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Jean-Baptiste Mallye, Salvador Bailon, Corentin Bochaton, Monica Gala, Nathalie Serrand, et al.. Blanchard Cave 2: A historical period Audubon's shearwater (*Puffinus lherminieri*) nesting site in Marie-Galante (Guadeloupe islands, FWI). *Journal of Archaeological Science: Reports*, 2018, 17, pp.250-262. 10.1016/j.jasrep.2017.11.004 . hal-02347470

HAL Id: hal-02347470

<https://hal.science/hal-02347470>

Submitted on 6 Mar 2023

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Blanchard Cave 2: A historical period Audubon's shearwater (*Puffinus lherminieri*) nesting site in Marie-Galante (Guadeloupe islands, FWI)

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ABSTRACT — In this paper we present a natural deposit in Marie-Galante island (French West Indies), Blanchard 2, where historical-period Audubon's shearwater remains dominate the vertebrate assemblage. We combined a study of sediment geometry, a taphonomic analysis of molluscs, crustaceans and vertebrate remains, and direct radiocarbon dating on bird bone to demonstrate that the cave was used as a nesting ground during the island's colonial period. This approach also allows the discussion of the causes leading to the desertion of the site by birds.

Finally, we investigate hypotheses regarding the dynamics of Audubon's shearwater nesting during prehistoric and historical times and the impact of anthropogenic phenomenon on these birds

Received 23 July 2017; Received in revised form 30 October 2017; Accepted 4 November 2017.

Key words — Audubon's shearwater, Palaeobiogeography, Taphonomy, Human-induced impact, Lesser Antilles, Caribbean.

1. Introduction

Oceanic islands are known to be fragile environments where indigenous biotas are strongly vulnerable to human-induced modifications (van der Geer et al., 2010). This remark is especially valid for Caribbean islands which are home to numerous wild animal species threatened with extinction or which have already disappeared (Myers et al., 2000).

This area presents the worldwide highest extinction rate in the world of its endemic non-flying mammals, greater than 95% following Dávalos and Turvey (2012). Indigenous Squamates and bats also have very high extinction rates depending of the island (e. g. 60% to 70% on Marie-Galante Island: - Bailon et al., 2015; Stoetzel et al., 2016-). Concerning birds, many extinct species have been described (Turvey, 2009) and the description of the past Caribbean avian diversity is still ongoing (e.g. Gala and Lenoble, 2015; Takano and Steadman, 2015; Steadman and Takano, 2016). During the last decade several studies have highlighted the preponderant role of Man in these numerous extinction events (Steadman et al., 2005; Bailon et al., 2015; Soto-Centeno and Steadman, 2015; Stoetzel et al., 2016) and the minor role of natural modifications of the environment in these processes. However, much work has still to be done to determine the exact timing of extinctions and the exact relation between extinctions and human behaviours or historical event.

Amongst extinct species, marine bird species have seen an important reduction in their numbers (Lowrie et al., 2012). The Audubon's shearwater (*Puffinus lherminieri*), a small, land-nesting bird, is currently considered one of the most threatened, particularly due to the introduction of mammal species, such as the black rat, which feed on its eggs and hatchlings. In fact, these rodents have been shown to heavily impact marine bird colonies (Atkinson, 1985; Towns et al., 2006; Jones et al., 2008). Indeed, the extent to which black rat predation can impact breeding colonies of Audubon's shearwater was recently revealed following an attempt to eradicate the rodent from the islets of Saint-Anne, Martinique (Pascal et al., 2004).

Today, Audubon's shearwater nesting grounds are for the most part located on small coastal islets (Birdlife International, 2014; Lowrie et al., 2012; Bright et al., 2014). However, the discovery of Audubon's shearwater bones in archaeological or paleontological contexts on Caribbean islands where this bird is no longer present, such as Mona, Anguilla, Antigua and Barbuda (Wing et al., 1968; Pregill et al., 1994; Nieves-Rivera et al., 1995), suggests a reduction in nesting areas as a consequence of European colonisation, especially due to the intentional or accidental introduction of exogenous mammals such as the rat or mongoose. This, however, does not exclude the possibility of an earlier human impact.

In fact, the human exploitation of nesting ground marine birds is described as having almost immediately followed the settling of the first European colonists in the region in the early 17th century. For example, historical accounts mention that sterns on the islets of Les Saintes were heavily exploited by Europeans (Breton, 1647: 32) and that marine birds formed part of the subsistence strategies of indigenous populations (Du Tertre, 1667: 274–275; Breton, 1665: 164). However, the use of marine birds is likely to date to considerably earlier. For instance, the disappearance of Black-capped petrel from Martinique was advanced by Wetmore (1952) on the basis of the discovery of a bone of this

species in pre-Columbian middens of the Ceramic age period (ca. -300 BCE to 1500 CE). A much earlier human impact on native bird populations is even possible. Indeed, excavations at a preceramic site on Dog Island (Anguilla), one of the most important nesting grounds in the Caribbean (Hodge et al., 2008), led Crock (2005) to suggest that human predation on birds dates to the earliest occupation of the archipelago, some 5000 y BP.

The question is even more pertinent for the Audubon's shearwater, one of the most frequent marine birds found in Amerindian middens (Grouard, 2001; Wing, 2001), several of which amongst the oldest known in the archipelago (Hofman et al., 2006).

In addition to Amerindian middens, Audubon's shearwater remains have also been documented from caves and rock shelters (e.g. Pregill et al., 1994; Morgan, 1994; Nieves-Rivera et al., 1995). Nevertheless, these sites often lack chronological resolution and the agents responsible for the deposits (human and/or animal predation or nesting sites) more often than not remain difficult to determine. As a result, the historical biogeography of this species proves difficult to document.

Numerous studies have however provided criteria for determining the agent responsible for the accumulation of bird bones in fossil contexts. While the identification of butchery marks remains the most reliable evidence for human exploitation (Laroulandie, 2000, 2001, 2005; Vigne et al., 1991), the relative proportions of certain anatomical parts can provide arguments concerning the origin of avian material in both archaeological and natural contexts (Baales, 1992; Bovy, 2002; Bochenski, 2005; Ericson, 1987; Livingston, 1989). Besides, in a few rare cases, it has been possible to demonstrate that bird bone accumulations result from the use of caves as nesting sites, where numerous complete remains of both young and adult individuals occur in the context of a near total absence of evidence for either animal or human predation (Laroulandie, 2000, 2010; Mourer-Chauviré, 1975, 1983).

Here we discuss evidence from a site in Guadeloupe, Blanchard 2, where historic-period Audubon's shearwater remains dominate the vertebrate assemblage. Sedimentological data, a direct date on faunal material, and an analysis of mollusc, crustacean and vertebrate remains combined with a taphonomic approach indicates the site to have been a nesting ground during the island's colonial period. This taphonomic approach also allows the causes leading to the abandonment of the site as a nesting ground to be discussed, and by extension, investigate hypotheses concerning the dynamics of Audubon's shearwater nesting as a response to the region's prehistoric and historic settlement.

2. Site background

Blanchard 2 (15°52'55.82"N, 61°14'2.27"W, 10 m NGF) is a small crevice cave formed in the rhodolith limestone of Pliocene age (Lenoble et al., 2009). The cave opens onto the Capesterre cliff, not far from Blanchard 1. The site lies a few metres above the Petite Anse coastal plain in a dry deciduous forest on the southern part of Marie-Galante (Fig. 1) (Rousteau et al., 1994). Discovered in 2007, vertebrate and malacological material, together with a pierced, lozenge-shaped conch shell button and an unworked conch shell identified on the surface near the entrance alongside a flint flake recovered further within the cave suggested an Amerindian occupation. Moreover, the site is located

in an area rich in sites of both cultural and natural importance. Several dozen metres to the west on the same cliff face can be found the rock shelters of Cadet. Cadet 3 rock shelter contains Late Glacial to Holocene fossil deposits (Stouvenot et al., 2014), and Cadet 2 rock shelter, an Amerindian funerary cave also contains natural deposits and documents the islands final Pleistocene vertebrates (Courtaud, 2011; Bochaton et al., 2015). A test pit practised under the porch of the nearby Blanchard 1 site also produced an Amerindian burial (Stouvenot, 2005; Grouard et al., 2014), while the zone deeper within the cave contains substantial Pleistocene fossil deposits (Lenoble et al., 2009; Goetz et al., 2014; Bailon et al., 2015; Stoetzel et al., 2016). Amerindian settlements are also known from the vicinity of the cave, including the Saladoid and Troumassoid site of Tourlourous (Colas et al., 2002) located a little more than a kilometre to the northeast on the same plain, and the Troumassoid site of Petite Anse, a few hundred metres from Blanchard 2 on the littoral belt of the Anse (Lenoble et al., 2012; Casagrande, 2013).

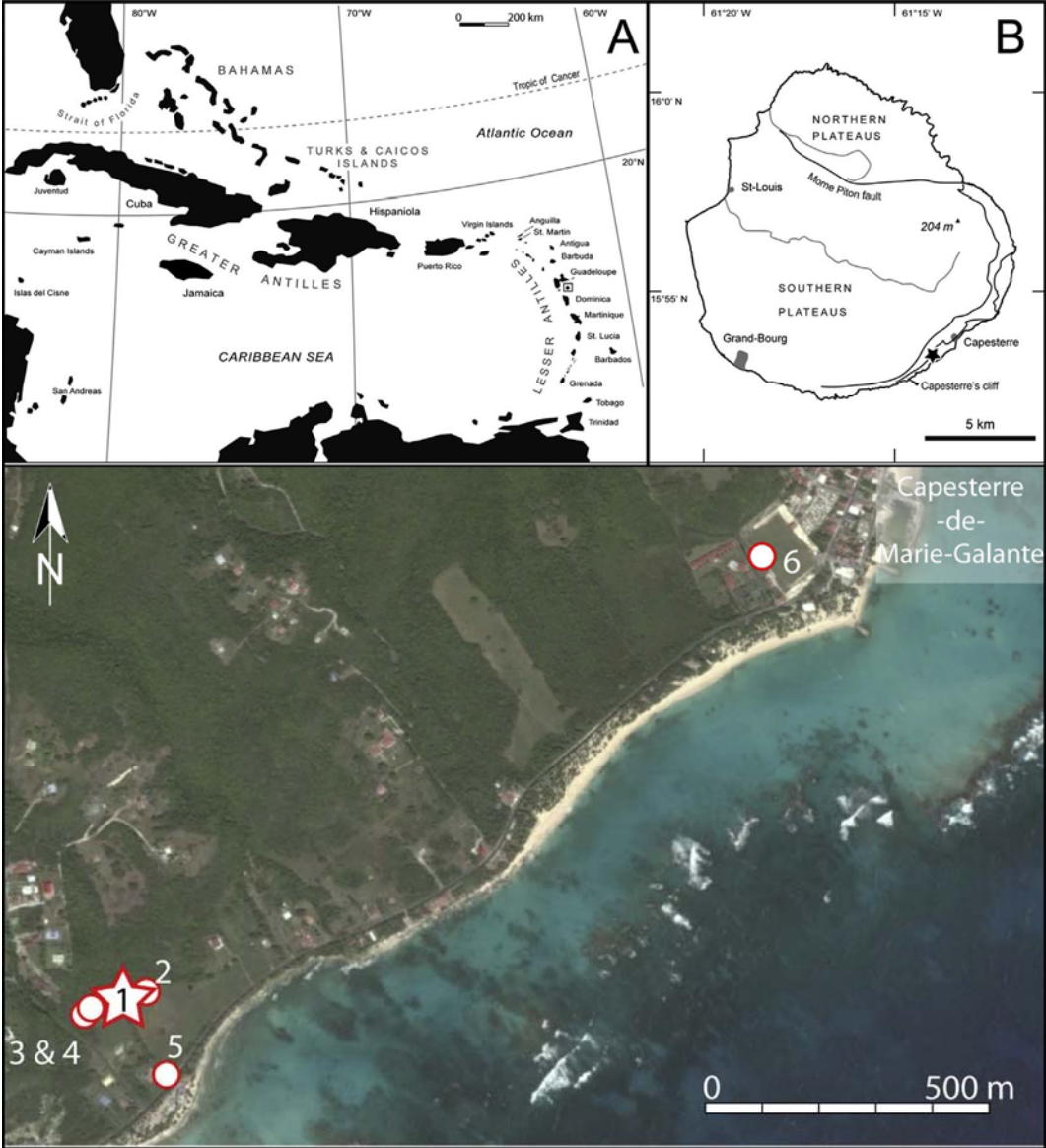


Figure 1. Location of the sites discussed in this study. 1: Blanchard 2 cave; 2: Blanchard 1 cave; 3, Cadet 2 rock shelter; 4: Cadet 3 rock shelter; 5: Petite Anse; 6: Tourlourous.

