud, G.; Kaneoka, I.; Allègre, C.J. (1980) – K/Ar ages and stress pattern in the Azores: geodynamic implications. *Earth and Planetary Science Letters*, 46(2):275-286. DOI: 10.1016/0012-821X(80)90013-8

Fernandes, J.P. (1993) – ECOGIS/ECOSAD: a methodology for the biophysical environmental assessment within the planning process. *Computers, Environment and Urban Systems*, 17(4):347-354. DOI: 10.1016/0198-9715(93)90031-Y

Fernandes, J.P. (2000a) – Landscape ecology and conservation management - evaluation of alternatives in a highway EIA process. *Environmental Impact Assessment Review*, 20(6):665-680. DOI: 10.1016/S0195-9255(00)00060-3

Fernandes, J.P. (2000b) – Data type and scale effects on an EIA process – context versus object approach: a case study of the evaluation of the impacts of the A2 road in southern Portugal on the Iberian Lynx. *Journal of Environmental Assessment Policy and Management*, 2(1):19-41. DOI: 10.1142/S1464333200000047

Fernandes, J.P.; Guiomar, N.; Soares, A.S. (2006) – Geometries in landscape ecology. *Journal of Mediterranean Ecology* (ISSN 1388-7904), 7(1-4):3-13, Urbino, Italy. Available at http://www.jmecology.com/%5Cpdf%5C2006%5CFernandes3-13.pdf

Fernández-Palacios, J.M.; Andersson, C. (2000) – Geographical determinants of the biological richness in the Macaronesian region. *Acta Phytogeographica Suecica* (ISSN 0084-5914), 85:41-50, Sweden. Available at http://jmferpal.webs.ull.es/other_scientific_papers_files/APSuecica2000.pdf

Fernández-Palacios, J.M.; de Nascimento, L.; Otto, R.; Delgado, J.D.; García-del-Rey, E.; Arévalo, J.R.; Whittaker, R.J. (2011) – A reconstruction of Palaeo-Macaronesia, with particular reference to the long-term biogeography of the Atlantic island laurel forests. *Journal of Biogeography*, 38(2):226-246. DOI: 10.1111/j.1365-2699.2010.02427.x

Ferreira, A.B. (2005) – Geodinâmica e perigosidade natural nas ilhas dos Açores. *Finisterra* (ISSN 0430-5027), 40:103-120, Lisboa, Portugal. Avalilable at http://www.ceg.ul.pt/finisterra/numeros/2005-79/79_09.pdf

Flather, C.H.; Hayward, G.D.; Beissinger, S.R.; Stephens, P.A. (2011) – Minimum viable populations: is there a 'magic number' for conservation practitioners? *Trends in Ecology & Evolution*, 26(6):307-316. DOI: 10.1016/j.tree.2011.03.001

Fonseca, G.A.B.; Mittermeier, R.A.; Mittermeier, C.G. (2006) – *Conservation of Island biodiversity: importance, challenges and opportunities*. 16p., Conservation International, Washington DC.

França, Z.T.M.; Tassinari, C.C.G.; Cruz, J.V.; Aparicio, A.Y.; Araña, V.; Rodrigues, B.N. (2006) – Petrology, geochemistry and Sr–Nd–Pb isotopes of the volcanic rocks from Pico Island-Azores (Portugal). *Journal of Volcanology and Geothermal Research*, 156(1-2):71-89. DOI: 10.1016/j.jvolgeores.2006.03.013

Furtado, D.S. (1984) – Status e distribuição das plantas vasculares endémicas dos Açores. *Arquipélago* (ISSN 0870-6581), 5:197-209, Ponta Delgada, Portugal. Available at https://repositorio.uac.pt/bitstream/10400.3/949/1/Status%20e%20distribui%C3%A7%C3%A3o%20das%20plantas%20vasculares%20end%C3%A9micas%20dos%20A%C3%A7ores.pdf

Gil, A.; Calado, H.; Bentz, J. (2011a) – Public participation in municipal transport planning processes – The case of the sustainable mobility plan of Ponta Delgada, Azores, Portugal. *Journal of Transport Geography*, 19(6):1309-1319. DOI: 10.1016/j.jtrangeo.2011.06.010

Gil, A.; Calado, H.; Costa, L.T.; Bentz, J.; Fonseca, C.; Lobo, A.; Vergilio, M.; Benedicto, J. (2011b) – A methodological proposal for the development of Natura 2000 sites management plans. *Journal of Coastal Research* (ISSN 0749-0208), SI64:1326-1330, Szczecin, Poland. Available at http://www.eurosite.org/files/SP64_1326-1330_A.Gil_.pdf

Gil, A.; Lobo, A.; Abadi, M.; Silva, L.; Calado, H. (2013) – Mapping invasive woody plants in Azores protected areas by using very high-resolution multispectral imagery. *European Journal of Remote Sensing*, 46:289-304. DOI: 10.5721/EuJRS20134616

Gilpin, M.E.; Soulé, M.E. (1986) – Minimum viable populations: processes of species extinction. Conservation biology: the science of scarcity and diversity. *In*: Soulé, M.E. (ed.), *Conservation biology: the science of scarcity and diversity*, pp.19-34, Sinauer Associates, Massachusetts. ISBN: 0878937951.

Henderson, D.; Jacobson, S.H.; Johnson, A.W. (2003) – The theory and practice of simulated annealing. *In*: Glover, F.; Kochenberger, G.A. (eds.), *Handbook of metaheuristics*, pp.287-319, Kluwer Academic Publishers, Dordrecht. DOI: 10.1007/0-306-48056-5_10

Horn, B.K.P. (1981) – Hill shading and the reflectance map. *Proceedings of the IEEE*, 69:14-47. DOI: 10.1109/PROC.1981.11918

Huston, M.A. (1999) – Local processes and regional patterns: Appropriate scales for understanding variation in the diversity of plants and animals. *Oikos*, 86:393-401. DOI: 10.2307/3546645

Hutchinson, M.F. (1989) – A new procedure for gridding elevation and stream line data with automatic removal of spurious pits. *Journal of Hydrology*, 106(3-4):211-232. DOI: 10.1016/0022-1694(89)90073-5

Ichter, J.; Evans, D.; Richard, D. (2014) – Terrestrial habitat mapping in Europe: an overview. 152p., European Environment Agency, Luxembourg. ISBN: 978-9292134204DOI: 10.2800/11055

Jenson, S.K.; Domingue, J.O. (1988) – Extracting topographic structure from digital elevation data for geographic information system analysis. *Photogrammetric Engineering and Remote Sensing*, 54(11):1593-1600. DOI: 0099-1112)88/5411-1593$02.25/0

Kelly, M.; Tuxen, K.A.; Stralberg, D. (2011) – Mapping changes to vegetation pattern in a restoring wetland: Finding pattern metrics that are consistent across spatial scale and time. *Ecological Indicators*, 11(2):263-273. DOI: 10.1016/j.ecolind.2010.05.003

Lagabrielle, E.; Botta, A.; Daré, W.; David, D.; Aubert, S.; Fabricius, C. (2010) – Modelling with stakeholders to integrate biodiversity into land-use planning – Lessons learned in Réunion Island (Western Indian Ocean). *Environmental Modelling & Software*, 25(11):1413-1425. DOI: 10.1016/j.envsoft.2010.01.011

Laliberté, E.; Grace, J.B.; Huston, M.A.; Lambers, H.; Teste, F.P.; Turner, B.L.; Wardle, D.A. (2013) – How does pedogenesis drive plant diversity? *Trends in Ecology & Evolution*, 28(6):331-340. DOI: 10.1016/j.tree.2013.02.008

Lamberson, R.H.; Noon, B.R.; Voss, C.; McKelvey, K.S. (1994) – Reserve design for territorial species: the effects of patch size and spacing on the viability of the northern spotted owl. *Conservation Biology*, 8(1):185-195. DOI: 10.1046/j.1523-1739.1994.08010185.x

Leitão, A.B.; Ahern, J. (2002) – Applying landscape ecological concepts and metrics in sustainable landscape planning. *Landscape and Urban Planning*, 59(2):65-93. DOI: 10.1016/S0169-2046(02)00005-1

Lourenço, P.; Medeiros, V.; Gil, A.; Silva, L. (2011) – Distribution, habitat and biomass of Pittosporum undulatum, the most important woody plant invader in the Azores Archipelago. *Forest Ecology and Management*, 262(2):178-187. DOI: 10.1016/j.foreco.2011.03.021

Madeira, J. (1998) – *Estudos de neotectónica nas ilhas do Faial, Pico e S. Jorge: Uma contribuição para o conhecimento geodinâmico da junção tripla dos Açores*. 481p., PhD dissertation, University of Lisbon. Lisbon, Portugal. *Unpublished*.

Madeira, J.; Brum da Silveira, A. (2003) – Active tectonics and first paleoseismological results in Faial, Pico and S. Jorge islands (Azores, Portugal). *Annals of Geophysics*, 46(5):733-761. DOI: 10.4401/ag-3453.

Madeira, M.; Pinheiro, P.; Madruga, J.; Monteiro, F. (2007) – Soils of volcanic systems in Portugal. *In*: Arnalds, Ó.; Bartoli, F.; Buurman, P.; Óskarsson, H., Stoops, G.; Garcia-Rodeja, E. (eds.), *Soils of volcanic regions of Europe*, pp.69-81, Springer Verlag, Berlin. DOI: 10.1007/978-3-540-48711-1_8

Martín-Martín, C.; Bunce, R.G.H.; Saura, S.; Elena-Rosselló, R. (2013) – Changes and interactions between forest landscape connectivity and burnt area in Spain. *Ecological Indicators*, 33:129-138. DOI: 10.1016/j.ecolind.2013.01.018

Martins, A.M.F. (1993) – The Azores – westernmost Europe: where evolution can be caught red-handed. *Boletim do Museu Municipal do Funchal* (ISSN 0870-3876), S2:181-198, Funchal, Portugal.

Moeslund, J.E.; Arge, L.; Bøcher, P.K.; Dalgaard, T.; Svenning, J.-C. (2013) – Topography as a driver of local terrestrial vascular plant diversity patterns. *Nordic Journal of Botany*, 31(2):129-144. DOI: 10.1111/j.1756-1051.2013.00082.x

Moreira, M. (2013) – *Valoração da biodiversidade no Parque Natural de Ilha do Pico através da metodologia InVEST*. Relatório técnico desenvolvido no âmbito do Projeto SMARTPARKS – Sistema de Ordenamento e Gestão de Áreas Protegidas em Pequenas Ilhas (PTDC/AAC-AMB/098786/2008), 37 p., Universidade dos Açores, Ponta Delgada. *Unpublished*.

Nogué, S.; de Nascimento, L.; Fernández-Palacios, J.M.; Whittaker, R.J.; Willis, K.J. (2013) – The ancient forests of La Gomera, Canary Islands, and their sensitivity to environmental change. *Journal of Ecology*, 101(2):368-377. DOI: 10.1111/1365-2745.12051

Nunes, J.C.C. (1999) – *A actividade vulcânica na Ilha do Pico do Plistocénico Superior ao Holocénico: mecanismo eruptivo e hazard vulcânico*. 357p., PhD dissertation, University of Azores. *Unpublished*.

Pinheiro, J.; Madeira, M.; Medina, J.; Sampaio, J.; Madruga, J. (1998) – *Andisols of the Azores Archipelago* (*Portugal*). *Characteristics and classification*. XVI World Congress of Soil Science, Montpellier, France.

Pinheiro, J.; Sampaio, J.; Madruga, J. (1987) – *Carta de capacidade de uso do solo da Região Autónoma dos Açores*. Departamento de Ciências Agrárias, Universidade dos Açores, Angra do Heroísmo. *Unpublished*.

Possingham, H.P.; Wilson, K.A.; Andelman, S.J.; Vynne, C.H. (2006) – Protected areas: goals, limitations, and design. *In*: Groom, M.J.; Meffe, G.K.; Carroll, C.R. (eds.), *Principles of conservation biology*, 3rd ed., pp.509-533, Sinauer Associates Inc., Sunderland. ISBN: 0878935975.

Richard, Y.; Armstrong, D.P. (2010) – Cost distance modelling of landscape connectivity and gap-crossing ability using radio-tracking data. *Journal of Applied Ecology*, 47(3):603-610. DOI: 10.1111/j.1365-2664.2010.01806.x

Robertson, P.; Bainbridge, I.; Soye, Y. (2011) – *Priorities for conserving biodiversity on European islands. Convention on the conservation of European wildlife and natural habitats*. Standing Committee, Strasbourg, France. http://www.ebcd.org/pdf/en/327-Priorities_for_Conserving_Biodiversity_on_European_Islands.pdf

Rodríguez-Sánchez, F.; Arroyo, J. (2008) – Reconstructing the demise of Tethyan plants: climate-driven range dynamics of Laurus since the Pliocene. *Global Ecology & Biogeography*, 17(6):685-695. DOI: 10.1111/j.1466-8238.2008.00410.x

Rodríguez-Sánchez, F.; Guzmán, B.; Valido, A.; Vargas, P.; Arroyo, J. (2009) – Late Neogene history of the laurel tree (Laurus L., Lauraceae) based on phylogeographical analyses of Mediterranean and Macaronesian populations. *Journal of Biogeography*, 36(7):1270-1281. DOI: 10.1111/j.1365-2699.2009.02091.x

Saffache, P.; Angelelli, P. (2010) – Integrated coastal zone management in small islands: A comparative outline of some islands of the Lesser Antilles. *Revista de Gestão Costeira Integrada / Journal of Integrated Coastal Zone Management*, 10(3):255-279. DOI: 10.5894/rgci228

Santos, C.F.S.; Gomes de Oliveira, A. (2013) – Land use mapping in a protected area of Lagoas de Guarajuba in Camacari, Bahia, Brazil. *Revista de Gestão Costeira Integrada / Journal of Integrated Coastal Zone Management*, 13(3):391-397. DOI: 10.5894/rgci396

Saunders, D.A.; Hobbs, R.J.; Margules, C.R. (1991) – Biological consequences of ecosystem fragmentation: a review. *Conservation Biology*, 5(1):18-32. DOI: 10.1111/j.1523-1739.1991.tb00384.x

Schaefer, H.; Hardy, O.J.; Silva, L.; Barraclough, T.G.; Savolainen, V. (2011) – Testing Darwin's naturalization hypothesis in the Azores. *Ecology Letters*, 14(4):389-396. DOI: 10.1111/j.1461-0248.2011.01600.x

Schirone, B.; Ferreira, R.C.; Vessella, F.; Schirone, A.; Piredda, R.; Simeone, M.C. (2010) – Taxus baccata in the Azores: a relict form at risk of imminent extinction. *Biodiversity & Conservation*, 19(6):1547-1565. DOI: 10.1007/s10531-010-9786-0

Shaffer, M.L. (1981) – Minimum population sizes for species conservation. *BioScience*, 31(2):131-134. DOI: 10.2307/1308256

Silva, L.; Smith, C. (2006) – A quantitative approach to the study of non-indigenous plants: an example from the Azores Archipelago. *Biodiversity & Conservation*, 15(5):1661-1679. DOI: 10.1007/s10531-004-5015-z

Silva, L.; Tavares J. (1997) – Factors affecting Myrica faya Aiton demography in the Azores. *Açoreana* (ISSN 0874-0380), 8(3):359-374, Ponta Delgada, Portugal. Available at https://repositorio.uac.pt/bitstream/10400.3/796/1/Factors%20affecting%20Myrica%20faya%20Aiton%20demography%20in%20the%20Azores.pdf

Silveira, P.; Dentinho, T. (2010) – Spatial interaction model of land use – An application to Corvo Island from the 16th, 19th and 20th centuries. *Computers, Environment and Urban Systems*, 34(2):91-103. DOI: 10.1016/j.compenvurbsys.2009.10.003

Sjögren, E. (2000) – Aspects on the biogeography of Macaronesia from a botanical point of view. *Arquipélago* (ISSN 0873-4704), S2PA:1-9, Ponta Delgada, Açores, Portugal. Available at http://www.db.uac.pt/pdf/faunaA/4_aspect.pdf

Smith, R.J. (2004) – *Conservation Land-Use Zoning (CLUZ) software*. Durrell Institute of Conservation and Ecology, Canterbury. http://anotherbobsmith.files.wordpress.com/2013/03/cluz_guide.pdf

Stephenson, N.L. (1990) – Climatic control of vegetation distribution: the role of water balance. *The American Naturalist*, 135(5):649-670. DOI: 10.1086/285067

Triantis, K.A.; Borges, P.A.V.; Ladle, R.J.; Hortal, J.; Cardoso, P.; Gaspar, C.; Dinis, F.; Mendonça, E.; Silveira, L.M.A.; Gabriel, R.; Melo, C.; Santos, A.M.C.; Amorim, I.R.; Ribeiro, S.P.; Serrano, A.R.M.; Quartau, J.A.; Whittaker, R.J. (2010) – Extinction debt on oceanic islands. *Ecography*, 33(2):285-294. DOI: 10.1111/j.1600-0587.2010.06203.x

Tscharntke, T.; Steffan-Dewenter, I.; Kruess, A.; Thies, C. (2002) – Characteristics of insect populations on habitat fragments: a mini review. *Ecological Research*, 17(2):229-239. DOI: 10.1046/j.1440-1703.2002.00482.x

Vanderpoorten, A.; Rumsey, F.J.; Carine, M.A. (2007) – Does Macaronesia exist? Conflicting signal in the bryophyte and pteridophyte floras. *American Journal of Botany*, 94(4):625-639. DOI: 10.3732/ajb.94.4.625

Vargas, P. (2007) – Are Macaronesian islands refugia of relict plant lineages?: A molecular survey. *In*: Weiss, S.; Ferrand, N. (eds.), *Phylogeography of Southern European refugia*, pp. 297-314, Springer, Netherlands. DOI: 10.1007/1-4020-4904-8_11

Wahba, G. (1990) – *Spline models for observational data*. CBMS-NSF Regional Conference Series in Applied Mathematics, Society for Industrial and Applied Mathematics, Philadelphia.

Watts, K.; Handley, P. (2010) – Developing a functional connectivity indicator to detect change in fragmented landscapes. *Ecological Indicators*, 10(2):552-557. DOI: 10.1016/j.ecolind.2009.07.009

Weigelt, P.; Kreft, H. (2012) – Quantifying island isolation - Insights from global patterns of insular plant species richness. *Ecography*, 36(4):417-429. DOI: 10.1111/j.1600-0587.2012.07669.x

Wong, P.P.; Marone, E.; Lana, P.; Fortes, M. (coord.) (2005) – Island systems. *In*: Hassan, R.; Schales, R.; Ash, N. (ed.), *Ecosystems and human well-being: current state and trends*, pp.663-680, Island Press, Washington DC. ISBN: 1559632275.

Wright, J.P.; Flecker, A.S.; Jones, C.G. (2003) – Local vs. landscape controls on plant species richness in beaver meadows. *Ecology*, 84(12):3162-3173. DOI: 10.1890/02-0598

Yanes, M.C.M.; Aguilar, M.C.A.; Vernet, J.-L.; Ourcival, J.-M. (1997) – Man and vegetation in northern Tenerife (Canary Islands, Spain), during the prehispanic period based on charcoal analyses. *Vegetation History and Archaeobotany*, 6(3):187-195. DOI: 10.1007/BF01372570

Zelený, D.; Li, C.-F.; Chytrý, M. (2010) – Pattern of local plant species richness along a gradient of landscape topographical heterogeneity: result of spatial mass effect or environmental shift? *Ecography*, 33(3):578-589. DOI: 10.1111/j.1600-0587.2009.05762.x

Zonneveld, I.S. (1989) – The land unit – A fundamental concept in landscape ecology, and its applications. *Landscape Ecology*, 3(2):67-86. DOI: 10.1007/BF00131171

APPENDIX 1

Table 2. Characteristics of the ERUs with an indication of the most frequent land use in each ERU and the most probable type of natural vegetation susceptible of occurring under those ecological conditions.
Tabela 2. *Características das UERs com indicação do uso do solo mais frequente em cada UER e o tipo mais provável de vegetação natural suscetível de ocorrer nessas condições ecológicas.*

ERU	Morpho-climatic characteristics[1]	Geology		Soil		Most probable natural vegetation	Most frequent land use[6]
		Formation[2]	Type[3]	Class[4]	Subclass[5]		
Aj	Ec	Td	V-Sr	NPA	NPA	Coastal halophilic and chasmophytic communities of escarpments and cliffs	Br
Ao	TzL	Td	V-Sr	IV+VI	NPA	*Myrica faya* woodlands	Ua
Ap	CA	Td	V-Sr	IV+VI	NPA	Transition between halophilic communities and mixed shrublands of *Myrica faya*, *Juniperus brevifolia* and *Erica azorica*	Oc
Bd	CZ3	StC	V-Sr	VII	e,s	Mosaics of *Juniperus brevifolia* woodlands and *Erica azorica* shrublands	Ohv
Bl1	P	StC	V-Sr	VII	e,s	*Deschampsia foliosa* grasslands above the timberline with vestigial patches of *Erica azorica* shrublands	WV
Bl2	P	StC	V-Sr	VI	e	Mosaics of *Erica azorica* shurblands and *Deschampsia foliosa* grasslands	Ea
Bn	V1	StC	V-Sr	VI	e	Mixed chasmophytic and riparian vegetation with sparse patches of *Erica azorica*	Ea
Cb	CZ1	SpC	Pm	IV	e	“Laurifolia” hydrophil forests	Cj
Cc	CZ2	SpC	Pm	IV	e	“Laurifolia” ultra-hygrophil forests	Cj
Cd	CZ3	SpC	Pm	IV	e	*Juniperus brevifolia* woodlands	P
Ce	CZ4	SpC	Pm	IV+III	e	Forest of clouds	Am
Cf	CZ5	SpC	Pm	IV	e	*Juniperus brevifolia* woodlands	Ea
Cg	CZ6	SpC	Pm	IV	e	Mixed shrublands of *Juniperus brevifolia* and *Erica azorica*	P
Ch	CZ7	SpC	Pm	V	e	“Laurifolia” mesic forests	Ea
Ci	CZ8	SpC	Pm	III	e	“Laurifolia” mesic forests	Am
Ck	L	SpC	Pm	V	e	Plant communities of oligotrophic lagoons	L
Cm	Pb	SpC	Pm	VI	e	Plant communities of ombrotrophic peat bogs	Pb
Co	TzL	SpC	Pm	NPA	NPA	*Myrica faya* woodlands	Oc
Cp	CA	SpC	Pm	NPA	NPA	Transition between halophilic communities and mixed shrublands of *Myrica faya*, *Juniperus brevifolia* and *Erica azorica*	Ua
Cq	M	SpC	Pm	V	e	Paludal communities and/or *Juniperus brevifolia* woodlands	Cj
Db	CZ1	CC	Pm	IV	e	Mosaics of “Laurifolia” hydrophil forests and mixed shrublands on volcanic sands	Cj
Dc	CZ2	CC	Pm	V	-	Mosaics of “Laurifolia” ultra-hygrophil forests and mixed shrublands on volcanic sands	Cj
Dd	CZ3	CC	Pm	V+VI	e	Mosaics of *Juniperus brevifolia* woodlands and mixed shrublands on volcanic sands	Ea
De	CZ4	CC	Pm	V	e	Forest of clouds and mixed shrublands on volcanic sands	Ea
Df	CZ5	CC	Pm	V+VI	e	Mosaics of *Juniperus brevifolia* woodlands and mixed shrublands on volcanic sands	Ea
Dg	CZ6	CC	Pm	IV+VI	-	Mixed shrublands of *Juniperus brevifolia*, *Erica azorica* and other shrubs on volcanic sands	Cj
Dh	CZ7	CC	Pm	V	e	Mosaics of “Laurifolia” mesic forests and mixed shrublands on volcanic sands	Cj

Di	CZ8	CC	Pm	IV	e	Mosaics of "Laurifolia" mesic forests and mixed shrublands on volcanic sands	Am
Dj	Ec	CC	Pm	NPA	NPA	Coastal halophilic and chasmophytic communities of escarpments and cliffs	Br
Dk	L	CC	Pm	VI	e	Plant communities of oligotrophic lagoons	L
Dl	P	CC	Pm	V+VI	e	Mosaics of *Erica azorica* shurblands, *Deschampsia foliosa* grasslands and other shrubs on volcanic sands	Ea
Dm	Pb	CC	Pm	VI	e	Plant communities of ombrotrophic peat bogs	Pb
Do	TzL	CC	Pm	III	-	*Myrica faya* woodlands or mixed shrublands on volcanic sands	Ua
Dp	CA	CC	Pm	IV+VI	e	Mosaics of halophilic communities and mixed shrublands on volcanic sands	Pu
Dq	M	CC	Pm	V	-	Paludal communities and/or mosaics of *Juniperus brevifolia* woodlands and mixed shrublands on volcanic sands	Am
Ee	CZ4	Pa-ML	Vr	V+VI	-	Forest of clouds	Am
Ei	CZ8	Pa-ML	Vr	VI+VII	-	"Laurifolia" mesic forests	Am
Fi	CZ8	Pa-MP	Vr	VI+IV	s	"Laurifolia" mesic forests	Pu
Fj	Ec	Pa-MP	Vr	NPA	NPA	Coastal halophilic and chasmophytic communities of escarpments and cliffs	Br
Fo	TzL	Pa-MP	Vr	NPA	NPA	*Myrica faya* woodlands	Pu
Fp	CA	Pa-MP	Vr	NPA	NPA	Transition between halophilic communities and mixed shrublands of *Myrica faya*, *Juniperus brevifolia* and *Erica azorica*	Pu
Ge	CZ4	Pa	Vr	VI	e	Forest of clouds	Cj
Gg	CZ6	Pa	Vr	VI	e	Mixed shrublands of *Juniperus brevifolia* and *Erica azorica*	Cj
Gh	CZ7	Pa	Vr	V+VI	e	"Laurifolia" mesic forests	P
Gi	CZ8	Pa	Vr	V+VI	e	"Laurifolia" mesic forests	Cj
Gj	Ec	Pa	Vr	III+IV	e	Coastal halophilic and chasmophytic communities of escarpments and cliffs	Br
Gk	L	Pa	Vr	VI	w	Plant communities of oligotrophic lagoons	L
Gn	V2	Pa	Vr	NPA	NPA	Mixed chasmophytic and riparian vegetation	Ua
Go	TzL	Pa	Vr	NPA	NPA	*Myrica faya* woodlands	Ua
Gp	CA	Pa	Vr	NPA	NPA	Transition between halophilic communities and mixed shrublands of *Myrica faya*, *Juniperus brevifolia* and *Erica azorica*	Ua
Gq	M	Pa	Vr	V+VI	e	Paludal communities and/or *Juniperus brevifolia* woodlands	P
He	CZ4	A, Pa	Vr	VI	s	Forest of clouds	Ea
Hl	P	A, Pa	Vr	VII+VI	s	Mosaics of *Erica azorica* shurblands and *Deschampsia foliosa* grasslands	P
Ib	CZ1	B1	Vr	V	e	"Laurifolia" hydrophil forests with important patches of *Erica azorica* shrublands	Cj
Ic	CZ2	B1	Vr	VI+VII	s	"Laurifolia" ultra-hygrophil forests with important patches of *Erica azorica* shrublands	Ea
Id	CZ3	B1	Vr	V+VI	e	*Juniperus brevifolia* woodlands with important patches of *Erica azorica* shrublands	Cj
Ie	CZ4	B1	Vr	IV+III	e	Forest of clouds with important patches of *Erica azorica* shrublands	Am
Ig	CZ6	B1	Vr	V+VI	s	Mixed shrublands of *Juniperus brevifolia* and *Erica azorica*	Ea
Ii	CZ8	B1	Vr	IV+III	e	"Laurifolia" mesic forests with important patches of *Erica azorica* shrublands	Am

Ij	Ec	B1	Vr	NPA	NPA	Coastal halophilic and chasmophytic communities of escarpments and cliffs	Br
In	V2	B1	Vr	VI	e	Mixed chasmophytic and riparian vegetation	Ea
Io	TzL	B1	Vr	NPA	NPA	*Myrica faya* woodlands or mixed shrublands of *Myrica faya* and *Juniperus brevifolia*	Am
Ip	CA	B1	Vr	NPA	NPA	Mosaics of halophilic communities and mixed shrublands of *Myrica faya* and *Juniperus brevifolia*	Ua
Iq	M	B1	Vr	VI+VII	s	Paludal communities and/or *Juniperus brevifolia* woodlands	Ea
Jh	CZ7	Pb-at	Vr	V	e	“Laurifolia” mesic forests	P
Ji	CZ8	Pb-at	Vr	NPA	NPA	“Laurifolia” mesic forests	Ua
Jj	Ec	Pb-at	Vr	NPA	NPA	Coastal halophilic and chasmophytic communities of escarpments and cliffs	Br
Jo	TzL	Pb-at	Vr	NPA	NPA	*Myrica faya* woodlands	Ua
Jp	CA	Pb-at	Vr	NPA	NPA	Transition between halophilic communities and mixed shrublands of *Myrica faya*, *Juniperus brevifolia* and *Erica azorica*	Ua
Jq	M	Pb-at	Vr	V	s	Paludal communities and/or *Juniperus brevifolia* woodlands	P
Kb	CZ1	B	Vr	IV	-	“Laurifolia” hydrophil forests	Cj
Kc	CZ2	B	Vr	V	-	“Laurifolia” ultra-hygrophil forests	Cj
Kd	CZ3	B	Vr	IV	-	*Juniperus brevifolia* woodlands	Cj
Ke	CZ4	B	Vr	III+IV	-	Forest of clouds	Am
Kf	CZ5	B	Vr	V	e	*Juniperus brevifolia* woodlands	Cj
Kg	CZ6	B	Vr	IV	-	Mixed shrublands of *Juniperus brevifolia* and *Erica azorica*	Am
Kh	CZ7	B	Vr	V	e	“Laurifolia” mesic forests	Cj
Ki	CZ8	B	Vr	NPA	NPA	“Laurifolia” mesic forests	Am
Kj	Ec	B	Vr	NPA	NPA	Coastal halophilic and chasmophytic communities of escarpments and cliffs	Br
Kk	L	B	Vr	V	e	Plant communities of oligotrophic lagoons	L
Kl1	P	B	Vr	VII	e,s	*Deschampsia foliosa* grasslands above the timberline	WV
Kl2	P	B	Vr	VI	e	Mosaics of *Erica azorica* shurblands and *Deschampsia foliosa* grasslands above the timberline	Ohv
Kl3	P	B	Vr	V+VI	e	Mosaics of *Erica azorica* shurblands and *Deschampsia foliosa* grasslands	Ea
Kn	V2	B	Vr	NPA	NPA	Mixed chasmophytic and riparian vegetation	Am
Ko	TzL	B	Vr	NPA	NPA	*Myrica faya* woodlands	Am
Kp	CA	B	Vr	NPA	NPA	Transition between halophilic communities and mixed shrublands of *Myrica faya*, *Juniperus brevifolia* and *Erica azorica*	Ua
Kq	M	B	Vr	IV+VI	-	Paludal communities and/or *Juniperus brevifolia* woodlands	Am

[1]CA: Coastal areas; M: Marshes; Ec: Escarpments and cliffs; TzL: Transition zones and lowlands Pb: Peat bogs; L: Lagoons; V1: Valleys with LS factor > 500; V1: Valleys with LS factor > 500 and < 50m wide; P: Pico; CZ1: Climatic zone 1 (P: h, M: h, W: h); CZ2: Climatic zone 2 (P: h, M: h, W: m); CZ3: Climatic zone 3 (P: h, M: m, W: h); CZ4: Climatic zone 4 (P: h, M: m, W: m); CZ5: Climatic zone 5 (P: m, M: h, W: h); CZ6: Climatic zone 6 (P: m, M: m, W: h); CZ7: Climatic zone 7 (P: m, M: h, W: m); CZ8: Climatic zone 8 (P: m, M: m, W: m) (P: Precipitation; M: Moisture; W: Wind; h: high; m: moderate)

[2]B: Basalts; Pa: Peridotic andesites; B1: Basalts from the historic eruptions of the 15th and 18th centuries; A: Andesites; Pa-ML: Peridotic andesites from “Mistério de Sta Luzia”; Pa-MP: Peridotic andesites from “Mistério da Prainha”; CC: Cinder cones; Pb-at: Peridotic basalts of andesitic trend; Td: Torrential dejections; SpC: Spatter cones; StC: Stratocone

[3]Vr: Volcanic rocks; Pm: Pyroclastic materials; V-Sr: Volcano-sedimentary rocks

[2]I to VII; NPA – Non-productive areas (urban areas, infrastructures and bare rocks)

[5]e: soils with high susceptibility to erosion; s: soil limitation at the level of the roots; w: soil with excess water (drenching); NPA – Non-productive areas (urban areas, infrastructures and bare rocks

[6]Am: *Acacia melanoxylon* stands; Cj: *Cryptomeria japonica* stands; Ea: *Erica azorica* shrublands; Pu: *Pittosporum undulatum* communities Ohv: Other herbaceous vegetation; Ua: Urban areas; Oc: Other crops; Br: Bare rocks; P: Pastures; L: Lagoons; Pb: Peat bogs; WV: Open spaces without vegetation

Revista da Gestão Costeira Integrada 14(2):267-288 (2014)
Journal of Integrated Coastal Zone Management 14(2):267-288 (2014)

GESTÃO COSTEIRA INTEGRADA
Journal of Integrated Coastal Zone Management

http://www.aprh.pt/rgci/pdf/rgci-475_Riddiford.pdf | DOI:10.5894/rgci475

The Albufera Initiative for Biodiversity: a cost effective model for integrating science and volunteer participation in coastal protected area management *

A Iniciativa Albufera para a Biodiversidade: um modelo exemplar em termos de custo, eficiência e benefício para a integração da ciência com a participação voluntária em processos de gestão de áreas protegidas costeiras **

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ABSTRACT

This paper puts forward a multi-disciplinary field project, set up in 1989 at the *Parc Natural de s'Albufera* in Mallorca, Balearic Islands, Spain, as an example of a cost effective model for integrating science and volunteer participation in a coastal protected area. Outcomes include the provision of a science base for the effective management of the site; training of Balearic and international biologists and protected area managers; and providing information materials for public awareness, education and general dissemination purposes. This has been achieved at low cost by using the voluntary sector. The project incorporates scientists, wetland managers, students, scholars and other citizens under the auspices of an international volunteer network (TAIB), working in partnership with the *Parc* management team. Long-term monitoring over a 25-year span of subjects as varied as insects, birds, land and aquatic ecosystems and communities has led to an improved ecological understanding of socio-economic as well as environmental impacts and threats for the catchment. This paper illustrates the added value of a long-term ecological knowledge base for decision making and capacity building in protected areas in order to reduce environmental impacts from socio-economic development in surrounding coastal zones. It describes how the science base has been used as a means of communication to encourage early action by policy makers to avoid negative outcomes of costly future impact on the public purse; and highlights how the economic value of long-term monitoring as an early warning system far outweighs the modest cost to society of an integrated participatory project based in the volunteer sector. The Albufera experience is offered as a cost effective model for other coastal and island sites.

Keywords: long-term studies, biodiversity, capacity building, environmental education, volunteers, economic values

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** Submission: 31 December 2013; Evaluation: 11 February 2014; Reception of revised manuscript: 15 May 2014; Accepted: 21 May 2014; Published on-line: 3 June 2014*
*** Translation to Portuguese (Title, Abstract, and Captions) by Artur Gil (on behalf of the Guest Editorial Board).*

RESUMO

Este artigo apresenta um projeto de campo multidisciplinar implementado em 1989 no Parque Natural de Albufera (Maiorca, Ilhas Baleares, Espanha) que pode ser considerado como um modelo exemplar em termos de custo, eficiência e benefício para a integração da ciência com a participação voluntária em processos de gestão de áreas protegidas costeiras. Os principais resultados deste projeto incluíram a produção de uma base científica para a gestão adequada do sítio; a formação de biólogos e gestores de áreas protegidas locais e internacionais; e a produção de materiais para educação, sensibilização e consciencialização ambiental da população local e grande público. Estes objetivos foram atingidos a baixo custo devido ao recurso ao voluntariado. Este projeto integrou cientistas, gestores de áreas protegidas, estudantes, bolseiros e outros cidadãos sob a égide de uma rede internacional de voluntariado (TAIB), que tem colaborado ativamente com a equipa de gestão do Parque Natural. A monitorização integrada a longo prazo durante um período de 25 anos em domínios científicos como a entomologia, ornitologia, ecologia terrestre e ecologia aquática, permitiu melhorar substancialmente o nível de conhecimento ecológico associado à componente sócio-económica da área de estudo, assim como os seus impactes ambientais e as ameaças que daí decorrem para a bacia hidrográfica. Este artigo demonstra a importância de uma monitorização ecológica integrada a longo prazo para apoio à decisão e para a capacitação de recursos em áreas protegidas, de modo a reduzir os impactes ambientais decorrentes do desenvolvimento sócio-económico das áreas costeiras da zona. Este trabalho descreve também como a ciência foi usada como meio de comunicação e sensibilização para estimular os decisores a agir antecipadamente, de modo a evitar os altos custos ambientais e financeiros para o erário público decorrentes dos impactes ambientais e sócio-económicos das políticas adotadas. Finalmente, este estudo realça a excelente relação custo-eficiência-benefício associada à monitorização ecológica integrada a longo prazo assente num projeto participativo integrado baseado em voluntariado, constituindo também um sistema de alerta precoce eficiente, de baixo custo e com elevado benefício para a sociedade. A experiência de Albufera é assim proposta como um modelo válido apto para ser aplicado com sucesso noutros sítios costeiros e pequenas ilhas.

Palavras-chave: *Estudos de longo prazo, biodiversidade, capacitação de recursos, educação ambiental, voluntariado, valoração económica.*

1. INTRODUCTION

Effective conservation management has a cost. The act of declaring a protected area does not in itself guarantee safeguarding its environmental values. The perception that management "looks after itself" is seriously flawed. Planning, defining objectives, drawing up and implementation of management plans all require science, personnel… and money.

The objectives of this paper are:

- to demonstrate the added value and cost effectiveness of long-term ecological field studies as an essential element of effective integrated coastal zone management;
- to illustrate the hidden financial contribution these studies make in revealing issues and impacts, which if not remedied, can lead to severe future costs to society well beyond the protected area;
- to offer a field research model which may prove of interest or relevance to other coastal and island sites in the Mediterranean.

The model is a long-term field project entitled *The Albufera Initiative for Biodiversity (TAIB)*. Launched in 1989, the project gives scientific support to the *Parc Natural de s'Albufera* on the island of Mallorca. The description outlines the structure of the initiative, the ways in which it feeds conservation knowledge into management of the *Parc*, and socio-economic implications of its findings. Most important of all, it puts forward a cost-effective model for maximizing results from limited financial outlay.

2. BACKGROUND

The concept for the project originated with Max Nicholson, doyen of World conservation, and was made possible by the support and intervention of Joan Mayol, then Director of the *Parc Natural de s'Albufera*.

Nicholson's vision was to create a multi-purpose approach to field conservation, incorporating scientists from different disciplines working alongside teams of volunteers in close partnership with the *Parc* Directorate and staff. This formula, often referred to nowadays as citizen science (Bäckstrand, 2004; van Vliet *et al.*, 2013), was designed to have implications for coastal zone management, didactics (Costa *et al.*, 2013) and capacity building (Echevarría *et al.*, 2013).

2.1. The Project

2.1.1. A brief history

In order to give the project initial impetus, Max Nicholson persuaded a succession of high profile UK scientists to fill the role of Principal Investigator: Professor Palmer Newbould 1989-90, Dr Franklyn Perring 1991-92 and Terry Wells 1993-1995. Professor Newbould devised and led the first ever University Environmental Masters course (University College London 1970); Perring devised and organised the first ever environmental Atlas, *The Botanical Atlas of the British Isles* (Perring & Walters, 1962); and Wells of Monks Wood Experimental Station, UK, was an acknowledged world expert on orchid demographics. Impetus in the first two years was also provided by students and teachers from the UCL Masters course. Administrator throughout was Nick Riddiford, ensuring a continuity which has lasted to this day.

Funding support came from the newly established Earthwatch Europe, an NGO originally developed in the United States to promote field research through the novel approach of finding volunteers willing to pay to participate alongside the scientists. Earthwatch Europe supported the project from 1989 to 1997, sending a stream of volunteers whose financial contribution ensured that the project had enough money to operate – though at low cost.

Subsequently, although Earthwatch no longer acknowledged the project as one of its own, Earthwatch Europe did find the project some financial support through an African training programme, 1995-99, funded by the European Union and the UK Government's Darwin Initiative and a teacher training programme for European senior biology teachers financed through Glaxo Wellcome Education and ARCO Chemicals Teacher Fellowships.

Throughout this period, the Nicholson concept of scientists working alongside volunteers was maintained. In 25 years (1989-2013), the project has welcomed seventy scientists from 10 countries, representing a wide range of biological, geographical and conservation management disciplines. The majority of scientists were invited for specific tasks but a core of these committed their free time to the project on a more regular basis.

The change in funding status from 1997 meant that the project was no longer "Earthwatch Europe Project S'Albufera". In response, the well established team of scientists formed themselves into The Albufera International Biodiversity group (team TAIB for short), an appropriate term as the team drew from several European countries. Tables 1 to 3 summarise the history and progress of Project S'Albufera.

2.1.2. The current structure

The current structure remains largely faithful to the format established in 1989. Two, three or four field sessions are held every year, each for a period of two weeks and usually in spring and autumn. Each team comprises 10-12 participants. The participants, scientists and volunteers, receive no remuneration. In return, on-site accommodation and meals are provided free of charge – though the participants share the preparation of meals on a rota basis.

Table 1. Key moments in the development of TAIB's Project S'Albufera programme.
Tabela 1. *Momentos-chave no desenvolvimento do Programa Albufera como projeto da TAIB.*

1988 S'Albufera de Mallorca awarded conservation status by the Balearic government as a *Parc Natural*.
1988 Start of ornithological monitoring programme led by *Parc* management, reintroduction of 3 bird species, grazing management, hydrological rehabilitation measures (all led by *Parc* management).
1989 Project S'Albufera is launched by Earthwatch Europe after initial impetus of Max Nicholson.
1989 The Balearic government registers S´Albufera de Mallorca in the Convention on Wetlands of International Importance (with special reference to water birds), better known as the Ramsar Convention.
1993 The wetland area is seriously impacted by fires in 1992-1994, long-term research conducted of habitat requirements by reed bed birds such as *Acrocephalus melanopogon* based on initial studies done by Taylor (1993).
1994 onwards *Parc* Management starts monthly monitoring programme for water quality (temperature, salinity, oxygen, conductivity) in PN s'Albufera at 33 sites within the *Parc*.
1997 Direct Earthwatch funding ends.
1999 Parc Natural de s'Albufera opens *Casa de las Universidades*, including laboratory and dormitory, funded by the Balearic government.
2000 Balearic government becomes a co-funder of the ecological field work.
2003 The title *The Albufera Initiative for Biodiversity* is introduced as an alternative to *Project S'Albufera*.
2003 Baseline data for a wide range of plant and animal groups are published in a Biodiversity catalogue, extending knowledge of faunal and floral biodiversity.
2004 The monthly water quality monitoring programme is extended to nutrient measurements as the Balearic government implements the European Water Framework Directive.
2005 Research priorities formalised between *Parc* Directorate and TAIB.
2006 onwards TAIB extends the participatory process through consultation with local stakeholders (Traveset *et al.*, 2006; Royo *et al.*, 2010; Férriz, 2012, 2013).
2007 *Associació TAIB* formed as independent body to provide opportunities for local scientists. Development marks the growing commitment and skill base of Balearic field scientists, working in partnership with the international research community.
2013 As a result of the global financial crisis, Balearic government withdraws co-funding of TAIB project, severely reduces *Parc* budget and staff for ecological field studies.
2014: Balearic government and *Parc* renew financial support for training of local field ecologists and environmental managers.

Table 2. Key developments in the nature conservation and ecological research programme.
Tabela 2. *Desenvolvimentos-chave no programa de investigação em ecologia e conservação da natureza.*

1989 onwards Baseline inventory of geophysical features and better known environmental groups initiated alongside ecological field studies which in the early years included reed bed ecology, ornithological fieldwork, botanical studies and entomological fieldwork (Earthwatch Europe, 1991; Martinez & Mayol, 1995). Long-term light trapping programme for Lepidoptera begins; and is still running, a significant example of the added value of long term ecological studies with new species discovered for Europe (*e.g.* Foster & Riddiford, 2011), changes in Lepidoptera populations including invasive species moving north (Honey *et al.*, 2007), alien pest species, relationships with climate variability (Abma, 2008; Associació TAIB, 2012; Férriz & Herrero, 2012) and habitat structure (Honey *et al.*, 2007).
1994 – 1996 Pilot study for *Monitoring Mediterranean Wetlands* (Riddiford & Mayol, 1996; Tomàs-Vives, 1996).
1995 – 2008 An accord with Wageningen University sees a series of Masters studies through its Environmental Systems Analysis Group extend knowledge of the wetland's functions and values in partnership with the project and *Parc*.
1997 onwards Coastal dune studies added to programme, in conjunction with Mediterranean Institute for Advanced Studies (IMEDEA) and University of the Balearic Islands (Servera, 2009; Gelabert *et al.*, 2002). Results show that biodiversity and dune development are strongly impacted by tourism development in both the coastline and Alcudia bay (Whittingham, 1999; Traveset *et al.*, 2006; Royo *et al.*, 2007, 2008; Férriz, 2009). Restoration recommendations are made.
1999 onwards Aquatic ecological fieldwork by TAIB (Veraart, 1999) is compared with similar pre-1989 data (Martinez, 1988) and monthly water quality time series collected by *Parc* staff. Outcome: a post-1988 decline in species diversity was mostly explained by increased salinity levels while high nutrient levels resulted in high abundancies of cosmopolitan aquatic species (see Veraart *et al.*, 2004). Study repeated in spring 2000-2001, 2003-2005 and at two year intervals 2008-2012 enabling TAIB to assess long-term changes within the structure and development of the aquatic vegetation in relation to water quality and inter-annual climate variability.
2002 – 2008 Studies by Sato (2002), Sato & Riddiford (2008), Sargeant (2002) and Salazar *et al.* (2006) use dragonflies and Ardeidae respectively to increase knowledge of the relationship between species diversity, niche partitioning, habitat requirements and management measures within s'Albufera de Mallorca.
2009 Various studies launched by Associació TAIB relating to socio-economic values of environmental conservation and planning both within (*e.g.* Férriz, 2010; Royo *et al.*, 2010) and outside the *Parc* boundaries (*e.g.* Royo *et al.*, 2010; Férriz, 2012, 2013).
2011 *Gabinet d'Analisi Ambiental i Territorial* (2011) combines research results for water quality, aquatic ecology & hydrology from TAIB fieldwork & University of Barcelona (Suarez & Pretus, 2008). TAIB data demonstrate further aquatic biodiversity decline since 1999; after 2000, additional loss in species diversity mainly explained by eutrophication. Long-term salinity and conductivity time series collected by *Parc* staff show the trend of increased salinity levels has halted at the southern edge of the wetland area since 2000 while the levels continue to increase near the coastal zone (Riddiford & Férriz, 2009).

Table 3. Key moments in the capacity building programme.
Tabela 3. *Momentos-chave no programa de capacitação de recursos*

1989 *Parc* Directorate and Earthwatch Europe sign protocol to incorporate local graduates in the fieldwork programme.
1995 – 1997 Programme of training for senior biology teachers from France, Netherlands and UK, funded by Glaxo plc.
1995 – 1999 African training programme launched, coordinated by TAIB, funded by European Union and UK Darwin Initiative.
2003 – 2007 Capacity building programme for Mediterranean wetland managers in conjunction with MedWet Coast.
2005 TAIB's first website is launched: www.taib-initiative.org.
2005 onwards Capacity building extended to staff of protected areas and environmental NGOs in conjunction with WWF Mediterranean and other international bodies.
2012 Protected Area Species and Habitats Coordinator for Guinea Bissau brings the participant country count to 50.
2013 Associació TAIB launches the new website: www.taib.info.
2014 New source of Balearic government funding targets training of local field ecologists and environmental managers.

The teams have a capacity building as well as a field research element so the ratio of scientists to volunteers is high, often approaching 1:1. Seven members of the scientific team have attended regularly for more than 10 years, and at least three are present with each team. This ensures continuity of the research and training programmes. Other scientific expertise is sought in relation to newly opened lines of study, thus adding fresh blood to the team on an annual basis.

2.1.3. Volunteers

In the Earthwatch years, the majority of volunteers were members or retired members of the professions, *e.g.* teachers, medics, administrators, etc. Earthwatch Europe also secured grants to sponsor other members of society, and from other European countries. To add to the international mix, two free places were reserved for local, Balearic, volunteers under an agreement with the Balearic Government's *Conselleria d'Agricultura i Pesca* (later the *Conselleria de Medi Ambient*). These were mainly graduate and post-graduate science students from the University of the Balearic Islands. Their participation allowed TAIB to develop its capacity building programme and this was further enhanced by the African programme which gave protected area managers from seven sub-Saharan countries, and others working in conservation and allied activities, the opportunity to experience at first hand the management and monitoring activities at the *Parc*.

