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Zooarchaeological and Isotopic findings from White Marl, Jamaica: Insights on Indigenous human-animal interactions and evidence for the management of Jamaican hutias

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*This paper offers a zooarchaeological analysis of a selection of units excavated in the summer of 2018 at the precolonial site of White Marl, Jamaica (AD 900-1500). This collaborative project by The University of West Indies (UWI) Mona and Leiden University, under the supervision of the Jamaica National Heritage Trust (JNHT), recovered an extensive artifact and faunal assemblage along with a series of human burials. Our zooarchaeological analysis shows evidence of an increasing reliance over time on terrestrial animals, in particular the Jamaican hutia (*Geocapromys brownii*), a species theorized to have been managed by Indigenous peoples due to its ubiquity at precolonial sites. To assess whether the management of this species was occurring, we conducted morphometric analysis on 118 hutia mandibles, allowing us to estimate body mass and mortality ages. Our findings suggest that prime age individuals were being killed, with no examples of juveniles and few fully mature hutias within the assemblage. Some examples of bone pathologies indicate that these hutias were able to survive with hampered mobility. Stable isotope analysis of hutia bone collagen and tooth enamel was conducted which suggests that most hutias had elevated carbon values beyond what should be expected of their natural diets. This study also provides results from time series isotope sampling of one hutia incisor which may suggest changing patterns in consumption relating to seasonality. Our evidence of pathologies, isotopic evidence and mortality profile all indicate there was likely some form of management of hutias by the people of White Marl.*

*Cet article propose une analyse archéozoologique d'une sélection d'unités fouillées à l'été 2018 sur le site précolonial de White Marl, Jamaïque (900-1500 après JC). Ce projet collaboratif de l'Université des Antilles (UWI) Mona et de l'Université de Leiden, sous la supervision du Jamaica National Heritage Trust (JNHT), a permis de récupérer un vaste assemblage d'artefacts et de faune ainsi qu'une série de sépultures humaines. Notre analyse zooarchéologique montre des preuves d'une dépendance croissante au fil du temps envers les animaux terrestres, en particulier le hutia jamaïcain (*Geocapromys brownii*), une espèce supposée avoir été gérée par les peuples autochtones en raison de son omniprésence sur les sites précoloniaux. Pour évaluer si la gestion de cette espèce avait lieu, nous avons effectué une analyse morphométrique sur 118 mandibules de hutia, nous permettant d'estimer la masse corporelle et les âges de*

mortalité. Nos résultats suggèrent que des individus d'âge très actif ont été tués, sans exemples de juvéniles et peu de hutias pleinement matures au sein de l'assemblage. Quelques exemples de pathologies osseuses indiquent que ces hutias ont pu survivre avec une mobilité entravée. Une analyse des isotopes stables du collagène osseux des hutias et de l'émail des dents a été réalisée, ce qui suggère que la plupart des hutias avaient des valeurs de carbone élevées au-delà de ce à quoi on pourrait s'attendre de leur alimentation naturelle. Cette étude fournit également les résultats d'un échantillonnage isotopique en série chronologique d'une incisive hutia, ce qui peut suggérer une modification des modèles de consommation liés à la saisonnalité. Nos preuves de pathologies, nos preuves isotopiques et notre profil de mortalité indiquent tous qu'il y avait probablement une certaine forme de gestion des hutias par les habitants de White Marl.

*Este artículo ofrece un análisis zooarqueológico de una selección de unidades excavadas en el verano de 2018 en el sitio precolonial de White Marl, Jamaica (900-1500 d. C.). Este proyecto colaborativo de la University of the West Indies (UWI) Mona and Leiden University, bajo la supervisión del Jamaica National Heritage Trust (JNHT), recuperó un extenso conjunto de artefactos y fauna junto con una serie de entierros humanos. Nuestro análisis zooarqueológico muestra evidencia de una creciente dependencia con el tiempo de los animales terrestres, en particular la jutía jamaicana (*Geocapromys brownii*), una especie que, según la teoría, fue manejada por pueblos indígenas debido a su ubicuidad en sitios precoloniales. Para evaluar si el manejo de esta especie estaba ocurriendo, realizamos análisis morfométricos en 118 mandíbulas de jutía, lo que nos permitió estimar la masa corporal y las edades de mortalidad. Nuestros hallazgos sugieren que los individuos en edad productiva estaban siendo asesinados, sin ejemplos de juveniles y pocas jutías completamente maduras dentro del conjunto. Algunos ejemplos de patologías óseas indican que estas jutías pudieron sobrevivir con movilidad reducida. Se realizó un análisis de isótopos estables del colágeno óseo y el esmalte dental de las jutías, lo que sugiere que la mayoría de las jutías tenían valores elevados de carbono más allá de lo que cabría esperar de sus dietas naturales. Este estudio también proporciona resultados del muestreo de isótopos de series temporales de un incisivo de jutía que puede sugerir cambios en los patrones de consumo relacionados con la estacionalidad. Nuestra evidencia de patologías, evidencia isotópica y perfil de mortalidad indican que probablemente hubo alguna forma de manejo de las jutías por parte de la gente de White Marl.*

Introduction

Though today it houses multiple communities and has been subjected to a multitude of infrastructural development projects, White Marl has a long history as one of Jamaica's most important and largest precolonial archaeological sites, spanning an occupational period of from 1073 ± 95 BP (Yale-1118) cal. AD 713-1164 (median cal. AD 939) into the early colonial period at cal. AD 1488-1645 (median cal. AD 1567) (Atkinson 2019; Mickleburgh et al. 2019). In the mid-19th century, Jamaican naturalist Richard Hill was among the first to draw attention to the vast quantities of artifacts, fauna and human burials exposed at White Marl during the initial construction of the roadway which now abuts the site (Allsworth-Jones 2008:161 which includes the Duerden 1897 publication as Appendix D). Around a century later, in the 1950s-70s, the first excavations at White Marl began (see Howard 1950, 1956, 1965; Silverberg et al. 1972; St. Clair 1970; Vanderwal 1967, 1968a, 1968b). Renewed threats to White Marl from proposed infrastructural development have paradoxically

given new life to archaeological research at the site. Ahead of a proposed highway expansion in 2016, the University of West Indies (UWI) Mona, Leiden University and the Jamaican National Heritage Trust (JNHT) were involved in collaborative excavations at several locations within White Marl. Excavations during the summer of 2018 in the forested area behind the now-closed White Marl Museum recovered an extensive artefactual and faunal assemblage associated with a series of kitchen middens and human burials.

Analysis of the zooarchaeological assemblage at White Marl serves to advance previous studies of precolonial environments and diets both at White Marl (see Wing 1972), and in a wider Jamaican context (see Allsworth-Jones 2008; Azevedo 2015; Carlson 2012; Keegan et al. 2003; Rampersad 2009; Scudder 2006). This paper details the findings of the analyses of faunal remains recovered from three 1x1m unit quadrants (U2.11.SW, U2.11.SE and U2.12.NE) excavated during the 2018 rescue excavations at White Marl (**Figure 1**). We have identified fauna from one unit (U2.12.NE) to further our

understanding of the subsistence practices of the Indigenous inhabitants of White Marl. In addition, we have employed morphometric analysis on Jamaican hutia (*Geocapromys brownii*) mandibles (n=118) recovered from all

three units, and isotopic analyses of selected samples from individual hutias (n=11) from U2.12.NE to assess whether animal management practices affecting hutia populations were occurring at White Marl.



Figure 1. Drone image of the southern section of the White Marl excavation area. Excavation units analyzed in this paper are highlighted in red: U2.11.SW, U2.11.SE and U.2.12.NE. The Google Earth (2021) map inset shows the approximate location (in red) of White Marl in Jamaica. Drone image taken by Z. Beier in January 2019.

The zooarchaeology of Jamaica and White Marl

The zooarchaeological evidence from the precolonial era of the insular Caribbean suggests that most animal exploitation likely occurred within 3-5 km of Indigenous settlements (Giovas 2013; Grouard 2002; Wing and Wing 2001), with a positive correlation between distance from the coast and an increasing ratio of terrestrial versus marine animals present within assemblages (Grouard 2010; Newsom and Wing 2004; Scudder 1991). Most terrestrial animal remains at Indigenous archaeological sites in Jamaica are of

the Jamaican hutia, which has led some researchers to speculate that they may have been managed in captivity, although no physical evidence of enclosures or other cultural indicators of captive management have ever been recovered (Allsworth-Jones 2008; Carlson 2012; Newsom and Wing 2004; Silverberg et al. 1972; Wilkins 2001; Wing 1972, 1993) which may be due to detrimental conditions affecting the poor preservation of organic material.

Despite such vast yields of hutia remains in the faunal assemblages of precolonial sites in Jamaica, the methods utilized by Indigenous

peoples for their capture or management are still unknown. This high abundance has variably been interpreted as either being due to natural hunting strategies or is reminiscent of some form of management of hutia populations by humans (Carlson 2012; Wilkins 2001). Animal management is not unprecedented in the insular Caribbean. Domestic guinea pigs (*Cavia porcellus*) have been identified at some sites (LeFebvre and deFrance 2014; Lord et al. 2018), and Indigenous peoples are known to have had close relationships with domesticated dogs (*Canis familiaris*) which have been commonly recovered at many sites throughout the region (Grouard et al. 2013; Laffoon et al. 2015, 2019; Newsom and Wing 2004; Shev et al. 2020), including at White Marl (Wing 1972). These instances suggest that managing domestic animals was within the cultural repertoire of Indigenous peoples (LeFebvre and deFrance 2018; Wing 2008).

Elizabeth Wing comprehensively analyzed the fauna recovered from Robert R. Howard's 1964 excavation of White Marl, providing us with a baseline from which to compare our results (Wing 1972). Wing's analysis suggests the faunal assemblage is largely dominated by Jamaican hutia, which formed 50% of the minimum number of individuals (MNI) of all identified vertebrates (MNI=713). Incorporating crab (Decapodae) remains, Wing identified a total MNI of 1,121 for the site. Fishes (MNI=272) were also an important food source for the inhabitants of White Marl, with species of snook (*Centropomus* sp.), snapper (Lutjanidae), mullet (*Mugil* sp.), porgies (Sparidae), and sharks (Squaliformes) being some of the more well-represented taxa. The majority of these fish species can be found in inshore estuarine environments, and to a lesser extent reef biomes. As White Marl is situated within 5 km of a large but shallow estuary, Kingston Harbour, it is apparent that the inhabitants of White Marl were focused on utilizing locally available animals (Wing 1972).