Blanchard 2 comprises a main corridor that follows the cliff line and from which several smaller, lower chambers can be accessed (Fig. 2). This configuration is typical of crevice caves that form following slope failure (Halliday, 2004). The cave has two entrances, the first, however, is impractical due to rock fall. The more accessible eastern entrance, although low (~1 m) is 8 m wide, allowing access to a slope leading to an 8 m long and 2 to 2.5 m wide corridor filled with rock fall. This north-south corridor runs approximately 15 m and cuts several pre-existing cavities that are too low to enter (0.3 to 0.5 m). It is likely that these smaller, interconnected chambers continue for several metres in the rock mass.

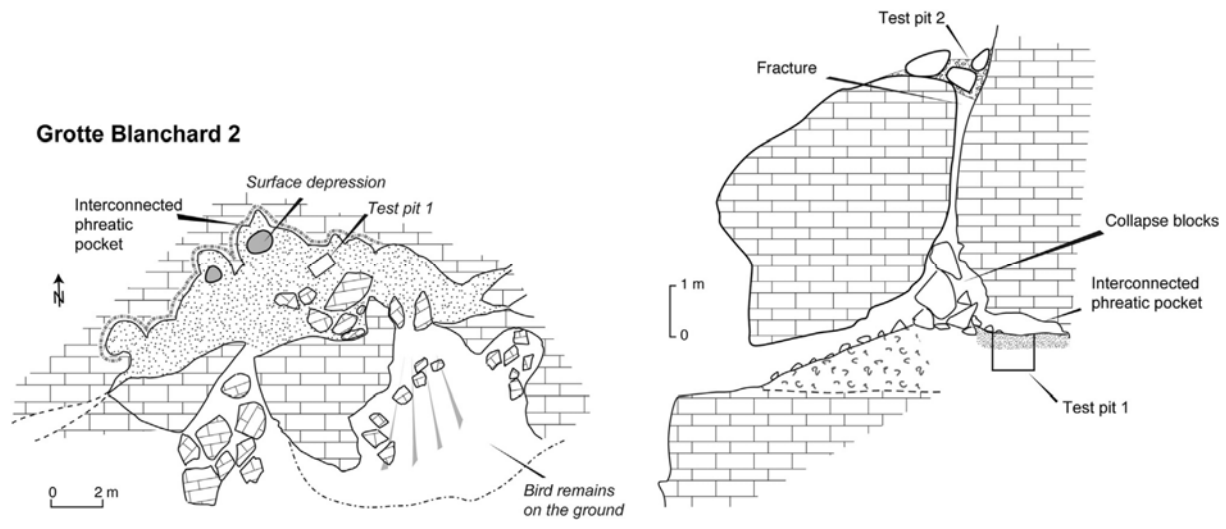


Figure 2. Cave topography. Left, view from the top; right, view from the East side of the cliff.

3. Material and methods

Following a comprehensive topographic survey of the cave's surface, a half-square metre test pit (test pit 1) was excavated towards the front of the central chamber in the northern section of the cave (Fig. 2). Excavations consisted of eleven 5-cm-thick spits that followed the geometry of the deposit. The excavated sediment was dry-sieved using a 2.8 mm mesh in order to recover all osseous materials. Additionally, bones were collected from the surface of the cave's eastern entrance. The stratigraphic analysis combined pedological (colour, texture and structure) and sedimentological criteria (bedding, clast type and orientation) complemented by a consideration of the geometry of the stratigraphic units and the nature of the contact between layers. A second 0.5 m by 0.5 m test pit (test pit 2) was dug to no deeper than 0.2 m on the slope overlying the site in order to control for the possible introduction of faunal material into the site.

Mollusc and crustacean remains were identified at the *Institut national de recherches archéologiques préventives* (Inrap) of Guadeloupe by S. Serrand. Vertebrate remains were determined to taxa with reference to the Comparative Anatomy collections held by the *Muséum national d'Histoire naturelle* in Paris (MNHN) and the PACEA laboratory at the University of Bordeaux. A fair portion of

the bird remains could not be identified due to their heavily fragmented state, the presence of young individuals presenting no clear diagnostic traits and numerous problems in identifying bones of small Passeriformes. This non-identifiable material was therefore grouped in four size classes: small passerines (class 1, e.g. *Loxigilla noctis*), specimens similar in size to pigeons (class 2, e.g. *Zenaida aurita*) or Audubon's shearwater (class 3, e.g. *Puffinus lherminieri*) and those equal to or larger than herons (class 4, *Nyctanassa violacea*). All of the vertebrate remains were counted by spit (number of identified specimen, NISP) in order to avoid overestimating the minimum number of individuals (MNI) [O'Connor, 2008]. On the other hand, the MNI could be estimated for the less-fragmented mollusc and crustacean remains.

All faunal material was examined under a binocular loupe at between $\times 10$ and $\times 40$ magnification in order to identify mechanical, biological or chemical surface alterations. Age of death for the birds was estimated as a function of the degree of long bone fusion and bone porosity (Lefèvre and Pasquet, 1994; Laroulandie, 2000). Finally, breakage patterns were assessed with reference to criteria published by Villa and Mahieu (1991) concerning long bone fracture morphologies and shaft fragmentation.

4. Results

4.1. Topography

A series of surface depressions recognisable in the chamber adjacent to the test pit were mapped (Fig. 3). The largest, measuring 70 cm in diameter and some 15 cm deep, cut two older depressions. These surface structures are accessible by a shallow gully dug into a small, approximately 10 cm high surrounding bank formed by displaced sediment. The form and dimensions of these features are consistent with nests or dens.

4.2. Stratigraphy

Two stratigraphic units were documented in the 60 cm deep test pit 1 (Fig. 4). The upper unit (Unit 1) is 40 to 50 cm thick and contains a dark brown (7,5YR 3/2) granular organic loam with numerous small roots. This poorly-sorted sediment, rich in sands and limestone granules, presents a poorly-expressed granular substructure with friable, millimetre-sized rounded aggregates. This unit presents a crude stratification expressed by (a) less than 1 m long lenses of sediments richer in limestone granules and (b) banded colour variations that follow the stratification plane defined by these lenses. Nearly all the faunal material recovered from the test pit derives from this unit (Fig. 5).

The lower unit (unit 2) is at least 20 cm thick and contains a massive light brown (7,5YR 5/4) loam with numerous limestone granules and blocks of various sizes. There is no contrast between the facies in terms of mineral content; both are composed of loams that infiltrated the cavity via the fissure responsible for the formation of the corridor and limestone fragments connected to the disaggregation

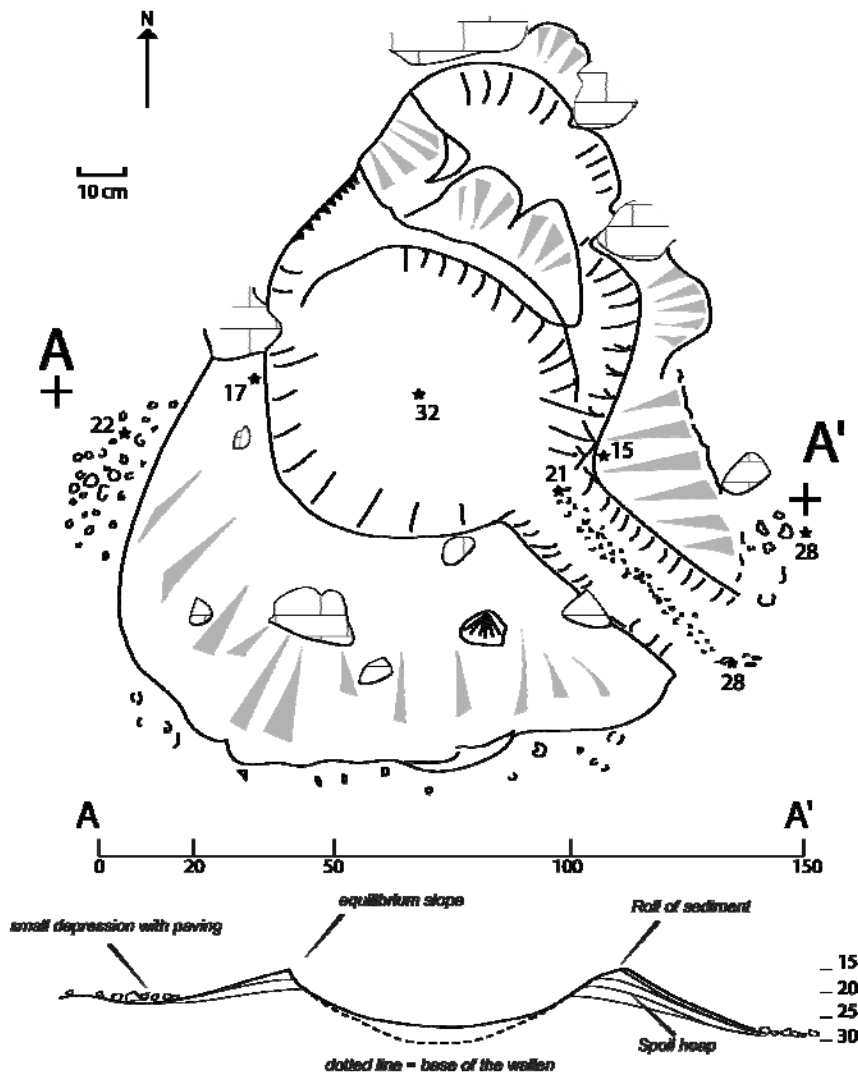


Figure 3. Plan of the nest to the right of the test pit within the cave.

