The NSS BULLETIN

Quarterly Journal of the National Speleological Society

July, 1981

VOLUME 43
NUMBER 3

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Cover Photos—**(upper left)** Arid zone thorn-scrub and cactus *(Opuntia* and *Cephalocereus)* forest on the Guánaca Peninsula, near Cueva de los Murciélagos. **(center)** Large chamber below skylight (entrance 5) of Cueva de los Murciélagos; ceiling height is 22 m. **(lower right)** Sampling aquatic fauna with plankton net in small pool, Cueva de los Murciélagos, Puerto Rico. *Photos by Stewart Peck.*

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A catalog of issues still in print and their cost can be obtained from our Business Office at no charge; facsimile copies of out-of-print issues can be supplied for a nominal fee.

The NSS Bulletin (ISSN 0146-9517) is published quarterly in January, April, July and October for $10.00 per year by the National Speleological Society, Inc., Cave Avenue, Huntsville, Alabama 35810. Entered as second-class matter at Huntsville, Alabama, and additional mailing offices. POSTMASTER: send address changes to *The NSS Bulletin*, Cave Avenue, Huntsville, Alabama 35810.

Graphic Publishing Co., Inc.
Lake Mills, Ia. 50450

Peck, S. B. and Jarmila Kukalova-Peck (1981)—The Subterranean Fauna and Conservation of Mona Island (Puerto Rico): A Caribbean Karst Environment: *NSS Bulletin* 43: 59-68.

THE SUBTERRANEAN FAUNA AND CONSERVATION OF MONA ISLAND (PUERTO RICO): A CARIBBEAN KARST ENVIRONMENT*

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SUMMARY

An investigation of the invertebrate cave and ground water faunas of Mona Island has yielded 46 species, including 35 taxa new to the Island's known fauna. Five are new endemics for Mona (already known to harbor five endemic plants, nine endemic vertebrates, and 24 endemic invertebrates in non-marine habitats). In the subterranean fauna, three species are troglobites, 18 are troglophiles, and 16 are guanophilous mites. A general summary is given of the history, flora, fauna, and geology of Mona, the island least altered by human activity of any in the Caribbean. Proposals for development and problems of conservation of this completely karst environment are briefly discussed.

BETWEEN the Greater Antillean islands of Puerto Rico and Hispañiola lies Mona Passage, a major gateway of the Caribbean. Near the middle of the Passage, some 68 km west of Puerto Rico, are two extraordinary islands, Mona and Monito. Although located some 8 km closer to the Dominican Republic, their history has attached them politically to Puerto Rico.

Mona and Monito are very different from the rest of Puerto Rico. They appear as great, flat, white slabs of floating limestone, bounded almost entirely by high cliffs rising vertically from the sea. Mona, 12 km long and 6 km wide, is kidney shaped, with 5,510 ha of surface. Monito, about 5 km northwest, is comparatively small with only 17 ha of area. Both islands are covered by xerophytic vegetation, consisting mostly of cactus, leguminous plants, shrubs, and dwarfed trees.

Mona and Monito are the least altered by human activity of any islands that we know in the entire Caribbean Basin. In 1972, the Economic Development Administration of Puerto Rico (FOMENTO) proposed the construction of a deep-water supertanker port and oil refinery on Mona. As a result of this proposal, the Puerto Rican Environmental Quality Board undertook a study to summarize the natural features and resources of the islands. This internal report, (the Junta Report [1973]), covered all aspects of Mona's natural history except the faunas of extensive caves known around the rim of the island. In June 1974, we studied the invertebrate cave faunas for a week in an attempt to complete the natural history survey.

*Part 5 in a series on the invertebrate faunas of tropical American caves.

Because Mona Island is little known to natural scientists outside of Puerto Rico, we are taking this opportunity to present a summary of its general natural history, as well as our findings. In this, we draw heavily on the Junta Report and on Kaye (1959). Additional data can be found in these references (but the Junta Report was prepared for use within the government and is not readily available to naturalists). Landing on Monito is difficult because of heavy surf on its cliffs, so most of the following account refers specifically to Mona.

BACKGROUND

Climate

The climate is semiarid. Mean annual temperature is 26°C, with a daily maximum of from 29°C to 32°C and a daily minimum of from 20.5°C to 24°C. Daily temperature change throughout the year is about 8°C. The mean annual rainfall is 840 mm, with annual totals ranging from 360 mm to 2080 mm. Evapotranspiration is estimated to be 710 mm.

Human History

A rich and varied human history (figs. 1 and 2) is attached to the island. The original occupants were Taino Indians, who left village sites, refuse heaps, ball courts, and pictographs and petroglyphs on cave walls. Columbus visited these Indians on Mona in 1494. Other early explorers included Ponce de Leon, Walter Raleigh, and John Smith. Three centuries of pirate and buccaneer history is attached to Mona, for the island served as a provisioning and water-supply source. There are rumors that one of the caves may be the hiding site of the yet-unrecovered treasure of Captain Kidd, but this seems unlikely. Guano and phosphate-rich soils were mined from the caves at three periods in the late 1800's and early 1900's.

About 200,000 metric tons of phosphorite were removed for conversion into fertilizer; some 80 percent of this mining occurred between 1877 and 1920. The island was a U.S. Forest Service and Civilian Conservation Corps camp in the 1930's, during which time some of the coastal plain was reforested with mahogany and coconut palms. From 1953 to 1962, the U.S. Air Force cleared a number of straight courses through the xeric forests on the plateau. For the past decade, Mona has been uninhabited except for a rotating shift of Puerto Rican police and rangers of the Department of Natural Resources, charged with protecting the island from illegal landing of refugees from the Dominican Republic, and with protecting sea turtles during nesting. Sport hunting of the feral goats and pigs that were introduced years ago is a long-established custom of some Puerto Ricans.

The apparent lack of any productive use of Mona has led to a growing interest in some sectors for its development. Suggestions for use have included an artillery and bombing range, a nuclear power station, and, most recently, a deep-water tanker port and petroleum refinery site.

Visitation

At present, there are only sporadic visits to Mona Island, usually for scientific study or weekend recreation. The police and ranger force has been inadequate for control of all recreational activities, such as beach parties, on nights that otherwise would be suitable for egg-laying by sea turtles. Visitors usually sleep in tents near the beaches and must bring all their food and water. Field trips for scientists are usually arranged with the Puerto Rico Department of Natural Resources (DNR). Most past research concentrated on the flora and on the ecology of the large, endemic Mona Ground Iguana, *Cyclura stejnegeri*. DNR groups have sleeping and living quarters in a few buildings, mostly at Playa Sardinera and at the lighthouse. Slightly brackish groundwater is available for washing at Pozo Portugués at Sardinera. Transportation to the island is by plane or by boat. The sand and coral-rubble landing strip SE of Playa Sardinera can take only small planes. The DNR uses Vorniak Flight Service from San Juan.

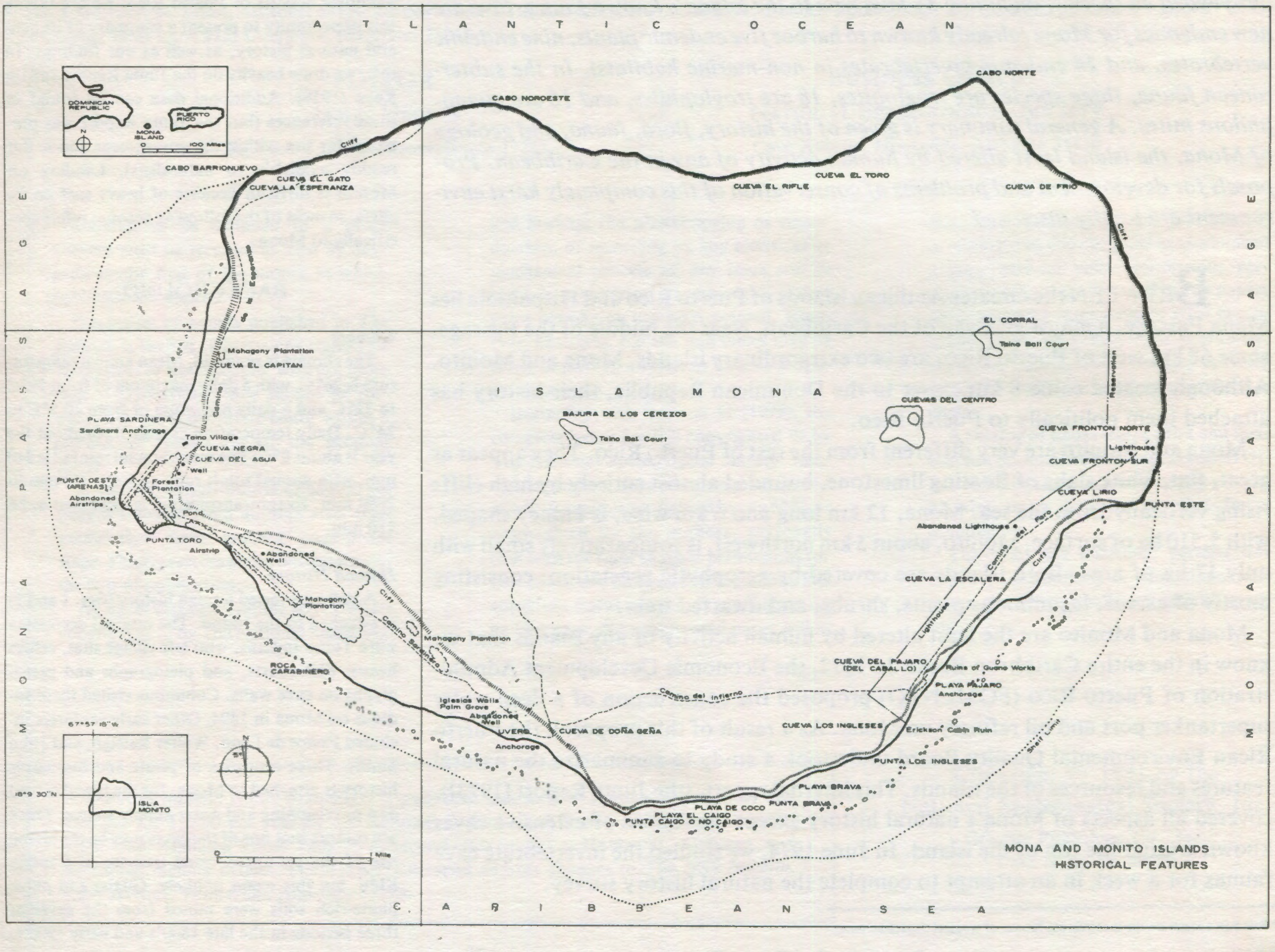
Flora

The vegetation of Mona includes 400 species of vascular plants, 50 of which are trees. The flora (Fig. 3) is similar to that of the xeric southwestern corner of Puerto Rico (Ewel and Whitmore, 1973) but also has affinities with that of the Dominican Republic. The island is the western range limit for 16 plants and the eastern range limit for five others. Five species are endemic. Some of the plants of Mona are long-range disjuncts, such as the Snow Cactus which also occurs in the British Virgin Islands but not on Puerto Rico. The vegetation once had economic significance, with tons of Lignum Vitae wood being removed. Some agriculture was previously conducted, but even the coastal plain is now judged to be sub-marginal for crops. Some alteration of the native vegetation has undoubtedly been caused by the browsing of introduced goats and the rooting of pigs, but the extent will probably never be known.

Fauna

Known land animals total nearly 700 species, not including those that may use the marine envi-

Figure 1. Mona Island, showing principal historical features. Insets show location of Mona (top), and plan of Monito (bottom). From Junta report.



ronment. Forty-six species of invertebrates and nine species of vertebrates are endemic. Seventy-five other species are not known to occur on Puerto Rico, itself. The only native non-marine mammals are two species of bats. Nearly 100 bird species are known, of which 14 are sea birds, 25 are shore birds, and two are endemic subspecies. Of the 9 known species of reptiles, 6 are endemic (2 snakes and 4 lizards). The endemic Coqui Tree-Frog, the islands only amphibian, can be heard calling in cave entrances, wells, and bromeliads. Several of the vertebrate species are threatened or endangered and are officially protected under the provisions of the Endangered Species Act of 1973 (Public Law 93-205), and all or large parts of Mona are designated or recommended as Critical Habitat. The invertebrate fauna is mostly composed of insects, with 526 known species, including 24 endemics. Of 16 land snail species, four are endemic. Mona and Monito are among the few places in the Caribbean where the Mongoose, that implacable foe of native animals, has not been introduced.

