CONSERVATION OF HAWAII'S SPELEOLOGICAL RESOURCES

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Hawaiian caves have long been known to have significant cultural and archeological values. Discoveries within the last decade have revealed important additional values in biology, paleontology, and geology. More recently, widespread publicity among national and international caving groups has emphasized the recreational and aesthetic values of Hawaiian caves. These seven major values represent a relatively rich resource which is matched by few cave areas elsewhere in the U.S., or even in the world. Unfortunately, conflicts arise among the various groups utilizing and attempting to preserve these resources. The unique values of Hawaiian caves, and the immediate nature of the threats to them by increased visitation, require that urgent and positive actions be taken to ensure their continued survival as a global scientific resource (Howarth in press; Howarth and Stone 1987).

Archeological and Cultural Values

The archeological importance of Hawaiian caves is great, as they hold a wealth of knowledge, documenting the cultures of the native Polynesians prior to European contact. Uses of caves by the early Hawaiians included shelter, habitation, food storage, water catchment reservoirs and crypts (Emory *et al.* 1969; Bonk 1969). For native Hawaiians today, these caves still have considerable cultural value, with traditional guardians ("kahunas") keeping watch over some important burial caves. Antagonism of the local people by thoughtless cavers, so common in other regions, would cause irremediable damage in Hawaii, and must be avoided.

Interestingly, the near-pristine condition of many Hawaiian lava tubes is partially due to a fear of burial caves by local residents, which has kept visitation at a low level until recently. Looting of pre-historic sites by artifact hunters is a serious problem, which has desecrated many sites already, partly in response to the publication of cave locations in archeological publications. However, up to now many caves have escaped this looting because of remoteness and lack of published locations.

Biological Values

The biological and evolutionary significance of Hawaiian caves has only been realized over the past decade, with the discovery in 1971 by Howarth (1972) of a cave-adapted fauna, now represented by over 50 species from all over the main islands. Maciolek's discovery of aquatic cave-adapted crustaceans on Maui (Maciolek and Brock 1974) led to the finding of over 20 aquatic species. New cave-adapted species are still being found regularly.

The evolutionary significance of Hawaiian cave-adapted species is immense: 1. They served as a bellwether for a more intensive search for troglobites in lava tubes and tropical caves with highly rewarding results. Past theories of cave adaptions, based on the presumed restriction of troglobites to the temperate zones, were no longer valid, and a new era of study and theorization was begun (Howarth 1980; Howarth 1982). 2. The isolated island characteristic of Hawaii allows for study of adaptive shifts, by which cave-adapted organisms evolved from native Hawaiian groups, much as other organisms have evolved to exploit novel habitats (Howarth 1981). These relationships are not often as clearly demonstrated in the more complex faunas of continental areas. Adaptions displayed by Hawaiian cave animals are truly remarkable, presenting such anomalies as underground tree crickets, blind planthoppers, a terrestrial water treader, and the ultimate of adaptive shifts, no-eyed, big-eyed hunting spider. 3. Environmental studies can be done, comparing cave species with their closely related surface relatives, revealing the effects of adaption to diverse habitats (Ahearn and Howarth 1982). Additional biological values of Hawaiian cave organisms, already known or remaining to be discovered, contribute to their great biospeleological potential.

It was fortunate that the biological survey of Hawaiian caves began before organized sport caving developed here. Our field data show that, other factors being equal, species diversity and population levels of cave organisms is inversely proportional to the level of visitation and human disturbance. For example, immature cixiid planthoppers and cave moths feed solely on living roots that penetrate the cave roof. If roots do not reach the floor, or are severed by human traffic, the dislodged nymphs starve. As a result, populations of these two species and their predators often reflect the level of human disturbance. Furthermore, hazardous refuse, such as carbide and batteries is detrimental to cave life. Tobacco smoke contains a powerful insecticide that can harm, or kill cave invertebrates in relatively enclosed caves.

In 1971, Joan Aidem discovered bird fossils on Molokai in sand dunes, followed by Howarth and Gagne's discovery of fossil bird skeletons in Maui lava tubes (Olson and Wetmore 1976). Since then, numerous species of hitherto unknown fossil birds have been discovered on all the islands including flightless ibises, rails and geese. Over 30 new species are known, with new finds occurring regularly, necessitating an ongoing revision of our knowledge of the evolution of bird life in the entire Pacific island region (Olson and James in press). These fossils, so crucial to understanding evolution of Hawaiian birds, are extremely vulnerable to destruction by unaware cave visitors.

