

# CONSERVATION STATUS OF THE AZOREAN LAVA TUBES AND PITS

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## ABSTRACT

The conservation status of the diverse vulcanospeleological patrimony of the Azores is the main subject of this paper. The lava tubes and volcanic pits from the Azores are being exposed to several types of disturbance, some of them with destructive effects. Unique geological structures and some cavernicolous endemic arthropods are enough justification to establish severe measures of conservation for such patrimony. This work focuses on the types of disturbance over the Azorean volcanic cavities and their fauna and possible ways of conservation. The main types of disturbance are: deforestation, pasture management, «cattle graveyard effect», touristic activities, water management and industrial and domestic waste.

## SUMÁRIO

Este trabalho tem como principal objectivo estabelecer o ponto da situação sobre o estado de conservação do património vulcanoespeleológico dos Açores. Os tubos de lava e algares vulcânicos destas ilhas têm sido sujeitos a vários tipos de distúrbios, alguns dos quais com efeitos destrutivos. A presença de estruturas geológicas únicas e de grande valor patrimonial assim como a ocorrência de artrópodes cavernícolas endémicos, constituem justificações suficientes para que se estabeleçam medidas de protecção rigorosas e severas. Este trabalho sumariza os tipos de distúrbios a que têm estado sujeitas as cavidades vulcânicas Açoreanas, indicando algumas soluções para medidas de conservação. Os principais tipos de distúrbio são os seguintes: deflorestação, manejo das pastagens, uso das cavidades como cemitério de gado bovino, visitação, manejo da água e lixo domésticos e industriais.

## 1. INTRODUCTION

The diverse vulcanospeleological patrimony of the Azores, so rich that we have yet to identify most of them, is the main subject of this paper.

Even the smallest islet of the archipelago is a potential place to find a volcanic or other type of cave. Good examples of it are the Gruta Brisa Azul at the Ilhéu das Cabras (near Terceira) and the Gruta do Romeiro in the Ilhéu do Romeiro at S. Lourenço (near St. Maria).

In recent times we are watching a noticeable rise in interest, among the people in general and the politicians in particular, in aspects related with the conservation and the natural patrimony. The recent accumulation of data about the Azorean lava tubes and pits (see Borges *et al.*, 1992, 1993 and 1994; Borges & Silva, 1994; Constância *et al.*, 1994; Nunes & Braga, 1992) give us an excellent opportunity to develop strategies of conservation and public education. The environmentalist approach should be complemented by a scientific advising in order to strength potential conservation measures.

The lava tubes and volcanic pits from the Azores are being exposed to several types of disturbance, some of them with destructive effects. Unique geological structures and some cavernicolous endemic arthropods are enough reason to establish severe measures of conservation for such patrimony.

This work focuses on the types of disturbance over the Azorean volcanic cavities and their fauna and possible ways of conservation.

## 2. THE HISTORY

### 2.1. THE CAVES

All the Azorean islands are of volcanic origin and therefore lava tubes and volcanic pits are common, mainly in the more recent islands, or in the recent parts of the older islands. Fig. 1 shows the location of the Azorean archipelago as well as the location in the islands of the volcanic cave hotspot areas based on the checklists recently published (Borges *et al.*, 1993 and 1994; Nunes & Braga, 1992).

Examples of recent volcanism are common throughout most islands. Historical eruptions with their impressive lava flows and lava tubes are of great importance, holding a huge diversity of geological structures and fauna. The caves and fauna of today are a result of many events that occurred during the last 20 million years (Constância *et al.*, 1994), and therefore should be carefully managed.