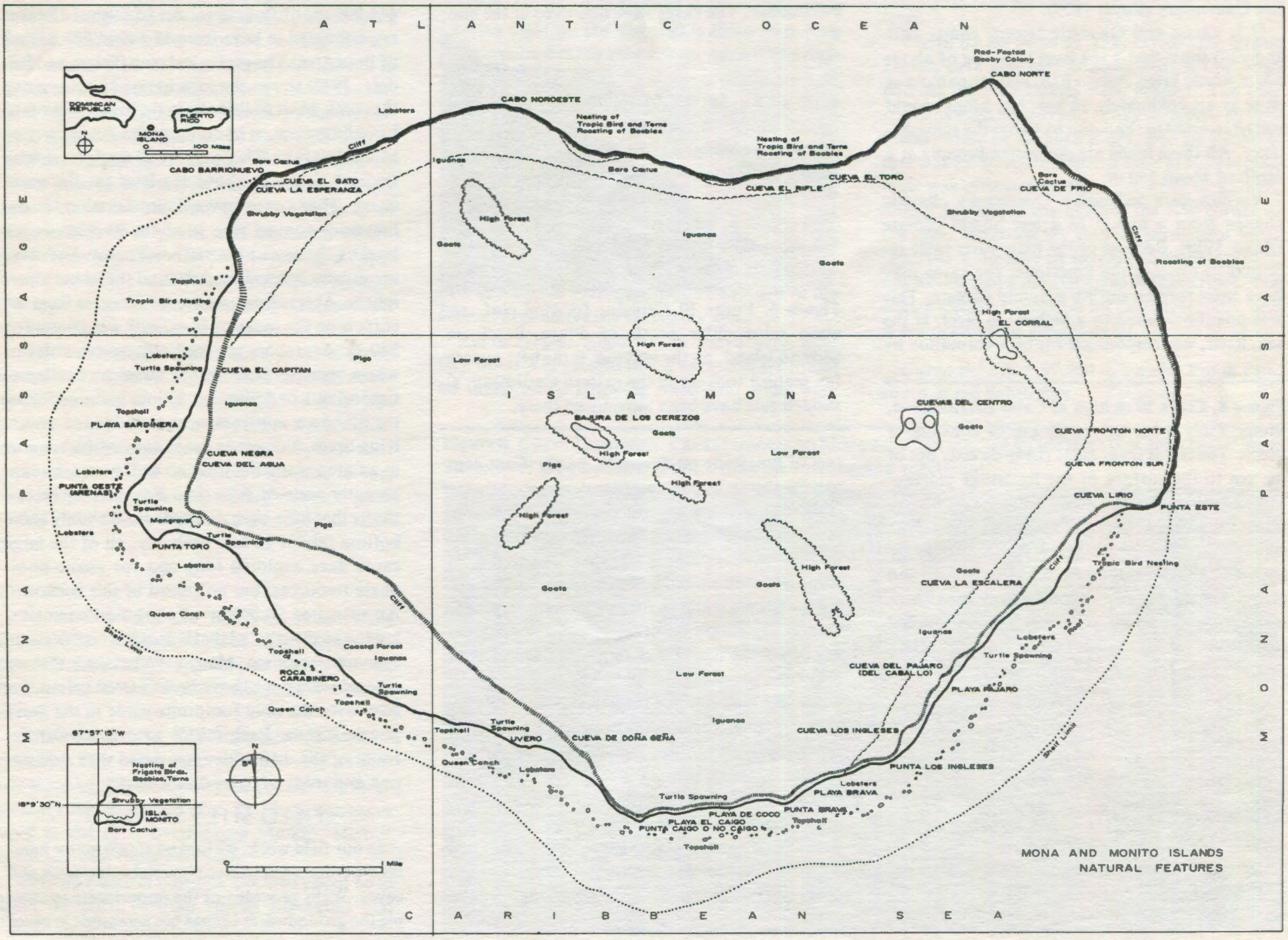
All of the fauna and flora are descendants of over-water immigrants. Mona has never been connected to another land mass since it was uplifted, possibly in the early Pleistocene. The marine passages between it and the Dominican Republic and Puerto Rico are too deep (more than about 400 meters or 200 fathoms) to emerge as land bridges connecting it with these islands at times of low sea stand in the Pleistocene (Heatwole and MacKenzie, 1967).

Geology

Mona Island is a limestone tableland (Fig. 4) bounded by steep to vertical cliffs and fringed on its southern perimeter by a narrow, low-lying, coastal terrace. We recommend Kaye (1959) and Briggs and Seiders (1972) for more extensive geological data. The lowlands comprise less than 6 percent of the total area of the island (Fig. 5). More than 90 percent of the island lies at 30 m or

Figure 3. *(left)* Mona's surface is covered with a semi-arid forest characteristic of xeric, lowland Caribbean sites. Bromeliads and aborescent *Opuntia* cactus grow from deeply solution-pitted limestone at an entrance to Cueva El Capitán.

Figure 2. Plan of Mona Island, showing principal natural biotic and geological features. From Junta report (1973).

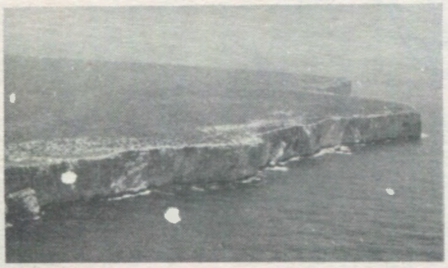


above in elevation, reaching a maximum elevation of 90m; thus, Mona was probably only partly inundated by eustatic sea level rises during interglacials. Isla Mona dolomite forms most of the mass of both islands. It is probably early or middle Miocene in age and is separated by an angular unconformity from the overlying and relatively thin Lirio limestone, which is thought (fossils are lacking) to be Pliocene or early Pleistocene in age (Kaye, 1959). Solution has removed an estimated 30 m of Lirio limestone from the surface of Mona without forming a karst surface of high relief. The great purity of the Mona dolomite and Lirio limestone suggests that Mona passage was probably already in existence in the Miocene. The nature of the limestone points to an ocean-reef depositional environment, far from a source of land-derived sediment. At the close of the period of deposition of the Lirio limestone, the island probably corresponded in size to the submarine bank which now surrounds Mona. This means that the shores of Mona have receded as much as 1.6 km since that time, while Isla Monito's shores have retreated as much as 3.2 km. Uplift was probably in the late Pliocene or early Pleistocene. Very little, if any, crustal movement has occurred at Mona in the late Quaternary (Kaye, 1959).

U.S. Coast and Geodetic Survey charts (901 and 920) show that a sea level lowering of about 370 m would bring Puerto Rico and Hispañiola as close as approximately 15 km, but Mona would still be isolated to the south by about the same distance. All these lands are connected broadly at a depth of about 550 m.

Various data indicate a Quaternary climatic change from a humid to a less humid climate (Kaye, 1959). Because of the high water table required to dissolve the limestone, the caves may have been formed during a humid climate. This was possibly related to a higher sea level. If the sea, itself, was responsible for cave formation by wave action and solution, then Mona has the world's largest and most extensive systems of sea caves (Quinlan, 1974). After the caverns were formed, they were occupied by numerous bats. The large size of the bat population is indicated by the great quantities of guano, but the time span of deposition is not known. Only a humid climate could support the myriads of insects eaten by such numerous bats. Guano deposition was abruptly terminated and followed by a less humid period during which dripstone was deposited over the guano (Fig. 6). Greater aridity may have resulted from climatic changes connected with a postglacial warm interval.

Figure 4. Cliffs 70 m high at Cabo Barrionuevo, Mona. Only 8 km of the 33 km of coastline is beach. The rest is sheer cliffs rising directly out of the sea to the surface of the limestone plateau. The seemingly level plateau is actually a sharp, pitted solution-pavement. The caves at Cabo Barrionuevo are about 10 m below the summit of the island, at the contact of the Lirio limestone and the underlying Mona dolomite. Many cave openings appear as a string of dark spots near the cliff top. Wave-eroded caves in the massive Mona dolomite of the cliffs are all shallow.



Our observations suggest an additional interval beside those just outlined in the historical development of the caves. Strongly eroded flowstones remaining on ledges and in wall pockets in Cueva al Lado del Faro and other caves nearby show that a period of intense solution followed what is probably the first period of flowstone deposition. A similar conclusion was independently reached by Quinlan (1974).

This interpretation, combined with the suggestions of Kaye (1959), yields the following speleogenetic scenario: Mona was elevated in the early Pleistocene. The caves were dissolved at the contact of limestone on dolomite, partly if not completely through marine control of groundwater level and zone of wave action. The caves were drained and the first flowstone-dripstone was deposited, perhaps during a glacial. The first flowstone was then eroded and the caves enlarged during a high sea stand in the following interglacial. Guano deposition occurred in the following glacial when the island was more moist, and some dripstone dissolution could have then occurred. Dripstone later covered the guano deposits during an interglacial (perhaps the present one). Verification of this chronology may be possible through the use of U/Th isotope dating of dripstone deposits, which will also indicate the times and duration of sea stands and Caribbean Pleistocene climates (Harmon, *et al.*, 1975). Additional data on the geological development of the island and its karst and caves were presented by Quinlan (1974).

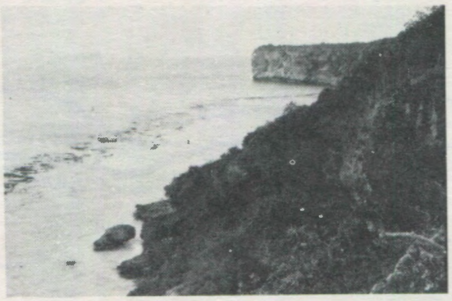


Figure 5. Punta El Capitán, fringing reef, and steep talus cliffs north of Playa Sardinera. Monito Island, on the horizon, is the best remaining seabird rookery in the eastern Caribbean, although rats have been introduced there.

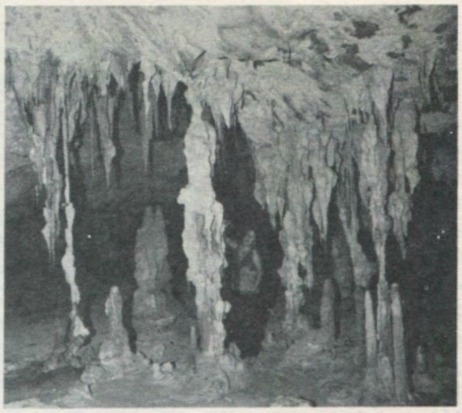


Figure 6. Dripstone speleothems in Cueva de los Pájaros. Some are still being deposited but others have been strongly dissolved by descending waters. Dripstone and flowstone deposits covered extensive, but now mostly mined-out, deposits of bat guano altered to phosphorite earth.

The Caves

Possibly 2 percent of the upland of Mona Island is underlain by caves. Briggs and Seiders (1972) determined that the 12 largest systems have 444,000 m^2 of floor area. An additional 15 caves are estimated to have from 18,500 to 225,000 m^2 of floor area. The geological map (Briggs and Seiders, 1972) shows the location of 25 caves along the coast. Most of these lie in the lower 10 m of the Lirio limestone, at its contact with the underlying Mona dolomite. The caves are all single level, with floors 7 to 10 m above sea level on the south coast. They range upwards in elevation, as the limestone contact rises to about 60 m above sea level on the more upraised north coast. The caves are mostly concentrated around the island's periphery. Average penetration of the caves from the cliffs is on the order of 50 m, with a maximum of 240 m. Entrances are typically on sea cliffs or where openings have formed due to roof collapse. Central sink or doline depressions in the middle of the island are apparently connected to few underlying caves. Numerous deep, narrow shafts occur in an area along the Camino de Cerezos, but apparently none of these join into caves. The few shafts that have been descended end blindly at the bottom (about 10 m). Probably, all of the large caves were explored long ago for guano-phosphate resources, but no record of this is known. An estimated 50,000 m^3 of phosphorite remains, but it is so distributed that it does not constitute an economic resource. Many cave passages that we entered seem not to have been entered before, for ours were the only footprints made in the deep, powdery soils. Beck (1975) gave a popular account of the difficulties associated with exploration and study of caves on the island.

FIELD SITES STUDIED

In our field work, we looked at two major habitat types for subterranean invertebrates: wells and caves. Wells provided us the opportunity to sample the groundwater faunas not accessible in caves lacking permanent water. Brief descriptions of the locations and conditions of the sites follow, in order of their occurrence from the northwestern corner of the island at Cabo Barrionuevo, south and east to near the lighthouse at Punta Este (see figs. 1 and 2).