Jamaican hutia: A candidate for management

The Jamaican hutia (*Geocapromys brownii*) is the only species of a group of caviomorph rodents known as hutias (family: Echimyidae, subfamily: Capromyinae; Courcelle et al. 2019; Woods et al. 2021) native to Jamaica (Woods and Kilpatrick 2005). *G. brownii*, is currently listed as endangered by the International Union for Conservation of Nature (IUCN) and is largely restricted to the interior of the island (Kennerley et al. 2018) where rocky landscapes and deep forest have provided refugia for isolated populations (Anderson et al. 1983; Wilkins 2001). Hutias were likely once much more abundant throughout Jamaica, as has been determined from archaeological findings which suggests they formed a significant component of the diet of Indigenous peoples at many sites (Newsom and Wing 2004; Scudder 1991, 2006; Wing 1972, 2008).

Hutia osteometrics and mortality age determinations

A previous study of modern Jamaican hutias has provided essential morphological information on this species to better interpret archaeological specimens. Laurie Wilkins (2001) conducted osteometric analysis on femurs, humeri, and lower tooth row lengths (LTRL) of 12 known-age *G. brownii* individuals, providing size estimations to determine the mortality ages of archaeological hutia bones. Establishing the mortality age profiles of fauna from archaeological sites provides important information about hunting or husbandry strategies that may have affected animal populations (Stiner 1990; Klein 1982; Lyman 1987). Wilkin's (2001) assumption was that managed hutias would likely have been being culled when they reach sexual maturity (8-12 months), however her study of hutia remains from the Bellevue site in St. Andrews Parish, located 10 km north of Kingston Harbour, did not establish a hutia mortality profile that was clearly suggestive of a managed population. Rather, it showed a spread of age classes reminiscent of the non-age selective hunting and trapping strategies conducted by modern Jamaican hunters (Wilkins 2001). Lisabeth Carlson (2012) employed the same criteria for age determinations from measuring LTRL of Jamaican hutias at the sites of

Wentworth (n=8), Green Castle (n=10) and Coleraine (n=9) in the north coast Parish of St. Mary. Contrary to Wilkins' (2001) study, at the site of Coleraine it seems fully grown adults were targeted, possibly to maximize meat yields, whereas at the sites of Wentworth and Green Castle hutias were killed at an average age of 13 months (Carlson 2012), just older than the 8-12 months optimal culling phase suggested by Wilkins (2001). Carlson's findings suggest that there may have been some selective hunting practices occurring, perhaps due to the presence of a larger and more stable hutia population in the past that allowed the selective targeting of prime aged animals. These findings also tentatively suggest there may have been some population management occurring (Carlson 2012).

In this study we have taken LTRL measurements on Jamaican hutia (*Geocapromys brownii*) mandibles (n=118), gathered from three excavation units, U2.12.NE, U2.11.SW and U2.11.SE, and employ the mortality age calculations based on the research by Wilkins (2001). This is the largest morphometric and mortality age profile study of archaeological Jamaican hutia that has been conducted to date.

Stable isotope ratio analysis of hutia remains

In the Neotropical Americas, stable isotope ratio analysis of animal remains has demonstrated potential for examining whether the diets of animals may have been influenced by human activities (LeFebvre et al. 2019; Shev et al. 2021; Sugiyama et al. 2015, 2020). In archaeological settings, stable isotope analysis of nitrogen ($\delta^{15}\text{N}$) and carbon ($\delta^{13}\text{C}$) is principally conducted on bone and teeth of animal remains. Nitrogen isotope ratio values can indicate the trophic level of an examined organism and can distinguish between a terrestrial or marine-based diet (DeNiro and Epstein 1981; Schoeninger and DeNiro 1984), while carbon isotope values are largely determined by the specific photosynthetic pathways of plants at the bottom of a food web (DeNiro and Epstein 1978; Schoeninger and DeNiro 1984). All C_3 -pathway plants, which form most species globally, exhibit $\delta^{13}\text{C}$ ranges between -35 to -20‰, more arid-adapted C_4 species have values ranging between -15 to -7‰, while crassulacean acid metabolism (CAM)

plants often overlap in value ranges with C_4 taxa (Kohn 2010; O'Leary 1988).

Within the Neotropics, including the insular Caribbean, human influence over animal diets has been observed in relatively high $\delta^{13}\text{C}$ values of animals that exceed the expected values of a wild diet consisting mainly of C_3 plants (LeFebvre et al. 2019; Shev et al. 2021; Sugiyama et al. 2015, 2020). This is due to agricultural maize (*Zea mays*), a C_4 plant, being a staple crop for many Indigenous societies in the Americas (Keegan and DeNiro 1988; Lee-Thorp et al. 1989). Although it was likely not the main staple consumed by Indigenous peoples in the Caribbean, maize starch grains have been positively identified at many archaeological sites in the Caribbean (Ciofalo et al. 2019; Figueredo 2015; Mickleburgh and Pagán-Jiménez 2012; Pagán-Jiménez et al. 2020), including from the dental calculus of buried human at White Marl (Mickleburgh et al. 2019).

The consumption of maize by humans may explain some relatively high carbon values that have been observed for other hutia species in the Greater Antilles. Isotopic studies have previously been conducted on Bahamian hutia (*Geocapromys ingrahami*) (LeFebvre et al. 2019), and extinct *Isolobodon portoricensis* from Hispaniola (Shev et al. 2021). Both studies showed that some hutias had relatively high carbon values perhaps indicating human influence over their diets. There are several non-mutually exclusive scenarios to explain these phenomena; hutias were consuming wild C_4 plants beyond what should be expected of their natural diets; hutias were habitually scavenging from human garden plots frequently enough to affect their isotopic values; or they were being purposefully fed maize by Indigenous peoples (LeFebvre et al. 2019; Shev et al. 2021).

Within our study we have conducted isotope analysis on 11 *G. brownii* specimens examining both enamel (n=10) and collagen (n=9) from one excavation unit (U2.12.NE). These results are compared to previously analyzed *G. brownii* enamel values (n=3), and human enamel (n=3) and collagen (n=3) values from White Marl in a study by Mickleburgh and colleagues (2019).

Materials and Methods

Excavation methodology

Excavations beginning in the summer of 2018 explored the southwestern portion of an occupational mound that is situated on the edge of the Nelson Mandela Highway; a roadway that was initially cut in the 19th century and further developed in the 1940s (Allsworth-Jones 2008: 162, 224). Multiple 1x1 m units were dug in 10 cm increments, forming a 5x2 m trench, reaching a maximum depth of 150 cm. Within level 10 (90-100 cm in depth) and below, sat a human burial (Feature 2) in a flexed supine position spanning units U2.12.NE and U2.11.SE. Subsequent excavations removed the burial fill and contents to document this well-preserved burial, bringing the maximum depth of this feature to 124 cm and the adjacent unit U2.11.SW to 150 cm. The midden stratigraphy exposed in this excavation area in 2018 is composed of a series of repetitive layers of sandy loam soil and ash containing mollusks, pottery, lithics, and faunal remains separated by loose marl sediments including pebble and cobble size rocks, which is interpreted as the intentional movement and reworking of sediments by the inhabitants of White Marl, as has been observed at other contemporaneous sites in the region (Pagán-Jiménez et al. 2020). Faunal material from the primary burial unit U2.12.NE was used for our analysis. In January 2019, archaeologists from the JNHT continued excavation at White Marl, adding additional 1x1 m units to the western and northern sections of the study area and extending the maximum depth to bedrock at approximately 2.2 m. Directly adjacent to the previously discovered burial, two additional human burials in flexed lateral positions were recovered along with associated artifacts.

Identification of Taxa

Faunal remains which overlaid the human burial and from within the burial fill of U2.12.NE were separated from other material and washed for ease of both taxonomic classification and the identification of pathologies, signs of burning, and butchery marks. All terrestrial and marine vertebrates present within U2.12.NE were identified. This was conducted with the aid of reference collections housed in the UWI Mona

Archaeology Laboratory, in particular the Green Castle collection excavated by Philip Allsworth-Jones and Kit Wesler. For fish classifications we also utilized online skeletal atlases: Osteobase (<http://osteobase.mnhn.fr/>), Fishbase (<https://www.fishbase.de/>), and the Florida Museum of Natural History Skeletal Atlas of Fishes (<https://www.floridamuseum.ufl.edu/fishatlas/>). Shark centra were identified following Kozuch and Fitzgerald (1989). As there were only two species of rodents extant prior to the arrival of Europeans most postcranial elements were distinguishable based on size and morphology.

The number of identified specimens (NISP) for each taxon was calculated for each level. By pairing similarly sized elements from the same taxa the minimum number of individuals (MNI) present within each level was established.

Osteometric Analysis

Using a digital vernier caliper, the lower tooth row length (LTRL) of all *G. brownii* mandibles with intact tooth rows (n=118) were recorded in millimeters (mm). These samples were recovered from units U2.11.SW, U2.11.SE and U2.12.NE. The body mass (BM) of each individual was calculated using the formula outlined by Hopkins (2008):

$$\ln(\text{body mass}) = a + b \ln(\text{LTRL})$$

With *a* and *b* representing regression intercepts used for Hystricomorpha, the subordinal clade containing hutias (*a* = -0.9125, *b* = 2.8134).

LTRL and BM from each unit were all grouped according to excavation level to represent distinct trends in consumption across occupational periods. After normality in the distribution of LTRL and BM data was confirmed, a Pearson's 2-tailed test for correlation was carried out on both sets of data. This assessed the statistical strength of a linear correlation between each set of data and excavation level. Following Wilkins (2001), we were able to generate mortality age calculations for all measured mandibles. Our measurements follow the previous applications of these estimations by Wilkins (2001) and Carlson (2012) (**Table 1**).

Table 1. Ranges of lower tooth row lengths (LTRL) and proposed age classes and mortality ages, after Wilkins (2001) and Carlson (2012).

LTRL (mm)	Age	Age class
<12	<10 months	juvenile
12 - 14.7	10 months	subadult
14.8	1 year	young adult of reproductive age
17.6	14 months	young adult
18	18 months	young adult
19	2 years	young adult
20	≥ 3 years	fully grown adult

Isotopic analysis of bone collagen and dental enamel

In total, 12 *G. brownii* mandibles were selected for isotopic analysis from U2.12.NE. Mandibles containing incisors were chosen so that both the bone collagen and tooth enamel could be analyzed from the same individuals. At least one sample was selected from each of the 10 cm excavation levels (20-100 cm) overlying the human burial context, with exception of the first level due to possible disturbances to the topsoil. Care was taken to choose the same side of the mandible within each level, or when this was not possible, mandibles of different sizes were selected to ensure that the same individuals were not repeatedly analyzed.