As a consequence we have now listed in the Azores 101 lava tubes and 27 pits (Borges *et al.*, 1993), but these numbers are still far from the reality. There are also more six (6) littoral caves and sixteen (16) other type of cavities referred. According to their occurrence in the islands of the archipelago, Borges *et al.* (1993) listed the following numbers of lava tubes, volcanic pits, littoral caves and other caves: Corvo (1; 0; 0; 0), Flores (0; 0; 0; 0), Faial (3; 1; 0; 0), Pico (28; 8; 0; 0), Graciosa (18; 2; 0; 0), S. Jorge (7; 5; 0; 0), Terceira (29; 8; 4; 9), S. Miguel (15; 3; 0; 6) and S. Maria (0; 0; 2; 1). However, Garcia (pers. comm.) referred for Pico almost 100 lava tubes and volcanic pits. Fig. 2 shows the distribution of the numbers of lava tubes and pits known to occur in the Azorean islands. It should be noted the absence of volcanic caves in S. Maria and Flores, two older islands. In S. Miguel all the caves occur in the recent part of the island.

As it should be expected, geological age is a good predictor of the number of volcanic cavities in the Azorean islands (Fig. 3). In fact, the regression model showed in Fig. 3 is consistent with the idea that younger islands have large numbers of lava tubes and pits ( $r = 0.68$ ,  $p << 0.05$ ). S. Miguel and Terceira behave as outliers for two different reasons. In spite of the Northeast part of S. Miguel be the second older island of the Azores, great part of the island has a recent age, and Terceira is probably the best surveyed island from the archipelago having also very recent areas in contrast with older ones.

### 2.2. THE FAUNA

The fauna was recently reviewed and listed by Borges & Oromí (1994). A total of 16 species of cavernicolous arthropods are known, most of them endemics to some caves or cave systems in one island. Fig. 4 shows the distribution of the number of cave arthropods by the nine Azorean islands. The islands of the Central group are hotspots in cavernicolous fauna, being Terceira and Pico the most rich islands. The regression model that best fitted the distribution showed in Fig. 4, was a log-log model between the number of cavernicole species and the number of volcanic cavities in the islands ( $r = 0.86$ ,  $p << 0.01$ ) (Fig. 5).

In spite the fact that some species show evidences of rarity (*e.g.*, the Cixiid species usually limited by their food resource, the roots of a particular tree species), some others appears to be largely distributed in the subterranean environment of the islands. This is the case of some *Trechus* species. Recently, Franz (1995) published an interesting work about the two species of *Trechus* from Pico and enlarged the known distribution of *Trechus montanheirorum* Oromí & Borges. This species was originally described from Gruta dos Montanheiros and referred as very rare because of his occurrence only near a skylight (Borges & Oromí, 1991), but now is also known from Furna do Frei Matias and Gruta dos Vimes, both lava tubes (Franz, 1995). Another example of wide distribution within an island is the case of *Trechus terceiranus* Machado (Terceira), where is known from several caves and also from the Mesocavernous Shallow Stratum - M.S.S. (Borges, 1993). The other *Trechus* from Pico, *Trechus picoensis* Machado, has also a large distribution having been referred from 13 lava tubes (Franz, 1995; Oromí & Borges, 1991).

Nonetheless, not all species are common or/and abundant and measures of protection should be carefully studied (see below).

