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VERTEBRATE PALEONTOLOGY OF ISLA DE MONA, PUERTO RICO

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*Vertebrate fossil materials were collected from over a dozen cave localities on Isla de Mona, Puerto Rico. Guano deposits at these localities were excavated and sifted to recover bone materials. The predominant vertebrate fossils recovered at every sifting site were Audubon's shearwater (*Puffinus lherminieri*) bones. Fragmentary undifferentiated lizard bones were also found sporadically in the sifted material. Fossil skeletal bones and fresh bones from other bird species were found on the surface of the cave floors at several localities. Extensive fossil guano deposits on the island are interpreted to be of mixed origin with deposits near entrances primarily derived from bird guano, and deposits from the darker interiors of the caves derived from bat guano.*

Isla de Mona is a small, isolated island located in the Mona Passage, 68 km west of Puerto Rico and 60 km east of Hispaniola. There are a limited number of native, non-flying, vertebrate species extant on Isla de Mona. These include nine species of terrestrial reptiles (six lizards and three snakes), one species of amphibian (coqui tree frog), and two species of native mammals, both bats (Wiewandt 1973). Five species of sea turtle live in the Caribbean region. Hawksbill, leatherback, and green turtles nest on Isla de Mona and the others may nest there occasionally, as well.

Mammals on the island presently include rats, mice, goats, pigs, and wild house cats, and in the recent past have also included dogs, burros, and cattle. All non-native species were brought to the island by settlers, miners, and pirates (Weiwandt 1973). Remains of a large rodent *(Isolobodon potoricensi)* were reported from the island by Anthony (1926) and later workers, but always in association with Taino archaeological sites. These rodents were a common item in the diet of the Taino Indians and could easily be carried by them from one island to another (Weiwandt 1973). Rafaele (1973) provides a list of 97 species of birds that have been observed on the island, but only 14 have significant breeding populations. Similar patterns of endemicism and cross-island affinities are apparent in the vegetation on the island (Woodbury 1973) and terrestrial arthropods (Velez 1973; Martorell 1973; Peck & Kuklova-Peck 1981). The particular terrestrial species represented and the limited diversity, or departerate nature are characteristic of island populations established by waif dispersal as described most recently by Stehli and Webb (1985) and Perfit and Williams (1989). In waif dispersal, animasl are carried to oceanic islands primarily by clinging to floating debris that has been washed out to sea or carried by flying birds or bats to the island.

PALEONTOLOGICAL INVESTIGATIONS

There have been few investigations of Isla de Mona vertebrate paleontology. The earliest work of note was by H.W. Anthony in 1926 (Anthony 1926, Goodwin 1926). Anthony was interested in finding mammal bones on that expedition, but met with little success. He found isolated fragments of *Isolobodon sp.*, but all were associated with Taino sites. Fragments of unidentified bird bones were found in indurated crevice fill material. Fish bones were in a phosphate bed within extensive guano deposits. He attributed the origin of this deposit as altered guano from a fish-eating bat (*Noctilio leporinus mastivus*). The most significant discovery was tortoise bones from two localities on the eastern side of the island. The first was from an unidentified crevice fill, the second was a more complete skeleton from the Cathedral Chamber in Cueva del Lirio at Punta Este. The material from the later skeleton *(Geochelone (Monachelys) monesis)* was first described by Williams (1952), revised by Auffenberg (1967). The reconstructed skull was 6 cm long, suggesting a shell size of ~0.5 m. *Geochelone* is the only genus yet found in the fossil record in the Caribbean. *Geochelone* specimens have been found in Cuba, Sombrero Island, New Providence Island, Navassa, Curacao, and Antigua (Auffenberg 1967; Pregill 1991).

