BAHAMA ISLANDS

by

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I - GENERALITIES

The Bahama Islands occupy an area of approximately 11,400 sq. km to the southeast of Florida. There are 18 main islands, and over 700 smaller cays (islets), distributed on several "banks" which make up the main Bahama platform. Of these banks, the two largest are the Great Bahama Bank, which contains the islands of Andros, Exuma, New Providence, Eleuthera, Long, and Cat, and the Little Bahama Bank, to the north, with Grand Bahama and Abaco.

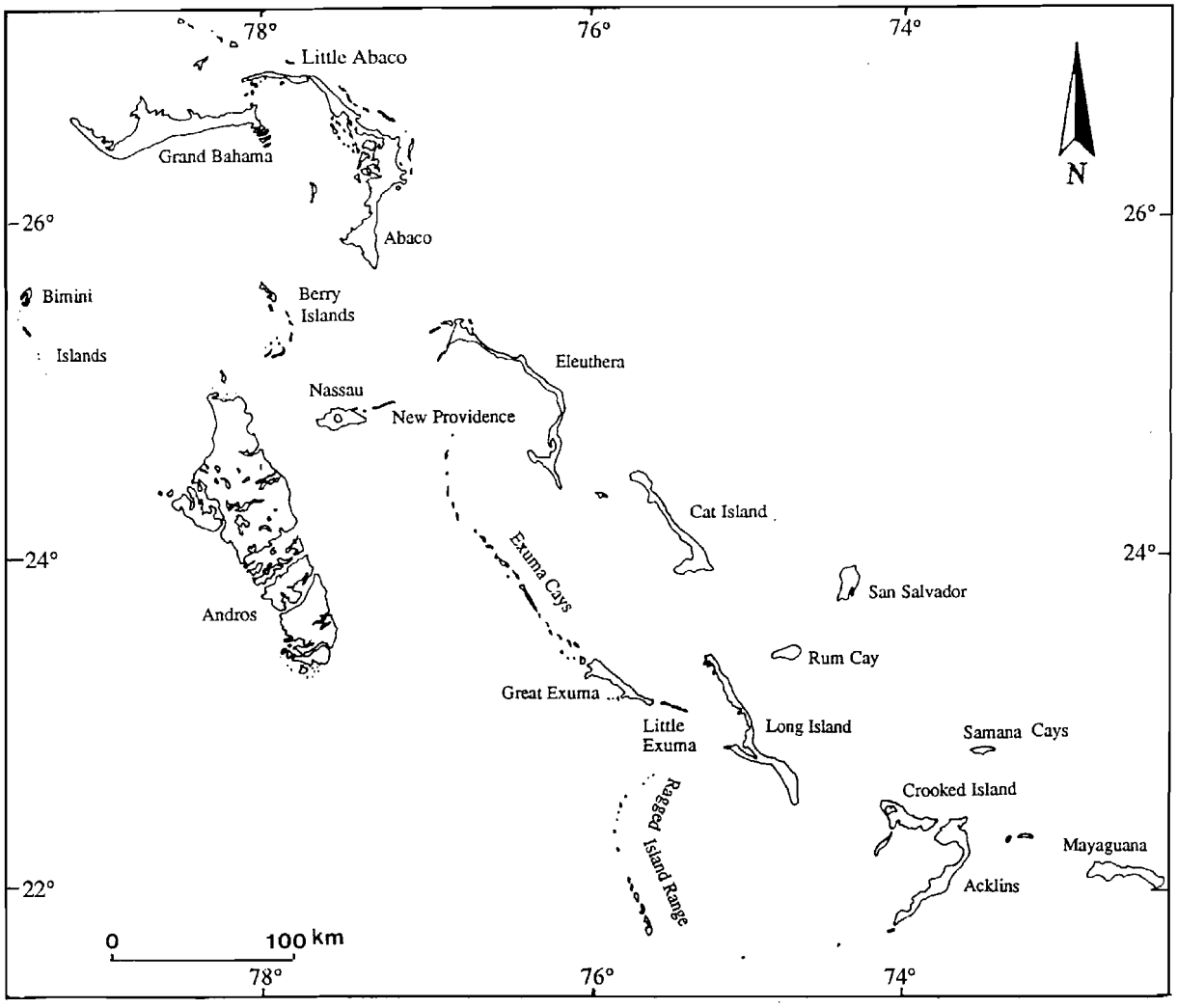

Fig. 1 - Map of the Bahama Islands.

