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Indigenous animal management practices on the eve of Columbus' landfall: Isotopic and zooarchaeological investigations in the Dominican Republic and Jamaica

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Citation
Shev, G. T. (2022, December 6). *Indigenous animal management practices on the eve of Columbus' landfall: Isotopic and zooarchaeological investigations in the Dominican Republic and Jamaica*. Retrieved from https://hdl.handle.net/1887/3494380

Version:	Publisher's Version
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Note: To cite this publication please use the final published version (if applicable).

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INTRODUCTION

To demystify our understanding of human interactions with animals during the precolumbian era of the Caribbean, our main lines of evidence derive from the study of animal skeletal remains from archaeological sites. Unfortunately, we have only limited 16th century ethnohistorical records of Indigenous lifeways that provide some vague understanding of human-environmental management practices, albeit from a late-medieval European perspective. Beyond this, we can analyze stylistic depictions of animals in petroglyphs, cave paintings, sculpted idols, lapidary works, and decorative additions to ceramic vessels known as ***adornos*** to better understand animal symbolism (Fernández Ortega et al., 2011; Oudhuis, 2008; Paulsen, 2019; Waldron, 2010; Wauben, 2018). This dissertation primarily examines the biological remains of animals as found in archaeological sites in the region, with a particular focus on assessing whether Indigenous peoples were managing some native species prior to the European invasions of post-AD 1492. The aim of this dissertation is to further elaborate on how Indigenous people were interacting with animals that do not fit succinctly into categorial preconceptions of 'wild' or 'domestic'. To do this, zooarchaeological methods as well as stable isotope ratio analysis of animal skeletal remains have been employed, providing five methodologically, conceptually, and geographically related studies that were submitted to peer-reviewed academic journals.

Archaeological research of the period preceding the arrival of Europeans in the Caribbean alludes to food production strategies in which Indigenous peoples were cultivating an extensive suite of domesticated plants. This is particularly the case during the Ceramic Age (500 BC – AD 1500) which is characterized by the flourishing of sedentary, horticultural societies (Newsom & Wing 2004; Pagán Jiménez et al. 2005; Pagán-Jiménez et al. 2015; Pagán-Jiménez et al. 2020). Nonetheless, these same cultures evidently had limited interactions with domesticated animals, with only two domestic species having been recovered from precolumbian contexts, the dog (***Canis familiaris***) and the guinea pig (***Cavia porcellus***), both of which were introduced from the mainland Americas into the Caribbean archipelagos during the Ceramic Age. The former is ubiquitously recovered from many sites throughout the region and is notably commonly found within burials often alongside humans (Grouard et al., 2013), while the latter, although widespread, is found less frequently and is theorized to have been a rare animal commodity primarily used to reinforce social identities and foster regional exchange (LeFebvre & deFrance, 2014). Because of these limited observations, Indigenous peoples in the Caribbean have often been labelled as 'hunter-fishers' and horticulturalists that generally did not manage animals, which stands in stark contrast to the common cultivation of a myriad of domestic plant species.

Yet Indigenous human-animal relations in the insular Caribbean were likely more complex than the label 'hunter-fisher' would imply. There are certain animals that researchers have long theorized that, although they may not have been domesticated, may have been managed by Indigenous peoples. In the Greater Antilles, populated by Indigenous cultures often labelled as 'Taíno' in the literature (S. Fitzpatrick, 2015; Keegan & Hofman, 2017; Rouse, 1992), a wide radiation of caviomorph rodents known collectively as hutias (Family: Echimyidae, Subfamily: Capromyinae) are the primary candidates for having been managed (Figure 1). Propounded theories of management or 'semi-domestication' of hutias are mainly inferred from the ubiquity of hutia remains in archaeological sites, and evidence for the translocation of some hutia species between islands (Díaz-Franco & Jiménez Vázquez, 2008; Giovas, 2019; Newsom

& Wing, 2004; Oswald et al., 2020; Wing, 2008, 2012), as well as some limited morphological evidence (Carlson, 2012; Carlson & Steadman, 2009; DuChemin, 2013; LeFebvre, DuChemin, et al., 2019).