Groundwater Sites

Dry cistern near beach below Cueva Capitán. Does not connect with groundwater, and we found no trace of the nearby seep in boulders mentioned by Briggs and Seiders (1972).

Pozo del Portugués. A covered cistern sitting in recent sediments at the base of a cliff near Playa Sardinera, penetrating the lense of "fresh" groundwater for about 1 m. Water temperature 26°C. Water was slightly brackish, with about 1,000 ppm dissolved solids in one measurement, and 1,900 ppm TDS (total dissolved solids) in another. Ostracods were abundant, but no other fauna were seen or captured with plankton net tows or at baits of crushed crabs.

Shallow well at water trough along road near Pozo Portugués. Collapsed and filled with debris and rocks. Water was present under the debris, but conditions seemed strongly anaerobic.

Well at edge of airstrip. This well, which has a broken windmill tower above it holding the airstrip wind sock, is 1.3 m wide and penetrates 3 m to water. The water is slightly brackish on the surface, with about 1,000 ppm dissolved solids. Another measurement gave 2,400 ppm TDS. Plankton nets baited with crushed crabs yielded no fauna after 12 hours. The water seemed strongly anaerobic at the well bottom from the decay of large additions of guano and discarded insect-food fragments from the cricket colony occupying the top of the well. This well was the source of the type series of the interesting groundwater shrimp, *Typhlatya monae* (Fig. 7).

Well at Desembarcadero Uvero. This abandoned well, open to daylight and near an abandoned watering trough, is about 1 m wide and penetrates about 2 m to water 0.6 m deep. Crickets were in the rock sides of the well, and their guano dropped into the water. Mosquito larvae, veliid bugs, and crabs were all that we could catch or see in the water, which had a salinity of 3,300 ppm.

Cave Sites

We studied 15 caves for their invertebrate faunas. The names and floor area figures are those used by Briggs and Seiders (1972), but we have given names to small sites not known to them.

Cueva Esperanza. 5,000 m², near Cabo Barrionuevo. Side arches and passages were all that remained of this cave when the roof of the large central room collapsed (Fig. 8). Many entrances open in the cliffs overlooking Monito. Hermit crabs and goat dung were seen.

Cave on Punta el Capitan. Located about 30 m from the cliff, between cuevas Esperanza and Capitán, with entrances on both sides of the trail going out onto the point. It contains about 150 m of wandering passage, with rooms and several breakdown entrances. Goat dung was abundant.

Figure 7. Sampling groundwater with plankton net in the 3 m deep well at the edge of the Playa Sardinera airstrip. This is the type locality and only known site on Mona for the subterranean shrimp, *Typhlatya monae.*

Cueva Capitán. 41,000 m², south of Punta el Capitán. It was extensively mined for phosphorite (Fig. 3).

Cueva Cabros. This is our name for a cave with a collapse entrance in the first shallow sink along Camino Cabros. The chamber is about 50 m long and contained many mosquitoes using it as a daytime retreat.

Cueva del Esqueleto. 20,500 m², a very large system paralleling the cliff face for about 300 m. It is dry, but contained a large, inactive guano pile about 3 m across from which we took a sample for Berlese extraction of animals.

Cueva del Diamante. 18,000 m², a nearly continuous southward extension of Cueva del Esqueleto. It is much altered by mining. Sites identified as "Cueva Esqueleto-Diamante" are in the general area where the two caves join.

Cueva Negra. 5,000 m², at Playa Sardinera. Dry wood was present in the cave, but we found no fauna on it. Dripping water and pools were present, but dung and carrion baits in the moist areas attracted no fauna. Here, the air was 23°C, and the relative humidity was nearly 100 percent.

Cueva del Agua. At Playa Sardinera. It is a large, complicated, heavily mined cave. Dry wood and some small piles of old guano were present. Pools at two spots contained no fauna. Air temperature was 29°C, and relative humidity was 92 percent. This cave was generally the wettest cave we saw, except near the bat colony in Cueva de las Losetas.

Singing Hole. Our name for the cave hollowed out at the bottom of a large boulder, near the cliff base east of the pond at Punto Toro. It has a walled entrance and was once used as a goat pen. Many crickets were constantly singing in the cave, and various flies used it as a daytime retreat.

Cueva de Doña Geña. 2,500 m², along the road at Desembarcadero Uvero where it ascends from the coastal plain to the upper plateau. Tree roots have grown into the lower cave level, and eyeless cixiid bug nymphs were feeding on them. Some fauna were concentrated around a small pile of bat guano.

Cueva de la Casa de Erichson. 5,000 m². This is essentially a single, dry tunnel, 10 m above sea level.

Cueva de los Pájaros. 128,000 m², the largest known cave and very complicated. A few small patches of fresh guano were present. The cave contains both eroded and active dripstone speleothems. Most of the cave is dry, and air temperature was 25°C. An interesting suite of sulfate minerals was efflorescing from the walls of a small, humid passage in the back of the NW corner of the cave. We could not find the permanent water reported in the cave by Briggs and Seiders (1972), but we did find a dry cistern in the cave floor. The cistern outside the cave is for rainwater, only, and is not open to the groundwater.

Cueva del Lirio. 97,000 m², under Punta Este, south of the lighthouse.

Figure 8. Cueva Esperanza. Cave entrances on Mona are often marked by the trees that grow out of them. These trees are greener and taller than the surrounding vegetation.

Cueva al Lado del Faro. 61,500 m^2, under the cliff, east of the lighthouse. Although very dry, it contained many eroded dripstone speleothems.

Cueva de las Losetas. 43,500 m^2, NNE of the lighthouse. It is the most moist cave of all we encountered. Many dripstone speleothems were active, and large, temporary rimstone pools were filled, but no fauna was seen in them. The air temperature was 27°C. A large nursery colony of the insectivorous bat *Mormoops blainvillii* Leach was present. This bat probably accounts for the other recent guano piles we encountered. A large guano pile from which many mites were recovered by Berlese funnel extraction was under the bat roost. Other faunal elements found in guano in caves of the Caribbean region were absent.

ANNOTATED LIST OF SUBTERRANEAN INVERTEBRATES

The following list of our invertebrate findings is presented in the format of an earlier list of Puerto Rican cave invertebrates (Peck, 1974). The terms "trogloxene," "troglophile," and "troglobite" are used to indicate the relative levels of ecological restriction and morphological specialization to subterranean habitats. A trogloxene must leave the cave to complete some part of its life cycle. A troglophile can permanently maintain itself in caves but generally shows no morphological specialization for cave live. Troglobites are limited to, and specialized for, subterranean life.

The term "liminal" indicates that an animal is only seeking a daytime retreat in the cooler, more moist, or darker parts of the cave. This category includes the "parietal association" of European cave faunal literature (Vandel, 1965). "Guanophiles" are those organisms restricted to guano deposits (the "guanobia" of Vandel [1965]); they are not true cavernicoles. An ecological categorization about feeding habits is used to indicate the trophic function of the species in the community.

PHYLUM ARTHROPODA
CLASS ARACHNIDA
ORDER ACARINA*

Family Anoetidae
New genus?
Cueva de las Losetas, 5 f.
Possible strainer-feeder of microorganisms of surface water films (on wet guano pellets?).

Family Argasidae
Antricola coprophilus (McIntosh)
Cueva de las Losetas, 4 m, 5 n.
An obligate blood-feeding ectoparasite of bats (and other vertebrates).

Family Ascidae
Protogamasellus primitivus Karg
Cueva de las Losetas, 1 f.
Possibly feeding on nematodes, or other small prey.

Family Galumnidae
Erogalumna sp.
Cueva Diamante, 1 f, 1 m.
Oribatei, saprophagous and/or fungivorous, feeders on decaying guano materials.

Family Laelapidae
Hypoaspis (Stratiolaelaps) miles (Berlese)
Cueva de las Losetas, 5 f, 2 m, 1 n.
This and the next species are probably free-living predators of small arthropods (and nematodes?).
Hypoaspis sp., nr. *intermedia* Hirschmann
Cueva Diamante, 1f, 1n.

Family Lohmaniidae
Lohmannia sp.
Cueva de las Losetas, 1 f, 1 lar.
Saprophagous.

Family Malaconothridae
Malaconothrus sp.
Cueva de las Losetas, 2 f, 1 n.
Oribatei, saprophagous or fungivorous, generally in more moist microhabitats.

Family Oribatulidae
Scheloribates sp. 1
Cueva de las Losetas, 1 f.
Oribatei, saprophagous or fungivorous.

Family Phytoseiidae
Amblyseius sp., *obtusus* group
Cueva de las Losetas, 1 f.
Free-living predator.

Family Sphaerochthoniidae
Sphaerochthonius sp.
Cueva Diamante, 4 f.
Oribatei, probably saprophagous.

Family Tarsonemidae
Tarsonemus fusarii Cooreman
Cueva de las Losetas, 1 f.
Fungivorous.
Tarsonemus sp. 1
Cueva de las Losetas, 1 f.
Fungivorous?
Tarsonemus sp. 2
Cueva de las Losetas, 1 f.
Fungivorous?
Tarsonemus sp. 3
Cueva de las Losetas, 1 f.
Fungivorous?

Family Tydaeidae
Microtydaeus sp.
Cueva Diamante, 2 f.
Fungivorous?

Family Uropodidae
Uroactinia sp., nr. *hippocrepoides* (Vitzthum)
Cueva de las Losetas, 1 n.
Fungivorous grazer?

ORDER AMBLYPYGI

Family Phrynidae
Paraphrynus viridiceps (Pocock) (?), new family record for Mona.
Cueva de Doña Geña, Cueva de las Losetas

*The list of 17 species of mites, all recovered from bat guano, seems a surprisingly rich one. It is the first detailed documentation of this association from bat guano caves in the New World tropics, and it is of interest to note the low abundance of taxa that are predators and ectoparasites. The identifications were all made by Dr. Evert Lindquist, Agriculture Canada, and are based on the numbers of slide-mounted individuals shown as females (f), males (m), nymphs (n), and larvae (lar). Additional material is unmounted. For a summary of classification and general feeding, see Krantz (1978). For the details of specific feeding habits in the oribatei group of families, see Luxton (1972). All these mites, except the *Antricola*, may collectively be called guanophiles.

The species in Puerto Rico has variously been placed in the genus *Tarantula* or *Phrynus* under the specific names *fuscimana* or *palmata*. However, too-few West Indian collections have been studied to be certain of the range of the above species, known certainly from Cuba and the Bahamas (see Mullinex [1975] for details). We also found one specimen under rocks in the forest near the airstrip. Troglophile, predator.

ORDER OPILIONES

Family Phalangodidae
Stygnomma sp., C. and M. Goodnight det., new family record for Mona.
Cueva de Doña Geña, Cueva Esqueleto-Diamante
This genus occurs on islands and the mainland in the Caribbean area. A species has become a troglobite in Jamaica. Troglophile?, predator.

ORDER ARANEAE

Family Linyphiidae
Meioneta sp., W. J. Gertsch det., new family and generic record for Mona.
Cueva Esqueleto-Diamante, 1 f.
Troglophile?, predator.

Family Ochyroceratidae
Theotima minutissima (Petrunkevitch), W. J. Gertsch det., new species record for Mona.
Cueva de Doña Geña, 1 f.
This species is also associated with caves on Jamaica and Puerto Rico (Peck, 1974, 1975). Troglophile, predator.

Family Oonopidae
Oonops sp., W. J. Gertsch det., new family and generic record for Mona.
Cueva de Doña Geña, 1 f.
This eyeless species is undescribed and probably evolved from a weakly hygrophilic litter ancestor. Troglobite, predator.

Family Pholcidae
Modisimus sp., W. J. Gertsch det., new generic record for Mona.
Small cave on Cabo Barrionuevo, 1 m. This is an undescribed species. Several other species in the genus occur on Puerto Rico and are associated with caves (Peck, 1974; Petrunkevitch, 1929). Troglophile, predator.

Family Scytodidae
Loxosceles caribbaea Gertsch, W. J. Gertsch det.
Cueva de los Pájaros, 3 immatures; Singing Hole, 1 f; Cueva Cabro, 2 immatures.
Previously known from Mona. The species is also known from the Dominican Republic, Jamaica, and Puerto Rico. It occurs in caves in the last two islands (Gertsch, 1958; Peck, 1974). Troglophile, predator.