The structural base for these islands is the Bahama platform, which covers an area of over 100,000 km^2 The Bahama Platform is surrounded by steep oceanic dropoffs, including the Florida Straits, separating it from the North American mainland, and the Old Bahama Channel, which separates it from the islands to the south (FAIRBRIDGE, 1975). The entire block is composed of horizontally-bedded limestones, of shallow-water marine origin extending to a known depth of 4450 meters (SPENCIER, 1967). The base of the platform lies

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at a depth of approximately 8000 meters and represents a shallow water zone of vigorous carbonate formation during post-Pangean times (circa 200 million years ago). The sediments forming the bank represent one of the most tectonically stable limestone regions on the planet.

The top of the banks are composed of shallow marine, coral and eolian limestones and living reefs, together with carbonate sands. The banks subside at a rate of about 1 cm per 250 years, but this is replaced by new carbonate deposits, maintaining surface stability in the area.

The entire region was affected by glacio-eustatic sea-level changes in the Pleistocene, encouraging karst erosion. There are numerous caves and sinkholes, occasionally reaching depths of 100 m that represent the estimated lowest sea-level from Pleistocene times. Water-filled cavities are known as "Blue Holes" due to their colouration. The larger islands (Andros, Grand Bahama, Abaco etc.) have well-developed freshwater lenses beneath their surface.

Higher surface land forms are largely composed of eolianite limestones, blown into dunes during periods of emergence, and later consolidated into rock. A distinction can be made between these dune-chains, which form the eastern margins of many of the islands, and the relatively low areas of shallow-marine origin. Lithified dunes also exhibit cave-development. Dunes reach a maximum elevation of 67 meters on Cat Island, representing the highest point in the Bahamas.

In the larger Islands a fresh-water lens forms by displacing sea water. A distinct halocline is maintened by density and temperature. This lens has been responsable for extensive solutionial activity within the Bahama Banks. During the last million years, this lens oscillated vertically over a range exceeding 100 m in correlation to the changes of sea level due to glaciations, giving rise to caves and a complex karst (WILLIAMS, 1980).

I. 1 - The Blue Holes

Blue Holes are cavernous features of solutional origin found within the limestone bedrock of the Bahama Islands, which have been reported from elsewhere in the Caribbean, Cuba, Honduras, Yucatan and Turks and Caicos Islands. (COUSTEAU, 1973; DILL, 1977). They are the result of phreatic development within the freshwater lenses of the islands and of further modification during periods of low sea-level. They are divisible into two sub-types :

- Inland Blue Holes (Cenotes). Circular, often deep shafts that bell out beneath the surface into a wider cavern. These frequently penetrate through the freshwater lens into the underlying salt-water. On Andros, of 78 holes depth-sounded on the island, four exceeded 100 meters. Some are known to contain stalactites at depth. Few have evident horizontal cave development associated with them.
- Oceanic Blue Holes ("Boiling holes"). Cave systems opening out on the surface, generally beneath sea-level, which contain horizontal and, usually, vertical development, often stretching for considerable distance. Most of these caves are subject to strong tidal currents. Oceanic holes have been discovered off Andros that reach depths of over 100 metres and lengths in excess of 1.5 km.

Andros Island. Andros is the largest of the Bahama Islands. It forms an extensive limestone plateau, the origins of which date back to the early Cretaceous, and the upper 120 m of which has been exposed during periods of glacio-eustatic activity within the Pleistocene ice epoch.

Andros is more accurately a group of islands, with three main land areas, North Andros, Mangrove Cay, and South Andros, separated respectively by the tidal creecks of North, Middle and South Bights.

The island supports a series of freswater lenses, in accordance with the Ghyburn-Hertzberg principle.

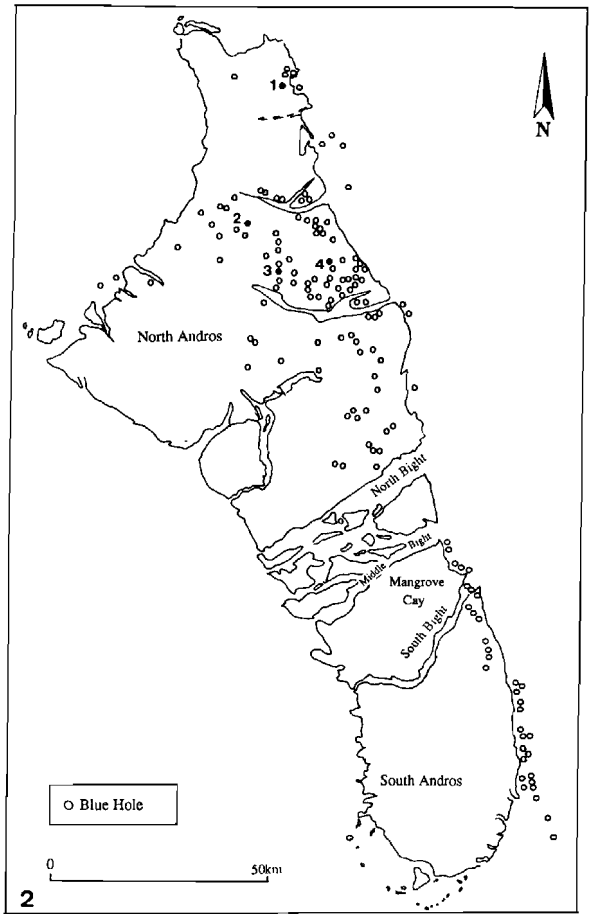
Access to these lenses is possible by entering Blue Holes, caves which descend throught the freshwater zone, often penetrating into the saline zone beneath. There are at least 200 Blue Holes on Andros, including both inland and oceanic types with several of these extending to 100 m depth (BENJAMIN, 1970, 1984; DILL, 1977; PALMER and WILLIAMS, 1984; PALMER 1986a, b). Long and often extremely complex cave systems can be formed horizontally along the halocline at freshwater saline surface.