Collagen and enamel extraction took place at the Faculty of Archaeology, Leiden University. All teeth were removed prior to chemical treatment. The extraction procedure for collagen was slightly modified from Müldner and Richards (2005) and is published elsewhere (see Shev et al. 2021). Enamel extraction followed protocol outlined in Laffoon et al. (2012) and Laffoon et al. (2015). Collagen samples were analyzed by a ThermoQuest IRMS Delta XP Plus interfaced with a Flash elemental analyzer. Enamel samples were analyzed by a Finnigan DeltaPlus IRMS after reaction with H₃PO₄ [100%], and the isolating of O₂ was done using a

Gasbench II universal automated interface. All mass spectrometry was conducted at the Earth Science Stable Isotope Laboratory at VU Amsterdam.

To assess whether seasonal changes in diet can be assessed by analyzing *G. brownii* incisors, time series sampling was conducted on one sample (WM5). This involved the lateral drilling of bands of enamel powder 3 mm apart from the crown of the incisor to the base of the enamel casing near the root, providing eight enamel powder samples from the one hutia tooth.

An approximation of C₄ input percentages based on our enamel data was conducted by applying the formula used by LeFebvre et al. (2019) for Bahamian hutias, which follows Somerville et al. (2013): with a terminus of -25‰ for 100‰ C₃ consumption, with -12‰ for 100% C₄ consumption, 9.7% Δ¹³C_{en-diet} spacing, and 16 being the value difference between a 100% C₃ consumer and an assumed value of -9‰ for agricultural maize. This formula is as follows:

$$\%C_4 = (-25 - (\delta^{13}C_{ap} - 9.7) / -16) * 100$$

Carbon (δ¹³C), oxygen (δ¹⁸O), and nitrogen (δ¹⁵N) isotope ratio values are all written in δ notation as parts per thousand (‰). Carbon and oxygen values are determined against the Vienna Pee Dee Belemnite (VPDB) standard, and nitrogen against the N_{AIR} standard.

Radiocarbon samples

Three *G. brownii* mandibles from U2.12.NE were selected for radiocarbon dating from levels 3 (WM2), 6 (WM20) and 9 (WM18), all located above the burial context. Samples were analyzed at the University of Groningen Radiocarbon Dating lab. Conventional radiocarbon dates (in years BP) were calibrated USING OrAU OxCal software (v4.4) with the IntCal20 calibration curve (Reimer et al. 2020) to produce reliable dates recorded in years AD at 95.4% confidence. To provide a reliable date range for this deposit from our three radiocarbon samples we calculated Bayesian start and end dates using a single-phase Bayesian model in OrAU OxCal software (v4.4). Bayesian start and end models are reported at 95.4% confidence, and we provide a statistical median of each of these models.

Results

Radiocarbon results

Based on sample WM18 in level 9 the deposits above the burial begin at cal. AD 1284 to 1393, median cal. AD 1339 (654 ± 24 BP, GrM-27784), and based on sample WM2 recovered from level 2 terminates sometime after cal. AD 1399 to 1439, median cal. AD 1419 (519 ± 21 BP, GrM-27783). Sample WM20, taken from level 6, ranges from cal. AD 1318 to 1423, median date cal. AD 1371 (566 ± 24 BP, GrM-27785). From these available chronological dates these deposits can be securely determined as being from within the timeframe of cal. AD 1284 – 1439.

General zooarchaeological findings

Compared to other islands in the Greater Antilles, Jamaica exhibits one of the highest rates of biodiversity in floral species and in avian taxa, however only 33 endemic reptile species, and only two non-volant mammal species inhabited the island during the occupation of White Marl: Jamaican hutia and Jamaican rice rat (*Oryzomys antillarum*) (Lee 2006). This paucity in terrestrial fauna was reflected in our identification of only five terrestrial species. In summary, the total sample NISP was calculated as 5,315 faunal elements, of which approximately 50% were unidentifiable largely due to a high degree of fragmentation (Figure 2; Table 2). A lack of a more comprehensive reference collection also hampered the accurate identification of many fish vertebrae and vertebral spines, which made up a large portion of the unidentifiable remains. Identified specimens (NISP) consisted of 1,061 terrestrial vertebrate, 362 marine vertebrate, and 240 crab elements.

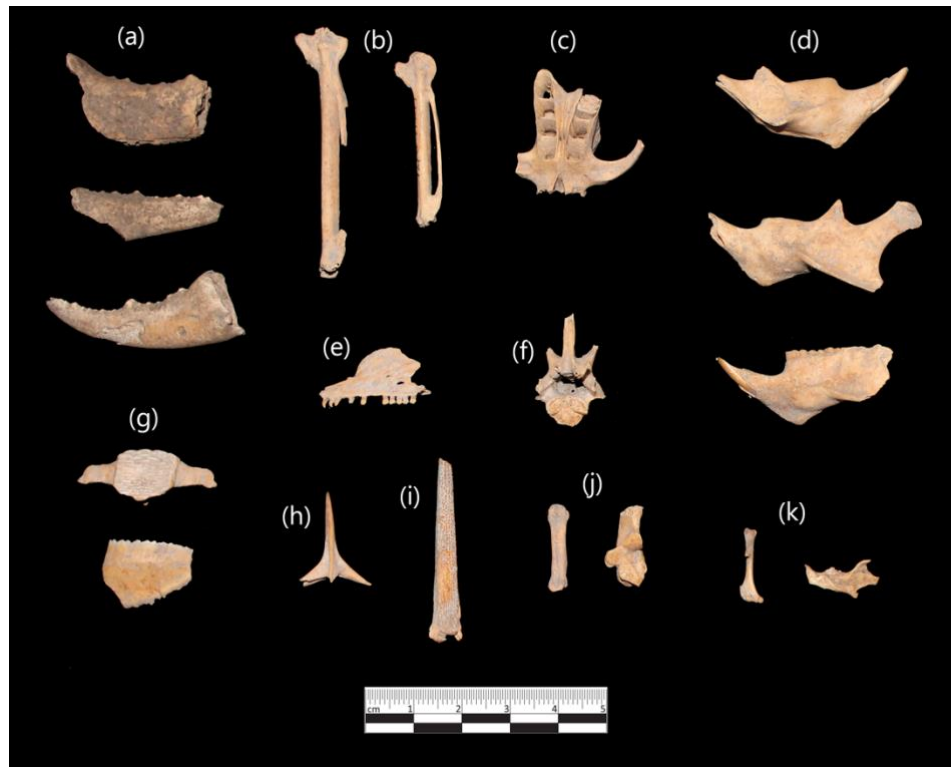


Figure 2. Assortment of faunal material from U2.12.NE: (a) Decapodae chelipeds; (b) Aves carpometacarpal; (c) *Geocapromys brownii* maxilla; (d) *G. brownii* mandibles; (e) *Cyclura collei* maxilla; (f) *G. brownii* thoracic vertebra; (g) parrotfish (Scaridae), top - lower pharyngeal grinder, bottom - dentary; (h) Diodontidae spine; (i) Balistidae first dorsal spine; (j) *G. brownii* podials, left - metapodial, right - calcaneus; (k) *Oryzomys antillarum*, left - humerus, right - mandible.

Terrestrial vertebrates

The most abundant terrestrial species in our study units was Jamaican hutia. From 939 hutia elements approximately an MNI of 88 individual animals were represented. Thirty-one elements (MNI=15) of the now extinct Jamaican rice rat (*Oryzomys antillarum*) were among the identified mammals. Endemic reptiles include an MNI of 18 Jamaican rock iguanas (*Cyclura collei*), identified from 42 skeletal fragments, all of which were vertebrae and cranial elements. One *C. collei* vertebrae, taken from Level 8 within the burial, exhibited significant signs of burning. Jamaican rock iguana was the most prolific of the recovered reptilian remains, outnumbering anoles (*Anolis* spp., NISP=6, MNI=6). The assemblage contained a low number of avian remains (NISP=38; MNI=10).

Two hutia long bones exhibited pathologies which likely led to difficulties in

movement and hampered their survivability (**Figure 3**). One of these elements (WM4) was found in U2.12.NE Level 4; a radius exhibiting exostosis possibly from a bone fracture that healed in dislocation. Collagen from this specimen was analyzed and is discussed below. From Level 6, a *G. brownii* tibia (WM7) was recovered that exhibited exostosis and periosteal lesions on the anterior midshaft, deformations that might be the result of an injury or pathogen (Bartosiewicz 2008). Injured or diseased fauna typically do not survive for very long in the wild, especially when pathologies affecting their locomotion are sustained, suggesting that these animals may have been tended to. However, with few endemic terrestrial predators known to target hutia and the extensive documentation of herbivores healing successfully from similar injuries, natural recoveries cannot be overlooked.