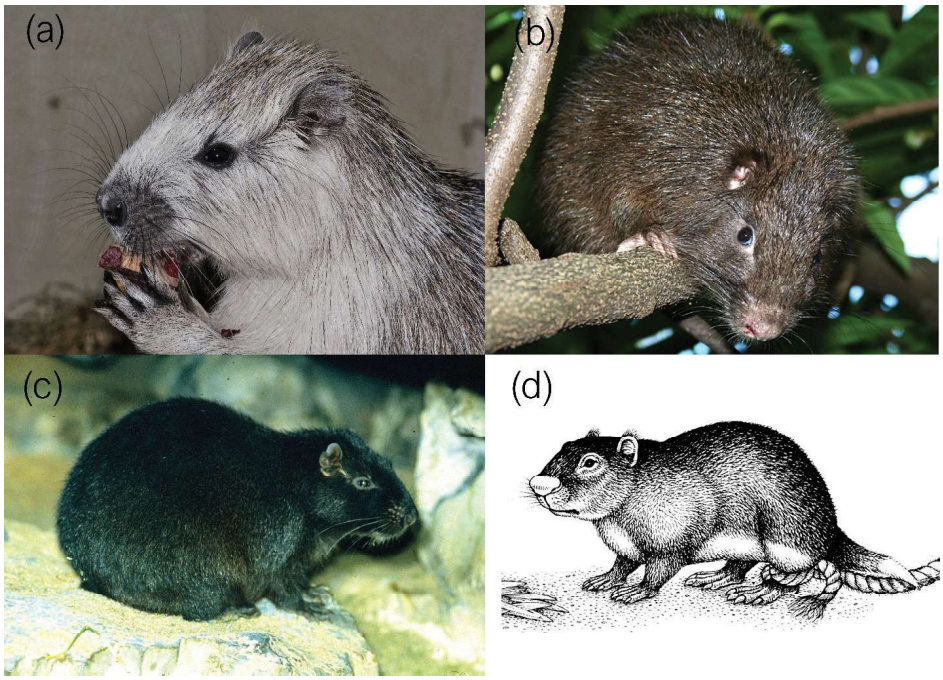

Figure 1: Examples of extant hutia species: (a) Cuban or Demarest's hutia (***Capromys pilorides***), image by Quartl, Wikimedia commons CC 3.0; (b) Hispaniolan hutia (***Plagiodontia aedium***), image from Turvey (et al., 2015); (c) Jamaican hutia (***Geocapromys brownii***), image by Klaus Rudloff, http://www.biolib.cz; and (d), artistic depiction of ***Isolobodon portoricensis*** with a rope around its leg, image from Flemming & MacPhee (1999).

Within Hispaniola, Puerto Rico and the Virgin Islands, the now extinct ***Isolobodon portoricensis***, is found abundantly within archaeological assemblages and was likely spread to the latter islands outside its original range in Hispaniola by humans (Newsom & Wing, 2004; Wing, 2008, 2012). In Cuba, several studies have suggested the husbandry of ***Capromys pilorides***, and some other hutia species based on their high abundance particularly at inland situated sites (Castellanos & Pino, 1988; Díaz-Franco, 2004). In Jamaica, ***Geocapromys brownii***, has also been suggested as having been managed based on its ubiquity at archaeological sites and estimated mortality profiles that are disparate from what would be expected based on traditional hunting practices (Allsworth-Jones, 2008; Carlson, 2012; Wilkins, 2001; Wing, 1972) with some evidence suggesting their limited translocation to Cuba (Díaz-Franco & Jiménez Vázquez, 2008). While in the Bahamas, ***Geocapromys ingrahami*** likely shared some degree of commensality with humans and was purposefully seeded to new island environs (LeFebvre, deFrance, et al., 2019; LeFebvre, DuChemin, et al., 2019; Oswald et al., 2020).

Hutias serve as a likely candidate for management by Indigenous peoples, however there is only limited historic mention to support these assumptions put forth by archaeologists. The 16th century Spanish chronicler, Bartolomé de las Casas, provides a brief secondhand witness account of the existence of corrals built by Indigenous peoples in the region of Vega Real, northern Hispaniola for the housing of hutias (Las Casas, 1875, p. 73; Lovén, 2010). This solitary mention of the captivity of hutias is the only appearance in the literature of such a practice, however this lack of documentation might be symptomatic of the rapidness of cultural change, and the devastation of Indigenous lifeways and environmental practices that occurred shortly after the arrival of the Spanish (Deagan, 1988; Pons, 1992). Unfortunately, detrimental preservation conditions in the tropics may also mean that any physical remains of cultural materials associated with the captive management of animals, such as corrals or cages, likely has long ago perished, or has not been accurately identified archaeologically. This leaves a notable blind spot in our capacity to determine whether the husbandry of hutias was occurring.

Most of our understanding of 'Taino' culture comes from archaeological investigation. Only limited ethnohistoric accounts exist from late 15th and early 16th century European chroniclers, most notably from Columbus himself, Las Casas, Gonzalo Fernández de Oviedo y Valdez, Peter Martyr d'Anghiera, Girolamo Benzoni, and Fray Ramón Pané (Allen, 2010; Fernández de Oviedo, 2007; Pané, 1999; Roth, 1887). Of these, only Pané, a Franciscan monk, spent time within a 'Taino' settlement, recording their cosmological practices and religious beliefs but little regarding the quotidian aspects of their society including their environmental management practices (Pané 1999). We can nevertheless garner some general understanding of the foodways of the Indigenous inhabitants of Hispaniola from the limited historical records we have at our disposal. Diego Alvarez Chanca, a Spanish crown-appointed physician who was present during Columbus' second expedition in AD 1493, accounts that the peoples of Hispaniola ate small indigenous rodents native to the island which were about the size of rabbits [hutias], a variety of insects, many kinds of birds, snakes, and small numbers of crocodilian-like lizards called Iuannas [iguanas] which they considered a delicacy (Columbus & Alvarez Chanca, 1870, p. 68; Roth, 1887, ***parentheses my own***).

In the absence of material evidence that would denote the management or captivity of animals, biochemical analyses of animal remains can provide empirical evidence of certain forms of human-animal interactions. Examining the dietary isotope values of animal remains can indicate human influence over animal diets, therefore providing empirical evidence of an important aspect of animal management practices. By analyzing the nitrogen ($\delta^{15}N$) and carbon isotope values of bone collagen ($\delta^{13}C_{co}$) and apatite or dental enamel ($\delta^{13}C_{ap}$) of animal remains recovered from archaeological contexts, evidence of human influence on the diets of 'wild' and 'domestic' animals in the Americas can be determined (Laffoon et al., 2019; LeFebvre, deFrance, et al., 2019; Sugiyama et al., 2015, 2020).

Proof of close human-animal interactions is predicated on the fact that in much of the Americas domesticated maize (***Zea mays***) was a dietary staple. Maize, which is not self-propagating, is a plant with a C_4 photosynthetic metabolic pathway that raises carbon isotope values within the tissues of animals that consume it in great enough quantities (Lee-Thorp et al., 1989). Raised carbon values in animal bones and tooth enamel may indicate their consumption of maize, and may suggest a closeness in human-animal interactions that might be the result of habitual scavenging from human produce or refuse, or from

the purposeful supplementing of animal diets by humans (Guiry et al., 2021; Guiry, 2012; LeFebvre, deFrance, et al., 2019; Makarewicz & Tuross, 2012; Sugiyama et al., 2015, 2020).