No shallow inland system resembling the Lucayan Caverns of Grand Bahama Island has been discovered on Andros.

Grand Bahama. Lucayan Cavern. This submerged cave, explored for over 9 km, has nine surface openings. Exploration has necessitated swims of over 700 m horizontally, because there are no air bells or dry chambers (WILLIAMS, 1980). This cave system is approximateley one kilometer from the Atlantic Ocean and connects to the sea via passages which open into a tidal, salt-water creek. The fresh-water layer has an average depth of 14 meters. The sea-water temperature is seasonally variable from 23°-25°C. Temperature of the fresh-water remains around 22 °C.

Zodiac Caverns. This complex system of at least eight caves lies beneath the small island of Sweeting's Cay, forming a fossil hydrologic link between the north and south shores via three surface lakes (PALMER 1985). Average depth is 15 to 20 m with haloclines reported at 16.5 m (in 1983) and 19 m (in 1984). Extensive deposits of submerged speleothem are present.

Sagittarius Cave, one part of the Zodiac system, has a length of 380 m and depth of 22 m.



Cat Island. The island is about 80 km long, between 2 and 16 km wide, and rises to 67 m at Mt. Albernia. Cat Island formed from the remains of Pleistocene age calcarenite dunes, deposited during a

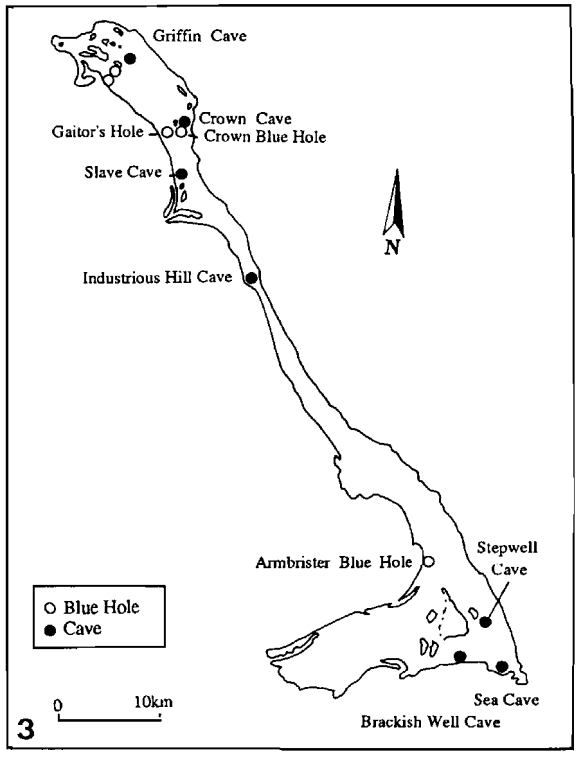


Fig. 2 - Map of Andros Island with the distribution of Blue Holes. 1 = Uncle Charlies Blue Hole. 2 = Ken's Blue Hole. 3 = East Twin Blue Hole. 4 = Cousteau's Blue Hole. Fig. 3 - Map of Cat Island with the location of Blue holes and caves.

period of eustatic exposure of the Bahama Banks. Caves lie entirely in Pleistocene eolian limestone.

New Providence Island. This island consists primarily of elevated marine sand-flat and protected lagoonal deposits (GARRET and GOULD, 1984). The most extensive of these deposits correlate with the 125,000 yr high stand of sea level.

Both Blue Hole and horizontal solution caves exist on New Providence (MYLROIE *et al.*,1991).