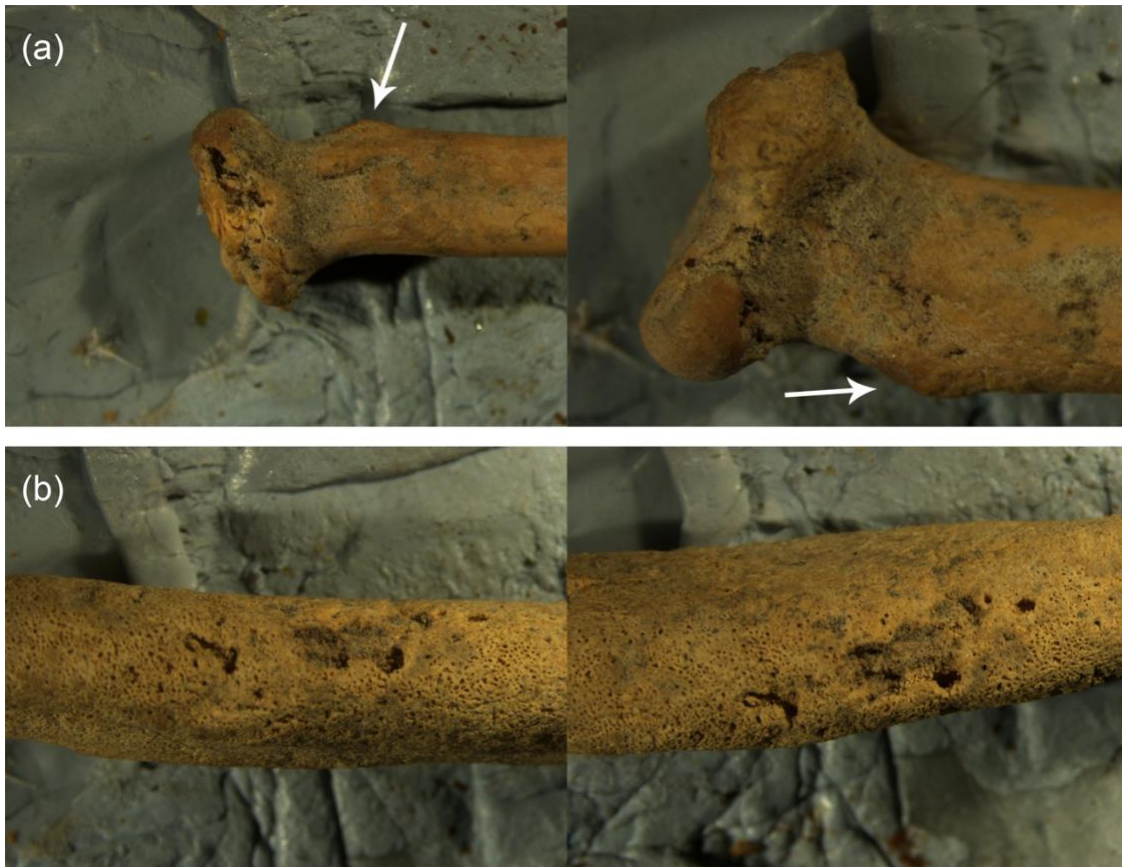


Figure 3. a) Sample WM4: Proximal end of a *Geocapromys brownii* radius showing a possible fracture that healed in dislocation to the axis of the shaft. Arrows indicate points of exostosis. b) Sample WM7: anterior midshaft of a *G. brownii* tibia exhibiting posterior-anterior exostosis with bone lesions on the anterior margin, possibly from a pathogen or injury.

Decapodae remains

Second to hutia in relative abundances were crabs (Decapodae) (NISP = 240, MNI = 96), of which more than 50% showed signs of burning. Though numerous carapace fragments were recovered, the majority of specimens were chelipeds, likely due to the higher survivability of these relatively thick elements. Most probably much of the crab remains represent blue land crab (*Cardisoma guanhumi*) or Caribbean black land crab (*Gecarcinus ruricola*). Some specimens might also be representative of aquatic species such as the common blue crab (*Callinectes sapidus*).

Marine vertebrates

Of marine vertebrates there were 2,496 unidentified elements, 1,643 were vertebrae, vertebral spines and fragments. Members of the snapper family (*Lutjanidae*) (NISP=37, MNI=23), and groupers (*Serranidae*) (NISP=27, MNI=16) were the most prominent. Several vertebrae and teeth of Chondrichthyes, the order containing sharks and rays, were recovered. Among the identified is bull shark (*Carcharhinus leucas*), which commonly enters coastal, brackish or freshwater ecosystems, and the sandbar shark (*Carcharhinus plumbeus*) which dwells most frequently in coastal or freshwater ecosystems (Compagno 1984). A heavily degraded rib fragment of West Indian manatee (*Trichechus manatus*) was recovered, which was the largest animal we identified.

Table 2. List of Taxa identified from unit U2.12.NE with their calculated MNI and NISP.

Family	Genus	Species	Common Name	MNI	%MNI	NISP	%NISP
Mammalia:			Mammals	104	22.56	971	18.27
Rodentia	<i>Geocapromys</i>	<i>brownii</i>	Jamaican hutia	88	19.09	939	17.67
Rodentia	<i>Oryzomys</i>	<i>antillarum</i>	Jamaican rice rat	15	3.25	31	0.58
Trichechidae	<i>Trichechus</i>	<i>manatus</i>	West Indian manatee	1	0.22	1	0.02
Reptilia:			Reptiles	28	6.07	56	1.05
Cheloniidae	-	-	Sea turtles	1	0.22	3	0.06
Dactyloidae	<i>Anolis</i>	sp.	Anoles	6	1.3	6	0.11
Iguanidae	<i>Cyclura</i>	<i>collei</i>	Jamaican rock iguana	18	3.9	42	0.79
Unidentified	-	-	lizards	3	0.65	5	0.09
Aves:			Birds	10	2.17	38	0.71
Unidentified	-	-	UID	10	2.17	38	0.71
Arthropoda:			Arthropods	96	20.82	240	4.52
Gecarcinidae	-	-	Land crabs	96	20.82	240	4.52
Osteichthyes:			Bony Fish	208	45.12	338	6.36
Acanthuridae	<i>Acanthurus</i>	sp.	Surgeonfish	7	1.52	61	1.15

Balistidae	-	-	Triggerfish	3	0.65	3	0.06
Carangidae	-	-	Carangid	6	1.3	9	0.17
Carangidae	<i>Caranx</i>	sp.	Jack	2	0.43	2	0.04
Carangidae	<i>Chloroscombrus</i>	<i>chrysurus</i>	Atlantic bumper	1	0.22	1	0.02
Carangidae	<i>Oligoplites</i>	sp.	Leatherjacket	1	0.22	1	0.02
Centropomidae	<i>Centropomus</i>	sp.	Snook	4	0.87	4	0.08
Diodontidae	-	-	Porcupinefish	6	1.3	8	0.15
Eleotridae	-	-	Sleeper goby	3	0.65	3	0.06
Eleotridae	<i>Gobiomorus</i>	<i>dormitor</i>	Bigmouth sleeper	8	1.74	11	0.21
Gerreidae	-	-	Mojarra	4	0.87	4	0.08
Gerreidae	<i>Diapterus</i>	sp.	Mojarra	1	0.22	1	0.02
Haemulidae	-	-	Grunts	9	1.95	10	0.19
Haemulidae	<i>Anisotremus</i>	sp.	Grunt	2	0.43	3	0.06
Haemulidae	<i>Haemulon</i>	sp.	Grunt	2	0.43	2	0.04
Haemulidae	<i>Haemulon</i>	<i>album</i>	White margate	1	0.22	1	0.02
Haemulidae	<i>Haemulon</i>	<i>sciurus</i>	Blue-striped grunt	3	0.65	3	0.06
Holocentridae	-	-	Squirrelfish	6	1.3	7	0.13
Labridae	-	-	Wrasse	2	0.43	2	0.04
Lutjanidae	-	-	Snapper	35	7.59	55	1.03
Lutjanidae	<i>Lutjanus</i>	sp.	Snapper	5	1.08	9	0.17
Lutjanidae	<i>Lutjanus</i>	<i>apodus</i>	Schoolmaster snapper	3	0.65	4	0.08
Lutjanidae	<i>Lutjanus</i>	<i>campechanus</i>	Northern red snapper	2	0.43	2	0.04
Lutjanidae	<i>Lutjanus</i>	<i>griseus</i>	Grey snapper	5	1.08	6	0.11
Lutjanidae	<i>Lutjanus</i>	<i>synagris</i>	Lane snapper	1	0.22	1	0.02
Lutjanidae	<i>Ocyrus</i>	<i>chrysurus</i>	Yellowtail snapper	1	0.22	1	0.02
Lutjanidae	<i>Pristipomoides</i>	sp.	Snapper	1	0.22	1	0.02
Lobotidae	<i>Lobotes</i>	<i>surinamensis</i>	Atlantic tripletail	1	0.22	1	0.02
Mullidae	-	-	Goatfish	2	0.43	2	0.04
Muraenidae	-	-	Moray eel	2	0.43	2	0.04
Scaridae	<i>Sparisoma</i>	sp.	Parrotfish	2	0.43	3	0.06
Scaridae	<i>Sparisoma</i>	<i>aurofrenatum</i>	Redband parrotfish	2	0.43	2	0.04
Sciaenidae	-	-	Drums	10	2.17	13	0.24
Sciaenidae	<i>Bairdiella</i>	sp.	Croaker/perch	1	0.22	1	0.02
Sciaenidae	<i>Cynoscion</i>	<i>jamaicensis</i>	Jamaican weakfish	7	1.52	16	0.3

Scombridae	-	-	Mackerels and tunas	4	0.87	8	0.15
Scombridae	<i>Thunnus</i>	sp.	True tunas	2	0.43	2	0.04
Serranidae	-	-	Bass and grouper	9	1.95	14	0.26
Serranidae	<i>Epinephelus</i>	sp.	Groupers	26	5.64	40	0.75
Serranidae	<i>Mycteroperca</i>	<i>bonaci</i>	Black grouper	3	0.65	3	0.06
Sparidae	-	-	Porgy	8	1.74	9	0.17
Sparidae	<i>Calamus</i>	sp.	Porgy	1	0.22	1	0.02
Sphyraenidae	<i>Sphyraena</i>	sp.	Barracuda	1	0.22	1	0.02
Sphyraenidae	<i>Sphyraena</i>	<i>barracuda</i>	Great Barracuda	3	0.65	5	0.09
Chondrichthyes			Cartilaginous fish	15	3.25	20	0.38
Elasmobranchii	-	-	Shark and ray	2	0.43	2	0.04
Carcharhinidae	-	-	Requiem shark	1	0.22	1	0.02
Carcharhinidae	<i>Carcharhinus</i>	sp.	Shark	1	0.22	1	0.02
Carcharhinidae	<i>Carcharhinus</i>	<i>acronotus</i>	Blacknose shark	1	0.22	2	0.04
Carcharhinidae	<i>Carcharhinus</i>	<i>leucas</i>	Bull shark	6	1.3	10	0.19
Carcharhinidae	<i>Carcharhinus</i>	<i>plumbeus</i>	Sandbar shark	3	0.65	3	0.06
Carcharhinidae	<i>Carcharhinus</i>	<i>perezi</i>	Caribbean reef shark	1	0.22	1	0.02
Unidentifiable fragments						3652	68.71
Terrestrial	-	-	-			1156	21.75
Osteichthyes	-	-	-			2496	46.96
<i>Total</i>				<i>461</i>		<i>5315</i>	

Aquatic biomes targeted and fishing techniques

The diversity of fish species is suggestive of the exploitation of a range of aquatic ecosystems by the inhabitants of White Marl. Following biome designations by Wing (1972), 41% fish species can be found in reef environments or close to the shore. Only about 7% of fish were freshwater, however around 20% were species capable of thriving in brackish environs, and 26% of species are found in littoral environments, perhaps located relatively close to the site. There were few identified pelagic species such as tunas, mackerels, and bonitos (Scombridae), totaling 6% of the MNIs. Almost

half (45%) of the identifiable species can be captured by hook and line including all groupers, snappers and grunts (Haemulidae), 31% by net or seine such as snappers, grunts and drums (Sciaenidae), and 21% by traps such as parrotfish (Scaridae). Only 3% can be fished using projectiles such as spears, harpoons, or arrows, such as large bull sharks.