Similar to the application of these methods in this dissertation, Sugiyama and colleagues (2020) applied zooarchaeological and isotopic studies to investigate mutualistic relationships between indigenous peoples and animals at Parita Bay, Panama. They analysed 146 carbonate (enamel) and 114 bone collagen samples from 12 different species, including both wild and domestic Muscovy duck (***Cairinia moschata***), deer, dogs, big cats, parrots, and waterfowl. Animal remains were analysed from the sites of Cerro Mangote (5900-3020 cal BC), Playa don Bernardo (4200-3600 cal BC), Sitio Sierra (200 cal BC – cal AD 1521), Cerro Juan Díaz (200 cal BC – cal AD 1600) and Isla Coiba (modern AD 2010) (Cooke et al., 2013; Smith-Guzmán & Cooke, 2019; Sugiyama et al., 2020). Their results indicated that across sites some white-tailed deer (***Odocoileus virginianus***), and most waterfowl and parrots had persistently elevated $\delta^{13}C_{en}$ values beyond that accountable by garden browsing alone, suggesting that substantial purposeful feeding was occurring. At Sitio Sierra in particularly, white-tailed deer had consistently elevated $\delta^{13}C_{en}$ values, with the authors suggesting that this reflects a mixed dietary regime involving both garden browsing and purposeful feeding of what was likely maize to these animals by the inhabitants of the settlement (Sugiyama et al., 2020).

Another study by Guiry and colleagues (2021) looks at the dietary isotope values of fauna recovered from Late Woodland sites (~AD 900 – 1650) in southern Ontario, which is a region also known for maize cultivation in the past. They studied the isotopic values of 23 taxa from 39 sites, with results indicating that some animals had access to maize, in particularly smaller mammals such as voles, mice, rabbits/hares and squirrels. These results suggest that maize plots were habitually scavenged by these animals and indicates that garden hunting involving the hunting and trapping of animals within maize fields was widely and consistently practiced over time by Indigenous peoples. The authors make note that detecting garden hunting via isotopic analysis of animal remains is likely more successful when these methods are applied to small-scale societies that are reliant on C_4 crops such as maize, millet or sugarcane (Guiry et al., 2021).

The feasibility of applying isotopic methods for the pre-1492 Caribbean is predicated on paleoethnobotanical evidence that indicates the ubiquitous consumption of maize throughout the region (Figueredo 2015; Mickleburgh & Pagán-Jimenez 2012; Pagán-Jiménez et al. 2015; 2020; Pagán-Jiménez & Mickleburgh 2022), although it was likely not the main staple crop and formed part of a broad spectrum diet (Laffoon et al. 2019; Pagán-Jiménez & Mickleburgh 2022; Pestle 2010). There is notably also historical mention of the use of maize in the Caribbean. Benzoni notes that 'Taino' people s commonly made bread from maize by soaking a quantity of grains overnight, and then grinding it using a metate and an instrument resembling a rolling pin. Maize was also used to make an intoxicating drink using methods likened to the brewing of ***chicha*** in the Andes (Benzoni, 1857, p. 68; Roth, 1887). Although it was likely not the mainstay of plant consumption in the Caribbean, there is currently no strong evidence of the cultivation and consumption of other domestic C_4 plants in the region. Like in contexts from the mainland Americas, elevated carbon values in animal skeletal remains found in association with humans may therefore indicate human influence over animal dietary regimes.

1.1 Research questions and approaches

This dissertation seeks to examine modes of animal management practices in the Caribbean with focused case studies from Late Ceramic Age (AD 500 – AD 1500) sites from the Dominican Republic and Jamaica. I hereby posit the research questions:

Were Indigenous peoples in the insular Caribbean managing native animals prior to the European invasion?

> *What does the zooarchaeology and isotopic data suggest about the relationships between Indigenous peoples and the domestic species present in the precolumbian Caribbean*
>
> *What evidence exists for close interactions between humans and endemic 'wild' species, such as hutias, that are theorized to have been managed?*
>
> *What does the zooarchaeological data from Indigenous archaeological sites suggest about the management of native animals and the general environmental management practices in the region?*
>
> *How can zooarchaeological and isotopic analyses be used in conjunction to assess human-animal interactions in the Caribbean?*
>
> *What insights are gained in relating the findings from zooarchaeological and isotopic investigations of fauna recovered from Caribbean archaeological sites to other palaeoenvironmental data gathered from the region?*

To answer these questions, I have utilized zooarchaeological methods and employed isotopic analyses of animal remains recovered from archaeological sites in the Dominican Republic and Jamaica (Figure 1). Moreover, to assess the composition of faunal assemblages from archaeological sites and how Indigenous animal management practices related to wider human impacts on the environment, I have relied upon niche construction theory (NCT) as an interpretive framework. This dissertation analyses dietary and mobility similarities between humans and dogs, the most ubiquitous domestic animal found in pre-Columbian contexts, but the principal focus is on assessing human interactions with hutias, and importantly to place these interactions within the wider schema of human-environmental management practices. Dietary isotope studies of hutias and other endemic species provides insight into the potential dietary linkages between Indigenous peoples and some animals. A zooarchaeological study of archaeological deposits from the site of El Flaco in the northern Dominican Republic, which has high proportions of hutia remains, serves to assess human impacts on surrounding biomes, establish Indigenous foodways and exchange networks, but also speculates as to the effects humans had on the surrounding landscape and how this might be reflected in the human-hutia interactions. Similarly, a zooarchaeological and isotopic study of fauna from White Marl, Jamaica, serves to establish whether the management of different species of hutias was occurring on that island.