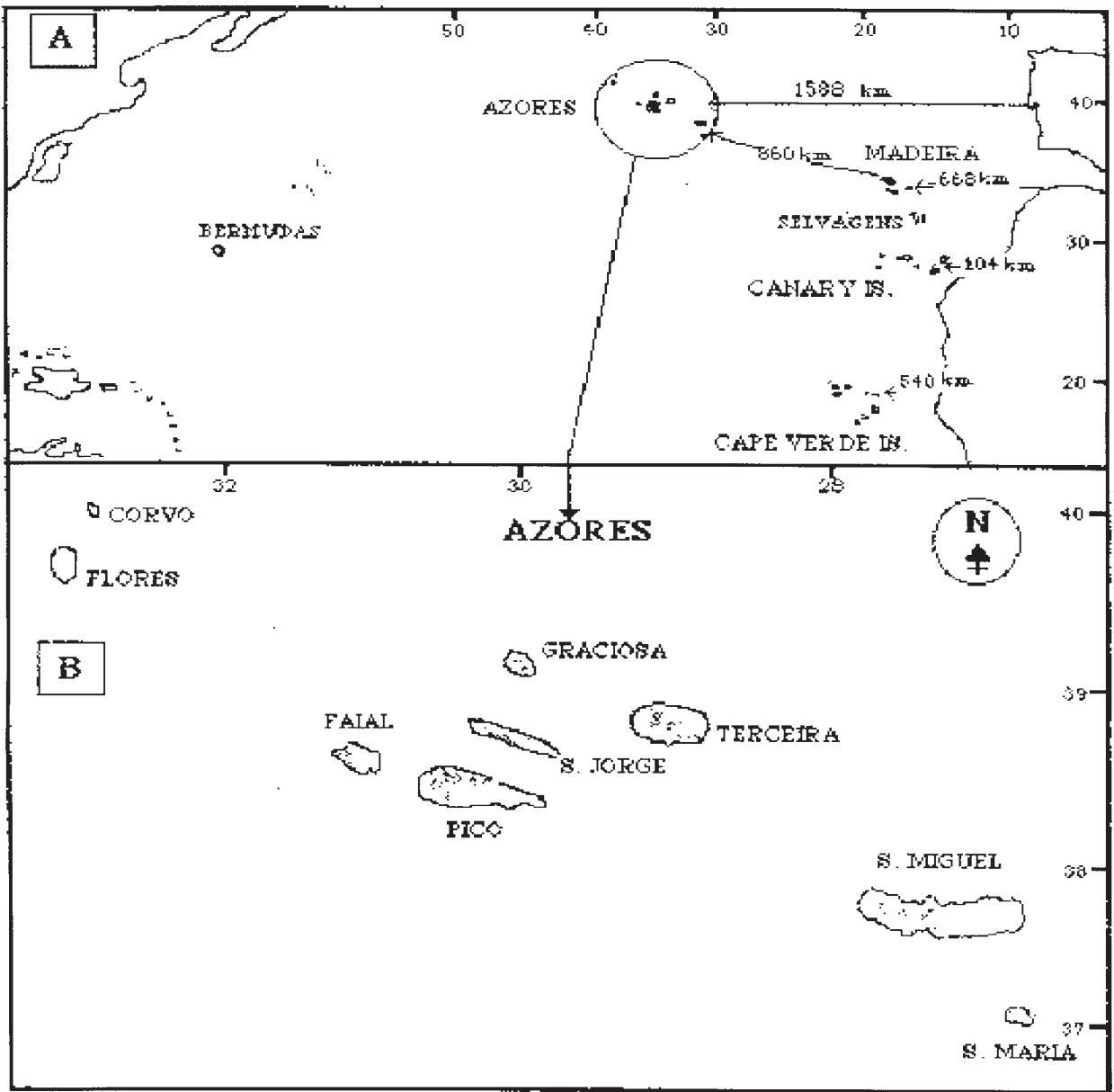


Figure 1. Map of the region where the work was carried out, showing the Macaronesian region (A) and the nine islands of the Azores (B). In B, the main location of lava tubes and volcanic pits is presented for each island giving an idea of the hotspot areas.