Mermaid's Pool is a particularly notheworthy cave. This water-filled sinkhole, penetrating the freshwater lens to the underlying salt water, is located in the Golden Gates subdivision. It is the type locality and only one of three caves on New Providence from which the blind brotulid *Lucifuga speleotes*, described by COHEN and ROBINS (1970), was reported. Recently, organic pollution in the pool has resulted in oxygen depletion and hydrogen sulphide accumulation, such that the fish population at this site has been destroyed.

Abaco. Norman's Castle Blue Hole is a water-filled inland sinkhole reaching a depth of 58 m. This vertical shaft extends trough the freswater lens into the underlying salt water. At the halocline, a layer of turbid anoxic water reduces visibility to zero, keeping the underlaying crystal clear salt water in total darkness.

Dan's Cave, another inland Blue Hole, contains remipedes (YAGER 1989). Several submarine Blue Holes are located at Cherokee Sound. Eight Mile Cave near the south end of Abaco is a dry horizontal cave with bats.

Eleuthera. Eleuthera is a long, narrow island situated on the eastern margin of the Great Bahama Bank and composed of low hills of eolian limestone. Hatchet Bay Cave is located several km north of the settlement of Hatchet Bay and is about 1 km inland from the west coast of the island. The cave is developed on three levels. An entrance chamber, floored with blocks of collapse limestone, contains inactive stalactites and stalagmites and is inhabited by a colony of bats. An extensive middle level contains dry passages and larger chambers of phreatic origin. The lowest level consists of a chamber half-filled with water. Maximum depth in the central depression of this anchialine pool was about 3 m. Surface water had a salinity of 32‰, a temperature of 21.7°C, and 6 ppm dissolved oxygen. Altrough no water currents were observed in the pool, levels clearly fluctuated with the tides.

Ocean Hole at Rock Sound is a 60 m diameter inland Blue Hole.

San Salvador Island. This island occupies an isolated, steep-walled carbonate pedestal. It has never had a shallow water connection with any of the other Bahama Islands.

Lighthouse Cave is in the northeast part of the island, about 1 km inland from the coast. The limestone in which the cave is formed is an emergent coral reef, about 125,000 years old, while the oldest stalagmites within the cave have been dated at 51,000 years B. P. (CAREW *et al.*, 1984); therefore, placing maximum and minimum ages on the cave itself. Lighthouse Cave consists of a series of rooms interconnected by tubular phreatic passageways (MYLROIE 1980). It was formed at an earlier, higher stand of sea level and has since drained. Anchialine pools to 2 m depths are present along the northern and western side of the cave. Surface water in these pools had a salinity of 32. 5 $^{0}/_{00}$, a temperature of 24.7° C and 4 ppm dissolved oxygen. At 0.7 m depths, salinity and temperature were nearly the same as in the surface waters but dissolved oxygen had decreased to 0.7 ppm.

I. 2 - Dissolution caves

They are many abandoned dissolution caves at elevations between two and seven metres above sea level. The development of dissolution caves in these tropical carbonate islands is dependent on the position of the freshwater lens. In stable platforms like the Bahamas, the lens position is controlled by sea level, which is a function of glacio-eustatic sea levels. Dissolution subaerial caves in the Bahamas must have developed during

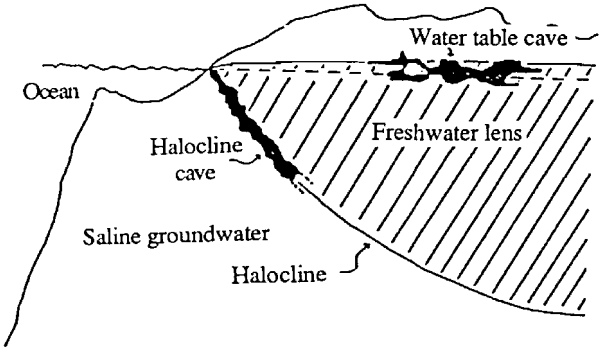


Fig. 4 - Schematic showing the two zones of formation of dissolution caves; one at the top of the freshwater lens (Ghyben-Herzberg), the other along the halocline, at the contact between the fresh and sea water (From Mylroie and Carew, 1988, modified).