Family Theridiidae
Thymoites guanicae (Petrunkevitch), W. J. Gertsch det., new generic and species record for Mona.
Cueva de las Losetas, 1 f.
The species was described from SW Puerto Rico in the genus *Theridion*, moved to *Sphyrotinus* (Levi, 1959), and then to *Thymoites* (Levi, 1964). It is known from Jamaica, Hispañiola, Puerto Rico, the Virgin Islands, and various Mexican localities (Levi, 1959). It lives in litter and under stones as well as in caves. Troglophile, predator.

ORDER SCHIZOMIDA

Family Schizomidae
Schizomus monensis Rowland and Reddell, 1979; new ordinal record for Mona, and the species is endemic.
Cueva del Agua, Cueva de Doña Geña, Cueva Negra
Troglophile, predator.

CLASS CRUSTACEA

ORDER OSTRACODA

Family, genus, and species undetermined
Pozo Portugués
Many from meat baits in water and from plankton net tows. Troglophile, scavenger.

ORDER DECAPODA

Family Atyidae
Typhlatya monae Chace
The type series was taken on Mona Island in concrete catchment basins, where they had been dumped with water pumped up for livestock by the windmill at the edge of the airstrip (Chace, 1975). We found none in this well, whose waters were anaerobic from large deposits of cricket guano. We also did not find the species at the other water sources investigated such as Pozo Portugués, various pools, or the well at Playa Uvero. We know of no collections of this shrimp from Mona except the type series. However, the species is also known from groundwater on other West Indian islands (Hispañiola, Puerto Rico itself, and Barbuda) and thus has a linear range of at least 850 km (Chace, 1954, 1975; Chace and Hobbs, 1969; Hobbs, Hobbs, and Daniel, 1977; Peck, 1974). This presents interesting questions of evolution and distribution. Troglobite, scavenger.

Family Gecarcinidae
Gecarcinus ruricola (Linnaeus)
Cueva de las Losetas
This land crab was seen only in this cave, but burrows and tracks are abundant in soils in many caves. Trogloxene, scavenger.

ORDER ISOPODA

Family Oniscidae
Metaponorthus pruinosus (Brandt)?
Cueva de los Pájaros
Ten on old mining railway ties and in dry cistern. This is a widespread species transported by man. Troglophile, scavenger.

Family, genus, and species undetermined
Cueva de las Losetas
A small-eyed, terrestrial isopod on guano. Troglophile, scavenger.

CLASS DIPLOPODA

ORDER POLYXENIDA

Family Polyxenidae, H. F. Loomis det., new class, ordinal, and family record from Mona.
Genus and species undetermined
Cueva Negra, Cueva del Agua
Common on dry wooden ties of guano mining railways. These millipedes are often found in very dry coastal situations, and even in mangroves, where they probably scavenge on plant debris. Berlese funnel sampling of forest debris found no other millipedes. Troglophile, scavenger.

CLASS COLLEMBOLA

ORDER ENTOMOBRYOMORPHA

Family Entomobryidae
Metasinella topotypica Bonét, J. Mari Mutt det., new generic record for Mona.
Cueva de Doña Geña

Nine found on debris. This is a tiny, eyeless species, also known from Cuba. Troglophile, scavenger.

Pseudosinella sp., K. Christiansen det., new generic record for Mona.
Cueva Diamante
Five in a 2 l sample of slightly moist guano. Troglophile, scavenger.

CLASS INSECTA

ORDER BLATTARIA

Family Blattidae
Periplaneta americana (Linnaeus), A. B. Gurney det.
Cueva Negra, 4 n; Cueva de los Pájaros, 1 f, 5 n; Cueva Esqueleto-Diamante, 1 f, 2 n.
Previously known. This Old World cockroach is now widespread in the New World and frequently is found in caves around the Caribbean (Peck, 1974). Troglophile, omnivore.

ORDER ORTHOPTERA

Family Gryllidae
Amphiacusta sp., T. J. Walker det.
Well at airstrip; Singing Hole; in outhouse at Desembarcadero Uvero; heard chirping in shafts along Camino de los Cerezos (Fig. 9)
This is an undescribed species that should not be confused with *A. caraibea* Saussure reported on Mona by Ramos (1946). It sings in the caves and is at least partially predatory, judging from the insect fragments in its guano. Other species in the genus frequent caves on Puerto Rico, Hispañiola, and Jamaica (Peck, 1974). Trogloxene, omnivore.

ORDER HEMIPTERA

Family Veliidae
Microvelia albonotata Champion, R. C. Froeschner det., new species record for Mona.
Well at Playa Uvero
This small water-strider ranges widely from Michigan to Peru and through the Caribbean. It is reported from cave pools in central Florida (Drake and Hussey, 1955). Troglophile, omnivore.

Family Cixiidae
Genus and species undetermined, new family record for Mona.
Cueva de Doña Geña
Two nymphal eyeless bugs were taken on roots in this cave. Eyeless species are also known from caves in Jamaica, Mexico, and Hawaii (Fennah, 1973). Troglobite?, herbivore.

ORDER PSOCOPTERA

Family Psyllipsocidae
Psocatropas microps (Enderlein), E. L. Mockford det., new generic record for Mona.
Singing Hole, 1 m.
This is a widespread species in houses throughout the tropics and subtropics. Liminal trogloxene, scavenger.

Ectopsocus sp., E. L. Mockford det., new generic record for Mona.
Cueva Esqueleto-Diamante, 1 n, 1 f.
From a 2 l guano sample. The species is widespread in the West Indies and the adjacent mainland but not usually found in caves. Troglophile, scavenger.

Figure 9. *Amphiacusta* sp., an undescribed cricket often heard singing in caves and wells. Mature males chirp with their wings, but mature females are wingless. Insect fragments in its droppings show that the species is largely if not exclusively predatory.

ORDER LEPIDOPTERA

Family Tineidae
Tinea sp., D. R. Davis det., new family record for Mona.
Cueva Diamante, 10 lar.
In dry guano. Tineids are common on guano in caves in Puerto Rico, Jamaica, and elsewhere (Peck, 1974, 1975). Troglophile, scavenger.

ORDER COLEOPTERA

Family Lyctidae
Genus and species undetermined, new family record for Mona.
Cueva de las Losetas
Sticks deep in the cave contained borings of this powder post beetle, but adults could not be reared from them. Trogloxene, scavenger.

ORDER DIPTERA

Family Tipulidae
Trentepohlia dominicana Alexander, C. P. Alexander det., new species record for Mona.
Singing Hole
In dark zone of this rock shelter. Liminal trogloxene, scavenger.

Family Culicidae
Culex (Tinolestes) americanus (Nevea-Lemaire), D. M. Wood det., new species record for Mona.
Singing Hole, Cueva Cabros
In dark zone of these rock shelters. The species is widely distributed in the West Indies. Liminal trogloxene, predator?

Family Cecidomyiidae
Genus and species undetermined
Singing Hole
Eight in dark zone. Liminal trogloxene, scavenger?

Family Milichiidae
Leptometopa sp., J. F. McAlpine det., new generic record for Mona.
Cueva Esqueleto-Diamante
The larvae of these flies feed on bat guano, in which they were abundant. Troglophile, scavenger.

DISCUSSION

A total of 46 species of non-accidental macroscopic invertebrates are now known from subterranean habitats on Mona Island. Of these, 25 are known by species name or are recognized as new. The total count is not precise, because groups like isopods cannot now be specifically determined and because additional field work should find some others.

Two species are endemic troglobites (a spider and a cixiid bug), and another troglobite *(Typhlatya monae)* occurs elsewhere as well. Three species are endemic troglophiles. Six species are known to associate with caves in other parts of their range, and at least 3 species have certainly been distributed by man. At least 35 taxa are new additions to the knowledge of the fauna of Mona Island.

The cave fauna, with 3 troglobites and 34 troglophiles and guanophiles, must be considered remarkably rich and varied in view of the small size and remoteness of Mona. In addition, the caves are dry, and food input is limited. This fauna reached Mona and occupied its subterranean habitats since the island was elevated above the sea at some time in the Pleistocene. None of the invertebrates are spectacular finds in themselves, but in combination they add to the interest of the unique biota of Mona. None of the invertebrates seems to be immediately threatened by increased visitor use of this island. However, *Typhlatya monae* could be endangered if there is any large scale pumping of the freshwater lens that it still must occupy under Mona. Increased pollution of the groundwater at Pozo Portugues by soap, detergent, and shampoo is probably the greatest present threat to aquatic faunas.

None of our field experience in faunal studies of cave and forest litter arthropods in temperate and tropical regions has given us such a thrill of exploration and discovery, as well as access to such pristine habitats, as the work on Mona. Protection of the caves must be considered in the future. This might seem paradoxical in light of the extensive alteration of many of the larger caves by past mining activities, but many cave passages seem not to have been previously entered. Protection must include the remaining mining relics as well as the Indian pictographs and petroglyphs. The bat nursery colony and the dripstone speleothems must likewise be protected from thoughtless vandalism. Perhaps this can best be done by encouraging visitation to only some selected caves, and not publicizing other, more sensitive locations.

THE FUTURE

By late 1974, plans to develop Mona as a supertanker port and oil refinery were apparently abandoned as a result of the transfer of naval bombing and gunnery target ranges from the partially inhabited island of Culebra to uninhabited Desecheo and Monito Islands. Construction of a port and refinery on Mona, so close to the artillery and bombing target of Monito would be inappropriate. We hope that Monito, the last remaining large seabird rookery of the eastern Caribbean will not be used for this new function.

Mona and Monito are both registered National Landmarks. They are at present under the protective administration of the Puerto Rico Department of Natural Resources, which is preparing a plan for the wisest use and preservation of the islands. Another study has been conducted to determine feasibility of including the islands in the federal system of lands protected by the National Park Service. Federal legislation, and cooperation from the Commonwealth, would be required to change their present status. Correspondence with Park Service officials indicates that they presently have more urgent land acquisition priorities. So far, the islands remain "as is", as an alternative to massive settlement, utilization, or industrialization as ports or refineries.

However, some sort of active protection and plan for limited development is necessary as a greater guarantee against gradual loss of the natural value of the islands. Their potential contribution is to health, education, employment, and leisure activities.

At the time of this writing, Mona (but not Monito) and all the record that it yet contains of tropical karst and its attendant biological and geological phenomena, seems to have been "saved." The Department of Natural Resources is to be commended for working to establish Mona as a Natural Reserve, for its protection and preservation. Six uniformed Conservation Rangers with law enforcement powers are now stationed on Mona (Dodd, 1978), and we hope they will fully enforce both Commonwealth and federal regulations to protect what is still the least altered (but nevertheless a fragile) ecosystem yet remaining in the Caribbean.

ACKNOWLEDGEMENTS

We wish to thank Dr. Barry F. Beck (formerly of DNR) for generous hospitality, for helping in making arrangements for our visit to Mona, and for refractometer water salinity determinations. The DNR encouraged our study and provided lodging and water supplies on Mona. Dr. James F. Quinlan, Jr. made available a copy of his report on the caves and karst of Mona. The taxonomic specialists who contributed determinations of the collections are warmly thanked, because without their help our attempts at synthesizing information on this and other tropical cave communities could not succeed. The field work was partially supported by a Canadian National Research Council operating grant. Manuscript comments were provided by drs. Francis Howarth, John R. Holsinger, and E. L. Bousfield, and by two anonymous reviewers.

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Manuscript received by the editors 8 May 1979.
Revised manuscript accepted 17 March 1980.

The first qualification of a writer, is a perfect knowledge of the subject which he undertakes to treat; since we cannot teach what we do not know, nor can properly undertake to instruct others while we are ourselves in want of instruction. The next requisite is, that he be master of the language in which he delivers his sentiments; if he treats of science and demonstration, that he has attained a style clear, pure, nervous, and expressive; if his topics be probable and persuasory, that he be able to recommend them by the superaddition of elegance and imagery, to display the colours of varied diction, and pour forth the music of modulated periods.

If it be again inquired, upon what principles any man shall conclude that he wants these powers, it may be readily answered, that no end is attained but by the proper means; he only can rationally presume that he understands a subject, who has read and compared the writers that have hitherto discussed it, familarized their arguments to himself by long meditation, consulted the foundations of different systems, and separated truth from error by a rigorous examination.

In like manner, he only has a right to suppose that he can express his thoughts, whatever they are, with perspicuity or elegance, who has carefully perused the best authors, accurately noted their diversities of style, diligently selected the best modes of diction, and familiarized them by long habits of attentive practice.