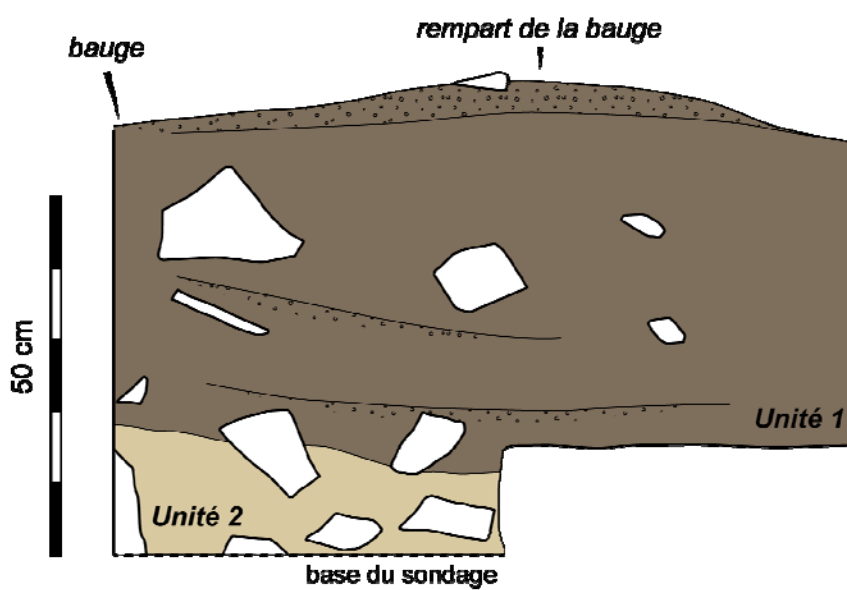


Figure 4. Stratigraphy of test pit 1. The numbers to the right indicate the different spits.

of the cave walls. Conversely, the two facies differ in sedimentary structure, organic content, and bone and gastropod composition, all of which are significantly more abundant in the upper unit.

The unit 1 facies is easily explained by its relation to the current topography of the soil surface – the lens of limestone granules at the top of the unit corresponds to the bank of the nest bordering the test pit (Fig. 4). This lens, identical in both extension and facies to the buried structures, indicates that unit 1 is connected to the repeated accumulation of sediments displaced by nesting animals. This is further supported by colour differences observable in the sedimentary bedding, demonstrating the deposit to reflect the superimposition of successive digging/displacement events, as has been documented in other fossil contexts (Zeitoun et al., 2010). Unit 2 is composed of sediment trapped in the cave that preserves evidence for a biogenic structure related to animal activity.

In sum, the preserved stratigraphy of Blanchard Cave 2 represents the natural accumulation of slope deposited sediments, with the upper unit reorganised and enriched with organic debris connected to the cave's use by sheltering or burrowing animals responsible for the nests.

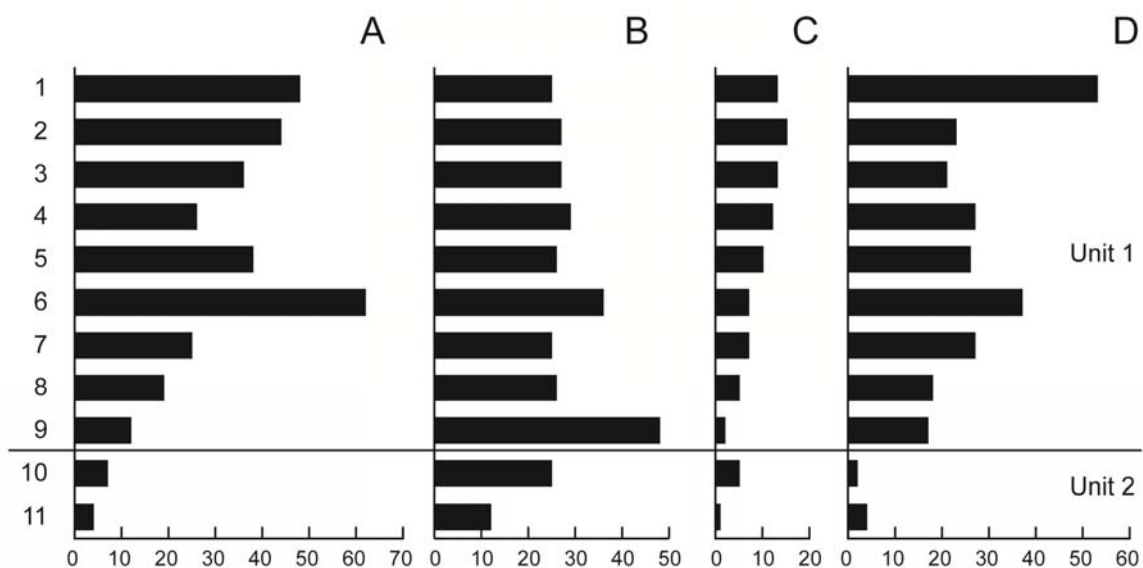


Figure 5. Vertical changes in the number of faunal remains by category. A – bones, B – terrestrial malacofauna, C – marine malacofauna, D – crustaceans.

4.3. Radiocarbon dating

Although a sample from an Audubon's shearwater bone collected from the base of unit 1 (spit 9) could not be dated due to insufficient collagen preservation, a second sample recovered from the middle of the same unit (spit 6) returned a non-calibrated date of 760 ± 30 BP (Lyon-9663_Sac-31250). When calibrated using Calib 7.0 and the Marine13 isotope curve, the Audubon's shearwater having an exclusively marine based diet, this date produces an age range of between 1479 and 1638 CE (95.4% probability).

4.4. The Blanchard 2 faunal assemblage: composition and taphonomic observations from the test pit 1

The Blanchard 2 faunal material comprises 1333 remains (Table 1, Table 2), a quarter (NISP= 357) recovered from the surface of the cave. This fairly large assemblage is dominated by molluscs (NISP =609) and bird remains (NISP= 399), whose proportions vary by depth (Fig. 5), and a slightly smaller sample of crustaceans (NISP =325).

4.4.1. Molluscs (Table 1)

Over 600 mollusc shells representing at least 214 individuals (MNI) were recovered from the test pit 1 (Table 1). The majority is composed of land gastropods (NISP= 397, 65.5%) alongside several different marine taxa (NISP= 209, 34.5%). The first category is dominated by *Amphibulima patula* (NISP =207, MNI = 87) and *Pleurodonte josephinae* (NISP = 144, MNI = 52), which are found together throughout the deposits. Amongst the marine molluscs, only a single bivalve fragment (Pectinidae) was identified in the surface material, with the remainder of the marine assemblage dominated by gastropods, particularly the West Indian top shell (*Cittarium pica*). This large sea snail is represented by 165 remains, largely found on the surface (NISP =91), corresponding to only 14 individuals.

The number of shell fragments is generally very high in all spits, particularly spits 11, 10, 7 and 5, and never falls below 60%. This is especially the case with the *A. patula*, *P. josephinae* and *C. pica* shells. A large majority of the *C. pica* shells (90%) belong to small-sized individuals while most of other marine taxa are small-sized species (e.g. *Thais*, *Littorina*, *Cenchritis*). This pattern combined with marks of shell wear strongly suggests the introduction of most of the marine shells by hermit crabs, apart from the bivalve and the two polyplacophoran fragments that are unsuited to this crustacean.

Amongst the *Amphibulima* shell fragments, only seven bare clear traces of impact on the edge of the opening located on the columella edge, or occasionally both on both opposite sides (Fig. 6). These semi-elliptical impacts are wider than they are deep and result from a blow delivered from the exterior to the interior of the test. These types of traces are particularly clear on nearly-complete shells (4 of 207 remains), and it is very likely that additional similar traces were unnoticed due to the heavily fragmented nature of the mollusc assemblage.

4.4.2. Crustaceans (Table 1)

Apart from several elements attributable to the hermit crab *Coenobita clypeatus* (14 remains of 3 individuals), crustaceans are represented by 311 fragments from at least 49 terrestrial land crabs of the genus *Gecarcinus*. Although documented in every spit and particularly high in the surface collection and first spit, the number of *Gecarcinus* remains decreases with depth, apart from a slight increase in spit 6 (z = 30 cm). Breakage is relatively low and a fair number of almost complete crab legs (dactyls and propodi) were documented.

Class/order	Taxa	Surface	1	2	3	4	5	6	7	8	9	10	11	Total	
Bivalve	Pectenidae	1												1	
Terrestrial gastropods	<i>Amphibulima patula</i>	57	15	10	14	13	11	15	14	16	23	11	8	207	
	<i>Bulimus cf. guadelupensis</i>	2	1	2				2	1		1	2	1	12	
	<i>cf. Drymaeus</i>				2	3	3							8	
	<i>Chondropoma crenulatum</i>	1	1	2		2	1			1				8	
	<i>Helicina sp.</i>					1								1	
	<i>Pleurodonte cf. josephinae</i>	21	8	12	9	9	10	17	10	9	24	12	3	144	
	<i>Subulina octona</i>	3		1	2	1	1	2						10	
	subulinidae	4													4
	<i>Achatina fulica</i>	3													3
	Marine gastropods	<i>Lithopoma tuber</i>	1			1									2
<i>Lithopoma sp.</i>							1							1	
<i>Cittarium pica</i>		91	13	13	8	9	5	7	7	5	2	4	1	165	
<i>Cymatium sp.</i>									1					1	
Unidentified Gastropod.		3										1		4	
<i>Thais sp.</i>					1									1	
<i>Nerita peloronta</i>		4												4	
<i>Nerita sp.</i>		7		1	2	1			1		1			13	
<i>Nerita cf. versicolor</i>		2												2	
<i>Nerita cf. tessellata</i>		5												5	
<i>Echinolittorina tuberculata</i>		1												1	
<i>Cenchritis muricata</i>		1		1	1	2	3							8	
<i>Thais = Mancinella cf. deltoidea</i>		1												1	
Muricidae								1							1
Polyplacophora		<i>Acanthopleura granulata</i>	1												1
	<i>Chiton marmoratus</i>									1				1	
Total molluscs		209	38	42	40	41	36	43	34	32	51	30	13	609	
Crustaceans	<i>Coenobita clypeatus</i>	4	3			1	1	1	2	1	1			14	
	<i>Gecarcinus sp.</i>	66	50	23	21	26	25	36	25	17	16	2	4	311	
Total crustaceans		70	53	23	21	27	26	37	27	18	17	2	4	325	
Grand Total		357	139	109	97	94	100	142	86	69	80	39	21	1333	

Table 1. List of molluscs and crustaceans including number of remains (NISP) by spit.

Class/order	Taxa	Surface	1	2	3	4	5	6	7	8	9	10	11	Total
Teleostei									2					2
Anura	<i>Eleutherodactylus sp.</i>	1												1
Squamata	<i>Anolis cf. ferreus</i>	5	1	8	3	3	2	10	4	1	1			38
	<i>Iguana sp.</i>	1		1								1		3
	Lizard	2	1					2						5
	<i>cf. Pholidoscelis turukaeraensis</i>	1												1
Birds	<i>Athene cunicularia guadeloupensis</i>	10	2	9	3	3	2	12	4	1	1	1	0	48
	<i>Nyctanassa violacea bancrofti</i>	4	1							1				5
	<i>Puffinus lherminieri</i>	16	6	7	7		3		2	5		1	1	48
	<i>Puffinus cf. lherminieri</i>	3	10	6	3	2	6	13	4	1	2			50
	<i>Puffinus sp.</i>				1				1					2
	Small-sized Passeriformes		2					1						3
	Small-sized bird (1)										2			2
	Small-sized bird (2)			2	2		2							6
	Medium-sized bird (2/3)		1	1	1			1				1		5
	Medium-sized bird (3)	17	15	10	7	11	13	21	6	5	3	1	2	111
Medium-sized bird (3/4)		1						1	1				3	
Large-sized bird (4)				1		1							2	
Mammals	<i>Herpestes auropunctatus</i>		1											1
	<i>Rattus sp.</i>	11	2	1	2									16
	<i>Megalomys sp.</i>	4	5		4	1	2	3	3		1			23
	<i>Dasyprocta sp.</i>	1												3
	Molossidae					1								1
	Phyllostomidae				1	1								2
	<i>Artibeus jamaicensis</i>				1			1						2
	<i>cf. Artibeus</i>				1									1
<i>Brachyphylla cavernarum</i>	3												3	
Unidentified bat	3				2		6						11	
Unidentified vertebrates	5	2	8	2	5	9	4	2	5	3	3	1	50	
Total vertebrates		78	48	44	36	26	38	62	25	19	12	7	4	399

Table 2. List of vertebrates including number of remains (NISP) by spit.