2.1.4. The capacity building programme

As the project became better known, regionally and internationally, the number of volunteers from the Balearic Islands and mainland Spain grew. The *Conselleria de Medi Ambient* intervened with funding support from 2000 and this was crucial because it allowed TAIB to use some of its funding to host conservation workers from countries around the Mediterranean and beyond. International awareness of the capacity building opportunities encouraged organisations such as WWF Mediterranean, MedWetCoast and the UNDP/GEF regional unit for Arab States to send protected area managers and conservation workers for TAIB's capacity building experience.

The capacity building courses incorporated into TAIB fieldwork periods are designed to be entirely practical and with flexibility to structure each course to the particular needs of the participants. The main aims of the courses are to: provide participants with practical experience of monitoring techniques, species identification and data collection; undertake capacity building in wetland management and protected area management generally; and permit participants to study and experience all aspects of nature reserve management alongside TAIB scientists and the *Parc* management team.

Over 450 volunteer trainees from 50 countries and all parts of the world have participated over the 25 years. A high proportion of oversees trainees have been protected area managers and conservation workers from developing countries. They took away with them practical knowledge of management planning, applying the MedWet monitoring protocol (Tomàs-Vives, 1996) to their own monitoring programme and much more. Many have stayed in contact with the project or its scientists and have benefited from further assistance and advice through email.

2.1.5. The cost

The annual cost of running a programme of this kind normally requires some €15,000 to €20,000. This may sound expensive but it covers day to day expenses, including administration, food and equipment, for up to 50 days in the field; and there is considerable added value when one takes into account that several of the scientists who volunteer their time and expertise free of charge would normally be contracted in their professional lives at €500 per day or more. Thus, an outlay of €20,000 brings in more than 10 times that value over the course of a year.

2.2. The Site

S'Albufera de Mallorca is the largest wetland in the Balearic Islands and is separated from the sea by a belt of coastal dunes (Fig. 1). A total of 1688 ha, incorporating approximately 1450 ha of wetland and over 200 ha of dune, received designation as a *Parc Natural* by the Balearic Government in 1988.

The wetland zone comprises a complex network of canals – products of a failed attempt to drain the site in the 1860s (Picornell & Ginard, 1995) – extensive reed beds and shallow, open lagoons. The wetland is largely freshwater but with anomalies including extensive saltmarsh and saline lagoons in the north-east and a small set of abandoned salt pans in the south-east. An incomplete set of fossil dunes, remnants of an ancient coastline formed during the Riss glacial some 100,000 years before present, runs through the wetland parallel to the coast (Barceló & Mayol, 1980; Servera, 2004). This, along with an intact band of coastal dunes, Es Comú (Fig. 1), and a strip of dune woodland on the southern border, add diversity to the *Parc*. The entire area is flat and at or just above sea level. The *Parc*'s eastern boundary abuts Alcudia Bay, whose coastal strip has been heavily developed for tourism (Fig. 2).

Bordering the *Parc*'s inland perimeter is an extensive zone largely given over to agriculture, much of it intensive (Fig. 3). Immediately beyond the perimeter are hundreds of small properties called *Veles*, many of them abandoned or with low levels of activity (Férriz, 2013). Though not in the Parc, the closest are incorporated within the Natura 2000 site. They act as a buffer zone between the Parc and the intensive agriculture which has developed over the last 50 years or so in the large plateau beyond which extends to the nearest towns of Sa Pobla and Muro (Royo *et al.*, 2010; Férriz, 2013).

A series of settlements lie within the catchment area. The resident population has increased by nearly 50% in that area over the last 17 years (Table 4), as has the number of tourists which during the summer season outnumber residents ten-fold (Andrew, 2011; Hof & Blázquez-Salom, 2013; Figure 4). This puts enormous pressure on water resources and facilities, not least at pre-tourism sewage works inadequate for processing current volumes of wastewater.

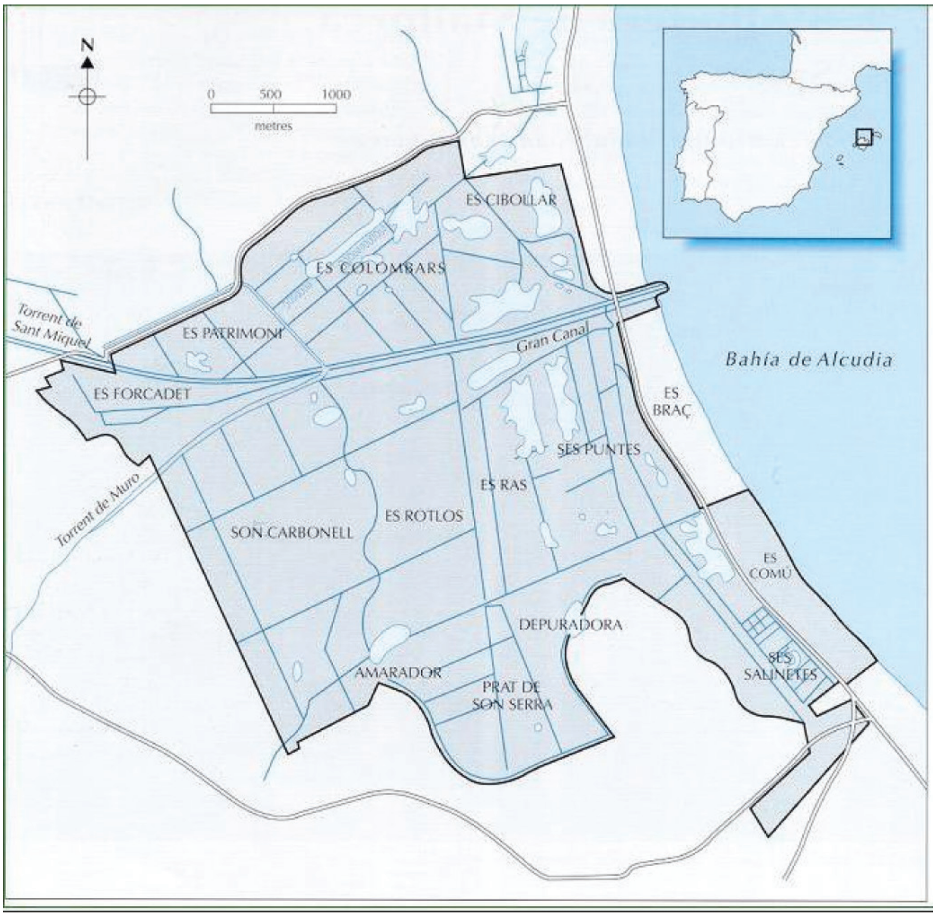

Figure 1. Map of the Parc Natural de s'Albufera, Mallorca and its regional context.
Figura 1. *Enquadramento regional e localização do Parque Natural de Albufera em Maiorca.*

Figure 2. The Parc Natural de s'Albufera, Mallorca, showing extensive tourist urbanisation on its north-eastern border.
Figura 2. *Ilustração da excessiva concentração urbanística de cariz turístico na fronteira nordeste do Parque Natural de Albufera.*
Photo: courtesy of P.N. s'Albufera de Mallorca

Figure 3. The Parc Natural de s'Albufera, Mallorca showing two main water channels entering from extensive agricultural zone beyond.
Figura 3. *Ilustração da área de extensificação agrícola na zona ocidental do Parque Natural de Albufera (parte superior da figura).*
Photo: courtesy of P.N. s'Albufera de Mallorca

Table 4. Catchment and whole Island (Mallorca) population growth, 1996-2003
Tabela 4. *Representação da evolução demográfica na bacia hidrográfica e Ilha de Maiorca entre 1996 e 2003*

Population Centre	1996 Census	2013 Census
Alcúdia	10,284	20,163
Muro	6,060	6,977
Pollença	12,945	16,200
Sa Pobla	10,213	12,901
Santa Margalida	6,789	12,243
MALLORCA	609,150	864,763

source: INE (2014)

2.2.1. Parc administration

The lead authority in the management of the *Parc* is the Balearic Government's *Conselleria de Agricultura, Medi Ambient i Territori* (Agriculture, Environment and Land) and it is one arm of this authority, the Directorate General of Natural Environment, Environmental Education and Climate Change (*Direcció General de Medi Natural, Educació Ambiental i Canvi Climàtic*), which has the greatest role. This body is responsible for all aspects of environmental conservation including biodiversity and natural resources, natural protected area management, terrestrial and marine ecosystems, landscape and forestry.

Another arm of the same body, its Secretariat General, is responsible for guarding and surveillance through its Environmental Agents Corp (*Cos d'Agents de Medi Ambient*) while the Directorate General of Hydric Resources (*Direcció General de Recursos Hídrics*) manages water resources through planning, control, rates for water usage and application of legal hydrological statutes. The Balearic Agency for Water and Environmental Quality (*Agència Balear de l'Aigua i la Qualitat Ambiental*, ABAQUA) is responsible for water purification plants and the Balearic Institute for Nature (*Institut Balear de la Natura*, IBANAT) provides the manpower for prevention and extinction of forest fires, forest management and conservation of natural protected areas.

Whereas main responsibilities come under the direct jurisdiction of the Balearic Autonomous Government, the Spanish State retains responsibility for the maritime and coastal public domain and its Ministry of Agriculture, Food and Environment is associated with coastal management through its Demarcation of the Balearic Islands Coasts (*Demarcación de Costas de las Islas Balears*).

Overall day to day activities are guided by the *Parc* Conservation Director whose small team of staff is assigned to specific tasks of maintenance and public use. A field biologist was employed to apply and monitor the condition and status of the *Parc's* habitats and wildlife until December 2012 when financial constraints ended the post.

The work programme responds to an annual plan drawn up by the Director in conjunction with his staff and a *Parc* Governing Council (*Junta Rectora*). The *Junta Rectora* incorporates representatives of the afore-mentioned management authorities as well as local municipalities and

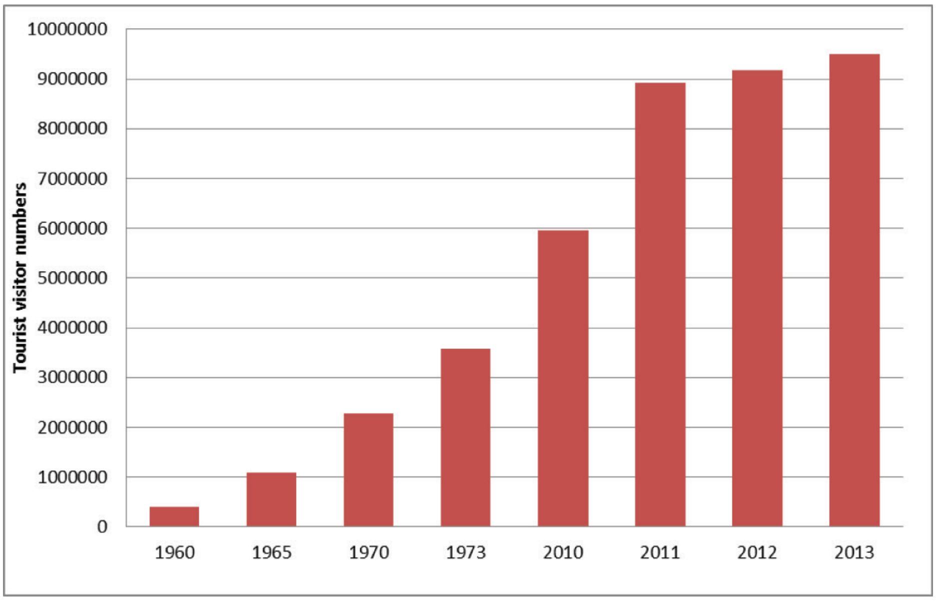

Figure 4. Visitor numbers for selected years to show trend of tourism growth, Mallorca, over the period 1960-2013. [1960-1973 data: Forcades & Martorell (2003); 2010-2013 data: IBESTAT (2014)]

Figure 4*. Número de visitantes em determinados anos de modo a evidenciar a tendência de crescimento turístico em Maiorca, no período entre 1960 e 2013.*

conservation NGOs. This should provide a unified approach to management as well as ensuring the feasibility of the plan before it is passed to the *Conselleria* for approval.

2.2.2. The facilities

The *Parc* is open all year. Facilities include a reception area, exhibitions room and interpretation centre. The *Casa del Parc* has offices and other facilities for staff. In the early years of the project, accommodation for volunteers was basic. A generator provided electricity but was limited to four hours a day and teams of up to 20 were crammed into one large dormitory in the *Casa del Parc*. Teams are much better served now. The *Parc* has installed 24-hour mains electricity while the accommodation comprises four-bed dormitories complete with en suite facilities. The dormitories are part of the *Casa de las Universidades*, a purpose-built research block opened in 1999. The building includes a spacious laboratory, which is extremely well equipped thanks to a generous donation by the Bishop family in memory of the late Dennis Bishop, and is appropriately named the Bishop Lab.

2.3. Project objectives and feedback to *Parc*

The visionary Max Nicholson set the project some ambitious objectives (Earthwatch Europe, 1991). They appeared an immense challenge at the outset, but team TAIB has remained faithful to them all. They are:

a) to assemble full and detailed ecological data for the site and its surrounding area;
b) to provide data for evidence of local, regional and global change;
c) to afford material for application in further research and reserve management at s'Albufera and in general conservation practice;
d) to provide resources for interpretive programmes and dissemination;
e) to serve as a focus for education in terms of training and creating environmental awareness and commitment.

It was determined that the first three years (1989-1991) should be dedicated to assembling the ecological data. In fact, this has proved to be a gradual, continuous process which has continued throughout the 25 years. At the same time, the team was already engaged in pilot studies for long-term monitoring in year one and launched some of the schemes in year two.

An absolute priority was to ensure good communication with the *Parc*. As the original scientific team was British, learning the local language was an important starting point. During fieldwork periods, the teams worked closely with *Parc* staff and this allowed an effective informal means of communication as well as providing a two-way flow of information. It was vital that *Parc* staff should feel included and valued and their thoughts, ideas and joint activities were important contributions to the development of the project.

A more formal feedback process was established through the provision of annual reports. These were necessary not only to communicate to a wider audience, including the environmental team at the *Conselleria de Medi Ambient*, but to allow for a more measured, analytical – albeit provisional – presentation of findings. Early reports comprised a limited run of bound copies, published by Earthwatch Europe. TAIB, however, wished to make these reports more widely accessible and has transcribed all its publications, from 1989 onwards, to its website (TAIB, 2014).

2.3.1. Shaping of the studies

The annual programme of work was inevitably shaped by the original objectives, though the themes and emphasis in any one year were often determined by the availability of researchers. TAIB also looked to respond to the immediate needs and interests of the *Parc* Directorate and staff, whether it was for scientific, educational or public awareness purposes. This was put on a more formal footing from 2005. A new system was put in place which identified investigations or actions deemed of priority to the *Parc*. The *Parc* Directorate proposed three priority tasks each year, though they were always finalised after consultation with TAIB scientists. The designated studies were different each year, thus greatly extending the remit of team TAIB. The team, however, was by then experienced and well established so was able to carry out the new tasks whilst still maintaining the vital long-term monitoring programme.

2.3.2. Implementing the studies

The ultimate goal of the studies was to seek an understanding of the key elements and processes which determine how the *Parc*'s ecosystem functions as the basis for identifying impacts on the system and, if these are environmentally damaging, the means of resolution.

However, despite the involvement of some experienced scientists, the first few years were something of a step into the unknown. The first objective, to assemble full ecological data, did at least provide an early focus but it was a steep learning curve. In truth, that learning curve has hardly diminished, particularly as *Parc* policy has led the research group into new areas widening not only knowledge of the specific issue but a better understanding of its role in the ecosystem.

The scientific team at the time quickly formed a view that evaluation of global change was not possible at one site operating on its own, particularly one exposed to a number of local anthropogenic pressures, in line with international scientific opinion then (Moore, *et al*., 2001; Adger *et al*., 2009). It might be different now. Viewpoints are changing: the regional vulnerability approach to global change is becoming seen more often as a promising approach to increase our knowledge about these complex cause-and-effect relationships (Rosenzweig & Wilbanks, 2010; Veraart *et al*., 2014). In addition, the digital revolution (internet) makes knowledge exchange between field sites much easier than in 1989.

Irrespective, it was clear that the project had a role in assessing local and regional impacts on the *Parc* and its environment. Designating a protected area is only the first step towards the conservation of the zone. It does not safeguard the area within from outside factors. Major issues were identified: nutrient enrichment and other pollution impacts; salt contamination of the aquifer due to over extraction of freshwater in adjacent agricultural areas; changes in the hydrology (Salamanca & Rodríguez-Perea, 1999; Galimont *et al*., 2003; Candela *et al*., 2009); illegal release of non-indigenous fauna; losses of biodiversity through the impacts of beach tourism; urbanisation and other inappropriate developments in buffer zones adjacent to the *Parc*. Conservation management could not proceed without knowledge of their impacts and planning to mitigate them.

The only way to address these issues was first to investigate, then set up a long-term monitoring programme (Table 5). Certain investigation and monitoring tasks were achievable during the fieldwork periods but others required longer time periods or more prolonged study.

With limited resources, the *Parc* had insufficient staff availability to monitor more than the birds, meteorology and water quality (Table 6). TAIB took on a major role in extending that information pool. Birds are not the best subjects for environmental monitoring – at least at single sites – as they tend to react slowly to change. TAIB uses other bio-indicators to assess habitat and ecosystem quality. Biota such as submerged macrophytes and aquatic invertebrates are essential components of the system (Mitsch & Gosselink, 1993; Scheffer, 1998); and their communities are ready indicators of the state of the water and of changes which are occurring (Veraart *et al*., 2004; Riddiford & Férriz, 2009; Table 7). Long-term fieldwork has enabled us to increase our knowledge of the relationship between trends, seasonality and variability in water quality; and the ecological response (in this case aquatic communities and biodiversity).

In order to collect further sets of data, TAIB sought collaborations with outside organisations. Institutes such as the Tour du Valat Biological Station in France, University College London and the Universities of Newcastle and York in the UK sent researchers to investigate a range of ecological and conservation management issues. A particularly strong link was established with the Environmental Systems Analysis Group from Wageningen University, Holland. The Wageningen input was mainly in the guise of Masters studies and covered such key topics as bio-indicators for monitoring the impacts of agriculture and tourism (Veraart, 1999), water policies and water management (Cathala *et al*., 2002) and grazing as a management tool (Portero-Marti, 2004). In all, 22 theses have been generated through TAIB and include other relevant subjects such as anthropogenic impacts on the coastal environment (Whittingham, 1999), feeding ecology of *Acrocephalus melanopogon* in relation to fires (Taylor, 1993), niche partitioning in Ardeidae (Sargeant, 2002) and conservation priorities for dragonflies (Sato, 2002).

This partnership approach of *Parc*, collaborators and TAIB has led to an ever growing store of information on weather, water quality, birds, orchid populations, aquatic and terrestrial invertebrates, aquatic macrophytes, terrestrial plant communities, habitats and a range of human impacts. Baseline data have been collected for a wide range of plant and animal groups and published in a Biodiversity Catalogue (Riddiford, 2002), now expanded into a biodiversity database held at the *Parc*.

2.3.3. The biodiversity database

TAIB uses MS Access databases to maintain records of its long-term bird, moth, butterfly and dragonfly monitoring

Table 5. Key elements of TAIB's surveillance and monitoring programme
Tabela 5. *Elementos-chave do programa de monitorização e vigilância da TAIB*

Subject	Method	Frequency	Purpose
Aquatic invertebrates	Standardised sweep-netting, water quality sample sites	Spring & autumn (formerly each year, now converted to 3-4 year intervals)	Indicators for water quality; invertebrate community structure & health
Submerged macrophytes	Standardised sweep-netting, water quality sample sites	Spring & autumn (formerly each year, now converted to 3-4 year intervals)	Indicators for water quality; habitat condition; monitoring change in face of salinisation, eutrophication & alien species (*Cyprinus carpio*) impacts
Common birds of marsh & woodland	Transects	Spring & autumn	Population trends, habitat use, habitat management
Butterflies & dragonflies	Transects	Every 10 days, spring & autumn	Population trends, habitat use, habitat management
Moths	Nightly light trapping	Spring & autumn	Population changes; species moving north (climate change); detect alien species
Coastal erosion	Beach profiles; pioneer vegetation monitoring; public use studies	Spring, summer & autumn (formerly annual now at 5 year intervals)	Public awareness; management actions; monitoring success of management actions
Marshland orchid *Anacamptis robusta*	Full census	Annually from early May, 1991-2010; monitoring now by local University (UIB)	Improve management for conservation priority species
Thymelaea velutina	Full survey; mapping; soil & vegetation associations	Spring 2008; repeat survey planned, 2018 – earlier if radical change noted	Provide knowledge of distribution, soil and habitat requirements for improved management; conservation priority species (endemism)
Fish	Inventory; trapping at sample sites; historical research from local contacts	Spring & autumn 2008; repeat surveys planned at 5-10 year intervals	Inventory; fish community changes; habitat & water quality issues, management; status of endemic form of *Gasterosteus*
Diatoms	Sample sites	Pilot study, 2011	Indicators for wetland habitat conditions, change (present & past)
Vegetation community recovery after fire	Random sampling with quadrats	Annually 1995-2004, then repeat surveys at 10-year intervals	Provide knowledge for habitat and rare plants management
Impacts of livestock in dune grassland	Random sampling with quadrats	Repeat surveys every 2-3 years	Monitor plant diversity in livestock exclusion zone; habitat management

Note: table indicates preferred time scales; the voluntary character of TAIB means that flexibility is needed to meet the availability of appropriate scientists. The data, however, are sufficient to determine trends and interactions between different parts of the ecosystem.

Table 6. Environmental monitoring activities undertaken by *Parc* staff
Tabela 6. Atividades de monitorização ambiental desenvolvidas pela equipa do Parque Natural.

Subject	Method	Frequency	Purpose
Water quality	Fixed sample sites	Monthly	Monitor eutrophication, salinisation; provide hard data for hydrological planning
Meteorology	Automatic Weather Station (see note 1)	Constant updates	Baseline information; reference for weather events, climate change etc.
Birds	Fixed point counts; waterfowl breeding productivity; mid-winter waterfowl survey; migration log	Daily observations; mid-winter count part of international wildfowl census	Population change; provide knowledge of distribution and habitat requirements for improved management; conservation priority species

Note 1: http://www.mallorcaweb.net/salbufera/meteo/davis_albufera.htm

Table 7. Submerged macrophyte and invertebrate indicators for the quality of the aquatic environment at s'Albufera de Mallorca.
Tabela 7. *Indicadores derivados de índices de macrófitos submersos e invertebrados para a avaliação da qualidade do ambiente aquático na Albufera em Maiorca.*

Species	Status	Indicator for	Parameters
		Flora	
Cymodocea nodosa	Potential colonist of coastal lagoons	Hypersaline conditions	Presence
Ceratophyllum demersum	Decreasing	Rehabilitation of freshwater	Re-colonisation of former sites
Lemna minor	Now restricted to areas on western border of Parc	Low salinity	Presence
Rorippa nasturtium-aquaticum	Restricted to Síquia des Polls	Oligohaline water	Presence
Typha domingensis	Dominant in some canals	Eutrophication	Presence in dense stands
Typha angustifolia	Abundant in some canals	Eutrophication	Presence in dense stands
Polygonum salicifolium	Good population, Siquia des Polls	Low phosphate levels	Presence
Sparganium erectum	Only certain recent record in *ses Veles* (outside *Parc*)	Mesotrophic water	Presence
		Algae: Chlorophyta	
Chaetomorpha	Widespread, increasing	Increased salinity combined with eutrophication	Presence and abundance; increased distribution
Enteromorpha intestinalis	Widespread on surface of water bodies	Eutrophication	Presence and dominance levels
Cladophora	Dominant in places	High phosphate/nitrate levels	Presence/abundance
Spirogyra	Abundant and widespread	Anoxic conditions	Presence/abundance
		Mollusca: Pelecypoda	
Rudicardium tuberculatum	Common and widespread in hypersaline waters	Hypersaline conditions, including through rising sea levels	Presence; colonisation of new areas
		Mollusca: Gastropoda	
Ovatella myosotis	Brackish water and salt marshes	Brackish conditions	Presence/abundance; increased distribution
Amnicola similis	In decline	Unpolluted waters	Distribution and abundance
		Crustacea: Cladocera	
Daphnia mediterranea	Freshwater but with tolerance of salinity exceeding 3.5 g/l	Saline intrusion	Presence
		Insecta:Lepidoptera	
Paraponyx stratiotata	Captures previously regular, now infrequent	Submerged macrophyte cover	Presence/abundance

studies. A system is now being developed to extend the information system to all biota. The initial task was to capture and bring to a central source the various and disparate sets of data held by the project. But the main objective from the very start was to provide a ready and immediate resource for the *Parc* and other associated parties to guide and enhance conservation management. A baseline capture of all biota recorded at s'Albufera has been achieved. The next stage is to complete the task of relating those data to issues such as status, ecology, conservation value and management needs through a quick and easy access system. Tables 8 and 9 present two examples of the types of information already available. The database uses a simple yes/no format for these criteria so the requisite species can be determined at a glance and extracted in report form. The database has allowance for a range of criteria (*e.g.* population trends, endemisms, indicator species, etc.), a number of which are still in development. The database is open and available for *Parc* staff and TAIB scientists who also act as moderators for others wishing to use the resource. Plans to make the database information more widely available through international platforms such as the MedWet Web Information System (MedWet, s/d) and the Europe-wide ALTER-Net (A Long-Term Biodiversity, Ecosystem and Awareness Research Network) (ALTER-Net, s/d) have been stymied so far through lack of manpower and financial means to achieve such a major task.

Table 8. Alien Species per Group recorded at s'Albufera, source TAIB Biodiversity Database.
Tabela 8. *Espécies invasoras registadas na Albufera, por Grupo. Fonte: TAIB Biodiversity Database.*

Group	*Biota*	*Exotics*	*% Exotics*
Higher Plants	714	9	1.26
Bryophytes	66		0
Algae	202		0
Fungi/Lichens	288		0
Bacteria	3		0
Birds	307	32	10.42
Mammals	28		0
Amphibia	2		0
Reptiles	13	6	46.15
Fish	39	2	5.13
Molluscs	118	1	0.85
Insects	1995	3	0.15
Arachnids	113		0
Centipedes	2		0
Crustacea	75	1	1.33
Rotifers	23		0
Other Invertebrates	45	1	2.22
TOTALS	**3890**	**55**	**1.41**

2.3.4. Outreach

TAIB's principal activity is to gather information which can advise and guide biodiversity conservation in the *Parc*. However, its remit extends beyond the *Parc* in many ways. Regionally, team members have been active in socio-economic studies of the catchment area (Royo *et al.*, 2010; Férriz, 2012, 2013), ecological studies in other protected areas of Mallorca and biodiversity studies in Menorca, Ibiza and Formentera (Honey *et al.*, 2003; Honey & Riddiford, 2003; Férriz *et al.*, 2006). Further afield, the training given to protected area managers has extended the reach of TAIB internationally. Indeed, TAIB team members have taken their capacity building and conservation management skills to various countries of sub-Saharan Africa and the southern and eastern rim of the Mediterranean. Much of the basis for this training derives from the key MedWet publication, *Monitoring Mediterranean Wetlands* (Tomàs-Vives, 1996). TAIB led a pilot study to test the monitoring framework and process (Riddiford & Mayol, 1996); and TAIB principal investigator, Nick Riddiford, acted as scientific editor for the publication.

The Biodiversity Catalogue (Riddiford, 2002) was another means of meeting an original objective: to afford material for application in further research and reserve management. These technical documents were followed by publications designed to help members of the general public get the most out of their visit: a guide to the plants of the *Parc*'s tracks, marsh and meadows (McLennan & Newbould, 2003); guides to the common birds of s'Albufera (Owens, 2007; Owens & Vicens, 2009) and to the common butterflies and dragonflies of the *Parc* (TAIB, in prep.). The plant guide was innovative in its approach, using colour and symbols but minimum text, thus making the guide accessible to all nationalities irrespective of language. Most important of all, the guides are aimed at the non expert, although the plant guide particularly is used by expert botanists as well.

Publications are expensive, so TAIB has turned to the internet for dissemination, education and public awareness. A great deal of non-technical as well as technical information is available on TAIB's website (TAIB, 2014); and in 2012 members of the scientific team established a website (Associació TAIB, 2014) whose primary aim is to make the general public aware of moths and butterflies as part of an ecosystem shared by humans and influenced by human activities. The site uses Lepidoptera to demonstrate how small adjustments by people, as well as bigger actions by society, can reduce negative impacts on the populations and well-being of these and other overlooked members of the ecosystem. The concept of conservation begins with the young. This project also includes some entertaining and informative posters specially designed for schoolchildren.

Mallorca has a very good environmental education system with teacher-naturalists operating in several protected areas including s'Albufera. Over the years, TAIB has worked closely

Table 9. Conservation Status of Birds per Order recorded at s'Albufera, source: TAIB Biodiversity Database.
Tabela 9. *Estatuto de conservação de Aves registadas na Albufera, por Ordem. Fonte: TAIB Biodiversity Database.*

Order	*Biota*	*Habitat Directive*	*Birds Directive*	*Spanish National Catalogue*	*Balearic Catalogue*
Anseriformes	35	14	2	3	
Apodiformes	3				
Caprimulgiformes	1				
Charadriiformes	66	18	16	3	2
Ciconiiformes	8		2	1	
Columbiformes	4	4			
Coraciiformes	4		1		
Cuculiformes	2				
Falconiformes	27		12	6	
Galliformes	7	1			
Gaviiformes	1				
Gruiformes	13	3	1	1	1
Passeriformes	105	7	1	7	
Pelicaniformes	12		7	3	
Phoenicopteriformes	2		1		
Piciformes	1				
Podicipediformes	4				
Procellariiformes	2		1	2	
Psittaciformes	5				
Strigiformes	5		1		
TOTALS	**307**	**47**	**45**	**26**	**3**

with the educators, responding to requests for material, information and advice and holding joint workshops with the educators and volunteers as part of the capacity building programme. It is a matter of pride to TAIB that a number of the teacher-naturalists from the Balearics have progressed through TAIB training as previous participant volunteers.

2.3.5. Feeding into wider local issues

Effective conservation management of s'Albufera requires the involvement and cooperation of a range of stakeholders, both within and outside the *Parc*. Tourist developments and agricultural systems immediately outside the Parc boundaries have human and environmental implications for the management of the Parc's ecosystems and biodiversity (Veraart, 1999; Veraart *et al.*, 2004; Férriz, 2010, 2012). Interacting with stakeholders is therefore a major part of the *Parc* Directorate's work. This is achieved through its *Junta Rectora* but also through regular communication. TAIB's contribution was originally indirect, providing comments, advice and recommendations which were then pursued by the *Parc* or the *Conselleria*. However, TAIB has taken an increasingly pro-active role as knowledge and experience evolved. This has been achieved through Project Open Days, involvement in the *Parc's* own Activity days, cooperative links with the local conservation NGO (Grup Balear de Ornitologia i Defensa de la Naturalesa, GOB), the University of the Balearic Islands, the Mediterranean Institute for Advanced Studies (IMEDEA) and other bodies;

and, since 2009, TAIB has direct representation on the *Junta Rectora*, currently Laura Royo of Associació TAIB.

The project has also sought the comments and opinions of a range of key stakeholders and administrative bodies on specific, conservation management related issues. This was first achieved through the activities of the Wageningen Masters students whose focus on various elements of the Parc's functions and values necessarily took into account wider catchment issues (*e.g.,* Borggreve, 1997; van der Perk, 1997; Feenstra, 1998; Veraart, 1999; Cathala *et al*., 2002; and see de Groot, 1992 and de Groot *et al*., 2002 for the functions and values concept approach). Whereas team TAIB is limited in what it can achieve during fieldwork sessions, members of the locally established Associació TAIB have taken the lead in a series of initiatives to engage with local stakeholders. In the coastal zone, Royo used TAIB team members in a dune restoration programme which included interviewing tourists about their use of the beach and their views on actions to protect dune erosion, whilst the same study worked with the various coastal management agencies to initiate appropriate restoration measures (Traveset *et al*. 2006). Stakeholders played an integral part in the information gathering process for TAIB studies on the agricultural systems and tourism developments immediately outside the *Parc* boundaries (Veraart, 1999; Whittingham, 1999; Stuip, 2001; Veraart *et al*., 2004; Royo *et al*., 2010; Férriz, 2012, 2013) which have impacts on the ecology of the *Parc* and, by association, the *Parc* biodiversity. TAIB specialists in hydrology and aquatic ecology participated in catchment, regional and national meetings discussing implementation of the EU's Water Framework Directive; and have acted as consultants for the currently evolving catchment-wide hydrological plan.

Seeking the views of local stakeholders was an important element of Associació TAIB's multi-criterial ecosystem services assessment of the area (Royo *et al*., 2010). The assessment was accompanied by recommendations for future sustainability of the *Parc* and its adjacent area and was undertaken to provide the *Parc* with the socio-economic background it will need to prepare a future *Pla d'Ordenació de Recursos Naturals* (Natural Resource Plan). In another study, Férriz (2012) undertook a socio-ecological diagnosis of the *Pla de sa Pobla* (Sa Pobla Plain) agricultural zone, which incorporated interviews with experts, key people from the town of Sa Pobla and many of the people working in local agriculture. The main objective was to capture the relationship between agriculture and natural resources conservation in order to establish the main causes of negative impacts and seek common ground for means of resolution which change these to positive.

Consultation with stakeholders brings with it an environmental awareness element. This is an ongoing conversation towards a land management system which addresses the role of farmers and other stakeholders in good stewardship of natural resources and the landscape. Such a utopic goal will not be achieved overnight but the engagement process has already produced some interesting responses. As part of a study into changes in the fish community of s'Albufera (Riddiford & Fernández, 2009), a workshop was organised in a local town with fishermen who had traditionally fished in the wetland. They were not only extremely helpful in providing a historical perspective to fish population changes, particularly for eels *Anguilla anguilla*, but delighted their opinion was sought. Team TAIB interactions with local people and visitors from elsewhere (*e.g.,* Traveset *et al*., 2006; Royo *et al*., 2010; Férriz, 2010, 2012, 2013) have revealed a keen interest in the well-being of s'Albufera and acknowledgements of the need to achieve an environmental balance.

3. DISCUSSION

3.1. Ecosystem services provided by the *Parc*

Increasingly, the perspective of the ecosystem services (Costanza *et al*., 1997) provided by the *Parc* to the local populace and to society in general has determined the direction of many of TAIB's studies, in particular assessing the impacts of human activities on these services. The initial intent was to provide the scientific data to guide the *Parc* management team in maintaining and enhancing the environmental qualities of the site. As the studies developed it became clear that the information accruing not only improved knowledge of ecosystem functioning, it also revealed a number of issues which went far beyond pure environmental concern. Using various groups of biota as indicators of the state of the ecosystem, it became evident that trends and changes were emerging (*e.g.* Veraart *et al*., 2004); and these had potentially serious impacts of environmental, social and economic relevance.

Environmental impacts on the *Parc* included the loss of biodiversity through eutrophication and changes in salinity levels. Nutrient intrusion from farmland, phosphates escaping from water purification plants, over abstraction of water from the aquifer all challenge the tolerance levels of biota adapted to pre-modernisation eras. These accumulating pressures induce changes in ecological processes and biodiversity in the wetland despite measures of protection and conservation.

These impacts highlight issues of wider concern. Nutrient intrusion indicates injudicious use of agricultural fertilisers. The crops use what they need and the excess is absorbed into the ground water (*e.g.,* Carton *et al*., 2008; Daniel *et al*., 1998). Chemicals are expensive and over-use is the equivalent of throwing money directly into the canals. It can also lead to raised nitrate levels in water taken for human consumption. Indeed, in Sa Pobla, the agricultural town to the west of the Parc, people avoid drinking it even though water from the aquifer is treated by an expensive inverse osmosis station that reduces nitrate levels in drinking water to the maximum 50 mg/l permitted by the European Water Framework Directive; they prefer to buy bottled water or drink from traditional wells in their houses (Férriz, 2012). Phosphate intrusion indicates that wastewater treatment plants built prior to the growth in tourism, and the summer population explosion which goes with it, are no longer fit for purpose.

The *Parc Natural de s'Albufera* is an important buffer between the sea and Mallorca's most productive farmland area. Expanding tourism and the intensification of agriculture place considerable pressure on freshwater resources. A freshwater deficit in the groundwater leads to an imbalance reflected in increasing salinity levels and gradual saline penetration inland from the coast. This process has major long-term implications for the local area and its socio-economic well-being (Royo *et al*., 2010)

The height of reeds *Phragmites australis* bordering the *Parc* canals, reaching 7 to 8 metres in places, is a clear indication of the role they play in absorbing nutrients entering the *Parc*. Nevertheless, a portion of the nutrient-rich water passes directly to the sea where it can impact on the important sea-grass *Posidonia oceanica* beds of the adjacent Alcudia Bay (Whittingham, 1999). Nutrients promote rapid growth of filamentous algae and phytoplankton, threatening the slow growing *Posidonia* through smothering and by reductions in light penetration. This is more than just an environmental issue. The *Posidonia* beds are a refuge and nursery area for commercial fish, are home to biota which provide an average of 70% of the sand for Balearic beaches (Rodríguez-Perea *et al*., 2000), create a buffer and re-cycle sand lost from beaches, and act as a brake to waves during onshore storms, thus protecting the beaches and coastline from erosion (McRoy & Helfferich, 1977; Duarte & Chiscano, 1999; Rodríguez-Perea *et al*., 2000; Traveset *et al*., 2006). Nutrient enrichment can lead to toxic plankton blooms (*e.g.* the red tides of the Po Delta and northern Adriatic), which is not a risk the tourism-based municipalities around Alcudia Bay should be willing to take (Facca *et al*., 2014; Fonda Umani *et al*., 1989; Zingone, 2010).

Most of the wetland area lies at 0 to 2 m above sea level. It is protected from inundation by a band of coastal dunes. These dunes line much of the bay but only a small portion has escaped development and been incorporated into the *Parc*. They are the last stronghold for an endemic plant and contain other key habitats, plants and animals (Férriz, 2009). But they also serve a socio-economic purpose as a buffer against inundations which would otherwise take the sea water well inland. The dunes have developed in three phases over the last 12,000 or so years, with the final stage still developing into the 20th century (Gelabert *et al*., 2002). That building phase ended with the growth of tourism, and erosion of the fore dune has reversed the process (Servera *et al*., 2009). The dunes are 500 m wide but losses of up to 2 m width during storms demonstrate the vulnerability of this buffer in the longer term.

An almost continuous band of prickly juniper *Juniperus oxycedrus macrocarpa* lines the fore dunes. Erosion of the dune face where it meets the sea has accelerated in recent years (Rico, L., unpublished). Without the presence of *Juniperus oxycedrus macrocarpa*, the extent of this erosion would have been even more severe. The roots of *Juniperus oxycedrus macrocarpa* function as a consolidating agent for the sand, for the establishment of other vegetation and for holding the dunes together (Muñoz-Reinoso, 2004). With their roots exposed, however, there is considerable dieback of this band (Férriz, 2009) and low capacity for recovery (Traveset *et al.* 2006). Prevention of further damage to this band is not only a conservation issue but has practical implications for the long-term maintenance of the dunes and beach.

Much of the problem lies with current management of the beach, which is tourism-orientated. Mechanical cleaning of the beach removes cast *Posidonia*, which would trap and retain the sand, also removes quantities of sand and changes the profile of the beach from undulating to smooth. The impact derived from tourist use has led to the *Posidonia* meadows retreating seawards (Whittingham, 1999). With *Posidonia* absent from shallow inshore waters, its role in the formation and protection of beach and dunes is much reduced. Some remedial measures have been taken recently but a full management programme would recognise the long-term importance to society of maintaining the dune system in good order (Traveset *et al*., 2006).

Implications for society in the region extend to the role of the *Parc* as a rain-fed infiltration and buffering area for freshwater. The *Parc* Directorate is very sensitive of the hydrological needs of the entire system and makes every effort to manage the hydrological balance (both groundwater and surface water) for the benefit of the entire region. The main management purpose is to maintain the natural Mediterranean pattern of gradual drying out during the summer months and recharge at other times of year. However, during periods of prolonged drought the *Parc* makes every effort to retain freshwater, aware that the aquifer extends inland to the agricultural land and beyond, whilst after heavy periods of rain it channels as much of the excess as it can directly to the sea to prevent or reduce inundations extending landwards into the periphery.

3.2. Socio-economic importance of the *Parc*

The socio-economic relevance of management, whether to prevent dune erosion or to maintain a healthy water balance, is often overlooked or is not even perceived (Royo *et al*., 2010). Such actions come under the umbrella of *ecosystem services*. Nature tourism is another ecosystem service which has considerable socio-economic value. The *Parc* registers between 55,000-65,000 visitors per year (2003-2009 *Parc* annual reports). That figure is an underestimate because studies have revealed that at least 40% do not report to reception to register. The actual figure is more likely to be in the range 105,000-120,000 (B. Perelló *pers. comm*., 2014).

Being close to a major tourist area, the *Parc* adds to the diversity of choice for tourists during the summer months – particularly during cloudy days when the beach seems less attractive; and visits are free! It is in spring and autumn that the value of this protected area is at its greatest. S'Albufera is famous throughout Europe and beyond amongst birdwatchers (Owens & Vicens, 2009; Rebassa *et al*., 2009). It is known as a "hot spot" for rare birds, for spectacular numbers and diversity. The best times are spring and autumn, when migrant birds add to the interest. The birdwatchers and other naturalists come then, bringing income to the area and, most importantly, extending the tourist season for the accommodation outlets and supporting services.

The *Parc* manages visitors effectively to ensure that they can view the birds well without causing disturbance to the wildlife. Management extends to creating the conditions and habitats that the birds require. Long-term monitoring is a necessary part of that process. It provides a cost-effective early warning system so that measures can be put in place to address problems for the benefit of the ecosystem generally and, consequently, the birds which draw so many visitors to s'Albufera and Mallorca.

The current economic monetary system is an inappropriate tool for measuring biodiversity because it fails to take into account non-market values (de Groot, 1992; Gowdy, 1997; Costanza *et al.*, 1997; de Groot *et al.*, 2002). This is a real challenge for biodiversity conservation. TAIB has identified a role in investigating more deeply the services that s'Albufera and its ecosystem contribute to human well-being in order to raise the profile of the non-market values of biodiversity, particularly in terms of public perception and awareness of the benefits these services bring.

3.3. Recent focus of monitoring and research

TAIB's biodiversity studies began as a data collecting exercise, concentrating on the most popular and better known groups. One such study, focusing on moths attracted to light, has turned into one of the longest monitoring studies in the Mediterranean. Research has revealed important populations of rare moths, such as *Pelosia plumosa* and *Eilema rungsi*, which are reliant on old reed beds. This habitat type is itself a rarity in the Mediterranean as reed beds are often kept in an early stage through burning and grazing. Studies of Odonata (dragonflies and damselflies) have also demonstrated the importance of habitat quality, and generated conservation management recommendations for this attractive insect group (Sato & Riddiford, 2008).

In recent years studies have extended to other groups including flies (Diptera), bees and wasps (aculeate Hymenoptera) and aquatic beetles (Coleoptera). This has led to many exciting discoveries and expansion of knowledge for poorly studied groups in the western Mediterranean. For instance, the Diptera studies added 330 species to the Balearic list in just one year, 99 of which were also additions to the Iberian list published by Carles-Tolrá (2002); sixteen of these were from a single family, Chloropidae (Ebejer, 2006). New fauna for Europe include several moth species, most notably males of a species previously known only from females in West Africa (Fibiger & Agassiz, 2001), and the aquatic beetle *Cyphon lindbergi* (Foster & Riddiford, 2011). A bat, *Pipistrellus pygmaeus,* now known to be commonplace, was confirmed as new to Mallorca (Green & Riddiford, 2009). A lot of publicity has been given to the role of bees and their allies as pollinators in light of recent global declines. The hymenopteran studies have revealed the importance of s'Albufera for this group. The list of aculeates currently stands at over 200, including the re-discovery of the Mallorcan endemic *Miscophus belveriensis*, not seen since it was described in 1960 (Baldock, 2014).

3.4. Alien species

A number of additions will be naturally occurring species previously overlooked. However, an increasing number can be considered newcomers to Mallorca. These fit into two categories: species moving north from Africa and introduced species.

Many of the species moving north are from North Africa but others probably arrive from farther south. These arrivals often coincide with spells of Saharan dust falling on Mallorca; Honey *et al.* (2007) postulated that they are swept up by rapidly rising air in extreme conditions of heat south of the Sahara and carried northwards on the consequent winds. Thus their arrival may have been through inadvertent rather than intentional migration. This type of arrival relates to a singular climate event but the continued arrival, sometimes in increasing numbers, of others may be the result of expanding populations related to climate change.

This has implications for society. Names such as the Egyptian bollworm (*Earias insulana*), African cotton leafworm (*Spodoptera littoralis*) and maize wainscot (*Sesamia nonagrioides*) highlight the risks some of these biota could hold for agriculture north of the Mediterranean.

TAIB's long-term light trapping programme has detected an alarming growth in the occurrence and numbers of introduced species. The tomato leaf miner *Tuta absoluta* challenged our identification skills when first caught in 2008 but by November 2013 was consistently the commonest moth in the trap. A similar pattern was recorded for the citrus flatid planthopper *Metcalfa pruinosa*. The tomato leaf miner originates from South America and can devastate tomato crops (Desneux *et al.*, 2010; van der Straten *et al.*, 2011). *Metcalfa* is from North America where it causes problems amongst fig, grape, citrus and other fruit crops (Bagnoli & Lucchi 2000; Pons *et al.*, 2002). In 2011 TAIB caught the first harlequin ladybird *Harmonia axyridis* for the Balearic Islands. In 2013 it caught three more – in one night. This beetle, originally from eastern Asia, can do enormous damage as it emits a distasteful liquid which taints fruit and wine and, when large numbers overwinter in houses, can drive the occupants out with the same noxious smell (Koch, 2003; ISC, s/d).

The IUCN recognises invasive species as the second most important cause of biodiversity loss after habitat destruction (CBD, s/d). Invasive species have also been identified as one of the leading and most rapidly growing threats to food security and animal health (ISSG, s/d). All administrations and especially those of islands should be aware of the potential dangers of introductions not just for the biodiversity – which on small islands often includes important endemisms – but also for the unforeseen social and financial impacts on their citizens.

3.5. Preparing future managers and communicators

For administrations to act, they must know about the consequences and the steps required to put things right. TAIB annual reports take on the responsibility of making this information available by detailing the issues and their risks; and by making recommendations regarding the measures required to manage those risks. These annual reports, complete with the recommendations, are also made available to the public at large through TAIB's website (TAIB, 2014).

This is just the beginning of the dissemination process. Communication needs communicators: this is where the capacity building aspect dovetails comfortably with the field science. By 2012 participants had taken part from 50 countries. For all, it was an introduction to the value of knowledge, as a continuous process, not just in protected area management but in conveying that information to others.

The courses seek to instil in the participants a confidence in the application of field methodologies and other biodiversity conservation measures, skills which they can take back to their own area or country. But the dissemination element is never lost from view. TAIB's success in this area was demonstrated during a course focused entirely on the practicalities of environmental education, set up for educators from the Cape Verde Islands. The course included workshops with staff from the various environmental education outlets active in Mallorca, governmental and independent; it was noteworthy that a large proportion had passed through a TAIB capacity building course prior to entering into the environmental education system.

TAIB's policy of integrating local volunteers into the training process has seen impressive dividends. A stream of young Balearic and Spanish post graduates has passed through the project. A considerable number are now working in conservation and the environment, including at the international level, and making a difference in safeguarding the natural world. Many of the personnel now working in Balearic conservation circles had their first environmental training experience with TAIB.

This mix of local people with those from abroad, and students still to graduate with those already involved in conservation management, works extremely well; and it extends to TAIB's scientific team. A team that was largely British in 1989 is now a mix of international experts and talented home-grown scientists from the Balearic Islands and mainland Spain who have graduated from University and from the capacity building experience with TAIB. These graduates came with large amounts of enthusiasm and willingness to learn but were generally inexperienced and without in-depth knowledge of environmental field research. One of the greatest satisfactions for the scientific team, and one which has drawn members to return time and again, has been to witness these graduates build their capacity and skills: a number are now experts in their own right.

Some have joined the scientific team, making TAIB a balanced combination of local and international expertise. This integrated approach has revolutionised knowledge of the *Parc*'s important wetland and dune ecosystems; and of the rich biodiversity of the *Parc* and its adjacent catchment. Incorporating local scientists has many benefits, not least the availability of local team members to undertake studies or collect data at times of the year outside the fieldwork periods. Most important of all, it establishes a local identity for the project.

