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Oral Presentations

SESSION III- BIOSPELEOLOGY OF VOLCANIC CAVES

LONG-TERM STUDY OF POPULATION DENSITY OF THE TROGLOBITIC AZOREAN GROUND-BEETLE *TRECHUS TERCEIRANUS* AT ALGAR DO CARVÃO SHOW CAVE: IMPLICATIONS FOR CAVE MANAGEMENT

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Trechus terceiranus Machado (Coleoptera, Carabidae) is the commonest trogobitic insect species in several lava –tube caves and pits and in the Mesovoid Shallow Substratum (MSS) on Terceira (Azores). One of the sites where this ground beetle reaches highest densities is the show cave "Algar do Carvão", an impressive volcanic pit. The troglobitic fauna in this cave is particularly rich, with at least two endemic spider species occurring only in this site.

Cave arthropods were sampled once per month for three years (2001-2003) using baited pitfall traps. All collected specimens were counted and stored for later identification with the exception of the abundant *Trechus terceiranus*, which were counted and returned to their environment.

We found that adults are common all year-round, with some activity-density peaks in months between March and September. The most notable finding was an overall decrease in activity-density of *T. terceiranus* from year to year. The hours of artificial light in this cave also increased during these three years and this could have caused this decrease. We discuss the implications for management of the cave.

INDICATORS OF CONSERVATION VALUE OF AZOREAN CAVES BASED ON ARTHROPOD FAUNA

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All Azorean lava tubes and volcanic pits known to contain hypogean fauna (37 cavities) were evaluated for species diversity and rarity, based on arthropod populations. To produce an unbiased multiple-criteria index (*importance value for conservation,* IV-C) incorporating diversity and rarity based indices and geological and management based indices, an iterative partial multiple regression analysis was performed. In addition, an irreplaceability index and the complementarity method (using heuristic methods) were used to select the most important caves for conservation management.

Most hypogean endemic species have restricted distributions; some are known from only one cave. It was concluded that several well-managed protected caves per island are necessary to preserve an adequate fraction of endemic arthropods. For presence/absence data, suboptimal solutions indicate that protection of at least 50% lava-tubes with known hypogean fauna is needed if the goal is representation of 100% of endemic arthropod species in a minimum set of reserves.

The most diverse arthropod assemblages occur in large (and beautiful) caves; thus cave size plays an important role in explaining the faunal diversity of arthropods in the Azores. Based both on the uniqueness of species composition and/or high species richness, conservation efforts should be focused on the following unmanaged caves: Algar das Bocas do Fogo (S. Jorge); Gruta dos Montanheiros, Gruta da Ribeira do Fundo, Furna de Henrique Maciel, Gruta do Soldão and Furna das Cabras II (terra) (Pico); Gruta das Anelares and Gruta do Parque do Capelo (Faial); Gruta dos Balcões, Gruta das Agulhas and Gruta do Chocolate (Terceira); Água de Pau (S. Miguel).

INDICATORS OF CONSERVATION VALUE OF AZOREAN CAVES BASED ON ITS BRYOPHYTE FLORA AT CAVE ENTRANCES

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Cave entrances in the Azores are particularly humid habitats. These provide opportunities for the colonization of a diverse assemblage of bryophyte species. Using both published data and new field sampling, we evaluated species diversity and rarity of bryophytes at the entrance of all known Azorean lava tubes and volcanic pits with such flora. Most frequent species includes the liverworts *Calypogeia arguta*, *Jubula hutchinsiae*, *Lejeunea lamacerina*, and the mosses *Epipterygium tozeri*, *Eurhynchium praelongum*, *Fissidens serrulatus*, *Fissidens viridulus*, *Isopetrygium elegans*, *Lepidopilum virens*, *Tetrastichium fontanum*.

Several rare Azorean bryophyte species appear with dense populations at some cave entrances (e.g. *Archidium alternifolium*; *Asterella africana*; *Plagiochila longispina*), which highlights the importance of this habitat in terms of conservation of these plants.