SAMUEL JOHNSON

Adventurer, 11 December 1753

TECHNICAL NOTE

Style books, to guide authors in preparing their manuscripts, have been published by many journals and professional associations. *The NSS Bulletin* has none. We believe that yet another style book would be superfluous; moreover we consider written language to be an art form which should not be made to lie in a Procrustean bed.

Style, in one sense, is a series of rules ensuring that communication is complete and effective, that the data and interpretations are adequate, logically expounded, and fully documented. Following these rules is the author's responsibility, and they can be learned from any style book. We find the University of Chicago Press 'A Manual of Style' to be suitable for most purposes.

In another sense, style has to do with the arbitrary arrangement of headings, footnotes, citations, etc. within a publication. The typist should look at a recent issue of the journal to which the manuscript is to be submitted, in order to learn the correct form of presentation, before commencing the final draft.

Those are the mechanical forms of 'style,' ones which are verified by editors before a manuscript is sent to the printer. All too many writers (and editors!) act as though there were nothing further to do. In fact, the most important part of the author's job remains: That of making his story interesting, compelling, aye (!) irresistible. The most closely reasoned argument will fail if no one pays attention to it. Style, as artistry, must be developed by practice, by reading and emulating the work of good writers.

We realize that many *Bulletin* contributors are inexperienced. The editors are sometimes very heavy handed with poorly done manuscripts; such manuscripts tend to be recast in the mould of the individual editor. Where, however, it is clear that an author has definite ideas about style, we grant him full measure of independence. So long as the first two considerations of style (above) are satisfied, the third, artistic, element is his alone to decide.

A helpful brief source of information is the 'MLA Stylesheet,' published by the Modern Language Association. The 'Instant English Handbook,' published by the Career Institute, Mundelein, Illinois, is a comprehensive grammatical guide; another comprehensive work, one generally available in college bookstores, is the 'Harbrace College Handbook,' published by Harcourt Brace Jovanovich, NYC. The latter has the advantage of being revised every few years to accommodate changing literary fashions. Courses in technical writing are available through the extension divisions of some colleges. All of these sources should help the prospective author achieve a more artistic product.

The relationship between clear writing and sound logic is well stated in articles such as 'Sounder Thinking Through Clearer Writing' by F. P. Woodford (*Science,* **ns 156**:743-745), 'Freight Trains' by J. A. Peoples (*Science,* **ns 153**:480), and 'Little Thought Given to Requirements of Good Writing' by Norman Cousins (*Saturday Review,* 8 June 1963).

Writing styles, like clothing fashions, change with time. Thus, one should not spend time cultivating a literary style but try instead to make one's writing as clear as possible. For example, geologists seldom read Hutton; they read Lyell. Hutton used a style of writing which overlaid many of his ideas (however good the ideas were!) and confused rather than enchanted his readers. Lyell took nearly those same ideas, and he made them so simple and clear that 150 years later he is still read.

Authors should remember that written language must communicate through time as well as across space. The more traditional and general the style, the longer your paper will be intelligible to posterity. The editors intentionally discourage the use of hip jargon and the latest fads, although we realize that, should we drag our feet too hard, we won't be understood by our contemporaries, much less by future generations. **JH, Oscar Hawksley (Central Missouri State University), Donald W. Ash (Indiana State University), Karl Barnaby (Indiana State University)**

ADDITIONAL READINGS

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ZOOGEOGRAPHY OF INVERTEBRATE CAVE FAUNAS IN SOUTHWESTERN PUERTO RICO*

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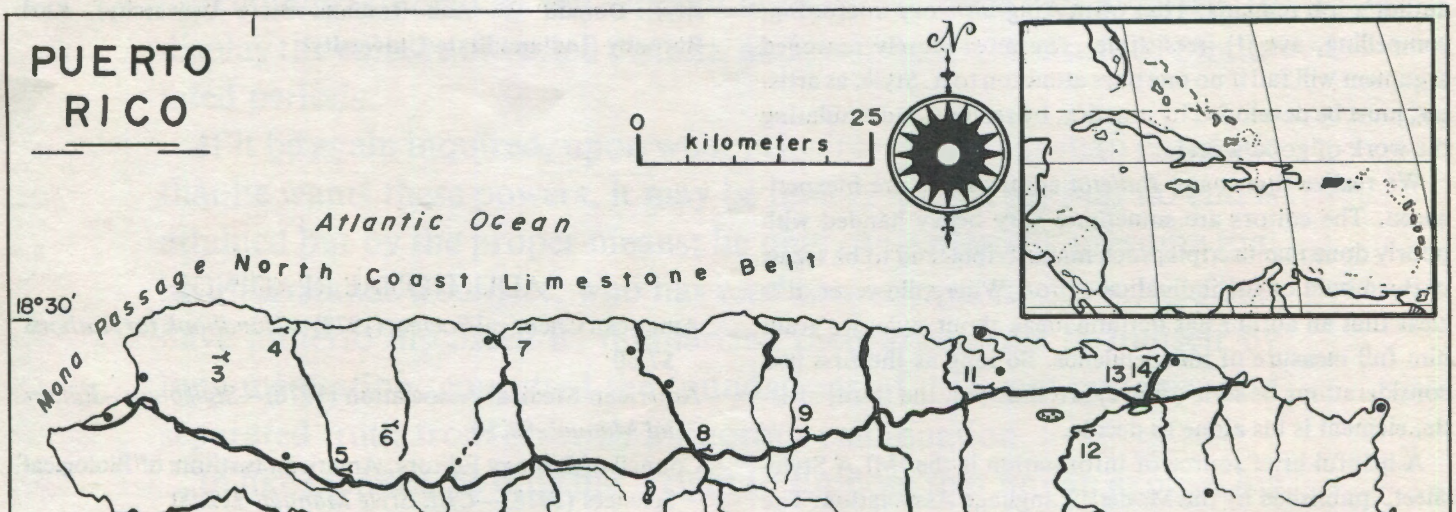
SUMMARY

Taxonomic data are given as results of new faunal investigations of 5 Puerto Rican caves. This adds 73 species (including 6 troglobites, or obligate cavernicoles) to the known list of non-accidental, cave-dwelling, macroscopic invertebrates; bringing the total to 151 for Puerto Rico (excluding Mona Island). The terrestrial troglophile community in caves in the subtropical, arid, forest life-zone of the south coast has a 43% faunal resemblance to the community in the caves of the subtropical, moist, forest life-zone of the north coast. The similarity is mostly due to species requiring moist environments; most of the species are also known from outside caves, being found in moist, forest leaf-litter. This suggests past climatic change and that the subtropical, moist, forest zone once included at least part of the area containing the south-coast caves. The former presence of moist forest around the caves gave colonizing access to the caves to some of the invertebrates living in the moist, forest leaf-litter. Cueva Los Chorros should receive protection to limit disturbance to its rich faunal community.

*Part 7 in a series on the invertebrate faunas of tropical American caves.

Figure 1. Puerto Rico, showing numbered locations of caves which have been biologically investigated. The North Coast Belt and the South Coast Belt are mostly composed of continuous and gently dipping limestones of Oligocene and Miocene ages and of Quaternary alluvium. Darkly shaded areas are windows of limestone of early Tertiary or Cretaceous ages (map adapted from Guisti, 1978 [after Briggs and Akers, 1965] and from Zapp, Bergquist, and Thomas, 1948). Caves for which new data are given in this paper are: **6.** Río Camuy System. **15.** Cueva Los Chorros. **16.** Cueva Tuna. **17.** Cueva de los Murciélagos and Shelter Cave in Guánica State Forest. **18.** Cueva El Convento. The dashed line roughly delimits the boundary between the subtropical moist forest life zone on the north and the subtropical arid forest life zone on the south (from Ewel and Whitmore, 1973). Even though Cueva Tuna seems to be in the moist forest life zone, climatic conditions here are still so strongly seasonal that many troglophilic species would probably be unable to exist in forest leaf litter today. Cueva El Convento is in the Los Cedros gorge, which supports an isolated enclave of subtropical moist forest (Cintrón and Beck, 1977). Inset shows Puerto Rico (darkened), at the east end of the Greater Antillian island chain.



Since the publication of an earlier paper on the invertebrate cave faunas of Puerto Rico (Peck, 1974), I have had the chance to conduct more cave-faunal field work on this West Indian island. In May 1973, I helped teach a two-week field course that intensively studied the subterranean ecosystem of Aguas Buenas Cave. Additional work was accomplished in June 1974, when I spent a week on Mona Island and a week and a half on Puerto Rico itself, mostly in the dry, southwestern corner of the island. The results of the Mona study are given elsewhere (Peck and Kukalova-Peck, this issue), and those for the Aguas Buenas study will be presented later. This paper provides data supplementary to that already published on the faunas of the caves of the north coast of Puerto Rico, and gives the results of the study of the faunas of caves located in the subtropical, arid, forest life-zone in southwestern Puerto Rico.

General data and discussion of Puerto Rican cave faunas and their evolution, given in my 1974 paper, will not be repeated here. Recent cave discovery and exploration efforts have continued to produce significant finds. Beck (1975a), Guisti (1978), and Monroe (1974, 1976a, 1976b, 1976c, 1979) have contributed additional papers important to the understanding of Puerto Rican karst developmental processes and landscapes. Beck (1973, 1975b) discusses the cave and karst features of southwestern Puerto Rico.

CAVE SITES STUDIED

The cave sites are numbered on Figure 1, sequentially building from those discussed in the 1974 paper.

North Coast

6. Río Camuy System. We explored from the Spiral Sink to the Tres Pueblos Sink entrances of this large cave. Additional collections from the Cueva Del Humo section were made for me by Mr. Forest Miller. Additional data, references, and maps on the cave system are given in Gurnee and Gurnee (1974), Davis and Zawlocki (1975), and Sullivan (1976).

15. Cueva Los Chorros. The cave is situated on the main highway, 15 km south of Arecibo, at about 35 m ASL. Two entrances are on the cliffside, SW of and above the road at the Restaurante Los Chorros. One entrance is a permanent spring resurgence, and the other is so only in wet weather. The cave is a chamber and stream passage only a few hundred meters long, with silt banks and guano patches.

The cave is one of the most important known in Puerto Rico, because of the abundant and unusually varied composition of its fauna and because it contains a troglobitic milliped and cockroach. Guano Berlese samples contained cydnid bugs, nitidulid beetles, terrestrial isopods, ants, centipedes, millipedes, 17 species of mites, and abundant fly larvae, ptiliid beetles and collembola.

South Coast

16. Cueva Tuna. This large-diameter cave is located in the Cotui limestone member of the Upper Cretaceous San German formation, on the top of a hill, about 3.5 km SE of Cabo Rojo. A chamber with a temperature of 25.5°C is at the base of the entrance slope. This ascends to a high-ceilinged bat chamber. An *Artibeus* bat nursery with temperatures of 29°C and higher is in a side passage near the cave front.

A rich guano fauna exists. A Berlese sample contained carabid and elaterid beetles, ants, pseudoscorpions, terrestrial isopods, tineid moth larvae, and many mites of about 7 kinds.

This may be the cave that I earlier listed as No. 2 known only as being 11 km from Yauco.

17. Guánica Forest Caves. These are located in the Guánica State Forest, in the middle Tertiary Ponce limestone, about 9 km E of Guánica. The cave is composed of several segments, which have received various names. The largest cave is locally called "the bat cave" or, more specifically, La Cueva de los Murciélagos de Guánica. This has several sink and collapse entrances on the north. Most of the southern half of the cave is floored by a brackish lake containing vast quantities of liquified guano (Lake Guano), usually reached by a large collapse (entrance 6). Rarely is the cave traversed from the northern to the southern entrances because of the large lake between them.

A small but deep and clear pool exists in the SW corner of the northern half of the cave. It contains a subterranean crustacean fauna of *Stygiomysis*, *Metaniphargus*, and *Typhlatya*. The water in this pool is hypersaline, with a conductivity of 68,000 μmhos at 26.5°C, which indicates a TDS of about 100,000 ppm. The pH was 8; Ca and Mg by AA were 94 and 63 ppm, respectively.

Water chemistry for Lake Guano is: conductivity, 23,000 μmhos at 29°C; chloride, 6,000 ppm; total hardness, 2,900 ppm $CaCO_3$ equivalent; Ca hardness, 1,100 pm $CaCO_3$ equivalent; H_2S, 20 to 50 ppm; pH, 7.65 to 7.9; dissolved oxygen, less than 2 mg/l; TDS, 35,000 ppm; Ca by AA, 174 ppm; Mg by AA, 174 ppm.