3.6. Citizen science

The use of volunteers to help the information gathering process for biodiversity conservation has a long tradition. Bodies such as the British Trust for Ornithology have organised national surveys and monitoring schemes for more than 70 years (BTO, s/d) and countless other national organisations now do the same (*e.g.,* Vliet *et al.*, 2013). Protected areas too work increasingly with volunteers for specific tasks, including routine monitoring (*e.g.,* RSPB, 2014; SEO, s/d). Volunteers also participate in regional and site specific environmental data gathering tasks, but normally restricted to a narrow, easy to recognise suite of biota such as birds, butterflies or moths (*e.g.,* AEN, 2009). In this way, once basic skills have been taught, surveys can be conducted with minimum involvement and intervention by scientists. There is evidence of greater scientist commitment to the volunteer sector in recent years (*e.g.,* NHM, s/d). Models also exist for capacity building in environmental management (Costa *et al.*, 2013; Echevarría *et al.*, 2013) though few base the training module in the field rather than mostly in the classroom or workshop.

TAIB Project S'Albufera remains novel in both its approach and its extent. It does not need to stand alone. The visionary Max Nicholson, initiator of major international conservation bodies such as the World Wide Fund for Nature (WWF, 2003), intended s'Albufera to be the forerunner of a concept which he hoped would be extended to protected areas throughout the world. The test of his concept has been this project and is described here in the hope that others will derive inspiration from it.

4. CONCLUSIONS

The aim of this paper is to put forward a cost effective integrated participative model for collecting the data required to support environmental management in a protected area. It also demonstrates the absolute need for long-term studies to understand the ecosystem, how it functions and the wider implications for society. This model has particular resonance as many of the issues and impacts will be recognised as common to protected areas generally.

TAIB's Project S'Albufera has achieved an enormous amount at low cost. From the very start the project has relied heavily on the volunteer sector. For a project to survive over a long period of time, some administrative funding is required. In the case of TAIB, funding has met various expenses, including equipment and materials; and to pay an honorarium to an administrator working part-time. The administrator responsibility demands planning and organisational time outside the fieldwork and capacity building sessions, amounting in the current case to approximately three months per annum. This is an important point to take into account. Very few people would be able to commit to such a time scale and such sustained administration commitment without monetary justification. Without this incentive, similar projects are likely to falter.

Evaluation of the cost effectiveness of such a project should not overlook the hidden values the programme provides for society. Some of TAIB's findings are described in detail above in order to reveal those hidden values. The paper uses a number of examples to flag up social and economic impacts. These need to be known and taken into account by planners, including government, to avoid negative and costly future outcomes. The economic value of long-term monitoring as an early warning system far outweighs the modest costs. The financial cost to society of inaction could run into millions.

The issues raised here are particularly relevant to island situations, but have wider implications too – especially for the Mediterranean. It is generally accepted in conservation management that planning should be based on knowledge.

Long-term studies at s'Albufera indicate that this should extend to land use and other economic planning as well. TAIB catchment socio-economic studies indicate that local people are essential to the planning process and their inclusion promotes a concept of shared responsibility and stewardship in caring for the natural environment.

Short-term studies are the norm and long-term studies a rarity in the environmental conservation world. This is partly because short-term studies are "affordable" because they are short - no more than three years and often less - and partly because the value of long-term studies is not yet appreciated. This paper challenges that perception. The information and knowledge which TAIB has accumulated over the years would not have materialised in a short time-span.

In 2013, TAIB had to survive without funding. The project had fallen victim of the European financial crisis, which is particularly severe in Spain. But is this a false economy? Indeed it is, not just for the project but also for long-term studies. *The Albufera Initiative for Biodiversity* is a 25-year old model which demonstrates the social, economic and environmental benefits of knowledge and the potential costs of management without it. A lot can be achieved for a little outlay: better to spend low now than expensive later.

ACKNOWLEDGEMENTS

We gratefully acknowledge the Balearic *Conselleria de Medi Ambient* and Directorate of the *P.N. s'Albufera de Mallorca* for their support and permission to operate in the *Parc*; the various funding agencies and other practical supporters of TAIB, especially Mrs Pat Bishop and family; the specialist advisors who have helped with identifications and other scientific input free of charge; and, above all, the numerous scientists and volunteers whose generous commitment has sustained the project over the last 25 years. We also thank the paper's referees for their contribution towards improving the initial draft. The catalyst for the entire venture was the far-sighted environmentalist Max Nicholson, 1904-2003.

REFERENCES

Abma, J. (2008) - *The moth and the climate. The effects of climate change on Lepidoptera species in s'Albufera de Mallorca*. 46p., Internship Report, Biology Masters, Entomology Group, Wageningen University, Wageningen, Netherlands.

Adger, W.N.; Eakin, H.; Winkels, A. (2009) - Nested and teleconnected vulnerabilities to environmental change. *Frontiers in Ecology and the Environment,* 7:150-157. DOI: 10.1890/070148

AEN (2009) - *Programa de seguiment de papallones diürnes a Mallorca (BMS-Mallorca)*. Associació per a l'Estudi de la Natura, Mallorca, Spain. http://www.aen.cat/projecte.php?id=13 .

ALTER-Net (s/d) – *ALTER-Net: A Long-Term Biodiversity, Ecosystem and Awareness Research Network.* Europe's biodiversity, ecosystem and ecosystem services research network. http://www.alter-net.info

Andrew (2011) - Too many people: Mallorca's population. *In*: *Alcudia Pollensa.* 2p. http://alcudiapollensa.wordpress.com/2011/01/07/too-many-people-mallorcas-population.

Associació TAIB (2012) - *Web dels papaions de Mallorca*. Associació Trebellam per s'Albufera iles Illes Balears. www.papaionsdemallorca.info

Bäckstrand, K. (2004) - Civic Science for Sustainability: Reframing the Role of Experts, Policy-Makers and Citizens in Environmental Governance. *Global Environmental Politics*, 3(4):24-40. DOI: 10.1162/152638003322757916

Bagnoli, B.; Lucchi, A. (2000) - Dannosità e misure di controllo integrate. *In*: Lucchi, A. (Ed.), *La metcalfa negli ecosistemi italiani*. pp.65-88, ARSIA Regione Toscana, Italy. ISBN: 978-8882950170.

Baldock, D. (2014) - A provisional list of the wasps and bees of Mallorca, Balearic Islands, Spain (Hymenoptera aculeata: Chrysidoidea, Scolioidea, Vespoidea, Apoidea). *Entomofauna*, 35:333-404.

Barceló, B.; Mayol, J. (coord.) (1980) - *Estudio Ecologico de la Albufera de Mallorca*. 406p., ICONA, Departamento de Geografia, Universidad de Palma de Mallorca, Spain.

Borggreve, C. (1987) - *Biodiversity conservation in S'Albufera Natural Park, an analysis of main relevant functions, (potential) land-use conflicts and related policies.* 38p., Graduate thesis, Centre for Environment and Climate Studies and Department of Terrestrial Ecology and Nature Conservation, Wageningen Agricultural University, Holland. *Unpublished*.

BTO (s/d) - *Volunteer surveys*. British Trust for Ornithology. *In*: http://www.bto.org/volunteer-surveys.

Candela, L.; von Igel, W.; Javier Elorza, F.; Aronica, G. (2009) - Impact assessment of combined climate and management scenarios on groundwater resources and associated wetland (Majorca, Spain). *Journal of Hydrology*, 376(3-4):510-527. DOI: 10.1016/j.jhydrol.2009.07.057

Carles-Tolrá, M. (coord.) (2002) - *Catálogo de los Diptera de España, Portugal y Andorra (Insecta)*. 323p., Monografías de la Sociedad Entomológica Aragonesa, Vol. 8, Zaragoza, Spain. ISBN: 84-93280704.

Carton, O.T.; Tunney, H.; Daly, K.; Ryan, M.; Kurz, I.; Doody, D.; Bourke, D.; Kiely, G.; Morgan, G.; Moles, R.; Jordan, P.; Ryan, D.; Irvine, K.; Jennings, E.; Magette, W.L.; Bruen, M.; Mulqueen, J.; Rodgers, M.; Johnston, P.; Bartley, P. (2008) - *Eutrophication from Agricultural Sources: Integrated Report*. EPA STRIVE Programme 2007-2013, Environmental Protection Agency, Co. Wexford, Ireland. Available at http://epa.ie/pubs/reports/research/water/ERTDI%20Report%2081_Web.pdf

Cathala, B.; Ducos, G.; Karatzos, S. (2002) - *Integrated assessment of water use, water policies and water management in the Inca-Sa Pobla catchment area (Mallorca) and analysis of selected management strategies in agriculture*. 42p., MSc Thesis, Environmental Systems Analysis Group, Wageningen University, Netherlands. *Unpublished*.

CBD (s/d) - *Invasive Alien Species*. Convention on Biological Diversity. http://www.cbd.int/invasive.

Costa, S.; Pardal, M.A.; Azeiteiro, U.M. (2013) - The use of an Estuarine System (Mondego estuary, Portugal) as Didactic Tool to incorporate Education for Sustainable Development into School Curricula. *Journal of Integrated Coastal Zone Management*, 13(2):243-251. DOI: 10.5894/rgci417

Costanza, R.; d'Arge, R.; de Groot, R.; Farber, S.; Grasso, M.; Hannon, B.; Limburg, K.; Naeem, S.; O'Neill, R.; Paruelo, J.; Raskin, R.; Sutton, P.; van den Belt, M. (1997) - The value of the world's ecosystem services and natural capital. *Nature* (ISSN 0028-0836), 387(6630):253-260. Available at http://www.esd.ornl.gov/benefits_conference/nature_paper.pdf

Daniel, T.C.; Sharpley, A.N.; Lemunyon, J.L. (1998) - Agricultural Phosporus and Eutrophication: A Symposium Overview. *Journal of Environmental Quality* (ISSN 1537-2537), 27(2):251-257. DOI: 10.2134/jeq1998.00472425002700020002x

de Groot, R. S. (1992) - *Functions of Nature: evaluation of nature in environmental planning, management and decision making*. 315p., Wolters-Noordhoff, Amsterdam. ISBN: 9001355943.

de Groot, R. S.; Wilson, M. A.; Boumans, R. M. (2002) - A typology for the classification, description and valuation of ecosystem functions, goods and services. *Ecological Economics*, 41(3):393-408. DOI: 10.1016/S0921-8009(02)00089-7

Desneux, N.; Wajnberg, E.; Wyckhuys, K.A.G.; Burgio, G; Arpaia, S.; Narváez-Vasquez, C. A.; González-Cabrera, J.; Catalán-Ruescas, D.; Tabone, E.; Frandon, J.; Pizzol, J.; Poncet, C.; Cabello, T.; Urbaneja, A. (2010) - Biological invasion of European tomato crops by *Tuta absoluta*: ecology, geographic expansion and prospects for biological control. *Journal of Pest Science* (ISSN 1612-4766), 83(3):197-215. DOI: 10.1007/s10340-010-0321-6

Duarte, C.M.; Chiscano, C.L. (1999) - Seagrass biomass and production: a reassessment. *Aquatic botany*, 65(1-4):159-174. DOI: 10.1016/S0304-3770(99)00038-8

Earthwatch Europe (1991) - *Project S'Albufera. A new model for environmental research.* 44p., Earthwatch Europe, Oxford, United Kingdom.

Ebejer, M.J. (2006) - Some Chloropidae (Diptera) from the Balearic Islands (Spain) with particular reference to Parc Natural de s'Albufera de Mallorca. *Bolletí de la Societat d'Història Natural de les Illes Balears* (ISSN 0212-260X), 49:173-184, Palma de Mallorca, Spain. Available at http://ibdigital.uib.cat/greenstone/collect/bolletiHistoriaNaturalVolums/index/assoc/Bolleti_/2006v049.dir/Bolleti_2006v049.pdf

Echevarría, L.; Gómez, A.; Piriz, C.; Quintas, C.; Tejera, R; Conde, D. (2013) - Capacity building for local coastal managers: a participatory approach for Integrated Coastal and Marine Zones Management in Uruguay. *Journal of Integrated Coastal Zone Management*, 13(4):1-18. DOI: 10.5894/rgci402

Facca, C.; Bilaničovà, D.; Pojana, G.; Sfriso, A.; Marcomini, A. (2014) - Harmful Algae in Venice Lagoon and in Po River Delta (Northern Adriatic Sea, Italy). *The Scientific World Journal*, 2014: art. ID 806032. DOI: 10.1155/2014/806032

Feenstra, B. J. (1998) - *Economic importance of the Parc Natural de s'Albufera*. 47p., MSc Thesis, Wageningen Agricultural University, Holland. *Unpublished*.

Férriz, I. (2009) - Distribution of the populations of *Thymelaea velutina* and *Juniperus oxycedrus* subspecies *macrocarpa* in the dunes of Es Comú, PN de s'Albufera, Mallorca. *In:* Nick Riddiford & Macu Férriz (eds.), *TAIB Project S'Albufera: A Mediterranean model for the study of biodiversity and environmental change.* The Albufera International Biodiversity Project Annual Report 2008, pp. 138-149, Mallorca, Spain. Available at http://www.taib.info/download/fieldwork-reports/TAIB-Report-2008.pdf

Férriz, I. (2010) - La potencialitat de l'ús públic d'Es Comú d'Abaix, PN de s'Albufera. Una primera aproximació a la seva anàlisi. *In:* Nick Riddiford & Macu Férriz (eds.), *TAIB Project S'Albufera: A Mediterranean model for the study of biodiversity and environmental change.* The Albufera International Biodiversity Project Annual Report 2009, pp. 112-186, Mallorca, Spain. Available at http://www.taib.info/download/fieldwork-reports/TAIB-Report-2009.pdf

Férriz, I. (2012) - *Diagnóstico socio-ecológico de la Plana de sa Pobla-Muro, Mallorca. Buscando el camino hacia la sustentabilidad*. 96p., Master's thesis, Universidad Pablo de Olavide & Universidad Internacional de Andalucía, Spain. *Unpublished*.

Férriz, I. (2013) - Inventari de la biota asociada a ses aigües de ses Veles d'es camí de son Fornari. *In:* Nick Riddiford (ed.), *TAIB Project S'Albufera: A Mediterranean model for the study of biodiversity and environmental change.* The Albufera International Biodiversity Project Annual Report 2012, pp. 25-50, Mallorca, Spain. Available at http://www.taib.info/download/fieldwork-reports/TAIB-Report-2012.pdf

Férriz, I.; Herrero, C. (2012) - *Les papallones nocturnes com a indicadors del canvi climàtic al Parc Natural de s'Albufera*. Commissioned report to Govern de les Illes Balears & Obra Social "La Caixa". Associació TAIB, Parc Natural de s'Albufera de Mallorca. *Unpublished*.

Férriz, I.; Honey, M.R.; Riddiford, N.J. (2006) - Els Heteròcers del Parc Natural de ses Salines d'Eivissa i Formentera (Illes Balears). *Bolletí de la Societat d'Història Natural de les Illes Balears* (ISSN 0212-260X), 49:199-211, Palma de Mallorca, Spain. Available at http://ibdigital.uib.cat/greenstone/collect/bolletiHistoriaNatural/index/assoc/Bolleti_/2006v049/p199.dir/Bolleti_2006v049p199.pdf

Fibiger, M.; Agassiz, D. (2001) - *Araeopteron ecphaea*, a small noctuid moth in the West Palearctic (Noctuidae: Acontiinae). *Nota Lepidopterologica* (ISSN 0342-7536), 24(1/2):29-35, Societas Europaea Lepidopterologica, Innsbruck, Austria. Available at http://ia601600.us.archive.org/4/items/notalepidoptero242001soci/notalepidoptero242001soci.pdf

Fonda-Umani, S.; Ghirardelli, E.; Specchi, M. (1989) - *Gli episodi di "mare sporco" nell'Adriatico dal 1729 ai giorni nostri*. 178p., Regione Autonoma Friuli-Venizia Giulia, Direzione Regionale Dell'ambiente, Trieste, Italy.

Forcades, A.; Martorell, O. (2003) - *Situación actual y perspectivas del turismo en las Illes Balears Bases para una contribución a la reflexión sobre su futuro*. 42p., Cercle de Comerç & Cambra d'Economia de Mallorca, Spain. Available at http://www.cambramallorca.com/documentos/Desp_324.pdf

Foster, G.N.; Riddiford, N.J. (2011) - *Cyphon lindbergi* Nyholm (Col., Scirtidae) New for Europe. *Entomologists'*

Monthly Magazine (ISSN: 0013-8908). 147:47-48, Pemberley Books, Iver, U.K..

Gabinet d'Anàlisi Ambiental i Territorial (2011) - *Estudi de delimitació cartogràfica i*
recuperació des ullals de s'Albufera de Mallorca. 149p., Conselleria d'Agricultura, Medi Ambient i Territori, Palma de Mallorca, Spain. *Unpublished*.

Galimont, A.; Candela, L.; Barón, A.; González, C. (2003) - Evolución de la intrusión salina en el llano de Inca-Sa Pobla, Mallorca. *In:* J. A. L. Geta, J. A. de la Orden, J. D. Gómez, G. Ramos, M. Mejías & L. Rodriguez, *Tecnología de la intrusión de agua de mar en acuíferos costeros: Países Mediterráneos I*. IGME, Madrid, Spain. ISBN: 8478404708. Available at http://aguas.igme.es/igme/publica/tiac-01/Area%20V-12.pdf

Gelabert, B.; Servera, J.; Rodríguez-Perea, A. (2002) - Características geomorfológicas del sistema dunar de la Bahía de Alcúdia (Isla de Mallorca). *Geogaceta* (ISSN 0213-683X). 32:215-218, Sociedad Geológica de España, Salamanca, Spain. http://www.sociedadgeologica.es/archivos/geogacetas/Geo32/Art54.pdf

Green, R.; Riddiford, N.J. (2010) - A new species of bat (*Pipistrellus pygmaeus*) confirmed for Mallorca. *Le Rhinolophe* (ISSN: 1011-8098), 18:31-36, Muséum d'Histoire Naturelle de Genève, Genève, Switzerland.

Gowdy, J.M. (1997) - The Value of Biodiversity: Markets, Society, and Ecosystems. *Land Economics* (ISSN: 0023-7639), 73(1):25-41, University of Wisconsin, Madison, WI, U.S.A..

Hof, A.; Blázquez-Salom, M. (2013) - The Linkages between Real Estate Tourism and Urban Sprawl in Majorca (Balearic Islands, Spain). *Land*, 2(2):252-277. DOI: 10.3390/land2020252

Honey, M.R.; Férriz, I.; Riddiford, N.J. (2007) - Additional evidence supporting the migration of *Cornifrons ulceratalis* Lederer (Lep.: Crambidae, Evergestinae) in the Mediterranean region in October 2006. *Entomologist's Record & Journal of Variation* (ISSN: 0013-8916), 119(5):237-238, Amateur Entomologists' Society, London, U.K.

Honey, M.R.; Orfila, M.; Riddiford, N.J. (2003) - Moths of s'Albufera des Grau and Illa d'en Colom (Menorca). *Buttletí científic dels Espais naturals protegits de les Illes Balears* (ISSN: 1696-0009), Series 3, 1:19-21, Conselleria de Medi Ambient, Palma de Mallorca, Spain.

Honey, M.R.; Riddiford, N.J. (2003) - Moth fauna (Lepidoptera: Heterocera) of s'Albufera de Mallorca and other areas of the Balearic Islands – towards an up-dated check list of the Lepidoptera. *Buttletí científic dels Espais naturals protegits de les Illes Balears* (ISSN: 1696-0009), Series 3, 1:35-39, Conselleria de Medi Ambient, Palma de Mallorca, Spain.

IBESTAT (2014) - *Turistas con destino principal las Illes Balears por periodo, isla y país de residencia*. Institut d'Estadística de les Illes Balears (IBESTAT). *In*: https://www.caib.es/ibestat/estadistiques/043d7774-cd6c-4363-929a-703aaa0cb9e0/ef88f7cf-8e0b-44e0-b897-85c2f85775ec/es/I208002_3001.px

INE (2014) - *Series de población desde 1996. Cifras oficiales de la Revisión anual del Padrón municipal a 1 de enero de cada año. Detalle municipal: Illes Balears*. Instituto Nacional de Estadística (INE), Madrid, Spain. *In*: http://www.ine.es/jaxiBD/tabla.do?per=12&type=db&divi=DPOP&idtab=9

ISC (s/d) - *Searching*. Invasive Species Compendium. *In*: http://www.cabi.org/isc/

ISSG (s/d) - *Biological invasions: a growing threat to biodiversity, human health and food security*. Invasive Species Specialist Group (ISSG), Species Survival Commission (SSC) of the International Union for Conservation of Nature (IUCN). *In*: http://www.issg.org/pdf/riopolicybrief.pdf

Koch, R.L. (2003) - The multicolored Asian lady beetle, *Harmonia axyridis*: A review of its biology, uses in biological control, and non-target imacts. *Journal of Insect Science* (ISSN 1536-2442) 3: 1-16, Entomological Society of America, Annapolis, MD, U.S.A.. Available at insectscience.org/3.32

Martínez, A.; Mayol, J. (eds.) (1995) - *S'Albufera de Mallorca*. 227p., Monografies de la Societat d'Historia Natural de les Illes Balears, Vol. 4. Editorial Moll , Palma de Mallorca, Spain. ISBN: 8427365063.

Martínez, A. (1988) - *Caracteristiques limnologiques de s'Albufera de Mallorca.* 708p., Doctoral Thesis, Departament de Biologia, Universitat de les Illes Balears, Palma de Mallorca, Spain. *Unpublished*.

McLennan, D.; Newbould, J. (2003) - *Albufera de Mallorca Parc Natural: Guía de les Plantes; Plants of Paths, Marsh and Meadows*. 176p., Pisces Publications, Oxford, UK. ISBN: 1874357242.

McRoy, C.P.; Helfferich, C. (1977) - *Seagrass ecosystems: A Scientific Perspective*. Marcel Dekker, New York, EEUU. ISBN: 0824764595.

MedWet (s/d) - *MedWet Web Information System*. www.wetlandwis.net

Mitsch, W.J.; Gosselink, J.G. (1993) - *Wetlands*. 722p., Van Nostrand Reinhold, New York. ISBN: 0442008058.

Moore, B.; Underdal, A; Lemke, P.; Loreau, M. (2001) - Amsterdam Declaration on Earth System Science. 2p. *In*: *Challenges of a Changing Earth: Global Change Open Science Conference, Amsterdam the Netherlands 10-13 July 2001*. International Geosphere-Biosphere Programme (IGBP), International Human Dimensions Programme on Global Environmental Change (IHDP), World Climate Research Programme (WCRP) and International biodiversity programme (DIVERSITAS). http://www.igbp.net/about/history/2001amsterdamdeclarationonearthsystemscience.4.1b8ae20512db692f2a680001312.html

Muñoz-Reinoso, J.C. (2004) - Diversity of maritime juniper woodlands. *Forest Ecology and Management*, 192(2-3):267-276. DOI: 10.1016/j.foreco.2004.01.039

Newbould, P.J.; Riddiford, N.J. (1990) - *Monitoring for Global Change: The Earthwatch Europe S'Albufera Project*. 80p., Earthwatch Europe, Oxford. Available at http://www.taib.info/download/fieldwork-reports/TAIB-Report-1989.pdf

NHM (s/d) - *Volunteering*. Natural History Museum, London, UK. *In*: http://www.nhm.ac.uk/about-us/jobs-volunteering-internships/volunteering-interns-information/index.html

Owens, N. (2007) - *Guide to the birds of s'Albufera Natural Park*. 96p., TAIB and Parc Natural de s'Albufera, Mallorca, Spain. Available at http://www.taib.info/download/guies/guide-to-the-birds-of-albufera-natural-park-mallorca-2007-en.pdf

Owens, N.; Vicens, P. (2009) - *Guia dels aucells del Parc Natural de s'Albufera de Mallorca*. 96p., Conselleria de Medi Ambient, Illes Balears, Spain. Available at http://www.mallorcaweb.net/gps/docs/guia_albufera_owens_vicens_2009.pdf

Perring, F.H.; Walters, S.M. (1962) - *Atlas of the British Flora*. 432p., BSBI, London.

Picornell, C.; Ginard, A. (1995) - John Frederic Latrobe Bateman. *In*: Martínez A.; Mayol, J. (eds.), *S'Albufera de Mallorca*. pp.39-46, Monografies de la Societat d'Història Natural de les Balears, Editorial Moll, Palma de Mallorca, Spain. ISBN: 8427365063. Available at http://www.mallorcaweb.net/gps/docs/bateman.pdf

Pons, X.; Lumbierres, B.; Garcia, S; Manetti, P.L. (2002) - *Metcalfa pruinosa* (Say) (Homoptera: Flatidae), ¿una plaga potencial de plantas ornamentales en espacios verdes urbanos de Cataluña? *Boletín de Sanidad Vegetal - Plagas* (ISSN: 0213-6910) 28(2):217-222, Ministerio de Agricultura, Alimentación y Medio Ambiente, Madrid, Spain. Available at http://www.magrama.gob.es/ministerio/pags/biblioteca/revistas/pdf_plagas/BSVP-28-02-217-222.pdf

Portero-Marti, C. (2004) - *Integrated Assessment of Grazing as a Management Tool in NP S'Albufera de Mallorca*. 65p., MSC Thesis in Environmental Sciences, Environmental Systems Analysis Group, Wageningen University, Holland. *Unpublished*.

Rebassa, M.; Machado, J.; Martínez, J.L.; Torrens, S.; Oriola, M.C. (2009) - *A Birding Tourist's Guide to Mallorca*. Palma, Mallorca, Spain. ISBN: 978-846161061 7.

Rico, L. - *Estudio piloto de los efectos de la erosión en las poblaciones de Juniperus oxycedrus sp. macrocarpa*. Biodiversity and Conservation Department, Institut Mediterrani d'Estudis Avançats, Mallorca, Spain. *Unpublished*.

Riddiford, N.J. (ed.). (2002). *Catàleg de Biodiversitat del Parc Natural de s'Albufera de Mallorca* [*Biodiversity Catalogue of the Albufera de Mallorca Natural Park*]. 88p., Inventaris tècnics de Biodiversitat, 3. Direcció General de Biodiversitat, Conselleria de Medi Ambient, Govern Balear, Palma de Mallorca, Spain. Available at http://www.mallorcaweb.net/salbufera/docs/cataleg_biodiversitat_2002.pdf

Riddiford, N.J. (2008) - The Albufera International Biodiversity Group (TAIB), un modelo de investigación aplicado a la conservación de especies. *In*: Mayol, J. y Viada, C. (eds.), *Actas de El Rumbo del Arca. Congreso Técnico de Conservación de Fauna y Flora Silvestres*, pp.181-189, Conselleria de Medi Ambient, Formentor, Mallorca, Spain. Available at http://www.caib.es/sacmicrofront/archivopub.do?ctrl=MCRST272ZI76862&id=76862

Riddiford, N.J.; Fernández, L. (2009) - The fish of s'Albufera de Mallorca. *In:* Nick Riddiford & Macu Férriz (eds.), *TAIB Project S'Albufera: A Mediterranean model for the study of biodiversity and environmental change.* The Albufera International Biodiversity Project Annual Report 2008, pp. 9-72, Mallorca, Spain. Available at http://www.taib.info/download/fieldwork-reports/TAIB-Report-2008.pdf

Riddiford, N.J.; Férriz, I. (2009) - Submerged macrophytes and aquatic invertebrates of s'Albufera. *In:* Nick Riddiford & Macu Férriz (eds.), *TAIB Project S'Albufera: A Mediterranean model for the study of biodiversity and environmental change.* The Albufera International Biodiversity Project Annual Report 2008, pp. 73-137, Mallorca, Spain. Available at http://www.taib.info/download/fieldwork-reports/TAIB-Report-2008.pdf

Riddiford, N.J.; Mayol, J. (1996) - Case studies: s'Albufera de Mallorca. *In:* P. Tomàs-Vives, P. (ed.). 1996, *Monitoring Mediterranean Wetlands: A Methodological Guide*. pp.103-118, MedWet Publication, Wetlands International, Slimbridge, UK and ICN, Lisbon, Portugal. Available at http://www.medwet.org/wp-content/pdf/monitoring2.pdf

Rodríguez-Perea, A; Servera, J.; Martín, J. A. (2000) - *Alternatives a la dependencia de les platges de les Balears de la regeneració artificial continuada: informe Metadona.* 40 p. Universitat de les Illes Balears and Ajuntament de Calvià, Pedagogia Ambiental Collection, Palma de Mallorca, Spain. ISBN: 8476326300.

Rosenzweig, C.; Wilbanks, T.J. (2010) - The state of climate change vulnerability, impacts, and adaptation research: strengthening knowledge base and community. *Climatic Change*, 100(1):103-106. DOI: 10.1007/s10584-010-9826-5

Royo, L.; Traveset, A.; Servera, J. (2007) - *(An) Integrated Coastal Management of a beach-dune system, Western Mediterranean. Identifying and quantifying the sediment budget.* International Conference on dune restoration and costal dune management, Santander, Cantabria, Spain. *Unpublished*.

Royo, L.; March, D.; Traveset, A. (2008) - Re-establishing the beach equilibrium for a public use and a sustainable conservation. *In:* Pons, G.X. (ed), *V Jornades de Medi Ambient de les Illes Balears*. *Ponències i resums*, pp 386-388, Societat d'Història Natural de les Balears, Palma de Mallorca, Spain. ISBN: 978-8496841574

Royo, L.; Noguera, M.; Reus, J. (2010) - *Valoració i diagnosi socio-econòmica de s'Albufera de Mallorca. Una aproximació (multi-criteri) a partir dels seveis ecosistèmics*. 274p., Associació TAIB and Conselleria de Medi Ambient, Mallorca, Spain. *Unpublished*.

RSPB (2014) - *Volunteering*. Royal Society for the Protection of Birds, Sandy, UK. *In*: https://www.rspb.org.uk/volunteering/

Salamanca, O.R.; Rodríguez-Perea, A. (1999) - Los problemas de abastecimiento de agua en las Islas Baleares. *In*: A. Gil & A. Morales, A., *Los usos de agua en España,* pp. 615-644, Caja de Ahorros del Mediterráneo, Instituto Universitario de Geografía de la Universidad de Alicante, Alicante, Spain. ISBN: 8475991866.

Salazar, R.D.; Riddiford, N.J.; Vicens, P. (2006) - A comparative dietary study of Cattle Egrets (*Bubulcus ibis*) and Little Egrets (*Egretta garzetta*) in S'Albufera Natural Park. *Bolletí de la Societat d'Història Natural de* *les Illes Balears* (ISSN: 0212-260X), 48:153-162, Palma de Mallorca, Spain. Available at http://ibdigital.uib.cat/greenstone/collect/bolletiHistoriaNatural/index/assoc/Bolleti_/2005v048/p153.dir/Bolleti_2005v048p153.pdf

Sargeant, L. (2002) - *What factors determine niche partitioning in Ardeidae on an island wetland in the Mediterranean under conservation management?* 37p., Thesis, MRes in Ecology and Environmental Management, University of York, UK. *Unpublished*.

Sato, M. (2002) - *Notes on Dragonflies and Damselflies (Insecta: Odonata) in s'Albufera Natural Park, Mallorca: Status, Conservation Priorities and Bio-indicator Potential.* 25p., Thesis, MRes in Ecology and Environmental Management, University of York, UK. *Unpublished*.

Sato, M.; Riddiford, N.J. (2008) - A preliminary study of the Odonata of s'Albufera Natural Park, Mallorca: status, conservation priorities and bio-indicator potential. *Journal of Insect Conservation*, 12:539-548. DOI: 10.1007/s10841-007-9094-5

Scheffer, M. (1998) - *Ecology of Shallow Lakes*. 357p., Chapman & Hall, London, UK. ISBN: 0412749203.

SEO (s/d) – *Voluntarios por las Aves y la Naturaleza*. Sociedad Española de Ornitología, Madrid, Spain. http://www.seo.org/participa/voluntariado/

Servera, J. (2004) - *Geomorfologia del Litoral de les Illes Balears*. 88p., Edicions Documenta Balear, Palma de Mallorca, Spain. ISBN: 8496376109.

Servera, J.; Gelabert, B.; Rodríguez-Perea, A. (2009) - Development and setting of the Alcudia Bay beach-dune system (Mallorca, Spain). *Geomorphology*, 110(3-4):172-181. DOI: 10.1016/j.geomorph.2009.04.008

Stuip, M. (2001) - *An integrated assessment of interactions between tourism and nature conservation: a case study of Park Natural de s'Albufera de Mallorca*. 63p., MSc Thesis, Wageningen University, Earthwatch Institute and Universitat de les Balears, Spain. *Unpublished*.

Suárez, M.G.; Pretus, J.L. (2008) - *Informe sobre la caracterització de les variables fisicoquímiques i seguiment del cicle agroramader al Parc Natural de s'Albufera de Mallorca.* 78p., Universitat de Barcelona Departament d'Ecologia, Fundació Bosch i Gimpera, Barcelona, Spain. *Unpublished*.

TAIB (2014) - *TAIB website*. The Albufera International Biodiversity group and Associació Treballam per s'Albufera i les Illes Balears, Mallorca, Spain. Available at http://www.taib.info/

Taylor, R. (1993) - *Habitat and feeding ecology of Acrocephalus melanopogon and the impact of recent fires and management practices at S'Albufera de Mallorca*. 55p., MSc in Conservation Dissertation, University College London, UK. *Unpublished*.

Tomàs-Vives, P. (ed.) (1996) - *Monitoring Mediterranean Wetlands: A Methodological Guide*. 150p., MedWet Publication: Wetlands International, Slimbridge, UK and ICN, Lisbon, Portugal. ISBN: 1900442043. Available at http://medwet.org/2010/02/monitoring-mediterranean-wetlands-a-methodological-guide/

Traveset, A.; Royo, L.; Servera, J. (2006) - *Evolución geomorfológica y de vegetación del sistema dunar en la playa de Muro; Informe final, Proyecto específico I+D+i GIZC-VegeDuna*. 53p., Govern Illes Balears and IMEDEA, Palma de Mallorca, Spain. Available at http://www.costabalearsostenible.es/ATenpdf/1.1MA/2.Bio/AnnaTraveset/Informefinal_VegeDuna_UGIZC_.pdf

van der Perk, J. P. (1997) - *Modelling the potential conflicts between Biodiversity Conservation and Water Quality Regulation in s'Albufera Natural Park, Mallorca*. 40p., MSc Thesis, Centre for Environment and Climate Studies, Wageningen Agricultural University, Holland. *Unpublished*.

van der Straten, M.J.; Potting, R.P.J.; van der Linden, A. (2011) - Introduction of the tomato leafminer *Tuta absoluta* into Europe. *Proceedings Netherlands Entomological Society Meetings* (ISSN: 1388-8390), 22:23-30. Available at http://www.nev.nl/pages/publicaties/proceedings/nummers/22/23-30.pdf

Veraart, J. (1999) - *Selection of bio-indicators to monitor effects of agriculture and tourist developments on water quality and aquatic biodiversity in s'Albufera Natural Park, Mallorca*. 122p., MSc Thesis, Wageningen University, Earthwatch Institute and Universitat de les Balears, Spain. *Unpublished*.

Veraart, J.; de Groot, R.S.; Perelló, G.; Riddiford, N.J.; Roijackers, R. (2004) - Selection of (bio) indicators to assess effects of freshwater use in wetlands: a case study of s'Albufera de Mallorca, Spain. *Regional Environmental Change*, 4(2-3):107-117. DOI: 10.1007/s10113-004-0070-2

Veraart, J.; Van Nieuwaal, K.; Driessen, P.P.J.; Kabat, P. (2014) - From climate research to climate compatible development: experiences and progress in the Netherlands. *Regional Environmental Change*, 14(3):851-863. DOI: 10.1007/s10113-013-0567-7

Vliet, A.H.; Bron, W.; Mulder, S.; Slikke, W.; Odé, B. (2013) - Observed climate-induced changes in plant phenology in the Netherlands. *Regional Environmental Change* (ISSN: 1436-378X), 14(3):997-1008. DOI: 10.1007/s10113-013-0493-8

Whittingham, E. (1999) - *The coastal zone of Alcudia Bay, Mallorca: an assessment of change and potential anthropogenic impacts on Posidonia oceanica seagrass habitat*. 54p., MSc Dissertation, Centre for Tropical Coastal Management, University of Newcastle-upon-Tyne, UK. *Unpublished*.

WWF (2013) – *WWF founder Max Nicholson dies*. WWF Articles, World Wide Fund for Nature, Surrey, UK. *In*: http://www.wwf.org.uk/wwf_articles.cfm?unewsid=1533

Zingone, A. (2010) - Harmful Algal Blooms in the Mediterranean: an historical overview. *In*: CIESM (2010), *Phytoplankton responses to Mediterranean environmental changes*, nº 40:19-24, CIESM Workshop Monograph, Tunis, 7-10 October 2009 (F. Briand Ed.), Monaco, France. Available at http://www.ciesm.org/online/monographs/download.php?file=Tunis10.pdf

Revista da Gestão Costeira Integrada 14(2):289-299 (2014)
Journal of Integrated Coastal Zone Management 14(2):289-299 (2014)

GESTÃO COSTEIRA INTEGRADA
Journal of Integrated Coastal Zone Management

http://www.aprh.pt/rgci/pdf/rgci-479_Cruz.pdf | DOI:10.5894/rgci479

Participative management of tourism in protected areas: Case-study from Lands of Priolo, São Miguel, Azores *

Gestão participativa do turismo em áreas protegidas: Caso de estudo das Terras do Priolo, São Miguel, Azores

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ABSTRACT

Community participation and adaptive management are commonly considered as good approaches for long-term success of environmental policies, however several challenges arise when confronted with practice. This paper presents the case-study of the application of the European Charter for Sustainable Tourism (ECST) in the Lands of Priolo (Eastern councils of São Miguel Island, Azores, Portugal). The participatory planning process took place in 2011 including a diagnosis, a strategy and an action plan (2012-2016).

More than one hundred people participated in the process, representing 50% of the stakeholders identified. Participation was higher in the initial diagnosis meetings (47%), which were held in every parish, than in the Forums (15%), despite the later being the actual decision meetings. After concluding the ECST process, in 2012, a Priolo brand was created to encourage and to allow companies to join the process; so far 15% of the stakeholders have applied for the brand. A clear reduction of participation of local institutions, little local businesses and individual people could be verified, while larger tourism related companies maintained their participation and joined the Priolo Brand. In terms of planning results, 55 actions were defined, of which 32 were of the responsibility of the Regional Government, 10 of the municipality of Nordeste, 5 of a national NGO, 3 of the Local Rural Development Association and 5 of other entities.

Although preliminary, these results allow to highlight some important conclusions in relation with the practical application of this kind of environmental planning processes such as: the importance of close-by or parish meetings; the relevance of non-formal information; the need for a balance between the number of stakeholders involved and the duration of the process; the importance of a facilitation entity that can rise trust among all involved stakeholders and the need of effective results to avoid disappointment.

Keywords: Sustainable Tourism; Participative methodologies; Social-ecological systems; Governance

RESUMO

A participação das comunidades e a gestão adaptativa são geralmente consideradas boas práticas para garantir o sucesso a longo prazo das políticas ambientais, mas a sua aplicação prática apresenta alguns desafios. Este artigo apresenta o caso de estudo da aplicação da metodologia da Carta Europeia de Turismo Sustentável (CETS) nas Terras do Priolo (concelhos na área leste da ilha de São Miguel, Açores, Portugal). O processo de planeamento participado decorreu em 2011 e incluiu um diagnóstico, uma estratégia e um plano de ação (2012-2016).

Mais de uma centena de pessoas participaram no processo, representando cerca de 50% dos stakeholders identificados. Porém, a participação foi muito superior nas reuniões iniciais de diagnóstico (47%) celebradas em todas as freguesias dos concelhos do que nos Fóruns (15%); apesar

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** Submission: 2 January 2014; Evaluation: 5 February 2014; Reception of revised manuscript: 9 May 2014; Accepted: 28 May 2014; Available on-line: 12 June 2014*

de estes últimos serem as reuniões decisoras. Após a conclusão do processo de adesão à ECST, em 2012, criou-se a Marca Priolo, que estimulou e permitiu a adesão das empresas ao processo e que, até a data, abrange 15% das empresas identificadas como stakeholders. Verificou-se ao longo do processo uma redução na participação das instituições locais, pequenos negócios e pessoas a título individual, enquanto que as empresas com maior dimensão relativa continuaram no processo e aderiram à Marca Priolo. O planeamento resultou em 55 ações, das quais 32 da responsabilidade do Governo Regional, 10 do município de Nordeste, 5 de uma ONG nacional, 3 da associação de desenvolvimento rural e 5 de outras entidades.

Apesar de serem ainda preliminares, os resultados permitem obter algumas conclusões sobre a aplicação prática deste tipo de processo de planeamento ambiental tais como: a importância de realizar reuniões de proximidade ou por freguesias, a relevância da recolha de informação não formal, a necessidade de encontrar um equilíbrio entre o número de stakeholders que participam no processo e a duração do mesmo; a importância de existir uma entidade facilitadora que conte com a confiança da maioria dos intervenientes e a necessidade de resultados efetivos de modo a não desapontar os participantes.

Palavras-Chave: *Turismo Sustentável;Metodologias participativas; Sistemas sócio-ecologicos; Governança*

1. INTRODUCTION

In recent years, the management of protected areas has evolved from mostly caring about biodiversity conservation to a wider concept, taking into account the social and economic aspects of local communities as a mean to guarantee long-term conservation, by incorporating the concept of sustainable development (WCDE, 1987). This approach is especially important when confronted with conflicts between conservation and use of resources, which is common in both terrestrial and marine protected areas (Eagles *et al.*, 2002). Considering sustainability whilst managing Protected Areas raises new challenges such as how to reach a balance between economic development and conservation (McCool, 2009) but it also provides opportunities to improve management of visitors and general management of protected areas (Eagles, 2009) with benefits for species and habitats conservation.

Sustainable tourism, defined as a type of tourism that promotes a balanced development of environmental, social and economic issues (Clarke, 1997), is regarded as an excellent tool for promoting an adequate visitation to Protected Areas (McCool, 2009; Plummer & Fennell, 2009) as well as a potential tool for local development along with the protection of cultural, social and environmental aspects (Castellani & Sala, 2010; Neto, 2003). Protected areas visitation has increased considerably during the last years (Eagles, 2002) and if not adequately managed, it can cause conservation problems (McCool, 2009). But on the other hand, this type of tourism could aid and support conservation itself (Eagles, 2007). For example, in 1999 South Africa recovered 80% of parks budget from tourism (Eagles, 2002)

Sustainable tourism requires specific policies that should be implemented in the territory in order to promote the values of the protected areas as a tourism destination, ensure the necessary infrastructures for the development of touristic activities while avoiding impacts to nature and guaranteeing that visitors understand the values of the protected area (Bushell *et al.*, 2007, Eagles *et al.*, 2002).

Environmental planning can raise important conflicts between stakeholders, since they have different objectives, values and concerns (Kontogianni *et al.,* 2005). In protected areas management, managers care mostly about conservation of natural resources while tourism companies and local population require exploring them to guarantee their well-being (Jamal & Stronza, 2009).

For this reason, in sustainable tourism planning several partnerships must be developed between the protected areas and territory managers, tourism companies and other entities in order to guarantee long-term application and compliance (McCool, 2009; Jamal & Stronza, 2009). These partnerships have proven several advantages, such as an increase in efficiency and productivity, innovation stimulation, a boost in conservation initiatives, a promotion of collaborative decision-making and conflict resolution, among others (Pfueller *et al.*, 2011). Participative planning has been suggested as a best practice in order to promote the establishment of partnerships between protected area managers and local communities (Simpson, 2001; Jamal & Stronza, 2009; Bramwell & Cox, 2009; Pfueller *et al.*, 2011) as well as to ensure that touristic activities are carried out without harming natural heritage (McCool, 2009). For example, participative methodologies applied in the management of Uruguay Coastal and Marine Zones enabled technicians and local leaders to increase their resource management capacity and promoted networking between them and scientists (Echevarria *et al.,* 2013)

Also, sustainable tourism planning in protected areas has to deal with some uncertainty in relation to the effects that tourism promoting practices will have on tourism attraction and on biodiversity conservation. Therefore, an adaptive approach would be necessary in order to evaluate and review policies along time (Olsson *et al.*, 2004) and aspects such as cross scale interplay of institutions, equity in benefits distribution and use of local knowledge should be taken into consideration (Berkes, 2003).

This paper describes the methodology and explores preliminary results of the process of the application of the European Charter for Sustainable Tourism (ECTS) (coordinated by EUROPARC) in the Lands of Priolo (Figure 1), comprising two rural councils of the island of São Miguel, Azores.

This process presents some peculiarities in relation to other known ECST processes. First, it was conducted within a LIFE project, EU's funding instrument for the Natura 2000 management, aimed for the restoration and sustainable management of priority habitats; secondly, it was started by a non-governmental institution, the Portuguese Society for the Study of Birds (SPEA – Birdlife International Portuguese partner) but quickly accompanied by the Regional Government, responsible for the management of the area and also a partner in the LIFE Sustainable Laurel

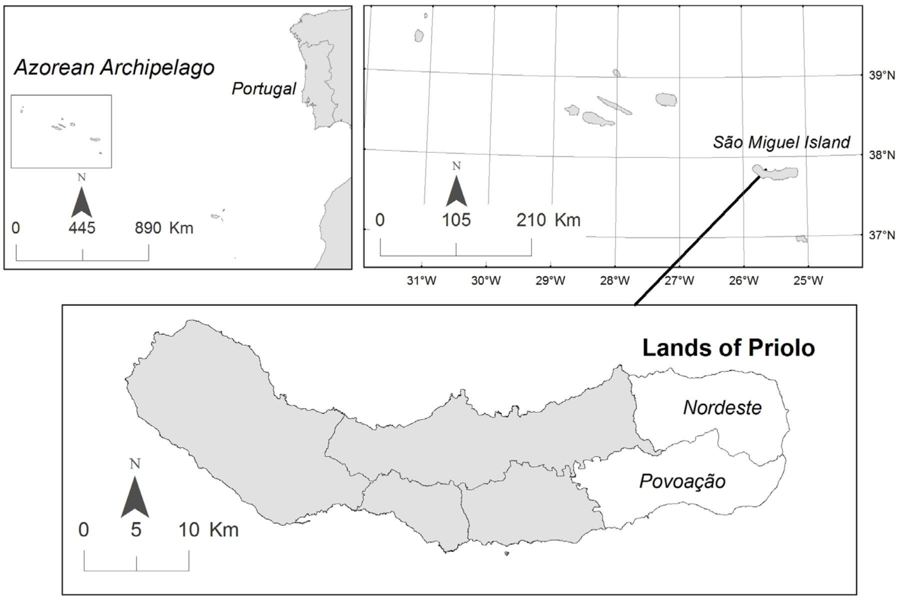

Figure 1. Location of the Lands of Priolo
Figura 1. *Localização das Terras do Priolo.*

Forest Project; thirdly, this ECST applies only to a part of the São Miguel Island Natural Park and not to the entire park that comprises all the protected areas in the island (Calado *et al.*, 2009).

2. METHODOLOGY

2.1. Why the Lands of Priolo?

Lands of Priolo's territory comprises the councils of Nordeste and Povoação in the island of São Miguel, Azores. These are the two most rural and less populated councils in the island, having suffered from rural exodus along the past decades. Their main economy consists in cattle raising for dairy products and has an incipient tourism activity (Cruz *et al.*, 2011a). Around 50% of their territory integrates the São Miguel Island Natural Park and includes the Special Protection Area (SPA) of *Pico da Vara/ Ribeira do Guilherme* (Figure 2), a Natura 2000 network area designated under the Birds Directive because it is home of the rare endemic Azores Bullfinch or Priolo (*Pyrrhula murina*). This is a very endangered bird that has been the target of conservation actions for the last 10 years, allowing its population to recover (Ceia *et al.*, 2011; Birdlife International, 2013) and upgrade its conservation status from Critically Endangered to Endangered (IUCN, 2010). Conservation actions have also allowed a considerable national and international disclosure about this bird and its habitat, becoming a good symbol for the territory. Therefore, the conservation of this bird can be regarded as a challenge but also an opportunity for the area, in terms of touristic promotion.

