Use of ATLANTIS TIERRA 2.0 in mapping the biodiversity (invertebrates and bryophytes) of caves in the Azorean archipelago

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Abstract: In this contribution the software ATLANTIS Tierra 2.0 is described as a promising tool to be used in the conservation management of the animal and plant biodiversity of caves in Macaronesia. In the Azores, the importance of cave entrances to bryophytes is twofold: i) since these are particularly humid, sheltered habitats, they support a diverse assemblage of bryophyte species and circa 25% of the Azorean brioflora is referred to this habitat and ii) species, either endemic or referred in the European red list due to their vulnerability (19 species) or rarity (13) find refuge there. Cave adapted arthropods are also diverse in the Azores and 21 endemic obligate cave species were recorded. Generally these species have restricted distributions and some are known from only one cave. ATLANTIS Tierra 2.0 allows the mapping of the distribution of all species in a 500 x 500 m grid in a GIS interface. This allows an easy detection of species rich caves (hotspots) and facilitates the interpretation of spatial patterns of species distribution. For instance, predictive models of species distribution could be constructed using the distribution of lava flows or other environmental variables. Using this new tool we will be better equipped to answer the following questions: a) Where are the current "hotspot caves" of biodiversity in the Azores?; b) How many new caves need to be selected as specially protected areas in order to conserve the rarest endemic taxa?; c) Is there congruence between the patterns of richness and distribution of invertebrates and bryophytes?; d) Are environmental variables good surrogates of species distributions?

1. INTRODUCTION

The study of Azorean cave fauna and flora only started in 1988 with two expeditions of "National Geographic" under the supervision of Pedro Oromí (Univ. de La Laguna) and Philippe Ashmole (Univ. de Edinburg) and with the support of the speleological Azorean group "Os Montanheiros" (see Oromí *et al*. 1990, González-Mancebo et al. 1991). After those two expeditions in 1988 and 1990, the University of the Azores and "Os Montanheiros" performed most of the biospeleological work in the Azores (see Borges & Oromí 1994, 2006, Gabriel & Dias 1994). In the Azores, the importance of cave entrances to bryophytes is twofold: i) since these are particularly humid, sheltered habitats, they support a diverse assemblage of bryophyte species and circa 25% of the Azorean brioflora is referred to this habitat and ii) species, either endemic or referred in the European red list (ECCB 1995) due to their vulnerability (19 species) or rarity (13) find refuge there. Cave adapted arthropods are also diverse in the Azores and 21 endemic obligate cave species were recorded (Borges & Oromí 2006). Generally these species have restricted distributions and some are known from only one cave (Borges & Oromí 2006).

There is a general agreement among scientists that biodiversity is under assault on a global basis and that species are being lost at greatly enhanced rates due to human processes such as habitat loss and fragmentation, invasive species, pollution and global climate change (Lawton & May 1995; Chapin et al. 2000). Moreover, some recent studies indicate that there are some concerns related with invasive species and the conservation of native biodiversity in the Azores (Silva & Smith 2004, Borges et al. 2006).

In this contribution, a new software, ATLANTIS Tierra 2.0, is described as a promising tool to be used in the conservation management of the animal and plant biodiversity of caves from the Azores.

2. ATLANTIS TIERRA 2.0 A NEW TOOL FOR MANAGING CAVE BIODIVERSITY.

Since 1998 the Government of the Canary Islands as been conducing an important project on biodiversity, Project BIOTA (see Izquierdo *et al.* 2001, 2004). A Visual Basic software, called ATLANTIS Tierra 2.0, was developed for biodiversity data storage. With this database it will be possible to gather detailed information about all species on the surveyed geographical areas of interest. This software has several important tools, namely a taxonomic tool and a conservation management analysis tool (Fig. 1) that allows the calculation of species richness, their rarity or complementarity in all 500x500 m cells of a particular island or, in any special area in one island.