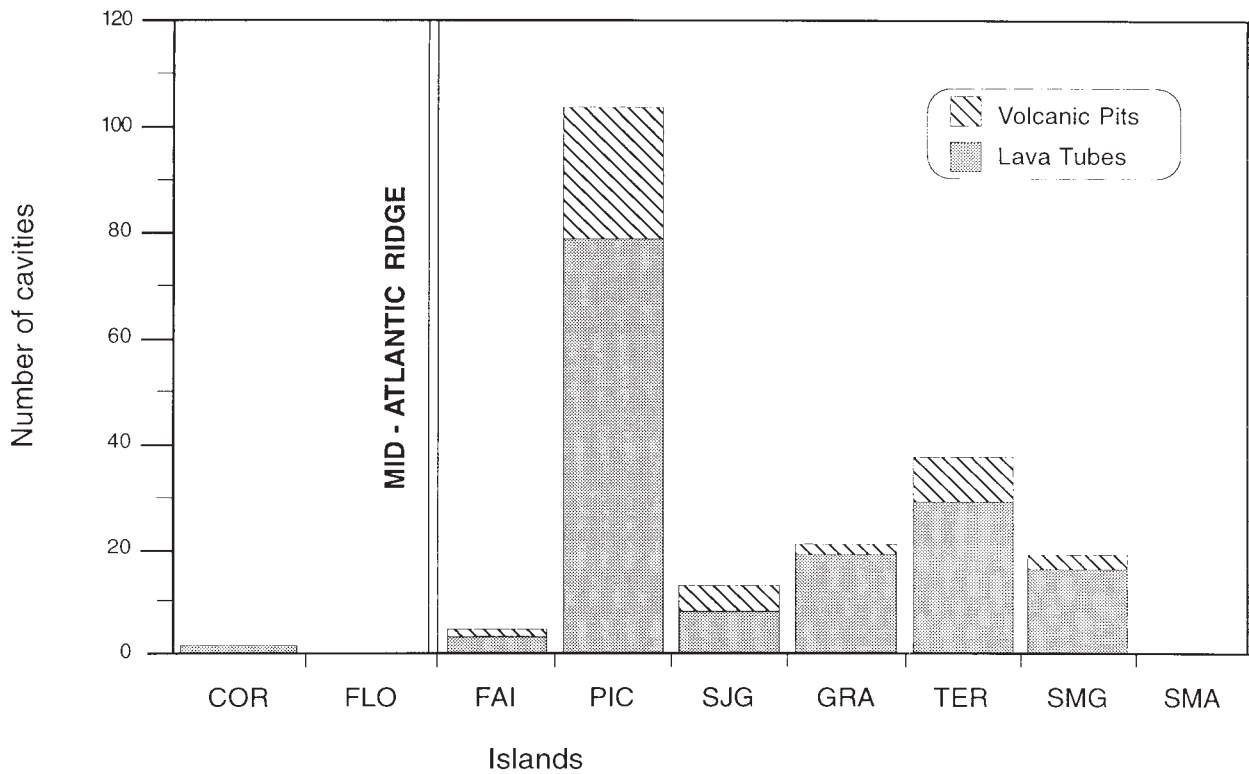


Figure 2. Numbers of lava tubes and volcanic pits referred for the Azorean islands. Data extracted from Borges *et al.* (1993) and Garcia (pers. comm.). COR= Corvo; FLO= Flores; FAI= Faial; PIC= Pico; SJG= São Jorge; GRA= Graciosa; TER= Terceira; SMG= São Miguel; SMA= Santa Maria.