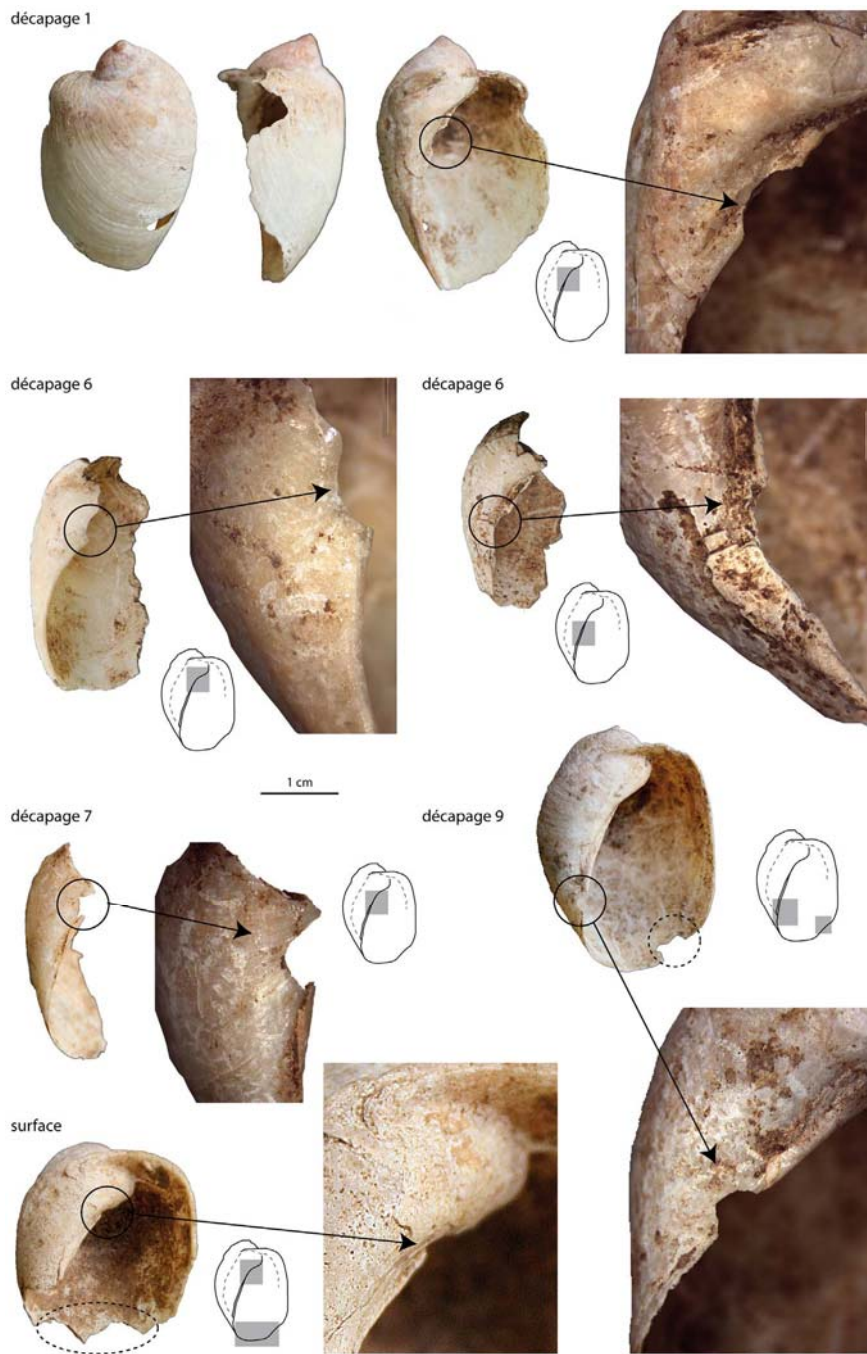


Figure 6. Notches and edge damage on *A. patula* shells.

4.4.3. Vertebrates

Vertebrates comprise almost a third (NISP = 399) of the faunal material recovered from the test pit (Table 2). Unequally distributed in the deposit, the vertebrate assemblage is dominated by bird bones, which represent more than two thirds of the identifiable remains, followed by mammals (18%).

4.4.3.1. Fish and herpetofauna. Squamates are primarily represented by large-sized anoles, likely *Anolis ferreus* (NISP= 38), the sole endemic species of Marie-Galante Island (Bochaton et al., 2017a, 2017b), as well as a single *Pholidoscelis* possibly also the endemic species of Marie-Galante (Bochaton et al., 2017a, 2017b) (cf. *Pholidoscelis turukaeraensis*) and three bones attributable to Iguana sp. that

does not present any characters allowing for a specific attribution (Bochaton et al., 2016). Two fish backbone fragments and the femur of an Eleutherodactylid frog (*Eleutherodactylus* sp.) were also recovered from test pit 1.

4.4.3.2. Birds. Bird bones comprise 60% (NISP= 238) of the vertebrate assemblage from Blanchard 2. The most well represented species is the Audubon's shearwater (*P. Iherminieri*), totalling nearly 100 identifiable remains (Fig. 7), followed by 111 bones that can fairly confidently be assigned to size class 3. Juvenile remains are relatively numerous, comprising nearly 49% (NISP = 74) of assemblage. Alongside the less well-represented species, we identified a claw of a burrowing owl (*Athene cunicularia*) in spit 8 (z = 75 cm) and five bones of a yellow-crowned night-heron (*Nyctanassa violacea*) on the surface of the cave and in spit 1. The remains of juvenile passerines (size class 2) were also found in spits 1 and 6.

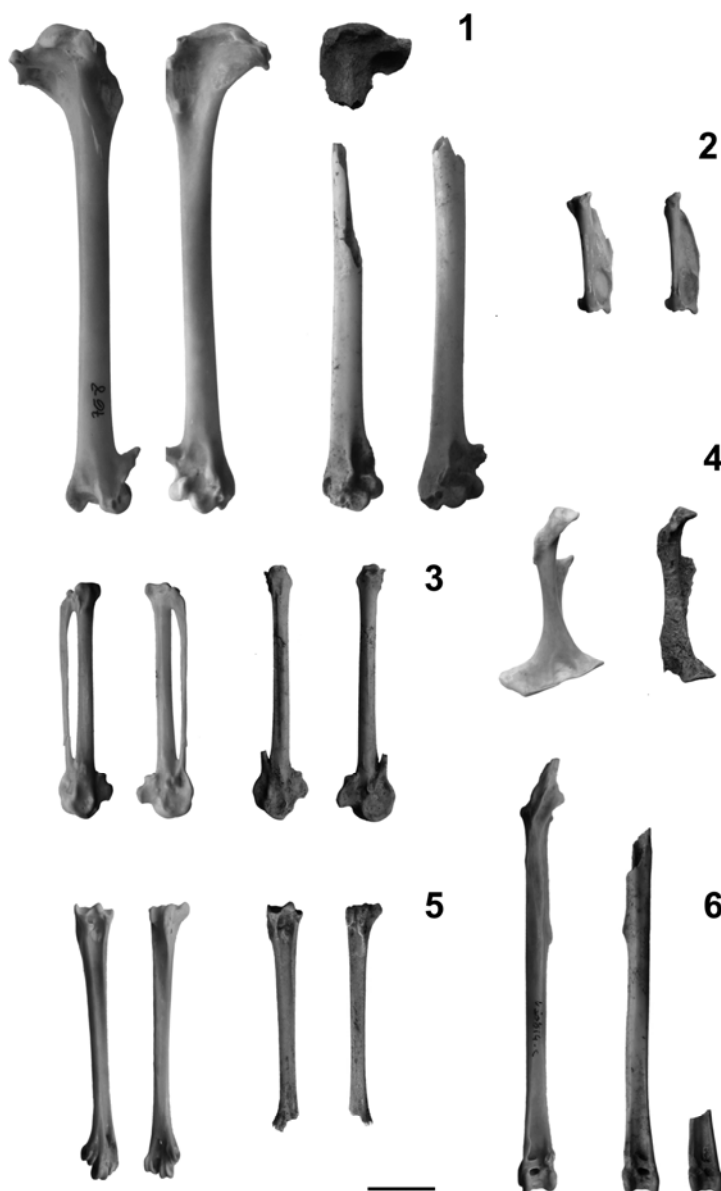


Figure 7. Audubon's shearwater remains from Blanchard. Comparison with a specimen from the type locality of Saint Barthélemy. 1: Humerus, 2: First Phalange of the third digit, 3: carpometacarpus, 4: Coracoid, 5: Tarsometatarsus, 6: Tibiotarsus. For each bone, comparative specimen is on the left and the fossil one is on the right.

4.4.3.3. **Mammals.** Mammals are represented by the small Asian mongoose (*Herpestes auropunctatus*), three rodent species and a variety of bats. While the mongoose remains were found uniquely in spit 1, those attributable to rat (*Rattus* sp.) were recovered both from the surface of the cave and more sporadically in spits 1 through 3. Rodents are also represented by a single agouti bone (*Dasyprocta* sp.) and 23 bones of a giant rice rat (*Megalomys* sp.). These 23 specimens could be assigned to the oryzomini undescribed species B of Steadman, which is a now-extinct large-sized rodent known to have inhabited the islands of Montserrat, Guadeloupe, Marie-Galante, Barbuda and Antigua in pre-Columbian times (Steadman et al., 1984). Bat bones, including the Antillean fruit-eating bat (*Brachyphylla cavernarum*), Jamaican fruit bat (*Artibeus jamaicensis*) and a free-tailed bat (*Mollosidea*) were found more dispersed in the deposits.

The vertebrate remains are heavily fragmented (72%), particularly the bird and mammals bones. Fractures are most frequently observed on long bone extremities (82.5%), with post-mortem (53.8%) breakage being significantly more common than green bone fractures (18%). Green bone breakage varies by spit; virtually no broken bones were recovered from the lowermost spits (8, 10, 11), medium values (< 15%) were recorded for the middle spits (spits 2, 3, 6, 7, 9) and higher values (> 20%) for spits from the middle and top of the test pit (spits 1, 4, 5) as well as the cave surface.

Of the 90 long bone extremities with typical green bone fractures, 16 are associated with traces of predation (e.g. crushing, perforations, notches, Fig. 8, Table 3). These traces can be observed on Puffinus remains (n = 9) as well as the bones of the yellow-crowned night heron and anoles (n = 4), all of which were recovered from either the surface (n = 12) or the first three spits of the test pit 1 (n = 2). The morphology of the traces and their association with a high degree of bone breakage are consistent with a carnivore contribution in the formation of the assemblage (Laroulandie, 2000)



Figure 8. Gnawing marks on Audubon's shearwater remains (spits 1 to 3). T: tooth marks, n: notches, c: crenulated edges.