Kaye (1959) described a deposit of bones from the Audubon's Shearwater (*Puffinus lherminieri*) intermingled with charcoal in the back of Cueva Negra on the southwestern side of the island. He hypothesized the remains to be a midden refuse deposit from paleo-Indian feasts. Recent radiocarbon dating of the associated charcoal remains yielded a conventional radiocarbon age of 380 $\pm$ 60, or a corrected nominal calendar age of 1525 AD, with a one deviation range of 1480 to 1655 AD (Frank 1998a). This age is consistent with Kaye's interpretation. This represents the period encompassing the contact between Taino populations and Europeans. Circumstantial evidence suggests that this deposit was a Taino midden, but a European origin can not be completely ruled out. None of the other samples collected in 1995 were associated with Taino archaeological materials and may be substantially older.

More recently Nieves-Rivera *et al.*. (1995) described sample collected from a water-filled portion of Cueva de Agua (Punta los Ingleses). Three species were identified from the samples: 1) Audubon's Shearwater (*Puffinus lherminieri*); 2) Mona Island Ground Iguana (*Cyclura stejnegeri*) and 3) Blainvilee's Leaf-chinned Bat (*Moormops blainvilli*). Ages of the deposits could not be specifically determined, but the authors estimated them to be on the order of tens of years rather than hundreds of years.

PRESENT INVESTIGATIONS

In 1995, sampling localities included Cueva de los Losetas on the east side, Bat Cave on the south side, Cueva Negra on the southwest side, and several sites within Cueva del Diamante on the west side of the island. Materials were also collected from grab sites in several other caves. At these sites guano and detrital material was dug from the cave floor and sifted on site through a shake table of 1/4" mesh wire screen. Bone material was picked from the screen surface and from the sifted tailings below. Samples of associated loose sediment and phosphate crust material were collected, as well as some specimens of *Cerion sp.* (snail shells), likely carried into the site by hermit crabs. Where practical, some of the material was re-sifted through finer mesh screens.

Identifications were made on the basis of specimens in the avian skeletal collection of the Bell Museum of Natural History, University of Minnesota. Most identified bird bones are Audubon's Shearwater (*Puffinus lherminieri*), the family Procellariidae. Audubon's Shearwater, which presently occurs on Isla de Mona (Raffaele 1973), is the only shearwater of any genus of its small size to occur in the Carribean (del Hoyo *et al.* 1992).

A single humerus of the Black-capped Petrel (*Pterodroma hasitala*), another member of the procellariid family, also occurs among the collected specimens. The humeri of this species differ from Audubon's Shearwater in being larger and having a less compressed shaft. The Black-capped Petrel is the only petrel inhabiting the Carribean (del Hoyo *et al.* 1992). Other specimens include Red-footed and Brown Boobies (*Sula sula and Sula leucogaster*), the latter represented by a hatchling age individual. Both of these species nest on Isla de Mona (Raffaele 1973). A single humerus of a large passerine bird, missing its proximal end, also occurs among the collected bones. The specimen is of a kingbird, the size of a Loggerhead or Gray Kingbird (*Tyrannus caudfasciatus* or *T. dominicensis*).

DISCUSSION

Aside from a few fragmentary, undifferentiated, lizard skeletal specimens, the samples collected were almost exclusively Audubon's Shearwater skeletal remains. Skeletal fragments from that species were found at all entrance locations and, surprisingly, in a completely dark chamber in the back of Cueva del Diamante. The Audubon's Shearwater specimens collected from Cueva Negra, Site C, in bag 108, are from the same locality as those collected by Kaye (1959) which he identified as exclusively Audubon's Shearwater. Audubon's Shearwater historically has nested in small numbers on Isla de Mona, and may presently be nesting on Isla Monito, Isla de Mona's small sister island (Raffaele 1973). It is the only representative of the family Procellariidae in Puerto Rico and the Virgin islands and is fast becoming extirpated from its few nesting cays in the Virgin Islands as a result of over-hunting or poaching (Raffaele 1973). The wide distribution of bones from this species suggests that it once was much more common, and possibly the predominant species of sea bird on the island.

Surface samples from various localities also included several other bird species: Red-footed Booby (*Sula sula*), Kingbird *(Tyrannus sp.*), Black-capped Petrel (*Pterodroma hastitata*), and Brown Booby (*Sula leucogaster*) which are still present in the area. These bones may be of recent origin.