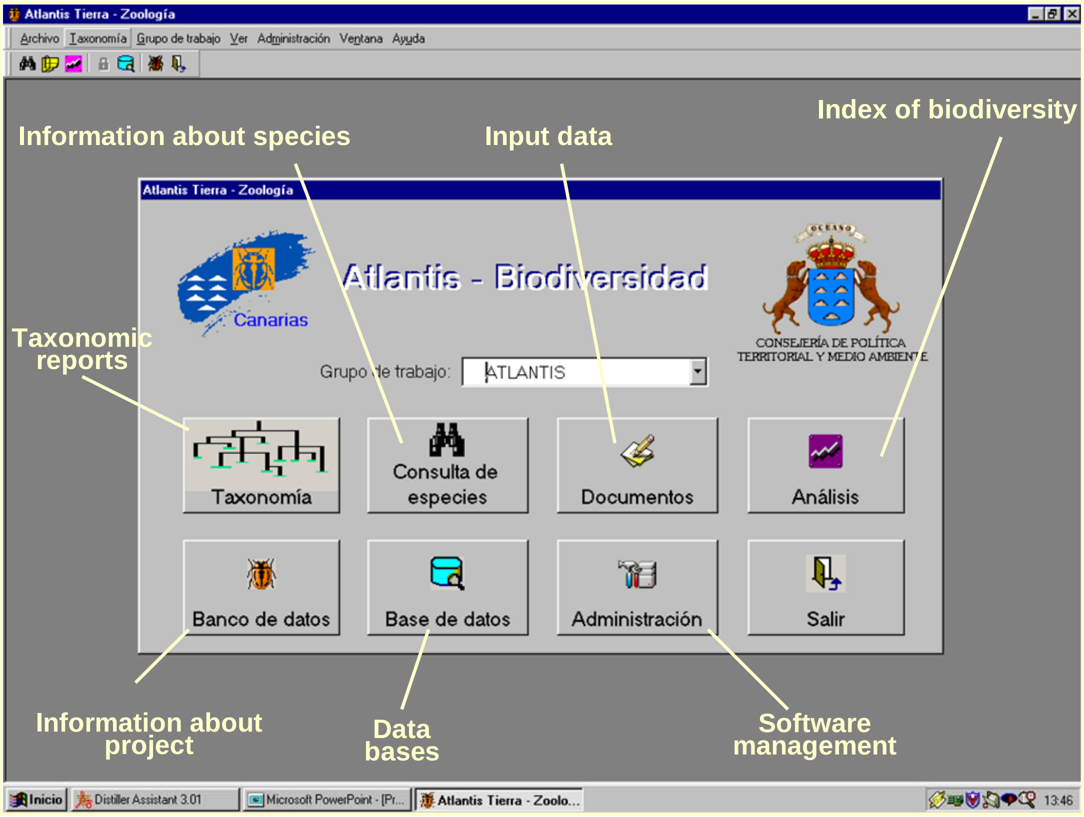

Fig. 1. Entrance window of ATLANTIS Tierra 2.0, in which it is possible to observe eight possible entrance gateways, the most relevant being the taxonomic reports ("Taxonomía"), information about species ("Consulta de espécies") and data analysis ("Consulta de análisis").

With this software all the information we could think of about a species (e.g. the cavernicolous ground-beetle *Trechus montanheirorum*) is available in clicking the **information about species ("Consulta de espécies")** window (see Fig. 2). In this window it is also possible to check the detailed distribution of the species in a 500 x 500 m scale (Fig. 3). With this tool we may also investigate the distribution of the species throughout time in asking for its distribution in different time intervals. To each signalized 500 x 500 m grid cell correspond a cave for which the species was signalized in the literature.