A dryish guano Berlese sample contained tenebrionid beetle larvae, pseudoscorpions, tineid moth larvae, and many mites of several kinds.

The second and disjunct part of the cave is what we have called the Shelter Cave. It opens at the edge of a small ravine, a hundred yards or so south and east of entrance 6 of Cueva de los Murciélagos. It is small, only about 30 m long and 25 m wide. Just 10 m inside is a pool extending the rest of the length of the cave. The ceiling is about 3 m high, and the floor is flat—sloping gently toward the back, where it lies under nearly 1 m of water. Tidal fluctuation of pool level was observed. Water temperature was 25.5°C. The pool contains 3 kinds of molluscs and the subterranean crustaceans *Metaniphargus, Typhlatya,* and *Antromysis.* The water is brackish, with a conductivity of 95,000 μmhos at 26.5°C. It undoubtedly has direct connections with the groundwater in nearby Cueva de los Murciélagos.

18. Cueva El Convento. This system is located in the middle Tertiary Juana Díaz formation, at the head of a karst gorge known as Quebrada de los Cedros, about 5 km ENE of Guayanilla. Beck (1974, 1975a) has described the geology and hydrology of the system and provides a map. Some aspects of its ecology are covered by Sullivan (1974). Cintrón and Beck (1977) have shown how the differing microclimate of the karst gorge containing the cave has isolated a forest type otherwise typical of sites that are moist and at higher elevations.

The Cueva El Viento section is a large and dry upper-level cave with an opening high above the valley floor. No fauna were seen here.

The Ojo de Agua and El Convento cave sections of the subterranean stream can be explored for about 500 m. Stream debris and guano support the fauna. A moist Berlese sample contained adult and immature schizomids, ants, terrestrial isopods, tineid moth larvae, and many mites.

ANNOTATED FAUNAL LIST

This faunal list contains new records of taxa previously known, as well as taxa new to the list of Puerto Rican invertebrate cave faunas. The numbering system is the same and a continuation of that in my 1974 paper. The list is still far from complete, because specialists are not available to work up all taxa; *e. g.*, terrestrial isopods. The organization, terms for ecological-evolutionary dependency on caves, and feeding categories follow those used in the 1974 paper. Distributional and other comments on previously listed species are not repeated.

PHYLUM ANNELIDA
CLASS OLIGOCHAETA

Family Lumbricidae

79. ***Eisenia*** sp., J. W. Reynolds det.

Cueva El Convento, 2-0-0 (juveniles, aclitellates, clitellate and mature adults; respectively) in big silt bank.

Troglophile, detritivore.

Family Octochaetidae

3. ***Dichogaster*** sp., J. W. Reynolds det.

Cueva Tuna, 0-0-1 in wet soil at guano.
Troglophile, detritivore.

PHYLUM MOLLUSCA
CLASS BIVALVIA
ORDER ANISOMYARIA

Family Dreissenidae
80. *Mytilopsis leucophaeata* (Conrad), K. W. Boss det.
Guánica Shelter Cave, many fastened by byssal threads to rocks in brackish pool.
The species is also found in a brackish pool in a Jamaican bat cave (Peck, 1975). Troglophile, detritivore.

81. Family, genus, and species undetermined.
Guánica Shelter Cave, 4 small spheriid-like clams from brackish pool.
Troglophile, detritivore.

CLASS GASTROPODA
ORDER BASOMMATOPHORA

Family Ellobiidae
82. *Tralia* sp., ?, G. Goodfriend det.
Guánica Shelter Cave, 4 of these snails from mud in brackish pool.
Troglophile, detritivore.

ORDER STYLOMMATOPHORA

Family Subulinidae
4. *Subulina octona* (Bruquiere)
Cueva Los Chorros, Cueva El Convento. Many on wet guano.
Troglophile, guano scavenger.

Family Philomycidae
83. *Philomycus* sp., W. Grimm det.
Cueva Tuna
A large population of dozens of these large (5 cm long) slugs was spread throughout the dark zone of the cave, but especially in the terminal chamber. I have never before encountered a population of slugs in a cave. Troglophile, guano scavenger (?).

PHYLUM ARTHROPODA
CLASS ARACHNIDA
ORDER AMBLYPYGI

Family Phrynidae
7. *Paraphrynus viridiceps* (Pocock)?
Cueva de los Murciélagos, Cueva los Chorros, Cueva El Convento, Cueva Tuna.
The species in Puerto Rico has variously been placed in the genus *Tarantala* and *Phrynus* under the specific names *fuscimana* and *palmata*. However, not enough West Indian collections have been studied to be certain of the range of the species. See Mullinex (1975) for details. Troglophile, predator.

ORDER SCHIZOMIDA

Family Schizomidae
8. *Schizomus portoricensis* (Chamberlin), M. J. Rowland and J. Reddell dets.
Cueva Los Chorros, Cueva El Convento, Cueva Tuna.
The species was originally described in the genus *Stenochrus*, and 4 other specific synonyms have been proposed for it over its range, which reaches from Florida and the Bahamas through Mexico, Central America, and the Greater Antilles to northern South America and the Galápagos. Since only females are known from many populations, they are most likely, at least in part, parthenogenetic (Rowland and Reddell, 1977). Troglophile, predator.

ORDER PHALANGIDA

Family Phalangodidae
84. *Stygnomma* sp., Clarence and Marie Goodnight det.
Cueva Los Chorros.
This genus is widespread in the islands and mainland of the Caribbean. One species is a troglobite in Jamaica. Troglophile ?, predator.
85. Genus and species undetermined.
Cueva El Convento.
One specimen in the subfamily Phalangodinae. Troglophile ?, predator.

ORDER ARANEAE

Family Clubionidae
86. *Corinna* sp., W. J. Gertsch det.
Cueva Tuna, 1 f, 1 m.
Several species are known in Puerto Rico. Troglophile ?, predator.

Family Lycosidae
87. *Lycosa atlantica* Marx, W. J. Gertsch det.
Cueva El Convento, 2 f, 1 m.
The species is listed as *L. fusca* by Petrunkevitch (1929) and is also known from Cuba and Bermuda. Troglophile ?, predator.

Family Pholcidae
15. *Modisimus montanus* Petrunkevitch, W. J. Gertsch det.
Cueva Los Chorros, 2 f; Cueva Tuna, 2 f, 1 m.
Troglophile, predator.
17. *Physocyclus globosus* Taczanowski, W. J. Gertsch det.
Spiral Sink (Río Camuy System), 1 f.
Troglophile, predator.

Family Scytodidae
18. *Loxosceles caribbaea* Gertsch, W. J. Gertsch det.
Cueva de los Murciélagos, 1 f, 8 immatures.
Troglophile, predator.
19. *Scytodes longipes* Lucas, W. J. Gertsch det.
Cueva Tuna, 2 f, 1 juvenile.
Troglophile, predator.
88. *Scytodes* sp., W. J. Gertsch det.
Cueva Los Chorros, 1 f, 1 immature.
This is an undescribed species. Troglophile, predator.

Family Theridiidae
20. *Theridion rufipes* Lucas, W. J. Gertsch det.
Cueva de los Murciélagos, 1 f; Cueva Tuna, 1 f, 1 immature; Cueva El Convento, 2 f.
Troglophile, predator.
21. *Archaeranea porteri* (Banks).
Listed (Peck, 1974) as the junior synonym *Theridion portoricensis* Pet., it is common in cave entrances in the southeastern United States (Levi, pers. comm.). Troglophile, predator.

Family Uloboridae
89. *Uloborus geniculatus* (Olivier), W. J. Gertsch det.
Cueva de los Murciélagos, 5 f, 3 immatures.
The species is tropicopolitan. Troglophile, predator.

ORDER ACARINA*

Family Acaridae
90. *Acotyledon* sp., nr. *krameri* (Berlese), E. Lindquist det.
Cueva Los Chorros, 2 hyp, guano Berlese.

Saprophagous or fungivorous.

91. *Rhizoglyphus* sp.
Cueva Los Chorros, 2 m, guano Berlese.
Saprophagous?

92. *Sancassania* sp.
Cuevo El Convento, 2 hyp; Cueva de los Murciélagos, 3 n, 1 hyp; guano Berlese.
Saprophagous.

Family Ameroseiidae
93. *Kleemannia* sp., nr. *gracilis* (Halbert).
Cueva de los Murciélagos, 1 f, guano Berlese.
Fungivorous or feeder on spores?

Family Aneotidae
94. *Histiostoma* sp.
Cueva Los Chorros, 1 f; Cueva de los Murciélagos, 1 f; guano Berlese.
Possibly a strainer-feeder of microorganisms of surface water films (on wet guano pellets?).

Family Argasidae
95. *Ornithodoros* sp.
Cueva Tuna, 1 n, guano Berlese.
An obligate blood-feeding ectoparasite of bats (and other vertebrates).

Family Cunaxidae
96. *Cunaxoides* sp.
Cueva de los Murciélagos, 1 n, guano Berlese.
Free-living predator on other mites or small mobile prey.

Family Eupodidae
97. *Benoinyssus* sp.
Cueva El Convento, 2 f, 1 n, guano Berlese.
Fungivorous?

Family Eviphididae
98. *Evimirus* sp.
Cueva Los Chorros, 1 f, 1 n, guano Berlese.
Feeding habits unknown.

Family Galumnidae
99. *Galumna* sp.
Cueva Los Chorros, 2 f, 2 m; Cueva El Convento, 4 f, 3 m; Cueva de los Murciélagos, 3 f, 4 m; Cueva Tuna, 3 f, 2 m; all in guano Berlese.
Saprophagous and/or fungivorous feeders on decaying guano materials.

Family Haplozetidae
100. *Haplozetes* sp.
Cueva El Convento, 2 f; Cueva de los Murciélagos, 1 f; guano Berlese.
Oribatei, saprophagous or fungivorous.

Family Ichthyostomatogasteridae
101. *Asternolaelaps fecundus* Berlese.
Cueva de los Murciélagos, 2 f, 1 m, guano Berlese.
Feeding habits unknown; often associated with bats, but not as an ectoparasite.

*The following list of 32 species of mites (17 from Cueva Los Chorros, alone), all recovered from bat guano, seems a surprisingly rich one. It is of interest to note the low abundance of taxa that are predators and ectoparasites. The identifications were all made by Dr. Evert Lindquist, Agriculture Canada, Ottawa and are based on numbers of slide-mounted individuals shown as females (f), males (m), nymphs (n), larvae (lar), and hypophi (hyp). Additional material is unmounted and may contain other taxa. For a summary of classification and general feeding, see Krantz (1978). For details of specific feeding habits in the oribatei group of families, see Luxton (1972). All these mites, except *Ornithodoros*, may collectively be called guanophiles and are here considered to be troglophiles.

Family Laelapidae
102. *Hypoaspis (Stratiolaelaps) miles* (Berlese).
Cueva Los Chorros, 1 m; Cueva El Convento, 1 f; guano Berlese.
This and the next are probably free-living predators of small arthropods (and nematodes?).

103. *Hypoaspis* sp., nr. *angusta* Karg.
Cueva Los Chorros, 1 f, guano Berlese.

Family Macrochelidae
23. *Macrocheles* sp.
Cueva Los Chorros, 1 f, guano Berlese.
Predators on small arthropods (including eggs) and nematodes.

Family Malaconothridae
104. *Malaconothrus* sp.
Cueva Los Chorros, 1 f, guano Berlese.
Oribatei, saprophagous.

Family Nanorchestidae
105. *Nanorchestes* sp.
Cueva El Convento, 1 m, guano Berlese.
A possible accidental, since these are only known to feed on green algae.

Family Oppiidae
106. *Brachioppia* sp.
Cueva Los Chorros, 1 m, guano Berlese.
This and the following are Oribatei; fungivorous or saprophagous.

24. *Multioppia* sp.
Cueva El Convento, 1 f, 1 m, guano Berlese.

Family Oribatulidae
107. *Scheloribates* sp. 1.
Cueva Los Chorros, 2 f, guano Berlese.
This and the following are Oribatei, saprophagous or fungivorous.

108. *Scheloribates* sp., 2?
Cueva Los Chorros, 2 m, guano Berlese.

Family Parasitidae
109. *Parasitus* sp.
Cueva Los Chorros, 1 m, guano Berlese.
Free-living predator on small arthropods.