	Complete bones	Fragmented bones	Long bone fragmentation				Root etching	Tooth marks	Digestion marks	Cut marks	Burning marks
			Intact	Fresh	Dry	Unidentified					
Anura	1	0	0	0	0	2	0	0	0	0	0
Birds	50	189	66	64	193	9	28	12	0	0	0
Indet.	0	39	0	9	49	2	4	0	0	0	0
Mammalia	26	47	25	15	28	8	8	0	0	0	0
Squamates	35	12	2	2	0	28	11	3	4	0	0
Total	112	287	93	90	270	49	51	15	4	0	0

Table 3. Fragmentation and bone surface modifications on the faunal assemblage recovered from test pit 1.

4.5. The faunal assemblage from test pit 2

Compared to the first test pit, the faunal assemblage from test pit 2 is very limited, comprising two Audubon's shearwater bones, a redrumped agouti (*Dasyprocta leporina*), a rat femur and incisor, a bat radius and an anole vertebrae. On the other hand, malacofauna are numerous (NISP= 506, MNI = 224) and, although in different frequencies, comprise essentially the same species as test pit 1 (Table 4). For example, gastropod species are the same as those found in test pit 1 and are all small individuals. Additionally, like test pit 1, hermit and land crabs (Gerarcinidae sp.) are well represented and a chiton fragment was also documented. The major difference between the two test pits is the proportion of different gastropods, the numbers of *A. patula* and *P. josephinae* decrease, *C. crenulatum* are abundant and *B. cf. guadalupensis* decrease significantly in the cave infill. The latter two taxa are almost certainly part of a natural death assemblage. Finally, breakage is generally high, except for the *Chondropoma*.

5. Discussion

5.1. Site formation

The absence of archaeological material, traces of human activity (ash, charcoal) or cut-marked bones demonstrate that the Blanchard 2 deposits to result from natural accumulation processes. Consequently, the artefacts collected from the cave surface (a button, flint flake and a spider conch shell) can likely be connected to the accumulation of slope-derived colluvium within the site. That being said, the site probably had a more complex formation history with several accumulation processes contributing to the composition of the faunal assemblage.

5.2. Use of the cave by animals

The numerous Audubon's shearwater remains, the lack of traces referable to predation on the majority of these remains, and the high proportion of juvenile remains (between 14% and 40% according to spit) argue in favour of a natural death assemblage linked to Blanchard 2 being a nesting site. This is further supported by the fact that this ground-nesting marine bird nests only in rock crevices or burrows (Lee and Mackin, 2009). While Audubon's shearwater nests sometimes take the

	Test pit 1	Test pit 2
	NISP (NMI)	NISP (NMI)
Bivalvia	1 (1)	-
<i>Amphibulima patula</i> (Brugière, 1789)	207 (87)	18 (4)
<i>Bulimulus cf. guadalupensis</i> (Brugière, 1789)	12 (11)	61 (19)
Bulimulidae	8 (5)	-
<i>Chondropoma crenulatum</i> (Potiez et Michaud, 1838)	8 (5)	231 (125)
<i>Helicina</i> sp.	1 (1)	6 (5)
<i>Pleurodonte cf. josephinae</i> (Férussac, 1832)	144 (52)	26 (18)
<i>Subulina octona</i> (Brugière, 1789)	10 (10)	20 (20)
<i>Subulina</i> sp.	4 (1)	-
<i>Achatina fulica</i> (Férussac, 1821)	3 (1)	-
<i>Lithopoma tuber</i> (Linné, 1758)	2 (1)	1 (1)
<i>Lithopoma</i> sp.	1 (1)	2 (2)
<i>Cittarium pica</i> (Linné, 1758)	165 (14)	47 (8)
<i>Cymatium</i> sp.	1 (1)	-
Unidentified	4 (1)	5 (1)
<i>Thais</i> sp.	1 (1)	1 (1)
<i>Nerita peloronta</i> Linné, 1758	4 (2)	1 (1)
<i>Nerita</i> sp.	13 (7)	-
<i>Nerita cf. versicolor</i>	2 (1)	-
<i>Nerita cf. tessellata</i>	5 (4)	2 (2)
<i>Echinolittorina tuberculata</i> (Menke, 1828)	1 (1)	-
<i>Cenchritis muricata</i> (Linné, 1758)	8 (3)	1 (1)
<i>Thais = Mancinella cf. deltoidea</i>	1 (1)	-
Muricidae	1 (1)	-
<i>Columbella mercatoria</i>	-	1 (1)
<i>Acanthopleura granulata</i> Gmelin, 1791	1 (1)	1 (1)
<i>Chiton marmoratus</i> Gmelin, 1791	1 (1)	-
<i>Coenobita clypeatus</i> (J.C. Fabricius, 1787)	14 (3)	3 (2)
<i>Gecarcinus</i> sp.	311 (49)	79 (12)

Table 4. Comparison of fauna recovered from test pits 1 and 2. NISP: Number of Identified Specimens; MNI: Minimal Number of Individuals.

form of burrows dug into sandy substrates, they are most often found, at least in the Lesser Antilles, in caves and rock shelters (Précheur, 2009; Burke and Brown, 2008; Collier and Brown, 2008a, 2008b, 2008c). For example, at Hardy cave in the Sainte-Anne islets off the southern coast of Martinique, Audubon's shearwaters were found to nest in the deepest and most inaccessible parts of the cave, where they lay their eggs in small nests in the ground (Pinchon, 1976: 26). The limited size (ca. 70 cm) of the Blanchard 2 nests, which could accommodate a bird of this size, and the fact that they are similarly located in small niches or against cave walls reinforce the likelihood of the cave being a nesting site. In behavioral terms, the nesting habits of the Audubon's shearwater recall those of tropicbirds (genus *Phaethon*), another burrow-nesting seabird that also prefers natural cavities and is known to burrow into loose ground to build their nests, producing similar depressions (Fig. 9). Furthermore, the bioturbation facies of unit 1 provides clear evidence for a biogenic sedimentary structure of a deposit connected to the repeated digging of nests. This, combined with the predominance of Audubon's shearwaters remains, especially juvenile individuals, supports the hypothesis of the cave having been used as a nesting site throughout the development of unit 1.



Figure 8. Nest dug by a tropicbird in a cave on the island of Saint Barthélemy (photo A. Lenoble).

Both hermit and land crabs are also known to frequent karstic contexts, where they take refuge during the day. While the abundance of terrestrial gastropod shell fragments is consistent with the cave being 200 m from the shore, the presence of marine gastropods (e.g. *Cittarium*, *Nerita*) is likely tied to the reuse of tests by hermit crabs that are still present in the cave's vicinity. All of these detritivore and scavenger crustaceans (hermit crabs and *Gecarcinus* sp.) have also been documented in Audubon's shearwater nesting sites, where they feed on the corpses of hatchlings (Pinchon, *op. cit.*: 25–26). The commensality between crabs and shearwaters implies the remains of the former to represent an attritional death assemblage. This is confirmed by the low degree of breakage observable in the crustacean remains coupled with the presence of leg fragments (dactyles and propodi). Such a commensality is also suggested by the fact that correlations in the relative abundance of crab and shearwater (Fig. 5) remains are not significantly different (Fischer's exact test $p=0.36$).

Finally, gnawing marks observed on bones recovered from the surface of the cave and the summit of the fossil deposit further highlight the frequentation of the cave by a carnivore preying on Audubon's shearwater. Three carnivores have been identified in the mammalian faunal assemblages from sites on Marie-Galante; dogs (*Canis familiaris*), introduced during the Amerindian period (Grouard et al., 2013) alongside domestic cats (*Felis catus*) and the small Asian mongoose, both of which were first brought by European colonists (Lorvelec et al., 2004). While the island is not home to feral dogs and cats, the mongoose is frequent on the island and its traces around the site are easily visible, making it the most likely agent responsible for the traces on the bones. This interpretation is consistent with the heavy fragmentation of the bones and the traces of gnawing on the entirety of the vertebrate assemblage. In fact, these traits are more typical of a viverrid rather than a small felid (Fig. 8 and Laroulandie, 2000: Figs. 49–52), which is in agreement with the presence of this taxon in the Blanchard 2 faunal assemblage.

5.3. Intrusive elements

The organo-mineral nature of the cave's infill and the morphology of the open crevice cave demonstrate that all or part of the sediment composing unit 1 represent slope-derived colluvium trapped in the site. As the colluvium in the test pit 2 on the slope above the site (test pit 2) contains both malacofauna and faunal material, it is safe to assume that at least part of the material recovered from the cave may derive from down-slope colluviation.

The fact that the Blanchard 2 land snail assemblage is dominated by *P. josephinae* and *A. patula* clearly illustrates this likelihood. *P. josephinae* are known to occur in the litter of non-degraded forests (Robinson et al., 2009), while *A. patula*, equally found in humid environments (Schramm, 1873; Mazé, 1877), are unknown from the east of the island (Mazé, 1876) and have not been observed alive since the late 19th century (Lenoble et al. in press).

Moreover, numerous *A. patula* bear notches identical to those left by birds preying on molluscs (Snyder and Snyder, 1969). Importantly, even though shell-feeding birds are known in the region, such as the hook-billed kite (*Chondrohierax uncinatus*; Smith and Temple, 1982; Johnson et al., 2007) or snail kite (*Rostrhamus sociabilis*; Snyder and Snyder, 1969), none of them lives in caves and the accumulations they produce are found on the ground immediately below nesting sites or in forests.

Therefore, the presence of numerous *A. patula* shells in the cave is more parsimoniously explained by the introduction of colluvium that reworked older shell deposits associated with markedly different climatic conditions. This interpretation is corroborated by the fact that in the nearby site of Cadet 3, *A. patula* shells are abundant in levels assigned to the mid-Holocene (Hodell et al., 1991), which is associated with regionally more humid conditions, and then become rare in more recent levels (Stouvenot et al., 2014).

Other elements of the faunal assemblage may also have accumulated in the site. For example, as the test pit 2 assemblage also contains bones, it is impossible to exclude the possibility that at least part of the faunal material recovered within the cave is in secondary position. This would include the rare agouti or passerine remains as well as the few archaeological pieces recovered from this site. This being said, this component of the Blanchard 2 assemblage has little bearing on the interpretation of the site as an Audubon's shearwater nesting ground (see above). This interpretation is supported by the bioturbation facies of unit 1 connected to the repeated burrowing of nesting birds and the abundance of hatchling remains. This is in stark contrast with the majority of other caves that yielded Audubon's shearwater remains, where human intervention is most often evoked to explain their presence (Frank and Benson, 1998; Kaye, 1959; Wetmore, 1938) whereas natural accumulations remain rare (Morgan, 1994; Nieves-Rivera et al., 1995).

In sum, the site of Blanchard 2 provides evidence for a faunal assemblage linked to the use of the cave as a nesting site, including a dominance of Audubon's shearwater remains, a high percentage of juvenile birds, a bioturbation facies linked to repeated burrowing, and the presence of numerous terrestrial crustaceans. These characteristics provide sound criteria for identifying fossil nesting sites.

5.4. Age of the fossil assemblage

The small Asian mongoose was introduced to Guadeloupe at the end of the 19th century and then spread from this island to Marie-Galante in the beginning of the 20th century (Horst et al., 2001). Further, the black rat was introduced substantially earlier, appearing in the Greater Antilles immediately after Columbus arrived in the Americas (Wing, 2001). The presence of this rodent is attested to from the outset of the French colonisation of Guadeloupe (Du Tertre, 1667; Breton, 1647), if not earlier, in connection with the Spanish presence in the archipelago during the 16th century. Unlike the rat remains, which are dispersed in the upper third of the fossil layer, mongoose bones are limited to the cave surface, suggesting that the deposit formed during the historical period or slightly before. This is consistent with a radiocarbon date obtained on an Audubon's shearwater bone from spit 6, which, when calibrated, falls between 1470 and 1638 CE.