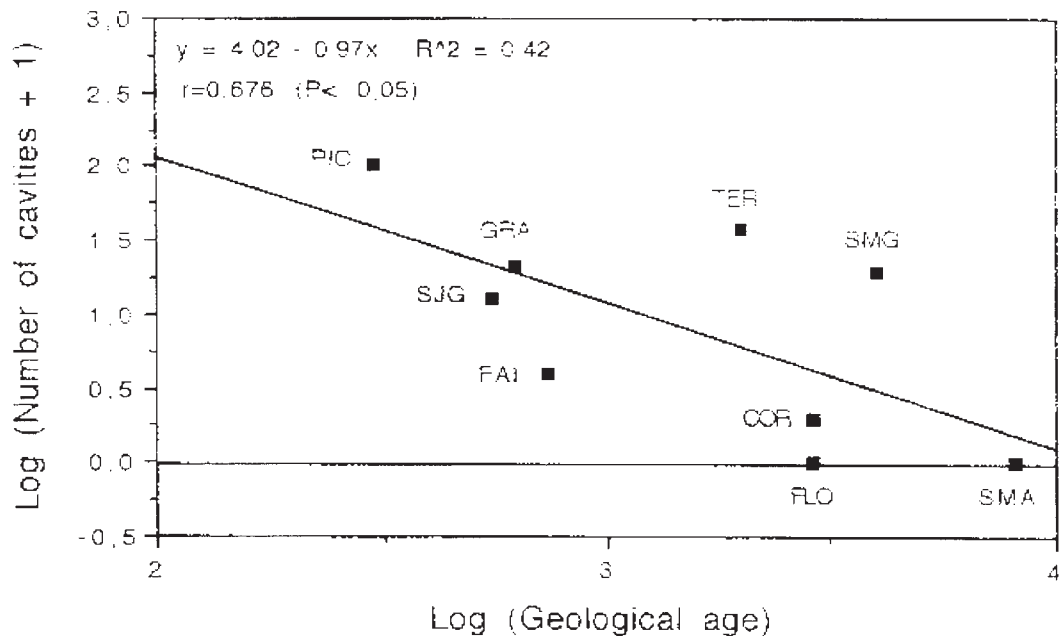


Figure 3. Linear regression between log number of cavities + 1 and log geological age of the islands. COR= Corvo; FLO= Flores; FAI= Faial; PIC= Pico; SJG= São Jorge; GRA= Graciosa; TER= Terceira; SMG= São Miguel; SMA= Santa Maria.

### 3. TYPES OF DISTURBANCE IN THE AZOREAN LAVA TUBES AND PITS.

#### 3.1. THE EARLY HUMAN ACTIVITIES.

After being colonized by the Portuguese in the mid 15th century, all the Azorean islands suffered major changes in their landscape as a consequence of human activities. Most probably, with the massive destruction of the natural forests and land management for agriculture some cave entrances were obstructed. However, the human impact on the cave structures themselves was probably of minor importance when comparing with the more recent examples of human dilapidation of the speleological patrimony. Thus, we may affirm that the main consequence of these early human disturbances was the closure of some caves. The known most remarkable examples are a lava tube from Corvo, the Furna do Moreno (Graciosa) and the Gruta do Fouqué (Terceira), the two former ones of large dimensions.

Other impacts were, for instance, the use of some caves for storing wine in Pico with the partial disruption of parts of the caves (*e.g.*, several lava tubes in Bandeiras, Pico).

#### 3.2. THE RECENT HUMAN ACTIVITIES

##### 3.2.1. Deforestation for pasture land using Caterpillars

This is probably the more disastrous recent disturbance on the Azorean lava tubes and pits. In fact, in Pico island, the most richest island in volcanic cavities, in the last ten years an unknown number of small and large lava tubes and pits were partially or completely destroyed for the creation of better pastures for dairy-cattle and beef-cattle. One of the most remarkable examples was the partial destruction of interesting parts of Gruta do Frei Matias.

On the other hand, such activities led also to the discovery of some unknown lava tubes and pits. In 1990 we had the opportunity of visit for the first time the actual largest lava tube from the Azores, the Gruta das Torres with 4 300 m, after a caterpillar driver had mentioned the discovery of a large entrance for a huge lava tube.

More recently one skylight of the Furna Frei Matias was destroyed by a caterpillar tractor. Fortunately we were able to stop the works and the other entrances are still intact.

##### 3.2.2. Pasture management

The pasture land is the main economic agriculture exploration in the Azores. Pasture is currently the dominant vegetation in this volcanic archipelago: in 1985 the estimated area of arable land in the Azores was 65,3 % of the total area of the archipelago; from that, 67,7% is good grazing land used for milk production. However, there is also poor arable land (mainly the high altitude semi-natural pasture) that reaches 11,2% of the total area. Therefore, some activities like new roads and construction of protections in the skylights and pits changed the original characteristics of some caves and pits.

In some cases, like in Pico, if the option is walls of volcanic rock protecting the skylights and pits, then a special vegetation and environment is created with conservation of the overall system. In other cases, if the hole is filled with large rocks and soil debris then the result is the obstruction of parts of lava tubes or destruction of pits.