Family Prothoplophoridae
110. *Cryptoplophora* sp.
Cueva de los Murciélagos, 2 f, guano Berlese.
Oribatei; saprophagous on decaying plant material?

Family Stigmaeidea
111. *Macrostigmaeus* sp.
Cueva de los Murciélagos, 2 f, guano Berlese.
Probably a free-living predator.

Family Trhypochthoniidae
112. *Archegozetes* sp.
Cueva Los Chorros, 2 f, guano Berlese.
Oribatei; saprophagous or fungivorous in moist habitats.

Family Triplogyniidae
113. *Triplogynium vallei* Fox.
Cueva Los Chorros, 4 f, 1 m, 1 n, guano Berlese.
Probably a free-living predator.

Family Tydeidae
114. *Tydeus* sp.
Cueva de los Murciélagos, 1 m, guano Berlese.

Probably fungivorous.

Family Uropodidae
115. *Uroobovella* sp., nr. *brasiliensis* Hirschmann.
Cueva El Convento, 3 f, guano Berlese.
Saprophagous-fungivorous.
116. *Uroobovella* sp. 2.
Cueva El Convento, 3 f, 1 m, 1 n; Cueva de los Murciélagos, 1 f; guano Berlese.
Saprophagous-fungivorous.
117. *Oplites* sp.
Cueva de los Murciélagos, 1 f, 2 n, guano Berlese.
Saprophagous?
118. *Uroactinia* sp., nr. *hippocrepoides* (Vitzthum)
Cueva Los Chorros, 3 f, 1 n; Cueva Tuna, 2 f, 2 m; guano Berlese.
Fungivorous grazer?
26. *Uropoda (Phaulodinychus)* sp., nr. *argasiformis* (Berlese).
Cueva Los Chorros, 1 m, guano Berlese.
Saprophagous?

ORDER PSEUDOSCORPIONIDA

Family Cheiridiidae
28. *Cheiridium* sp., W. B. Muchmore det.
Cueva Tuna, 1 m, 2 immatures.
Troglophile, predator.

Family Chernetidae
29. Genus and species undetermined, W. B. Muchmore det.
Cueva de los Murciélagos, 21 f, 33 m, 5 immatures.
Troglophile, predator.

CLASS CRUSTACEA

ORDER OSTRACODA

119. Family, genus, and species undetermined.
Guánica Shelter Cave, many from plankton net tow in brackish pool.
Troglophile, detritivore.

ORDER EUCOPEDODA

Family Cyclopidae
120. *Microcyclops panamensis* Marsh, A. Weaver and H. C. Yeatman det.
Guánica Shelter Cave, very abundant in brackish pool.
This is a brackish water species known from along the Gulf coast, Panama, Haiti, Bermuda, and from Massachusetts salt marshes. Troglophile, detritivore.

ORDER MYSIDACEA

Family Stygiomysidae
121. *Stygiomysis holthuisi* (Gordon), T. Bowman det.
Guánica Shelter Cave; Cueva de los Murciélagos, 3 from small, brackish pool.
This eyeless species is otherwise known only from subterranean waters on the Lesser Antillean island of St. Martin (Gordon, 1960). This distribution may result from pelagic dispersal of the species, perhaps in the Pleistocene. Another species occurs in Jamaica (Bowman, 1976). Troglobite, detritivore.

ORDER ISOPODA

122, 123. Family, genus, and species undetermined.
Cueva El Convento, abundant on moist guano; Spiral Sink (Río Camuy System); Cueva del Humo (F. Miller leg, Río Camuy System); Cueva Los Chorros, abundant on guano; Cueva Tuna, abundant on moist guano; Guánica Shelter Cave, 5 on moist soil near pool edge.
Several Families and about 5 species are represented in these collections, of which three were reported before. Troglophiles, detritivores, and guano scavengers.

ORDER AMPHIPODA

Family Gammaridae
124. *Metaniphargus bousfieldi* Stock.
Guánica Shelter Cave, 74; Cueva de los Murciélagos, 173 from small pool.
This species is near *M. Longipes,* known from subterranean waters on the Caribbean island of Aruba. Other species are known to occur in Caribbean groundwater (Holsinger and Peck, 1968; Stock, 1977). Sullivan (1974) reports a depigmented *Paraweckelia* amphipod from 3 pools in Cueva El Convento, but this determination cannot be verified because specimens have not been seen by specialists (J. Holsinger, pers. comm.).

ORDER DECAPODA

Family Atyidae
37. *Typhlatya monae* Chace, F. Chace det.
Guánica Shelter Cave, 136 in brackish pools in plankton net tow; Cueva de los Murciélagos, 36 in small pool.
Details of distribution of this species and others in this exclusively subterranean genus are discussed by Peck and Kukalova-Peck *(NSS Bulletin,* this issue). Troglobite, detritivore.
38. *Xiphocaris elongata* (Guérin-Méneville).
Cueva Los Chorros, one shrimp which is probably of this species was seen in the back of the cave, but escaped.
Troglophile, detritivore.

Family Palaemonidae
41. *Macrobrachium carcinus* (Linnaeus), H. H. Hobbs det.
Cueva El Convento, 1 f.
Troglophile, detritivore.

Family Pseudothelphusidae
42. *Epilobocera sinuatifrons* (A. Milne-Edwards).
Cueva Los Chorros, 2 near stream; Cueva El Convento, 3 m; Tres Pueblos Sink (Río Camuy System), 1 observed feeding on an earthworm on silt bank.
Troglophile, omnivore.

CLASS DIPLOPODA

ORDER POLYDESMOIDA

Family Chytodesmidae
43. *Iomus incisus* Cook, H. F. Loomis det.
Cueva Tuna, 7 m, 3 f, 1 juvenile.
Troglophile, detritivore.

Family Stylodesmidae
44. *Lophodesmus bituberculatus* Loomis.
Sullivan (1974) reports the species from Cueva El Convento.
Troglophile, detritivore.

Family Eurydesmidae
125. *Cylindromus uniporus* Loomis, H. F. Loomis det.
Cueva Los Chorros.
The slender body, antennae, and legs suggest that the species is a troglobite. The genus is known only from one female from this cave (Loomis, 1977). Troglobite, detritivore.

ORDER STEMMIULIDA

Family Stemmiulidae
126. *Prostemmiulus* sp., H. F. Loomis det.
Cueva Los Chorros, 1 juvenile f.
There are many West Indian and Neotropical species in this genus.
Troglophile?, detritivore.
127. *Stemmiulus compressus.*
Sullivan (1974) indicates this species in Cueva El Convento, but the record may actually represent the above genus.
Troglophile?, detritivore.

ORDER CHILOPODA

Family Henicopidae
128. Genus and species undetermined, A. Weaver det.
Cueva Los Chorros, 4 on guano.
Troglophile?, predator.

CLASS COLLEMBOLA

ORDER ENTOMOBRYOMORPHA

Family Entomobryidae
49. *Paronella* sp., K. Christiansen det.
Cueva Los Chorros, 5 on guano.
Mari Mutt (1976) has recently presented a key to the genera of Collembola from Puerto Rico. Troglophile, guano scavenger.

Family Isotomidae
129. *Folsomides* sp., K. Christiansen det.
Cueva Los Chorros, many on guano.
Troglophile, guano scavenger.

Family Onychiuridae
130. *Onychiurus.*
Cueva Los Chorros, many on guano.
Troglophile, guano scavenger.

Family Sminthuridae
131. *Collophora quadrioculata* (Denis), J. A. Mari Mutt det.
Cueva Los Chorros, many in Berlese of guano.
Troglophile, guano scavenger. The species was previously known only from Costa Rica; it is now known from this and two other Puerto Rican sites.

CLASS INSECTA

ORDER THYSANURA

Family Nicoletiidae
132. *Cubacubana* sp., P. Wygodzinsky det.
Cueva de los Murciélagos.
This is an undescribed species in a family in which all species are eyeless. The genus otherwise is known only from three species from Cuban caves. Troglobite?, detritivore.
133. *Nicoletia meinerti* Silvestri, P. Wygodzinsky det.
Cueva Tuna, 3 f.
This is a tropicopolitan species, distributed by man, even occurring in greenhouses in Europe. Most populations are parthenogenetic. Troglophile, detritivore.

ORDER DERMAPTERA

Family Labiidae
134. *Marava* sp., *cf. unidentata* (P. de B.), A. B. Gurney det.
Cueva Tuna, 3f, 1m.
Troglophile, omnivore (?).

ORDER BLATTARIA

Family Blaberidae
51. *Pycnoscelis surinamensis* (Linnaeus), A. B. Gurney det.
Cueva Tuna, 1 f.
Troglophile, omnivore.

Family Blatellidae
135. *Pseudosymploce* sp., A. B. Gurney det.
Cueva El Convento, 1 m, 2 nymphs.
An undescribed species, distinct from two other species known from the island, one from Aguas Buenas Cave. Troglophile, omnivore (?).
136. *Nelipophygus* sp., A. B. Gurney det.
Cueva Los Chorros, 12 f, 2 m, 48 nymphs; Spiral Sink (Río Camuy System), observed but could not catch roaches which are probably of the same species.
These are an undescribed species, eyed but with reduced wings and elongated legs. The genus also occurs in forests on Puerto Rico and Jamaica, and a Jamaican species is also a troglobite. Troglobite?, omnivore.

Family Blattidae
55. *Aspiduchus cavernicola*, J. W. H. Rehn.
Cueva Tuna, 1 immature.
This cave is probably the type locality for the species, judging from the description of the cave and its location. It is interesting that Rehn reports such a large population, and I could find only one specimen. Sullivan (1974) reports the species from Cueva El Convento, but I did not find it there. Troglophile, guano scavenger.
56. *Periplaneta americana* (Linnaeus), A. B. Gurney det.
Cueva Tuna, 1 m.
Troglophile, omnivore.

ORDER ORTHOPTERA

Family Gryllidae
58. *Amphiacusta* sp.
Cueva Los Chorros, 20; Cueva El Convento, 1 f, 3 m; Tres Pueblos Sink (Río Camuy System), 1.
This is the same species, as determined by male genitalia, as in Aguas Buenas and other caves. I have not yet found it outside of caves, though other species of *Amphiacusta* occur in forests. Sullivan (1974) applied the name *"A. annulipes"* to the Cueva El Convento population, but this cannot be taken with any certainty. Trogloxene, omnivore.

ORDER HEMIPTERA

Family Cydnidae
137. *Amnestus* sp., R. C. Froeschner det.
Cueva Los Chorros.
This is an undescribed species. Ten immatures from Cueva Tuna may be the same species. Troglophile, guano scavenger (?).

Family Reduviidae
138. *Ploiaria macrophthalma* (Dohrn), R. C. Froeschner det.
Cueva de los Murciélagos, large numbers on dry guano mounds.
This species is pantropical in distribution, most likely distributed by man. Other species in this subfamily (Emesiinae) are known to be cave-associated in other tropical areas (Wygodzinsky, 1966), but only *Nesidiolestes ana* Gagné and Howarth of Hawaii is a troglobite. Troglophile, predator.

Family Veliidae
61. *Microvelia portoricensis* Drake, R. C. Froeschner det.
Guánica Shelter Cave, 6 on surface of brackish pool. Troglophile, predator.

ORDER COLEOPTERA

Family Carabidae
63. *Masoreus brevicillus* Chevrolat.
Cueva Tuna, 7 associated with moist guano. Troglophile, predator.

Family Hydrophilidae
139. Genus and species undetermined.
Cueva Tuna, two with ridged elytra in wet guano.
Troglophile, guano scavenger.

Family Leiodidae
64. *Proptomaphaginus puertoricensis* Peck.
Sullivan (1974) first reported this beetle from south coast caves in Cueva El Convento, but I have not seen voucher specimens. I did not find it in the cave. Troglophile, guano scavenger.
140. *Aglyptinus puertoricensis* Peck.
Cueva del Humo (Río Camuy System), 1 f, 1 m (F. Miller leg.).
This is the first record of the species from a cave. Another species occurs commonly on guano in Jamaican caves (Peck, 1972, 1977). Troglophile, guano scavenger.

Family Ptiliidae
141. Genus and species undetermined.
Cueva Los Chorros, abundant in guano Berlese.
Troglophile, guano scavenger.

Family Nitidulidae
142. *Stelidota* sp., H. F. Howden det.
Cueva Los Chorros, in guano Berlese.
These beetles also occur on carrion. Troglophile, guano scavenger.