Jamaican hutia morphometrics and mortality age estimations

A total of 118 mandibles with intact tooth rows were measured (**Table 3**). The selected sample population had an overall mean LTRL of

18.39 mm, and therefore average weight of 1472.4 g. The smallest mandible (LTRL=13.95 mm) came from level 6 (50-60 cm) and the largest

(LTRL=21.06 mm) from level 8. These individuals would have weighed approximately 666.6 g and 2123.9 g respectively.

Table 3. Osteometrics of *Geocapromys brownii* lower tooth row length (LTRL) from units U2.12.NE, U2.11.SE, U2.11.SW used to estimate body mass calculations following Hopkins (2008), mortality age and age classes (Wilkins 2001; Carlson 2012).

Unit: U2.	Levels	LTRL (mm)	Body Mass (g)	Mortality Age	Age class
11.SE	1	18.74	1529.38	18 months	Young adult
11.SE	2	19.88	1805.81	2 years	Young adult
11.SE	2	19.05	1601.63	2 years	Young adult
11.SE	2	19.99	1834.06	2 years	Young adult
11.SE	2	20.4	1941.87	≥ 3 years	Fully grown adult
11.SE	2	19.1	1406.43	2 years	Young adult
11.SE	2	19.18	1632.57	2 years	Young adult
11.SE	2	19.5	1710.37	2 years	Young adult
11.SE	2	17.88	1340.04	14 months	Young adult
11.SW	2	18.61	1499.72	18 months	Young adult
11.SW	2	18.19	1406.43	18 months	Young adult
12.NE	3	17.69	1300.36	14 months	Young adult
12.NE	3	17.04	1170.37	1 year	Young adult - reproductive age
11.SE	3	19.97	1828.9	2 years	Young adult
11.SE	3	19.33	1668.75	2 years	Young adult
11.SE	3	18.88	1561.75	18 months	Young adult
11.SE	3	20.66	2012.31	≥ 3 years	Fully grown adult
11.SE	3	18.89	1564.07	18 months	Young adult
11.SE	3	19.11	1615.87	2 years	Young adult
11.SE	3	20.92	2084.37	≥ 3 years	Fully grown adult
11.SE	3	19.88	1805.81	2 years	Young adult
11.SE	3	19.62	1740.15	2 years	Young adult
11.SE	3	18.5	1474.92	18 months	Young adult
11.SW	3	19.31	1663.9	2 years	Young adult
11.SW	3	18.03	1371.91	18 months	Young adult
11.SW	3	18.01	1367.63	18 months	Young adult

11.SW	3	17.48	1257.4	1 year	Young adult - reproductive age
11.SW	3	17.79	1321.15	14 months	Young adult
11.SW	3	18.71	1522.5	18 months	Young adult
12.NE	4	19.12	1618.25	2 years	Young adult
12.NE	4	13.95	666.58	10 months	Sub adult
12.NE	4	18.02	1369.77	18 months	Young adult
12.NE	4	17.06	1174.24	1 year	Young adult - reproductive age
12.NE	4	18.67	1513.37	18 months	Young adult
11.SE	4	19.13	1620.63	2 years	Young adult
11.SE	4	19.55	1722.74	2 years	Young adult
11.SE	4	20.3	1915.21	≥ 3 years	Fully grown adult
11.SE	4	18.53	1481.65	18 months	Young adult
11.SE	4	19.05	1601.63	2 years	Young adult
11.SE	4	18.5	1474.92	18 months	Young adult
11.SE	4	18.35	1441.52	18 months	Young adult
11.SW	4	18.19	1406.43	18 months	Young adult
11.SW	4	18.97	1582.78	18 months	Young adult
11.SW	4	17.99	1363.36	14 months	Young adult
11.SW	4	18.86	1557.1	18 months	Young adult
11.SW	4	20.47	1960.67	≥ 3 years	Fully grown adult
11.SW	4	19.46	1700.52	2 years	Young adult
11.SW	4	18.72	1524.8	18 months	Young adult
12.NE	5	15.5	896.57	1 year	Young adult - reproductive age
12.NE	5	18.21	1410.79	18 months	Young adult
12.NE	5	17.93	1350.61	14 months	Young adult
11.SE	5	19.48	1705.44	2 years	Young adult
11.SE	5	16.78	1120.82	1 year	Young adult - reproductive age

11.SE	5	15.1	832.99	1 year	Young adult - reproductive age
11.SE	5	18.1	1386.94	18 months	Young adult
11.SE	5	18.09	1384.79	18 months	Young adult
11.SW	5	17.68	1298.29	14 months	Young adult
12.NE	6	18.82	1547.82	18 months	Young adult
12.NE	6	18	1365.49	18 months	Young adult
12.NE	6	16.32	1036.51	1 year	Young adult - reproductive age
12.NE	6	19.93	1818.61	2 years	Young adult
12.NE	6	18.75	1531.68	18 months	Young adult
12.NE	6	18.75	1531.68	18 months	Young adult
12.NE	6	16.65	1096.56	1 year	Young adult - reproductive age
12.NE	6	15.36	873.98	1 year	Young adult - reproductive age
12.NE	6	14.75	779.8	10 months	Sub adult
11.SE	6	18.13	1393.42	18 months	Young adult
11.SE	6	19.23	1644.57	2 years	Young adult
11.SE	6	17.67	1296.23	14 months	Young adult
11.SE	6	17.8	1323.24	14 months	Young adult
11.SW	6	17.63	1287.99	14 months	Young adult
11.SW	6	19.85	1798.15	2 years	Young adult
11.SW	6	18.6	1497.46	18 months	Young adult
11.SW	6	18.6	1497.46	18 months	Young adult
11.SW	6	16.18	1011.69	1 year	Young adult - reproductive age
11.SW	6	19.01	1592.19	2 years	Young adult
12.NE	7	17.01	1164.58	1 year	Young adult - reproductive age
12.NE	7	15.4	880.39	1 year	Young adult - reproductive age

12.NE	7	17.97	1359.1	14 months	Young adult
12.NE	7	18.53	1481.65	18 months	Young adult
12.NE	7	15.33	869.18	1 year	Young adult - reproductive age
12.NE	7	15.92	966.61	1 year	Young adult - reproductive age
12.NE	7	17.4	1241.27	1 year	Young adult - reproductive age
12.NE	7	15.54	903.1	1 year	Young adult - reproductive age
12.NE	7	14.69	770.91	10 months	Sub adult
11.SE	7	19.21	1639.77	2 years	Young adult
11.SE	7	20.72	2028.79	≥ 3 years	Fully grown adult
11.SE	7	18.92	1571.07	18 months	Young adult
11.SE	7	20.38	1936.52	≥ 3 years	Fully grown adult
12.NE	8	17.08	1178.11	1 year	Young adult - reproductive age
12.NE	8	17.52	1265.51	1 year	Young adult - reproductive age
12.NE	8	18.47	1468.2	18 months	Young adult
11.SE	8	21.06	2123.85	≥ 3 years	Fully grown adult
11.SE	8	20.03	1844.4	≥ 3 years	Fully grown adult
11.SE	8	18.72	1524.8	18 months	Young adult
11.SE	8	19.89	1808.36	2 years	Young adult
11.SE	8	18.78	1538.58	18 months	Young adult
11.SW	8	18.45	1463.73	18 months	Young adult
11.SW	8	18.55	1486.16	18 months	Young adult
11.SW	8	18.75	1531.68	18 months	Young adult
12.NE	9	15.89	961.5	1 year	Young adult - reproductive age
12.NE	9	17.61	1283.88	14 months	Young adult

11.SE	9	17.44	1249.32	1 year	Young adult - reproductive age
11.SE	9	17	1162.66	1 year	Young adult - reproductive age
11.SW	9	19.56	1725.22	2 years	Young adult
11.SW	9	20.55	1982.31	≥ 3 years	Fully grown adult
12.NE-11SE	10 (F2.L2)	17.31	1223.3	1 year	Young adult - reproductive age
11.SE	11	18.42	1457.04	18 months	Young adult
12.NE-11.SE	11 (F2.L3)	17.84	1331.62	14 months	Young adult
12.NE-11.SE	12 (F2.L5)	17.22	1205.49	1 year	Young adult - reproductive age
12.NE-11.SE	12 (F2.L6)	20.01	1839.22	≥ 3 years	Fully grown adult
12.NE-11.SE	13 (F2.L7)	19.54	1720.26	2 years	Young adult
12.NE-11.SE	13 (F2.L15)	18.72	1524.8	18 months	Young adult
11.SW	14	17.55	1271.61	1 year	Young adult - reproductive age
11.SW	15	19.91	1813.48	2 years	Young adult
11.SW	15	20.91	2081.57	≥ 3 years	Fully grown adult

Following the mortality age estimation criteria outlined by Wilkins (2001), most hutias (86.4%, n=102) were young adults, ranging from one to <3 years in age. Of these young adults, 20.3% (n=24) had just reached reproductive age so were around one year old. No juveniles (<10 months) are represented, the youngest being three subadults between 10-12 months in age. Only 11% (n=13) were fully mature adults over three years old (**Figure 4**).

A Pearson's r correlation test with a r value of 0.01 and significance (p) value of 0.05, indicated there is no linear correlation between level and mandible size (r=-0.07, p=0.449), or level and body mass (r=-0.06, p=0.502). An ANOVA test (critical $\alpha=0.05$) determined that there was also no statistically significant difference between mean mandibular lengths (df=14, F=1.66, p=0.076), or body mass (df=14, F=1.64, p=0.081) between levels, therefore suggesting there was no diachronic changes in hutia size or mortality age within these excavation units.