Despite São Miguel Island Natural Park comprises protected areas in all of island, the scope of this process was limited to only two councils with all the protected

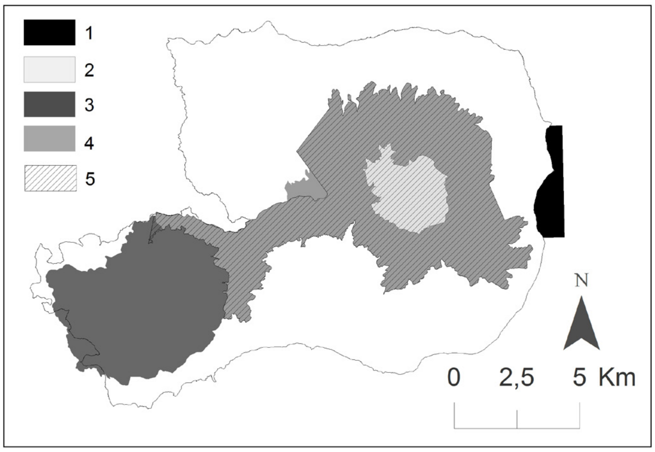

Figure 2. Protected Areas in São Miguel Natural Park (PNISM) (1 – Protected Area for resources management of Costa Este; 2-Natural Reserve of Pico da Vara; 3 – Protected Landscape of Furnas; 4 – Protected Area for the managment of habitat or species of Tronqueira/ Planalto dos Graminhais.) and Natura 2000 (5- Special Protected Area Pico da Vara / Ribeira do Guilherme)
Figura 2. *Áreas Protegidas no Parque Natural de Ilha de São Miguel (1 – Área Protegida para gestão de recursos da Costa Este; 2-Reserva Natural do Pico da Vara; 3 – Paisagem Protegida das Furnas; 4 – Área Protegida para a Gestão de Habitats ou Espécies de Tronqueira/ Planalto dos Graminhais.) e Natura 2000 (5- Zona de Proteção Especial Pico da Vara / Ribeira do Guilherme)*

areas within them (and the entire Azores bullfinch world distribution). This decision allowed to reduce the number of the stakeholders involved as well as the area to manage, allowing to develop a more close-by process and accomplish objectives in time, limited due to the availability of funding. Although the name "Lands of Priolo" had been previously used, it was not common. This name was chosen in order to define all territory as one and allow all participants to identify with it. During the process, this name was tested for acceptance.

2.2. Why the European Charter for Sustainable Tourism?

The choice of the methodology was based on the main objectives defined. Those were:

- To guarantee long-term maintenance of conservation work necessary to ensure the protected areas, priority habitats and the population of the Azores Bullfinch.
- To promote a sustainable tourism activity in the territory that would contribute to increase well-being among local population in social, environmental and economic terms.
- To increase the interaction and the cooperation among all stakeholders involved in the tourism activity and in the management of the territory with final focus on the conservation of the bird species and its habitat

It is commonly recognized that participative methodologies contribute to increase engagement of stakeholders with a common strategy (Innes & Booher, 2000; Kapoor, 2001; Reed, 2008) and therefore this was considered to be the best methodology to promote a joined work in the territory. The European Charter for Sustainable Tourism gathers, in our opinion, all of these advantages and therefore, this was the chosen methodology to apply in our case.

The European Charter for Sustainable Tourism in Protected Areas is a management tool designed by EUROPARC Federation in order to guarantee tourism contribution to sustainable development of protected areas in Europe. It proposes a participative planning process that resultes in a common Strategy and an Action Plan towards the implementation of a more sustainable tourism in the economic influence area of Protected Areas. In addition to this it provides an internationally recognized award present in a network of more than 107 protected areas in 13 countries of Europe and commonly related to sustainability and good quality tourism in protected areas (Europarc, 2002).

Furthermore, the ECST process promotes a three parties' adhesion. First, for protected areas and their socioeconomic influence area; second, the tourism companies that operate in the protected areas; and third, the tour-operators willing to promote visits in charter protected areas with charter companies. This way, the ECST aims to include all relevant stakeholders in tourism market and promote sustainability in all the stages of the touristic product (Europarc, 2002).

Finally, the ECST is one of the two methodologies recommended by the European Union for the development of Sustainable Tourism in Natura 2000 areas (European Commission, 2001) The alternative, PAN-Parks initiative is not applicable to our area, since it requires an area of around 10,000 hectares free of visiting and management. Unfortunately, all protected areas in the Lands of Priolo are smaller and require active management in order to restore and preserve native habitats and species.

Other sustainable tourism initiatives have been developed in the territory at the same time as this ECST initiative, such as the Azores Geopark (Lima *et al.*, 2009), which was an active partner in this process.

2.3. Participative methodology

The methodology applied (Figure 3) was based on the one suggested by the European Charter for Sustainable Tourism and was adapted to the specific characteristics of the territory. ECST application requires the fulfillment of a participative planning method, based on Deming Cycle (Deming, 1994 in Castellani & Sala, 2010).

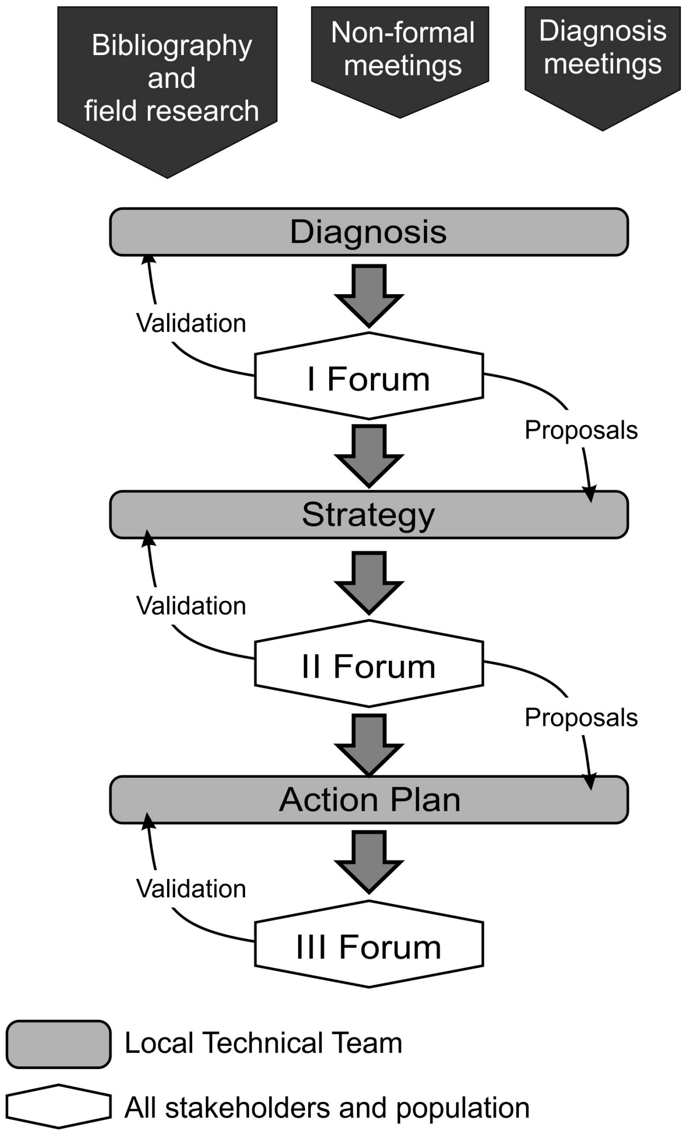

Figure 3. Scheme of the methodology applied for public participation
Figura 3. *Esquema da metodologia aplicada para a participação pública.*

The methodology applied in the Lands of Priolo had a preparatory phase that began with several institutional meetings with all partner institutions and potential stakeholders in order to determine whether the will of all parts matched the objectives of the process. This preliminary phase lasted for 1 year, in spite of not being a continuous process. As a conclusion, a workshop on "Business opportunities around protected areas" was held and presented examples of several initiatives for the promotion of sustainable tourism and visitation around protected areas. At the end, the main concerns of the participants about the process were discussed and subsequently taken into account for the definition of the participative methodology program.

After this meeting, a series of meetings took place in order to gather the partnership of all relevant institutions for the development of the process. This partnership was considered essential to ensure the effective application of the action plan, which was the main concern of local stakeholders. The first two institutions joining the process were the Regional Directorate of Environment and the Regional Directorate of Tourism, followed by the Regional Directorate of Forestry Resources, the municipalities of Nordeste and Povoação (although the later decided to quit after the I Forum) and the association for development and rural promotion – LEADER action group (ASDEPR). These institutions defined how the participative process would take place and named representatives to be a part of the Technical Local Team, responsible for monitoring the process and review it before the Forums in which all stakeholders and local population were invited to participate.

After the Local Technical Team had been constituted, the ECST planning process started. This process was open for participation of all population, but a group of essential stakeholders was defined. This group included local associations and institutions, accommodation, restoration, local handcraft and products and active tourism companies and a Public Participation Plan (not published) was developed. This plan had to be adapted along the process in order to effectively conclude the process in time, and some of the initially proposed meetings never took place.

The diagnosis phase aimed to produce a complete analysis of the initial touristic, environmental and socioeconomic situation of the territory. This diagnosis was both technical (regarding mostly bibliography and fieldwork) and participative (including meetings in every parish of the territory) and those two approaches took place at the same time being complementary. Local knowledge gathered in the diagnosis meetings was later contrasted with bibliographic information and fieldwork.

Diagnosis meetings counted with the support of parish authorities and some other local leaders and they aimed to identify local touristic resources, as well as to characterize potentialities, problems and proposals for the development of Sustainable Tourism in the territory. Another diagnosis meeting was held in Ponta Delgada, with touristic companies in order to assess the profiles of actual visitors to the territory as well as potentialities, problems and proposals for improving tourism activity.

All information acquired in these diagnosis meetings, bibliography reviews and fieldwork was gathered in a first draft of the "Sustainability and tourism diagnosis of the Lands of Priolo" (Cruz *et al.*, 2012a) that was presented to the public and discussed in the I Fórum of the ECST.

The I Forum took place the 23rd of May of 2011, and lasted all day. The morning was for the presentation and discussion of the diagnosis document and in the afternoon working groups were created in order to discuss Potentialities, Problems and Proposals – a simplified SWOT analysis – based on the objectives of the ECST (Europarc, 2002). At the end of the session, each group would present their conclusions to be discussed by the entire forum.

The I Forum allowed to define a clear common vision of the sustainable evolution of tourism in the territory stated as "*The Lands of Priolo as an integrated product of the Azores Destiny with a coherent definition of pedestrian trails, thematic routes, events, activities and products that allow the discovery of natural patrimony, culture, traditions and rural life of this territory*" (Cruz *et al.*, 2012b)

After this Forum, the Strategy definition process started. This process was led by the Technical Local Team that analyzed Potentialities, Problems and Proposals identified in diagnosis meetings and I Forum, split them into themes and defined general and specific objectives for each of them. This process resulted in 12 general objectives with 41 specific objectives, relating to all the principles in the ECST.

This Strategy was presented and discussed in the II Forum that took place in October 14th in the afternoon. Within this Forum, one new objective was included in the Strategy by suggestion of the public. After the presentation, participants were asked to prioritize these objectives, for this purpose they were given 5 stickers that could be placed at their will all in one objective or divided by those objectives they considered more important and urgent to assess. Prioritization results were presented and discussed with the public as a conclusion for the Forum.

Action Plan definition resulted in a longer process with the partner institutions and required several meetings in order to accomplish the final document. For starters, each partner institution was asked to identify those actions, in development or planned, that fitted the objectives of the strategy. Individual meetings with some institutions took place in order to identify those actions.

Later, identified actions were compared towards the objectives in the strategy and the principles in the ECST, with special regard to those objectives that had been identified as a priority, and suggestion of new actions were presented to partners. Also new partners were included in this process in order to increase the actions in the action plan. As a result, the action plan comprises 55 actions (Cruz *et al.*, 2012c) of the responsibility of the different partners in the ECST process as well as new partners.

The action plan concluded the process of application for the ECST, which was awarded to the Lands of Priolo in 2012, but not of the participative planning process. This should be a continuous process, with an annual analysis and revision of the Action Plan, that ensures the application of the proposed actions and allows adapting the objectives and actions to reality changes. This continuous process also allows any interested entity to be included in the Action Plan at any moment.

From all defined actions in the ECST Action Plan we would like to highlight one, the creation of the Priolo brand, since this action aims to include tourism related companies into the objectives of the strategy. For the development of this action, a manual with rules for the brand was established in a participative meeting with touristic companies that had participated in the ECST process. These rules provide some advantages to those companies in terms of promotion in exchange for their contribution to the ECST action plan. Each company has to define three voluntary actions that match the objectives of the ECST for the next three years. This brand can be considered as the actual partnership arrangement between tourism companies and the protected area managers.

3. RESULTS

In order to measure the preliminary success of this participative process, we evaluated the initial participation process regarding some indicators, such as the number of stakeholders involved, the strategy and action plan defined and the application of the plan on its first year.

For the participation's analysis, we considered three different stages of participation: the previous meetings, diagnostic meetings held in every parish of the territory, the forums, actual decision-making meetings, and the Priolo brand affiliation, which despite not being a part of the participative process is a direct consequence and determines the actual partnership between companies and the Protected Area managers.

More than 100 people were involved in the whole process (Table 1). Most of them only participated in the diagnosis meetings, most likely because of their proximity, but they might have accompanied the process afterwards (with more than 8000 visits to the process' blog and some e-mail feedback from stakeholders that remained interested in the process even if they couldn't participate).

Table 1. Dates and number of participants in meetings for the European Charter for Sustainable Tourism in the Lands of Priolo.
Tabela 1. *Datas e número de participantes nas Reuniões da Carta Europeia de Turismo Sustentável nas Terras do Priolo*

Meeting	Location	Date	Participants
Diagnosis meetings	Salga	1st February, 2011	3
	Achadinha	3rd February, 2011	4
	Achada	31st January, 2011	2
	Santana	4th April, 2011	3
	Algarvia	16th February, 2011	10
	Santo António	2nd February, 2011	9
	São Pedro	--	--
	Lomba da Fazenda	5th February, 2011	12
	Nordeste	21st February, 2011	9
	Agua Retorta	9th February, 2011	20
	Faial da Terra	17th March, 2011	6
	Nossa Senhora dos Remédios	23rd February, 2011	8
	Povoação	9th April, 2011	5
	Ribeira Quente	18th April, 2011	6
	Furnas	18th February, 2011	4
	Ponta Delgada	11th April, 2011	13
		SUBTOTAL	**114**
I Forum	**Povoação**	23rd May, 2011	60
II Forum	**Nordeste**	14th October, 2011	28
III Forum	**Furnas**	16th January, 2012	30

Although there was a considerable reduction from the I Forum (60 participants) to the II and III (around 30 people), the institutions represented in all the forums did not suffer the same reduction (17, 12 and 13 different stakeholders respectively). It is important to note that those companies where the most representative ones in terms of the number of tourist for the territory. This difference in total participants was due to a reduction on the number of representatives of each institution in the second and third forums.

In total, 50 % of the identified stakeholders participated in the process plus some individual people. From the identified tourism related companies 39% participated in the process. 83% of local institutions participated although mostly in the initial diagnosis meetings, while tourism companies participated in the forums as well. Only 3 local institutions maintained their participation in the forums and, from the tourism related companies, the smaller local businesses followed the same pattern, while bigger companies accompanied all the process. Catering and accommodation owners were those who more intensively participated in the process, but later affiliation to Priolo Brand was lead by active tourism and accommodation companies.

In terms of planning results, the final strategy had 13 general and 41 specific objectives with priority given to those relating pedestrian trails and promotion of activities in the territory. Those objectives were translated into 55 actions in 7 groups: Cooperation and coordination (8 actions); hiking trails and activities (10 actions); Cultural and environmental interpretation (11 actions); Protected area conservation (4 actions); Promotion and disclosure (11 actions); Sustainability of tourism (10 actions) and Monitoring (1 actions). All these actions matched the objectives defined in the strategy as well as the principles of the ECST. The Regional Directorate of Environment (DRA), leader of the process, was responsible for 26 actions, the municipality of Nordeste for 10 actions, the Regional Directorate of Tourism (DRT) and the Portuguese Society for the Study of Birds (SPEA) were responsible of 5 each and the Regional Directorate of Forestry (DRRF) and the Local Leader Group (ASDEPR) of 3 each. Another 5 actions were assumed by other private entities that were not part of the Local Technical Team (Figure 4)

We can also consider the number of actions accomplished

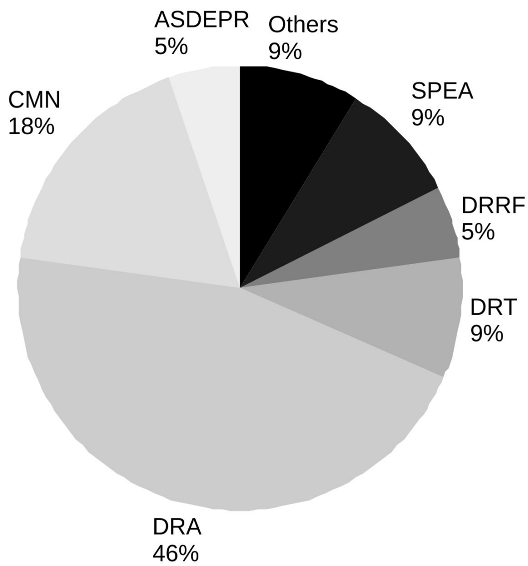

Figure 4. Distribution of actions in the action plan among partner institutions in the process.
Figura 4. *Distribuição das ações do plano de ação entre as entidades parceiras no processo.*

Table 2. Participants in each of the stages of the participation process as percentage of identified stakeholders (N). Participants column includes all stakeholders participating at least in one of the stages of the process, while diagnosis meetings and forums columns account for stakeholders participating in each stage. na = Not available data.
Tabela 2. *Participantes em cada uma das fases participativas do processo e percentagem em relação com os stakeholders identificados inicialmente (N). A Coluna "Partcipants" inclui todos os stakeholders que participaram pelo menos uma vez no processo, enquanto que a coluna "diagnosis meetings" e "forums" contam os stakeholders que participaram em cada uma dessas fases. na = sem dados disponíveis.*

	N	Participants	%	Diagnosis meetings	%	Forums	%	Priolo brand	%
Restaurants	29	12	41.38%	12	41.38%	5	17.24%	1	3.45%
Handcraft/ Local products	18	5	27.78%	5	27.78%	1	5.56%	1	5.56%
Active Tourism	22	6	27.27%	5	22.73%	3	13.64%	8	36.36%
Accommodation	43	21	48.84%	19	44.19%	10	23.26%	13	30.23%
Local institutions	36	30	83.33%	29	80.56%	3	8.33%	0	
Individual people	*na*	30	-	30	-	2			
Total	**148**	**74**	**50.00%**	**70**	**47.30%**	**22**	**14.86%**		**15.54%**

in the first year of application of the ECST (2012). From the 55 actions, 4 were to be accomplished in the first year of the action plan, and all of them were finished within that year. From the 48 actions that were planned to start that year, 34 were actually started and 14 have been postponed to 2013. Most of the postponed actions were considered to be developed during the 5 years of the plan; therefore it is still time to accomplish them. Anyway, it will be important in the future to pay special attention to some actions considered of high priority by participants, such as the improvement of official pedestrian trails network, which had to be postponed due to a reorganization of this network coordination. Also, it is important to note that all partner institutions developed at least one of the actions proposed in the action plan and that new entities included actions of their responsibility into the action plan, such as Azores Geopark and the Microbian Observatory of the Azores (OMIC) (CETS Terras do Priolo, 2013).

4. LESSONS LEARNT

The ECST in the Lands of Priolo application is a recent process, therefore it is yet soon to say whether if it is going to be successful. But we can analyze the initial indicators of participation and planning and take some conclusions about this process. Those conclusions will be useful for improving future stages of the participative planning process, but may also apply to other participative situations.

Firstly, the scope chosen for this process, reducing it to a part of the São Miguel Island Natural Park, the Lands of Priolo, proved to be effective in terms of involvement of stakeholders and effectiveness of methodologies with a small number of technicians involved (2 to 5 along the process). This scope allowed the implementation of diagnosis meetings in all parishes, which proved very useful in terms of diagnosis. This, would not have been possible to develop for all the parishes in the island, a total of 68, with such a small team and limited time. Also, the development of this process for the entire island would have obligated many of the stakeholders to longer travels to reach the forums and we already identified distance as a problem in a relatively small territory such as the Lands of Priolo. And last, but not least, the size of population in other councils of the island, especially Ponta Delgada and Ribeira Grande, would have obligated to a redefinition of participation techniques applied and probably to more than one meeting in some of the most populated parishes. Another important issue is the equity problem, since due to the small size in population of Nordeste and Povoação councils, it would have been more difficult to consider their needs in front of the wide majority.

The European Charter for Sustainable Tourism seem to be an adequate methodology and basis for this participative planning process, providing both motivation and guidance for the effective conclusion of the process. The cooperation with the Geopark process taking place in the Azores archipelago, showed that this two methodologies can be perfectly complementary. In our case, the Geopark promoted geotourism and sustainability in a larger territory, while the ECST served as a tool for a more close-up work with local communities in the Lands of Priolo territory.

Regarding the process itself, some conclusions match the general opinion of many participation studies, such as the importance and relevance of promoting participation since the first stages of planning (Simpson, 2001; Reed, 2008). This was clear at the III Forum where the action plan was unanimously adopted by stakeholders, as well as the affiliation to Priolo Brand that shows the support by local companies to the process. Also the need to adapt each process to the type of public that it is directed to and to include relevant institutional representatives in the process (Reed, 2008). The creation of the Local Technical Team was very important in managing the participative process and ensuring that all decisions counted with the necessary political support.

This process highlighted the importance of non-formal processes, such as informal questioning of local people or institutions representatives, in order to get a better understanding of the actual situation and conflicts. These revealed to be essential in order to accomplish some of the objectives of the process and are also recognized by several studies on participative methodologies (Reed, 2008) as an important information source. This non-formal processes contributed with integrating local traditional knowledge into the planning process. For example, the lack of information on needs of tourist in the territory was overcome by gathering information from the tourism related companies and local touristic resources identification was enriched in local meetings.

Analyzing the implementation process also shows that unforeseen situations might arise along the process, such as in our case, the quitting of one of the partner institutions. In those cases, it is essential to have a flexible process planning and to reflect whether the process is feasible regarding the new circumstances (Olsson *et al.*, 2004). In our case, and mostly due to stakeholders motivation we continued the process without this institution, expecting that some day it will be willing to participate again.

In relation to the differences with other known ECST process, we can state that the present and previous LIFE Projects carried out in the territory made possible to start this process. SPEA and the Regional Government have been working together in this territory since 2003 for the conservation of the Priolo and its habitat with highly positive conservation, social and economic results. Simultaneously to this process, a formal and non-formal educative program has been developed and caused a significant increase in the awareness on the importance of the Priolo and the natural habitats in the area (Cruz *et al.*, 2013), as well as on the economic potential of protected areas in tourism previous to this process in the overall population.

Also, the participation of SPEA was regarded as positive by stakeholders due to its independence and for the facilitator work done as a non-governmental institution, as stated in the participative Diagnosis (Cruz *et al.*, 2011a). In this case, we can consider that SPEA developed successfully the facilitation job, essential to the success of any participation process (Reed, 2008).

Regarding measured participation indicators we can conclude that it could have been higher, but considering that most stakeholders are not used to participative processes, 50%

can be considered acceptable. Recent studies underline that participation should be regarded as a continuous process, a long term commitment, instead of the application of a "tool-kit" of methods in a specific moment (Reed, 2008). Therefore, it is important to seek a balance between guaranteeing everyone's participation and time spent in the process, since a long process can lead to discouragement of participants and delay on decision making (Tosun, 2000). In the present case, time was chosen before participation, considering the previous statements, preventing the discouragement of the first participants and promoting results that would encourage other stakeholders to participate, therefore, we expect to see participation increased in the future. These expectations are supported by the increase in interest observed after the process was concluded and translated into a bigger number of stakeholders in Priolo Brand than those who participated in the process.

Individual people and local institutions participation decreased considerably from the initial diagnosis meetings to the forums. These individual people and voluntary representatives of institutions do not depend on tourism for their living and therefore have less interest or availability for moving to the forums, that were celebrated in the municipalities capitals. This fact highlights the importance of maintaining the meetings in the parishes in order to reach to a wider range of stakeholders, especially if their motivation for the process is not strong. The development of parish' meetings in all the stages of the process would have been a considerable improvement to this process, in order to promote small business or institutions participation in all the decisions. This was not possible due to the little time available for concluding the application, but we expect to fulfill this gap by developing annual parish' meetings during the application of the plan. Also it was relevant the choice of local leaders to promote this diagnosis meetings (Reed, 2008), for example, *Agua Retorta* was the most participated meeting since the priest talked about the process in the mass. Some other parishes showed also good participation thanks to the efforts of the parish's president in gathering the participants.

Considering planning results, we reckon an effort by all partner institutions in order to assume actions into the action plan. Many of the actions were based in the work actually undertaken by the institution, but the participative process allowed to improve or adapt it to the identified needs for the territory. This fact underlines the fact that sometimes, it is not necessary an increase of resources, which was not possible on our case, but just achieving an optimization of available resources towards a well defined goal (Reed, 2008).

A very relevant concern should be the management of participants' expectations about the process (Tosun, 2000). This was clear during all the process. Some stakeholders refused to participate in the initial phases because they wouldn't believe on the success of the process, but joined the process later, when the action plan was publicized and started. Since this is an adaptive process, stakeholders can be included at any step. Also, in order to avoid the disappointment of stakeholders it was very important to develop a previous process of gathering institutions commitment to the process. This was especially important since at initial stages the initiative came from an environmental NGO that has no decision power in many policies. Leadership of the process by the Regional Directorate of Environment fulfilled this problem and it is expected to guarantee long-term commitment of all parts.

Considering first year application results, we can also be optimistic about the accomplishment of the action plan. Specially considering the economic circumstances and the fact that some of the actions identified but lacking specific budget were used for the development of LIFE Terras do Priolo project, a new LIFE project started in July 2013 that will contribute to the application of the action plan. This last illustrates another advantage of participative planning processes they allow to identify need for action that can be used to promote projects for the area.

Results of first year also allow understanding the need for an adaptive management (Olsson, *et al.*, 2004, Carlsson & Berkes, 2005) through an annual review of actions. Only in one year, there was a legal change that made one of the actions redundant so in the annual forum it was removed from the action plan. Other actions were included from new stakeholders that contributed to the success of the plan.

CONCLUSIONS

This paper presents preliminary results of an environmental planning process aimed to promote sustainable tourism development and management within and around protected areas, that allow us to retrieve some important conclusions:

- Close-by participatory meetings are important in order to gather less motivated but still relevant stakeholders and subsequently, this kind of processes should reduce their scope or increase human resources in order to cope with this time consuming meetings.
- The European Charter for Sustainable Tourism proved to be an adequate methodology for the participative planning of a strategy towards sustainable tourism and complementary to other initiatives.
- Leadership by a decision-making entity, in this case the Regional Directorate of Environment, must be ensured, as well as the commitment by most of the relevant entities with competence in management of the territory and tourism industry. This is essential to rise trust in the process.
- It is relevant to this type of process to count on an impartial and locally implemented entity, in this case SPEA, as facilitator and to involve local leaders into the process.
- Flexibility is essential at all stages of the planning and participation process in order to be able to cope with unforeseen situations.
- Participants' expectations must be taken into consideration and managed in order to avoid disappointment.
- Continuous monitoring and evaluation of the process is necessary to guarantee the application of the action plan.

From now on, new challenges arise such as the effective application of all the actions included in the action plan, the maintenance of the motivation and participation of all stakeholders on the process and the effective improving of sustainability of tourism in this territory together with the preservation of natural values.

ACKNOWLEDGEMENTS

This paper was developed within the LIFE Project LIFE 07 NAT/P/000630. We would like to thank all participants in the European Charter for Sustainable Tourism process for the Lands of Priolo, especially to Paulo Castro and Concepción Fagundo for their guidance in the initial phases, Lourdes Perez Peñil for the map and Natália Melo for a latter review on the manuscript.

REFERENCES

Berkes, F. (2004) - Rethinking community-based conservation. *Conservation Biology*, *18*(3):621-630. DOI: 10.1111/j.1523-1739.2004.00077.x.

Bramwell, B.; Cox, V. (2009) - Stage and path dependence approaches to the evolution of a national park tourism partnership. *Journal of Sustainable Tourism*, *17*(2):191-206. DOI: 10.1080/09669580802495782

WCED (1987) – *Our Common Future*. 400p., WCED - World Commission On Environment and Development, Oxford University Press, Oxford, U.K. ISBN: 019282080X

Bushell, R.; Eagles, P.F. (eds.) (2007) - *Tourism and protected areas: benefits beyond boundaries: the Vth IUCN World Parks Congress*. 352p., CABI. (Commonwealth Agricultural Bureaux International), Wallingford, England, U.K. ISBN: 0851990223

Calado, H.; Lopes, C.; Porteiro, J.; Paramio, L.; Monteiro, P. (2009) - Legal and Technical Framework of Azorean Protected Areas. *Journal of Coastal Research*, SI56:1179-1183. Article Stable URL: http://www.jstor.org/stable/25737973

Carlsson, L.; Berkes, F. (2005) - Co-management: concepts and methodological implications. *Journal of Environmental Management*, 75(1):65-76. DOI: 10.1016/j.jenvman.2004.11.008

Castellani, V.; Sala, S. (2010) - Sustainable performance index for tourism policy development. *Tourism management*, 31(6): 871-880. DOI: 10.1016/j.tourman.2009.10.001

CETS Terras do Priolo (2013) – *Relatório de Progresso do Plano de Ação 2012-2016 CETS Terras do Priolo.* 104p., Gabinete da Carta Europeia de Turismo Sustentável nas Terras do Priolo, Direção Regional de Ambiente, Ponta Delgada, Açores, Portugal. Available at http://www.azores.gov.pt/NR/rdonlyres/4E27F196-A7DF-4974-8FB5-0ACE1F9B2E53/777523/RelatóriodeProgressodoPlanodeAção2012_Final.pdf

Ceia, R.S.; Ramos, J.A.; Heleno, R.H.; Hilton, G.M.; Marques T.A. (2011) - Status assessment of the Critically Endangered Azores Bullfinch *Pyrrhula murina*. *Bird Conservation International,* 21(4):477-489. DOI: 10.1017/S0959270911000025.

Clarke, J. (1997) - A framework of approaches to sustainable tourism. *Journal of Sustainable Tourism*, 5(3):224-233. DOI: 10.1080/09669589708667287

Cruz, A.; Batista, A.; Jiménez, S.; Guarinos, D.; Mendonça, A. (2013) - *Avaliação da sensibilização das populações. Relatório Final (2009 -2012)*. 25p., Sociedade Portuguesa para o Estudo das Aves, Lisboa, Portugal. Available on-line at https://docs.google.com/file/d/0Bx7JWv7fCeYPbWc0VGp3T2hiTFU/edit

Cruz, A.; Melo, R.; Mourato, C.; Caetano-Ferreira, R. (2012a) – *Diagnóstico Turístico e de Sustentabilidade das Terras do Priolo*. 96p. Direção Regional de Ambiente, Ponta Delgada, Portugal. Available on-line at http://www.spea.pt/fotos/editor2/diagnostico_cets_terrasdopriolo.pdf

Cruz, A.; Mourato, C.; Melo, R.; Caetano-Ferreira, R.(2012b) – *Estratégia de Desenvolvimento Turístico Sustentável para as Terras do Priolo*. 7p., Direção Regional de Ambiente, Ponta Delgada, Portugal. Available on-line at http://www.spea.pt/fotos/editor2/estrategia_cets_terrasdopriolo.pdf

Cruz, A.; Mourato, C.; Melo, R.; Caetano-Ferreira, R. (2012c) - *Plano de Ação para o Desenvolvimento Sustentável do Turismo nas Terras do Priolo.* 71p., Gabinete da Carta Europeia de Turismo Sustentável nas Terras do Priolo, Direção Regional de Ambiente, Ponta Delgada, Portugal. Available on-line at http://life-laurissilva.spea.pt/fotos/editor2/planoacao_cets_terrasdopriolo.pdf.

Echevarría, L.; Gómez, A.;Piriz, C.; Quintas, C.; Tejera, R.; Conde, D. (2013) - Capacity building for local coastal managers: a participatory approach for Integrated Coastal and Marine Zones Management in Uruguay. *Revista de Gestão Costeira Integrada*, 13(4):445-456. DOI: 10.5894/rgci402

Eagles, P.F. (2002) - Trends in park tourism: Economics, finance and management. *Journal of Sustainable Tourism*, 10(2):132-153. DOI: 10.1080/09669580208667158

Eagles, P.F.J. (2009) - Governance of recreation and tourism partnerships in parks and protected areas. *Journal of Sustainable Tourism*, 17(2):231-248. DOI: 10.1080/09669580802495725

Eagles, P.F.J.; McCool, S.F.; Haynes, C.D. (2002) - *Sustainable Tourism in Protected Areas. Guidelines for Planning and Management*. 183p., IUCN – The World Conservation Union, Gland, Switzerland / Cambridge, U.K. ISBN: 2831706483. Available on-line at http://cmsdata.iucn.org/downloads/pag_008.pdf

EUROPARC (2002) - European Charter for Sustainable Tourism in Protected Areas. 24p., *Europarc Federation,* Regensburg, *Germany.* ISBN: 3935676115

European Commission (2001) - Sustainable tourism and Natura 2000: Guidelines, initiatives and good practices in Europe. 63 p., *Office for Official Publications of the European Communities* 2001. *Luxembourg*. ISBN: 928941443X. Available on-line at: http://ec.europa.eu/environment/nature/info/pubs/docs/nat2000/sust_tourism.pdf

Innes, J. E.; Booher, D. E. (2000) - *Public participation in planning: new strategies for the 21st century*. 39 p., IURD Working Paper Series, Institute of Urban & Regional Development, Berkeley, California, U.S.A. Available on-line at: http://escholarship.org/uc/item/3r34r38h

BirdLife International (2013) - *Pyrrhula murina*. *In:* IUCN Red List of Threatened Species (ISSN: 2307-8235) [web page], Version 2013.2., International Union for Conservation of Nature and Natural Resources, Gland, Switzerland. http://www.iucnredlist.org/details/22720676/0

Jamal, T.; Stronza, A. (2009) - Collaboration theory and tourism practice in Protected Areas: stakeholders, structuring and sustainability. *Journal of Sustainable Tourism,*17(2):169-189. DOI: 10.1080/09669580802495741

Kapoor, I. (2001). Towards participatory environmental management? *Journal of Environmental Management*, 63(3):269-279. DOI: 10.1006/jema.2001.0478

Kontogianni, A.; Tziritis, I.; Skourtos, M. (2005) - Bottom-up Environmental Decision Making Taken Seriously: Integrating Stakeholder Perceptions into Scenarios of Environmental Change. *Human Ecology Review*, 12(2):87-95, Society for Human Ecology, Bar Harbor, ME, U.S.A. Available on-line at http://www.humanecologyreview.org/pastissues/her122/kontogianni.pdf

Lima, E.A.; Nunes, J.C.; Costa, M.P. (2009) - "Geoparque Açores" como Motor de Desenvolvimento Local e Regional. *15º Congresso da Associação portuguesa de Desenvolvimento Regional / 2º Congresso Lusófono de Ciência Regional / 3º Congresso de Gestão e Conservação da Natureza / 1º Congresso de Desenvolvimento Regional de Cabo Verde* - Livro de resumos, pp.238-249, Associação Portuguesa para o Desenvolvimento Rural. Cidade da Praia, Cabo Verde. Available on-line at http://www.apdr.pt/congresso/2009/pdf/Sessão 3/125A.pdf

McCool, S.F. (2009) - Constructing partnerships for protected area tourism planning in an era of change and messiness. *Journal of Sustainable Tourism*, 17(2):133–148. DOI: 10.1080/09669580802495733

Neto, F. (2003) - A new approach to sustainable tourism development: Moving beyond environmental protection. *Natural Resources Forum,* 27(3):212-222. DOI: 10.1111/1477-8947.00056

Olsson, P.; Folke, C.; Berkes, F. (2004) - Adaptive Comanagement for Building Resilience in Social–Ecological Systems. *Environmental Management*, 34(1):75-90. DOI: 10.1007/s00267-003-0101-7

Pfueller, S.L.; Lee, D.; Laing, J. (2011) - Tourism partnerships in protected areas: exploring contributions to sustainability. *Environmental Management*, 48(4):734-749. DOI: 10.1007/s00267-011-9728-y

Plummer, R; Fennell, D.A. (2009) - Managing protected areas for sustainable tourism: prospects for adaptive co-management. *Journal of Sustainable Tourism*, 17(2):149-168. DOI: 10.1080/09669580802359301

Reed, M.S. (2008) - Stakeholder participation for environmental management: a literature review. *Biological Conservation*, 141(10):2417-2431. DOI: 10.1016/j.biocon.2008.07.014

Simpson, K. (2001) - Strategic Planning and Community Involvement as Contributors to Sustainable Tourism Development. *Current Issues in Tourism*, 4(1):3-41. DOI: 10.1080/13683500108667880

Tosun, C. (2000) - Limits to community participation in the tourism development process in developing countries. *Tourism Management*, 21(6):613-633. DOI: 10.1016/S0261-5177(00)00009-1

Revista da Gestão Costeira Integrada 14(2):301-319 (2014)
Journal of Integrated Coastal Zone Management 14(2):301-319 (2014)

GESTÃO COSTEIRA INTEGRADA
Journal of Integrated Coastal Zone Management

http://www.aprh.pt/rgci/pdf/rgci-484_Lima.pdf | DOI:10.5894/rgci484

Basis for the geological heritage management in the Azores Archipelago (Portugal) *

Bases para a gestão do património geológico no arquipélago dos Açores (Portugal)

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ABSTRACT

The Azores archipelago, with a peculiar geodynamic setting, presents a huge geodiversity and important geological heritage, being considered a natural laboratory of volcanic geodiversity.

In the last decade, the geodiversity and geological heritage of the Azores archipelago is being inventoried, characterized, quantified, protected and promoted. Nowadays there are identified and characterized 121 geosites distributed through the nine islands and the surrounding seafloor. These geosites network ensure the representativeness of the Azorean geodiversity and reflects its geological and eruptive history with about 10 million years. Among the geosites, 57 were selected as priorities for the development of geoconservation strategies and implementation of promotion actions.

The analysis of the geosites included two main phases: a qualitative and a quantitative assessment, integrating the geological characterization, geomorphological and volcanological categorization, analysis of their relevance, identification of the potential type of use in each geosite, its scientific value and other associated values. The efforts resulted recognition of 6 geosites with international relevance [*e.g.* the Mid Atlantic Ridge, the Caldera of Furnas volcano (São Miguel island), the Pico Mountain (Pico island), the Caldera and Furna do Enxofre (Graciosa island), the Capelinhos volcano and Costado da Nau (Faial island) and Algar do Carvão volcanic pit (Terceira island)] and 52 geosites of national relevance. Besides its scientific value, most of the geosites have a relevant educational and geotouristic value. It is noteworthy that 93 geosites integrate the Regional Network of Protected Areas, lying under the management of the Island Natural Parks and the Marine Park.

The volcanic landscapes of the Azores have been promoted since the late twentieth century, especially for tourism campaigns, however since the begining of the work studies of the geological heritage of the archipelago in 2007, has also been promoted regionally, nationally and internationally.

The terrestrial geosites are monitored, focusing on the state of geosite, its geological conditions and the public characterization. Monitoring began in late 2013, pending the first results by the end of 2014.

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** Submission: 8 January 2014; Evaluation: 8 February 2014; Reception of revised manuscript: 27 May 2014; Accepted: 28 May 2014; Available on-line: 11 June 2014*

The recognition of the value of the Azorean geological heritage effectively occurs with its integration in the European and Global Geoparks Network, under the auspices of the UNESCO, in march 2013, being the first truly archipelagic geopark, with the motto "9 islands - 1 geopark" " where people can enjoy eruptions of flavours,smells and experiences".

With the mentioned background, there are established the basis for the definition of a methodology for the management of the geological heritage of the archipelago, in order to be compatible the usufruct and geoconservation, to be possible to maintain the quality of the geosites and pass this important legacy for future generations.

Keywords: geological heritage, geoconservation, management, Azores Geopark.

RESUMO

O arquipélago dos Açores, com um enquadramento geodinâmico singular, apresenta uma enorme geodiversidade e importante património geológico, sendo considerado um laboratório natural de geodiversidade vulcânica.

Nos últimos anos têm vindo a ser desenvolvidos estudos e ações de valorização do património geológico do arquipélago, estando, atualmente, identificados e caracterizados 121 geossítios distribuídos pelas nove ilhas e fundos marinhos envolventes, que garantem a representatividade da geodiversidade dos Açores e reflectem a sua história geológica e eruptiva de cerca de 10 milhões de anos. Destes, 57 geossítios foram selecionados como prioritários para o desenvolvimento de estratégias de geoconservação e para implementação de ações de valorização.

A análise dos geossítios incluiu duas fases principais: uma avaliação qualitativa e uma avaliação quantitativa, integrando a caracterização geológica, categorização geomorfológica e vulcanológica, análise da relevância, a identificação do potencial tipo de uso em cada geossítio, seu valor científico e outros valores associados. Dos trabalhos desenvolvidos resultaram o reconhecimento de 6 geossítios com relevância internacional [e.g. Dorsal Atlântica, a Caldeira do vulcãodas Furnas (ilha de São Miguel), a Montanha do Pico (ilha do Pico) a Caldeira e Furna do Enxofre (ilha Graciosa), o Vulcão dos Capelinhos e Costado da Nau (ilha do Faial) e o Algar do Carvão (ilha Terceira)] e 52 geossítios de relevância nacional. Para além do valor científico, a maior parte dos geossítios têm valor educacional e geoturístico. É de salientar que 93 geossítios integram a Rede Regional de Áreas Protegidas, encontrando-se sob gestão dos Parques Naturais de Ilha e do Parque Marinho dos Açores.

As paisagens vulcânicas dos Açores têm vindo a ser promovidas desde o final do século XX, principalmente por campanhas turísticas, contudo desde que se iniciaram os trabalhos de estudos do património geológico do arquipélago, em 2007, este também tem vindo a ser divulgado regional, nacional e internacionalmente.

Os geossítios terrestres estão a ser monitorizados, incidindo-se no estado do geossítio, suas condições geológicas de interesse e na caracterização do público que o visita. A monitorização iniciou-se no final de 2013 em todo o arquipélago, aguardando-se os primeiros resultados para o final do ano de 2014.

O reconhecimento do valor do património geológico açoriano concretiza-se com a integração do Geoparque Açores nas Redes Europeia e Global de Geoparques, em março de 2013, constituindo o primeiro geoparque verdadeiramente arquipelágico, com o mote "9 ilhas – 1 geoparque", onde se "Desfrutam de erupções de sabores, aromas e experiências!".

Estão, assim, estabelecidas as bases para se partir para a definição de uma metodologia de gestão do património geológico do arquipélago dos Açores, de forma a se compatibilizar, da melhor forma, o seu usufruto e geoconservação, para que se mantenha a qualidade dos geossítios e passe este importante legado para as gerações futuras.

Palavras- chave: *património geológico, geoconservação, gestão, Geoparque Açores.*

1. AZORES ARCHIPELAGO

The Azores archipelago is a Portuguese autonomous region located in the Atlantic Ocean (at a distance of 1815 km from Portugal mainland and 2625 km from Canada), composed by nine islands (with small dimension, between 17 and 745 sq. km), some islets and the surrounding seafloor. The islands are dispersed along approximately 600 km, between Santa Maria and Corvo islands, with an orientation WNW-ESE (Figure 1).

The Azores archipelago emerges from an extensive area of irregular bathymetry, defined by the 2000 meters bathymetric line, which makes the transitions to the surrounding abyssal seafloor.

In terms of the global geodynamics, the archipelago is located at the triple junction of the Eurasian, North American and African (or Nubian) lithospheric plates. The main structures that frame this junction are: i) the Mid-Atlantic Ridge (with an approximately N-S trend) - which corresponds to a pure distensive boundary between the North-American plate, on West, and the Eurasian and African plates, on East, and ii) the Gloria Fault (with a general W-E trend), that establishes the plate boundary Eurasia-Africa and integrates a major structure, the Azores-Gibraltar Fault.

The configuration of the islands of the central and eastern groups, with west-northwest - east-southeast, and Corvo and Flores islands through north-south direction, reflects the structural control by the main tectonic structures that interact at the Azores triple junction and influence the geomorphology of the islands (Nunes., 1991; França *et al.*, 2003;. Nunes *et al.*, 2009)(Figure 2).

All the Azorean islands are of volcanic origin, being identified 16 polygenetic volcanoes and 11 fissural volcanic systems, counting with a total of 1750 monogenetic volcanoes in the archipelago (Nunes & Lima, 2008). Given its complex geodynamic framework the Azores archipelago also presents an important seismicity on a global context, related either with the active tectonic activity in the Azores, either to the occurred volcanic activity.

The Azores archipelago has a rich and vast geodiversity and an important geological heritage, composed by several sites of scientific, educational and touristic interest. Volcanoes, calderas, lakes, lava fields, fumaroles, hot springs

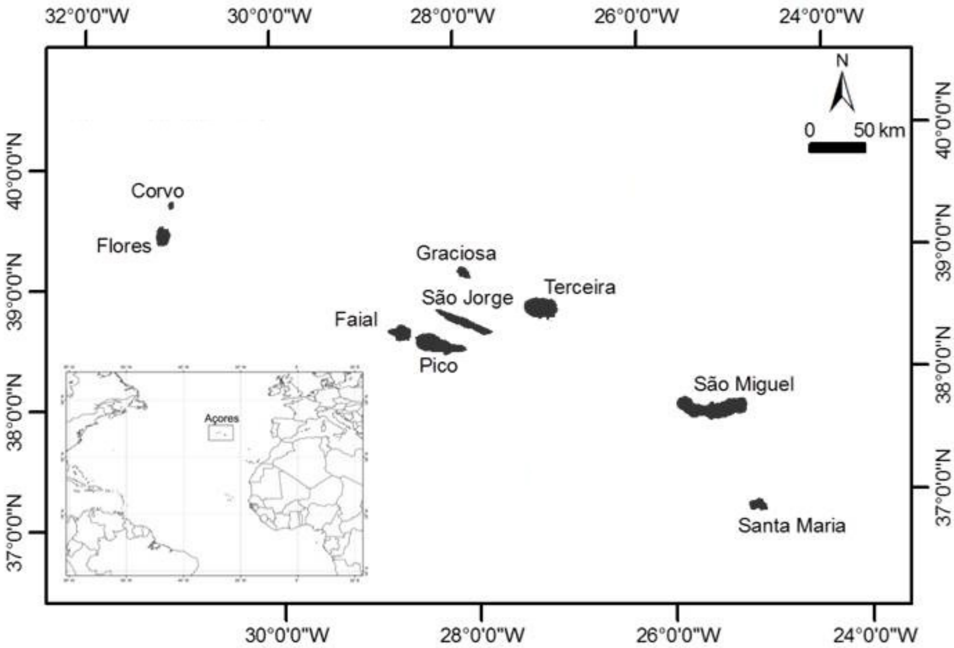

Figure 1. Geographic setting of the Azores archipelago, Portugal.
Figura 1. *Enquadramento geográfico do arquipélago dos Açores, Portugal.*

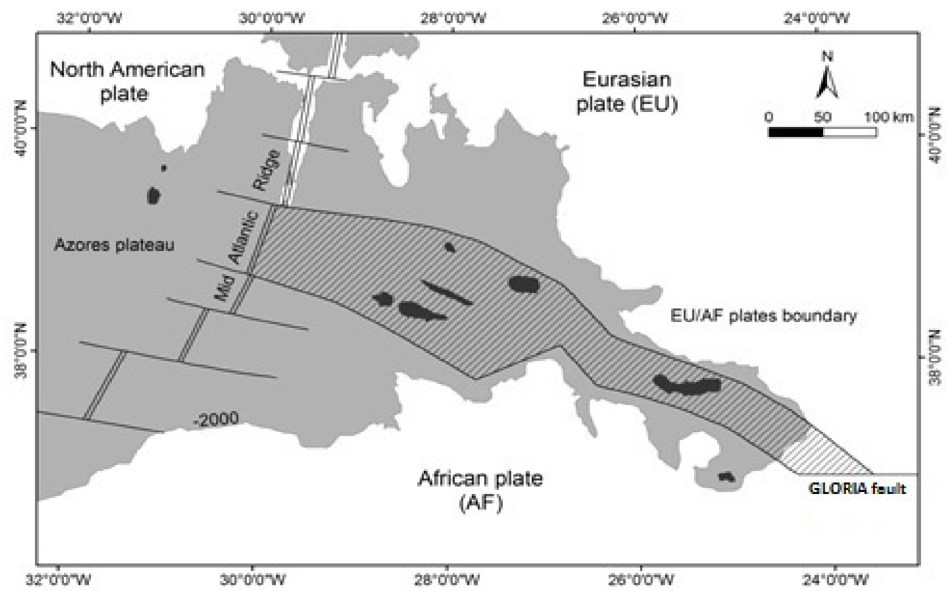

Figure 2. Geodynamic setting of the Azores archipelago, Portugal (adapted from Lourenço, 2007).
Figura 2. *Enquadramento geodinâmico do arquipélago dos Açores, Portugal. (adaptado de Lourenço, 2007).*

and thermal waters, volcanic caves, "fajãs", fault scarps and marine fossil deposits, among many others, are characteristic elements of the Azorean geological heritage.

The volcanic features toghether with the tectonic, paleontological and others, were the starting point for the identification, characterization and quantification of the value of the geodiversity and geological heritage of the Azores (Lima, 2007;. Nunes *et al.*, 2011).