To produce an unbiased multiple-criteria index (*importance value for conservation,* IV-C), several indices were calculated (based on bryophyte diversity and rarity, and also on geological and management features) and an iterative partial multiple regression analyses was performed.

Preliminary data sows that three pit caves are particularly diverse in bryophytes (e.g. Algar do Carvão, Bocas do Fogo and Furna do Enxofre). This indicates the importance of shaded and humid openings. Lava tubes with a diverse troglobitic fauna also are diverse in terms of bryophyte species (e.g., Algar do Carvão, Gruta dos Montanheiros, Gruta da Agostinha, Furna do Henrique Maciel). We also evaluate the utility of several cave management indices as surrogates of bryophyte diversity in Azorean volcanic cavities.

ON THE NATURE OF BACTERIAL COMMUNITIES FROM FOUR WINDOWS CAVE, EL MALPAIS NATIONAL MONUMENT, NEW MEXICO, USA

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One of the striking features of some lava tubes is the extensive bacterial mats that cover the walls. Yet, despite their prominence in lava tubes, little is known about the nature of these bacterial communities. To rectify this situation we have investigated the bacterial mats that cover the walls of Four Windows Cave, a lava tube in El Malpais National Monument, New Mexico (see Figure). These bacterial mats, which occur in the twilight zone adjacent to algal mats, and in dark zone of the lava tube, cover from 25-75% of the wall. Their macroscopic and microscopic visual appearance suggests that these bacterial mats are composed of actinomycetes, bacteria that commonly inhabit caves. Actinomycetes are a group of Gram-positive bacteria that break down complex organic matter and thrive in environments where nutrients are sparse and conditions extreme. With a temperature of 0-2°C and seeping organic matter for nourishment, Four Windows provides an excellent habitat for these bacteria. Some types of actinomycetes are medicinally and agriculturally significant because they excrete antibiotic products to repel invaders. Cave bacterial mats may have such antibiotic properties. Vacuuming of the bacterial mats and the adjacent algae, demonstrated the presence of collembola and mites on the algae and no invertebrates on the bacterial mats.

In an effort to phylogenetically characterize bacterial colony members, we extracted DNA from wall rock communities, using a soil DNA extraction technique developed at Los Alamos National Laboratories. The DNA was purified, the 16S rRNA gene was amplified using PCR, amplification products were cloned, and thirty clones were sequenced in their entirety. A restriction fragment length polymorphism (RFLP) analysis of 11 clones exhibited unique banding, an indicator of genetic diversity. Comparison of our sequences with those in the Ribosomal Database II revealed that the Four Windows bacterial sequences are most closely related to actinomycetes, as suspected. Some clones also showed similarities to environmental soil strains. Other clones are related to genera such as *Nocardia* and *Frankia*, although not closely. These results reveal a diverse community of bacteria and the presence of several novel bacterial species.

To investigate the degree to which the actinomycetes had adapted to the lava tube environment, we also investigated the ability of bacteria cultured from these mats to withstand the effects of ultraviolet (UV) radiation. Bacteria from the mats and from the surface rocks above the lava tube were cultured on R2A medium on-site in Four Windows Cave, were

allowed to grow for 24-hours in the cave environment, and were then transported to the laboratory where they were grown at 2°C in an incubator. We subjected twelve isolates from the lava tube to one dose (100 seconds) and a half dose (50 seconds) of UV radiation. For controls, we subjected six isolates from the cave surface to the same radiation treatments and also allowed replicates of all the isolates to grow without any radiation. The results showed a general trend in which microbes isolated from the lava tube were much more UV sensitive than the microbes isolated from the surface. However, all of the microbes tested displayed at least slight sensitivity to UV radiation. Based on the results, the bacterial colonies currently inhabiting the Four-Windows lava tube appear to be at least somewhat cave-adapted.