In Pico we have two recent interesting examples: in one case an interesting part of Furna do Frei Matias was obstructed for the construction of a better pasture; in another case the French Speleological Expedition that recently visited the Azores (July-August 1994) discovered more 300 m in the largest lava tube of the Azores, Gruta das Torres, after taking out some rocks and debris in the North extreme of the cave.

##### 3.2.3. Construction and urbanization

The construction of houses and roads also caused several cave destructions: a lava tube near Gruta das Agulhas (Terceira); one lava tube in S. Miguel (Braga, pers. comm.). The Gruta do Henrique Maciel in Pico was completely obstructed at middle for the construction of the supports of an Hospital.

#### 3.2.4. Animal graveyard

This is one of the commonest disturbances in the Azorean cave entrances, skylights and pits. In Pico and S. Miguel the farmers tend to use the caves as graveyards for dead animals, not only small animals like dogs and cats but also large cows. This is mainly a problem of civic education that can be solved with some well planned sessions or posters of education for the environment.

#### 3.2.5. Touristic activities (visitation)

In Terceira there is a tradition of visiting lava tubes since long time. As a consequence of that large amounts of picnic meals debris can be found in some caves like Gruta dos Balcões, Gruta do Natal, Gruta do Coelho and Gruta das Agulhas. Among the consequences of such activities we may say that the destruction of geological structures is common and the destruction of roots may have as a consequence the starvation of cixiid planthopper nymphs.

Moreover, the carbide and batteries left in caves by visitors may be a threat for cave life.

#### 3.2.6. Water management

Water impoundments with alteration of ground water flow occurred in several caves from Terceira and also S. Miguel. In Terceira several lava tubes in the Cabrito area were modified or adapted for such purposes and Gruta do Camelo was completely destroyed.

#### 3.2.7. Industrial waste

Pollution from waste water occurred in the largest cave from S. Miguel the Gruta do Carvão as a consequence of a Tobacco Factory. Fortunately, the «Amigos dos Açores» have a project for the recuperation of this important lava tube, some works having already been performed.

### 4. SOME SOLUTIONS

#### 4.1. MAINTAIN A PERMANENT INVENTORY OF CAVES, THEIR GEOLOGICAL STRUCTURES AND FAUNA

The expeditions of «Os Montanheiros» (speleological group from Terceira) to the several islands of the Azores is an important way of giving publicity to the Azorean vulcanospeleological patrimony. In fact, at local and regional scales, several news and comments about new caves or environmental hazards in caves are given by the journalists and the population becomes more familiar with the problems.

However, some effort should also be carried out in the formation of local groups of speleologists in islands like Pico, S. Jorge and Graciosa. In Faial we have the «Azorica» and in S. Miguel «Os Amigos dos Açores» both with a speleological section. In the case of S. Miguel some important work was already been done by «Os Amigos dos Açores».

In Pico, Mr. Albino Garcia started some interesting speleological activities in 1989-90, but is having some difficulties in the creation of a speleological group.

#### 4.2. RESTRICT THE VISITATION ACTIVITY IN A NUMBER OF SELECTED LAVA TUBES

The only known case in the Azores of restriction in visitation is the volcanic pit «Algar do Carvão» (Terceira), that is under the control of «Os Montanheiros». However, there are other similar projects for Gruta do Natal and Gruta das Agulhas (Terceira), Gruta do Carvão (S. Miguel) and Gruta do Soldão (Pico). This is a difficult task and only the caves located in places of very difficult access are truly protected.

#### 4.3. HELP THE OWNERS OF PASTURES TO BUILD NATURAL FENCES AROUND SKYLIGHTS AND PITS

This probably an urgent task for a real protection of not only the cave structures but also their environment and skylights adapted fauna. Urgent measures should be implemented in Pico.

#### 4.4. AS A LONG-TERM STRATEGY FOR THE PROTECTION OF CAVE FAUNA, MAKE THE PROTECTION OF THE ABOVE-GROUND HABITATS (E.G., CREATION OF NATURAL RESERVES)

This is a very complicated problem. In fact we have first to educate the politicians in order to have real measures of Conservation for the Azorean caves. Fortunately, some important natural areas are being studied by a LIFE project (EEC) in order to create protected areas in the Azores.