2. NATURE CONSERVATION IN THE AZORES ARCHIPELAGO

Since the settlement of the Azores, in the middle of the 15th century, the exceptional natural and landscape resources attract several visitors and distinguished naturalists and scientists. However nature conservation in the Azores becomes effective in 1972 with the creation of the first protected areas, the Integral Reserves of Faial Caldera and Pico Mountain (Decreto Legislativo n.º 78/72, de 7 de março, e Decreto Legislativo n.º 79/72, de 8 de março) (Lima, 2007).

After Goulart (1999), the main strategic actions in the archipelago in the conservation of nature are related to:

- the application of national law;
- the appropriateness of the legislation to the archipelagic specificities, from political-administrative status as an autonomous region;
- implementation of the regional ecological network;
- cataloging the natural heritage of the Azores;
- the implementation of measures for the development and management of classified areas;
- the allocation of a environmental monitoring staff (the nature guards);
- the promotion of information and dissemination campaigns about the natural heritage;
- encouraging the development of the scientific knowledge;
- the establishment of inter-regional, national and international projects of intersectoral cooperation.

Regarding the geological component of the Azorean natural heritage, the oldest descriptions of the geology of the islands were writen by Gaspar Fructuoso in the 16th century (Fructuoso, 1583; França *et al.*, 2003). However, only in the second half of the 20th century is introduced the concept of conservation of the geological heritage elements in the region with Victor Hugo Forjaz as a pioneer (Forjaz *et al.*, 2006; Forjaz, 2007; Lima, 2007).

The Environmental management in the archipelago, made in recent years, reflects the increased concerns safeguarding the rich geological heritage of the region, contributing also to their promotion and enhancement. Lima (2007) indicates several important steps to achieve this objective, presented in the following list:

- the opening to the public of some volcanic caves, such as *Furna do Enxofre* on the Graciosa island since 1939, the *Algar do Carvão* and *Gruta do Natal* at Terceira island since 1968 and 1969 respectively, and more recently, the *Gruta das Torres* in Pico island, *Gruta do Carvão* in São Miguel island, and showing part of the volcanospeleological heritage of archipelago;
- in 1998 the Azores Regional Government creates a multidisciplinary group to study the volcanic caves of the archipelago and their management, designated GESPEA;
- the Volcanological and Geothermal Observatory of the Azores, created in 1998, edited several publications for the dissemination and promotion of the geological heritage of the region; this institution has also promote public actions of geological education;
- some Azorean environmental non-governmental organizations (*e.g.* Amigos dos Açores - Ecological Association and Os Montanheiros - Speleological Society), also participate in the dissemination and promotion of the geological component of the natural heritage of the archipelago, through publications, proposed classification of geological interest sites, and recreational activities that promote the contact with the natural heritage;
- the volcanospeleological museum, opened to the public since the 1980's, property of Os Montanheiros – Speleological Society (Terceira island);
- the classification of some geosites as Natural Monuments in 2004 and 2005, such as *Pedreira do Campo* in Santa Maria island, *Gruta do Carvão*, *Pico das Camarinhas* and *Ponta da Ferraria* in São Miguel island and *Gruta das Torres* in Pico island, although there are other geological elements protected under others legal figures since 1972;
- in 2004 the project "GeoDIVA - Geodiversity of Protected Areas of the Azores" was implemented by the Azores University, providing scientific advice to the Environment Regional Directorate of the Azores Regional Government, regarding the promotion and enhancement of the geodiversity of these areas;
- several studies about the geodiversity and geological heritage of the Azores have been developed, such as publications about the "Azores islands of geodiversity" - Graciosa, Santa Maria and São Jorge islands (Nunes & Lima, 2005; Nunes *et al.*, 2007; Lima *et al.*, 2013a), "Geosites Maps" - Santa Maria, Graciosa, Corvo and São Jorge islands (Nunes *et al.*, 2008; Nunes *et al.*, 2009; Nunes *et al.*, 2010; Nunes *et al.*, 2013);
- there are also some academic studies and works on these topics, such as master's theses "Azorean Geologic Heritage: Valuing Geosites in Environmental Classified Protected Areas, Contribution to the Territorial Planning" (Lima, 2007), "Monitoring Strategies for the geosite ' Ponta da Ferraria e Pico das Camarinhas', S. Miguel Island: Contribution to the sustainable management of the geological heritage of the Azores Geopark "(Lima, 2012) and a degree thesis about "Geomonuments Map of Terceira Island (a contribution)" (Lopes, 2007);
- participation in dissemination sessions about the geodiversity and geological heritage of the Azores in regional, national and international events, providing

information about the work in progress and sharing experiences;

- in 2007 the Azores Regional Government announced its intention to create the Azores Geopark and submit its application to the European and Global Geopark Networks; in 2010 it was formally established the Azores Geopark Association, which manages the geopark; and in march 2013 occurred the inclusion in the networks, constituting the first archipelagic geopark, and thus being internationally recognized the value of their geological heritage and its importance in the social, cultural and economic dynamics of this region.

It is worth to note that the Regional Legislative Decree n. 15/2007/A, of 25 June, which reclassifies the protected areas of the region with uniform criteria, integrates, for the first time in regional and national environmental legislation, geological elements of the Azorean geodiversity (beyond those associated with biological aspect).

Therefore since the last decades of the 20th century there have been some initiatives that show concern for the protection of geological heritage of the archipelago, having stepped up the number of activities and studies for this purpose. As mentioned above, the geological heritage of the archipelago has its value, recently, recognized with the creation of the Azores Geopark.

3. GEOCONSERVATION IN THE AZORES ARCHIPELAGO

The set of strategies, policies and actions for an effective conservation of the geodiversity and geological heritage protection is called geoconservation (Sharples, 2002; Brilha, 2002, 2005; Gray, 2004).

The geoconservation is based on a working methodology that systematizes the tasks in the conservation of the geological heritage of given territory (Brilha, 2005). Some authors describe methods of work with that purpose, based generally on the same basic steps (Cendrero, 2000, Lago *et al.*, 2001; Brilha, 2005; Carcavilla *et al.*, 2007).

In general terms the steps to apply are:

- inventory and characterization - each geosite must be located and limited geographically, and characterized based on field work and bibliography;
- quantification of the value or relevance - calculated based on defined criteria;
- classification - the geosites that obtain greater importance should be proposed for classification in accordance with the existing legal framework;
- conservation - a geoconservation strategy should give concrete and practical answers to a preliminary assessment on the threats that may relate to the geosites;
- valorization and promotion - actions of information and interpretation that help the public to recognize the value of the geosites;
- monitoring - verification and analysis of the evolution of the geosites conservation, to ensure the maintenance of its value and relevance.

3.1. Inventory and characterization

The inventory and characterization of the geological heritage of the Azores was based on three studies: i) a Master thesis in Spatial and Environmental Planning at the Azores University, "Azorean Geologic Heritage: Valuing Geosites in Environmental Classified Protected Areas, Contribution to the Territorial Planning" by Lima (2007); ii) the works and studies leading the Azores Geopark application to the European Network and Global Geoparks (Nunes *et al.*, 2011); iii) and the scientific research project "Identification, characterization and conservation of geological heritage: a geoconservation strategy for Portugal" (2007-2010) (Brilha & Pereira, 2012).

3.1.1. Master thesis - Lima (2007)

The first systematic study of the geological heritage of the archipelago was carried out by Lima (2007). The analysis of the geological heritage of the 83 environmental areas classified in the Azores included two main steps: a qualitative and quantitative assessment.

The geological characterization of each environmental area and the selection of the sites that stand out for its geological features were based on the geological knowledge of the areas complemented with bibliography research, resulting in the identification of 59 geosites (56 terrestrial and 3 marine) (Figure 3).

Following the characterization of the geosites, these were categorized according to their geomorphological and volcanological characteristics, being based on the work performed by Nunes (2003).

According to the results obtained most of the geosites identified are coastal and marine areas (25), several altitude areas (19) and many integrate volcanic lakes or coastal lagoons (15), reflecting the morphological character of the islands, usually with a mountainous central zone and with great presence of water. In the remaining categories, we report the historical eruptions (13), areas of hydrothermal activity (10), calderas (9), surtseyan tuff cones (6), volcanic caves (4) and fields of scoria and spatter cones (3), portraying the diversity of morphologies and types of volcanic activity that gave rise to them.

About the quantitative assessment, Lima (2007) opted to adapt the methodology of Brilha (2005) to the territorial and geological reality of the archipelago. It is noted that the above method is based on the method described by Cendrero *et al.* (1996) and Cendrero (2000), but adjusted to the Portuguese reality. In this methodology three classes of criteria about the geosites are evaluated: A) intrinsic criteria (uniqueness, area, geodiversity, conservation status, association with other heritage elements, scientific knowledge), B) potential use (observation conditions, accessibility, potential audience, socio- economic conditions, different types of use) and C) need for protection (legal status, ownership, vulnerabilities and threats). Calculated the relevance or value of the geological heritage assigning numerical values to different criteria, allowed the comparison among the analyzed geosites, resulting the ranking and determining their international/national or regional/local relevance.

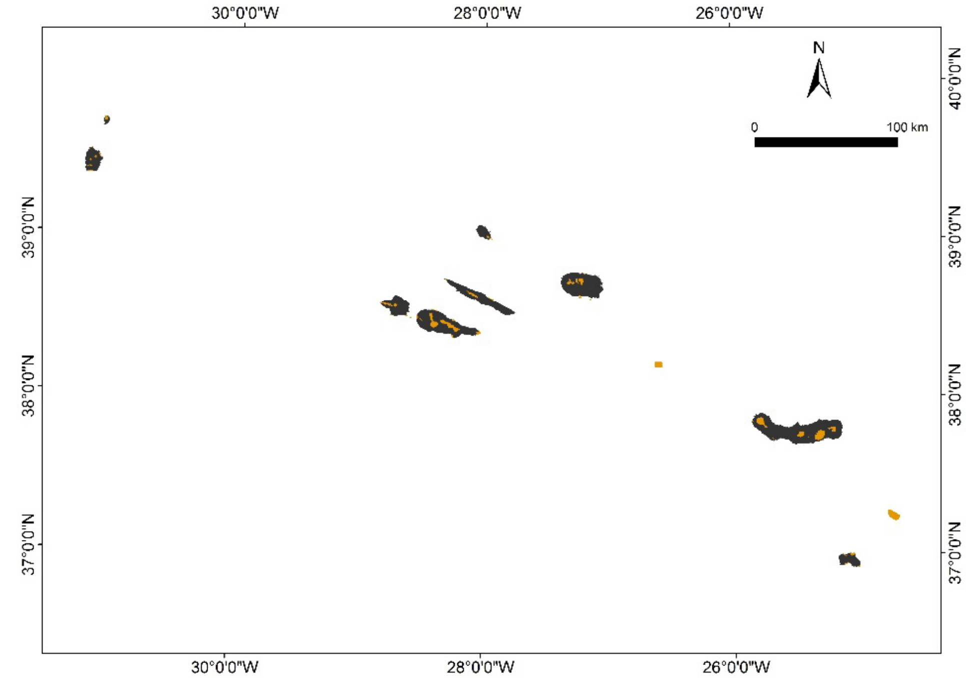

Figure 3. Geosites identified in the Azorean environmental areas, in 2007 (adapted from Lima, 2007).
Figura 3. *Geossítios (a laranja) das áreas ambientais dos Açores,em 2007 (adaptado de Lima, 2007).*

In the 59 geosites identified in the existing environmental areas of the Azores in 2007, 36 had international or national importance, and the other 23 had regional or local relevance. It was also found that the most valued sites are those that include a remarkable geodiversity. In the ranking the most importants sites are*Caldeira do vulcão das Furnas* (Furnas volcano caldera), on the island of São Miguel; *Montanha do Pico* (Pico Mountain); *Caldeira do Faial* (Caldera of the central volcano of Faial island); *Caldeira do vulcão das Sete Cidades* (Sete Cidades volcano caldera) and *Caldeira do vulcão do Fogo* (Fogo volcano caldera) both also in São Miguel.

3.1.2. Azores Geopark aplication to the European and Global Geoparks Networks

The inventory and characterization of geological heritage has been extended to the entire archipelago with the same methodology of Lima (2007), this analysis was crucial to the application of the archipelago internationally recognized as a geopark.

The developed works were based on the knowledge gathered about the geological characteristics of the territory, the eruptive history of each Azorean island and the elements of geological heritage identified in the islands and in the surrounding seafloor. Several researchers of the Region and national and foreigner scientists with assignments about the Azores in several areas have also contributed to this inventory, which have resulted in a sustained and wide approach (Nunes *et al.*, 2011).

The geopark is based on a network of 121 geosites spread over the nine islands and the surrounding seafloor (Figure 4) which ensures the representativeness of the geodiversity of the Azores and reflects its geological and eruptive history of about 10 million years. From these, 57 geosites were selected as priority for the development of geoconservation strategies and for the implementation of valorization actions at the aim of the project Azores Geopark, distributed by Santa Maria (5), São Miguel (10), Terceira (7), Graciosa (5), São Jorge (5), Pico (8), Faial (6), Flores (6) and Corvo (3) islands, and the Azores Plateau seafloor (2) (Lima *et al.*, 2009; Nunes *et al.*, 2011).

The choice of priority geosites relied on several parameters: i) the international or national relevance; ii) representativeness of the archipelago geodiversity; iii) its position in the geosites ranking; iv) category icons and v) characterization (vulnerability, usufruct, affluence, ...).

Qualitative and quantitative assesment were also performed, based on Lima (2007), incorporating not only the geological characterization, geomorphological and volcanological categorization and analysis of the relevance, as well as identifying the type of use in each geosite, its scientific value and others associated values. The geosites list and the most relevant results are presented in the Table 1 to 3.

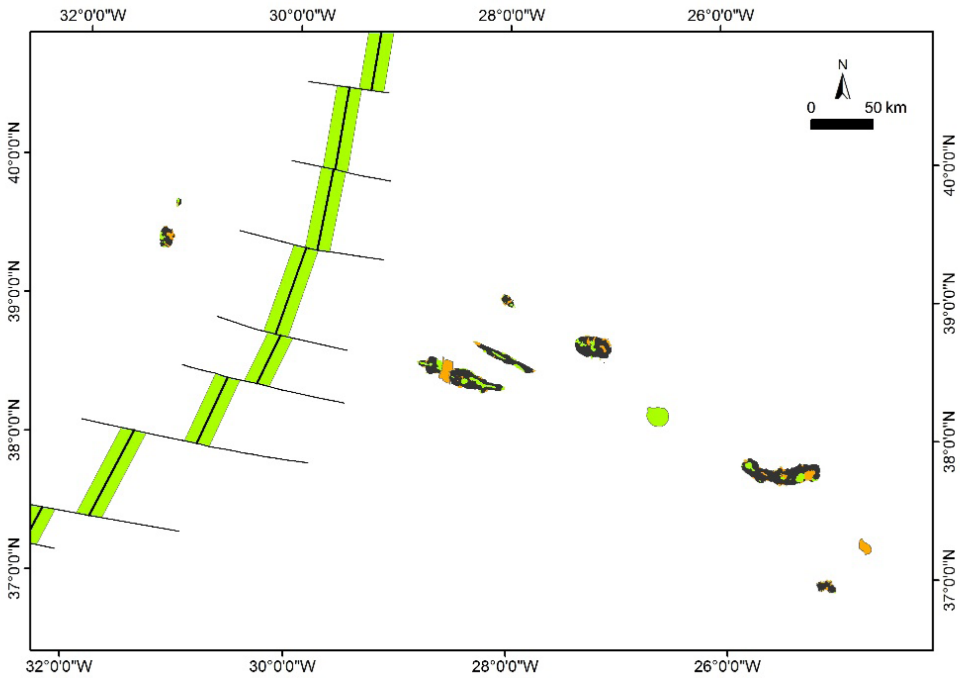

Figure 4. Location of the 121 Azorean geosites (main geosites – green, others geosites – orange) (in Nunes *et al.*, 2011).
Figura 4. *Localização dos 121 geossítios dos Açores (geossítios prioritários a verde e restantes geossítios a laranja) (in Nunes et al., 2011).*

Table 1. Geomorphological and volcanological categories of the geosites (adapted from Nunes, 2003; Lima, 2007; Wood, 2009).
Tabela 1. *Categorias geomorfológicas e vulcanológicas dos geossítios dos Açores (adaptado de Nunes, 2003; Lima, 2007; Wood, 2009).*

Geomorphological and volcanological categories			
1	Sea cliffs	13	Lava deltas (or lava "fajãs")
2	Calderas	14	Weathering phenomena/mud deposits-"barreiros"
3	Volcanic caves	15	Fossiliferous deposits
4	Fields of scoria and spatter cones	16	Volcanic lakes
5	Surtseyan tuff cones	17	Coastal lagoons
6	Volcanic ridges	18	*Pahoehoe* lava fields-"lajidos"
7	Quaternary deposits (*e.g.* beaches and slope deposits-"fajãs")	19	Maars
8	Prismatic and spheroidal jointing	20	Fluvial valleys
9	Domes and *coulées*	21	Polygenetic volcanoes
10	Historical eruptions	22	Areas of hydrothermal activity
11	Sub-volcanic structures (*e.g.* necks and dykes)	23	Others
12	Tectonic structures (*e.g.* faults and *grabens*)		

Table 2. Elements used in the evaluation of the Azorean geosites (in Nunes *et al.*, 2011).
Tabela 2. *Elementos utilizados na avaliação dos geossítios dos Açores (in Nunes et al., 2011).*

Relevance		Scientific Value		Others Values	
Int	International	**Geom**	Geomorphological	**Arq**	Archeological or similar
Nac	National	**Paleo**	Paleontological	**Cult**	Cultural
Reg	Regional	**Min**	Mineralogical	**Ecol**	Ecological
		Pet	Petrological	**Hist**	Historical
Use		**Estr**	Stratigraphic	**Pvist**	Scenic (Landscape)
Cie	Scientific	**Tect**	Tectonic		
Ec	Economic	**Hidro**	Hydrological		
Ed	Educational	**Hidrot**	Hydrothermal		
Geot	Geotourism	**Vulc**	Volcanic		
		Espeleo	Speleological		
		Sed	Sedimentary		

Table 3. List of Azores archipelago geosites, its geomorphological and volcanological categories, relevance, use and values. The 57 prioritary geosites are distinguished at gray (in Nunes *et al.*, 2011).
Tabela 3. *Lista de geossítios do arquipélago dos Açores, suas categorias geomorfológicas e vulcanológicas, relevância, uso e valores. Destacam-se, a cinzento, os 57 geossítios prioritários (in Nunes et al., 2011).*

Island	Geosite		Geomor phological and Volcanological Categories	Relevance	Use	Scientific Values	Other Values
Corvo	Caldeirão	(COR 1)	2 | 16 | 21	Nac	Cie | Ed | Geot	Geom | Hidro | Vulc	Cult | Ecol | Pvist
	Fajã lávica de Vila do Corvo	(COR 2)	13	Reg	Cie | Ed	Geom | Estr | Vulc	Cult | Pvist
	Ponta do Marco	(COR 3)	1 | 11	Reg	Cie | Geot	Estr | Vulc	Ecol | Pvist
	Coroínha e arriba de Pingas	(COR 4)	1 | 11	Reg	Cie | Ec | Ed	Geom | Estr | Vulc	
Flores	Caldeiras Negra, Comprida, Seca e Branca	(FLO 1)	16 | 19	Nac	Cie | Ed | Geot	Geom Hidro | Vulc	Ecol | Pvist
	Caldeiras Rasa e Funda das Lajes	(FLO 2)	16 | 19	Nac	Cie | Ed | Geot	Geom | Estr | Hidro | Vulc	Ecol | Pvist
	Fajã Grande e Fajãzinha	(FLO 3)	1 | 7 | 13 | 20	Nac	Cie | Ed | Geot	Geom | Estr | Tect | Hidro | Vulc | Sed	Cult | Pvist
	Pico da Sé	(FLO 4)	9	Reg	Cie | Ed | Geot	Geom | Vulc	Pvist
	Ponta da Rocha Alta e Fajã de Lopo Vaz	(FLO 5)	1 | 7	Reg	Cie | Geot	Geom | Estr | Sed	Ecol | Hist | Pvist
	Rocha dos Bordões	(FLO 6)	8	Nac	Cie | Ed | Geot	Geom | Vulc	Ecol | Pvist
	Costa Nordeste	(FLO 7)	1 | 8 | 11	Nac	Cie | Geot	Estr | Vulc	Pvist
	Filão dos Frades	(FLO 8)	11	Reg	Cie | Ed | Geot	Geom	Pvist
	Litoral de Santa Cruz	(FLO 9)	13	Reg	Cie | Ed | Geot	Geom | Pet | Vulc	Cult
	Ponta do Albarnaz - Ponta Delgada	(FLO 10)	1 | 8 | 11 | 14	Reg	Cie | Ed | Geot	Pet | Estr | Tect | Vulc	Cult
	Vale da Ribeira da Cruz e Ponta da Caveira	(FLO 11)	1 | 3 | 11 | 20	Nac	Cie | Ec | Ed | Geot	Geom | Hidro | Hidrot | Vulc	Pvist
	Vale das Ribeiras da Badanela e Além Fazenda	(FLO 12)	11 | 20	Nac	Cie | Ed | Geot	Geom | Hidro | Vulc	Pvist
	Vale e fajã lávica das Lajes	(FLO 13)	12 | 13	Reg	Cie | Ec	Geom | Min | Estr | Vulc	Pvist
	Ilhéu de Monchique	(FLO 14)	23	Reg		Geom	Pvist

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Tabela 3. *Lista de geossítios do arquipélago dos Açores, suas categorias geomorfológicas e vulcanológicas, relevância, uso e valores. Destacam-se, a cinzento, os 57 geossítios prioritários (in Nunes et al., 2011).*

Island	Geosite		Geomor phological and Volcanological Categories	Relevance	Use	Scientific Values	Other Values
Faial	Caldeira	(FAI 1)	2 | 10 | 21	Nac	Cie | Ed | Geot	Geom | Tect | Hidro | Vulc	Ecol | Hist | Pvist
	Graben de Pedro Miguel	(FAI 2)	1 | 12	Nac	Cie | Ec | Ed | Geot	Geom | Tect	Cult | Hist | Pvist
	Monte da Guia e Porto Pim	(FAI 3)	5 | 7	Nac	Cie | Ed | Geot	Geom | Pet | Vulc | Sed	Cult | Pvist
	Morro do Castelo Branco	(FAI 4)	1 | 9 | 14	Nac	Cie | Ed | Geot	Geom | Min | Vulc	Ecol | Pvist
	Península do Capelo	(FAI 5)	3 | 4 | 6 | 10 | 12	Reg	Cie | Ec | Ed | Geot	Geom | Tect | Vulc	Hist | Pvist
	Vulcão dos Capelinhos e Costado da Nau	(FAI 6)	1 | 5 | 10 | 11	Int	Cie | Ed | Geot	Geom | Pet | Estr | Tect | Vulc	Ecol | Hist | Pvist
	Arriba fóssil da Praia do Norte	(FAI 7)	1 | 7 | 18	Reg	Cie | Ec | Ed | Geot	Geom | Estr | Sed	Pvist
	Arriba fóssil do Varadouro	(FAI 8)	1 | 22	Reg	Cie | Ed | Geot	Geom | Estr | Hidrot	Cult | Pvist
	Ponta Furada	(FAI 9)	1 | 8 | 18	Nac	Cie	Geom | Vulc	
Pico	Arriba fóssil Sto António - São Roque	(PIC 1)	1 | 13	Reg	Cie | Ec	Geom | Pet | Estr | Vulc	
	Fajã lávica das Lajes do Pico	(PIC 2)	1 | 11 | 13 | 17	Reg	Cie | Ed | Geot	Geom | Vulc	Cult | Ecol | Pvist
	Gruta das Torres	(PIC 3)	3	Reg	Cie | Ec | Ed | Geot	Min | Vulc | Espeleo	Ecol
	Ilhéus da Madalena	(PIC 4)	5	Nac	Cie | Geot	Geom | Pet | Vulc	Pvist
	Lajido de Santa Luzia	(PIC 5)	1 | 10 | 18	Nac	Cie | Ed | Geot	Geom | Vulc	Cult
	Montanha	(PIC 6)	7 | 12 | 18 | 21 | 22	Int	Cie | Ed | Geot	Geom | Estr | Tect | Hidrot | Vulc | Sed	Ecol | Hist | Pvist
	Planalto da Achada	(PIC 7)	4 | 6 | 10 | 12 | 16	Reg	Cie | Ec | Ed | Geot	Geom | Estr | Tect | Hidro | Vulc | Espeleo	Ecol | Hist | Pvist
	Ponta da Ilha	(PIC 8)	1 | 8 | 18	Nac	Cie | Ec | Ed | Geot	Geom | Vulc	Cult | Ecol
	Algar/Gruta do Canto da Serra	(PIC 9)	3	Reg	Cie	Vulc | Espeleo	
	Fajã lávica de São Mateus	(PIC 10)	1 | 13	Reg	Cie | Ed	Geom | Vulc	
	Fajã lávica das Ribeiras	(PIC 11)	1 | 13	Reg	Cie | Ed	Geom | Min | Vulc	Pvist
	Furna Vermelha	(PIC 12)	3	Reg	Cie	Vulc | Espeleo	
	Gruta dos Montanheiros	(PIC 13)	3	Reg	Cie	Vulc | Espeleo	
	Hornitos e Furna do Frei Matias	(PIC 14)	3	Reg	Cie | Geot	Vulc | Espeleo	
	Lajidos da Criação Velha	(PIC 15)	1 | 18	Nac	Cie | Ed | Geot	Geom | Vulc	Cult | Pvist
	Lomba do Fogo	(PIC 16)	10 | 12	Reg	Cie	Geom | Tect | Vulc | Espeleo	Ecol | Hist | Pvist
	Ponta do Mistério	(PIC 17)	1 | 10 | 13	Reg	Cie | Ed | Geot	Geom | Pet | Vulc	Ecol | Hist | Pvist
	Cabeço Debaixo da Rocha	(PIC 18)	5	Nac	Cie | Ed	Pet | Estr | Vulc	Pvist
São Jorge	Arribas das Fajã dos Vimes – Fajã de São João	(SJO 1)	1 | 7 | 12 | 20	Nac	Cie | Ed | Geot	Geom | Tect | Sed	Cult | Ecol | Pvist
	Cordilheira vulcânica central	(SJO 2)	3 | 4 | 6 | 10 | 12 | 16	Reg	Cie | Ec | Ed | Geot	Geom | Tect | Hidro | Vulc | Espeleo	Hist | Pvist
	Fajãs do Ouvidor e da Ribeira da Areia	(SJO 3)	1 | 13	Reg	Cie | Ed | Geot	Geom | Estr | Vulc	Pvist
	Fajãs dos Cubres e da Caldeira de Sto Cristo	(SJO 4)	1 | 7 | 17	Nac	Cie | Ed | Geot	Geom | Hidro | Sed	Cult | Ecol | Pvist
	Morro de Velas e Morro de Lemos	(SJO 5)	1 | 5 | 15	Nac	Cie | Ed | Geot	Geom | Paleo | Pet | Vulc	Ecol | Pvist
	Ponta dos Rosais	(SJO 6)	1 | 11	Reg	Cie | Geot	Geom | Estr | Vulc	Cult | Pvist
	Mistério da Urzelina	(SJO 7)	1 | 10	Nac	Cie | Ed | Geot	Vulc	Hist
	Ponta e ilhéu do Topo	(SJO 8)	1 | 8	Reg	Cie | Ed | Geot	Geom | Pet | Estr | Vulc	Cult | Pvist

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Island	Geosite		Geomor phological and Volcanological Categories	Relevance	Use	Scientific Values	Other Values
Graciosa	Caldeira e Furna do Enxofre	(GRA 1)	2 | 3 | 9 | 16 | 21 | 22	Int	Cie | Ec | Ed | Geot	Geom | Min | Tect | Hidro | Hidrot | Vulc | Espeleo	Cult | Hist | Pvist
	Caldeirinha de Pêro Botelho	(GRA 2)	3	Reg	Cie | Ed | Geot	Vulc | Espeleo	Pvist
	Ponta da Barca e Ilhéu da Baleia	(GRA 3)	1 | 11 | 22	Nac	Cie | Ed | Geot	Geom | Estr | Hidrot | Vulc	Cult | Pvist
	Porto Afonso e Redondo	(GRA 4)	1 | 4 | 11	Nac	Cie | Ed | Geot	Geom | Estr | Vulc	Pvist
	Ponta do Carapacho, Ponta da Restinga e Ilhéu de Baixo	(GRA 5)	1 | 5 | 11 | 22	Nac	Cie | Ec | Ed | Geot	Geom | Estr | Hidrot | Vulc	Cult | Ecol | Pvist
	Arribas da Serra Branca e Baía do Filipe	(GRA 6)	1 | 9 | 11	Nac	Cie | Ed | Geot	Geom | Estr | Vulc	Pvist
	Baía da Vitória	(GRA 7)	18 | 22	Reg	Cie	Hidro | Hidrot | Vulc	
	Erupção do Pico Timão	(GRA 8)	1 | 4	Reg	Cie | Ec	Geom | Vulc	
	Santa Cruz da Graciosa	(GRA 9)	4 | 13	Reg	Cie | Ed | Geot	Geom | Hidro | Vulc	Cult | Pvist
Terceira	Algar do Carvão	(TER 1)	3 | 16	Int	Cie | Ec | Ed | Geot	Min | Hidro | Vulc | Espeleo	Ecol
	Caldeira de Santa Bárbara e Mistérios Negros	(TER 2)	2 | 9 | 10 | 12 | 21	Nac	Cie | Ed | Geot	Geom | Min | Tect | Vulc	Ecol | Hist | Pvist
	Caldeira de Guilherme Moniz	(TER 3)	2 | 3 | 18 | 21	Reg	Cie | Ed	Geom | Tect | Vulc | Espeleo	
	Furnas do Enxofre	(TER 4)	14 | 22	Reg	Cie | Ed | Geot	Hidrot	Pvist
	Monte Brasil	(TER 5)	1 | 5 | 12 | 15	Nac	Cie | Ed | Geot	Geom | Paleo | Pet | Estr | Tect | Vulc	Cult | Hist | Pvist
	Pico Alto, Biscoito Rachado e Biscoito da Ferraria	(TER 6)	2 | 9 | 21	Nac	Cie | Ec | Ed | Geot	Geom | Min | Estr | Tect | Vulc	Ecol | Pvist
	Ponta da Serreta e escoadas traquíticas	(TER 7)	1 | 9 | 12	Reg	Cie | Ed | Geot	Geom | Pet | Vulc	Ecol
	Fajã da Alagoa - Biscoito das Calmeiras	(TER 8)	1 | 7 | 9	Reg	Cie | Ed | Geot	Geom | Estr | Vulc | Sed	Pvist
	Graben das Lajes	(TER 9)	1 | 12	Nac	Cie | Ed | Geot	Geom | Pet | Tect	Pvist
	Ilhéus das Cabras	(TER 10)	5	Nac	Cie | Geot	Geom | Pet | Tect | Vulc	Pvist
	Mistério 1761 e sistema cavernícola da Malha Grande – Balcões	(TER 11)	3 | 10	Reg	Cie | Ec	Min | Vulc | Espeleo	Ecol | Hist
	Serra do Cume	(TER 12)	2 | 21	Reg	Cie | Ed | Geot	Geom | Vulc	Pvist
	Biscoitos - Matias Simão	(TER 13)	1 | 18	Reg	Cie	Geom | Vulc	Cult

Table 3. List of Azores archipelago geosites, its geomorphological and volcanological categories, relevance, use and values. The 57 prioritary geosites are distinguished at gray (in Nunes *et al.*, 2011).
Tabela 3. *Lista de geossítios do arquipélago dos Açores, suas categorias geomorfológicas e vulcanológicas, relevância, uso e valores. Destacam-se, a cinzento, os 57 geossítios prioritários (in Nunes et al., 2011).*

Island	Geosite		Geomor phological and Volcanological Categories	Relevance	Use	Scientific Values	Other Values
São Miguel	Caldeira do vulcão das Furnas	(SMG 1)	2 | 9 | 10 | 14 | 16 | 20 | 21 | 22	Int	Cie | Ec | Ed | Geot	Geom | Min | Estr | Tect | Hidro | Hidrot | Vulc	Cult | Hist | Pvist
	Caldeira do vulcão das Sete Cidades	(SMG 2)	2 | 7 | 10 | 16 | 21	Nac	Cie | Ed | Geot	Geom | Estr | Hidro | Vulc | Sed	Cult | Pvist
	Caldeira do vulcão do Fogo	(SMG 3)	2 | 7 | 10 | 16 | 21	Nac	Cie | Ed | Geot	Geom | Min | Hidro | Vulc	Hist | Pvist
	Caldeira Velha	(SMG 4)	20 | 22	Reg	Cie | Ed | Geot	Tect | Hidro	
	Gruta do Carvão	(SMG 5)	3	Reg	Cie | Ec | Ed | Geot	Vulc | Espeleo	Cult
	Ilhéu de Vila Franca	(SMG 6)	5	Nac	Cie | Ed | Geot	Geom | Pet | Vulc	Ecol | Pvist
	Lagoas do Congro e dos Nenúfares	(SMG 7)	16 | 19	Reg	Cie | Ed | Geot	Geom | Hidro | Vulc	Pvist
	Ponta da Ferraria e Pico das Camarinhas	(SMG 8)	4 | 13 | 22	Nac	Cie | Ec | Ed | Geot	Geom | Min | Estr | Tect | Hidrot | Vulc	Cult | Pvist
	Serra Devassa	(SMG 9)	4 | 6 | 12 | 16	Reg	Cie | Ec | Ed | Geot	Geom | Tect | Hidro | Vulc	Cult
	Vale da Ribeira do Faial da Terra e Fajã do Calhau	(SMG 10)	1 | 7 | 9 | 11 | 20	Reg	Cie | Ed | Geot	Geom | Estr | Hidro | Vulc | Sed	Cult
	Caldeira da Povoação	(SMG 11)	2 | 20 | 21	Reg	Cie | Ec | Ed | Geot	Geom | Pet | Hidro | Vulc	Cult | Pvist
	Coroa da Furna – Arrenquinha	(SMG 12)	3 | 4 | 6	Reg	Cie | Ec | Ed	Geom | Tect | Vulc | Espeleo	
	Fajã lávica e arriba fóssil da Caloura	(SMG 13)	1 | 8 | 11 | 13	Reg	Cie | Ec | Ed | Geot	Geom | Estr | Vulc	Cult | Ecol | Pvist
	Fajã lávica e ilhéus dos Mosteiros	(SMG 14)	1 | 5 | 7 | 12 | 13	Nac	Cie | Ec | Ed | Geot	Geom | Pet | Tect | Hidrot | Vulc	Cult | Pvist
	Morro das Capelas	(SMG 15)	1 | 5 | 15	Nac	Cie	Geom | Paleo | Pet | Vulc	Cult
	Morro de Sta Bárbara, praias e Bandejo	(SMG 16)	1 | 7 | 9 | 10	Reg	Cie | Ed | Geot	Geom | Vulc | Sed	Cult
	Pico da Vara e Planalto dos Graminhais	(SMG 17)	20 | 23	Reg	Cie | Geot	Geom | Hidro	Ecol | Pvist
	Pisão - Praia (Água d'Alto)	(SMG 18)	1 | 7	Nac	Cie | Ed | Geot	Pet | Estr | Sed	Pvist
	Ponta do Cintrão - Ladeira da Velha	(SMG 19)	1 | 9 | 22	Nac	Cie | Ed | Geot	Geom | Estr | Hidrot | Vulc	Cult | Pvist
	Praias do Pópulo, Milicias e São Roque	(SMG 20)	7	Reg	Cie | Ed | Geot	Vulc | Sed	Cult | Pvist
	Rocha da Relva	(SMG 21)	1 | 7	Reg	Cie | Ed	Geom | Estr | Sed	Pvist
	Salto da Farinha	(SMG 22)	8 | 14 | 20	Nac	Cie | Ed | Geot	Geom | Hidro | Vulc	Pvist
	Salto do Cabrito	(SMG 23)	20	Nac	Cie | Ec | Ed | Geot	Tect | Hidro	
	Vale da Ribeira Quente	(SMG 24)	1 | 7 | 20 | 22	Reg	Cie | Ed | Geot	Geom | Estr | Hidro | Hidrot | Vulc | Sed	Hist | Cult
	Vale das Lombadas	(SMG 25)	9 | 20 | 22	Reg	Cie | Ec | Ed | Geot	Geom | Min | Hidro | Hidrot	Cult | Pvist
	Fontanário da Ribeira Seca	(SMG 26)	10	Nac	Cie | Ed | Geot	Vulc	Hist | Pvist
	Campo Geotérmico do Vulcão do Fogo	(SMG 27)	22	Nac	Cie | Ec | Ed | Geot	Hidrot	

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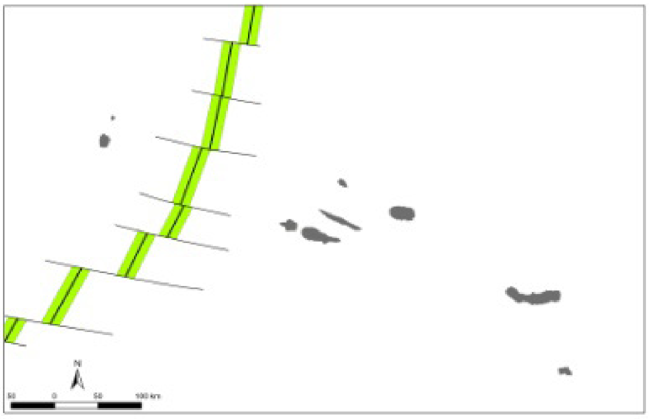
Tabela 3. *Lista de geossítios do arquipélago dos Açores, suas categorias geomorfológicas e vulcanológicas, relevância, uso e valores. Destacam-se, a cinzento, os 57 geossítios prioritários (in Nunes et al., 2011).*

Island	Geosite		Geomor phological and Volcanological Categories	Relevance	Use	Scientific Values	Other Values
Santa Maria	Barreiro da Faneca	(SMA 1)	14	Nac	Cie | Ed | Geot	Geom | Pet | Vulc	Pvist
	Pedreira do Campo	(SMA 2)	8 | 15	Nac	Cie | Ed | Geot	Paleo | Min | Pet | Estr | Vulc	Arq
	Poço da Pedreira	(SMA 3)	11 | 14	Nac	Cie | Ed | Geot	Geom | Vulc	Arq
	Ponta do Castelo	(SMA 4)	1 | 8 | 11 | 15	Nac	Cie | Ed | Geot	Geom | Paleo | Min | Pet | Estr | Vulc	Cult | Pvist
	Ribeira do Maloás	(SMA 5)	8 | 20	Nac	Cie | Ed | Geot	Geom | Vulc	Pvist
	Baía da Cré	(SMA 6	1 | 15	Reg	Cie | Ed | Geot	Geom | Paleo | Pet | Estr	Cult
	Baía de São Lourenço	(SMA 7)	1 | 7 | 15	Reg	Cie | Ed | Geot	Geom | Paleo | Sed	Pvist
	Baía do Raposo	(SMA 8)	1 | 8 | 20	Reg	Cie	Geom | Hidro	
	Baía do Tagarete e Ponta do Norte	(SMA 9)	1 | 14 | 15 | 20	Nac	Cie	Geom | Paleo | Hidro | Vulc	
	Baía dos Cabrestantes	(SMA 10)	1 | 5	Reg	Cie	Pet | Estr | Vulc	
	Barreiro da Malbusca	(SMA 11)	8 | 14	Nac	Cie | Ed	Min | Estr | Vulc	
	Cascata do Aveiro	(SMA 12)	8 | 20	Reg	Cie | Ed | Geot	Geom | Estr | Hidro	Pvist
	Figueiral	(SMA 13)	1 | 3 | 8 | 11 | 15	Reg	Cie | Ed | Geot	Paleo | Pet | Estr | Espeleo	Arq
	Porto de Vila do Porto	(SMA 14)	1 | 8 | 11	Nac	Cie | Ed	Estr | Vulc	Pvist
	Praia Formosa e Prainha	(SMA 15)	1 | 7 | 8 | 15 | 20	Nac	Cie | Ed | Geot	Geom | Paleo | Pet | Hidro | Sed	Cult | Pvist
Marine Areas	Banco D. João de Castro	(Marinha 1)	10 | 21 | 22	Reg	Cie | Geot	Geom | Tect | Hidrot | Vulc	Hist
	Dorsal Atlântica e Campos hidrotermais	(Marinha 2)	6 | 12 |22	Int	Cie	Geom | Min | Tect | Hidrot | Vulc	Ecol
	Canal Faial-Pico	(Marinha 3)	5 | 22	Reg	Cie	Geom | Tect | Hidrot | Vulc	
	Ilhéus das Formigas e Recife Dollabarat	(Marinha 4)	11 | 15	Reg	Cie | Geot	Geom | Paleo | Pet | Tect | Vulc	Ecol

The geosites were grouped in categories according to their geomorphological, geological and volcanological characteristics, having adopted the previous categorization performed by Lima (2007) and detailing aspects of volcanic morphology according the classification of Wood (2009). So 23 geomorphological and volcanological categories were established, highlighting sea cliffs, polygenetic volcanoes with caldera, volcanic caves, prismatic and spheroidal jointing, historical eruptions, sub-volcanic structures (*e.g.* necks and dykes), fluvial valleys and areas of hydrothermal activity, confirming the archipelagic and volcanic nature of the territory.

In the analysis of the geosites relevance it was applied the same quantitative methodology of Lima (2007), but distinguished themselves in geosites with international relevance (6 geosites), national relevance (52 geosites) and regional relevance (63 geosites). The geosites of international relevance are: the *Dorsal Atlântica e Campos hidrotermais* (Mid-Atlantic Ridge and deep-sea hydrothermal fields), as it is a global tectonic boundary; the *Caldeira do vulcão das Furnas* (Furnas volcano caldera) (São Miguel island), which besides being a volcano-lab, has an important hydrothermal and hydrological system (mineral, thermal and CO_2-spring gas waters) richness; *Montanha do Pico* (Pico Mountain polygenetic volcano), because is the 3rd highest central volcano on North Atlantic; the *Caldeira e Furna do Enxofre* (Graciosa volcano caldera and "Furna do Enxofre" volcanic cave) (Graciosa island), by its size, shape and genesis of the volcanic cave; *Vulcão dos Capelinhos e Costado da Nau* (Capelinhos volcano and Costado da Nau volcano) (Faial island), due to the relevance of the Capelinhos eruption for volcanology science; and *Algar do Carvão* volcanic pit (Terceira island), because it includes the top ten worldwide volcanic cave in terms of mineral deposits (silica speleothemes) (Nunes *et al.*, 2011) (Figure 5).

Most geosites are used for scientific studies, also being realized in most of them geotouristic and education activities. In about one third of the geosites occur economic activities directly related to the geology of the site, either through paid visits to the geosites (*e.g.* volcanic caves), either by quarries or geothermal energy production (Figure 6).



Mid-Atlantic Ridge and deep-sea hydrothermal fields

Furnas volcano caldera (São Miguel island)

Pico Mountain
(Pico island)

Graciosa volcano caldera and Furna do Enxofre volcanic cave
(Graciosa island)

Capelinhos volcano and Costado da Nau volcano (Faial Island)

Algar do Carvão volcanic pit (Terceira Island)

Figure 5. Geosites with international relevance.
Figura 5. *Geossítios de relevância internacional.*

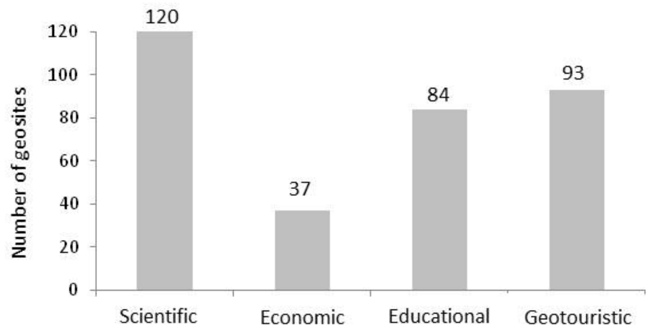


Figure 6. Types of use of the Azores geosites.
Figura 6. *Tipos de uso dos geossítios dos Açores.*

The scientific value of each geosite was decomposed in different geological areas, verifying that the main types of scientific values expressed by the Azorean geosites are in terms of geomorphology and volcanology, as it is expected in a volcanic archipelago (Figure 7).

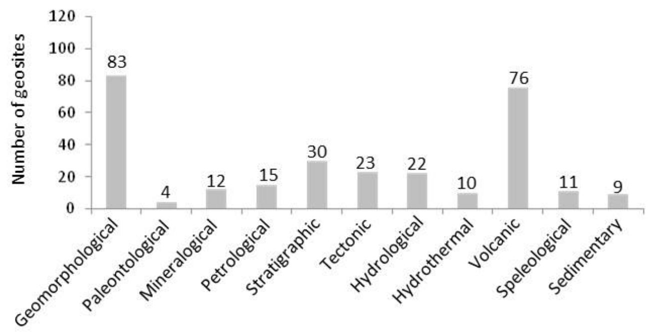


Figure 7. Scientific value of the Azores geosites.
Figure 7. *Valor científico dos geossítios dos Açores.*

The geological heritage is sometimes associated to other types of heritage, valuing them, and in some cases, complementing them. Most of the Azorean geosites have associated other value types, being the most common the scenic, cultural (highlighting the close relationship between the Azorean people and their volcanoes), and ecological (several geosites are the substrate and create conditions for the existence of important habitats and ecosystems) (Figure 8).

An analysis made to the 117 geosites of the insular territory, having in account the related urban and industrial pressure, has shown that 54% of the geosites present a reduced actual or potential pressure and only 10% (12 geosites) are subject to a high urban pressure. Concerning the vulnerability to human interventions, in 10 geosites (*e.g.* volcanic caves, Fountain of Ribeira Seca, in São Miguel

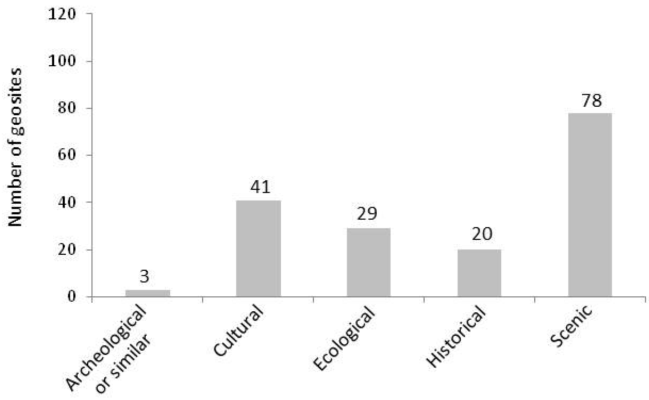


Figure 8. Other values of the Azores geosites.
Figura 8. *Outros valores associados aos geossítios dos Açores.*

island, and the coastal lagoons associated to the Lajes do Pico lava delta, in Pico island) several elements of geodiversity may be destroyed even by little anthropic interventions or by small structures of easy depreciation. In an opposite way, 86 geosites present geomorphological aspects or large geological structures that, by its dimensions, relief, etc., are hardly affected, in a significant way, by the anthropic activities, or its destruction is not likely to happen (Nunes *et al.*, 2011).

Considering the vulnerability to the natural evolutionary processes of the geosites (*e.g.* erosive actions, cliff retreats, fauna activity, vegetation growth), only two geosites are under high pressure, due to the marine erosive processes (Pisão – Praia, at Água d'Alto, São Miguel island) and the vegetation growth (Capelinhos and Costado da Nau, Faial island) (Nunes *et al.*, 2011).

3.1.3. Scientific research project "Identification, characterization and conservation of geological heritage: a geoconservation strategy for Portugal" (2007-2010)

Additionally, there was an evaluation of the scientific value of the 121 geosites in the Azores archipelago and of its degree of vulnerability, taking into account the criteria commonly used in several European countries. This evaluation took place in the context of the research project "Identification, characterization and conservation of geological heritage: a geoconservation strategy for Portugal", funded by the FCT - Foundation for Science and Technology (2007-2010), which sought to implement, in whole Portuguese territory, a methodology for the inventory and the classification of geological heritage, from the perspective of its geoconservation, valorization and dissemination (Brilha *et al.*, 2006; Brilha & Pereira, 2012). This analysis assigned numerical values to various criteria such as uniqueness, recognition as a local standard, scientific knowledge, integrity, diversity and rarity. The obtained results confirmed the relevance of the main geosites already mentioned from the previous methodologies: the Mid-Atlantic Ridge and deep-sea hydrothermal fields, followed by the Caldera of Furnas silicic polygenetic volcano (São Miguel island), Pico Mountain polygenetic volcano (Pico island), Graciosa volcano caldera and "Furna do Enxofre" volcanic cave (Graciosa island), and the Capelinhos volcano and "Costado da Nau" volcano (Faial island).

The vulnerability of the 121 geosites was evaluated under the same project - using criteria such as the possibility of deterioration of the geological content, the proximity to potentially degrading areas, accessibility and population density - resulting in 10 geosites with high vulnerability (*e.g.*quarries - *Pico Timão*, Graciosa island, or urban pressure - *Fajã lávica e arriba fóssil da Caloura*, São Miguel island), while the remaining geosites present a moderate vulnerability (63%) or low (29%) (Nunes *et al.*, 2011).