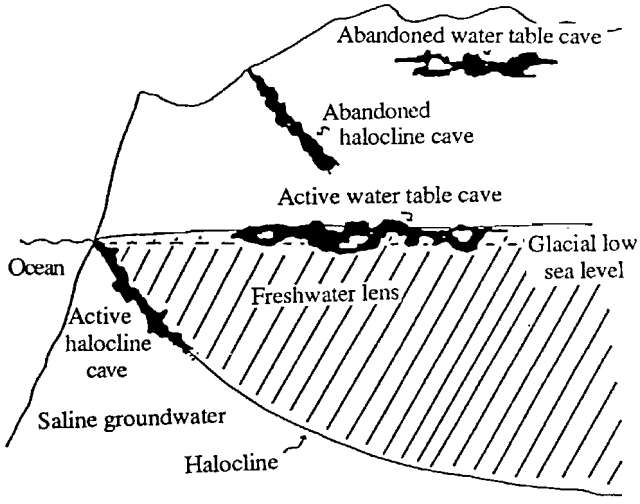


Fig. 5 - Schematic showing the role of sea level on the location of dissolution caves in the limestones (From Mylroie and Carew, 1988, modified).

Late Quaternary past higher levels. Most subaerial Bahamian caves are found in limestones that are less than 150,000 years old. Sea levels higher than present have been relatively short-lived, so the developement of large dissolution caves under the limitations of time and size of the lens requires a powerful dissolutional mechanism ; the mixing of discharging freshwater with tide-pulsed incoming marine water under the flanks of emergent dune ridges may have produced the necessary conditions (MYLROIE and CAREW, 1990).

II - Flora and Fauna of Inland Blue Holes

II. 1 - Anchialine and Freshwater Flora

The Algae. All inland Blue Holes contain some algae (PROUDLOV, 1984).

Blue-green algae (Cyanophyta). The most abundant freshwater algae, present in all Blue Holes and in road-side ditches, were blue-green algae. All holes contained great masses, usually laid down in mats on horizontal and sloping surfaces. In Cousteau's Blue Hole on Andros Island, small red water mites were observed entering the mats suggesting that the algae may be their main food source. The biomass of blue-green algae in most Blue Holes is enormous.

Charophytes. These were present only in Ken's Blue Hole and in East Twin Blue Hole, and in discrete patches.

Green algae (Chlorophyta). Probably represented only by the genus *Cladophora*, present in all holes, but restricted to small patches.

Although there is a very high biomass of algal material in the Blue Holes, there seems to be very few species present.

Bryophyta. They are present only in two holes, Ken's and East Twin, found at depths to 10 m.

II. 2 - Anchialine Fauna

Biotic surveys. Several faunal and floral surveys have been conducted on the Blue Holes of Andros (WARNER and MOORE 1984; TROTT and WARNER 1986) and Grand Bahama Island (CUNLIFFE 1985).

Porifera. Three new species of sponges, *Pellina penicilliformis*, *Prosuberites geracei* and *Cinachyra subterranea*, were described from the anchialine pool in Lighthouse Cave, San Salvador (VAN SOEST and SASS 1981).

Polychaeta. A macellicephalan polynoid polychaete, identified by M. H. PETTIBONE, is perhaps a young *Pelagoacellicephala iliffei*, was collected in Hatchet Bay Cave on Eleuthera. This species was previously known only from the Turks and Caicos Islands.

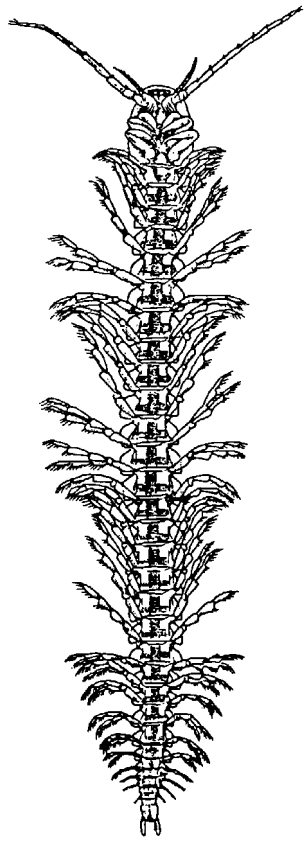


Fig. 6 - Remipede (From Yager).

Remipedia. The first remipede, *Speleonectes lucayensis*, was collected in 1979, by J. YAGER, from Lucayan Cavern, an anchialine cave on Grand Bahama Island. Specimens were collected in a zone of total darkness, in salt water, at a depth of 19 m. Others aquatic inhabitants of Lucayan caverns include species of Amphipoda Hadziidae (*Bahadzia williamsi*), thermosbaenaceans, cirolanids, isopods, ostracods, a Mysidacea *Stygiomisis*, and a blind cave fish (*Lucifuga spelaeotes*) (YAGER, 1981). Subsequent subaquatic exploration of others Blue Holes in the Bahama has resulted in the discovery of four new genera and five new species of Remipedes, *Cryptocorynetes haptodiscus*, *Pleomothra apletocheles*, *Godzillius robustus*, *Godzilliognomus frondosus*, *Speleonectes benjamini*, in anchialine caves on Grand Bahama Island and *Speleonectes lucayensis* in Andros Island (YAGER 1981a, 1989). Dan's Cave (Abaco Island) and Sagittarius Cave (Grand Bahama Island) are inhabited by the five genera and the six species of remipedes.