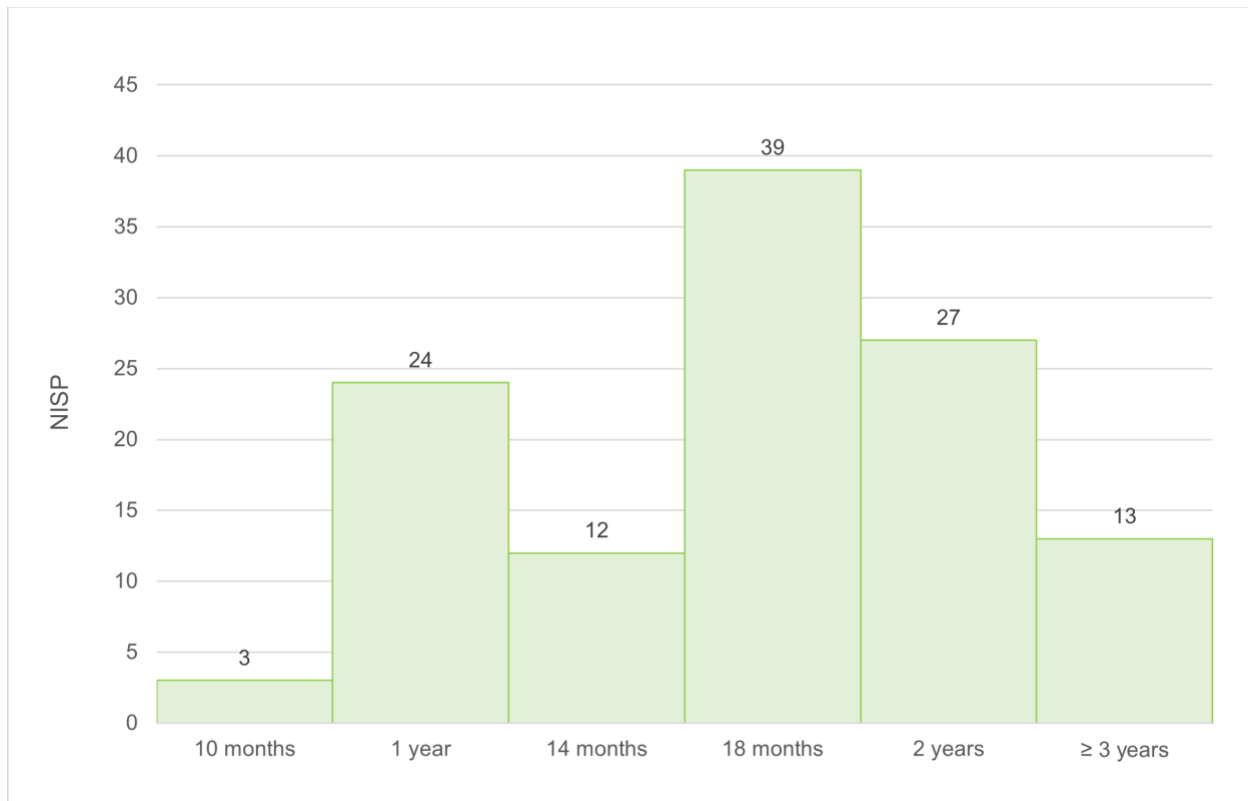


Figure 4. Mortality profile of *Geocapromys brownii* using estimated ages based on lower tooth row length (LTR) of known-aged individuals studied by Wilkins (2001). No juveniles below 10 months in age, and few completely mature individuals ≥ 3 years in age were present in the assemblage.

Results of enamel and collagen isotope analyses

Nine of the ten *G. brownii* collagen samples yielded results that adhered to recommended quality control indicators, but one sample (WM21) was outside the accepted collagen C:N range of 2.9-3.6 (Ambrose 1990). This sample also did not yield enough enamel for analysis, likely due to its degraded state of preservation, and therefore will not be discussed further. All our isotope samples were from young adults: eight were of reproductive age at around 12 months old, two were approximately 18 months, and one was 14 months old. Nine samples yielded carbon ($\delta^{13}C_{co}$) and nitrogen ($\delta^{15}N$) results from collagen, and 17 enamel samples yielded carbon ($\delta^{13}C_{en}$) and oxygen ($\delta^{18}O$) results which includes the eight time series

samples from WM5, while eight individuals yielded both collagen and enamel results for all four proxies (**Table 4**). All values from the time series sampling of incisor WM5 were averaged when comparing with other individuals. We compared our isotopic results to human enamel ($n=3$) and human collagen ($n=3$) values, as well as *G. brownii* enamel ($n=3$) values, from White Marl (Mickleburgh et al. 2019).

Most hutias were mainly subsisting off a C_3 plant-based diet; however some individuals consumed more C_4 plants than others. Approximations of % C_4 input indicate that C_4 consumption by hutias ranged from 9.8% to 50.9%, while the three analyzed humans (Mickleburgh et al. 2019) had a % C_4 range between 13.1% and 22.88% (**Table 4**).

Table 4. Isotopic results for our studied sample. Table includes estimated mortality ages of specimens, estimations of %C₄ plants that were consumed, and isotopic values of humans (n=3) and Jamaican hutia (n=3) from Mickleburgh et al. 2019.

Specimen	Species	Element	Unit	Layer	δ ¹³ C _{col} (‰ vs VPDB)	δ ¹⁵ N (‰ vs N _{air})	δ ¹⁸ O (‰ vs VPDB)	δ ¹³ C _{en} (‰ vs VPDB)	Δ ¹³ C _{col-en}	% C ₄ ¹	LTRL (mm)	Age Class (Wilkins 2001)	Age (Wilkins 2001)
WM1	<i>Geocapromys brownii</i>	mandible	U2.12NE	2	-21.15	8.93	-6.1	-13.42	7.73	11.75%	17.62	Young adult	14 months
WM2	<i>Geocapromys brownii</i>	mandible	U2.12NE	2	-14.23	11.61	-2.5	-7.49	6.74	48.81%	15.75	Young adult - reproductive age	1 year
WM3	<i>Geocapromys brownii</i>	mandible	U2.12NE	3	-21.43	8.22	-2.77	-11	10.43	26.88%	18.07	Young adult	18 months
WM8	<i>Geocapromys brownii</i>	incisor	U2.12NE	6			-3.68	-13.02		14.25%	16.61	Young adult - reproductive age	1 year
WM4	<i>Geocapromys brownii</i>	radius	U2.12NE	4	-16.06	7.83					17.49	Young adult - reproductive age	1 year
WM16	<i>Geocapromys brownii</i>	mandible	U2.12NE	7	-20.84	7.76	-2.32	-12.49	8.35	17.56%	18.12	Young adult	18 months
WM17	<i>Geocapromys brownii</i>	mandible	U2.12NE	8	-18.92	6.59	-4.99	-11.88	7.04	21.38%	17.01	Young adult - reproductive age	1 year
WM18	<i>Geocapromys brownii</i>	mandible	U2.12NE	9	-18.6	7.85	-2.49	-10.67	7.93	28.94%	16.12	Young adult - reproductive age	1 year
WM15	<i>Geocapromys brownii</i>	mandible	U2.12NE	7	-22.49	9.38	-4.52	-13.74	8.75	9.75%	16.38	Young adult - reproductive age	1 year
WM20	<i>Geocapromys brownii</i>	mandible	U2.12NE	10	-19.54	8.3	-4.84	-11.6	7.94	23.13%	16.86	Young adult - reproductive age	1 year
WM5 averaged	<i>Geocapromys brownii</i>	incisor	U2.12NE	5			-4.53	-8.14		44.76%	17.29	Young adult - reproductive age	1 year
WMS-1 - crown							-3.84	-8.76		40.88%			
WMS-2							-4.37	-8.21		44.31%			
WMS-3							-4.32	-7.44		49.13%			
WMS-4							-4.69	-7.59		48.19%			
WMS-5							-4.17	-7.83		46.69%			
WMS-6							-5.57	-8.15		44.69%			
WMS-7							-4.89	-8.02		45.50%			
WMS-8 - root end							-4.38	-9.11		38.69%			
Coney incisor enamel 1 ²	<i>Geocapromys brownii</i>	tooth enamel						-7.16		50.88%			
Coney incisor enamel 2 ²	<i>Geocapromys brownii</i>	tooth enamel						-12.76		15.88%			
Coney incisor enamel 3 ²	<i>Geocapromys brownii</i>	tooth enamel						-10.84		27.88%			
Human tooth 4.1 ²	<i>Homo sapiens</i>	tooth			-17.2	13							
Human tooth enamel 1.5 ²	<i>Homo sapiens</i>	tooth enamel						-11.81		21.81%			
Human tooth 1.3 ²	<i>Homo sapiens</i>	tooth			-14.1	12.4							
Human tooth enamel 3.5 ²	<i>Homo sapiens</i>	tooth enamel						-11.64		22.88%			
Human long bone (tibia) ²	<i>Homo sapiens</i>	tibia			-19.4	8.6							
Human tooth 3.4 ²	<i>Homo sapiens</i>	tooth enamel						-13.21		13.06%			

¹ %C₄ calculations adapted from LeFebvre et al. 2019 and Somerville et al. 2013

² Sample data taken from Mickleburgh et al. 2019.

Comparisons between hutia and human diets

There is a considerable overlap in enamel carbon values between humans and Jamaican hutias (**Figure 5**). The mean δ¹³C_{en} value for *G. brownii* (n=13) is -11.09‰ (Mdn=-11.6‰, s.d.=2.13) with a range of -13.74 to -7.16‰, which is comparable to the White Marl human (n=3) mean value of -12.22‰ (Mdn=-11.81‰, s.d.=0.70) and range of -13.21‰ to -11.64‰. An unpaired *t*-test indicates that there is no

statistically significant difference between the δ¹³C_{en} value means of humans and hutia (t=0.8453, df=14, SED=1.333, p=0.4121). In total, seven hutia samples exceeded the maximum δ¹³C_{en} values of humans, indicating that just over half of the analyzed hutias were likely consuming more C₄ plant foods than the three buried humans that were sampled in the study by Mickleburgh et al. (2019).