3.2. Classification

Currently a significant number of the Azores geosites (93 geosites) are under legal protection of the Island Natural Parks and the Azores Marine Park. Additionally several geosites are covered by other classifications and protection and enhancement measures such as Natura 2000 Network, Ramsar, OSPAR, Important Bird Areas, and some also integrate classified areas as UNESCO World Heritage sites (*e.g.* the Historical Centre of Angra do Heroísmo, Terceira island, and Landscape of the Pico Island Vineyard Culture), or Biosphere Reserves of Graciosa, Flores and Corvo islands. Although there are 19 geosites without any legal classification or protection (Nunes *et al.*, 2011).

But it was not always like this, though in 1972 the first sites of geological interest were classified (as mentioned above: Pico Mountain and *Caldeira* from Faial island), they were not protected for its geological features, happening the same with others 50 now recognized as geosites, that were classified essentially by their biological and/or ecological factors, and others few (22) were classified by geological and biological or ecological factors abreast (Lima, 2007).

This change happened with the contribution and cooperation of the technical staff of the Azores Geopark in the reviewing of the protected areas performed, in recent years, under the 15/2007/A Regional Legislative Decree, of 25 June.

3.3. Valorization and promotion

The Azores geological heritage has been promoted and disseminated since the beginning of its studies in 2007 (Lima *et al.*, 2012), although the Azorean geolandscapes are promoted since the late 20th century, mainly through tourism campaigns at national and international levels. However, it has been a lack of information and promotion in the archipelago itself, so that the Azorean people can be aware of the value and importance of their geosites often used in the daily and leisure activities.

As it use to say "people only value what they know" and with this purpose several promotional and informational products of the Azores geological heritage have been developed, directed to: i) the general public (a newspaper page published every two weeks "Geodiversidades" in the newspaper with largest circulation in the archipelago - "Açoriano Oriental", leaflets and brochures about the geosites and the Azores Geopark, the web page and the participation in social networks and newsletters), ii) to the student audience (through the educational programs of the Azores Geopark, the Children's Guide "Volcanoes of the Azores", some games and activities development in the school context or at study visits), and iii) the specialized geological heritage public (through the participation in national and international events on geological heritage, geoparks and geotourism or projects with other specialists) (Lima *et al.*, 2012).

Several partners of the Azores Geopark also contribute to the dissemination of the value and importance of the Azorean geosites, either through his explanation at the Environmental Interpretation Centres or the Science Centres or through the geological heritage usufruct with tourism companies.

A community informed will value its geological heritage and ensure a greater commitment to its conservation (Lima *et al.*, 2012).

3.4. Monitoring

Monitoring ensures a better conservation of geological heritage and improves the management practiced in a given geosite (Lima, 2012).

The first monitoring plan applied to a geosite in the archipelago was carried out by Lima (2012) at the *Ponta da Ferraria e Pico das Camarinhas* geosite (São Miguel island), from October 2011 to October 2012, with the goal to identify the threats that endanger the integrity of the geosite and to quantify the gains or loss of relevance that it has suffered over time due such threats. It was made a direct count of the number of visitors, observation of their behavior and questionnaires were administered.

By observing the behavior adopted it was found that most visitors follow the rules, and only a minority goes out the marked trails or ride motorized vehicles outside the proper areas; it appears however that the accumulation of waste is a problem, also due to ineffective collection performed. By the questionnaires analisys it is know that most of the public want to spend 1-2 hours on this place and are interested in knowing it better, so it is justified to bet on additional measures and specific interpretation [being indicated by Lima (2012): a geodiversity interpretation trail, production of interpretive brochures and creating a visitants centre]. With the count of visitors it was concluded that about 72,000 people visit this geosite per year, being 850 the highest number of visitors recorded in a day, but not reaching the load capacity calculated for geosite, which is 2050 visitors a day (Lima, 2012).

At the end of the year 2013 began the experimental monitoring of the Azores geological heritage with several tests in Faial, Pico, Terceira and Santa Maria islands, reaching at a final monitoring checklist to be applied systematically in all terrestrial geosites of the archipelago. It includes parameters such as: the geosite status (cleanliness, accessibility, signage), its geological conditions of interest (conservation, threats, natural evolution) and the characterization of the public.

Given the geosites number and their dispersion in the archipelago, this monitoring counts with the cooperation of the Nature Vigilants of the 9 Island Natural Parks

(Azores Geopark partners), with a periodic verification by the technical staff of the geopark. The first results and conclusions are expected at the end of 2014, after monitoring throughout the calendar year, covering different seasons and inherent changes in natural conditions, and high and low visitation seasons.

In the work plan is also set for 2015 start the monitoring of the submarine part of the coastal geosites and even the submarine geosites, also relying on the stablished partnerships for this purpose (*e.g.* regional diving companies and the Oceanography and Fisheries Department of the Azores University.

4. ANALISYS OF THE INTEGRATION OF GEOHERITAGE HERITAGE IN THE ENVIRONMENTAL AND LAND-USE POLICIES

The analysis of the integration of the geological heritage in environmental and use policies of the archipelago was made by Lima (2007), checking the inclusion of this issue in key strategic and operational instruments and documents.

All documents considered (32) integrate a nature conservation component, but only 9 explicit the geological component in their policies for the conservation and valorization of nature, and of these, only 6 used the appropriate nomenclature of the subject. There is also the note that the instruments surveyed are more indicative than operating, regarding the topic of geological heritage.

In 2013, Lima *et al.* (2013b) returned to do this analisys, and this time from the 49 planning instruments analyzed (with 21 new documents for environmental and land use planning implemented), 16 included a geological component of the natural heritage. Then it appears that although the main strategic and operational tools integrate existing nature conservation, only about a third (the same proportion as in 2007) of these refer their geological component, verifying that there is still much to do to raise awareness of the work teams of spatial planning concerning this subject.

5. GEOLOGICAL HERITAGE USUFRUCT

The Azorean people learned to live with its volcanoes and earthquakes, taking advantage of the fertile soils, the geological resources and beautiful landscapes to promote their socioeconomic development.

The relationship human/geodiversity marks the daily life of the Azorean society, namely: the regional architecture (popular, religious and military) with the use of local ornamental rocks; religious events (pilgrimages, processions and the Holy Spirit festivities) closely related to the occurrence of natural events (volcanic eruptions and earthquakes); the traditional enjoyment of secondary manifestations of volcanism through baths in thermal pools, the use of mineral and CO_2-sparkling waters, the use of mud as peloids and the degustation of food that is steamed in the fumarolic field of the Furnas Volcano; toponomy like “Lajedo”, “Lajidos”, “Biscoitos” and “ Mistérios”, among other geological names used on the islands as well as in geoproducts as in the case of wines such as “Terras de Lava”, “Basalto”, “Magma” or “Pedras Brancas”, and even on Azorean stories and legends (Nunes *et al.*, 2011).

The Azoreans geolandscapes also assume the main motto of interest and development of nature tourism in the archipelago and feature a wide range of possibilities for sustainable use , where it can be practice different activities and develop associated tourism products, such as the geotourism through walking trails and trekking, volcanic speleology, geotours, and hydrotherapy among others. The Azores geotourism is also supported on different thematic routes that promotes the region based on the volcanism and the geolandscapes: i) the volcanic caves route; ii) the belvederes route; iii) the walking trails route; iv) the thermal route; v) the science and interpretation centres route, vi) urban routes and vii) litoral routes (Machado *et al.*, 2013). It is noteworthy that besides the contribute to the socio-economic development mainly in rural areas, these products have highlighted the importance of the geotourism as a tool to promote and preserve the geological heritage of the Azores, turning, also, as an important instrument of environmental awareness through the local and foreign people (Lima *et al.*, 2013).

6. GEOLOGICAL HERITAGE MANAGEMENT

The Azores geological heritages constitutes an ex-libris of the archipelago and is an important resource that must be promoted and used in a sustainable way. To reach this goal a good management of the recreational, educational and tourism uses should coexist with a geoconservation policy (Lima *et al.*, 2013b).

There are several papers about inventory methodologies for geological heritage and its scientific, educational and tourism uses, however, management methodologies for geological heritage are still poorly developed. They should be included in environmental and land-use planning and nature conservation policies, in order to support a holistic approach to natural heritage. This gap is explained by the fact that geoconservation is a new geoscience and still need of more basic scientific research, like any other geoscience (Henriques *et al.*, 2011).

Also in the Azores, despite the developed works on the inventory, characterization and monitoring of the geological heritage, there isn’t an integrated planning for their management. Also lacking studies to identify threats and to propose guidelines for their sustainable management that constitute basic tools to an adequate geoconservation (Caetano & Lima, 2005).

Lima (2007) refers some existing management measures and informal management plans for some geosites:

- as verified in the previous analysis, most of the Azorean geosites are integrated in the Island Natural Parks and other legal figures, being subjected to its management measures;
- some geosites have load capacities defined, such as the *Vila Franca do Campo* islet, São Miguel island (400 visitors per day), and Pico Mountain (160 visitors simultaneously and 40 people in *Piquinho* per 30 minutes);
- some geosites have restricted access and their visitation is controlled, as in *Caldeira* from Faial Island and the

volcanic caves with guided tours (*Gruta do Carvão* in São Miguel island, *Gruta das Torres* in Pico Island, *Furna do Enxofre* in the Graciosa island, *Algar do Carvão* and *Gruta do Natal* in Terceira island) with load capacities also defined.

Then becomes necessary to establish mechanisms and protocols targeted for conservation and management of geological heritage. This management is complex because it serves not only the natural features and aspects, seen from a scientific perspective, but also legal, economic, cultural, educational and recreational aspects, also taking into account the variety of natural and anthropogenic (Lima *et al.*, 2013b).

With the integration of the archipelago in the European and Global Geopark Networks increases the challenge and reinforces the commitment of the management of its geological heritage.

A PhD in Environmental Geology about the "Definition of a methodology for the management of geological heritage. An application to the Azores archipelago" is being developed in the Azores University, under which it is intended to investigate, evaluate and define a methodology for the management of the geological heritage, with a view to mainstreaming of spatial and environmental planning. The application to the Azores is expected to set management measures to the proper functioning of the geosites and better enjoyment by those who visit or use them daily.

7. CONCLUSIONS

The Azores archipelago, despite its small territorial dimension, presents a wide range of morphologies, rocks and structures, arising, among other factors, from the nature of the magmas, the type of eruption that originated, its dynamics and the subsequent action of external agents, such as the hydrosphere, atmosphere and biosphere. The expression of this geodiversity is reflected in volcanic calderas, lava fields, volcanic ridges, volcanic lakes, prismatic jointings, etc.

The geodiversity of the Azores islands, along with other determinants factors as their size, dispersion, geographic location and climate, are responsible for distinctive ecological conditions, which translate, in a unique way, the close relationship between the geodiversity and biodiversity of the archipelago.

There have been developed, in recent years, studies and actions of inventory, characterization, classification, valuation and monitoring of geological heritage and there are currently identified and characterized 121 geosites (117 terrestrial geosites and 4 marine geosites), with high relevance (6 of international relevance, 52 of national relevance and the others with regional relevance), some protected (93), some vulnerable (22), and almost all with usufruct by the Azoreans and visitors.

Interpretation and dissemination resources about the geological heritage were produced, and developed awareness and promotion activities with the general public and the school population.

It is also noteworthy that the identified geosites have been taken into account in the recent environmental and land use planning policies and in the review of the protected areas of the archipelago.

It is missing to manage systematically the geological heritage, defining measures for a proper management of each geosite.

So, now that the inventory, characterization and evaluation of the Azorean geological heritage are done, are created the bases to work on a management methodology of geological heritage of the archipelago, which given their characteristics (size, dispersion of the islands and its genesis), may also be adapted later to other Macaronesian archipelagos (Madeira, Canary and Cape Verde).

ACKNOWLEDGMENT

This work is a contribution to the doctoral research project "Definition of a methodology for the management of geological heritage. An application to the Azores archipelago (Portugal)", Ref. M3.1.2/F/033/2011, supported by the Science Regional Fund of the Azores Government, and co-financed by the European Social Fund through the EU Pro-Employment Program.

REFERENCES

Brilha, J. (2002) - Geoconservation and protected areas. *Environmental Conservation*, 29(3):273-276. DOI: 10.1017/S0376892902000188

Brilha, J. (2005) - *Património geológico e geoconservação: a conservação da natureza na sua vertente geológica*. 190p., Palimage Editores, Viseu, Portugal. ISBN: 9728575904

Brilha, J.; Pereira, P. (coord.) (2012) – *Património Geológico / Geological Heritage. Geossítios a visitar em Portugal / Geosites to visit in Portugal.* 144p., Porto Editora, Porto, Portugal. ISBN: 978-9720320087

Brilha, J.; Andrade, C.; Azeredo, A.; Barriga, F.J.A.S.; Cachão, M.; Couto, H.; Cunha, P.P.; Crispim, J.A.; Dantas, P.; Duarte, L.V.; Freitas, M.C.; Granja, H.M.; Henriques, M.H.; Henriques, P.; Lopes, L.; Madeira, J.; Matos, J.M.X.; Noronha, F.; Pais, J.; Piçarra, J.; Ramalho, M.M.; Relvas, J.M.R.S.; Ribeiro, A.; Santos, A.; Santos, V.F.; Terrinha, P. (2006) - Definition of the Portuguese frameworks with international relevance as an input for the European geological heritage characterisation. *Episodes* (ISSN: 0705-3797), 28(3):177-186, International Union of Geological Sciences, Washington, DC, U.S.A. Available on-line at http://repositorium.sdum.uminho.pt/handle/1822/5663

Caetano, S.D.; Lima, E.A. (2005) - Geodiversidade em Áreas Protegidas - enquadramento histórico e perspectivas futuras. *Vidália – Boletim da Associação Ecológica Amigos dos Açores*, 24:12-13. Ponta Delgada, Portugal. Available on-line at http://www.amigosdosacores.pt/?page_id=830

Carcavilha, L.U.; Lopez, J.M.; Durán, J.J.V. (2007) - *Patrimonio geológico y geodiversidad: investigación, conservación, gestión y relación con los espacios naturales protegidos*. 350p., Instituto Geológico y Minero de España, Madrid, España. ISBN: 978-8478407101

Cendrero, A. (2000) - Patrimonio Geológico: diagnóstico, clasificación y valoración. *In:* Suárez, J.P. (Coord.), *Jornadas sobre Patrimonio Geológico y Desarrollo Sostenible*, Ministério de Medio Ambiente, Series Monografías,. pp.23-37. Ministerio de Medio Ambiente, Madrid, España. ISBN: 848-3201070

Cendrero, A.; Elizaga, E.; Gallego, E.; Garcia-Cortes, A.; Morales, J.; Palacio, J. (1996) - *Patrimonio Geológico. Bases para su valoración, protección, conservación y utilización*. MOPTMA Serie Monográfica, 112p., Madrid, España. *Não Publicado.*

Forjaz, V.H. (2007) - *Carta GeoAmbiental e GeoTurística dos Açores (Açores)*. Observatório Vulcanológico e Geotérmico dos Açores, Lagoa, Portugal. ISBN: 978-9899522190

Forjaz, V.H.; Fontiela, J.; França, Z.; Serralheiro, A.; Nunes, J.C. (2006) - *Carta GeoAmbiental e GeoTurística da Ilha do Faial (Açores)*. Escala 1/50.000. Observatório Vulcanológico e Geotérmico dos Açores, Lagoa, Portugal. ISBN: 972-9746699

França, Z.; Cruz, J.V.; Nunes, J.C.; Forjaz, V.H. (2003) - Geologia dos Açores: uma perspectiva actual. *Açoreana - Revista de Estudos Açoreanos* (ISSN: 0874-0380), 10(1):11-140, Ponta Delgada, Açores, Portugal. Available on-line at https://www.researchgate.net/publication/236164394_GEOLOGIA_DOS_AORES_UMA_PERSPECTIVA_ACTUAL%28%2A%29

Frutuoso, G. (1876 [2011]) - *Saudades da Terra, volume IV (Açores: São Miguel).* [manuscrito do século XVI]. 3ª tiragem (2011), 554p., Instituto Cultural de Ponta Delgada, Ponta Delgada, Portugal. ISBN: 972-9216614

Goulart, M.E. (1999) - O Ambiente no contexto do VII Governo Regional, Plano Estratégico para a Conservação da Natureza. *ECOlógico, O Ambiente nos Açores* 7:5-8, Direcção Regional do Ambiente, Serviços de Promoção Ambiental, Horta, Portugal.

Gray, M. (2004) - *Geodiversity:valuing and conserving abiotic nature*. 448 p., Jonh Wiley and Sons, Chichester, England. ISBN: 0-470848952

Henriques, M.H.; Pena dos Reis, R.; Brilha, J.; Mota, T.S. (2011) - Geoconservation as an Emerging Geoscience. *Geoheritage*, 3(2):117-128. DOI: 10.1007/s12371-011-0039-8

Lago, M.; Arranz, E.; André, J.A.; Soria, A.R.; Galé, C. (2001) - *Patrimonio Geológico: Bases para su Estudio y Metodología.* 107p., Consejo de Protección de la Naturaleza de Aragón, Zaragoza, España. ISBN: 847-7538484

Lima A.F. (2012) - *Estratégias de monitorização do geossítio Ponta da Ferraria e Pico das Camarinhas: Contributo para a gestão sustentada do património geológico do arquipélago dos Açores*. 217 p., Tese de Mestrado, Departamento de Ciências da Terra, Universidade do Minho. *Não Publicado.*

Lima E.A. (2007) - *Património Geológico dos Açores: valorização de locais com interesse geológico das áreas ambientais, contributo para o ordenamento do território*. 108 p., Tese de Mestrado, Departamento de Biologia, Universidade dos Açores. *Não Publicado.*

Lima, E.A.; Nunes, J.C.; Costa, M.P. & Porteiro, A. (2010) - Main geosites of the Azores Geopark project. *Schriftenreihe der Deutschen Gesellschaft für Geowissenschaften*, 66:18-19, Hannover, Deutschland. ISBN: 978-3510492145

Lima, E.A.; Nunes, J.C.; Costa, M.P.; Porteiro, A. (2009) - O geoturismo como instrumento de valorização do "Geoparque Açores". In: Carvalho, C.N.; Rodrigues, J.; Jacinto, A. – *Geoturismo e Desenvolvimento Local*, pp.149-160, Câmara Municipal de Idanha-a-Nova/Geoparque NaturTejo, Lda., Idanha-a-Nova, Portugal. ISBN: 978-9728285531

Lima, E.A.; Nunes, J.C.; Costa, M.P.; Viveiros, C.; Gonçalves, F. (2012) - Communication tools of the Azores Geopark Project. *In:* Sá, A.A.; Rocha, D.; Paz, A. & Correia, V., *Proceedings of the 11th European Geoparks Conference*, pp.179-180, Arouca, Portugal. ISBN: 978-9899605565

Lima, E.A.; Nunes, J.C., Medeiros, S.; Ponte, D. (2013a) – Geodiversidade e Geossítios da Ilha de São Jorge. *Relatórios e Comunicação do Departamento de Biologia* [XV Expedição Científica do Departamento de Biologia - São Jorge 2011, ISBN: 978-9728612849], 40:19-43, Universidade dos Açores, Ponta Delgada, Açores, Portugal. Available on-line at https://repositorio.uac.pt/handle/10400.3/1588

Lima, E.A; Lima, A.F.; Brilha, J.; Calado, H.; Nunes, J.C. (2013b) - Integration of the geoheritage management in environmental and land-use policies. *Rendiconti Online della Societá Geologica Italiana* (ISSN: 2035-8008)), 28:102-105, Roma, Italia.

Lopes, M.R. (2007) - *Carta de Geomonumentos da Ilha Terceira (Uma contribuição)*. 84 p., Trabalho de final de Licenciatura, Universidade de Aveiro, Aveiro, Portugal. *Não Publicado*.

Lourenço, N. (2007) - *Tectono-magmatic Processes at the Azores Triple Junction*. 267p., Tese de Doutoramento em Ciências do Mar, Faculdade de Ciências do Mar e Ambiente, Universidade do Algarve, Faro, Portugal. *Não Publicado*.

Machado, M.; Viveiros, C.; Lima, A.; Lima, E.A. (2013) - Contributions of the Azores Geopark to the geotourism development in the archipelago. In: Aloia A.; Calcaterra D.; Cuomo A.; De Vita A.; Guida D.- *Proceedings of the 12th European Geoparks Conference.* National Park of Cilento, Vallo di Diano e Alburni - Geopark, pp. 192-196, Vallo di Diano, Italia. ISBN: 978-8890728105

Nunes, J.C. (1991) - *Microssismos e neotectónica - Contribuição para o seu estudo nos Açores.* 245 p., Provas de Aptidão Pedagógica e Capacidade Científica, Departamento de Geociências, Universidade dos Açores, Ponta Delgada, Portugal. *Não Publicado*

Nunes, J.C. (2003) - Geologia e Vulcanologia das Áreas Classificadas dos Açores. *VI Encontro Regional de Educação Ambiental*, p.22., São Jorge, Portugal. ISBN

Nunes, J.C.& Lima, E.A. (2005) - Geodiversidade da Ilha Graciosa, Açores. *Açoreana - Revista de Estudos Açoreanos* (ISSN: 0874-0380), 10(2):319-343. Ponta Delgada, Portugal.

Nunes, J.C.; Lima, E.A. (2008) - Paisagens Vulcânicas dos Açores: Valor Intrínseco Enquanto Recurso Natural e Património Geológico. *IV Congresso Nacional de Geomorfologia, Livro de Resumos*, pp.31, Braga, Portugal. ISBN

Nunes, J.C.;. Lima, E.; Medeiros, S. (2007) – Os Açores, Ilhas de Geodiversidade, O contributo da Ilha de Santa Maria. *Açoreana - Revista de Estudos Açoreanos* (ISSN: 0874-0380) 5:74-111, Ponta Delgada, Portugal.

Nunes, J.C.; Lima, E.A.; Medeiros, S. (2008) - *Carta de geossítios da Ilha de Santa Maria (Açores). Escala 1/50.000*. Departamento de Geociências da Universidade dos Açores, Ponta Delgada, Portugal. ISBN: 978-9728612474.

Nunes, J.C.; Lima, E.A.; Medeiros, S. (2009) - *Carta de geossítios da Ilha Graciosa (Açores). Escala 1/50.000.* Geoparque Açores / Departamento de Geociências da Universidade dos Açores, Ponta Delgada, Portugal. ISBN: 978-9728612566.

Nunes, J.C.; Lima, E.A.; Medeiros, S. (2010) - *Carta de geossítios da Ilha do Corvo (Açores). Escala 1/25.000*. Geoparque Açores / Departamento de Geociências da Universidade dos Açores, Ponta Delgada, Portugal. ISBN: 978-9728612658.

Nunes, J.C.; Madeira, J.; Brilha, J. (2009) –The Azores Archipelago in the America-Eurasia-Africa triple junction: a geological Framework as the scientific background for the creation of the Azores Geopark. *In:* Carvalho, C.N. & Rodrigues, J., *New Challenges with Geotourism, Proceedings of the VIII European Geoparks Conference*, pp.176-179, Idanha-a-Nova, Portugal. ISBN: 978-9728285524.

Nunes, J.C.; Lima, E.A.; Medeiros, S.; Ponte, D. (2013) - *Carta de geossítios da Ilha de São Jorge (Açores). Escala 1/75.000*. Geoparque Açores / Departamento de Geociências da Universidade dos Açores, Ponta Delgada, Portugal. ISBN: 978-972-8612-78-8.

Nunes, J.C.; Lima, E.A.; Ponte, D.; Costa, M.P.; Castro, R. (2011) - *Azores Geopark Application*. 50p., Azores Geopark, Horta, Portugal. Available on-line at http://www.azoresgeopark.com/media/docs/candidatura_ga/Application.pdf

Sharples, C. (2002) - *Concepts and principles of Geoconservation*. 79p, Tasmanian Parks & Wildlife Service, Hobart, Tasmania, Australia. http://www.dpiw.tas.gov.au/inter.nsf/Attachments/SJON-57W3YM/$FILE/geoconservation.pdf

Wood, C. (2009) - *World Heritage Volcanoes: Thematic Study, Global Review of Volcanic World Heritage Properties: Present Situation, Future Prospects and Management Requirements*. 65p., IUCN (International Union for Conservation of Nature), Gland, Switzerland. Available on-line at https://portals.iucn.org/library/efiles/edocs/2009-065.pdf

Revista da Gestão Costeira Integrada 14(2):321-334 (2014)
Journal of Integrated Coastal Zone Management 14(2):321-334 (2014)

GESTÃO COSTEIRA INTEGRADA
Journal of Integrated Coastal Zone Management

http://www.aprh.pt/rgci/pdf/rgci-494_Antunes.pdf | DOI:10.5894/rgci494

Hydrogeochemistry assessment of volcanic lakes in the Flores Island Protected Areas (Azores, Portugal) *

Monitorização hidrogeoquímica de lagos vulcânicos das áreas protegidas na ilha das Flores (Açores, Portugal)

P. Antunes [@, 1, 2] & F.C. Rodrigues [2]

ABSTRACT

Azorean lakes represent strategic freshwater resources and are subject to unprecedented levels of anthropogenic disturbance. The Flores Island lakes contribute 5% of the total water volume of aquatic systems in the Azores and are an important habitat for freshwater species. Sampled lakes are located inside maars structures. Lake Negra, with a depth of 115m, is the deepest lake. The lakes water is cold, with thermal stratification observed during sampling campaigns. pH has varied from 5.43 to 9.94 and they are very dilute waters. Aquatic systems waters are fresh and of the Na-Cl and Na-Ca-HCO3 types. It is possible to identify three major processes that control the hydrogeochemical evolution of the lake water studied here: (1) a marine sea salt input due to atmospheric transportation and deposition; (2) the hydrolysis of volcanic rock and; (3) a contribution of mineral water flowing through the rim of the crater. Aquatic systems have no direct interaction with seepage of magmatic fluids, a common process in Azores lakes. The highest decline in lake water quality is related to anthropogenic activities.

Keywords: Volcanic lakes, hydrogeochemistry, eutrophication, Flores Island (Azores).

RESUMO

Os lagos vulcânicos dos Açores são reservas estratégicas de água doce que estão sujeitos a distúrbios no seu equilíbrio natural devido a factores antropogénicos. Os lagos dos Açores representam 5% do total do volume de água doce que os sistemas lacustres dos Açores encerram, constituindo um importante habitat para as espécies que habitam ou fazem uso destes recursos naturais. Os lagos estudados localizam-se no interior de maars e a Lagoa Negra, com uma profundidade de 115m é o lago mais profundo dos Açores., Durante as campanhas de amostragem, os lagos apresentaram estratificação de origem térmica, o pH varia entre valores ligeiramente ácidos a básicos, a água tem baixa mineralização e é fria. Os sistemas aquáticos estudados possuem água doce de tipologia cloretada sódica e as amostras de água dos sistemas de maior volume demonstram um enriquecimento em bicarbonato e cálcio. Foi possível identificar 3 processos que controlam o quimismo da água dos lagos: (1) a entrada de sais de origem marinha através do acarreio atmosférico; (2) a entrada em solução de elementos químicos através da interação água-rocha e (3) a entrada de água ligeiramente mineralizada na Lagoa Comprida através de duas nascentes localizadas no flanco SE desta lagoa. Os sistemas lacustres estudados apresentam resultados que indicam não haver interação de fluidos de origem magmática, processo que ocorre noutros lagos dos Açores. A degradação da qualidade da água dos sistemas lacustres estudados está relacionada com o processo de eutrofização.

Palavras chave: *Lagos vulcânicos, hidrogeoquímica, eutrofização, Ilha das Flores (Açores).*

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** Submission: 27 January 2014; Evaluation: 25 February 2014; Reception of revised manuscript: 13 May 2014; Accepted: 27 May 2014; Available on-line: 16 June 2014*

1. INTRODUCTION

Lakes are generally regarded as strategic sources of fresh water. The increase in world population and improved living standards as well as the need for more resources has recently contributed to a growing demand for fresh water resources. Freshwater habitats are under unprecedented levels of pressure by humans, not only to satisfy people's basic needs, but also to satisfy agricultural and industrial demands, which has led to the subsequent deterioration of freshwater quality worldwide. In the Azores archipelago, three lakes are utilized for human water supplies. The island's geomorphology and climate have provided the Azores with significant quantities of groundwater and lakes. The Azores archipelago contains a total of 88 lakes (Porteiro, 2000), occupying a surface area of approximately 0.5% of the archipelago. The Azorean lakes gained important attention after the eutrophication process arose in a significant number of the archipelago's aquatic systems (UNL, 1991; Gonçalves, 1997; INOVA, 1999). The Azores archipelago is a remote region comprising nine small islands. With limited resources and a fragile environment, agriculture and livestock are the main economic activities creating environmental challenges. Nutrient emissions from agricultural activities are the main source of nutrient loads into lakes, and eutrophication has been increasing because of agricultural and livestock activities.Volcanic lakes may also receive magmatic fluids inputs (Delmelle & Bernard, 2000; Varekamp *et al.*, 2000; Antunes, 2009), which are extremely concentrated and acidic (Rowe *et al.*, 1992; Christenson, 2000; Delmelle & Bernard, 2000; Varekamp, 2008) and contributes to the degradation of the water quality of groundwater and surface water in volcanic areas. The quality of ground and surface water is a sensitive environmental topic (Saunders *et al.*, 2002; Simeonov *et al.*, 2003). Lake water quality is a measure of the physical, chemical, and biological health of an aquatic system and it is difficult to define a single standard threshold for water quality beyond which the system will be degraded (Karr, 1993; Brabec *et al.*, 2002).

Protection of natural areas is a partial solution to habitat degradation, but specific protections of groundwater and surface water are rarely implemented worldwide (Hockings *et al.*, 2006; Saunders *et al.*, 2002; Hockings, 2003). Freshwater is commonly protected when lakes are integrated incidentally in natural reserves. However, inclusion in protected areas does not guarantee protection (Moyle *et al.*, 1998; Saunders *et al.*, 2002). The Flores lakes chosen for the present study, Lakes Negra, Comprida, Funda and Rasa, located in the Natural Reserves, are classified by the Regional Legislative Decree Law nº 15/2007/A, June 25 and created through the Regional Legislative Decree Law 15/87/A, July 24 (Fig. 1). Lake Negra and Comprida are located in the designated Natural Reserve of Morro Alto e Pico da Sé and Lake Funda and Rasa are located in the Natural Reserve of Caldeiras Funda e Rasa.

The main goals for these protected areas are to establish mechanisms of conservation and preservation, and ecosystem management of biodiversity, natural resources and landscapes. The Natural Reserves are humid zones located at high altitude in the designated Central Plateau. The area is characterized as a turf zone occupied by different species of *Sphagnum* and the endemic Azores Juniper (*juniperus brevifolia*), important to the hydrological equilibrium of the island. The island of Flores is located in a bird migration corridor and the humid zones are an important habitat for these birds to feed and rest. The aim of this work is to perform a hydrogeochemical survey of aquatic systems located in a Natural Reserve system in Flores, and identify and describe the main mechanisms that control the water chemistry. It also aims to improve the understanding of mechanisms of water degradation and contribute chemical data to data base that will allow for a temporal scale study in the future. With the present study we intend to contribute to a better hydrogeochemical understanding of the dynamic of aquatic systems, primarily identifying if volcanic fluid contamination exist and how it affects the lakes water quality in order to improve the planning and management plans for protected areas in small islands. Biological processes will be taken in consideration, but they are not the focus of the study.

1.2. Geological setting

The Azores Islands represent the emerged portion of the Azores Plateau, limited by the bathymetric of 2000m (Fig 2). The Azores are located at the junction between the North American, Eurasian and African lithospheric plates (in a complex geodynamic setting reflected by several tectonic structures, which explains the high level of seismicity and volcanic activity). The Mid-Atlantic Ridge (MAR) crosses the archipelago between the islands of Flores (West Group) and Faial (Central Group) (Krause & Watkins, 1970; Laughton & Whitmarsh, 1974; Steinmetz *et al.*, 1976; Searle, 1980; Forjaz, 1983; Lourenço *et al.*, 1998). Flores Island lies west of the Mid-Atlantic Ridge (MAR) on the American Plate.

The Azores archipelago is located in the North Atlantic Ocean, between the latitudes of 37º- 40ºN and the longitudes of 25º-31ºW and can be divided in three groups according to the geographical distribution of the nine inhabited islands (Fig. 2). Flores Island is located in the Western group and has an area of 143km^2 with a population approximately 4000 inhabitants. The Central Plateau, located between 500m and 915m high, represents 40% of Flores inland plain area (Azevedo, 1998).

Lake Negra and Comprida are located in the central western part of the Central Plateau and Lake Funda and Rasa are located in the southernwest part of the Central Complex (Fig. 1). The lakes are emplaced within Maar structures (except Rasa lake) produced by violent phreatomagmatic eruption. Morriseau (1987) classified Lake Rasa as emplaced in a cinder cone. Although, there is no evidence of a crater and the lake could have resulted from a tectonic depression. Lake Comprida shows an elliptical shape since it is hosted within coalescent hydromagmatic eruptions. Table 1 presents other relevant physical characteristics of the studied lakes.

1.3. Climate

The archipelago position influences Azorean weather. The Azores are located in the middle North Atlantic Ocean

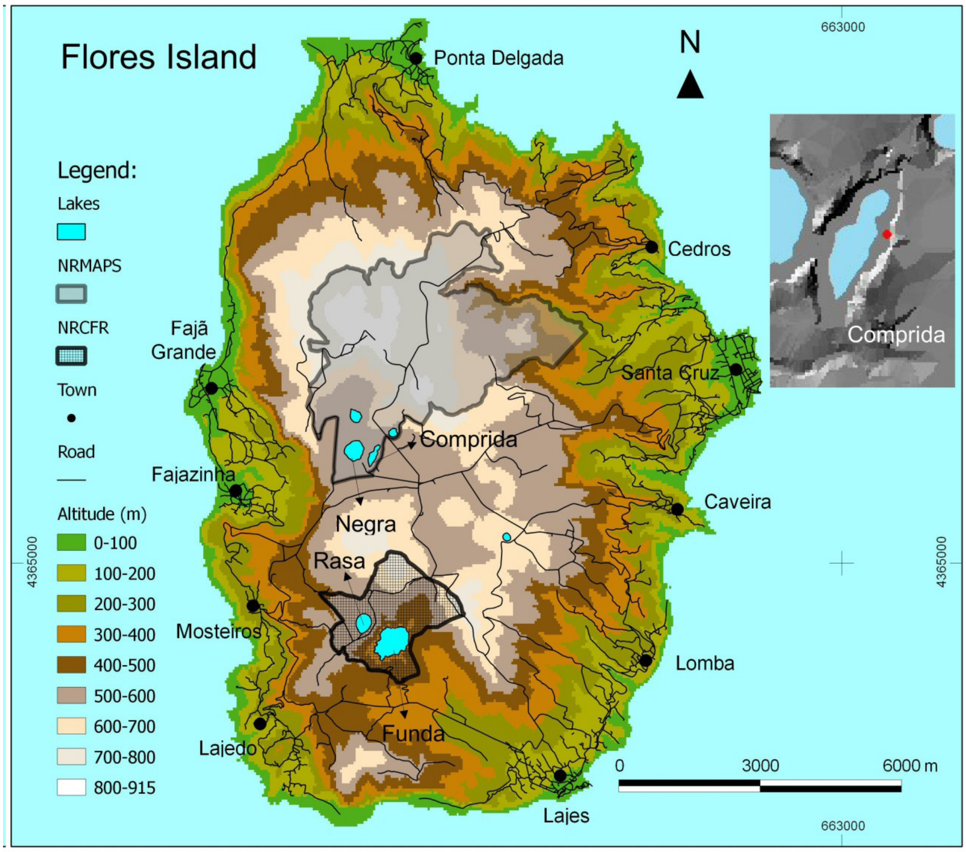


Figure 1. Map showing Flores Island, the location of the study lakes and the limit of natural areas. NRMAPS – Natural Reserve of Morro Alto and Pico da Sé, NRCFR – Natural Reserve of Caldeiras Funda and Rasa, ● spring I and II location in Lake Comprida rim (sketch is not scaled).

Figura 1. *Localização dos lagos estudados e dos limites das Reservas Naturais na ilha das Flores. NRMAPS – Reserva Natural do Morro Alto e Pico da Sé; NRCFR – Reserva Natural das Caldeiras Funda and Rasa,* ● *localização das nascentes na margem da Lagoa Comprida (esquema não está à escala).*

under the influence of subtropical high pressure (Azores anticyclone) resulting in a humid subtropical climate. It is possible to distinguish two seasons: (1) a relative humid season with high precipitation between September and March, and with steady wind due to the frequent crossing of low pressure systems associated with the polar front, and (2) a dry season during the other months controlled by the influence of Azorean anticyclone (Bettencourt, 1979; Azevedo, 1996). The climate is largely influenced by the Gulf warm current and the ocean that has an important role in air temperatures (Agostinho, 1938; Miranda *et al.*, 2006). The temperature variation with 100m altitude is approximately 0.6ºC and a 2.4% increase of humidity saturation (Agostinho 1938; Bettencourt, 1979). The average annual rainfall in the Azores is 1585 l/m^2 and evapotranspiration is 597 l/m^2.

Flores weather is influenced by the orography of the island with lower temperatures throughout the year (average 17.8ºC) and an average annual precipitation of 1430mm (Bettencourt, 1979).

2. SAMPLING AND ANALYTICAL METHODS

Water from Flores Lakes were sampled in July 2005 and July 2007. Negra Lake was sample once in May 2006. Rasa Lake was sampled in July 2005 and July 2007. Comprida and Funda Lakes were sampled in July 2005, May 2006 and July 2007. Samples were taken along the vertical water column at defined locations during the two campaigns. Water samples were collected at different intervals from a pneumatic boat with a VanDorne sampler. During the sample campaigns, pH, temperature, electrical conductivity and dissolved oxygen (DO) concentration were recorded with portable digital meters. In the field, dissolved CO_2 and alkalinity were determined by titration, and samples were filtered (0.2 μm) and stored in HDPE bottles. Samples for cation analyses were acidified with suprapur nitric acid. In the laboratory, major cation concentrations were determined by atomic-absorption spectrometry, while Si and Fe were analyzed by ICP-MS at Activation Laboratories, Canada. The major anion concentrations were determined by ion chromatography.

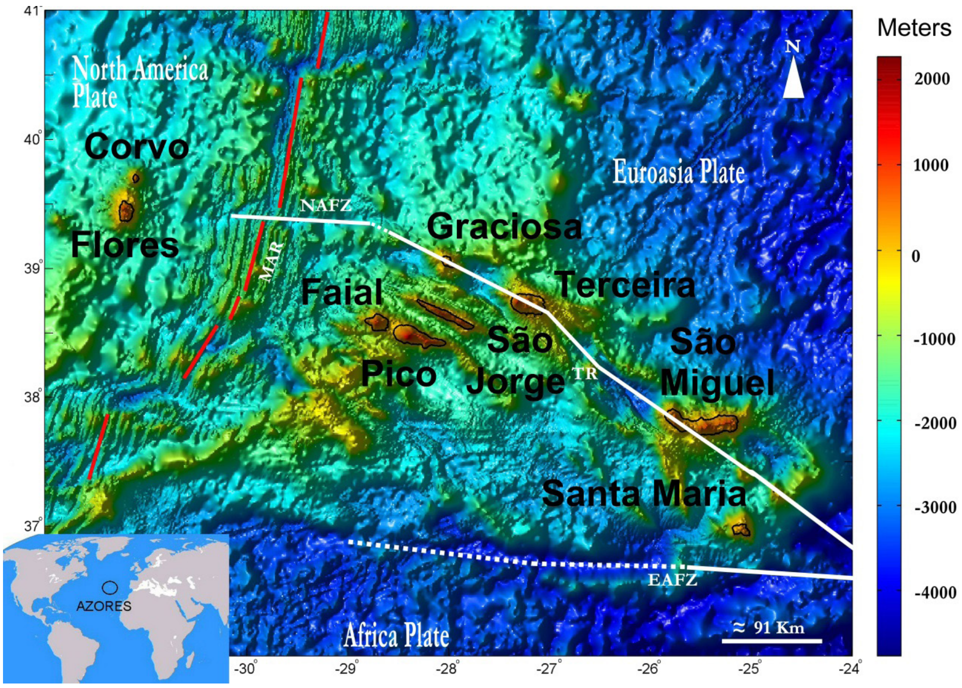


Figure 2. Location of the Azores Archipelago. Azores islands represent the emerged portion of Azores plateau, which is defined by the batimetric line of the 2000 meters. The Terceira Rift (TR), a structure that is part of the complex geodynamic setting, and is responsible for important seismovolcanic activity. MAR – Mid-Atlantic Ridge; NAFZ – North Azores Fracture Zone; EAFZ – East Azores Fracture Zone.

Figura 2. *Localização do Arquipélago dos Açores. As ilhas representam a parte emersa da plataforma dos Açores que é definido pela linha batimétrica dos 2000m. O Rift da Terceira, estrutura que pertence ao referido complexo geodinâmico, é responsável pela importante actividade sismovulcânica. MAR – Crista Média Atlântica; NAFZ – Zona de Fractura Norte dos Açores; EAFZ – Zona de Fractura Este dos Açores.*

Table 1. Geophysical characteristics of studied lakes (a - data from PRA; b - data from Morriseau, 1987; c - data from Gonçalves, *et al.*, 2005; M and P in WGS 84; n/a – no data available).

Tabela 1. *Características físicas dos lagos estudados (a – dados do PRA; b – dados de Morriseau, 1987; C – dados de Gonçalves et al., 2005; M e P no WGS 84; n/a – sem dados).*

Lake	Location M	Location P	Altitude (m)	Area (km^2)	Lenght (m)	Width (m)	Depth (m)	Volume (10^3m^3)	Geological classification	Water quality (c)
Negra	652681	4367372	550	0.13	451	389	122	14822.2	Maar (S.L)[b]	n/a
Comprida	652973	4367020	550	0.05	496	155	17	378 (a)	Maar (S.L)[b]	High
Funda	653325	4363026	355	0.35	873	635	33.5	n/a	Maar (S.L)[b]	Bad
Rasa	652795	4363508	527	0.1	423	323	17	754 (a)	Cinder cone[b]	High

3. RESULTS

Results of the field data (Table 2) show that the lake water was cold (13 – 23.4ºC) and thermally stratified during field work, except for Lake Comprida (May 2006). However, the profile did not reach the lake bottom. The Lake Negra thermocline occurs around 10 m to 30 m depth, which is deeper than at Funda, Comprida and Rasa Lakes (Fig. 3).

Despite the thermal stratification, the lake's water column was chemically close to homogeneous in all sampling profiles (Fig. 4). Lakes Negra and Comprida have the relatively highest concentration for all chemical elements, and the water samples taken from the other lakes are more diluted.

The ionic composition of the water samples induces relatively variable chemical facies. The smaller size lakes are Na-Cl dominated, while the larger lakes become more Ca-HCO3 dominated (Fig. 5).

The dissolved chemical elements in Negra and Funda Lakes show a relative distribution, which decreases in order for cations Na>Ca>Mg>K and for anions HCO_3>Cl>SO_4. However, the relative distribution of dissolved chemical

Table 2. Major chemical elements compositions of Flores Lakes. All concentrations in ppm, depth in meters, Temperature (Temp.) in ºC and electrical conductivity (Cond) in µS/cm.
Tabela 2. *Resultado dos elementos maiores nos lagos estudados. As unidades dos elementos analisados estão em mg/L. A profundidade é medida em metros, a temperatura (Temp.) em ºC e a Condutividade Eléctrica (Cond) em µS/cm. Elementos não determinados em branco.*

Lake	Date	Depth	pH	Temp	Cond	DO	freeCO_2	totalCO_2	HCO_3	Alk	Cl	SO_4	Na	K	Mg	Ca	SiO_2	Fe	NO_3
Negra	May-06	0	7.54	14.8	143	9.4	1.8	37.0	48.8	40	16.1	3.8	14.1	1.6	4.8	7.2	12.1	0.12	3.6
	May-06	10	7.77	14.6	142	10.0	1.6	23.6	30.5	25	16.3	3.5	14.2	1.5	5.0	6.8	10.9	0.00	2.6
	May-06	20	8.20	14.2	142	9.6	3.0	38.2	48.8	40	16.3	3.6	14.1	1.5	4.7	7.0	11.4	0.00	1.4
	May-06	30	8.18	13.1	142	9.3	3.2	38.4	48.8	40	16.3	3.7	14.1	1.6	4.9	7.6	12.5	0.01	1.0
	May-06	40	7.84	13.0	141	8.2	2.6	37.8	48.8	40	16.1	3.7	14.2	1.6	5.2	7.8	12.5	0.01	1.5
	May-06	50	7.78	13.1	142	8.1	3.6	38.8	48.8	40	16.7	3.6	14.2	1.7	4.9	6.8	13.3	0.12	9.1
	May-06	60	8.21	13.1	141	8.3	2.8	40.2	51.9	43	16.4	3.8	14.1	1.6	4.9	6.8	13.6	0.06	0.7
	May-06	70	8.21	13.1	141	8.3	2.4	37.6	48.8	40	16.5	3.7	14.0	1.7	4.7	7.5	12.8	0.07	0.7
	May-06	80	8.08	13.5	140	8.2	2.8	38.9	50.0	41	16.5	3.6	14.2	1.6	4.7	7.4	13.2	0.07	1.8
	May-06	90	7.87	13.1	141	8.3	2.5	40.3	52.5	43	16.5	3.9	14.1	1.6	4.7	6.8	13.4	0.04	1.9
	May-06	100	8.09	13.1	141	8.2	3.3	41.1	52.5	43	16.2	3.7	14.1	1.6	5.0	6.9	13.0	0.01	
	May-06	110	8.22	13.1	141	8.3	2.6	37.8	48.8	40	16.6	3.8	14.3	1.6	4.7	7.2	13.0	0.04	5.2
	May-06	115	8.44	13.3	141	8.3	2.2	39.2	51.2	42	16.4	3.9	14.2	1.6	5.0	7.1	13.1	0.00	2.2
Comprida	Jul-05	0	7.56	19.9	77		0.6	11.2	14.6	12	14.0	2.7	10.8	1.1	1.9	4.4	3.4	0.08	
	Jul-05	3	7.40	19.0	76		0.8	10.5	13.4	11	13.6	2.6	10.3	0.9	1.8	3.7	3.9	0.07	
	Jul-05	6	7.30	16.8	78		1.3	11.0	13.4	11			10.9	1.1	2.0	3.6	4.4	0.06	
	Jul-05	9	7.18	16.2	79		2.1	10.9	12.2	10			12.1	1.1	2.0	4.1	5.0	0.05	
	Jul-05	12	7.05	15.8	80		2.2	11.9	13.4	11	14.5	2.8	15.7	1.4	2.5	5.3	5.6	0.05	
	Jul-05	15	6.95	15.7	81		2.8	13.4	14.6	12	14.4	2.7	12.4	1.2	2.2	3.8	5.7	0.06	
	Jul-05	17	6.84	15.7	81		2.6	13.2	14.6	12	14.5	2.7	9.8	1.0	2.3	1.8	6.1	0.07	
	May-06	0	7.71	14.6	92	8.5	2.6	14.0	15.9	13	16.1	3.1	10.5	1.0	2.7	2.4	3.8	0.08	
	May-06	3	7.42	14.8	92	8.8	2.4	15.6	18.3	15	15.9	3.0	10.4	1.0	2.6	2.3	3.3	0.05	
	May-06	6	7.39	14.7	91	8.7	2.0	14.3	17.1	14	16.2	3.0	10.6	1.0	2.6	2.3	3.4	0.05	0.5
	May-06	9	7.22	14.6	92	8.6	2.2	15.4	18.3	15	16.1	2.9	10.5	1.0	2.7	2.4	3.0	0.09	0.8
	May-06	10	7.32	14.7	91	9.2	1.7	14.9	18.3	15	16.0	3.0	10.4	1.0	3.1	2.3	3.1	0.04	
	Jul-07	0				10.6	3.2	14.6	15.9	13	15.6	3.0	9.8	1.3	2.4	1.9	5.0	0.12	
	Jul-07	8				9.9	2.8	14.2	15.9	13	15.7	2.9	9.8	1.2	2.4	1.9	5.6	0.10	
	Jul-07	15				9.9	3.3	14.3	15.3	13	15.5	3.0	9.8	1.3	2.4	1.9	5.3	0.15	
Funda	Jul-05	0	9.94	23.4	148		1.0	24.8	32.9	27	17.7	3.0	12.5	1.5	3.5	4.4	7.4	0.02	
	Jul-05	5	8.30	17.9	124		1.4	27.8	36.6	30	18.6	3.2	14.3	1.7	3.6	8.0	7.5	0.03	
	Jul-05	10	7.85	16.9	125		2.8	26.6	32.9	27	17.7	3.2	13.1	1.6	3.4	7.4	8.0	0.02	
	Jul-05	15	7.51	15.1	130		3.0	27.6	34.2	28	18.4	3.3	13.3	1.7	3.5	7.8	7.2	0.01	
	Jul-05	20	7.85	14.9	128		4.2	29.3	34.8	29	18.7	3.3	13.2	1.7	3.4	7.4	6.5	0.03	
	Jul-05	25	7.56	14.4	131		6.6	33.0	36.6	30	18.8	3.2	13.2	1.7	3.6	7.6	7.1	1.23	
	Jul-05	30	7.10	14.0	135		8.4	38.3	41.5	34	18.8	3.1	12.9	1.7	3.6	7.7	7.0	0.04	
	Jul-05	33	6.71	13.8	123		7.2	36.2	40.3	33	18.9	2.9	13.4	1.9	3.7	4.0	7.2	0.48	
	May-06	0	9.26	16.0	137	9.6			45.1	37	18.0	3.2	13.9	1.7	4.0	6.0	5.2	0.05	
	May-06	3	9.35	16.0	137	9.3			40.3	33	18.2	3.4	13.9	1.7	4.6	6.4	5.4	0.08	4.9
	May-06	6	9.46	16.0	137	9.3					17.7	3.2	13.8	1.7	4.4	5.8	5.9	0.04	2.3
	May-06	9	9.53	16.0	137	9.3			43.9	36	17.7	3.5	14.0	1.7	4.6	7.6	6.0	0.06	1.2
	May-06	12	9.42	14.4	134	7.0			42.7	35	17.7	3.4	13.8	1.7	4.4	6.6	6.9	0.09	1.5
	May-06	15	9.02	13.6	132	7.1			40.9	34	18.1	3.3	13.7	1.7	4.5	5.9	6.6	0.03	3.1
	May-06	18	8.45	13.5	131	7.1			40.6	33	17.4	3.3	13.6	1.7	4.4	5.6	6.4	0.03	1.0
	May-06	21	8.19	13.5	132	7.1			41.5	34	17.7	3.1	13.7	1.7	4.1	5.6	6.3	0.03	2.4
	May-06	24	7.93	13.4	131	4.5	5.0	34.0	40.3	33	11.4	2.3	13.6	1.7	4.5	5.8	6.9	0.11	1.8
	May-06	27	7.76	13.3	133	3.3	6.8	36.3	40.9	34	17.3	3.2	13.5	1.7	4.3	5.9	7.3	0.09	2.3
	Jul-07	0							40.3	30	19.2	3.4	13.8	1.5	4.4	6.3	5.7	0.01	
	Jul-07	6							39.7	33	18.9	3.5	13.5	1.5	4.2	6.2	4.8	0.03	
	Jul-07	12					1.5	31.4	41.5	34	18.9	3.8	14.0	1.7	4.2	6.4	6.6	0.14	1.0
	Jul-07	16					7.2	35.8	39.7	33	19.1	3.7	13.8	1.6	4.5	5.9	5.6	0.02	0.6
	Jul-07	23					8.0	34.0	39.0	32	19.1	3.7	13.8	1.7	4.2	5.7	5.8	0.25	
Rasa	Jul-05	0	7.38	21.6	66		1.0	2.3	1.8	2	15.6	2.8	9.2	0.6	0.7	1.4	1.5	0.09	
	Jul-05	5	7.10	19.8	66		1.0	2.3	1.8	2	15.8	2.8	8.8	0.4	0.4	1.3	2.4	0.03	
	Jul-05	10	6.87	17.1	66		1.2	2.1	1.2	2	16.1	2.9	8.9	0.4	0.4	1.3	2.3	0.12	
	Jul-05	17	6.22	16.7	67		3.2	4.5	1.8	2	16.2	2.8	8.7	0.4	0.4	1.4	3.0	0.08	
	Jul-07	0	6.26	19.6	68	7.0	2.6	6.1	4.9	4	17.1	3.1	9.2	0.4	0.4	1.3	1.3	0.08	
	Jul-07	7	6.27	18.7	68	6.6	2.3	4.1	2.4	2	17.2	3.1	9.2	0.4	0.4	1.3	1.1	0.04	
	Jul-07	14	5.43	15.1	71	3.5	2.6	7.0	6.1	5	17.6	3.1	9.5	0.5	0.4	1.4	1.5	0.11	

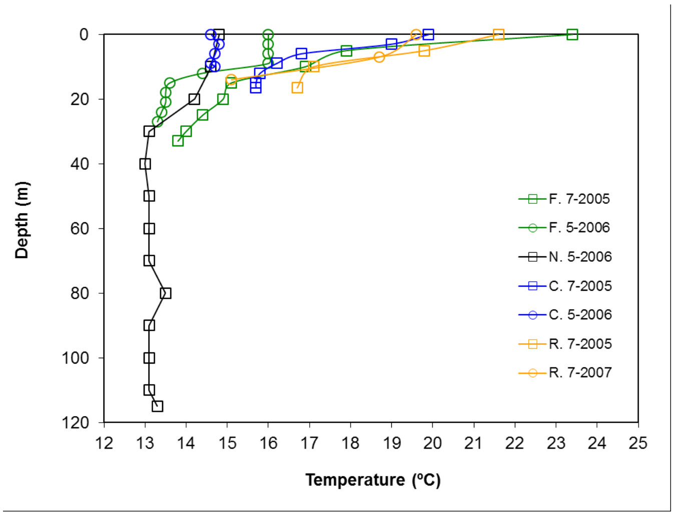


Figure 3. Temperature variation with depth. Vertical profile from Negra Lake show a depth thermocline compared with other lakes. F. – Funda Lake, N. – Negra Lake, C. – Comprida Lake, R. – Rasa Lake.