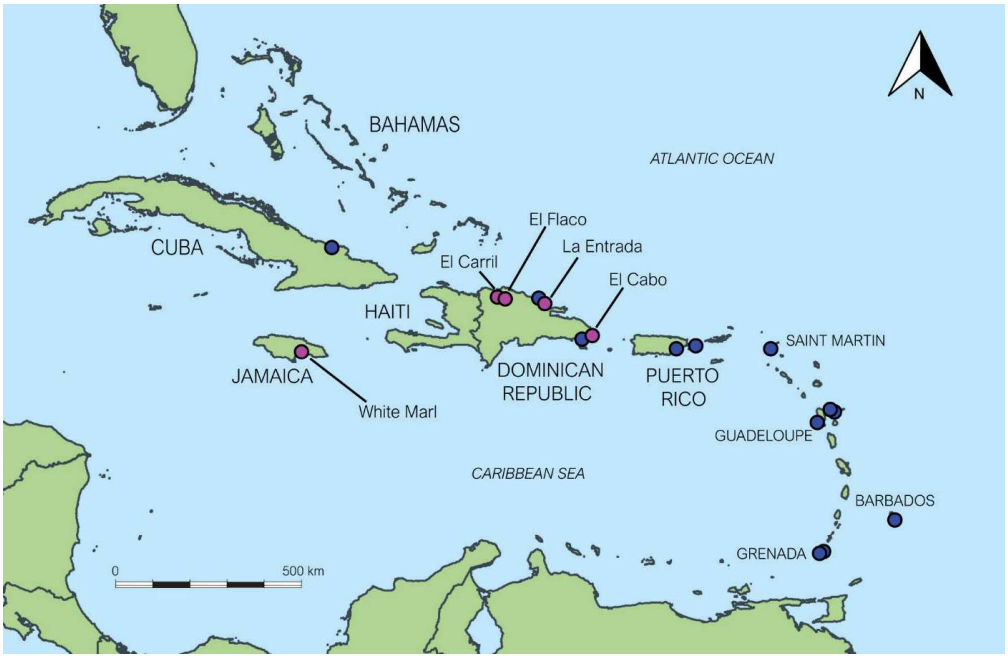

Figure 2: Map of the Caribbean region showing the sites investigated in this dissertation. Blue circles represent the approximate locations of sites from which the isotopic values of dogs (***Canis familiaris***) were analyzed in Chapter Two. Purple circles show the approximate locations of sites from which zooarchaeological and isotopic analyses was conducted on animal remains in Chapters Three, Four, Five and Six.

1.2 The historical ecology of the Caribbean region: a prolonged history of human impacts on the environment

To set the scene, this section serves to provide some definitions of the geographic locations discussed in this dissertation, to deliver some background information pertaining to the environment and climate of the insular Caribbean, to detail what is generally found in zooarchaeological assemblages, and to highlight the long history of human impacts on Caribbean environments that is evident from paleontological and palaeoenvironmental research.

When archaeologists discuss the 'insular Caribbean' they refer to a region with broad similarities in environments, climate, and cultural histories that pertains to a defined geographic boundary, and any further reference to the 'Caribbean' in this dissertation is as follows. The insular Caribbean is a collection of oceanic islands that falls into the Neotropics biogeographic zone. It is a region traditionally divided into three island chains encompassing roughly 230,000km^2 of landmass: the Lesser Antilles which include the Leeward Antilles off the coast of Venezuela, and the Windward and Leeward islands which comprise an arc of islands stretching from northern South America at Trinidad in the south to the Virgin Islands in the north; the Greater Antilles which include the largest islands of Cuba, Jamaica, Hispaniola (split

between modern day Dominican Republic and Haiti) and Puerto Rico; and the Bahamas located within the Atlantic Ocean to the north of the Greater Antilles. The constituent islands of the Greater Antilles account for approximately 90% of the landmass of the Caribbean islands. In virtue of their sheer sizes these islands accommodate the greatest variety biotopes, from which Indigenous peoples trapped and hunted animals and cultivated and gathered a wide array of plant foods (Grouard, 2010; Newsom & Wing, 2004)

Amerindian communities that inhabited the Caribbean existed within an ecologically diverse realm that had a relatively stable tropical climate, with seasonal fluctuations in precipitation being the most important meteorological variant (Taylor & Alfaro, 2005). It was in landscapes of taxonomic plenty that Indigenous peoples sustained their societies. The region is taxonomically rich and renowned for the prodigious degrees of endemism witnessed in its native flora and fauna (Hedges, 2007; Kier et al., 2009; Meijía, 2006). It is one of the few oceanic island systems that was colonized by terrestrial mammals, many of which went extinct at the advent of European colonization and the resulting biotic interchange between Eurasia and the Americas that occurred, including most species of native hutias, edible rats (***Brotomys*** spp.) and West Indies shrews (***Nesophontes*** spp.) (Hansford et al., 2012; Orihuela et al., 2020; Turvey et al., 2017; Turvey et al., 2007). The Greater Antilles are particularly renowned for high degrees of endemism in reptile and amphibian species (Hedges, 2007; Powell, 2012), but is also home to many species of endemic and migratory birds (Dickinson & Christidis, 2014).

Marine resources are particularly bountiful, with both the Caribbean Sea and Atlantic Ocean coasts providing access to a plethora of marine foods. Populating the seas of the Caribbean are at least 1500 different fish species of which 45% are endemic to the region, at least 3,032 species of Mollusca, and over 12,000 marine species in total (Humann, 2002; Miloslavich et al., 2010). Not all fish and mollusks were regularly targeted by Indigenous peoples, and what animals appear in zooarchaeological assemblages are largely determined by the types of resources available close to where settlements were located (Giovas, 2016; Grouard, 2010; Newsom & Wing, 2004). Some key families are represented most commonly within the archaeological record, including bony fish such as parrotfishes (Scarinae), wrasses (Labridae), groupers (Serranidae), snappers (Lutjanidae), tunas and mackeresl (Scombridae), grunts (Haemulidae), and marine invertebrates such as queen conchs (***Aliger gigas***), mangrove oysters (***Crassostrea rhizophorae***) and West Indian topshells (***Cittarium pica***) to name just a few (Newsom & Wing, 2004). Marine foods were clearly the mainstay of meat consumption at many sites in the Caribbean but particularly coastally situated settlements, as is evidenced in zooarchaeological assemblages (Carder & Crock, 2012; Giovas, 2013; Grouard, 2001, 2010; Newsom & Wing, 2004; Wing & Wing, 2001), and deduced from dietary isotopic studies of human remains (Keegan & DeNiro, 1988; Laffoon et al., 2019; Laffoon & Vos, 2011; Pestle, 2010, 2013).