Amphipoda. A new genus of Amphipoda in the family Hadziidae, *Bahadzia*, composed of two closely similar stygobiont species was recently discovered from anchialine caves in the islands of Grand Bahama and Abaco (HOLSINGER and YAGER, 1985). HOLSINGER *et al.* (1986) suggests that Bahadzia is an ancient relict that was derived from an early hadziid fauna in the old Tethyan seaway. *Lucayarina catacumba*, a new genus of lysianassid amphipod was described from Cemetery Cave on Grand Bahama and Blue Holes on Andros (CLARK and BARNARD 1985).

Ostracoda. Two new troglobitic halocyprid ostracods *Danielopolina bahamensis* and *Deeveya jillae* were collected from Hatchet Bay Cave (KORNICKER and ILIFFE 1989). *Deeveya bransoni* inhabits several Blue Holes on South Andros (KORNICKER and PALMER 1989). Six new halocyprid ostracods from four anchialine caves were described by KORNICKER *et al.*, (1990). These include *Spelaeoecia styx* (El Dorado Cave, S. Andros), *S. sagax* (Sagittarius Cave, Grand Bahama), *S. capax* (Alfonso Dean Blue Hole, Long Island), *Deeveya styrax* (Dan's Cave, Abaco and Sagittarius Cave), *D. hirpex* (Dan's Cave), and *D. medix* (Sagittarius Cave).

Isopoda. Two new aquatic isopods have been described from Lighthouse Cave. These include *Neosteneroides stocki*, a new asellote isopod (CARPENTIER and MAGNIEZ 1982) and *Bahalana geracei*, a new cirolanid isopod (CARPENTIER 1981a). A second species of *Bahalana*, *B. cardiopus*, inhabits Mount Misery Cave on Mayaguana (NOTENBOOM 1981). *Dodecalana yagerae* represents a new genus and species of troglobitic marine cirolanid from Lucayan Caverns (CARPENTER, 1994).

Mysidacea. *Heteromysoides dennisi* is a new mysid from Cemetery Cave, an oceanic Blue Hole on Grand Bahama (BOWMAN 1985). *Stygiomysis holthuisi*, originally reported from the West Indian islands of Saint-Martin, Anguilla and Puerto Rico, is also found in Lucayan Caverns on Grand Bahama (BOWMAN *et al.*, 1984).

Cumacea. Six new species from the genus *Cumella*, *C. anae*, *C. andri*, *C. angelae*, *C. bacescui*, *C. bahamensis*, and *C. radui* were described from Blue Holes on Andros Island (PETRESCU and ILIFFE 1992).

Thermosbaenacea. Two new species from the genus *Tulumella* inhabit various Bahamian caves (YAGER, 1987). *T. grandis* has been collected from Lucayan Caverns, Sagittarius Cave, Bahama Cement Cave, Asgard Cave (Grand Bahama), Dan's Cave (Abaco), and Stargate Blue Hole (S. Andros). *T. bahamensis* inhabits Lucayan Caverns, Mermaid's Lair (Grand Bahama), Dan's Cave (Abaco), Stargate Blue Hole and El Dorado Cave

(S. Andros).

Copepoda. *Enantiosis cavernicola*, a new calanoid copepod, has been described from Lighthouse Cave (BARR 1984). A possible new genus of calanoid copepod inhabits Hatchet Bay Cave (Audun FOSSHAGEN, pers. comm.). Two new species, *Speleoithona eleutherensis* and *S. salvadorensis*, from the new family Speleoithonidae were described from Hatchet bay and Lighthouse Caves, respectively (ROCHA and ILIFFE, 1991). Five species of Harpacticoida have been described: *Paralaophonte echinate, Echinolaophonte horrida, Lipomelum heteromelum* (FIERS, 1986), and *Esola longicaudata* (EDWARDS, 1891) from Lighthouse Cave in San Salvador, and McKays Bluff Sea Cave in Crookeed Island.