Figura 3. *Variação da temperatura ao longo da coluna de água. O perfil realizado na Lagoa Negra mostra a existência de uma termoclina mais profunda comparativamente com os restantes lagos. F. – Lagoa Funda, N. – Lagoa Negra, C. – Lagoa Comprida, R. – Lagoa Rasa.*

elements in Lake Comprida (Na>Ca-Mg>K; HCO_3-Cl>SO_4) is distinct from Lake Rasa (Na>Ca>Mg-K; Cl>SO_4>HCO_3). Water samples from Lake Comprida, a smaller lake in area and volume, show a slightly more concentrated water composition and provide mixed facies with a Ca-Mg-HCO3 enrichment compared to Lake Rasa.

The pH values for all sampled lakes range between 5.43 and 9.94 and decrease with depth to slightly acidic values, except for Lake Negra waters which have alkaline values and the pH increases slightly with depth (Fig. 6). The total CO_2 concentrations show a pattern to increase in the hipolimnion (Fig. 7)

The DO vertical profiles show well oxygenated waters for Lake Negra and Comprida (Fig. 8). Lake Funda and Rasa have an oxygen-rich epilimnion above the thermocline and an anoxic hipolimnion.

4. DISCUSSION

Temperature affects the chemical equilibrium of aquatic systems (Wetzel, 1993; Lampert *et al.*, 2007). Thermal stratification is common in Azorean lakes in the summer with depths greater than 12m and thermoclines between 3 and 20m (Antunes, 2009). Lake Negra is the deepest lake in the Azores and shows a thermocline larger than the other lakes. Lake water stratification prevents water from circulating between the epilimnion and the hypolimnion. However, lakes sampled in Flores do not show strong compositional stratification. More campaigns are needed to determine the thermal water gradient over the course of the year at the study lakes. Lake waters show low levels of mineralization, with low electrical conductivity values (<148μS/cm; Table 2). The marine contribution, due to sea salt input by atmospheric deposition, partially controls the hydrogeochemical evolution of the lakes where water samples are near the line that characterizes the sea water line (Fig. 9).

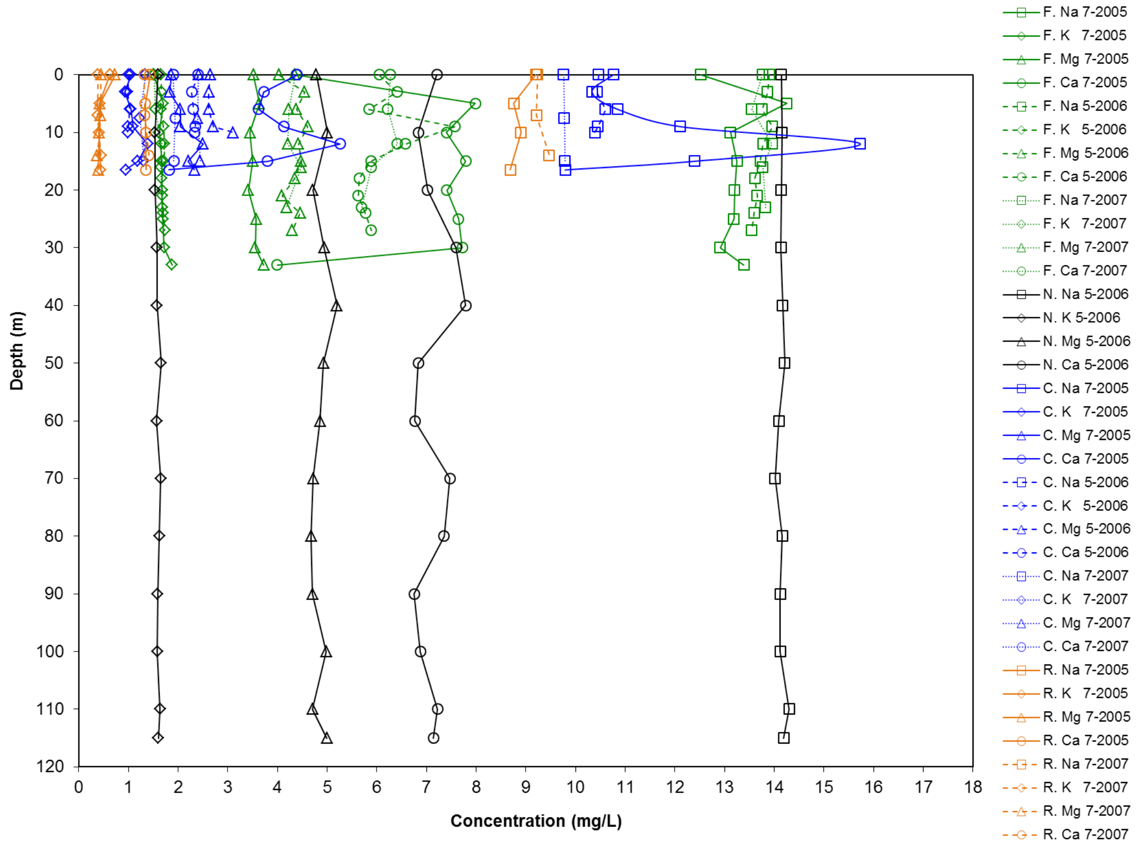
Marine contribution is the main mechanism that controls the water chemistry of Lake Rasa, which has the most dilute water of the sampled lakes with Na-Cl facies (Fig. 5) that are located close the sea water line. Lake Comprida water samples are disperse on the plot, which results from the mixed mineral water springs that drain into the lake and contribute to slightly more concentrated water than Lake Rasa (Table 3 and Figure 9).

Despite the marine contribution, the effect of water-rock interaction processes contributes to water composition in the large mass lakes with the large concentration of alkali metal (Fig. 10). The slightly CO_2 production by organic matter contributes to the acidity of the hipolimnion and is responsible for the pH decrease (Fig. 6, 7 and 11).

Figure 11 compares the studied Flores lakes with the Congro and Furnas Lake at São Miguel Island and with Furna do Enxofre Lake (F. Enxofre) at Graciosa Island. F. Enxofre is a small lake inside a basaltic lava cave located at the Caldera of Graciosa volcano (Fig. 12).

There is a fumarole field inside the cave and it is possible to see vapour at 1 meter depth along the lake margin. In the summer, CO_2 concentrations above the surface water reaches 17% and it is the Azorean lake with the highest CO_2 concentration. Furnas Lake water contamination has a contribution from a hydrothermal surface manifestation, with fumarole discharge located on the northern margin of the lake. Congro Lake water contamination by volcanic fluids does not have a clear pattern, but magmatic contribution cannot be excluded (Antunes 2009). The free CO_2 concentration in Flores water lakes are lower than lakes with clear signatures of volcanic fluids contamination and show a different trend. Lake Rasa has the lowest pH values resulting from the process that controls the water chemistry, suggesting a low water residence time. Lake Funda shows the highest values of pH at the water surface due to the intense biological activity that occurs in this system. Indeed, the phytoplankton enriched epilimnion, shown by the chlorophyll *a* and phaeopigments, exceeds the concentration present at other lakes (Table 4).

Lake water eutrophication is the main source of aquatic system degradation. The lakes have been subject to unprecedented level of anthropogenic disturbance and eutrophication, which makes Azorean lakes highly productive systems (INOVA, 1999; Gonçalves, 1997; Gonçalves *et al.*, 2005, Aguiar *et al.*, 2008; Gonçalves, 2008). Biological production by photosynthesis, leads to high pH values on lake epilimnions and the increase of water opacity contributes to increased heat retention. Highly productive aquatic systems represent a potential hazard as the cyanobacteria produce hepatic toxins and neurotoxins, which are responsible for acute lethal, acute, chronic and sub-chronic poisonings of animals and humans (Carmichael, 2001; Ellwood *et al.*, 2005).



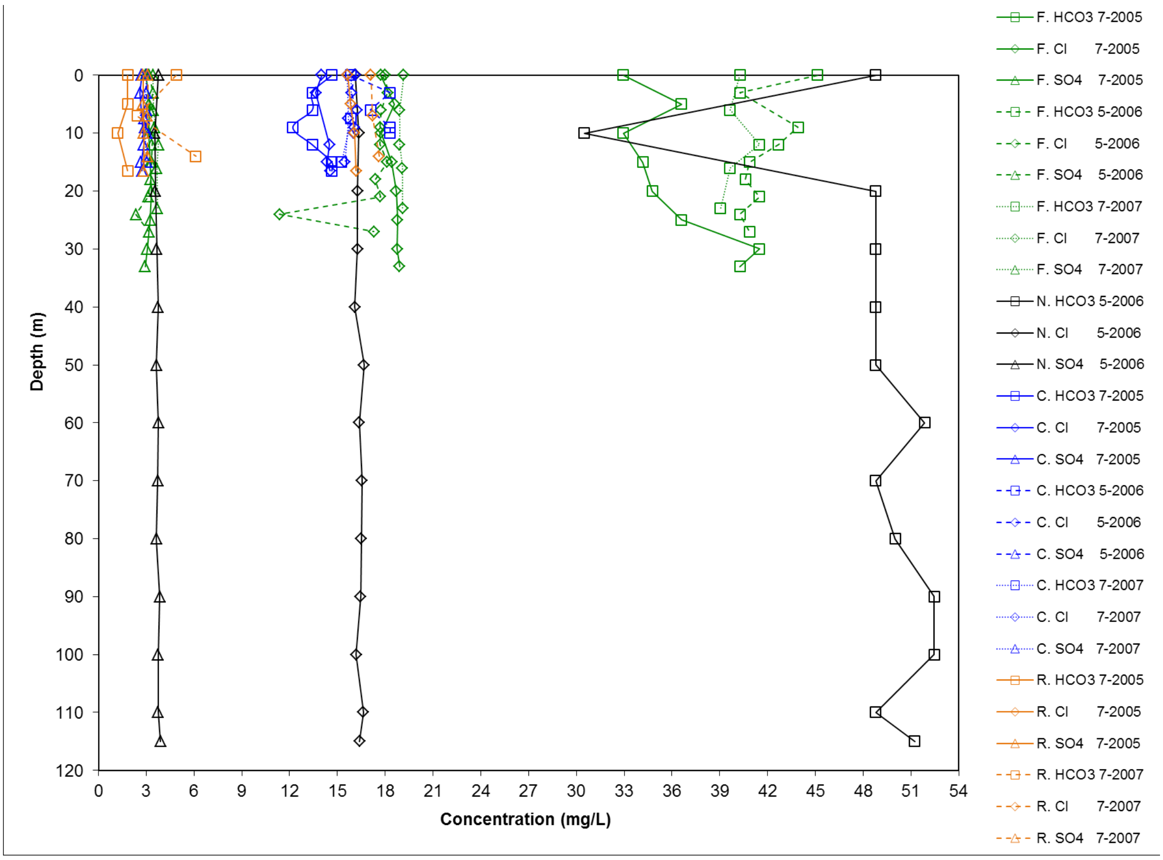


Figure 4. Vertical profiles showing the major chemical elements in the studied aquatic systems. F. – Lagoa Funda, N. – Lagoa Negra, C. – Lagoa Comprida, R. – Lagoa Rasa.
Figura 4. *Resultado dos elementos maiores ao longo da coluna de água nos lagos estudados. F. – Funda Lake, N. – Negra Lake, C. – Comprida Lake, R. – Rasa Lake.*

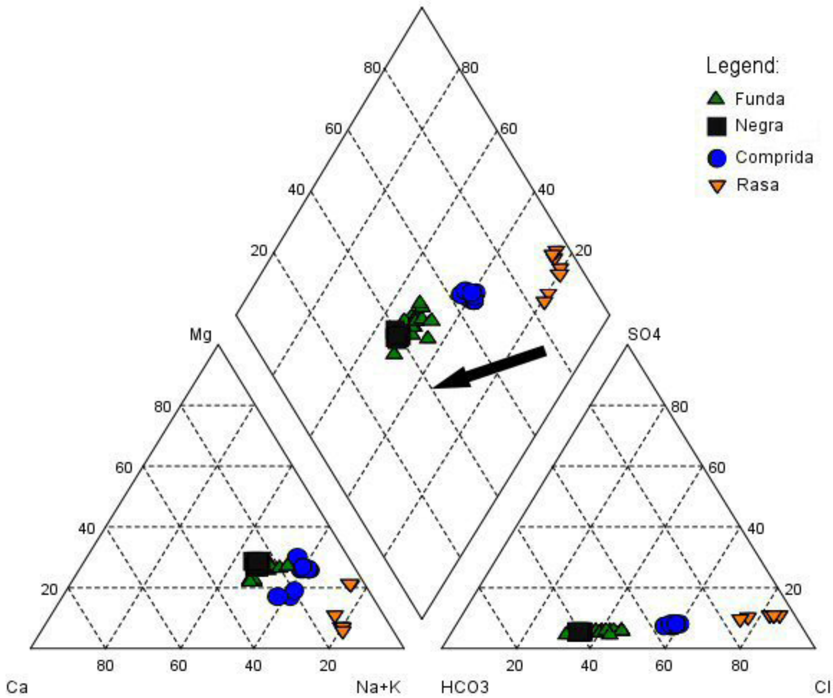


Figure 5. Piper diagram applied to a representative set of samples (data from Table 2).
Figura 5. *Diagrama de Piper representado por um conjunto significativo de amostras de água dos lagos amostrados e que constam na Tabela 2.*

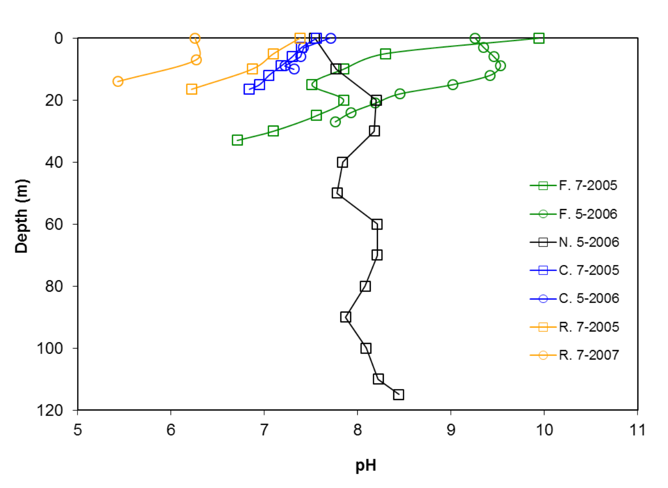


Figure 6. Variation of pH with depth in the sampled lakes. Lake Negra is the only lake pH increased in depth. F. – Funda Lake, N. – Negra Lake, C. – Comprida Lake, R. – Rasa Lake.
Figura 6. *Variação do pH em profundidade nos lagos estudados. A Lagoa Negra é o único lago que mostra um aumento do valor de pH em profundidade. F. – Lagoa Funda, N. – Lagoa Negra, C. – Lagoa Comprida, R. – Lagoa Rasa.*

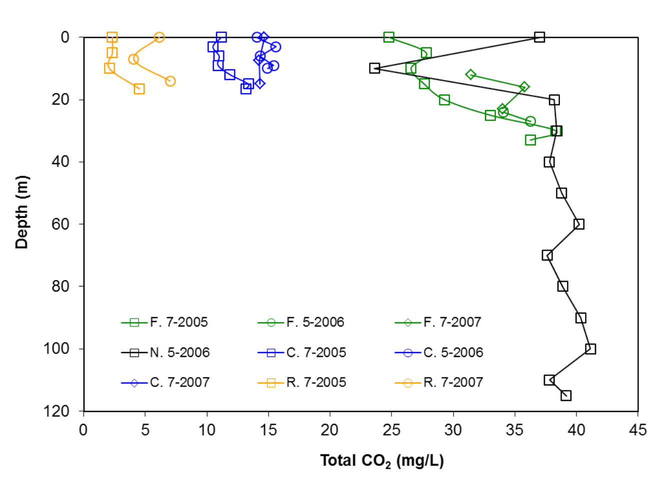


Figure 7. TotalCO2 concentration variation with depth for the sampled lakes. F. – Funda Lake, N. – Negra Lake, C. – Comprida Lake, R. – Rasa Lake.
Figura 7. *Resultado do dióxido de carbono total em profundidade nos lagos estudados. F. – Lagoa Funda, N. – Lagoa Negra, C. – Lagoa Comprida, R. – Lagoa Rasa.*

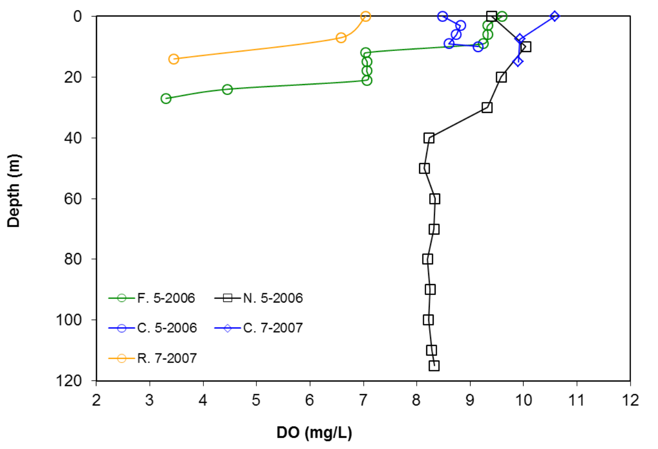


Figure 8. DO variation with depth for the sampled lakes. F. – Funda Lake, N. – Negra Lake, C. – Comprida Lake, R. – Rasa Lake.
Figura 8. *Variação do oxigénio dissolvido em profundidade nos lagos estudados. F. – Lagoa Funda, N. – Lagoa Negra, C. – Lagoa Comprida, R. – Lagoa Rasa.*

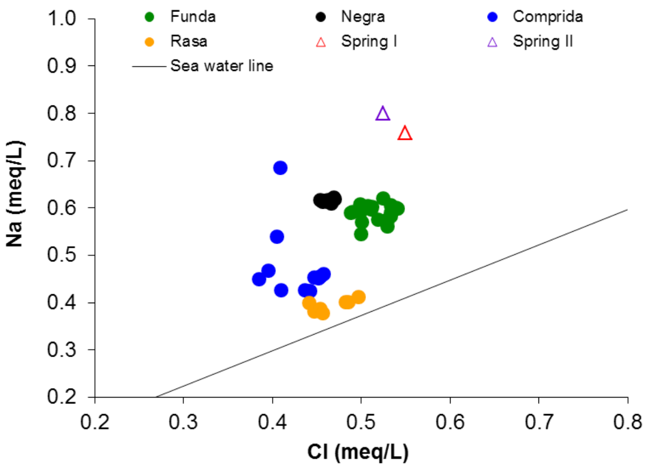


Figure 9. Compositional distribution of water samples related with the seawater line.
Figure 9. *Distribuição da amostras de água em relação à recta que caracteriza a água do mar.*

Table 3. Major chemical elements composition of springs located at the SE rim of Lake Comprida. All concentrations in ppm, temperature (Temp) in ºC and electrical conductivity (Cond) in µS/cm.
Tabela 3. *Resultado dos elementos maiores das nascentes localizadas no flanco SE da Lagoa Comprida. As unidades dos elementos analisados estão em mg/L, excepto para o pH. A temperatura (T) em ºC e a Condutividade Eléctrica (Cond) em µS/cm.*

Springs	pH	Temp	Cond	DO	freeCO_2	totalCO_2	HCO_3	Alk	Cl	SO_4	Na	K	Mg	Ca	SiO_2	Fe
I	6.68	12.6	365	0.3	21	159	192	157.5	19.5	1.9	17.5	6.6	21.6	69.9	43.7	0.05
II	7.08	14.5	367	0.3	24	181	218	178.5	18.6	1.5	18.4	6.6	24.3	98.7	43.7	3.08

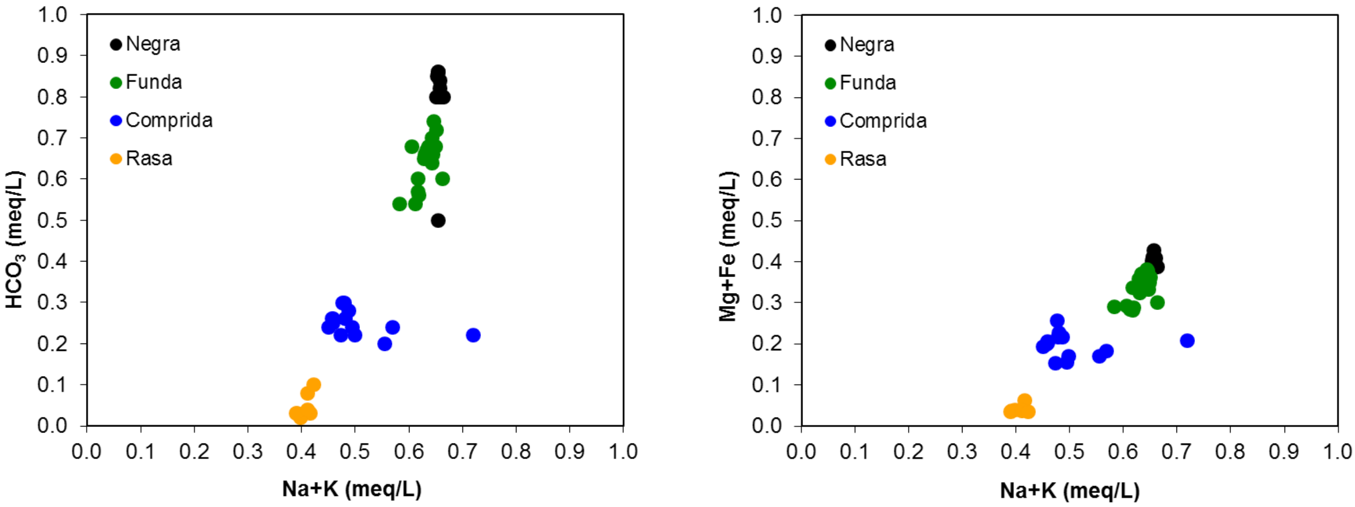


Figure 10. Compositional trend show an increase concentration for the large lakes.
Figura 10. *A distribuição da amostras de água demostra a entrada dos elementos químicos nos lagos de maiores dimensões.*

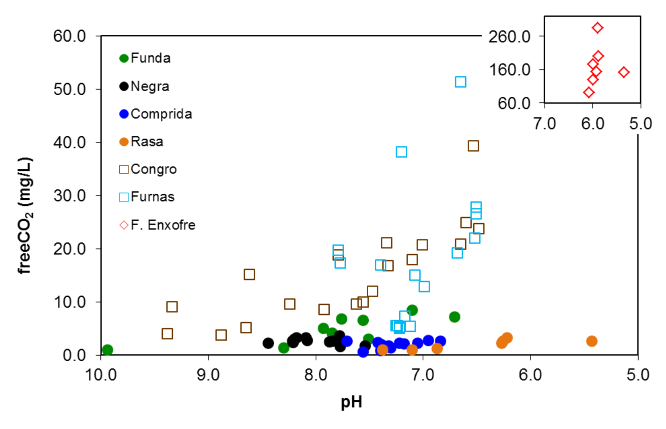


Figure 11. Variation of free CO_2 vs pH in the studied lakes compared with Congro, Furnas and F. Enxofre Lakes.
Figura 11. *Relação entre o dióxido de carbono dissolvido e o pH nos lagos estudados, na Lagoa do Congro, das Furnas e da Furna do Enxofre.*

Table 4. chlorophyll ***a*** and phaeopigments values sampled in Lakes Funda Comprida and Rasa during the samples campaign of 2007 (in Aguiar *et al.*, 2008).
Tabela 4. *Valores da clorofila a e de feopigmentos das amostras de água analisada nas Lagoas Funda, Comprida e Rasa durante a campanha de amostragem de 2007 (in Aguiar et al., 2008).*

	Depth (m)	Chlorophyll *a* (ug/L)	Phaeopigments (ug/L)
Lake Funda	6	29.24	7.23
	11	6.8	2.72
	23	2.27	0.62
Lake Comprida	0	2.68	0.64
	7.5	3.09	1.09
	10	2.88	1.3
Lake Rasa	0	0.82	0.04
	7	1.03	0.41
	14	1.85	1.17

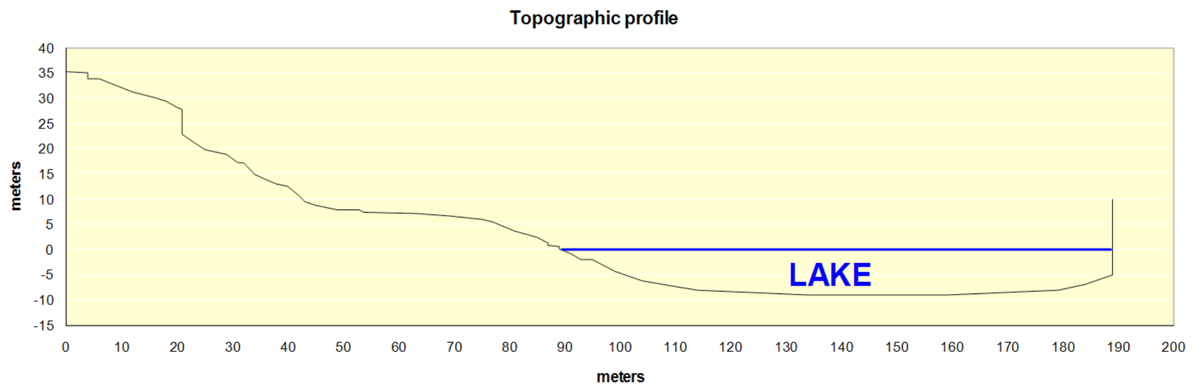


Figure 12. Topographic profile made along the interior of Furna do Enxofre cave. The lake occupied the lower and final part of the cave. The interior ceiling has a vault shape.
Figura 12. *Perfil topográfico realizado no interior da Furna do Enxofre. O lago ocupa a zona mais deprimida da gruta localizada na parte oposta à sua entrada. O tecto da gruta tem forma de abóboda.*

The CO_2 concentration is dominant in the large mass of the lakes and Lake Funda shows a slight increase in CO_2 with depth that might be explained by the decay of organic matter (Fig. 7). Funda lakes are anoxic during the sampling campaigns and the production of organic CO_2 by anaerobiosis is inefficient compared with the aerobiosis process. The larger CO_2 prodution in Funda lake can be explain by the large biological production as the phytoplankton enriched epilimnion shows.

The alkalinity acts as a buffer and neutralizes the acidic solutions that enter the aquatic systems. This buffer system protects aquatic organisms against changes in pH, which converts the acid carbon into carbonate or bicarbonate (Wetzel, 1993; Wilson, 1995; Deutsch, 1997). Funda and Negra Lakes have the largest alkalinity values resulting from the neutralization of acid solution from the slightly free CO_2 input by the chemical weathering of the volcanic rocks. This geochemical process contributes to the hydrogeochemical evolution of the larger mass lakes. Figure 10 shows the slight enrichment of alkali metals in Negra and Funda Lakes. Adding the Congro, Furnas and F. Enxofre results to the same plots, it is possible to identify two trends: one for São Miguel Lakes and another for Flores Lakes (Fig. 13).

Negra and Funda Lakes show a small increase in alkali metals related to bicarbonate. However, São Miguel Lakes show a higher increased in alkali metals due to the volcanic contribution, mainly in Furnas Lake. Comprida Lake shows an alkali metal increase independent of the bicarbonate content related to the water drained by mineral springs, which has a higher concentration in sodium and potassium

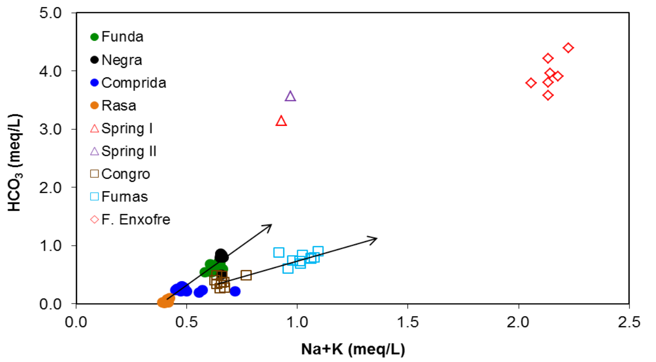


Figure 13. Compositional trend comparing the increase concentration for Flores, São Miguel and Graciosa Lakes. Congro e Furnas Lakes data correspond to the average of monthly sampling profiles and F. Enxofre data correspond to July and November sampling profiles.
Figura 13. *Comparação da distribuição dos metais alcalinos vs bicarbonato entre os lagos estudados e aos lagos localizados na ilha de São Miguel e Graciosa. Os dados referentes à Lagoa do Congro e Furnas dizem respeito às médias dos perfis efectuados mensalmente. Os resultados apresentados da Furna do Enxofre correspondem aos perfis efectuados em Julho e Novembro de 2006.*

than Comprida Lake. Nevertheless, the higher content of alkali metals in F. Enxofre Lake is related to the weathering of silicate minerals due to hydrothermal water seepage (Fig. 13). Potassium is a conservative element present in minerals more resistant to hydrolysis, however this element is preferentially leached by high temperature fluids (Berner & Berner, 1996; Albarède, 2003). São Miguel lakes, mainly Furnas Lake present a potassium increase consistent with the large mobilization of this element related to hydrothermal water seepage.

The compositional trend in large mass lakes at Flores Island shows quite clearly that bicarbonate increases independently from potassium.

Rock hydrolysis explains the slightly concentrated water in Funda and Negra Lakes compare to Comprida and Rasa Lakes. Although, the carbon dioxide, major ions and silica fluxes are very modest in the studied aquatic systems, which suggest no interaction with volcanic fluids. A contribution of CO_2 from dominant volatile sources in Azorean lakes located at the summit of active craters is common and present an increase of bicarbonate and electrical conductivity at the hipolimnion (Antunes, 2009).

The profile variation of Ca, HCO_3 and SiO_2 at Lake Funda could be explained by the phytoplankton metabolism (Wetzel, 1993).

The lake water quality degradation is related to anthropogenic influences. The input of artificial nutrients is the major cause of water quality degradation, inducing for example the extinction of small lakes such as Lagoa do Ginjal on Terceira and Lagoa dos Nenúfares on São Miguel due to eutrophication (Antunes & Rodrigues, 2011). In general, the most eutrophic aquatic systems in the Azores occur in basins where the surrounding land is exploited by the livestock industry. In the Regional Water Plan for the Azores, fertilizer application rates for the agricultural area (UAA) were 352 and 707kg ha-1 for PK and NPK, respectively (DROTRH-INAG, 2001), and excessive use of these compounds may lead to greater mobility of nutrients into lakes. Nitrate (NO_3), phosphate (PO_4) and potassium (K) are largely consumed by plants (Oren *et al.*, 2004). Studied lakes show relative low NO_3 concentrations (Fig. 14; Table 2). Plot K vs NO_3 and the vertical profile of potassium suggest this element in Flores Lakes is not affected by aquatic organism metabolisms. Although, data suggests there may exist a permanent input of nitrate in Negra and Funda Lakes. Figure 15 show the NO_3 variation in depth suggesting that nitrate can be affect by organism metabolism along the water column. However, nitrate results are of a short, timescale, no phosphate data is available and sampling was made in the period when phytoplankton are more productive (summer) for further consideration.

5. CONCLUSION

The studied aquatic ecosystems at Flores Island are emplaced in volcanic craters associated with hydromagmatism (maars). Lakes show thermal water stratification in the summer due to water density variations. Despite the thermal stratification, lakes do not show marked chemical composition stratification. In general, the lake waters correspond to freshwater with low mineralization. The smaller mass lakes are Na-Cl dominated, whereas the larger mass lakes show a Ca-HCO_3 chemical facies. Three major processes control the hydrogeochemical properties of the studied lakes: (1) the marine sea salt contribution due to atmospheric transportation and deposition that influence the water chemistry of all lakes and is the main process that control the chemistry of Rasa Lake; (2) the contamination of Comprida Lakes by mineral water; (3) the input of rock

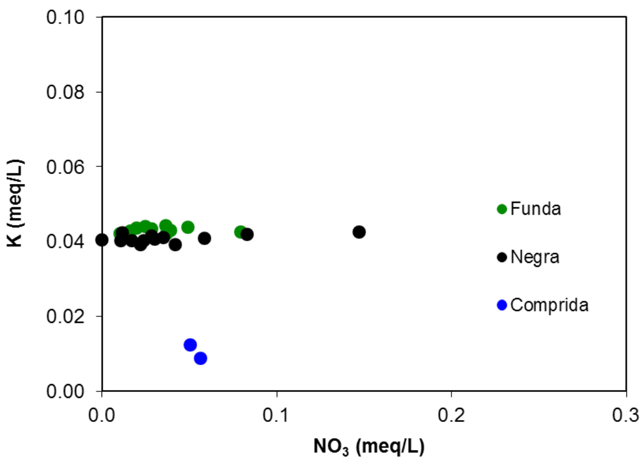


Figure 14. Variation of K compared to NO_3 concentrations in the studied lakes.
Figura 14. *Relação entre potassio e o nitrato nos lagos estudados.*

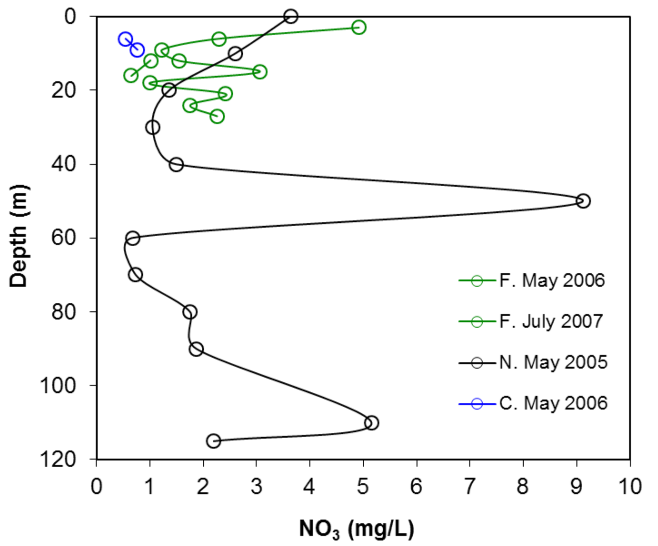


Figure 15. Vertical profiles showing the nitrate concentration variation in the studied lakes.
Figura 15. *Resultado da concentração do nitrato ao longo da coluna de água nos lagos estudados.*

forming elements into the larger lakes as a result of weathering of rocks. Rock hydrolysis explains the more concentrated waters in Lakes Funda and Negra. All four lakes have no interaction with the seepage of magmatic fluids and the only source of CO_2 is related to organic matter degradation that explains the low concentration of free CO_2 in these aquatic systems. The concentrations of major chemical species in all of the studied lakes are well below the European Union standards and Portuguese law for drinking-water quality. The lake water quality degradation is related to anthropogenic influences with the input of artificial nutrients causing the increase in biological productivity.

More sampling campaigns are needed over the year to determine the thermal evolution, the spatial and temporal variation, the mixing properties of the lakes and analyze the artificial nutrient input related to groundwater and surface water interaction, mainly phosphate for further consideration related to safe water resources for drinking water. Further studies should consider the European Union environmental directives to reduce the impact of human activities on the aquatic environment, namely the Nitrates Directive, the Groundwater Directive and the Water Framework Directive to improve the planning and managing plans for protected areas in small islands.

ACKNOWLEDGEMENTS

We thank Lilly Corenthal for reviews comments greatly improved the clarity of the manuscript. The research for this paper was supported by a grant from Fundação para a Ciência e a Tecnologia (Portugal).

REFERENCES

Agostinho, J. (1938) – Clima dos Açores. *Açoreana* (ISSN: 0874-0380), 1(2):35–65, Angra do Heroísmo, Açores, Portugal. Available at http://www.azoresbioportal.angra.uac.pt/files/publicacoes_Agostinho38_ClimaDosAores.pdf

Aguiar, P.; Antunes, P.; Mestre, R.; Raposeiro, P. M.; Costa, A. (2008) – A Dinâmica Biogeoquímica de Sistemas Aquáticos da Ilha das Flores. *In:* João António Cândido Tavares & Duarte Soares Furtado (Coord.), *XIII Expedição Científica do Departamento de Biologia - Flores e Corvo 2007*, Relatórios e Comunicações do Departamento de Biologia, n.o 35, pp. 15-27, Universidade dos Açores, Ponta Delgada, Portugal. ISBN: 978-9728612382. Available at http://repositorio.uac.pt/bitstream/10400.3/708/1/Dinâmica%20biogeoqu%C3%ADmica%20de%20sistemas%20aquáticos%20da%20Ilha%20das%20Flores.pdf

Antunes, P. (2009) - *Estudo hidrogeoquímico e vulcanológico de lagos no arquipélago dos Açores: aplicações para a mitigação de riscos naturais*. 306 p., Dissertação de Doutoramento, Universidade dos Açores, Ponta Delgada, Portugal. ISBN: 978-9728612795. Available at https://repositorio.uac.pt/handle/10400.3/1304

Antunes, P.; Rodrigues, F.C. (2011) - Azores Volcanic Lakes: factors affecting water quality. *In:* N. Peters, V. Krysanova, A. Lepisto, R. Prasad, M. Thoms, R. Wilby & S. Zandaryaa (eds.), *Water Quality: Currents Trends and Expected Climate Change Impacts*, pp. 106-114, International Association of Hydrological Sciences, Wallingford, U.K. ISBN: 978-1907161230

Azevedo, E.M.V.B., (1996) - *Modelação do clima Insular à escala local*. 247p., Dissertação de Doutoramento, Universidade dos Açores, Angra do Heroísmo, Portugal. *Unpublished*.

Azevedo, J.M.M. (1998) – *Geologia e Hidrogeologia da Ilha das Flores (Açores-Portugal)*. 403p., Dissertação de Doutoramento, Universidade de Coimbra, Coimbra, Portugal. Available at https://estudogeral.sib.uc.pt/handle/10316/1892

Berner, E. K.; Berner, R. A. (1996) - Global Environment: Water, Air, and Geochemical Cycles. 444p., Prentice Hall, New Jersey, USA. ISBN: 0691136785" entre Azevedo, J.M.M. (1998) e Bettencout, M.L. (1979).

Bettencout, M.L. (1979) – *O clima dos Açores como recurso natural, especialmente em agricultura e indústria do turismo*. 104p., Instituto Nacional de Meteorologia e Geofísica, Lisboa, Portugal.

Brabec, E. (2002) – Impervious surfaces and water quality: a review of current literature and its implications for watershed planning. *Journal of Planning Literature*, 16(4):499-514. Available at http://works.bepress.com/elizabeth_brabec/11/

Carmichael, W.W. (2001) - Health effects of toxin-producing cyanobacteria: "The CyanoHABs". *Human and Ecological Risk Assessment*, 7(5):1393-1407. DOI: 10.1080/20018091095087

Christenson, B.W. (2000) – Geochemistry of fluids associated with the 1995-1996 eruption of Mt.

Ruapehu, New Zealand: signatures and processes in the magmatic-hydrothermal system. *Journal of Volcanology and Geothermal Research*, 97(1-4):1-30. DOI: 10.1016/S0377-0273(99)00167-5

Delmelle, P.; Bernar, A. (2000) – Volcanic lakes. *In*: H. Sigurdsson, S., McNutt:, H. Rymer, H. & D. Six (org.*), Encyclopedia of Volcanoes*, pp. 877-895, Academic Press, San Diego, CA, U.S.A.

Deutsch, W.J. (1997) – *Groundwater geochemistry: fundamentals and applications to contamination*. 232p., CRC Press, New York, NY, USA.

DROTRH; IA (2001) - *Plano Regional da Água - Relatório Técnico - Versão para Consulta Pública*. 414p., Secretaria Regional do Ambiente, Direcção Regional do Ordenamento do Território e dos Recursos Hídricos, Ponta Delgada, Portugal. Available at http://portaldaagua.inag.pt/PT/InfoTecnica/PGA/PRPlaneamento/Documents/relatorio_PRA.pdf

Ellwood, N. T. W.; Mosello, R.; Albertano, P. (2005) - A seasonal survey on the water quality and phytoplankton dynamics of Lake Albano. *In: Convegni Lincei 218-Ecosistema Roma,* pp. 209-262, Bardi Editore, Roma, Italy.

Forjaz, V.H. (1983) - *Azores tectonic sketch*. 1p., Centro de Vulcanologia, Universidade dos Açores, Ponta Delgada, Portugal. *Unpublished.*

Gonçalves, V. (1997) – *Estrutura da Comunidade Fitoplanctónica da Lagoa das Furnas*. 229p., Provas de Aptidão Pedagógica e Capacidade Científica, Departamento de Biologia, Universidade dos Açores, Ponta Delgada, Portugal. *Unpublished*.

Gonçalves, V. (2008) - *Contribuição para o estudo da qualidade ecológica das lagoas dos Açores: Fitoplâncton e diatomáceas bentónicas*. 331p., Dissertação de Doutoramento, Universidade dos Açores, Ponta Delgada, Portugal. *Unpublished*.

Gonçalves, V.; Costa, A.C.; Raposeiro, P.M.; Marques, H. (2005) – *Caracterização biológica das massas de* água *superficiais das ilhas de São Miguel e Santa Maria*. 164p., Centro de Conservação e Protecção do Ambiente, Universidade dos Açores, Ponta Delgada, Portugal.

Hockings, M.; Stolton, S.; Dudley, N. (2006) - *Evaluating effectiveness: A framework for assessing the management of protected areas*. 105p., IUCN (International Union for Conservation of Nature and Natural Resources), Gland, Switzerland / Cambridge, U.K. ISBN-13: 978-2831709390. Available on-line at https://portals.iucn.org/library/efiles/edocs/PAG-014.pdf

Hockings, M. (2003) - Systems for assessing the effectiveness of management in Protected Areas. *BioScience*, 53(9):823-832. DOI:10.1641/0006-3568(2003)053[0823:SFATEO]2.0.CO;2

INOVA (1999) – *Análise das* Águas *das Lagoas da Região Autónoma dos Açores.* 291p., INOVA (Instituto de Inovação Tecnológica dos Açores), Ponta Delgada, Portugal. *Unpublished.*

Karr, J.R. (1993) – Defining and assessing ecological integrity: Beyond water quality. *Environmental Toxicology and Chemistry*, 12(9):1521-1531. DOI: 10.1002/etc.5620120902

Krause, D.; Watkings, N. (1970) - North Atlantic crustal genesis in the vicinity of the Azores. *Geophysical Journal International*, *19*(3):261-283. DOI: 10.1111/j.1365-246X.1970.tb06046.x

Lampert, W.; Sommer, U. (2007) – *Limnoecology: the ecology of Lakes and streams*. 324p., Oxford University Press, Oxford, England, U.K.

Laughton, A. S.; Whitmarsh, R. B. (1974) - The Azores-Gibraltar plate boundary. In: *Geodynamics of Iceland and the North Atlantic area,* pp. 63-81, Springer Netherlands, Dordrecht, Netherlands.

Lourenço, N.; Miranda, J.M.; Luis, J.F.; Ribeiro, A.; Victor, L.A.M.; Madeira, J.; Needham, H.D., (1998) – Morpho-tectonic analysis of the Azores Volcanic Plateau from a new bathymetric compilation of the area. *Marine Geophysical Researches*, 20(3):141–156. DOI: 10.1023/A:1004505401547

Miranda, P.M.A.; Valente, M.A.; Tomé, A.R.; Trigo, R.; Coelho, M.F.E.S.; Aguiar, A.; Azevedo, E.B. (2006) – O clima de Portugal nos Séculos XX e XXI. *In*: F. D. Santos & P. Miranda (org.), *Alterações climáticas em Portugal - Cenários, impactos e medidas de adaptação,* Ed. Gradiva, Lisboa, Portugal. Available at http://siam.fc.ul.pt/siamII_pdf/SIAMII.pdf

Morrisseau, M. (1987) – *Les éruptions hydromagmatiques et les xenolites associes: signification geothermique (exemples de Flores et de Faial, Açores).* 487p., Thèse de Doctorat, Université de Paris 11, Paris, France.