There is nevertheless a correlation on bigger islands, with their greater taxonomic diversity and carrying capacities for terrestrial animals, between the distance a site is from the coast and an increasing reliance on terrestrial animals as food sources (Grouard, 2010; Newsom & Wing, 2004; Scudder, 1991, 2006). Some terrestrial animals that were relied upon by Indigenous peoples include endemic rodents such as hutias, edible rats and rice rats (***Oryzomys*** spp.), freshwater turtles, birds, lizards, snakes, amphibians,

and land crab species (Grouard, 2001, 2010; Newsom & Wing, 2004). In islands relatively depauperate of reliable terrestrial food sources there is evidence to suggest that animals were translocated from either the mainland or other islands, likely to bolster food availabilities in newly colonized territories (Giovas, 2019; Giovas et al., 2016; Wing, 2008).

Human impacts on the environment are evident throughout the sporadic human colonization of the Caribbean archipelagos. Four distinct colonization waves are thought to have occurred and are associated with increasing degrees of complexity in material culture, namely the Lithic (7000-4000BP), Archaic (5000-2000 BP), and Ceramic Ages (2500-500BP). The latter is commonly split into the Early Ceramic Age (500BC – AD 500), associated with the spread of agroceramicist Saladoid cultures, and the post-Saladoid Late Ceramic Age (AD 500-1500). Along with bringing a suite of domesticated plant species to the islands (Pagán Jiménez et al., 2005; Pagán-Jiménez et al., 2015), the colonization of the region by Amerindians led to the extirpation or extinction of some endemic species, but also the importation of domesticated animals from the mainland, and the translocation of synanthropic 'wild' species between islands (Giovas, 2019; Newsom & Wing, 2004; Stahl, 2006, 2009).

The Caribbean region has undergone several precolumbian animal extinction events that can be causally linked with different waves of human colonization. Recent revisions of radiocarbon dates pertaining to the earliest known human expansion into the Greater Antilles suggest the first islands to be colonized were Cuba, Puerto Rico and Hispaniola, with the colonization of Cuba (5360-4675 cal. BP) likely predating Puerto Rico (4655-4305 cal. BP) and Hispaniola (4545-3930 cal. BP) (Cooper, 2010; Napolitano et al., 2019). It is probable within this early period of mid-Holocene colonization that some endemic species went extinct. On Cuba, extirpated taxa include monkeys, land tortoise (***Chelonoidis cubensis***) and Antillean sloths (order: Pilosa) (Orihuela et al., 2020). Antillean sloths were morphologically diverse and ranged in size from around 200kg for the ground-dwelling ***Megalocnus rodens*** in Cuba, to the arboreal ***Neocnus toupiti*** from Hispaniola at around 4kg (Macphee et al., 1999; Steadman et al., 2005). ***Megalocnus rodens*** has a last occurrence date of 4844-4584 cal BP (MacPhee et al. 2007), while in Haiti, the last occurrence date of the small species ***Neocnus comes*** dates to approximately 5000 cal BP, close to the range of human settlement of the island (Steadman et al., 2005). In Puerto Rico last occurrence dates of some native rodents such as insular cave rats (***Heteropsomys***) and giant hutias (***Elasmodontomys***) also date to the mid-Holocene and may coincide with early human settlement of the island (McFarlane, 1999; Woods, 1996). The fact that these species persisted in the Caribbean islands well into the mid-Holocene (ca. 8.2-4.2 ka) beyond the Pleistocene-Holocene climatic transition (ca. 11.7ka), and have last occurrence dates roughly matching up with the earliest dates for the arrival of humans in the islands, suggests that these were human-caused extinctions rather than due to climate change (Orihuela et al., 2020; Soto-Centeno et al., 2017; Steadman et al., 2005). However, these extinctions were likely minimal compared to the dramatic changes that occurred after the arrival of Europeans, with many species notably persisting for millennia after the arrival of Amerindians in the region (Turvey et al., 2007). It may be that some species were better suited to environmental transformations that Amerindians were responsible for, possibly hinting at a degree of synanthropy.

Beyond the palaeontological evidence, other palaeoenvironmental proxies such as sediment coring and

palaeobotanical studies indicate that there were alterations to Greater Antillean ecosystems coinciding approximately with early human arrivals. At Lake Miragoāna, Haiti at around 5370 - 3950 yr BP charcoal particulates increase substantially concurrent with a near complete disappearance of forest taxa such as Palmae and an increase in fire-resistant ***Ambrosia*** and ***Pinus*** pollen. This increase in fire in the landscape also contrarily coincides with evidence of wetter conditions in this period and therefore may indicate early human disturbances to the environment (Higuera-Gundy et al., 1999). Similarly, an increase in charcoal influx and concentration at Laguna Tortuguero, Puerto Rico began around 4560 ±70 yr BP (5321-5055 cal yr BP) and continued for 2000 years (Burney et al., 1994).