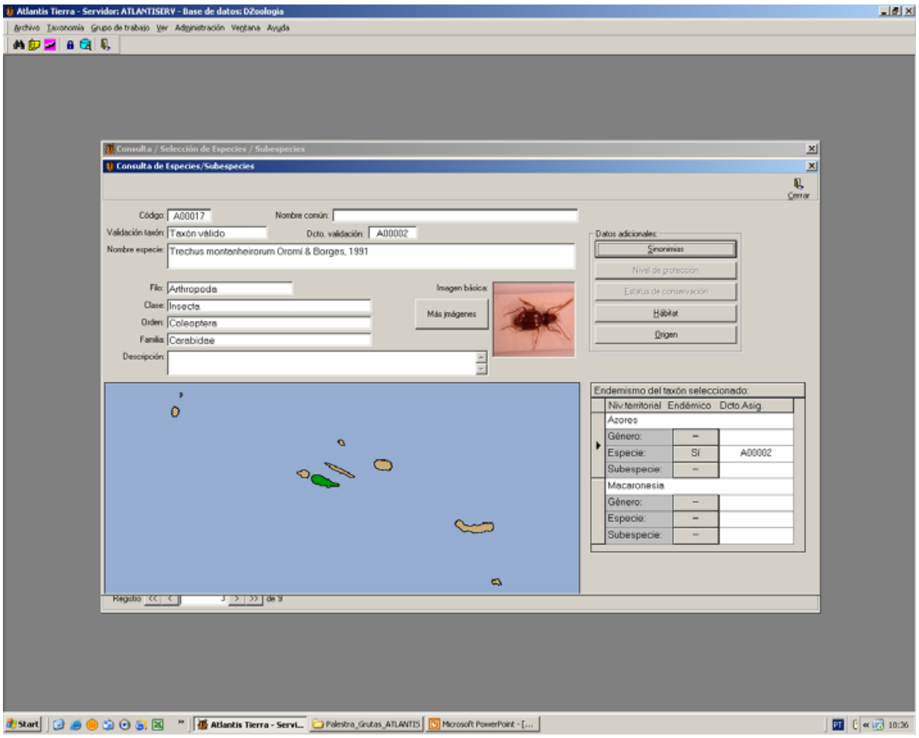

Fig. 2. Species management window of ATLANTIS Tierra 2.0, in which it is possible to observe the nomenclature of the species, a picture, the distribution of the species in the archipelago (green island) and other relevant information concerning the habitats, conservation status, biogeographical origin, etc..

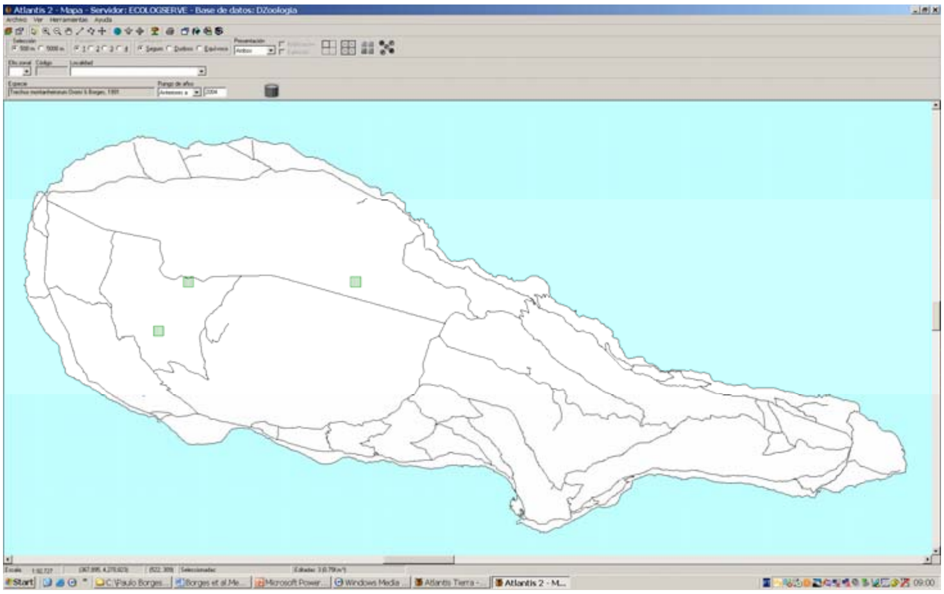

Fig. 3. Species managment window of ATLANTIS Tierra 2.0, in which it is possible to observe the detailed distribution of *Trechus montanheirorum* in the island of Pico (lines are main roads in the island).

However, it is in the data analysis facility that ATLANTIS Tierra 2.0 is more interesting in terms of its application in a conservation management study. As an example in Fig. 4 we see the species richness of the European Rare Bryophytes (ECCB 1995) in caves from Graciosa Island (Azores). The grid-cell with the highest number of species corresponds to the location of Furna do Enxofre, currently a volcanic pit protected by law and under the special management of the Government. In Fig. 4 we can see also the list of species in grid cell with the highest number of species and that list could be exported to another software (e.g. Excel).