#### 4.5. EDUCATION

Some effort should be taken by conservationists in educating not only the young people, but also groups of farmers using selected information about caves and their importance. However, there should be some caution in not publicize to much the location of caves to avoid an increase in the «visitation effect» (Howarth, 1981).

### 5. DISCUSSION

The numbers cited for the Azores of lava tubes, volcanic pits and their fauna give us little information about historical disturbances in cave structures or arthropod species extinctions. In fact, according to the data it seems that in some islands a better survey will have as a consequence an increase in the numbers rather than a list of new cases of cave disturbance. A true diagnosis requires a more reined analysis.

In some islands the human population is growing (*e.g.*, Terceira, S. Miguel) (DREPA, 1994) and this results in more water and land necessities, therefore, more cave destruction. Good examples of this occurred recently in Terceira, Pico and S. Miguel.

In Pico, the richest island in terms of vulcanospeleological patrimony, two different processes are occurring: (1) during the last ten years there was an enormous pressure to ameliorate the pasture land and produce meat and milk. A large area of natural forest and semi-natural grassland was converted to pasture «monocultures» (a mixture of *Trifolium repens*, *Lotus uliginosus*, *Lolium perenne*, *Dactylis glomerata*, *Poa trivialis*) with disastrous effects in the total area of natural forests at middle altitude. In lots of cases lava tubes and volcanic pits were also destroyed. In most cases the sown pastures were rapidly invaded by native herbs, grasses, rushes and ferns, becoming less productive. Moreover, the milk is not a real necessity in economical terms and we may affirm that in some years a great part of those new pastures will be abandoned. Thus, after a decade of huge efforts of conversion of land to better pasture with the consequent habitat destruction, the results are poor; (2) during the last twenty years there was also an abandonment of the lowlands usually used for wine production. As a consequence of that some weed plants (*e.g.*, *Pittosporum undulatum*) invaded the lava flows and lots of cave entrances are now difficult to be located, but preserved from human visitation and disturbance.

In Terceira and S. Miguel, because of the high value of land, many remaining lava tubes are probably facing urban and agricultural effects. In several islands lava tube entrances, lava tube skylights and pits have been plugged in several ways: (1) filling with rocks and debris during urban works; (2) intentional filling by farmers to protect the cattle, and (3) use for sewage disposal by local residents. The biodiversity of the cave fauna is another important and complicated subject. Most certainly there are a large set of species not yet discovered, which reinforces the importance of more efforts in survey studies. Concerning the known fauna (see Fig. 4), in spite of not being very rich is composed of endemics, thus has a high patrimonial value. Control over habitat destruction is essential to protect the cavernicolous fauna and their habitats. If we consider the fact that some species are restricted to particular parts of a particular cave, thus the disturbance of such habitats may have disastrous results.

Of course that there are inevitable conflicts that need to be carefully managed and solved by the environmental authorities in the Azores. For instance, an important question is: «What are the benefits and costs of a particular investment project?».

Several interesting projects of management and conservation of lava tubes and volcanic pits are being made by Azorean Speleological groups (*e.g.*, «Os Montanheiros» in Terceira and «Amigos dos Açores» in S. Miguel), but a more planned work should be undertaken by the environmental authorities.