It is with the movement of sedentary agroceramicists into the Caribbean during the Ceramic Age that human impacts on Caribbean ecosystems become more apparent in the palaeoenvironmental record. On the island of Barbuda in the Leeward Islands, substantial impacts on the environment are noted in the charcoal and sedimentary record that indicates the use of fire as a form of land clearance during the Early Ceramic Age (Bain et al., 2018). Increased use of fire occurred later in Hispaniola as is suggested from sedimentary records obtained from the Cibao Valley in the north of the island. There we see that sporadic deforestation events and human use of fire in Hispaniola increased during the Late Ceramic Age. According to the sedimentary record from Laguna Biajaca within the Cibao Valley, human-driven deforestation occurred between AD 1150-1500 (800–700 cal BP), with more widespread crop cultivation evident between AD 1250-1450 (700-500 cal BP) (Castilla-Beltrán et al., 2018, 2020) the site of Los Indios, also in the Cibao valley, indicates the presence of pollen from plant cultivates dating between AD 200-560 (1750-1390 cal BP), with an intensified use of fire after AD 1410 (540 cal BP) (Hooghiemstra et al., 2018). Observations of increased charcoal and changes in vegetation communities allude to widespread human use of fire for land clearance and slash-and-burn farming during the Late Ceramic Age but reflects only one aspect of suite of Indigenous food production practices and human-environmental interactions.

1.3 Domesticated animals in the precolumbian Caribbean

The widespread introduction of horticultural practices such as slash-and-burn farming during the Ceramic Age also coincided with the introduction of domesticated animals into the region. The domesticated dog (***Canis familiaris***) was likely introduced by agroceramicists sometime around 500 BC, and their appearance is associated with the colonization of Puerto Rico and parts of the Lesser Antilles by peoples bearing Saladoid style ceramics (Grouard et al., 2013; Newsom & Wing, 2004, p. 204; Rouse, 1992). Dogs shared a unique relationship with Indigenous peoples in the Caribbean as they are commonly found in burial contexts often in association with human inhumations. Canid burials have been recovered from Saladoid-era contexts at Indigenous sites in Puerto Rico and throughout the Lesser Antilles (Crespo, 1991; Grouard et al., 2013; Hoogland & Hofman, 2013; Narganes Storde, 1983; Pérez Merced, 2000; Rodriguez, 2007; Wing, 1991).

People bearing Saladoid style ceramics were likely responsible for introducing domesticated dogs into the islands, however a notably long pause occurred between the agroceramicist colonization of Puerto Rico

and parts of the Lesser Antilles, and the colonization of Hispaniola, Jamaica, Cuba, and the Bahamas to the west. The reasons for this delayed colonization are unknown, however the presence of Archaic peoples throughout these islands may have acted as a deterrence for Saladoid colonists (Fitzpatrick, 2015; Giovas & Fitzpatrick, 2014). Migrations again occurred during the period known as the Late Ceramic Age (AD 500 – 1500) with agroceramicists intensifying their colonization of Hispaniola, Jamaica, Cuba and the Bahamas. This Late Ceramic Age migration coincides with several notable changes within Indigenous societies culminating in a demographic flourishing, cultural change, and increasing sociopolitical and economic complexity (Hofman et al., 2007, 2008; Keegan & Hofman, 2017).

It was with the Late Ceramic Age spread of agroceramicist cultures west from Puerto Rico that the dog burial phenomenon appears at White Marl in Jamaica (Wing 1972), at sites in Cuba such as Corrales de Ojo del Toro, Cayo Bariay and Cueva Bélica (Fernández Ortega et al., 2011), in Hispaniola at San Pedro de Macoris, Boca del Soco, El Cabo San Rafael, En Bas Saline, and El Carril de Valverde (Calderón, 1985; Lawrence, 1977; Rodriguez, 2007), as well as at El Flaco (Hofman et al., 2020; Hofman & Hoogland, 2015; Shev, 2018) which is one of the case study sites of which an isotopic and zooarchaeological study forms part of this dissertation. The impact of the introduction of dogs on Caribbean ecosystems is poorly understood, however there is limited taphonomic evidence to suggest that certain endemic species such as solenodons (***Solenodon*** spp.) and some endemic rodents were predated upon by dogs (Orihuela León et al., 2016).

Dogs not only shared deathways with humans as is exhibited in the commonality of their burials, but also lifeways, with isotopic evidence suggesting a close relationship as reflected in shared diets and dual migration patterns with humans (Laffoon et al., 2015, 2019). Interestingly, similarities in dietary isotope values between dogs and humans is a global phenomenon, and this sharing of foodways is testament to the longstanding close relationship between humans and dogs (Guiry, 2012). Because of this close, dually symbolic and quotidian relationship between humans and dogs, they serve as an ideal isotopic baseline for assessing the closeness of human relationships with other animals. It is for this reason that the first case study in this dissertation works to further assess the degrees of dietary and mobility entanglement between humans and dogs throughout the Caribbean region during the Ceramic Age.

Guinea pigs are the only other known domesticated animal that was imported to the Caribbean islands, being initially introduced to the Greater Antilles sometime after AD 500 (LeFebvre & deFrance, 2014). They are relatively widespread throughout the Caribbean region and have been recovered from at least 19 sites on nine different islands throughout the Lesser Antilles, but also in Jamaica, Hispaniola and Puerto Rico in the Greater Antilles (Kimura et al., 2016; Lord et al., 2018). This is a revised figure from the most recent published literature, as one guinea pig mandible was recovered from deposits at El Flaco as discussed in this dissertation. Mitogenomic sequencing of archaeological guinea pigs indicate that there were at least two different introductions into the region, possibly one into Puerto Rico from the Isthmo-Columbian region, and a second into Carriacou in the Lesser Antilles from elsewhere in South America (Lord et al., 2018). Although widespread, guinea pigs are not found in great numbers, with around half of all 219 specimens coming from the site of Finca Valencia in Puerto Rico. It is likely that their spread was linked to an intensification of exchange networks and population movements between

different islands and the mainland during the Late Ceramic Age (LeFebvre & deFrance, 2014). Guinea pigs, as a domesticated animal, also serve as a dietary isotope proxy to aid us in establishing the differences between 'wild' and 'domestic' animal diets.