Our studies of the actinomycete communities in Four Windows Cave reveal a diverse community of bacteria that may produce secondary compounds that make them unpalatable to invertebrates. These bacteria appear to have become at least somewhat cave-adapted as evidenced by their loss of UV resistance.

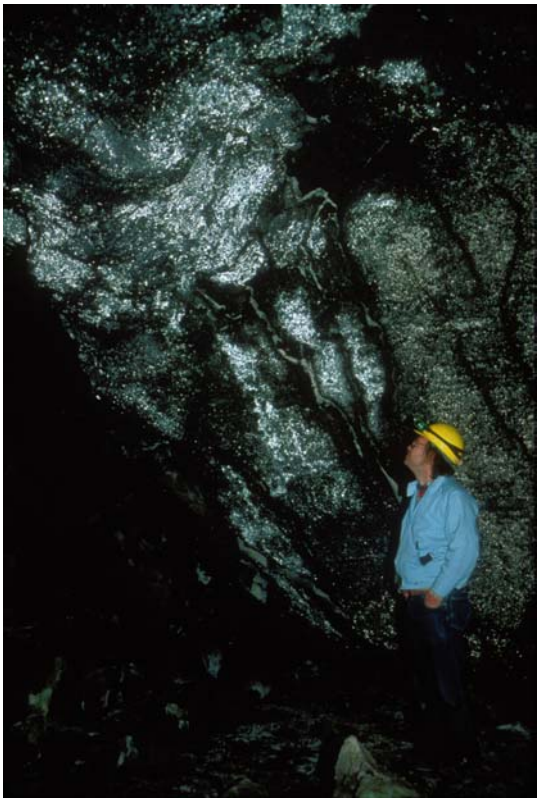

Figure: Mats of actinomycete bacterial spread across walls in Four Windows Cave, El Malpais National Monument. During some seasons the bacterial mats are hydrophobic and the walls appear "silvered" when light is shone upon them.

LARGE INVERTEBRATE DIVERSITY IN FOUR SMALL LAVA TUBES OF MADEIRA ISLAND

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The epigean fauna of Madeira is well known, highly diversified and very rich in endemic species. In contrast, its cave-dwelling fauna was not very well known. Madeira is a comparatively old island (5 My) with few modern lavas and therefore only a comparatively small number of lava tube caves are known: 21 volcanic caves have been reported. Of these, some already have been destroyed and others (e.g. São Vicente caves), have been heavily modified for tourism. To date, only two significant complexes of lava tubes have been studied: São Vicente (Cardais Caves) and Machico (Cavalum Caves). The Machico lava tubes are under serious pressure because of frequent visitation but still represent the best preserved group of lava tubes in Madeira. Yet their cave-dwelling fauna is little known. Although a few reports have been published, they have dealt only with few taxa. Further, these were reported merely from the complex as a whole without indication of which individual species was noted in which cave. At present, its fauna is at special risk because of current plans for construction of a tunnel. The resulting urgent need for detailed information led us to study biodiversity in four of its five small caves.

Invertebrates were sampled by sight and by 32 baited pitfall traps set during a seven months period. Of 8,497 sampled specimens, 14.3% were Phoridae, representing 9 species. This family was excluded from further consideration.

The remaining specimens belong to 69 taxa. Of these, 8 were known endemisms, 5 were new species and 1 was a new record to Madeira. Previously only 18 species were known from these caves, and 8 of these were not found in this study. The estimated number of species in this complex is 79. For a small cave complex with less than 300 m in total length, this is a considerable number. Cavalum II had the greatest number of species. Although many species were present in more than one cave, some were found in only one. For example the endemic spider *Centromerus sexoculatus* was sampled only in Cavalum I, the pseudoescorpion *Microcreagrina madeirensis* in Cavalum III and the carabid *Trechus fulvus maderensis* in Landeiros Cave.

This sampling thus demonstrated that protective measures are urgently needed.for the cave-dwelling fauna of the Machico complex.