Decapoda. *Barbouria cubensis*, an orange to red hippolytid shrimp, inhabits caves and open anchialine pools on Grand Bahama, Abaco, and San Salvador (HOBBS 1978). The same species also occurs in similar habitats in Bermuda, Cuba, the Cayman Islands and Jamaica. An as yet undescribed species of *Typhlatya* occurs in Abaco. *Somersiella sterreri* and *Janacia antiguensis* are present in two oceanic Blue Holes, Cemetery and Chimney Caves on Grand Bahama. *J. antiguensis* also occurs in Gemini Cave, part of the Zodiac Caverns on Grand Bahama. Other shrimp from Blue Holes on Grand Bahama include *Rhynchocinetes rigens, Alpheus formosus, Brachycarpus biunguiculatus, Macrobrachium faustinum* and *M. lucifugum* (C.W. HART, Jr., pers. comm.).

The Grapsid crab *Sesarma angustipes* was found in Uncle Charlie's Blue Hole.

Chaetognatha. The eyeless and unpigmented *Paraspadella anops* from Sagittarius Cave on Grand Bahama Island is the second troglobitic chaetognath (BOWMAN and BIERI, 1984).

Fishes. The cave dwelling fish *Lucifuga speleotes* was found in Uncle Charlie's Blue Hole, in Andros. Fisches from 2-12 cm in length were of various colours, from pink to black. *L. speleotes* is also present on Grand Bahama and New Providence.

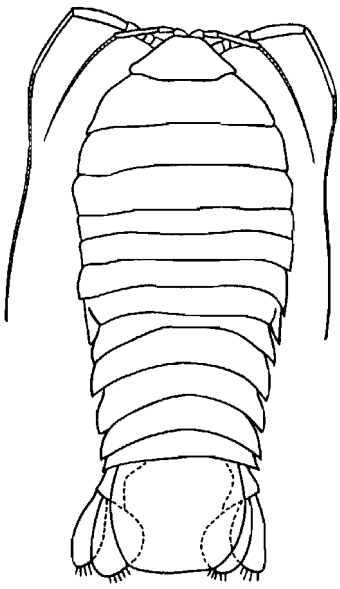


Fig. 7 - Isopoda. *Bahalana cardiopus* Notenboom, 1981, from Lighthouse Cave (From the author).

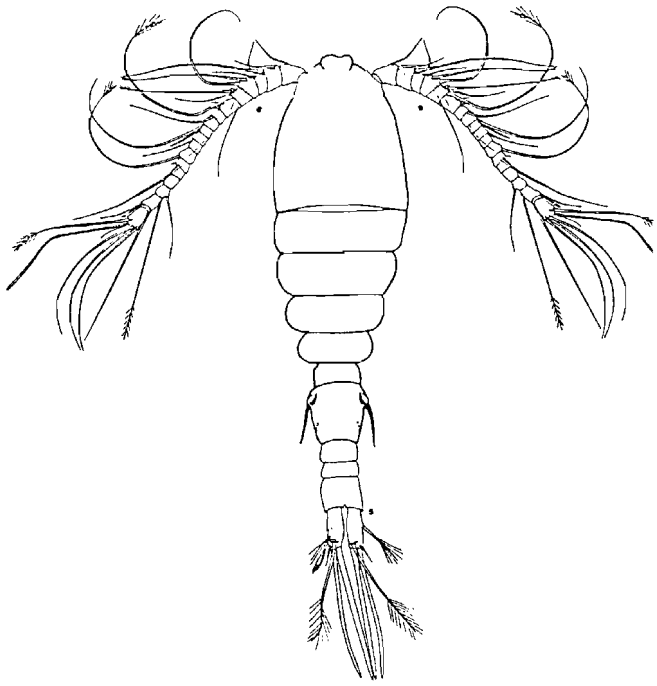


Fig. 8 - Copepoda Speleoithonidae. *Speleoithona eleutherensis* Rochas and Iliffe, 1991, from Hatchet Bay Cave (From the authors).

To conclude, a new class of Crustacea, the remipede, and over 40 new stygobite species have been described from anchialine caves (Blue Holes) in Bahamas: Remipedia 6; Amphipoda 3; Ostracoda 9; Isopoda 4; Mysidacea 1; Cumacea 6; Thermosbaenacea 2; Copepoda 8; Decapoda 2; Chaetognatha 1; Fishes 1.

II. 3 - The Terrestrial Fauna

The diverse terrestrial fauna of Lighthouse Cave, San Salvador, includes bats, cockroaches, isopods, snails, and pseudoscorpions. Food webs in this cave have been discussed by CARPENER (1981b).

Chiroptera. Bats were present in the majority of caves examined in Cat Island often in great numbers (2000 + estimated in Strawline Cave). These were *Macrotus waterhousii compressus* (Big eared bat), *Natalus lepidus* (Gervais funnel-eared bat), *Tadarida brasiliensis bahamensis (*Brazilian Freetailed bat) and *Erophylla sezekorniplanifrons* (Buffy flower bat). *Macrotus* and *Eraphylla* eat pollen, nectar or fruit eaters with some insects. The species *Natalus* and *Tadarida* feed exclusively on insects. Insect remains, fruit stones and seed cases often form a loose litter over guano beds.