1.4 Animal translocations and human-hutia interactions

During the Ceramic Age, Indigenous peoples not only introduced domesticated animals into the Caribbean from the mainland but were also responsible for the translocation of mainland 'wild' taxa into the islands, and endemic Caribbean species between islands. In the Lesser Antilles, we have established evidence of the precolumbian introduction of South American mammals to certain islands, most commonly agoutis (***Dasyprocta*** sp.), opossums (***Didelphis marsupialis***), peccaries (***Taysassu/Pecari*** sp.), and armadillos (***Dasypus*** cf. ***novemcinctus***), and rarer instances of pacas (***Cunniculus*** sp.), deer (***Odocoileus*** sp. and ***Mazama*** sp.), and monkeys (***Cebus paella***) (Antczak, 1995; Antczak & Antczak, 2006; Giovas et al., 2012, 2016; Giovas, 2019; Grouard, 2010; Laffoon et al., 2018; Masseti, 2011; Stahl, 2009; Wing, 2008). Many of these species can be considered to be synanthropic and may benefit from close association with humans (Giovas, 2019). In the Greater Antilles, rather than an introduction of mainland 'wild' taxa into the islands, the archaeological evidence indicates that certain endemic mammals were translocated between islands. These include several hutia species and possibly the now-extinct West Indies shrew (***Nesophontes*** spp.) (Díaz-Franco & Jiménez Vázquez, 2008; Newsom & Wing, 2004; Oswald et al., 2020; Wing, 2008, 2012).

The hutia species primarily spread by Amerindians throughout the eastern half of the Greater Antillean islands is the unfittingly named Puerto Rican hutia, ***Isolobodon portorcicensis***. This species was likely introduced into Puerto Rico and the Virgin Island by Indigenous peoples from its original territory in Hispaniola sometime during the Early Ceramic Age (Miller, 1918; Reynolds & Williams, 1953; Wing, 2001, 2012; Woods, 1996; Woods et al., 2001), therefore its designation as the 'Puerto Rican hutia' is somewhat of a misnomer. A strong dependence on this species is seen within zooarchaeological deposits at many Ceramic Age sites in Hispaniola, Puerto Rico and the Virgin Islands, which coupled with evidence of their translocation has compelled researchers to infer that this was a managed species (Carlson & Steadman, 2009; Wing, 2008, 2012). Recent microscopic and genetic analysis of 1400 to 540 years old human coprolites at the Huecoid-Saladoid site Sorcé on Vieques, Puerto Rico may support this notion. That study identified the presence of zoonotic parasites that are indicative of close interactions of humans with dogs and native rodents such as spiny rat (***Heteropsomys insulans***) and hutias (Wiscovitch-Russo et al., 2020). As previously noted, historical mention of corrals to house hutias is laid forth by Las Casas (Las Casas, 1875; Lovén & Curet, 2010; Wing, 1993), however their existence has never been positively identified archaeologically.

Isolobodon portoricensis is by no means the only hutia species that is theorized to have been managed. Recent isotopic, morphological and genetic studies of Bahamian hutia (***Geocapromys ingrahami***) hint at some degree of commensalism and translocation of this species by humans into new island environs (LeFebvre, deFrance, et al., 2019; LeFebvre, DuChemin, et al., 2019; Oswald et al., 2020). A similar

phenomena likely occurred with Jamaican hutia (*Geocapromys brownii*) as their estimated mortality profiles at some sites might be more reminiscent of animal management practices rather than from non-age selective hunting (Carlson, 2012; Wilkins, 2001). This dissertation seeks to expand the isotopic and morphometric study of both *Isolobodon portoricensis* from Ceramic Age sites in the Dominican Republic, and *Geocapromys brownii* from the Late Ceramic Age site of White Marl, Jamaica to assess whether management of these species was occurring prior to the European invasion of the region.

1.5 Defining 'domestication' and 'management'

This dissertation does not seek to establish whether hutias from precolumbian Greater Antillean sites were domesticated by Indigenous peoples. The methods employed are best at determining a closeness in human-animal relations as indicated by a sharing of dietary sources, and in establishing the hunting or trapping strategies as determined from morphometry and mortality age determinations. These methods cannot assess whether humans intentionally controlled all aspects of native animal lifeways, nor are they capable of assessing whether phenotypical change affecting species occurred during the Ceramic Age of the Caribbean. Even so, for the sake of clarity it serves to define the terms 'domestication', 'husbandry' and 'management'.

There is wide disagreement as to what the term 'domestication' entails but definitions tend to focus on delineating the extent of human control over animal lifeways, but disagree as to the form and intensity of human dominance in these relationships (Zeder, 2012, 2015). Domestication has been defined as a process that places humans in a dominating position within human-animal relations, with humans responsible for the purposeful removal of an animal species from wild, free-roaming populations, and subsequently mastering its feeding habits and breeding behavior (Bökönyi, 1969, pp. 219–220, 1989), and as exerting control over behaviour and cultural transmission in animals (Clutton-Brock, 1994, pp. 28–30). Taking the middle road, domestication has also been described as a relationship in which both domesticator and domesticate dually benefit and is borne out of a mutualistic or commensal interactions between humans and animals that lead to a "behavioural coevolution" in both species (O'Connor 1997). For Frederick Zeuner (1963), human intentionality was likely absent from early domestication scenarios altogether as domestication only occurred with animals that habitually scavenged from human settlements, such as pigs or dogs. Zeuner frames domestic relationships with some herd animals such as goats, sheeps and cattle as originating from human parasitism of these species, suggesting that animal agency is the primary determinant for closeness between humans and animals (Zeuner, 1963). In some scenarios, animal agency is further emphasized with animals considered as social beings with their own intent (Orton, 2010), and in other definitions animal species are even seen to have benefited greater in these mutualistic relationships than their human counterparts (Rindos, 1984).