A small vertebra, less than 1 cm in length, in a sample from Cueva de los Losetas (Bag 133) is tentatively identified as crocodile vertebrae based upon typical procoelous characters. This is the first report of crocodile remains from Isla de Mona, although crocodylidea presently live, or have been found in the fossil record, from other Carribean localities including: Cuba, Hispaniola, Jamaica, Isla de Juventud, Cayman Islands, Grenada, and New Providence Island, Bahamas (Pregill 1981, 1982). The cave itself is atop a 45 m high, overhung cliff above the sea and kilometers in distance from any presently easy sea level access.

The caves where these skeletal materials were found contain extensive fossil guano deposits. In the late 1880s and early 1900s, ~150,000 metric tons of guano were commercially mined from caves on the island (Kaye 1959; Frank 1998b). Determining the origin of these fossil guano deposits, bat or bird, was one of the goals of the sampling effort. Bat bones were not found in any of the sifted fossil guano material. However sifting fresh guano from an active bat colony in Bat Cave also yielded no bat bones. Bat bones are digested by chemical and biological activity within the fresh guano deposits and do not survive incorporation into the fossil record. The thickness of the fossil guano deposits in entrance areas, the numbers of Audubon's Shearwater bones, hermit crab claws, and associated *Cerion sp.* shells suggests that the deposits in these areas are primarily derived from bird guano. The bulk of the cave deposits, however, are in twilight to total darkness. Given that there are no remains of echolocating birds, such as the Oil-Bird (*Steatornis caripensis*) of South America, we interprete these deposits as bat guano.

Whatever the origin of the deposits, a significantly larger population of bats and birds than currently on the island would be required to produce deposits of this volume. ^{14}C dating was not performed on the guano deposits from these Isla de Mona caves because geomorphologic evidence indicates that many of the deposits are probably on the order of hundreds of thousands of years old, beyond the range of ^{14}C dating. Individual

deposits may vary from over 2 Ma to recent and dating would not yield information of significant interpretive or diagnostic value. Also, Audubon's Shearwater fossils are not particularly age diagnostic.

If migration of species across the Caribbean Islands took place by dispersal from populations originating in South America, North America, Central America, or Cuba, then the fossil record of Isla de Mona species might be expected to include examples of species that migrated from Puerto Rico to Hispaniola or from Hispaniola to Puerto Rico, and some species that are on only one or the other of the islands. Isla de Mona is a stepping stone bridging one of the longest gaps in the migration routes from island to island in the Lesser and Greater Antillies island chains. Because of deep water on all sides of Isla de Mona, during past low sea level stands the length of this gap would not be significantly different than it is today. The lack of a diversified fossil faunal record is likely a combination of three major factors: (1) the fossils could be present, but simply have not been found yet, (2) specific species may have moved from one large island to the other bypassing Isla de Mona, or (3) the transient species may not have established a breeding population on Mona because of its small size, or lack of appropriate habitat.

A persistent problem when evaluating vertebrate fossil records from the Caribbean is determining the ages of the specimens. Many of the prime fossil localities are within caves or infilled karst features. Uranium-thorium dates (Ruiz 1993) and paleomagnetic investigations (Panuska 1998) provide evidence that many of the caves on Isla de Mona may be in excess of 2 Ma. Williams (1952) tentatively assigned a sub-recent age for the tortoise fossil from Cueva del Lirio. There is no empirical basis for this age assignment, and we would suggest the specimen may potentially be as old as 2 Ma or as young as subrecent.

Some fossil materials preserved in these caves and other fossil bearing caves on other islands similarly may be upwards

Table 1. Identifications, Minimum Number of Individuals (MNI) tabulations, and general listings of avian bone material collected on Isla de Mona, Puerto Rico, July 1995.

Cueva Negra Site C, Bag 08; (Specimens are charred).
Puffinus lherminieri (Audubon's Shearwater)
MNI=5, based on 5 distal ends of right humeri.
ID based on distal end of a left humerus with procellariid characters. Also present are a pair of left and right carpometacarpi.