Consequently, Blanchard 2 likely served as an Audubon's shearwater nesting site during a period shortly before the French colonisation of Marie-Galante that began in 1648 (Du Tertre, 1667). On the other hand, carnivore traces (see above) on Audubon's shearwater bones recovered from the final three spits (1 to 3) of the test pit 1 demonstrate that these birds were still nesting in the cave after the early 20th century introduction of the mongoose. While it is difficult to fix a precise chronology for the cave's use, the fact that no current inhabitants recall Audubon's shearwaters nesting on the island suggests that it ceased to be a nesting site no later than the mid-twentieth century.

The nature of the bioturbated deposits does, however, not rule out the possibility that the dated bone was reworked from deeper sediment by burrowing animals. Consequently, two chronological hypotheses can be imagined for the time period over which fossil unit 1 formed. If the dated bone derives from the base of unit 1, the fossil deposit would have formed over a 400-year period beginning shortly before the arrival of the first French colonists and ending sometime in the early 20th century. On the other hand, if we assume the dated bone to be associated with spit 6 and a constant sedimentation rate for the underlying 20 cm, unit 1 would have begun to form between the 13th and 14th centuries or just before Columbus arrived on the island. Notwithstanding this uncertainty, radiometric, sedimentological and biological data all favour the cave being occupied during both the 'contact period' between Columbus' arrival when the indigenous Carib population still controlled the island and the ensuing period of European colonisation (i.e, 1648 to the beginning of the 20th century).

5.5. Landscape change

It is interesting to note that the dated Audubon's shearwater bone was recovered from a depth of 40 cm, too deep to be explained uniquely by the surface burrows, which are no deeper than 15 cm. This suggests that the sediment accumulated in the cave during its use by nesting birds. As discussed above, the open morphology of the crevice cave likely trapped colluvium, which, based on the stratigraphy, account for some 50 cm of the deposits accumulated in the cave during the historic period. However, this type of sedimentation is not observable in the preceding millennia otherwise the cave would have been quickly and completely infilled even if we assume a sedimentation rate of

several centimetres per century. Moreover, if colluviation had continued into the early 20th century, the burrows documented on the cave surface would have been obscured. Taken together, this suggests that sediment contemporaneous with the use of the cave by Audubon's shearwater accumulated over a relatively short period of time during the historical period and can be connected to human alteration of the local environment.

These different elements support soil erosion to have followed the deforestation of the Guadeloupe islands after the arrival of European populations. This “erosional crisis” during the historical period has been documented on other islands of the archipelago. For example, Lasserre (1961) considers it to be tied to “itinerant” Creole gardening of less fertile areas of the island coupled with slash and burn practices and charcoal production. These activities would have concerned the entirety of the limestone hills throughout the Guadeloupe Islands. This would effectively exclude the fossil deposit developing before the landscape had been significantly altered by erosion. Consequently, a large part of deposit would have formed during the historical period, making the shorter, 400-year chronology for the deposition of unit 1 the most likely.

5.6. Evolution of Audubon's shearwater nesting sites

The Audubon's shearwater is the only shearwater that currently nests in the Lesser Antilles (Lowrie et al., 2012), present in Barbados, Dog Island, Martinique, Marie-Galante, La Désirade, Saint Martin, Saint Barthélemy and Saba. Their nesting areas are found on small deserted islets off the coasts of the larger islands (Burke and Brown, 2008; Collier and Brown, 2008b, 2008c; Lemoine and Dubief, 2008; Levesque et al., 2008; Bright et al., 2014) or, as in the case of Marie-Galante, La Désirade and Saba, on inaccessible cliffs (Levesque and Mathurin, 2008; Collier and Brown, 2008a).

The case of Blanchard 2 shows the nesting area of these birds to have been larger in the past, with breeding sites found in zones other than the most inaccessible ones. The main causes that biologists assumed to underlie this reduction is the introduction of predators, such as the mongoose, but, above all, the rat (Pascal et al., 2004; Daltry et al., 2013; Bright et al., 2014). The probable presence of the rat on Marie-Galante from the very outset of European colonisation, as well as the presence of rat bones in the upper third of the fossil deposit, suggests that this intrusive rodent did not have a sufficiently important impact, at least on the scale of several centuries, to provoke the abandonment of the nesting site. Moreover, gnawing marks on bones from the upper portion of the deposit reveal that a mammalian carnivore, in this case, the small Asian mongoose, to likely have been the contributing factor to Blanchard 2 ceasing to function as an Audubon's shearwater nesting site.

Moreover, this carnivore is known regionally as the main predator of ground-breeding birds (Pinchon, 1976; Lescure, 1987), including sea birds (Lorvelec et al., 2004; Lewis et al., 2011). In this respect, the Blanchard 2 data are consistent with the mongoose having a decisive impact on the island's historical Audubon's shearwater populations. Accordingly, human predation during the historical period, as clear from the example of the black-capped petrel (*Pterodroma hasitata*) in Guadeloupe and Dominique (Labat, 1722; Feilden, 1890; Goetz et al., 2012), would have had only a moderate, if any impact on Audubon's shearwater populations on Marie-Galante. Moreover, the

possibility that historical exploitation destabilised Audubon's shearwater colonies is contradicted by the lack of evidence for human intervention. The fact that Blanchard 2 was occupied prior to the arrival of European colonists and continued thereafter suggests only a limited historical impact, whether in the form of direct predation or the modification of the landscape for agricultural purposes. On the other hand, it is interesting to note that the initial use of the cave as a nesting site some 500 y ago followed the abandonment of the southern coast of the island by Amerindian groups.

Indeed, the southern coast of Marie-Galante was occupied during the ceramic period (ca. -300 BCE to 1500 CE, Delpuech, 2001), as made evident by the nearby sites of Tourlourous and Petit Anse (Serrand, 2010; Lenoble et al., 2011; Casagrande, 2013). On the one hand, the most recent dates come from Amerindian burials at Blanchard and Cadet 2, which demonstrate a continuous Amerindian presence into the 14th century (Stouvenot, 2005; Courtaud, 2011) and on the other one, seventeenth-century European sources describe Marie-Galante as free of indigenous settlement (Breton, 1647; Coppier, 1645; Pacifique de Provins, 1646; Du Tertre, 1667). This is in accordance with the choice to move villages to difficult access positions (Breton, 1647, 1665) in response to the expanded influence of Tainos populations in the Greater Antilles in the decades preceding the arrival of Europeans in the Americas (Hofman et al., 2008) or as a consequence of regular confrontations with European colonists during the contact period (e. g. Lafleur, 1992). Regardless the reasons underlying these changes, it is clear that between the 14th century, which sees the island's final Amerindian occupation, and the arrival of European colonists in the 17th century, coastal plains of islands such as Marie-Galante and especially its southern coast no longer saw a permanent Amerindian presence. Interestingly, it is during exactly this same period that Audubon's shearwaters first occupied Blanchard 2, suggesting that these birds used the southern coast of Marie-Galante during a 400-year period following the departure of the final Amerindian groups.

This would imply that Amerindian populations had a significant impact on the distribution of Audubon's shearwater reproductive colonies, a likelihood reinforced by the sequence from the nearby Cadet 3 rock shelter. Audubon's shearwater first appears in the Cadet 3 vertebrate faunal assemblage at the beginning of the Holocene and subsequently decreases from the mid-Holocene onwards, when the first Amerindian populations arrived in the archipelago (Hofman et al., 2006). This is also in agreement with archaeological evidence that shows Audubon's shearwater remains, while the most frequent sea bird found in pre-Columbian sites (Grouard, 2001; Wing, 2001), can also form a large part if not dominate Amerindian middens (Wing et al., 1968; Hofman et al., 2006). Taken together, this data and the evidence from Blanchard 2 support the hypothesis of a non-negligible Amerindian impact on Audubon's shearwater breeding sites.

6. Conclusion

A combination of paleontological, taphonomic, sedimentological, and chronological information clearly demonstrates Blanchard 2 Cave to have been an Audubon's shearwater nesting site from sometime around the middle of the second millennia to the beginning of the 20th century. Moreover,

the use of the cave as a nesting site began after the abandonment of the area by Amerindian population, suggesting that the exploitation of marine birds by Amerindian societies significantly influenced Audubon's shearwater colonies. Additionally, traces of chewing on bones found in the upper portion of the test pit, as well as mongoose bones collected from the cave surface, indicate a recent reduction in the nesting area of Audubon's shearwater on Marie-Galante primarily due to the introduction of this carnivore. This is not to say that predation by humans, landscape changes connected to agricultural practices or the introduction of the rat did not have consequences for Audubon's shearwater colonies. Rather, the arrival of the mongoose had a major influence, which, alone or in combination with others factors, led to the abandonment of Blanchard 2 as a nesting site.

Finally, determining the exact role each factor played in the reduction of seabird nesting sites on Marie-Galante and other Caribbean Islands requires complementary data from additional sites. The biogenic sedimentary structure of the Blanchard 2 deposits and the unique faunal associations characteristic of this type of site do, however, already provide new criteria for identifying Audubon's shearwater nesting sites in the fossil record.

Acknowledgements

We would like to thank the Natural Reserve of Saint Bartholomew for donating modern specimens of *P. Iherminieri* used for osteological comparison. We also wish to thank Alain Queffelec and Myriam Boudadi-Maligne for their help during the excavations at Blanchard 2.

This study was conducted as part of the BIVAAG Program established by the Centre National de la Recherche Scientifique (CNRS), with support from a European PO-FEDER grant 2007–2013 n°2/2.4/-33456, the Guadeloupe Regional Council, the Direction de l'Environnement et de l'Aménagement du Territoire (DEAL) of Guadeloupe, and the Direction des Affaires Culturelles (DAC) of Guadeloupe.

References

- Atkinson, I.A.E., 1985. The spread of commensal species of *Rattus* to oceanic islands and their effects on island Avifaunas. In: Conservation of Island Birds. 3. pp. 35–81.
- Baales, M., 1992. Accumulations of bones of *Lagopus* in Late Pleistocene sediments. Are they caused by man or animals? *Cranium* 1, 17–22.
- Bailon, S., Bochaton, C., Lenoble, A., 2015. New data on Pleistocene and Holocene herpetofauna of Marie-Galante (Blanchard Cave, Guadeloupe Islands, French West Indies): insular faunal turnover and human impact. *Quat. Sci. Rev.* 128, 127–137.
- Birdlife international, 2014. *Puffinus Iherminieri*. The IUCN Red List of Threatened. Version 2014. 2. <http://www.iucnredlist.org/details/45959182/0>.
- Bochaton, C., Grouard, S., Cornette, R., Ineich, I., Lenoble, A., Tresset, A., Bailon, S., 2015. Fossil and subfossil herpetofauna from Cadet 2 Cave (Marie-Galante, Guadeloupe Islands, F.W.I.): evolution of an insular herpetofauna since the Late Pleistocene. *C.R. Palevol* 14 (2), 101–110.