Geological Values

In 1971, Mauna Ulu, a new volcanic vent, began erupting in earnest, and for the first time modern geologists had a front row seat during the formation of a shield volcano. They quickly realized that lava tubes, which form by the crusting over of pahoehoe lava channels, play an important role in the formation of volcanic shields by efficiently conveying lava great distances through the insulated interior of a lava flow (Peterson and Swanson 1974). This discovery catapulted lava tubes from mere geologic curiosities to valuable scientific resources.

Additional geological values derive from the formations within lava tubes: lavacicles, driblet spires, and other structures and mineral deposits which give clues to processes of lava tube formation and evolution. These deposits also add to the aesthetic values of lava tubes, but as in limestone caves, they are vulnerable to accidental breakage and vandalism.

Human Impact on Cave Resources

Cave conservation elsewhere provides possible solutions to conservation problems in Hawaiian caves. Cave exploration as a sport began in earnest in the last century in Europe, to some extent in America, and elsewhere. It has mushroomed in popularity in the last few decades as a result of increased leisure, improved techniques, and increasing ease of travel. Everywhere caves have experienced increased use and abuse by humans. As caving pressure increases, so does human impact; vandalism, accidental breakage and trampling, pollution, et al. Unchecked, these impacts irreversibly damage biological, paleontological, archeological, geological and aesthetic resources (Stitt 1977). Five stages can be recognized: **1.** local use, **2.** discovery, **3.** escalation of caving, **4.** resource destruction becomes critical, **5.** cave protection begins in order to preserve what little remains.

Caves share with other discrete habitats such as montane bogs and sand dunes a vulnerability to human traffic. However, scientists studying surface habitats often need only go a few hundred meters away from a well-worn trail to find relatively undisturbed study sites. In caves, however, traffic is narrowly confined, and unless there is access control, study areas will be trampled or vandalized.

In addition, caves have been closed to researchers because of increasing conflicts with exploration parties. Many caves have entered the last phase with little left to preserve. In England, for example, Britton (1976) lamented that: "In the entire country, no cave now exists which has a man-sized entrance and undisturbed biology or [paleontological] sediments."

Impacts on Hawaiian Caves

Until recently, principal impacts on Hawaiian caves have resulted indirectly from clearing forest land, construction of roads and buildings, and use as dump sites. For example, cave entrances on Hawaii island have been illegally bulldozed shut by well-meaning but misinformed construction workers who were unaware of the rich resources thus destroyed.

Hawaii is now in the discovery phase (No. 2 above) with recreational use increasing dramatically. However, this is rapidly escalating to the next stage in which use will exceed carrying capacity. Popular accounts of recent expeditions have generated more visits (e.g., Wood 1980), and several expeditions from North America, Asia and Europe are planned within the near future. Even though these groups represent responsible experienced cavers, without special training they are not likely to be sensitive to local resources and management problems in Hawaii. Unique values of Hawaiian caves makes them particularly sensitive to visitor pressure, and makes a special protection imperative.

PROTECTION AND MANAGEMENT STRATEGIES FOR HAWAIIAN CAVES

1. Protection from destructive land use practices. It is not practical to save all caves from destruction from improper land use, but through workable management schemes including alternatives, the significant caves may survive without undue economic loss. For example, on Kauai, caves with significant biological and archeological values are being protected within a golf course by a management agreement between the county and the developers. Land managers, environmental agencies, and environmental groups must be kept informed of cave resources.

2. Caves in the national parks. Currently, Hawaiian Volcanoes National Park has realized the need for a management plan for the caves there. This realization resulted from a rapid increase of requests to visit the lava tubes, stemming from articles in international caving journals. The park is developing a management plan and beginning a survey to determine which lava tubes require restricted access due to scientific values.

3. Protection for caves outside the parks. Additional efforts by the caving community are necessary to extend protection to scientifically and culturally important caves outside the parks. A Hawaii Cave Conservation Task Force of the National Speleological Society is presently being formed by representatives of groups concerned with preservation of the unique values of Hawaiian caves.