Bat Cave, surface material, Bag 67.
Tyrannus sp. (Kingbird)
MNI=1, based on distal end of a right humerus.
ID based on distal end of a right humerus of a large tyrannid.
Tyranni, family unidentified
MNI=1
The proximal end of a right ulna of another, but smaller, suboscine passerine, not yet identified, is also present.

Cueva del Diamante, southernmost entrance, Bag 113 and 115.
Puffinus lherminieri
MNI=11, based on 11 right humeri.
ID based on a complete procellariid right femur, left ulna and carpometacarpus, manual phalanges, and right tibiotarsus. Also present are procellariid sacrum and pelvis, scapula, humeri, ulnae, carpometacarpi, manual phalanges, and tibiotarsi, and 5 tarsometatarsi.

Cueva del Diamante, back of cave in dark, Bags 123 and 124.
Puffinus lherminieri
MNI=5, based on 5 proximal ends of left humeri.
ID based on a left coracoid and humerus, a right tibiotarsus, a tarsometatarsus, right humerus and ulna, left carpometacarpus, and right tibiotarsus and tarsometatarsus of a procellariid. Specimens are very encrusted, so that surface details are obliterated; identification is by general outline and size.

Cueva de Espinal, Pictograph Room, Bag 117.
Pterodroma hasitala (Black-capped Petrel)
MNI=1, based on distal end of right humeri.
ID based on the single specimen in bag, the distal end of a right humerus.

Cueva de Espinal, Pictograph Room, Bag 118.
Sula leucogaster (Brown Booby)
MNI=1.
ID based on the extremely unossified partial skeleton of a hatchling.

Cueva de los Losetas, Layer 5, Bag 112.
2 unidentified long-bone shafts.

Cueva de los Losetas, Bag 119.
Sula sula (Red-footed Booby)
MNI=1, based on 1 sulid pelvis.
ID based upon a sulid pelvis.

Cueva de los Losetas, from surface, Bag 111.
Puffinus lherminieri
MNI=1, based on distal end of a left humerus.
ID based on distal end of a left humerus identical to that listed for Bag 08 above.
Sula sula
MNI=1, based on a pair of right and left sulid radii.
ID based upon a pair of sulid radii. The left radius is complete, however only the proximal end of the right radius is present. Also present is a clavicular fragment of a furcula.

Cueva de los Losetas, Crunchy Room, Bag 126.
Puffinus lherminieri
MNI=1, based on the proximal ends of a pair of left and right tarsometatarsi.
ID based upon the proximal ends of a pair of left and right tarsometatarsi.

Cueva de los Losetas, 2nd phosphate layer, Bag 127.
Puffinus lherminieri
MNI=4, based on 4 left and right proximal ends of humeri.
ID based on procellariid humeri and tarsometatasi. Also present are the ventral fragments of a right coracoid and a right ulna.

Cueva de los Losetas, 2nd phosphate layer, Bag 128.
Puffinus lherminieri
MNI=3, based on 3 left proximal ends of humeri.
ID based on coracoids and humeri of the type identified as this species.

Cueva de los Losetas, Bag 131.
Puffinus lherminieri
MNI=3, based upon 3 left humeri.
ID based upon procellariid humeri, radius, femur, and tibiotarsi.

Cueva de los Losetas, Bag 133.
Puffinus lherminieri
MNI=3, based on 3 left coracoids.
ID based on procellariid coracoids, humeri, left ulna and left femur. Also present is a symphyseal fragment of a furcula consistent with a *Puffinus* of this size.

Cueva de Esquelleto, Bag 120.
Puffinus lherminieri
MNI=2, based on 2 left humeri.
ID based on left humerus and tarsometatarsus.

Cueva de Esquelleto, Bag 122.
Puffinus lherminieri
MNI=2, based on 2 right coracoids.
ID based on left and right humeri, left carpometacarpus, sacrum, and right femur and tibiotarsus.

of several million years old. The speed of karst processes is highly variable. We urge other researchers to consider that many fossil deposits may be older than they first appear and to interpret the available stratigraphic and empirical dating information accordingly. Paleontologists and karst scientists can both benefit from working more closely together to better establish ages for fossil localities and time lines for trans-island migrations.

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