- Bochaton, C., Grouard, S., Breuil, M., Ineich, I., Tresset, A., Bailon, S., 2016. Osteological differentiation of the Iguana Laurenti, 1768 (Squamata: Iguanidae) species: *Iguana iguana* (Linnaeus, 1758) and *Iguana delicatissima* Laurenti, 1768, with some comments on their hybrids. *J. Herpetol.* 50, 295–305.
- Bochaton, C., Boistel, R., Grouard, S., Ineich, I., Tresset, A., Bailon, S., 2017a. Evolution, diversity and interactions with past human populations of recently extinct *Pholidoscelis* lizards (Squamata: Teiidae) from the Guadeloupe Islands (French West-Indies). *Hist. Biol.* 1–17. <http://dx.doi.org/10.1080/08912963.2017.1343824>.
- Bochaton, C., Bailon, S., Herrel, A., Grouard, S., Ineich, I., Tresset, A., Cornette, R., 2017b. Human impacts reduce morphological diversity in an insular species of lizard. *Proc. R. Soc. B Biol. Sci.* 284, 20170921.
- Bochenski, Z.M., 2005. Owls, Diurnal Raptors and Humans: Signatures on Avian Bones. In: O'Connor, T. (Ed.), *Biosphere to Lithosphere: New Studies in Vertebrate Taphonomy*. Proceedings of the 9th International Congress for Caribbean Archaeology; 2002; Durham, United Kingdom. Oxbow Books, Durham, pp. 31–45.
- Bovy, K.M., 2002. Differential avian skeletal part distribution: explaining the abundance of wings. *J. Archaeol. Sci.* 29 (9), 965–978.
- Breton, R., 1647. *Relations de l'île de la Guadeloupe*. In: New Edition 1978. Basse-Terre, Bibliothèque d'histoire antillaise.
- Breton, R., 1665. *Dictionnaire caraïbe-français*. New Edition 1999. IRD, Karthala, Paris.
- Bright, J.A., Soanes, L.M., Mukhida, F., Brown, R., Millett, J., 2014. Seabird surveys on Dog Island, Anguilla, following eradication of black rats find a globally important population of red-billed tropicbirds (*Phaethon aethereus*). *Journal of Caribbean Ornithology* 27, 1–8.
- Burke, W., Brown, A., 2008. Barbados. In: Wege, D.C., Anadon-Irizarry, V. (Eds.), *Important Bird Areas in the Caribbean: Key Sites for Conservation*. BirdLife International, Cambridge, pp. 82–89.
- Casagrande, F., 2013. *Petit-Anse, Capesterre-de-Marie-Galante*. Direction des Affaires Culturelles de Guadeloupe, Basse-Terre.
- Colas, C., Bertran, P., Chancerel, G., Chancerel, A., Richard, J.-M., 2002. *Marie-Galante Le Tourlourous (97108005AH)*. Direction des Affaires Culturelles de Guadeloupe, Basse-Terre.
- Collier, N., Brown, A., 2008a. Saba. In: Wege, D.C., Anadon-Irizarry, V. (Eds.), *Important Bird Areas in the Caribbean: Key Sites for Conservation*. BirdLife International, Cambridge, pp. 259–262.
- Collier, N., Brown, A., 2008b. St-Maarten. In: Wege, D.C., Anadon-Irizarry, V. (Eds.), *Important Bird Areas in the Caribbean: Key Sites for Conservation*. BirdLife International, Cambridge, pp. 284–289.
- Collier, N., Brown, A., 2008c. St-Martin. In: Wege, D.C., Anadon-Irizarry, V. (Eds.), *Important Bird Areas in the Caribbean: Key Sites for Conservation*. BirdLife International, Cambridge, pp. 290–294.
- Coppier, G., 1645. *Histoire et voyage des Indes Occidentales et de plusieurs autres régions maritimes [et] esloignées: divisé en deux livres*. Jean Hugué, Paris.
- Courtaud, P., 2011. La cavité sépulcrale de Cadet 2 (Capesterre-de-Marie-Galante, Guadeloupe) et la question du cannibalisme. In: Grunberg, B. (Ed.), *Les Indiens des Petites Antilles. Des premiers peuplements aux débuts de la colonisation européenne*. L'Harmattan, Paris, pp. 49–58.
- Daltry, J.C., James, K.J., Otto, A., Ross, T.N., 2013. Evidence that Eradicating Black Rats Has Boosted the Recovery of Rare Reptiles and Seabirds on Antiguan Islands. In: *Biodiversité Insulaire: la flore, la faune et l'homme dans les Petites Antilles*. Direction de l'Environnement, de l'Aménagement et du Logement de Martinique – University Antilles Guyane, Fort-de-France, pp. 146–157.

- Dávalos, L.M., Turvey, S.T., 2012. West Indian mammals: the old, the new, and the recently extinct. In: Patterson, B.D., Costa, L.P. (Eds.), *Bones, Clones, and Biomes: The History and Geography of Recent Neotropical Mammals*. University of Chicago Press, Chicago, pp. 157–202.
- Delpuech, A., 2001. *Guadeloupe amérindienne*. Editions du patrimoine, Paris.
- Du Tertre, J.-B., 1667. *Histoire générale des Antilles habitées par les Français*. Thomas Jolly, Paris.
- Ericson, P.G.P., 1987. Interpretations of archaeological bird remains: a taphonomic approach. *J. Archaeol. Sci.* 14 (1), 65–85.
- Feilden, H.W., 1890. The deserted domicile of the Diablotin in Dominica. *Transactions of the Norfolk and Norwich naturalists. Society* 5 (1), 24–38.
- Frank, E.F., Benson, R., 1998. Vertebrate Paleontology of Isla de Mona, Puerto Rico. *J. Cave Karst Stud.* 60 (2), 103–106.
- Gala, M., Lenoble, A., 2015. Evidence of the former existence of an endemic macaw in Guadeloupe, lesser Antilles. *J. Ornithol.* 156 (4), 1061–1066.
- Goetz, J.E., Norris, J.H., Wheeler, J.A., 2012. Conservation action plan for the blackcapped petrel (*Pterodroma hasitata*). In: International Black-capped Petrel Conservation Group, Available at: <http://www.birdscaribbean.org/wp-content/uploads/2015/BCPEWG/PlanFinal.pdf>.
- Goetz, D., Nagau, J.-L., Turland, H., 2014. Des fouilles dans la grotte Blanchard, près de Capesterre-de-Marie-Galante. In: *Le magazine de Marie-Galante et des îles*. 7. pp. 4–9.
- Grouard, S., 2001. Subsistance, systèmes techniques et gestion territoriale en milieu insulaire antillais précolombien : exploitation des vertébrés et des crustacés aux époques Saladoïdes et Troumassoïdes de Guadeloupe (400 av. JC à 1500 ap. JC). Unpublished PhD thesis. Paris 10 University.
- Grouard, S., Perdikaris, S., Debue, K., 2013. Dog burials associated with human burials in the West Indies during the early pre-Columbian ceramic age (500 BC–600 AD). *Anthropozoologica* 48 (2), 447–465.
- Grouard, S., Bonnissent, D., Courtaud, P., Fouéré, P., Lenoble, A., Richard, G., Romon, T., Serrand, N., Stouvenot, C., 2014. Fréquentation amérindienne des cavités des Petites Antilles. In: Berard, B. (Ed.), *Proceedings of the 24th International Congress for Caribbean Archaeology, 2011, Fort-de-France, Martinique (France)*. International Association of Caribbean Archaeology, Fort-de-France, pp. 277–295.
- Halliday, W.R., 2004. Crevice caves. In: Gunn, J. (Ed.), *Encyclopedia of Cave and Karst Science*. (NY): Fitzroy Deaborn New-York, pp. 249–252.
- Hodell, D.A., Curtis, J.H., Jones, G.A., Higuera-Gundy, A., Brenner, M., Binford, M.W., Dorsey, K.T., 1991. Reconstruction of Caribbean climate change over the past 10, 500 years. *Nature* 352 (6338), 790–793.
- Hodge, K., Holliday, S., Mukhida, F., 2008. Anguilla. In: Wege, D.C., Anadon-Irizarry, V. (Eds.), *Important Bird Areas in the Caribbean: Key Sites for Conservation*. BirdLife International, Cambridge (UK), pp. 27–34.
- Hofman, C.L., Bright, A.J., Hoogland, M.L.P., 2006. Archipelagic resource procurement and mobility in the northern lesser Antilles: the view from a 3,000-year-old tropical forest campsite on Saba. *J. Island Coast. Archaeol.* 1, 145–164.
- Hofman, C.L., Bright, A.J., Hoogland, M.L.P., Keegan, W.F., 2008. Attractive ideas, desirable goods: examining the late ceramic age relationships between greater and lesser Antillean societies. *J. Island Coast. Archaeol.* 3, 17–34.
- Horst, G.R., Hoagland, D.B., Kilpatrick, C.W., 2001. The mongoose in the West Indies: the biogeography and population biology of an introduced species. In: Woods, C.A., Sergile, F.E. (Eds.), *Biogeography of the West Indies: Patterns and Perspectives*, 2nd ed. CRC Press, Boca-Raton, pp. 409–424.

- Johnson, J.A., Thorstrom, R., Mindell, D.P., 2007. Systematics and conservation of the hook-billed kite including the island taxa from Cuba and Grenada. *Anim. Conserv.* 10 (3), 349–359.
- Jones, H.P., Tershy, B.R., Zavaleta, E.S., Croll, D.A., Keitt, B.S., Finkelstein, M.E., Howald, G.R., 2008. Severity of the effects of invasive rats on seabirds: a global review. *Conserv. Biol.* 22 (1), 16–26.
- Kaye, C.A., 1959. Geology of Isla de Mona, Puerto Rico and notes of the age of Mona passage. *Geol. Surv. Prof. Pap.* 317, 141–178.
- Labat, J.-B., 1722. *Nouveau voyage aux isles de l'Amérique*. Guillaume Cavelier, Paris.
- Lafleur, G., 1992. In: *Les Caraïbes des Petites Antilles*. Karthala editions, Paris, pp. 226.
- Laroulandie, V., 2000. Taphonomie et archéozoologie des Oiseaux en grotte : applications aux sites paléolithiques du Bois-Ragot (Vienne), de Combe Saunière (Dordogne) et de La Vache (Ariège). Unpublished PhD Thesis. University Bordeaux, pp. 1.
- Laroulandie, V., 2001. Les traces liées à la boucherie, à la cuisson et à la consommation d'oiseaux: apport de l'expérimentation. In: Bourguignon, L., Ortega, I., Frère-Sautot, M.-C. (Eds.), *Préhistoire et Approche Expérimentale*. Monique Mergoual, Montagnac, pp. 97–108.
- Laroulandie, V., 2005. Anthropogenic Versus Non-anthropogenic Bird Bone Assemblages: New Criteria for their Distinction. In: O'Connor, T. (Ed.), *Biosphere to Lithosphere: New Studies in Vertebrate Taphonomy*. Proceedings of the 9th ICAZ Conference, 2002, Durham (United Kingdom). Oxbow Books, Durham, pp. 25–30.
- Laroulandie, V., 2010. Alpine Chough *Pyrrhocorax Graculus* from Pleistocene Sites between Pyrenees and Alps: Natural Versus Cultural Assemblages. In: Prummel, W., Zeiler, J.T., Brinkhuizen, D.C. (Eds.), *Proceedings of the 6th Meeting of the ICAZ Bird Working Group, 23rd–27th August 2008, Groningen*. Barkhuis Groningen University Library, Groningen pp, pp. 219–232.
- Lasserre, G., 1961. *La Guadeloupe: étude géographique*. Union française d'impression, Bordeaux.
- Lee, D.S., Mackin, W.A., 2009. Audubon's shearwater. *West Indian Breeding Seabird Atlas*. Last Updated: 24 June 2010. Available at. www.wicbirds.net/aush.html, Accessed date: 10 December 2014.
- Lefèvre, C., Pasquet, E., 1994. Les modifications post-mortem chez les oiseaux : l'exemple de l'avifaune holocène de Patagonie australe: micromammifères, oiseaux et problèmes taphonomiques. In: *Artefacts*. 9. pp. 217–229.
- Lemoine, V., Dubief, L., 2008. Martinique. In: Wege, D.C., Anadon-Irizarry, V. (Eds.), *Important Bird Areas in the Caribbean: Key Sites for Conservation*. BirdLife International, Cambridge, pp. 220–229.
- Lenoble, A., Stouvenot, C., Courtaud, P., Grouard, S., Scalliet, M., Serrand, N., 2009. Formes et remplissages du karst littoral guadeloupéen. In: Vanara, N., Douat, M. (Eds.), *Le karst, indicateur performant des environnements passés et actuels*. Orthez: Association française de karstologie – fédération française de spéléologie, pp. 226–233.
- Lenoble, A., Boudadi-Maligne, M., Grouard, S., Mallye, J.-B., Queffelec, A., Stouvenot, C., 2012. Nettoyage du fossé de Petite Anse (Capesterre-de-Marie-Galante, Guadeloupe). Direction des Affaires Culturelles of Guadeloupe, Basse-Terre.
- Lenoble, A., Bertran, A., Charles, L., Mallye, J.-B., Serrand, N., Stouvenot, C., 2017. Past occurrence of the rare landsnail *Amphibulima patula* (Bruguières, 1789) in Guadeloupe (Mollusca; Amphibulimulidae). *Caribb. J. Sci* in press.
- Lescure, J., 1987. Le peuplement en reptiles et amphibiens des Petites Antilles. *Bull. Soc. Zool. Fr.* 112 (3–4), 327–342.
- Levesque, A., Mathurin, A., 2008. Guadeloupe. In: Wege, D.C., Anadon-Irizarry, V. (Eds.), *Important Bird Areas in the Caribbean: Key Sites for Conservation*. BirdLife International, Cambridge, pp. 183–192.