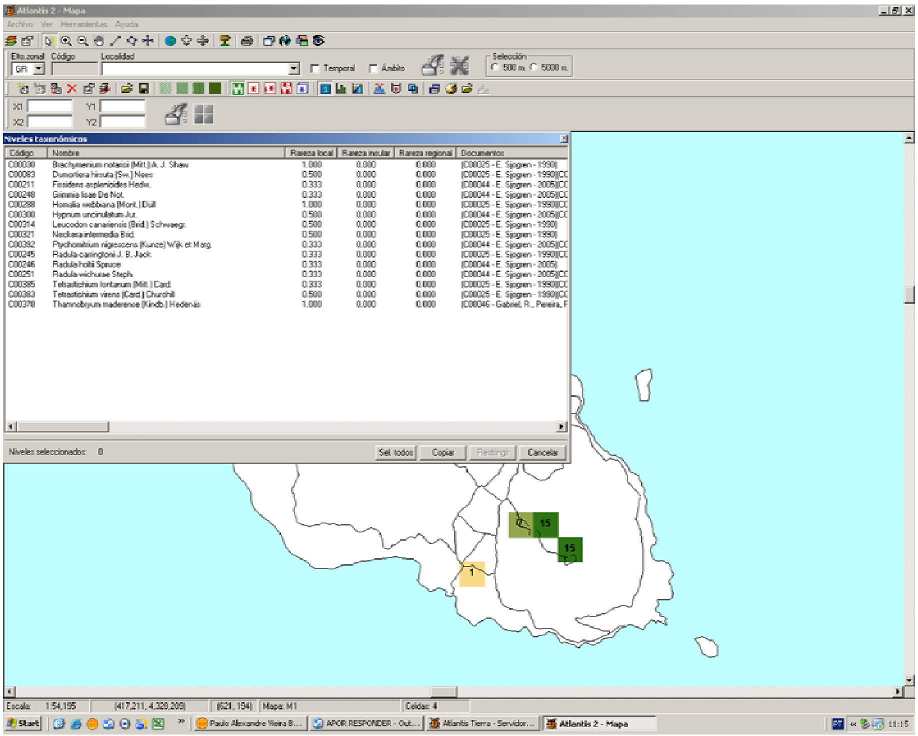

Fig. 4. Data analysis window of ATLANTIS Tierra 2.0, in which it is possible to observe the number of bryophyte species in the European Red List present in caves from Graciosa Island (Azores). The list of species in the window corresponds to the grid cell with 15 species (Furna do Enxofre).

Very important in conservation management studies is to ask: “Ho many sites are needed to include all species of interest at least once?”. To answer this question, we could use the complementarity procedure, in which we get the minimum set of caves that combined have the highest representation of species (see Williams 2001). ATLANTIS Tierra 2.0 uses the heuristic suboptimal simple-greedy reserve-selection algorithm: first, the grid-cell with the highest species richness is selected. Then, these species are ignored and the grid-cell with the highest complement of species (that is, the most species not represented in the previous selected grid-cell), and so on, until all species are represented at least once. One good example of the application of the complementarity procedure is showed in Fig. 5, in which only four out of the eleven grid-cells with caves are necessary to protect the 26 endemic arthropod species occurring in the caves of this island. Those four grid-cells are signalized with a green dark border (the first selected grid-cell) and with a reddish dark border (the three other selected grid-cells). Therefore, with only four caves well managed we may protect all the endemic arthropod species know to occur in caves at Terceira Island (Azores). However, we should call attention to the fact that the complementarity procedure could be made more complex asking for the minimum set of caves that combined have at least each species represented twice, therefore assuring that species are protected in more than one place.