Moyle, P.B.; Randall, P.J. (1998) – Evaluating the Biotic Integrity of Watersheds in the Sierra Nevada, California. *Conservation Biology*, 12(6):1318–1326. DOI: 10.1111/j.1523-1739.1998.97161.x

Oren, O.; Yechieli, Y.; Bohlke, J.K.; Dody, A. (2004) – Contamination of groundwater under cultivated fields in an arid environment, central Arava Valley, Israel. *Journal of Hydrology*, 290(3-4):312-328. DOI: 10.1016/j.jhydrol.2003.12.016

Porteiro, J. (2000) – *Lagoas dos Açores: elementos de suporte ao planeamento integrado*. 344 p., Dissertação de Doutoramento, Universidade dos Açores, Ponta Delgada, Portugal. *Unpublished.*

Rowe Jr, G.L.; Brantley, S.L; Fernandez, M.; Fernandez, Borgia, A.; Barquero, J.; (1992) – Fluid-volcano interaction in an active stratovolcano: the crater lake system of Poás volcano, Costa Rica. *Journal of Volcanology and Geothermal Research*, 49(1–2):23-51. DOI: 10.1016/0377-0273(92)90003-V

Saunders, D.L.; Meeuwig, J.J.; Vincent, A.C.J. (2002) – Freshwater Protected Areas: Strategies for Conservation. *Conservation Biology*, 16(1):30–41. DOI: 10.1046/j.1523-1739.2002.99562.x

Searle, R. (1980) – Tectonic pattern of the Azores spreading centre and triple junction. *Earth and Planetary Science Letters*, 51(2):415-434. DOI: 10.1016/0012-821X(80)90221-6

Simeonov, V.; Stratis, J.A.; Samara, C.; Zachariadis, G.; Voutsa, D.; Anthemidis, A.; Sofoniou, M.; Kouimtzis, T. (2003) - Assessment of the surface water quality in Northern Greece. *Water Research*, 37(17):4119-4124. DOI: 10.1016/S0043-1354(03)00398-1

Steinmetz, L.; Hirn, A.; Sapin, M.; Whitmarsh, R.; Moreira, V. (1976) - Zones of P wave attenuation beneath the crest of Mid-Atlantic Ridge. *Bulletin de la Société Géologique de France*, V. Series 7, XVIII(4):931-936. DOI: 10.2113/gssgfbull.S7-XVIII.4.931

UNL (1991) – *O controle da eutrofização nas lagoas de S. Miguel – Açores.* DCEA/FCT, Universidade Nova de Lisboa, Lisboa, Portugal. *Unpublished.*

Varekamp, J.C. (2008) – The volcanic acidification of glacial Lake Cavihue, Province of Neuquen, Argentina. *Journal of Volcanology and Geothermal Research*, 178(2):184–196. DOI: 10.1016/j.jvolgeores.2008.06.016

Varekamp, J.C.; Pasternack, G.B.; Rowe Jr.; G.L. (2000) - Volcanic lake systematics II. Chemical constraints. *Journal of Volcanology and Geothermal Research*, 97(1-4):161-179. DOI: 10.1016/S0377-0273(99)00182-1

Wetzel, R.G. (1993) - *Limnologia*. 919p., Fundação Calouste Gulbenkian, Lisboa, Portugal. ISBN: 0030579139.

Wilson, N. (1995) – *Soil water and groundwater sampling*. 188p., CRC Press, New York, NY, USA. ISBN: 1-56670-073-6.

Revista da Gestão Costeira Integrada 14(2):335-344 (2014)
Journal of Integrated Coastal Zone Management 14(2):335-344 (2014)

http://www.aprh.pt/rgci/pdf/rgci-496_Calado.pdf | DOI:10.5894/rgci496

Developing a Planning and Management System for Protected Areas on Small Islands (The Azores Archipelago, Portugal): the SMARTPARKS Project *

Desenvolvimento de um Sistema Integrado de Planeamento e Gestão de Áreas Protegidas em Pequenas Ilhas Oceânicas (Arquipélago dos Açores, Portugal): o Projecto SMARTPARKS

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ABSTRACT

Small Islands face particular challenges in their sustainable development, and therefore require specific tailored approaches for planning and management. Unsurprisingly, protected areas have a special role in the conservation of biodiversity and natural resources crucial to the sustainability of such territories. How should the management and planning system of protected areas in small islands be, therefore, structured and operated so it can face the threats and challenges falling upon the already fragile and vulnerable insular ecosystems? This is the central question of SMARTPARKS Project. The core objective of the project consists of the conceptual development of a planning and management system for protected areas that can be integrated with the territorial management instruments in force, and that takes into consideration the specificities of insular ecosystems, correcting or perfecting the insufficiencies or flaws already pointed out to traditional planning systems of protected areas. This paper presents the SMARTPARKS Project, its rationale and main outcomes. Taking Pico Island Natural Park (Azores, Portugal) as its case study, the SMARTPARKS Project has adopted the ecosystem approach and the conciliation of conservation objectives with human needs and activities. Throughout its five tasks several studies were developed, and contributed to the functional analysis (developed during the last task) of each protected area constituting the Island Natural Park, in terms of their conservation and development values. This innovative application allows not only an integrated assessment of the protected areas but also a sustained monitoring.

Keywords: Small Islands; Island Natural Park; Planning; Management; Azores.

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** Submission: 11 February 2014; Evaluation: 7 March2014; Reception of revised manuscript: 10 April 2014; Accepted: 10 June 2014; Available on-line: 17 June 2014*

RESUMO

As pequenas ilhas oceânicas enfrentam desafios particulares com vista ao seu desenvolvimento sustentável, necessitando consequentemente de abordagens técnicas de base científica específicas no desenvolvimento das suas estratégias de planeamento e gestão territoriais. É inquestionável a relevância do papel das áreas protegidas quer na conservação da biodiversidade e dos recursos naturais, quer na sustentabilidade dos territórios por elas abrangidos. De que modo deve ser então definido o modelo de planeamento e gestão de áreas protegidas em pequenas ilhas oceânicas para poder fazer face a todas as ameaças e desafios com que se deparam estes frágeis e vulneráveis ecossistemas costeiros? Esta é a questão principal pela qual se rege o projecto SMARTPARKS. O objectivo nuclear deste projecto consiste no desenvolvimento conceptual de um sistema integrado de planeamento e gestão de áreas protegidas que possa integrar, complementar e fortalecer os instrumentos de gestão territorial vigentes, e que tenha em consideração as particularidades e especificidades destes ecossistemas insulares, corrigindo ou minimizando as falhas e insuficiências já identificadas das ferramentas e técnicas tradicionais de planeamento territorial de áreas protegidas. Este artigo apresenta o projecto SMARTPARKS, o seu contexto, a sua abordagem conceptual e os seus principais resultados. O Parque Natural de Ilha do Pico (Arquipélago dos Açores, Portugal) constitui o caso de estudo deste projecto, estando o desenvolvimento conceptual do SMARTPARKS especialmente focado numa sinergia definida pela abordagem ecossistémica e pela sua tentativa de conciliação com os objectivos de conservação com todas as necessidades e actividades humanas de cariz sócio-económico e cultural desenvolvidas no território abrangido. Ao longo do seu desenvolvimento metodológico dividido em 5 grandes tarefas, vários estudos específicos foram realizados, contribuindo nomeadamente para a análise funcional (em termos de valores para a conservação e desenvolvimento) que foi feita para cada área protegida que compõe o Parque Natural de Ilha do Pico. Esta abordagem metodológica inovadora permite não só uma avaliação integrada das áreas protegidas como também a sua monitorização sustentável.

Palavras-chave: *Pequenas ilhas oceânicas; Parque Natural de Ilha; Planeamento; Gestão; Açores.*

1. INTRODUCTION

Small islands are ipso facto largely coastal entities (Saffache & Angelelli, 2010). Island ecosystems are inherently vulnerable systems, and anthropogenic pressures, such as land use changes, are one of the main threats to its biodiversity conservation (Lagabrielle et al., 2009). Islands vulnerability (Rietbergen *et al.,* 2007) associated with remoteness, isolation, smallness, and closed systems represent an additional challenge in scientific and technical terms for Planning and Management on small islands (Calado *et al.*, 2007; Calado *et al.,* 2013), including the SIDS (Small Island Developing States) and Ultra-Peripheral European Regions (UPER), such as the Azores archipelago in Portugal (Gil *et al.,* 2011; Gil *et al.,* 2012).

Protected areas (PA) are the basis of local, regional, and global strategies for the conservation of biodiversity (Gaston *et al.,* 2008; EEA, 2012). Conservation can be traced back almost as far as recorded history, however public awareness and the development of organizations to implement it has taken place within the last century (Green, 1996).

The concepts of conservation and protected areas have evolved significantly over time, reflecting the rules, attitudes and values of each generation (Mulongoy & Chape, 2004; Ervin *et al.,* 2010). First areas intended for conservation were in fact deemed to have significance for spiritual and religious reasons, and later when land was set aside for hunting reserves (EEA, 2012).

Conservation as we know it nowadays was only generally recognized in the latter half of the 19th century. The first real protected areas were declared in Germany in the 1820s (EEA, 2012) and the first “National Park” been created was the Yellowstone National Park in the United States in 1872 (Mulongoy & Chape, 2004). At that time protected areas were almost free of human influence, and were managed mainly for visitors and tourists, placing high value on wilderness and natural sceneries with little regard for the local communities (Phillips, 2003a). Societal benefits were mostly considered as incompatible with protected area objectives, compromising nature conservation and landscape protection (EEA, 2012).

During the Second World Conference on National Parks (held in 1972, in Yellowstone and Grand Teton national parks, USA) were adopted recommendations on what were the priorities for protected areas. Phillips (2003a) highlights the failure to address the connections between protected areas and questions of development in general, and between protected areas and the areas around them in particular.

However, by the 1970s, planners of protected areas began to acknowledge the importance of local communities, and started to address the need for more systematically and comprehensively designed networks of protected areas. Protected areas began to be viewed more as social enterprises to be managed also accordingly to the needs of local communities (EEA, 2012).

Currently, more than just protection of biodiversity is expected from protected areas. They are viewed as a critical component of a life support system, as nodes of environmental resilience, and a source of ecosystem services (EEA, 2012). And it is currently recognized that several ecosystems, some of them humanized, have high value and whose conservation depends on appropriated and/or human-induced management actions (Ervin *et al.,* 2010; Cruz *et al.,*, 2011).

Considering the specificities of islands, it is even more important to integrate both perspectives of conservation and development, and find a balance between objectives of both, especially in small islands. The small size and well defined boundaries difficult the connections with other territories, whether they are key connections for biodiversity preservation or key connections for human activities development. Mainland Planning Systems rely on these connections to face constraints and shortcomings. Islands Planning Systems don’t have that choice.

These tremendous challenges faced by Small Islands Protected Areas demand the highest possible levels of strategy, planning and activity programming. They further necessitate that managers proceed with the utmost transparency and rigor while sharing the responsibility of management in the search for the optimal utilization of human, technical, technological and financial resources of each of the strategic stakeholders (Gil *et al.,* 2011).

In order to ensure maximum effectiveness, and accomplish conservation and sustainable development objectives, planning and management systems of protected areas need to be adjusted to the specific context of small islands (Fonseca *et al.,* 2011). In what way should this adjustment be structured and operated is the central question of the SMARTPARKS Project.

The main objective of the SMARTPARKS Project – "Planning and Management System for Small Islands Protected Areas" was, therefore, the conceptual development of a planning and management system for protected areas in small islands. This system should consider the specificities of islands ecosystems, correcting and improving the insufficiencies and gaps of traditional planning systems. Moreover, it should be able to be integrated in the territorial management instruments in force and to be applied in other islands or archipelagos, but especially in small islands.

This article intends to present the SMARTPARKS Project, its rationale and main outcomes in order to contribute to management systems of protected areas in the Azores, as well as other small islands.

The SMARTPARKS Project (PTDC/AAC-AMB/098786/2008) was funded by the Fundação para a Ciência e a Tecnologia (FCT). The Project is already finished and is under final procedures from FCT. Although the Project is finished, its implementation in Pico Island depends on Regional Government Agencies, as well as the Natural Park Administration.

2. DEVELOPMENT OF THE SMARTPARKS PROJECT

2.1. Rationale of the SMARTPARKS

The rationale of the SMARTPARKS Project relies mainly on two approaches (Fonseca *et al.,* 2011): the so called "new paradigm" (Phillips, 2003b) of protected areas' classification, planning and management to the insular ecosystems' specificities, and the ecosystem approach (SCBD, 2004). That "new paradigm" focuses on the compatibility of conservation and human activities, and explicitly considers that human communities are part of ecosystems. This new perspective allows the emergence of new economic and cultural development opportunities within protected areas, such as ecotourism, integration of protected areas in conservation networks, their integration in territorial management systems, and the involvement of locals and stakeholders in achieving protected areas' objectives. The ecosystem approach considers the protected area as an integrating part not dissociable from the island's ecological structure and biophysical system (Vieira, 2007), reflecting the effects that planning policies and territorial management measures may have in the entire island. The combination of these approaches extends beyond the conservation strategy focused only on the protection of species or on the management of areas, habitats or hotspots. It integrates environmental components, as well as socio-economic, contributing to the sustainable development of the protected area and, ultimately, of the island as a whole (Fonseca *et al.,* 2011).

The Project developed its own mnemonic for the acronym "SMART" which tries to translate what is intended with this Project (Figure 1).

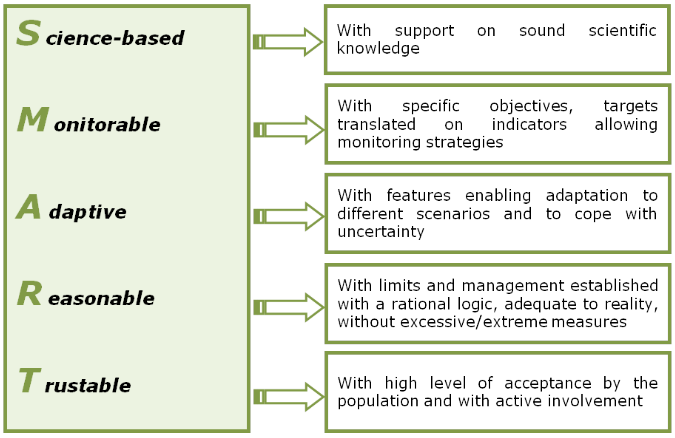

Figure 1. SMART Protected Areas mnemonic.
Figura 1. *Mnemónica de Áreas Protegidas "SMART".*

The development of the SMARTPARKS Project was based on the study, conception and methodological development of each of the following 5 tasks (which will be described below) for Island Parks:

(1) Island Park's Characterization, Assessment and Diagnosis;
(2) Island Park's Ecosystems Services Assessment and Valuation;
(3) Island Park's Land Planning;
(4) Island Park's Management and Monitoring Strategies;
(5) Environmental Strategic Assessment of Island Park´s Planning and Management System.

The various studies conducted on each task were applied and validated in Pico Island (the Azores, Portugal), chosen as the case study of the project.

Considering the basis of the Project and its objectives, Pico Island Park was chosen due to its percentage of classified area and diversity, and representativeness of protection categories. Pico Island Park is emblematic at the regional and national scale, not only due to its natural and ecological values but also due to the balance between nature and human use, well exemplified by the landscape of the Pico Island vineyards culture, a UNESCO World Heritage Site.

Due to its political and administrative autonomy from Portugal mainland, the Azorean Regional Government has authority to adapt national legislation to regional specific needs. The Azorean Government recognizes the importance of preserving the natural resources, as well as to accomplish with the international commitments undersigned by the

Portuguese Republic, and proceeded to the re-classification of its Protected Areas Network (Calado *et al.,* 2009). That re-classification complies with the IUCN Category System. In the Azores, this conceptual classification model is based on management criteria for each area. The competences to do it are concentrated in one management structure for each island (Calado *et al.,* 2009). This led to the creation of an Island Natural Park for each island, which comprises all the classification categories and considers the entire island as a territorial base unit for management (where each island's assemblage of PA represents an Island Natural Park).

2.2. The Azores Archipelago and Pico Island

The Azores Archipelago comprises nine volcanic islands distributed along 600km in the middle of the North Atlantic, circa 1500 km from Lisbon and 3900 km from the east coast of North America. The islands are divided into three groups: the Western Group (Flores and Corvo), the Central Group (Pico, Faial, São Jorge, Graciosa and Terceira) and the Eastern Group (São Miguel and Santa Maria) (Figure 2).

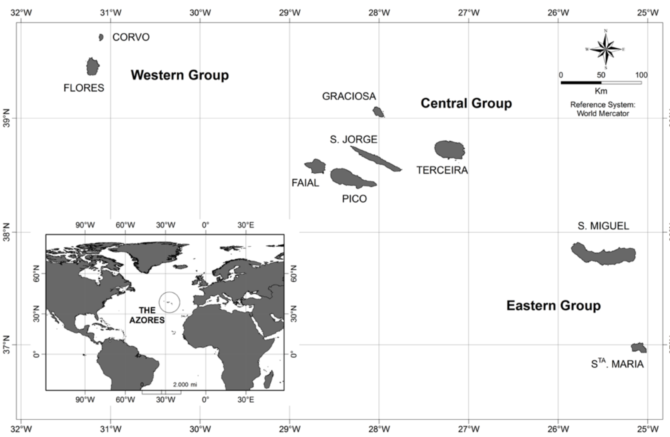

Figure 2. Azores archipelago.
Figure 2. *Arquipélago dos Açores.*

Along with Madeira archipelago (Portugal), Canary Islands (Spain) and Cape Verde, the Azores are part of the biogeographically region of Macaronesia, one of Europe's richest in terms of fungi, plants and animals. This ecoregion presents exceptional plant, animal and ecosystem endemisms (Petit & Prudent, 2010), namely associated with its typical Laurel forest, and high levels of vulnerability (Cardoso *et al.,* 2008).

The Azores is close to the triple junction of the American, Eurasian and African plates, and is subject to intense seismic activity (Cruz, 2003). Its exposed northern mid-Atlantic location, morphology and plate-tectonics setting make the Azores highly vulnerable to natural hazards, such as tsunamis associated with landslides and seismic or volcanic triggers (Andrade *et al.,* 2006).

Pico Island is the second largest and most recently formed island of the archipelago (Cruz & Silva, 2000), with 447km^2 area and 151.8km perimeter, between coordinates 38º22'57" and 38º33'44"N and 28º01'39" and 28º32'33"W (SRAM, 2008). It is regionally known as the "Mountain Island" due to its most striking feature: a volcanic mountain (Figure3), the highest mountain in Portugal, reaching an altitude of 2351m.

Pico's climate is classified as marine temperate (Cruz, 2003). This fact together with the island small size contributes to a small diversity of water resources and to watersheds of little dimension (usually less than 30km^2) (DROTRH/IA, 2001).

Pico Island is divided into three municipalities: São Roque do Pico, Madalena, and Lajes do Pico. This is essentially a rural territory with a population density of approximately 32.8inhab/km^2 (SREA, 2010). Similarly to the other Azorean islands, its geological, geomorphologic and climatic constraints, as well as its dependence on the sea as the most important communication route, are mainly responsible for the location of settlements, human activities and transportation infrastructures along the coastline (Porteiro *et al.,* 2005).

The current economy of the Archipelago is mainly based on a small domestic market, dependent on agriculture, cattle grazing, tourism and fisheries. Manufacturing relies mostly on primary products (mainly livestock, dairy and fish) and tourism is currently increasing both in terms of supply and demand.

The coastal zone of Pico is essentially covered by urban and agricultural areas, including the traditional viticulture area. The middle ring of the island is mostly covered by pasture mixed with semi-natural vegetation and significant presence of invasive and non-indigenous species. Higher areas are predominantly covered by pasture mixed with natural areas and a significant presence of endemic species.

Pico Island Natural Park includes 19 terrestrial protected areas and 3 marine protected areas. It is the largest Natural Park of the Azores comprising 156 km^2 of terrestrial surface, around 35% of the island territory, and 79 km^2 of marine area. Of its 22 protected areas, 4 are classified as nature reserve, 1 as natural monument, 8 as protected area for species/habitats management (mainly coastal areas), 6 as protected landscape and 3 as protected area for resources management (all marine areas) (Figure 3).

2.3. Tasks and Main Outcomes

Task 1. Island Park´s Characterization, Assessment and Diagnostic

In this task the aim was to develop a new diagnosis and characterization strategy for the Island Park, based on the collection, study and analysis of existing methodologies for characterization, mapping and evaluation of protected areas in islands. To achieve that, some studies were performed and their outcomes used as inputs in the following tasks.

Summary Tables:

- Setting specific objectives: Area of Pico Island Park.
- Preliminary analysis of the reasons for the classification,

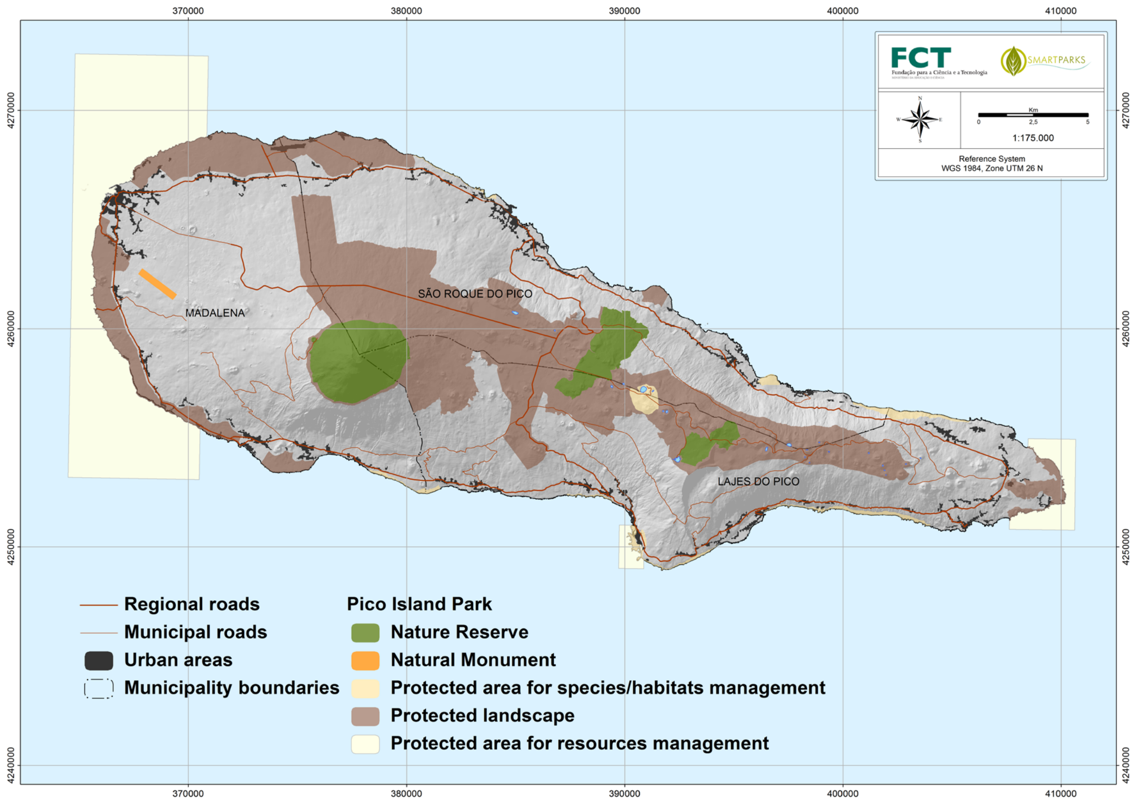

Figure 3. Pico Island Park (adapted from data provided by *Direcção Regional do Ambiente dos Açores*).
Figura 3. *Parque Natural de Ilha do Pico (adaptado de informação cedida pela* Direcção Regional do Ambiente dos Açores*).*

objectives and interdictions in the Protected Area of Pico Island Park.

- Characterization of the Natura 2000 Network on the Pico Island.

The main objectives of these studies were to develop a starting point and an overview of the current situation of Protected Areas included in the Island Park. Identifying gaps and trends allows developing a more suitable proposal of the planning and management system.

Technical Reports:

- Preliminary Coastal Vulnerability Assessment for Pico Island - the aim of this report was a preliminary analysis of the level of coastal vulnerability according to the Delphi method, in which 14 sites were observed considering the interactions between coastal dynamics, natural environment and developed anthropogenic activities.
- Land Cover Map of Pico Island 2008 through Photointerpretation - the main objective was to identify the main classes of land use on Pico Island and its Natural Park, weaving comparisons between them. This study also provided a base map that was available to other team members in order to develop work that needed mapping of occupation and land use.
- Relevant data and information for a comprehensive conservation planning in Small Islands - this study incorporates an analysis of the mapping data produced and adapted to the level required by the biophysical component (type of habitats, ecosystems, species richness and endemics entities, main pressures on the island biodiversity), anthropogenic (human history influences) and legislative (conservation policies with special attention to the concept of "Island Natural Park") for the entire Pico island.
- Assessment of Pico Island Park Biodiversity through the InVEST methodology - the main objective was the valuation of habitats and the identification of priority areas in terms of recovery and conservation, through the analysis of the quality of habitats and the level of degradation of these.
- Update of the Land Use Map 2013 - in applying the InVEST Biodiversity methodology a field work campaign was undertaken between September 1-6, 2013, to support the update of the Land Use Cartography. Its specific objectives were: (i) to define the study areas and to discuss the INVEST methodology through meetings with local technicians and experts from the Pico Island Natural Park and the Regional Directorate for Nature Conservation (DRCN); (ii) to validate and update the Land Use Map (v.2008) by obtaining GPS points for the classes in question (groundtruth), focusing on areas of bogs, and by identifying studied species and their respective habitats.
- Analysis and Evaluation of Pico Landscape - identification of main landscape values and weaknesses of protected

areas of lower and higher altitude, based on field work and on the results of surveys to the resident population and tourists.

- Analysis of the relationship between Pico Island Park and the Geopark - this study concluded that most of Pico geosites (priority or not) totally or partially match with areas of the Natural Park.
- Pico Island Socioeconomic Characterization - a key component of the project focused on the social and economic analysis of the Pico Island, in order to integrate both conservation and development approaches.
- Public Participation in Pico Island – Tourists Survey - this study aimed to gather information regarding the perceptions and expectations of the resident population and visitors to the Pico Island protected areas.
- Territorial Conflicts in Small Island Protected Areas: the case of Pico Island, Azores - Portugal - the main objectives of this analysis were: (i) identification of the background for conflicts emergence; (ii) characterization of the types of territorial conflicts; (iii) identification of conflicts locations; (iv) identification of the problems derived from the main instruments of spatial planning targeted towards nature conservation objectives; and (v) location of existing and potential territorial conflicts in the volcanic islands spatial organization model.
- Validation Proposal of the Pico Island Park Areas - contribution of predictive species distribution models – this study was developed in order to diagnose the probability of occurrence of the most relevant species in a conservationist point of view, subsequently evaluating if the areas of higher probability are within the limits of the Pico Island Park. This study supported the study on the valuation of biodiversity and also allowed to some considerations regarding areas potentially important for protected species outside protected areas.

Task 2. Island Park´s Ecosystems Services Assessment

Task 2 was designed to propose a new strategy for the Island Park's ecoservices assessment and valuation, based on the collection, study and analysis of existing methodologies for economic assessment and ecoservices valuation. This approach was intended to promote public awareness and participation and to support cost-benefit analysis of planning policies and management measures. Different studies were developed under this task.

Technical Reports:

- Economic Valuation - analysis tools - literature review exploring the different categories of values and methodologies available for their assessment and quantification.
- Multitemporal Analysis of the Environmental Value of Pico Island Natural Ecosystems - this study aimed to contribute to the analysis of the ecosystems economic valuation. It was carried out through: (i) analysis of land uses available in four different time periods (1999, 2005, 2007, and 2009); (ii) identification of land use modifications between these periods; (iii) correspondence between land use types found in the classification of the Pico Forest Inventory, GlobeCover and Corine Land Cover, and ecosystems identified by Costanza *et al.* (1998); (iv) estimate the economic value of natural ecosystems and land uses for these periods based on the values identified. This allowed the economic valuation of gains and losses resulting from land use changes.
- Ecosystem Function Identification and Spatialization in Pico Island - identification and spatialization of the major groups of ecosystem functions and analysis of whether or not the current boundaries of the protected areas correspond to the location of such functions.

Task 3. Island Park´s Land Planning

The information produced during the previous tasks was integrated and the need of a new territorial planning strategy for the Island Natural Park was assessed, taking into consideration the existing Planning Instruments and their legal framework under the Portuguese legal Framework.

Technical Reports:

- Pico Island Ecological Reserve - Analysis of the application of the National Ecological Reserve (NER) in the insular context of Azores Autonomous Region. This study was applied to Pico Island, integrating zoning and conflict analysis. The result was a proposal for delimitation of NER in the island.
- Island Ecological Structure: Pico Island - the aim of this study was to propose a network of green and natural spaces contributing to preserve values and functions of natural ecosystems that provide benefits to society. This ecological structure intends to contribute to harmonize local communities and the conservation of natural systems on which they depend.

Internship Report:

- Contribution of Territorial Management Instruments (TMI) for the Sustainability of Pico Island Park - this work comprised the following objectives: (i) to identify TMI in force on the Pico island; (ii) to identify the scope and specific objectives of each TMI; (iii) to identify overlapping between the intervention area of each instrument and the Natural Park; (iv) to evaluate the adequacy/compatibility between the ITM resolutions and the protected areas' management objectives.

Task 4. Island Park´s Management and Monitoring

In order to be able to design future monitoring programs it is necessary to understand the relationship between different scales and spaces. Therefore in this task a major theoretical discussion about this issue was produced in a technical report.

Technical Report:

- A multi - scale approach to conservation planning in Small Island Archipelagos: The Azores - this study suggests that planning and management in small islands are tested in three scales. The first, at the archipelago level, comprises the analysis regarding the weight of insularity and the limitations and implications for management. The second, at the level of the island groups (Eastern, Central and Western), analyzes the strengths and weaknesses of connectivity between islands of the same group (internal connectivity) and between groups (external connectivity), as well as the resulting environmental and socioeconomic impacts and potential vulnerabilities. And the third, at the island scale, with the case study of Pico Island, with the proposal to apply the model of "volcanic islands" as the basis for monitoring actions and measures implemented.

Task 5. Environmental Strategic Assessment of Island Park´s Planning and Management System

In this final task a proposal for the Strategic Environmental Assessment (SEA) of the Island Park´s Planning and Management System was designed, introducing a new tool in SEA, the Functional Analysis.

Technical Report:

- Functional Analysis and Strategic Environmental Assessment of the Pico Island Park – Functional Analysis method (adapted from Cendero & Fischer, 1997) is able to integrate all the information produced during the Project and provide valuable directions for management and decision-making. It identifies a series of characteristics which can be used to describe environmental, as well as socio-economic, components using different indicators. Numerical indices can be used to assess different qualities on the basis of these indicators. A "conservation *versus* development" diagram (such as Figure 4) is used as a tool to help identify and assess planning conflicts. This diagram is also an easy way to visualize and to help determine if environmental quality in a particular area is decreasing or increasing and, consequently, if the existing management and policy trends are moving away or towards sustainability.
  The main objective of this analysis was to evaluate each area of the Natural Park, in terms of its potential for both conservation and development objectives (since most areas have direct and indirect use by residents and tourists, as demonstrated by the studies on the previous tasks).
  Figure 4 exemplifies the diagram produced during the Functional Analysis, here applied to the 22 protected areas comprised in Pico Natural Park. Each protected area is identified in the diagram with a number[1]. The x-axis and the y-axis represent respectively the status of potential for development and conservation value. When both statuses have low values the protected area is under low conflicts. When both statuses have high values the protected area is under high conflicts between development and conservation objectives.
  Through this tool, the several protected areas were evaluated and compared in terms of their potential for development and of their conservation value (Figure 4), considering ecological (e.g. conservation status and pressures on protected areas, water and climate regulation) and socioeconomic (e.g. goods and benefits from primary sectors, tourism and recreation) parameters properly weighted according to their importance for the objectives of conservation and/or development.

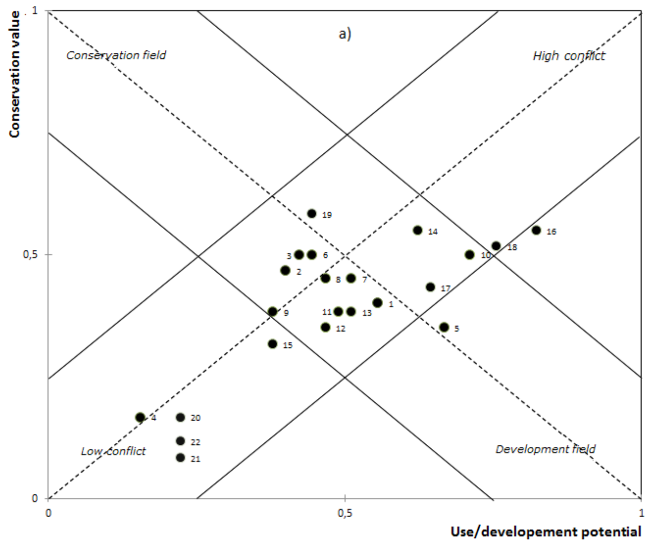

Figure 4. Functional Analysis for Pico Protected Areas.
Figura 4. *Análise functional das Áreas Protegidas do Pico.*

3. DISCUSSION AND CONCLUSION

The SMARTPARKS Project attempted the conceptual development of a planning and management system for protected areas in small islands, integrating nature conservation and human activities, as well as a sound balance between them.

This project allowed an extensive information collection about Pico Island. This will be useful also for further studies in the island.

1 - 1-Nature Reserve of Montanha do Pico; 2-Nature Reserve of Caveiro; 3-Nature Reserve of Mistério da Prainha; 4-Nature Reserve of Furnas de Santo António; 5-Natural Monument of Gruta das Torres; 6-Protected area for species/habitats management of Lagoa do Caiado; 7-Protected area for species/habitats management of Lajes do Pico; 8-Protected area for species/habitats management das Furnas de Santo António; 9-Protected area for species/habitats management of Silveira; 10-Protected area for species/habitats management of Mistério de São João; 11-Protected area for species/habitats management da Terra Alta; 12-Protected area for species/habitats management of Ribeiras; 13-Protected area for species/habitats management of Zona do Morro; 14-Protected landscape of Cultura da Vinha - Ponta da Ilha; 15-Protected landscape of Cultura da Vinha - Ponta do Mistério; 16-Protected landscape of Cultura da Vinha - Zona Norte; 17-Protected landscape of Cultura da Vinha - São Mateus/São Caetano; 18-Protected landscape of Cultura da Vinha - Zona Oeste; 19-Protected landscape of Cultura da Vinha of Central Zone; 20-Protected area for resources management of Porto das Lajes; 21-Protected area for resources management of Ponta da Ilha; 22-Protected area for resources management of Faial-Pico channel.

Each developed task came out with interesting reports, some of them with new questions and opportunities for further research studies.

One of the major outcomes of the Project was the Functional Analysis tool applied to Protected Areas management, developed during Task 5.

The functional analysis applied as a technique for monitoring the 22 protected areas of the Pico Island Natural Park, proved to be a versatile tool. Land Use and Planning Systems in Portugal and the Azores are based on "land laws" instruments and therefore presenting rigid and static rules. In this sense, Functional Analysis may help by providing a dynamic follow up in a rigid system.

Marine protected areas (identified in Figure 4 with the numbers 20, 21, and 22) present low values for both conservation and development potential. This occurred because they lacked basic information for some indicators and a smaller number of indicators was used for these protected areas, resulting on their position in the "low conflict" area of the diagram. Future works on evaluation will determine this balance between conservation and development in protected areas by improving new basic information.

The SMARTPARKS Project shows the central need of multidisciplinarity and of joining scientific know-how with practical experience.

The innovative methodology developed by SMARTPARKS Project was based on several strategic assumptions that we consider being of core importance when planning and managing small islands protected areas:

- "Small Islands" are unique and particular ecosystems whose management requires specific approaches and methodologies;
- Association and integration of the planning and management of the Protected Areas Network into the planning and management of the whole island, following a predominantly ecosystem approach (CBD, 2004) that considers the Protected Area as intrinsic and inseparable part of the Island's Ecological Structure and its Biophysical System, reflecting the direct and indirect effects of the planning policies and territorial management measures applied to the entire island;
- Adoption of the so-called "new paradigm" (Phillips, 2003) that focuses on the compatibility of conservation and human activities, encouraging the development of new economic and cultural opportunities associated to the protected areas, their full integration in territorial management systems, and also the synergetic engagement of stakeholders and local population in achieving those same objectives;
- Reinforcement of protected areas' effectiveness regarding the associated nature conservation and biodiversity maintenance objectives, as well as the introduction of assessment methods for this effectiveness (Hockings *et al.*, 2005) among which the "gap analysis" (Langhammer *et al.*, 2007), by identifying their strengths, weaknesses, and solutions;
- Integration, within the planning policies and management measures to be implemented, of mitigation strategies and strategies to fight the greatest threats hanging over small island ecosystems (CBD, 2009): climate change and variability, proliferation of invasive exotic species, accelerated growth of touristic activity, natural catastrophes, overexploitation of natural resources, pollution and waste management;
- Integration of the "geodiversity" concept and the need to promote and ensure "geoconservation" in the planning and management policies of protected areas (Lima, 2007);
- Integration and promotion of public engagement in all stages of the Planning and Management System of Protected Areas on Small Islands;
- Integration of the economic assessment and valuation concept of services rendered by the ecosystems (ecoservices) to support the promotion of stakeholder involvement and public engagement, as well as to support the cost-benefit analysis regarding planning.

The outcomes of this Project, although valuable on future management and planning actions, should be validated by further application in the other Island Parks of the Azores. Also, a specific approach for marine/coastal areas should be tailored and built upon SMARTPARKS achievements.

REFERENCES

Andrade, C.; Borges, P.; Freitas, M.C. (2006) - Historical tsunami in the Azores archipelago (Portugal). *Journal of Volcanology and Geothermal Research*, 156(1-2):172-185. DOI: 10.1016/j.jvolgeores.2006.03.014

Calado, H.; Braga, A.; Moniz, F.; Gil, A.; Vergílio, M. (2013) - Spatial planning and resource use in the Azores. *Mitigation and Adaptation Strategies for Global Change*, First Published on-line in November 2013. DOI: 10.1007/s11027-013-9519-2

Calado, H.; Lopes, C.; Porteiro, J.; Paramio, L.; Monteiro, P. (2009) - Legal and Technical Framework of Azorean Protected Areas. *Journal of Coastal Research* (ISSN: 0749-0208), SI56:1179-1183. Available on-line at http://www.jstor.org/stable/25737973

Calado, H.; Quintela, A.; Porteiro, J. (2007) - Integrated Coastal Zone Management Strategies on Small Islands. *Journal of Coastal Research* (ISSN: 0749-0208), SI50:125-129, ICS2007 (Proceedings), Australia. Available on-line at http://www.redmic.es/bibliografia/Docum_03049.pdf

Cardoso, P.; Borges, P.A.V.; Costa, A.C.; Tristão da Cunha, R.; Gabriel, R.; Martins, A.M.F.; Silva, L.; Homem, N.; Martins, M.; Rodrigues, P.; Martins, B.; Mendonça, E. (2008) - A perspectiva arquipelágica: Açores. *In:* J. L. Martin; M. Arechavaleta; P. A. V. Borges; B. Faria (org.), *Top 100. Las 100 especies amenazadas prioritarias de gestión en la región europea biogeográfica de la Macaronesia*, pp. 421-449, Consejería de Medio Ambiente y Ordenación Territorial, Gobierno de Canarias, Spain. ISBN: 8489729387. Available on-line at https://repositorio.uac.pt/handle/10400.3/1962

Cendrero, A.; Fischer, D. (1997) - A Procedure for Assessing the Environment Quality of Coastal Areas for Planning and Management. *Journal of Coastal Research* (ISSN: 0749-0208), 13(3):732-744. Article Stable URL: http://www.jstor.org/stable/4298668

Costanza, R.; d'Arge, R.; de Groot, R.; Farber, S.; Grasso, M.; Hannon, B.; Limburg, K.; Naeem, S.; O'Neill, R.V.; Paruelo, J.; Raskin, R.G.; Sutton, P.; van den Belt, M. (1998) - The value of the world's ecosystem services and natural capital. *Ecological economics*, 25(1):3-15. DOI: 10.1016/S0921-8009(98)00020-2

Cruz, A.; Benedicto, J.; Gil, A. (2011) - Socio-economic Benefits of Natura 2000 in Azores Islands – a Case Study approach on the ecosystem services provided by a Special Protected Area. *Journal of Coastal Research* (ISSN: 0749-0208), SI64:1955-1959, ICS2011 (Proceedings), Polonia. Available on-line at http://cita.angra.uac.pt/ficheiros/publicacoes/1322865720.pdf

Cruz, J.V. (2003) - Groundwater and volcanoes: examples from the Azores archipelago. *Environmental Geology*, *44*(3):343-355. DOI: 10.1007/s00254-003-0769-2

Cruz, J.V.; Silva, M.O. (2000) - Groundwater salinization in Pico Island (Azores, Portugal): origin and mechanisms. *Environmental Geology*, 39(10):1181-1189. DOI: 10.1007/s002540000109

DROTRH; IA (2001) - *Plano Regional da Água - Relatório Técnico - Versão para Consulta Pública*. 414p., Ed. Secretaria Regional do Ambiente, Direcção Regional do Ordenamento do Território e dos Recursos Hídricos, Ponta Delgada, Portugal. Available on-line at http://portaldaagua.inag.pt/PT/InfoTecnica/PGA/PRPlaneamento/Documents/relatorio_PRA.pdf

EEA (2012) - *Protected Areas in Europe — an overview*. 131p., European Environment Agency, Copenhagen, Denmark. ISBN: ISBN: 978-9292133290. DOI: 10.2800/55955

Ervin, J.; Sekhran, N.; Dinu, A.; Gidda, S.; Vergeichik, M.; Mee, J. (2010) - *Protected Areas for the 21 st Century: Lessons from UNDP/GEF's Portfolio*. 132p., United Nations Development Programme, Montreal, Canada, Convention on Biological Diversity, New York, USA. ISBN: 9292252747. Available on-line at https://www.cbd.int/cms/ui/forums/attachment.aspx?id=89

Fonseca, C.; Calado, H.; Silva, C.P.; Gil, A. (2011) - New approaches to environment conservation and sustainability in small islands: the project SMARTPARKS. *Journal of Coastal Research* (ISSN: 0749-0208), SI64:1970–1974, ICS2011 (Proceedings), Poland. Available on-line at http://cita.angra.uac.pt/ficheiros/publicacoes/1322869324.pdf

Gaston, K. J.; Jackson, S. F.; Cantú-Salazar, L.; Cruz-Piñón, G. (2008) - The Ecological Performance of Protected Areas. *Annual Review of Ecology, Evolution, and Systematics*, 39:93-113. DOI: 10.1146/annurev.ecolsys.39.110707.173529

Gil, A.; Fonseca, C.; Lobo, A.; Calado, H. (2012) - Linking GMES Space Component to the development of land policies in Outermost Regions - the Azores (Portugal) case-study. *European Journal of Remote Sensing*, 45:263-281. DOI: 10.5721/EuJRS20124524

Gil, A.; Calado, H.; Bentz, J. (2011) - Public participation in municipal transport planning processes – the case of the Sustainable Mobility Plan of Ponta Delgada, Azores, Portugal. *Journal of Transport Geography*, 19(6):1309-1319. DOI: 10.1016/j.jtrangeo.2011.06.010

Gil, A.; Calado, H.; Costa, L.T.; Bentz, J.; Fonseca, C.; Lobo, A.; Vergilio, M.; Benedicto, J. (2011) - A Methodological Proposal for the Development of Natura 2000 Sites Management Plans. *Journal of Coastal Research* (ISSN: 0749-0208), SI64:1326-1330, ICS2011 (Proceedings), Poland. Available on-line at http://cita.angra.uac.pt/ficheiros/publicacoes/1322869287.pdf

Green, B. (1996) - *Countryside Conservation – Landscape ecology, planning and management* (3rd Ed.). 359p., Spon, E & FN, London, U.K.. ISBN: 0419218807

Hockings, M.; Stolton, S.; Leverington, F.; Dudley, N.; Courrau, J. (2006) - *Evaluating Effectiveness: a framework for assessing management effectiveness of protected areas*, 2nd edition. 105p., IUCN, Gland, Switzerland and Cambridge, UK. ISBN: 2-8317-0546-0. Available on-line at https://portals.iucn.org/library/efiles/edocs/PAG-006.pdf

Lagabrielle, E.; Rouget, M.; Payet, K.; Wistebaar, N.; Durieux, L.; Baret, S.; Lombard, A.; Strasberg, D. (2009) - Identifying and mapping biodiversity processes for conservation planning in islands: A case study in Réunion Island (Western Indian Ocean). *Biological Conservation*, 142(7):1523-1535. DOI: 10.1016/j.biocon.2009.02.022

Langhammer, P.; Bakarr, M.; Bennun, L.; Brooks, T.; Clay, R.; Darwall, W.; Silva, N.; Edgar, G.; Eken, G.; Fishpool, L.; Fonseca, G.; Foster, M.; Knox, D.; Matiku, P.; Radford, E.; Rodrigues, A.; Salaman, P.; Sechrest, W.; Tordoff, A. (2007) - *Identification and Gap Analysis of Key Biodiversity Areas: Targets for Comprehensive Protected Area Systems*. 116p., IUCN, Gland, Switzerland. Available on-line at http://www.iucn.org/dbtw-wpd/edocs/PAG-015.pdf

Lima E.A. (2007) - *Património Geológico dos Açores: valorização de locais com interesse geológico das áreas ambientais, contributo para o ordenamento do território*. 108 p., MSc Thesis, Departamento de Biologia, Universidade dos Açores, Ponta Delgada, Portugal. *Unpublished*.

Mulongoy, K.J.; Chape, S. (2004) - *Protected areas and biodiversity: An overview of key issues*. 52p., CBD Secretariat, Montreal, Canada and UNEP-WCMC, Cambridge, UK. ISBN: 9280424045. Available on-line at https://archive.org/details/protectedareasbi04mulo

Petit, J.; Prudent, G. (2010) - *Climate Change and Biodiversity in the European Union Overseas Entities*. 192p., IUCN, Gland, Switzerland / Brussels, Belgium. ISBN: 978-2831713151. Available on-line at https://portals.iucn.org/library/efiles/edocs/2010-064.pdf

Phillips, A. (2003a) - Turning ideas on their head – the new paradigm for Protected Areas. *The George Wright Forum* (ISSN: 0732-4715), 20(2):8-32, Hancock, MI, U.S.A. Available on-line at https://www.uvm.edu/conservationlectures/turning.pdf

Phillips, A. (2003b) - Un paradigma moderno. *Conservación Mundial*, 34(2):6-7. Available on-line at http://cmsdata.iucn.org/downloads/vth_iucn_es.pdf

Rietbergen, S.; Hammond, T.; Sayegh, C.; Hesselink F.; Mooney, K. (2007) - *Island voices – island choices: Developing strategies for living with rapid ecosystem change* *in small islands*. 43p., IUCN, Gland, Switzerland. Available on-line at https://portals.iucn.org/library/efiles/edocs/CEM-006.pdf

Saffache, P.; Angelelli, P. (2010) – Integrated coastal zone management in small islands: A comparative outline of some islands of the Lesser Antilles. *Revista de Gestão Costeira Integrada / Journal of Integrated Coastal Zone Management*, 10(3):255-279. DOI: 10.5894/rgci228

SCBD (2004) - *The Ecosystem Approach - CBD Guidelines*. 53p., Secretariat of the Convention on Biological Diversity, Montreal, Canada. ISBN: 929225023x. Available on-line at https://www.cbd.int/doc/publications/ea-text-en.pdf

SRAM (2008) - *Plano de Ordenamento das Bacias Hidrográficas das Lagoas do Caiado, Capitão, Paul, Peixinho e Rosada – Fase A – Caracterização/Diagnóstico Prospectivo*. Secretaria Regional do Ambiente e do Mar da Região Autónoma dos Açores, Ponta Delgada, Portugal. *Unpublished*.

SREA (2010) - *Séries Estatísticas 1998-2008*. Serviço Regional de Estatística dos Açores, Ponta Delgada, Portugal. Available on-line at http://estatistica.azores.gov.pt/Conteudos/Relatorios/lista_relatorios.aspx?idc=392&idsc=2641&lang_id=1

Vieira, C.P. (2007) - *Estrutura ecológica em ilhas : o caso de S. Miguel.* 116 pp., MSc Thesis, Departamento de Biologia, Universidade dos Açores, Ponta Delgada, Portugal. Available on-line at https://repositorio.uac.pt/handle/10400.3/303