Family Cerylonidae
143. *Euxestus erithacus* Chevrolat, J. F. Lawrence det.
Cueva Tuna, abundant in guano.
The species is widely distributed in the Neotropics and is also known from Jamaican cave guano (Peck, 1975; Lawrence and Stephan, 1975). Troglophile, guano scavenger.

Family Elateridae
144. *Esthesopus* sp., E. C. Becker det.
Cueva Tuna, 2 from guano.
Troglophile, guano scavenger.

Family Tenebrionidae
145. *Alphitobius diaperinus* (Panzer), T. J. Spillman det.
Cueva Tuna, abundant in guano.
The species is also known in guano caves, attics, and/or chicken coops from Ontario to Venezuela. Troglophile, guano scavenger.

ORDER LEPIDOPTERA

Family Pyralidae
146. *Pyralis manihotalis* Guenee, D. R. Davis det.
Cueva de los Murciélagos, many of these large moths on dry guano in the dark zone.
The species is circumtropical, and the larvae are a stored products pest.
Troglophile, guano scavenger.

Family Tineidae
62. *Tinea* sp., D. R. Davis det.
Cueva de los Murciélagos, many in guano.
This undescribed species is known from bat caves on several West Indian islands. Troglophile, guano scavenger.

ORDER DIPTERA

Family Phoridae
60. Genus and species undetermined.
Cueva Tuna, on guano and bat bodies.
Troglophile, guano scavenger.

ORDER HYMENOPTERA

Family Braconidae
147. *Apanteles carpatus* (Say), W. M. Mason det.
Cueva Tuna, 5.
This wasp is a parasitoid of clothes and flour moths and, apparently, on tineid moths in guano in the cave. It is worldwide in distribution, apparently carried by man, and is probably introduced to Puerto Rico. Troglophile, parasitoid.

Family Evaniidae
148. *Evania polita* Schlett., L. Masner det.
Cueva Tuna, 1.
This wasp is a Neotropical, synanthropic, and widespread (by Man?) parasitoid of cockroach eggs (probably *Aspiduchus* and/or *Pycnoscelis* in this cave). Troglophile, parasitoid.

Family Formicidae
149. *Anochetus mayri* Emery, W. J. Brown det.
Cueva Tuna, 5 foraging on guano.
Troglophile, predator?.
150. *Crematogaster, cf. steinheili* Forel, W. J. Brown det.
Cueva Tuna, many winged queens from guano Berlese.
Troglophile, predator?
151. *Hypoponera* sp. 2, W. J. Brown det.
Cueva Los Chorros, in guano Berlese; Cueva El Convento, in guano Berlese.
The species is also known from Jamaican caves (personal data). Troglophile, predator?.
75. *Odontomachus brunneus* Patton, W. J. Brown det.
Cueva Tuna, 1 near guano.
Previously listed as the synonym *O. ruginodis* Wheeler. Troglophile, predator?.

DISCUSSION

Seventy-three non-accidental macroscopic species of invertebrates have been added to the fauna previously known from Puerto Rican caves, bringing the total number of species to 151. This number should increase with more careful observation and field work, especially in taxa such as mites and terrestrial isopods. The above additions come from the study of only 5 new caves. The results add 6 troglobites (obligate cavernicoles) to the fauna of Puerto Rico, itself (excluding Mona Island). These are the mysid shrimp *Stygiomysis holthuisi*, the amphipod *Metaniphargus bousfieldi*, the atyid shrimp *Typhlatya monae*, the millipede *Cylindromus uniporus*, the silverfish *Cubacubana* sp., and the cockroach *Nelipophygus* sp. The previously known troglobites are the amphipod *Alloweckelia gurneei* and an unidentified terrestrial isopod. (*Typhlatya monae* was previously known from Mona Island, but not the main island of Puerto Rico). The other 68 additions to the list are judged to be troglophiles.

Cave Significance

A listing of the scientifically most significant caves in Puerto Rico must start with the Rio Camuy System, because of its size and interest as a record of karst hydrology and cave developmental processes. Aguas Buenas Cave must be included for similar reasons, as well as for being biologically the richest and most diverse cave in Puerto Rico. The two Guánica Forest caves must be added, because of the presence of the three troglobitic groundwater crustaceans in them. Lastly, Cueva Los Chorros must be included, not

Table 1. Data (numbers identify species in lists in this paper and in Peck [1974]) for faunal similarity analysis of distribution of native terrestrial trogloxenes and troglophiles from North (including Aguas Buenas Caves) and South Coast cave areas of Puerto Rico. Poorly known groups like terrestrial isopods and Diptera are excluded. Further work will add taxa, refine knowledge of distributions of the taxa, and eliminate non-native taxa from the list (*e.g.*, introduced species), but the overall results are expected to show more rather than less faunal similarity between the north and south coast cave faunas.

	North Coast Caves Only	South Coast Caves Only	In Caves On Both Coasts
	1 5 6 84 9 10 11 12 13 14 16 17 88 21 22 126 128 46 47 49 50 129 130 131 54 137 59 60 140 141 142 71 72 73 74 76	2 79 83 85 86 87 29 127 134 135 55 139 143 144 145 149 150	3 7 8 15 18 19 20 28 43 44 58 61 62 63 64 151 75
(excluding mites)	36	18	17
	90 91 98 23 104 106 107 108 109 112 113 26	92 93 95 96 97 101 110 111 114 115 116 117 118	94 99 100 102 24 15
(mites)	12	13	6
(TOTAL)	48	31	23

for its size, but for its rich invertebrate community, including two terrestrial troglobites.

Most of these caves and their faunas are relatively safe from *small scale* habitat alteration and faunal destruction resulting from simple cave visitation. However, because of the relatively small size of Cueva Los Chorros, its microhabitats and their faunas cannot withstand much human impact. Visitation to it by many and/or large groups, even biology or ecology student groups, would soon degrade the community by trampling it into the mud. This cave and its community should somehow receive protection and visitation to it should be strictly limited.

Faunal similarity

A field naturalist cannot help but be struck by the vegetational differences between the karst country of the north and of the south coasts of Puerto Rico. The north coast is well watered (1000 to 2000 mm mean annual rainfall) and possesses a verdant, subtropical, moist, forest of tall trees (when undisturbed) with a nearly closed canopy. The south coast, in contrast, in the rain shadow of the Cordillera Central (receiving from 600 to a maximum of 1000 mm mean annual rainfall), supports a dense and low-statured, subtropical, arid, forest of thorn-scrub and cactus vegetation. Additional data and details on forest types and climates are given by Ewel and Whitmore (1973), Beck (1974), and Cintrón and Beck (1977).

Since the forests overlying the caves in the two regions are so different, we can ask how different or similar are the cave faunas of the two regions? Are the caves mostly inhabited by species found today in epigean sites adjacent to the caves? If so, the faunas should have a low similarity, because of the strong differences in the two forest zones from which the cave faunas have come. If there is a high similarity, how can it be explained, because the modern forest source of the fauna of the caves is so dissimilar? Only trogloxenes and troglophiles which are terrestrial and native should be used in making such a distributional comparison: troglobites and aquatics are obviously too limited in dispersal abilities or habitat requirements to indicate general faunal similarities; introduced species are probably too vagile to have meaning for the purposes of this comparison. Poorly known groups, such as terrestrial isopods and diptera, are excluded.

Examination of the faunal lists thus restricted, in this and in an earlier paper (Peck, 1974) yields two sets of comparative data (Table 1). When mites are excluded from the lists, 36 species are known only from north coast caves (including only the published data for Aguas Buenas Cave), 18 species are known only from south coast caves, and 15 species are known to occur in caves in both the north and south coasts. When mites are included, 48 species are known only from the north coast, 31 from the south coast, and 23 occur in caves on both coasts.

Most of the species known only from south coast caves are in fairly dry situations, an environment that is not commonly found in north coast caves. That many species occur in north coast caves which are not known from the south should be expected because of the lower number of cave sites that have been studied (and that probably exist) on the south coast. It is important to note that most of the species known from both regions are associated with moist sites in the caves; when known from non-cave habitats, these are usually more-moist forest sites on the north coast and interior mountains, not arid forest litter or like habitats.

Simpson's faunal resemblance index for the smaller (south coast) fauna to the larger (north coast) is $Rb = 100 \times c/b$, when c is the number of commonly occurring species and b is the number of species in the smaller fauna. Computation for the faunas can either exclude or include the mite data, because of its possible incompleteness. This yields, respectively, a faunal similarity of 47% or 43%. The difference probably reflect the inadequate level of knowledge of the mites more than anything else. Udvardy (1969) discusses the limitations of such comparisons.

Although directly comparable data seem not to have been published, this similarity of the two cave faunas is much higher than expected for an analysis of similarly restricted epigean arthropods or vegetation (Ewel and Whitmore 1973). The epigean habitats of the two coasts have converged, resulting from the degradation accompanying clearing and agricultural activity.

The strong similarity of the two faunas is mostly due to species found in the Cueva El Convento system and in Cueva Tuna. However, the similarity is still higher than would be expected by the field naturalist if the south coast caves had been colonized only by troglophilic and trogloxenic invertebrates directly from the surrounding arid forest. The similarity is not due to invertebrates that are found in arid forests, but rather to the presence of those species requiring moist conditions, whether in caves or leaf litter and similar sites in moist forests. The explanation is probably due to a combination of several historical and dynamic zoogeographic processes, as follows:

1. The species may have reached the cave sites in the past, at the close of the Pleistocene, when climatic zones were different. The moist forest may have covered more of southwestern Puerto Rico than it does today. Heatwole and MacKenzie (1967) show the extension of the Puerto Rican coastal plain due to sea-level lowering in a glacial. However, there is no direct evidence available for Pleistocene climatic change in Puerto Rico and a shifting of the boundaries of life zones. Since the arid zone is caused by a rain shadow, it probably would not change much in extent unless there was a shift of atmospheric circulation. Reduced evaporation due to cooler air temperatures would allow an expansion of the moist forest, as would an increase in rainfall in southwestern Puerto Rico. The cave faunas (and other fauna and flora) of the Quebrada De Los Cedros gorge (Cintrón and Beck, 1977) persisting since these hypothetical conditions would be climaticly disjunct populations, and the caves would then serve as refugia.

2. The cave fauna (as well as the epigean flora and fauna) may have reached the Quebrada De Los Cedros gorge by active and passive dispersal throughout the Recent, but this was terminated with the human degradation of the natural epigean habitats in historical times. This implies that the species could live in and move through epigean forested habitats (even though they were strongly seasonal) during some portion of each year to reach the caves until one hundred or so years ago. The cave populations are now restricted to habitat islands by Man's fragmentation of the connecting epigean habitats and dispersal avenues. The fauna now has little or no ability to cross to the other habitat islands, because the intermediate regions have been made unsuitable. This is actually the precarious situation now faced by much of the fauna of the world's remaining forests.

3. Species may be today continually reaching and occupying anew the caves. Ballooning spiders and winged insects may be actively travelling some 20 km downwind from the mountain forests to the southwestern caves in suitable seasons. Flightless arthropods may find the habitat degradation or seasonal drought not to be so severe that they cannot still survive in forest-like remnants near the caves today. Passive dispersal of arthropods by bats is possible but probably limited to only a few species of mites. Annual passive dispersal by rainy-season stream-wash from montane forest habitats into the El Convento system is probably very important in continuing to introduce species into this cave.

In conclusion, some mixture of the above is probably responsible for the unexpectedly high faunal similarities between the two cave regions. Guesses can be made about which category may be most important for a particular species in particular caves. But so little is known about the biologies and tolerances of the epigean forest soil and litter arthropods of Puerto Rico that they can be related only with much uncertainty to the questions of the dynamics of the occupation of Puerto Rican cave habitats.

ACKNOWLEDGEMENTS

Dr. Barry F. Beck is thanked for hospitality and help with my study of the caves reported here. Dr. Beck also provided water chemistry data. My wife Jarmila helped with the field work. Norman Veve of San Juan helped in our exploration of the Río Camuy System. The work could not have been completed without the help of all the systematists who provided determinations. The Puerto Rican Department of Natural Resources gave assistance in allowing use of facilities of the Guánica State Forest. Francis G. Howarth provided comments on the manuscript. The field work was partially supported by an operating grant from the Canadian National Research Council, for study of the systematics, biology, distribution, and evolution of cave and leaf litter arthropods.

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Manuscript received by the editors 1 August 1978.
Revised manuscript accepted 11 October 1979.

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