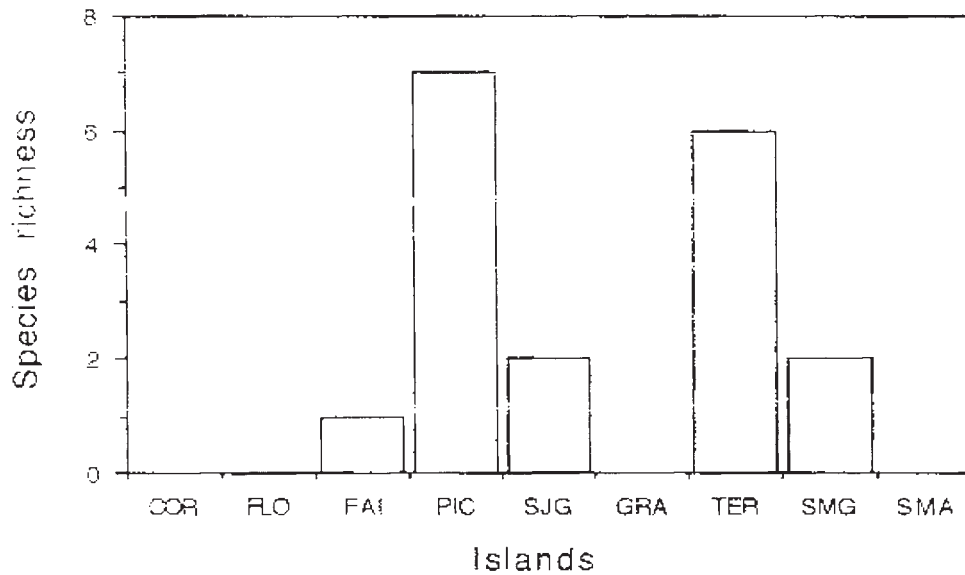


Figure 4. Number of species of cavernicolous arthropods referred for the Azorean islands. Data extracted from Borges & Oromí (1994). COR= Corvo; FLO= Flores; FAI= Faial; PIC= Pico; SJG= São Jorge; GRA= Graciosa; TER= Terceira; SMG= São Miguel; SMA= Santa Maria.

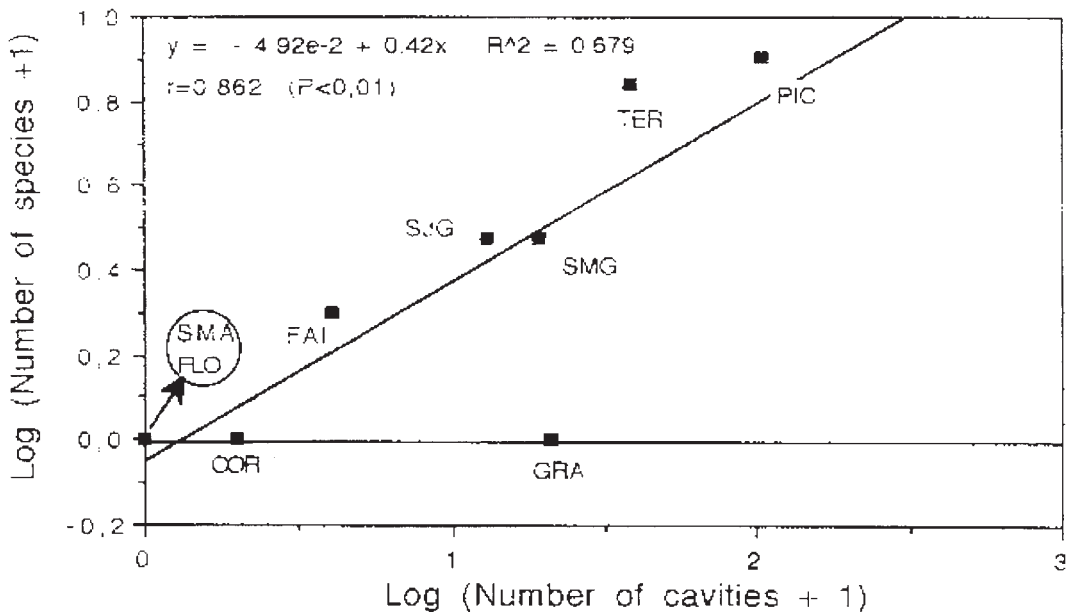


Figure 5. Linear regression between log species of cavernicolous arthropods + 1 and log number of cavities + 1. COR= Corvo; FLO= Flores; FAI= Faial; PIC= Pico; SJG= São Jorge; GRA= Graciosa; TER= Terceira; SMG= São Miguel; SMA= Santa Maria.



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