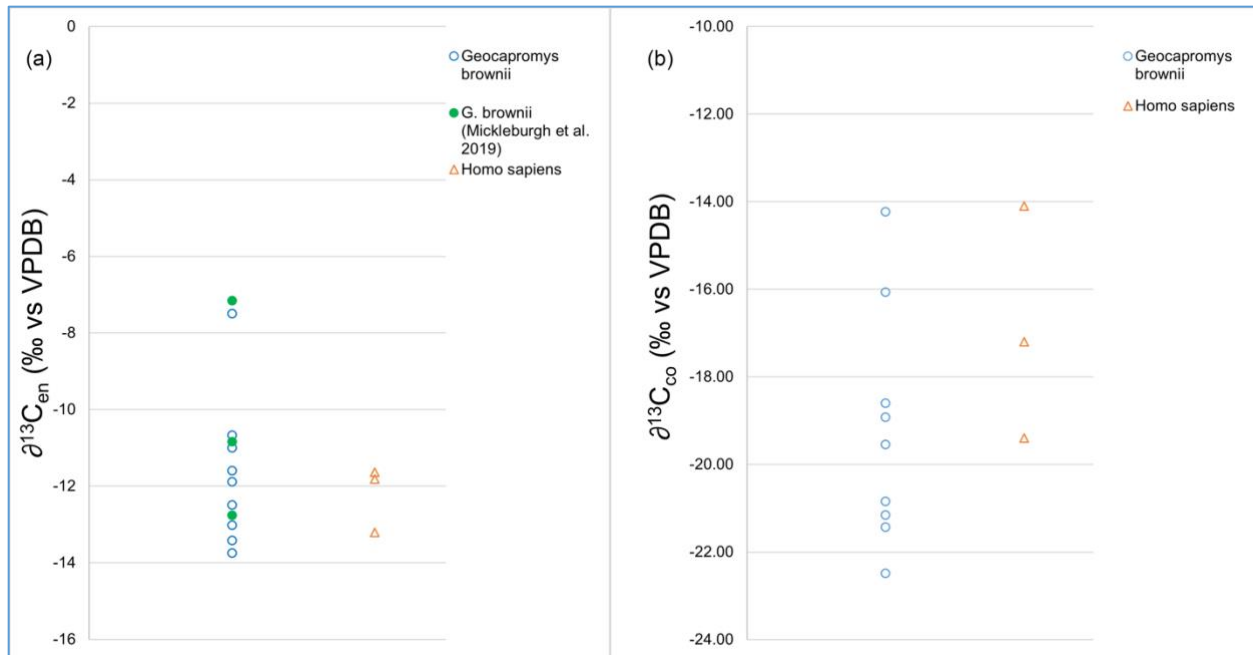


Figure 5. (a) $\delta^{13}C_{en}$ values of *Geocapromys brownii* and *Homo sapiens* from White Marl. Just over half of hutia samples exceed the human range of values. Three *G. brownii* values and all *H. sapiens* values are from Mickleburgh et al. (2019); (b) *G. brownii* $\delta^{13}C_{co}$ values from this study compared to *H. sapiens* from Mickleburgh et al. (2019).

The collagen results dictate some differences between humans and hutias, particularly in nitrogen values. The mean $\delta^{13}C_{co}$ for *G. brownii* (n=6) was -19.25‰ (Mdn=-19.54‰, s.d.=2.52) with values ranging between -22.49‰ to -14.23‰, whereas humans (n=3) had a mean value of -16.9‰ (Mdn= -17.2‰, s.d.=2.17) and ranged between -19.4‰ to -14.10‰. Interestingly, the second highest $\delta^{13}C_{co}$ value of any hutia was from the hutia radius that exhibited a pathology (**Figure 3a**). An unpaired *t*-test confirmed there was little significant difference between the mean $\delta^{13}C_{co}$ values of humans and hutia ($t=1.3183$, $df=10$, $p=0.2168$). Differences between species are more apparent in their nitrogen values. Hutias (n=9) had a mean $\delta^{15}N$ value of 8.5‰ (Mdn=8.22, s.d.=1.33) and had a larger range of between 6.59‰ to 11.61‰, compared to the mean human (n=3) value of 11.33‰ (Mdn=12.4‰, s.d.=1.95) with values ranging between 8.6‰ to 13‰. An unpaired *t*-test confirmed a significant difference in the mean $\delta^{15}N$ values between species ($t=2.5798$, $df=10$, $p=0.0274$).

Time series sampling of one Geocapromys brownii incisor

Time series sampling of one *G. brownii* incisor suggests that there may have been some change in dietary intake over time (**Figure 6**). Unfortunately, establishing the enamel growth period of this incisor was not possible as the incisor growth rates of *G. brownii* are unknown, and rodent tooth wear is dictated by the coarseness of foods consumed and gnawing activities which may be environmentally or species specific. However, it is estimated that rat incisors grow at a rate of 0.4-0.6 mm per day (Park et al. 2017), while for guinea pigs (*Cavia porcellus*) this is 0.3 mm per day (Müller et al. 2015). If the more related caviomorph rodent species from the Americas, guinea pig, is to be used as a proxy, our incremental time series sampling may represent around 70 days of growth.

Our data shows that carbon values roughly increase from the crown towards the middle of the tooth and decrease again closer to the root of the incisor. The obverse pattern is seen

somewhat with oxygen ($\delta^{18}\text{O}$), and a Spearman's correlation test suggesting some weak negative

correlation between the two isotopic proxies ($r_s = -0.215$, Sig. 2-tailed = 0.609).

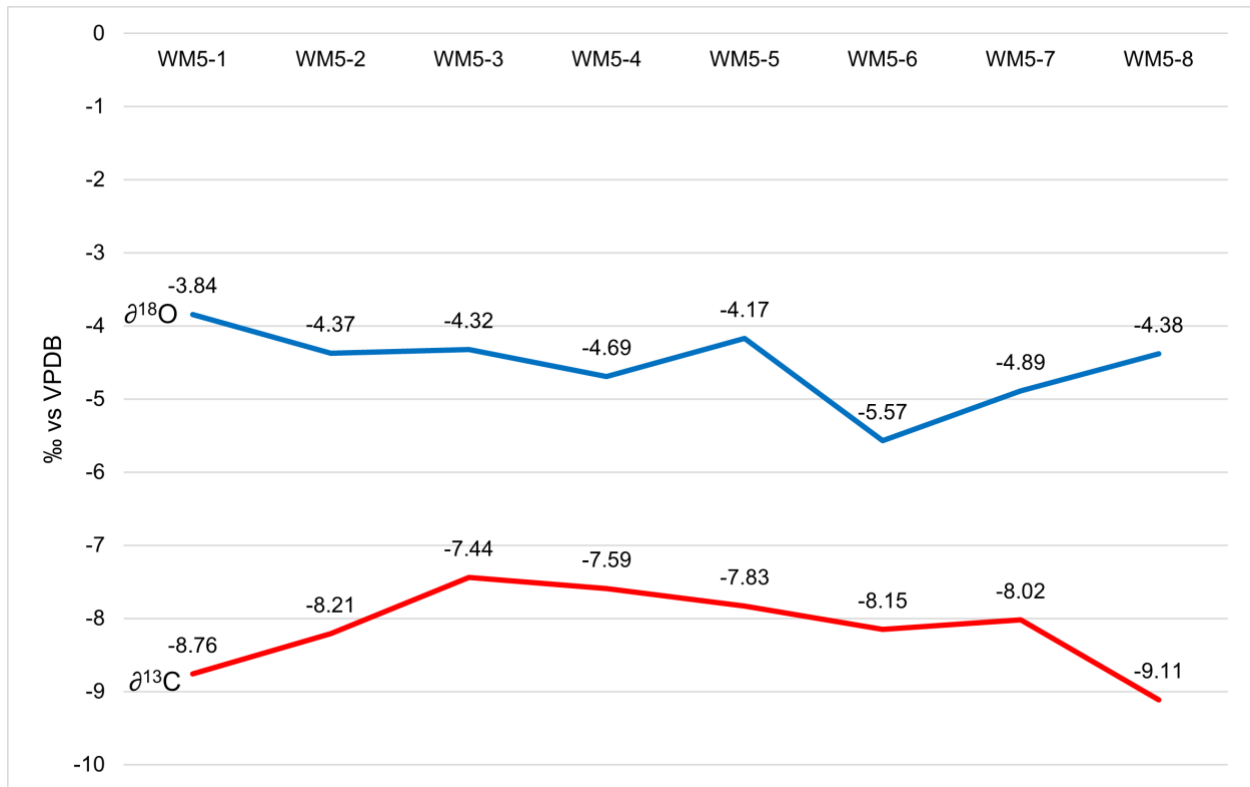


Figure 6. Isotopic values from time series sampling of a *Geocapromys brownii* incisor (WM5). Each sample was taken 3mm apart, beginning at the oldest part of the tooth, the crown (WM5-1), and terminating at the more recently developed enamel casing near the root (WM5-8). Blue represents oxygen ($\delta^{18}\text{O}$ ‰), and red represents carbon ($\delta^{13}\text{C}$ ‰) isotope ratio values.

Oxygen values represent seasonal variation precipitation with lower $\delta^{18}\text{O}$ values representing periods of higher rainfall in tropical regions that consistently have temperatures over 20°C (Dansgaard 1964; Pederzani and Britton 2019; Rozanski et al. 1993). However, as Jamaican hutia is a non-obligate drinker that obtains most of its water from foods (Eisenberg and Woods 2012), this time series likely more indicates dietary seasonality than it does directly indicate changes in rainfall. This is due to food sources, rather than water, playing a larger role in determining non-obligate drinker's oxygen isotope values (Pederzani and Britton 2019). The fluctuations in carbon values likely represent differential consumption of C₄ plants, or

alternatively may reflect changing consumption of C₃ plants from different locations that are variably subject to the “canopy effect” in which the $\delta^{13}\text{C}$ values of plants closer to forest floors tend to be lower than those existing higher up within or outside of canopy coverage (van der Merwe and Medina 1991). Our results are inconclusive, but perhaps do hint at some seasonal changes in diets, although this is difficult to ascertain given the relatively short period captured within these continually renewing rodent incisors.

Discussion

Trends in animal exploitation

A diachronic trend is seen in which there is an increased preference for littoral marine resources and terrestrial sources of protein, with an intensifying reliance on hutias over all other animals between the timeframe covered within these deposits of approximately cal. AD 1284 – 1439 (**Figure 7**). Changes in the environments targeted by the inhabitants of White Marl are observable, as evidenced by a notable absence of

estuarine fish in the unit's upper two levels dating from cal. AD 1399 onwards, along with a decreasing number of pelagic fish. This contrasts to an increase in the consumption of reef and inshore fish. This may suggest a heightened dependence on local resources, particularly inshore fish and hutias which may relate to an increasing degree of sedentism; however there was likely a decrease in use of estuarine resources which are also located relatively close to the site.