- Levesque, A., Mathurin, A., Le Quellec, F., 2008. St Barthélemy. In: Wege, D.C., Anadon-Irizarry, V. (Eds.), *Important Bird Areas in the Caribbean: Key Sites for Conservation*. BirdLife International, Cambridge, pp. 263–267.
- Lewis, D.S., van Veen, R., Wilson, B.S., 2011. Conservation implications of small Indian mongoose (*Herpestes auropunctatus*) predation in a hotspot within a hotspot: the Hellshire Hills, Jamaica. *Biol. Invasions* 13 (1), 25–33.
- Livingston, S.D., 1989. The Taphonomic interpretation of avian skeletal part frequencies. *J. Archaeol. Sci.* 16 (5), 537–547.
- Lorvelec, O., Delloue, X., Pascal, M., Mège, S., 2004. Impacts des mammifères allochtones sur quelques espèces autochtones de l'Îlet Fajou (Réserve Naturelle du Grand Cul-de-Sac Marin, Guadeloupe), établis à l'issue d'une tentative d'éradication. *Revue d'Ecologie* 59, 293–307.
- Lowrie, K., Lowrie, D., Collier, N., 2012. *Seabird breeding atlas of the Lesser Antilles*. CreateSpace Independent Publishing Platform - Environmental Protection in the Caribbean, Charleston.
- Mazé, H., 1876. Découverte de l'*Amphibulima patula*, Bruguière, à Marie-Galante. *J. de Conchyliol.* 24, 394–396.
- Mazé, H., 1877. Note sur les moeurs et les habitudes de l'*Amphibulima patula*, Bruguière. *J. de Conchyliol.* 25, 347–348.
- Morgan, G.S., 1994. Late Quaternary fossil vertebrates from the Cayman Islands. In: Brunt, M.A., Davies, J.E. (Eds.), *The Cayman Islands: Natural History and Biogeography*. Kluwer Academic Publisher, Dordrecht, pp. 465–508.
- Mourer-Chauviré, C., 1975. Les oiseaux du Pléistocène moyen et supérieur de France. Lyon (France): University of Lyon 1. Doc. Lab. Géol. Fac. Sci. Lyon 64.
- Mourer-Chauviré, C., 1983. Les oiseaux dans les habitats paléolithiques : gibier des hommes ou proies des rapaces? In: Grigson, C., Clutton-Brock, J. (Eds.), *Animals and Archaeology: 2- Shell Middens, Fishes and Birds*. British Archaeological Report (International Series; vol 183), Oxford, pp. 111–124.
- Myers, N., Mittermeier, R.A., Mittermeier, C.G., Da Fonseca, G., Kent, J., 2000. Biodiversity hotspots for conservation priorities. *Nature* 403 (6772), 853–858.
- Nieves-Rivera, A.M., Mylroie, J.E., McFarlane, D.A., 1995. Bones of *Puffinus Lherminieri* lesson (Aves: Procellariidae) and two other vertebrates from Cueva Del Agua, Mona Island, Puerto Rico (West Indies). In: *National Speleological Society Bulletin*. 57. pp. 99–102.
- O'Connor, T., 2008. *The Archaeology of Animal Bones*, 2nd ed. Texas A&M University Press, College Station.
- Pacifique de Provins, R.P., 1646. *Brève relation du voyage des îles de l'Amérique*. Nicolas et Jean Coste Editions, Paris.
- Pascal, M., Brithmer, R., Lorvelec, O., Vénumière, N., 2004. Conséquences sur l'avifaune nicheuse de la réserve naturelle des îlets de Sainte-Anne (Martinique) de la récente invasion du rat noir (*Rattus rattus*), établies à l'issue d'une tentative d'éradication. *Revue d'Ecologie* 59 (1–2), 309–318.
- Pinchon, R., 1976. *Faune des Antilles françaises Les oiseaux*. 2nde édition. Fort-de-France.
- Prêcheur, C., 2009. *Étude de la dynamique de population du Puffin d'Audubon (Puffinus Lherminieri) de la réserve naturelle des îlets de Sainte-Anne*. Unpublished Master thesis. Université Antilles-Guyane, Fort-de-France.
- Pregill, G.K., Steadman, D.W., Watters, D.R., 1994. Late quaternary vertebrate faunas of the lesser Antilles: historical components of Caribbean biogeography. *Bull. Carnegie Mus. Nat. Hist.* 30, 1–51.

- Robinson, D.G., Hovestadt, A., Fields, A., Breure, A.S.H., 2009. The land mollusca of Dominica (Lesser Antilles), with notes on some enigmatic or rare species. In: Zoologische Mededelingen. 83. pp. 615–650.
- Rousteau, A., Portecop, J., Rollet, B., 1994. Carte Écologique de La Guadeloupe. ONF -University Antilles-Guyanne, Point-à-Pitre.
- Schramm, A., 1873. Note sur l'habitat du *Succinea patula*, Bruguière. J. de Conchyliol. 21, 127–129.
- Serrand, N., 2010. Stade José Bade, Guadeloupe, Marie-Galante, Capesterre. Direction des Affaires Culturelles of Guadeloupe, Basse-Terre.
- Smith, T.B., Temple, S.A., 1982. Feeding habits and bill Polymorphism in Hook-billed Kites. The Auk 99, 197–207.
- Snyder, N.F.R., Snyder, H.A., 1969. A comparative study of mollusc predation by limpkins, everglade kites, and boat-tailed grackles. In: Living Bird. 8. pp. 177–223.
- Soto-Centeno, Steadman, D.W., 2015. Fossils reject climate change as the cause of extinction of Caribbean bats. Sci. Rep. 5 (7971).
- Steadman, D.W., Takano, O.M., 2016. A new extinct species of snipe (Aves: Scolopacidae: Gallinago) from the West Indies. Zootaxa 4109 (3), 345–358.
- Steadman, D.W., Watters, D.R., Reitz, E.J., Pregill, G.K., 1984. Vertebrates from archaeological sites on Montserrat, West Indies. Ann. Carnegie Museum 53, 1–29.
- Steadman, D.W., Martin, P.S., MacPhee, R.D.E., Jull, A.J.T., McDonald, H.G., Woods, C.A., Iturralde-Vinent, M., Hodgins, G.W.L., 2005. Asynchronous extinction of late quaternary sloths on continents and islands. PNAS 102 (33), 11763–11768.
- Stoetzel, E., Royer, A., Cochard, D., Lenoble, A., 2016. Late quaternary changes in bat palaeobiodiversity and palaeobiogeography under climatic and anthropogenic pressure: new insights from Marie-Galante, lesser Antilles. Quat. Sci. Rev. 143, 150–174.
- Stouvenot, C., 2005. Capesterre de Marie-Galante. Grotte Blanchard. In Bilans scientifiques du Service Régional de l'Archéologie Guadeloupe. Direction Régionale des Affaires Culturelles of Guadeloupe, Basse-Terre, pp. 26.
- Stouvenot, C., Grouard, S., Bailon, S., Bonnissent, D., Lenoble, A., Serrand, N., Sierpe, V., 2014. L'abri sous roche Cadet 3 (Marie-Galante): un gisement à accumulations de faune et à vestiges archéologiques. In: Bérard, B. (Ed.), Proceedings of the 24th International Congress for Caribbean Archaeology, 2011, Fort-de-France, Martinique (France). International Association of Caribbean Archaeology, Fort-de-France, pp. 126–140.
- Takano, O.M., Steadman, D.W., 2015. A new species of woodcock (Aves: Scolopacidae: Scolopax) from Hispaniola, West Indies. Zootaxa 4032 (1), 117–126.
- Towns, D.R., Atkinson, I.A.E., Daugherty, C.H., 2006. Have the harmful effects of introduced rats on islands been exaggerated? Biol. Invasions 8 (4), 863–891.
- Turvey, S.T., 2009. Holocene Extinctions. Oxford University Press, New York, pp. 352.
- van der Geer, A., Lyras, G., de Vos, J., Dermitzakis, M., 2010. Evolution of Island Mammals: Adaptation and Extinction of Placental Mammals on Islands. Wiley-Blackwell, pp. 496.
- Vigne, J.-D., Lefevre, C., Thibault, J.-C., Guyot, I., 1991. Contribution archéozoologique à l'histoire récente des oiseaux marins de l'île Lavezzi (Corse - XVe-XXe Siècles). Alauda 59 (1), 11–21.
- Villa, P., Mahieu, E., 1991. Breakage patterns of human long bones. J. Hum. Evol. 21 (1), 27–48.
- Wetmore, A., 1938. Birds remains from the West Indies. Auk 55 (1), 51–55.
- Wetmore, A., 1952. A record for the black-capped petrel, *Pterodroma Hasitata*, in Martinique. Auk 69 (4), 460.

- Wing, E.S., 2001. Native American Use of Animals in the Caribbean. In: Woods, C.A., Sergile, F.E. (Eds.), *Biogeography of the West Indies: Patterns and Perspectives*, 2nd ed. CRC Press, Baco Raton, pp. 481–518.
- Wing, E.S., Hoffman, C.A., Ray, C.E., 1968. Vertebrate remains from Indian sites on Antigua, West Indies. *Caribb. J. Sci.* 8 (3–4), 123–139.
- Zeitoun, V., Lenoble, A., Laudet, F., Thompson, J., Rink, W.J., Mallye, J.-B., Chinnawut, W., 2010. The cave of the monk (Ban Fa Suai, Chiang Dao wildlife sanctuary, northern Thailand). *Quat. Int.* 220, 160–173.