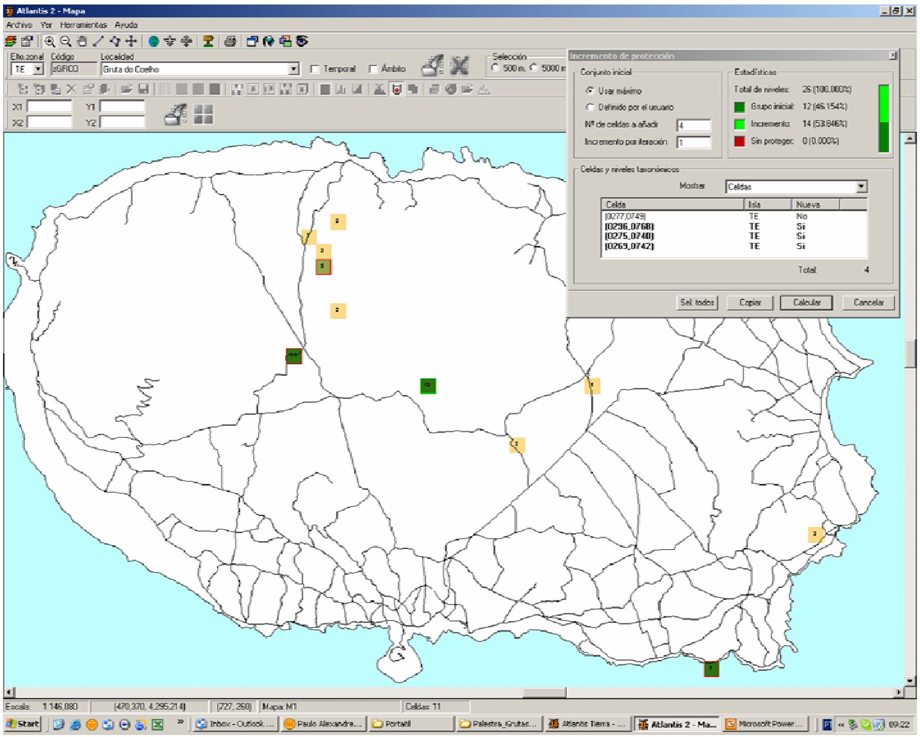

Fig. 5. Data analysis window of ATLANTIS Tierra 2.0, in which it is possible to observe the four grid-cells that are necessary to include all the endemic arthropods occurring in caves from Terceira island (see text for further explanations).

Another important facility available in ATLANTIS Tierra 2.0 is related with the investigation of the species composition in different areas of a region. For instance, we could have the list of species that are common in two different cave systems (Fig. 6). We could also get the list of species for each cave system and by exclusion obtain the lists of species that are exclusive to each cave system.

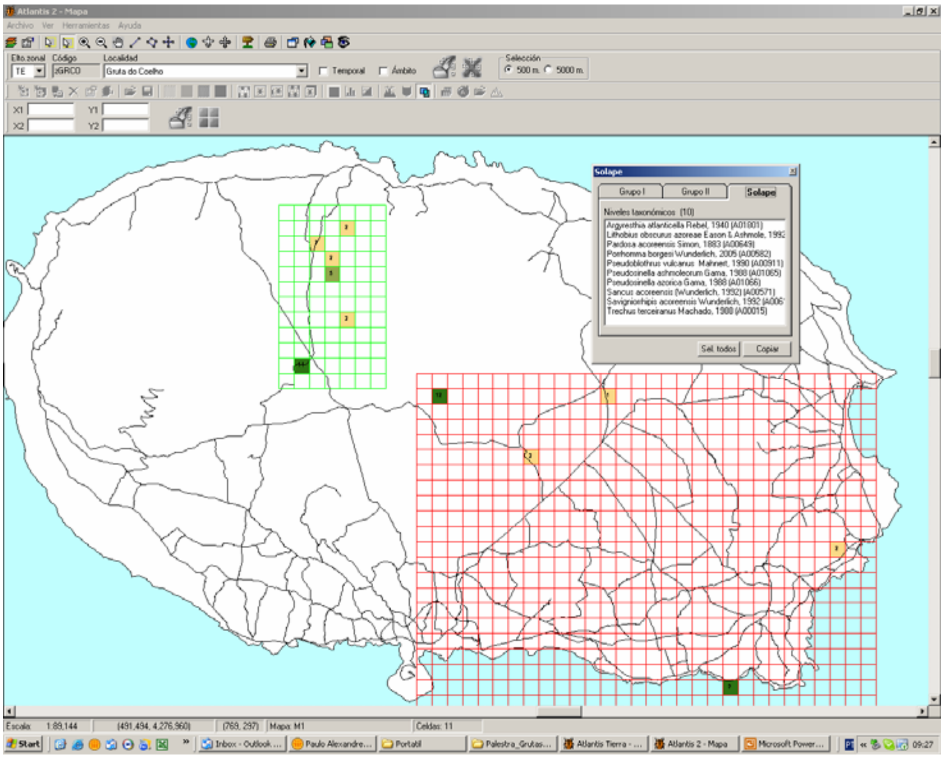

Fig. 6. Data analysis window of ATLANTIS Tierra 2.0, in which it is possible to observe the list of endemic arthropods that occur in two distinct cave systems at Terceira island (see text for further explanations).

3. CONCLUSION

There is some urgency in the conservation of the diverse community of mosses and liverworts (Bryophyta) as well as of the rich cave adapted arthropods occurring in the Azorean lava tubes and volcanic pits. The general pattern that emerges is that ATLANTIS Tierra 2.0 will be an important tool not only for the Azorean Government in managing the territory and designing natural protected areas, but also for research in de areas of applied ecology and conservation.

Using the ATLANTIS Tierra 2.0 new tool we will be better equipped to answer the following important questions: a) Where are the current "hotspot caves" of biodiversity in the Azores?; b) How many new caves need to be selected as specially protected areas in order to conserve the rarest endemic taxa?; c) Is there congruence between the patterns of richness and distribution of invertebrates and bryophytes?; d) Are environmental variables good surrogates of species distributions?

4. ACKNOWLEDGEMENTS

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