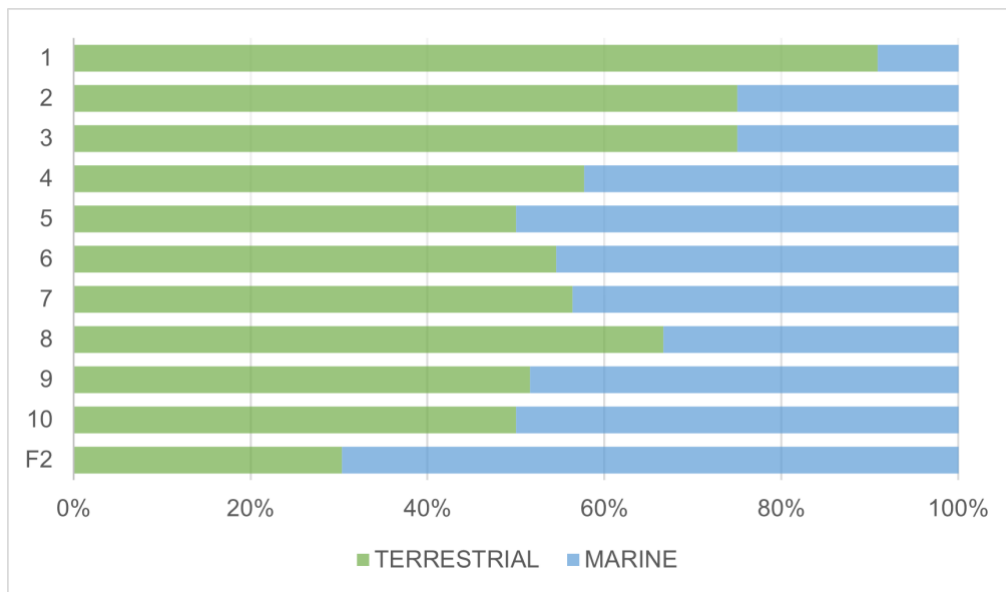


Figure 7. Trends in the percentage of terrestrial versus marine resources (based on MNI) within the 10cm excavation levels of U2.12.NE. There is a greater reliance of marine resources (blue bars) in older occupational levels with a gradual increase in terrestrial faunal remains (green bars), with the Jamaican hutia being the primary terrestrial animal targeted. F2, the burial fill, encompasses mixed sediments of an approximate depth of 24cm.

“Our described findings provide a glimpse into the environments Indigenous peoples utilized and the diets that sustained daily life at White Marl for approximately 150 years. It is likely that a wide range of marine environments were exploited, however most of these were available within 5-10 km of the site. Reef fish, particularly Lutjanidae, dominate the assemblage, whereas there is a significant component of fish sourced from estuarine or mangrove areas up until the most recent deposits in levels 1 and 2 dating from after at least cal. AD 1399. These findings contrast to Wing’s (1972) study that suggested

that estuarine environments were the most targeted, however this difference may be associated with disparities in sample size the likely shorter time period analyzed which date to a late period of White Marl’s occupation. Compared to the marine component, there is a distinct lack in taxonomic diversity observable in the terrestrial component of the assemblage, with Jamaican hutia clearly dominating. Our results suggest localized food acquisition strategies for the inhabitants of White Marl, with a clear reliance on hutias as the dominant source of meat.”

Evidence of close human hutia relationships

Our mortality age calculations, evidence of dietary similarities between humans and hutias as determined from isotopic analyses, and observations of bone pathologies in some hutia remains are all suggestive of close interactions between humans and hutias. These form several strong lines of evidence suggesting that there was some degree of management of Jamaican hutias, although we cannot confirm whether hutias were being managed in captivity from our data.

Our isotopic analyses of *G. brownii* tooth enamel and bone collagen reveals dietary linkages between humans and hutias. It is likely that hutias were consuming C₄ plants in proportions that were similar to or exceeded that of humans. Over half our studied hutia population had higher $\delta^{13}\text{C}_{\text{en}}$ values than humans according to our isotopic analysis of *G. brownii* tooth enamel, with only two hutias demonstrating values below that of humans. Analysis of nitrogen values from *G. brownii* however suggest greater differences in diets, with nitrogen being significantly lower on average in hutias compared to humans. As bone collagen isotope values are dictated by approximately 75% protein consumption (Ambrose and Norr 1993; Schwarcz 2002), and considering the herbivorous dietary behavior of *Geocapromys brownii*, these differences can be accounted for by the higher trophic positioning and consumption of meat by humans

We cannot discount the possibility that hutias were eating natural C₄ plant sources, however the %C₄ consumption within our samples exceeds that expected from normal dietary behavior. Observational feeding studies conducted on modern *G. brownii* have noted that they will consume some wild C₄ grasses such as *Pharus glaber* and *Panicum maximum*, and frequently scavenge non-native domesticated sugar cane (*Saccharum officinarum*) which only arrived in the region after the European invasion. These C₄ plants formed 5.2% of the plants eaten by observed modern *G. brownii* (Borroto-Páez and Woods 2012; Eisenberg and Woods 2012), however that also includes colonially introduced sugarcane. Unfortunately, there is little information available regarding the habitual consumption of other native Jamaican C₄ plants by hutias, nor are there comprehensive

compendiums detailing native Jamaican C₄ plants. Notwithstanding these limitations, according to our %C₄ estimates some hutias had diets consisting of close to 50% C₄ plants, which is far beyond what was recorded in observational studies. It is feasible that the raised carbon values in tooth enamel are the result of either the habitual scavenging of maize crops, or their diets being purposefully supplemented with agricultural maize, for which starch grain have previously been recovered from human dental calculus at White Marl (Mickleburgh et al. 2019).

Evidence of hutia management

Of the 188 *G. brownii* mandibles which were measured, the majority of these (n=102) were determined to have come from young adults between one to less than three years of age. No juveniles were identified from our sample population, and only 13 hutias were fully grown. This mortality profile is not a “catastrophic”, or a “living structure” profile, which may represent non-selective hunting strategies, such as trapping (Lyman 1987; Stiner 1990). Archaeological hutias from the site of Bellevue show a catastrophic mortality profile, reminiscent of non-selective hunting practices of modern Jamaican hunters which do not target particular age groups of hutias (Wilkins 2001). Nor does our assemblage have an “attritional” profile that may result from hunting techniques that are unsuited to capturing prime age individuals, or the scavenging of dead animals (Klein 1982; Stiner 1990). The abundance of young adults within our assemblage suggests that prime age hutias were being targeted by the inhabitants of White Marl.

Based on our evidence there are several non-mutually exclusive theories regarding the possible management of hutias at White Marl:

- A strong bias towards prime aged adults may suggest that people used selective hunting techniques that specifically targeted individuals that yielded the most meat (Carlson and Steadman 2009; Steele 2003). This scenario does not explain the relatively raised carbon values in some hutias, although an unexpectedly strong reliance on wild C₄ plant foods such as grasses cannot be completely overlooked as a possibility.

- A mortality profile consisting of mostly prime-aged adults may indicate that hutia populations were being managed and culled upon reaching an optimal size, which may have occurred in captivity (Wilkins 2001). In support of this scenario, the two hutia bones exhibiting pathologies may indicate that these animals were being fed by humans to survive, although natural healing cannot be discounted (Bendrey 2014; Udrescu and Van Neer 2005). Additionally, our isotopic data suggests that some individual hutias shared dietary linkages with the three human samples from White Marl, with values exceeding humans in terms of C₄ plant consumption and well beyond what would be expected of their dietary behavior according to observational feeding studies. It may be that some hutias had human-influenced diets involving C₄ maize. Of note, the second highest $\delta^{13}\text{C}_{\text{co}}$ value (-16.1‰) within our study came from the *G. brownii* radius that exhibited a pathology (**Figure 3a**).
- Another similar scenario does not involve the keeping of hutias in captivity. It is possible that humans were intentionally supplementing hutia diets with cultivated C₄ plants, therefore attracting hutias close to human settlements. With sufficiently tame hutias, those of optimal size may have easily been captured.
- An alternative scenario is that hutias were either habitually scavenging from garden plots that contained C₄ plants and humans were trapping animals that were consuming their crops, therefore providing the dual benefit of pest elimination and also providing a reliable source of meat, a practice known as “garden hunting” (Linares 1976). However, this last scenario does not explain the mortality profile, as theoretically a wider range of age classes should be represented if humans were opportunistically capturing any hutia they found raiding their crops.

It is possible that any of these scenarios were at play here, however in restating our three lines of evidence: our mortality profile consisting primarily of young adults, our isotope data showing relatively raised carbon values possibly indicative of unnatural C₄ consumption, and the two examples of healed bone pathologies which may indicate these animals were tended to, it is likely that scenarios that entail humans supplementing hutia diets are the most parsimonious. Whether this occurred in captivity, or represents non-captive commensalism, is not answerable without archaeological evidence of enclosures or other material culture that would indicate as such. In our opinion, our evidence suggests that hutias were being managed at White Marl but how this exactly occurred is unclear.

Conclusions

Our findings suggest that particularly Jamaican hutia formed the mainstay of animal meat consumption for the inhabitants of White Marl, while marine resources were also a significant dietary component as they are elsewhere in the Caribbean. Several marine biomes that were targeted included locally reachable reefs, estuarine and inshore environments, with few examples of pelagic species found within the assemblage. It is however evident that the reliance on marine resources diminishes over time, possibly reflecting increasingly localized subsistence strategies with greater importance placed on hutias as a food source. We have provided strong evidence of some form of management of this species occurring at White Marl, however, to suggest whether this was part of a process of incipient domestication is not answerable from our data. Rather than being held in captivity, for which there is currently no material evidence, it may have been that they were scavenging and consuming maize relatively unhindered and in great enough quantities to have had a strong influence on their isotopic values, or more likely, that humans were supplementing the diets of relatively tame hutias with C₄ plants, most probably maize.

This study provided further insight into the modes of faunal exploitation previously outlined by Elizabeth Wing from material excavated as part of the Robert R. Howard

excavation (Wing 1972), however further work on the faunal material from White Marl is needed. Incorporating other excavated units from recent investigations would increase the sample size and allow us to make more succinct evaluations of Indigenous subsistence strategies. Ideally, all marine invertebrates need to be identified and included in this analysis to provide greater clarity as to the types of aquatic biomes that were targeted. Our time series sampling of one hutia incisor has demonstrated some feasibility for reconstructing seasonality in hutia diets, although the tooth growth period recorded within rodent incisors is short. Analyzing other specimens

concurrently may allow us to assess whether time series sampling of hutia incisors can indicate mortality seasons and possibly serve as a paleoenvironmental proxy. Additionally, starch grain analysis of hutia tooth calculus may be able to provide direct evidence of whether maize was being ubiquitously consumed by hutias, as the isotopic data may suggest. The study of White Marl is ongoing, but more transdisciplinary work is needed so that a more holistic overview of the form and function of human-environmental interactions that took place before the European invasion of Jamaica can be achieved.

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