Tabl. 1 - Stygobitic genera and species from Blue Holes on Bahama Islands.

Groups and Species	Blue Hole
Polychaeta	
Pelagoacellicephala iliffei	Hatchet Bay Cave (Eleuthera)
Remipedia	
Speleonectes lucayensis Yager, 1981	Lucayan Cavern (Grand Bahama), Andros
Speleonectes benjamini Yager, 1987	Sagittarius Cave (Grand Bahama), Dan's Cave Abaco
Cryptocorynetes haptodiscus Yager, 1987	Asgard Cave (Grand Bahama)
Pleomothra apletocheles Yager, 1987	"
Godzillius robustus Schram, Yager, Emerson 1986	"
Godzilliognomus frondosus Yager, 1989	"
Ostracoda	
Danielopolina bahamensis	Hatchet Bay Cave (Eleuthera)
Deeveya (5 sp.)	Eleuthera, South Andros, Abaco
Spelaeocia (3 sp.)	South Andros, Grand Bahama, Long Islan d
Copepoda	
Harpacticoïdea	
Paralaophonte echinate Fiers, 1986	Dixon Hill Lighthouse Cave (San Salvador)
Echinolaophonte horrida Fiers 1986	McKays Bluff Sea Cave (Crookeed I.)
Lipomelum heteromelum Fiers 1986	McKays Bluff Sea Cave (Crookeed I.)
Esola logicaudata Edwards, 1891.	Dixon Hill Lighthouse Cave (San Salvador)
Calanoidea	
Eniantosis cavernicola Barr, 1984	San Salvador
Speleoithonidae	
Speleoithona (2 sp.)	Eleuthera
Isopoda	
Neostenetroides stocki Carpenter and Magniez, 1982	Bahamas
Protohadzia schoernerae Fox, 1973	Mount Misery Cave, Little Bay (Mayaguana Island)
Bahalana cardiopus Notenboom, 1981	Dixon Hill Lighthouse Cave (San Salvador)
Bahalana geracei Carpenter, 1981	Lucayan Cavern (Grand Bahama)
Dodecalana yagerae Carpenter, 1994	Lucayan Cavern (Grand Bahama)
Mysidacea	
Hetreomysoides dennisi Bowman, 1985	Grand Bahama
Stygiomysis holthuisi Gordon, 1958	Grand Bahama I and Great Abaco I
Cumacea	
Cumella (6 sp.)	Andros
Amphipoda	
Hadziidae	
Bahadzia williamsi	Lucayan Cavern (Grand Bahama) Stargate Blue Hole (Andros), Dan's Cave (Abaco)
Lysianidae	
Lucayana catacumba Clark & Barnard, 1985	Cemetary Cave (Grand Bahama)
Thermosbaenacea	
Tumulella grandis Yager, 1987	
Tulumella bahamensis Yager, 1987	Uncle Charlie's Blue Hole (Andros)
Decapoda	
Grapsidae	
Sesarma angustipes	
Atyidae	
Typhlaya sp	Abaco
Hypolytidae	
Janicea antiguensis (Chace, 1972)	Grand Bahama
Somersiella sterreri Hart & Manning, 1981	Grand Bahama
Chaetognatha	
Paraspepadella anops Bowman & Bieri, 1984.	Grand Bahama
Pisces	
Bythitidae	
Lucifuga spelaeotes	Stafford Creek, n° 2 Blue Hole
Lutjanidae	
Lutjanus griseus	Cat Island

Fresh Guano Fauna. The most interesting cave habitat encountered on Cat Island was that provided by undisturbed fresh guano (McHALLE, 1986). It is somewhat surprising, that given the large numbers of bats in the caves and their wide distribution, that only three caves had large deposits of fresh guano. These sites were Strawline, Griffin and Crown Caves - deposits up to 700 m^2 were seen in the latter site.

The guano was covered with the seed-like egg cases of tineid moths, many containing pupae. Adult moths were also abundant above the guano. The substrate was also utilised by various mites and collembola. More interesting, was a species of 'isopod-like' beetle or beetle larva which was extremely abundant, all over the guano and able to dig into the substrate.

A species of opilionid was also common, and this may prey on the other inhabitants, as may the numerous pseudoscorpions observed in the guano. These are the same species of pseudoscorpion seen in the dry and disturbed guano habitat. The terrestrial fauna of Eight Mile Cave on Abaco includes bats, isopods, pedipalpi, milipedes and spiders.

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