Preservation of Hawaiian cave resources requires a concerted effort by the caving community at large, without which the efforts of the task force will have limited effectiveness. Recognizing this need, in July, 1982, the Board of Governors and the Biology Section of the National Speleological Society passed the following resolution:

Whereas, Hawaiian caves, including lava tubes, have unique internationally recognized important values to science, especially in the fields of biology, archeology, paleontology and geology; and,

Whereas, Many of these important scientific resources are particularly vulnerable to unrestricted recreational caving; and,

Whereas, Once destroyed these values cannot be recreated; and,

Whereas, Popularizations of the sporting potential of Hawaiian caves in mass media encourages recreational caving by the general public; and,

Whereas, The National Speleological Society recognizes these problems elsewhere in the United States;

Therefore, be it resolved that the National Speleological Society urges all cavers to assist in the conservation of Hawaii's cave resources; and,

Be it further resolved that the Board of Governors encourages all N.S.S. members and all cavers visiting Hawaiian caves to exercise special caution to prevent the destruction of these resources; and,

Be it resolved that the National Speleological Society opposes the publication in the popular press of articles describing the sporting potential *or locations* of sensitive caves; and,

Be it resolved that the National Speleological Society supports the efforts of the Hawaii Caves Conservation Task Force, the National Park Service, the Bernice P. Bishop Museum and others in their efforts to conserve Hawaii's cave resources.

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BIOTA OF VOLCANIC CAVES: AN INTRODUCTION

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In recent years, cave biologists have been more and more of the opinion that troglobites, or so-called "obligate cave fauna," are primarily inhabitants of the network of fissures, interstices, and small cavities that is more-or-less continuous throughout large areas, rather than existing in isolated cave populations (for discussion see Husmann, 1967; Culver, et al, 1974; Henry, 1979; Crawford, 1981; and below). In view of this, one might expect that the most diverse and abundant troglobitic faunas will be found in regions where this widespread subterranean habitat has certain favorable qualities. Among these might be availability of moisture and food, and the size and interconnectivity of the "living spaces."

Clearly, a crevice system with no connection to surrounding cavities, or a material like clay, with many available spaces but all of them microscopic, is not likely to support animal life. Both these factors — size and connectivity of spaces — are reflected in the permeability of a medium to groundwater, which can be measured. Permeability is an intrinsic quality of a medium analogous to electric resistivity, and is proportional to the rate at which groundwater, under a given set of conditions, can pass through it. Its dimensions are length squared. Brown, et al, (1975) gives the permeability ranges of most common bedrock and sediment types. Three materials show maximum permeabilities near the top of the scale, or about 0.152. They are gravel, limestone, and basalt. Since both limestone and basalt contain caves, their subterranean faunas can be investigated. Both kinds of cave should be expected to have diverse and abundant troglobitic faunas, and that expectation is proving to be justified. Oddly, though, the large subterranean faunas of basaltic terrain remained almost unsuspected until very recently.

Although a few troglobites were described from volcanic caves as early as the 1930s, only a handful had been reported before the late 1960s. Beginning in 1966, lava troglobites were described individually in increasing numbers from Japan, Korea, Idaho, Washington, and elsewhere. Then Leleup (1967) reported the presence of an entire fauna in the Galapagos Islands. In quick succession, Ueno, et al, (1970, 1971) reported large subterranean faunas from volcanic caves in Japan, Howarth (1972) from Hawaii, and Peck (1973) from western North America. Thus, volcanic cave biology blossomed from nothing to a substantial subject in an extraordinarily short time.

Currently, the Galapagos fauna is being published in the Resultats Scientifiques, Mission Zoologique Belge aux Iles Galapagos et en Ecuador (1968-date); the Japanese fauna in the Bulletin of the National Science Museum, Tokyo (Volume 13, 1970, to date), and the Hawaiian Fauna in Pacific Insects (Volume 15, 1973, to date). The North American results are scattered in many journals. About 40 lava troglobites have been described from Japan; 13 from the Galapagos; 24 from Hawaii; and 16 from Washington, Oregon and Idaho, with many more awaiting description. Species described include the fish *Luciogobius albus*, Regan (Japan), and *Caecoqilbia galapagosenis*, Poll and Leleup, as well as such diverse invertebrate groups as earwigs, flatworms, harvestmen, true bugs, actinaria (Japan), and pseudoscorpions, beetles, and crickets, collembola, spiders, mites, and numerous millipede and crustacean species.

Even in these four studied areas, probably the majority of the fauna awaits discovery. Almost nothing has been done on