Here I follow the definition outlined by Melinda Zeder, which recognises that domestication processes are varied and have their genesis in mutually beneficial relationships, but acknowledges that humans always eventually assume the dominating role in these commensal or mutualistic relationships:

> "*Domestication is a sustained multigenerational, mutualistic relationship in which one or-*

ganism assumes a degree of influence over the reproduction and care of another organism in order to secure a more predictable supply of a resource of interest, and through which the partner organism gains advantage over individuals that remain outside this relationship, thereby benefitting and often increasing the fitness of both the domesticator and the target domesticate" (Zeder 2015)

This is not exclusive to human-animal relations, with instances of animals domesticating other animals well established in the natural world. However, following this statement Zeder notes that due to the human ability for cultural transmission, we tend to "...opportunistically invent and modify behaviors that enhance benefits gained from coevolutionary relationships with target species..." (Zeder, 2015). In a sense, our mental acuity, capacity for teaching and learning, and ability to communicate abstract concepts provides us with the conscious capability to adapt our behaviors over generations and eventually establish complete control over an animal's lifeways. This is what sets human-animal domestication relationships apart from other examples of domestication in the natural world.

It is in this vein that Zeder (2012) proposes three main pathways towards domestication: the commensal pathway, the predation pathway, and the directed pathway. The commensal pathway involves the initial sharing of food between species that occurred due to the attraction of an animal to human settlements to scavenge, the key example often used is dogs. The predation pathway in which humans originally hunted animals such as cattle or sheep and goats, but gradually changed their hunting strategies or manipulated the environment in such a way that eventually benefited and bolstered animal populations, progressively leading to the corralling and controlling of these species. Lastly, the directed pathway is more deliberate attempt of humans to initiate domestication for specific gain, such as the use of equids for transportation, or modern aquaculture practices (Zeder, 2012).

Domestication often, but not always, results in phenotypical change in the domesticated species. Such alterations include its body size, coat colour and hair follicle shape, retention of neotenous (juvenile) features (Clutton-Brock, 1999), but also behavioral changes that are likely impacted by changes in brain size and biochemical function. Several studies have demonstrated that brain size can decrease in domesticated animals compared to their wild forebearers, which may be linked to a decrease in wariness and low reactivity to external stimulus (Ebinger, 1995; Ebinger & Röhrs, 1995; Kruska, 1996). To use an example from the Americas, domestic guinea pigs are known to be less aggressive and more sociopositive than wild cavies (Künzl & Sachser, 1999). Phenotypical changes such as decreased brain size do not necessarily occur with all species that have been domesticated, and epigenetic factors such housing conditions of animals may also be associated with a decrease in brain size (Mehlhorn & Petow, 2020). From the archaeological hutias that were examined in this dissertation phenotypical changes resulting from domestication cannot be examined with the methods employed. Instead, I focus primarily on assessing dietary linkages between humans and animals that may suggest the management of the latter by the former.

Another two terms arise in this dissertation that I have used interchangeably, 'husbandry' and 'management'. These two terms are employed to denote some human control over animal lifeways which can be seen as mutually beneficial for both species. In a general sense, 'husbandry' does not necessarily denote a relationship between humans and a domesticated animal, and rather generally refers to the overall

management, care or custodianship over any species humans interact with (Smith, 2001). According to Zvelebil (1995) 'husbandry' is the intentional promotion of strategies to increase control over and optimize the productivity of nonhuman species but entails practices that fall in the intermediary between the keeping of livestock on one side of the spectrum and hunting and gathering on the other (Zvelebil, 1995). Zeder (2015) echoes this definition for 'management' but extends this to include intentional environmental changes by humans, stating that management is "... the manipulation of the conditions of growth of an organism, or the environment that sustains it, in order to increase its relatively abundance and predictability and to reduce the time and energy required to harvest it." These definitions are acceptable, and any mention of 'management' or 'husbandry' in this dissertation should be taken to indicate as a manipulation strategy affecting animal behavior or habitats but does not imply a total control over animal lifeways.

Management over an animal can achieve a degree of tameness because of ongoing close interactions with humans and their behavioral conditioning by repetitive positive associations. By providing necessities such as nutrition, shelter and affection humans may become associated with positive stimuli, reducing an animal's fear response when encountering people. This amenability for handling is seen as one of the desirable traits for an animal to be a candidate for domestication. However, tameness does not necessarily lead to domestication. That process depends on several physical and behavioral factors that define an animal's candidacy for being domesticated (Driscoll et al., 2009; Price, 1999). Additionally, we must also consider ontological perspectives which may affect the way Amerindian people view animal entities and interact with them, possibly inhibiting people from assuming a dominating role over the breeding and feeding habits of an animal (Descola, 2013). The terms 'husbandry' and 'management' are therefore employed in this dissertation in describing human influence over aspects of animal lifeways such as diet, but I differentiate this from 'domestication' which denotes a closer relationship between humans and animals in which the former has total dominance over the social structures, breeding and feeding behavior of the latter.

1.6 Human-animal interactions in the Neotropics: between wild and domestic

Animal domestication as a form of managed food production has in the past been seen teleologically as part of a suite of developments that are requisite for a culture's trajectory towards greater social complexity (Childe, 1952; Cucchi & Arbuckle, 2021; Diamond, 2002). With exclusion of dogs and guinea pigs, the lack of animal domestication in the Caribbean has in some ways relegated Indigenous societies as developmentally set apart from the complex urban societies of the mainland Americas. Within the Americas this scantness of domesticated animals is however not exclusive to the Caribbean islands, as only five species of native animals are known to have been domesticated prior to arrival of Europeans. This does not include dogs, which comigrated with humans from Eurasia during the peopling of the Americas and possibly originally descending from a common canid ancestor shared by Eurasian grey wolves (***Canis lupus***) (Bergström Anders et al., 2020; Frantz et al., 2020; Leonard et al., 2002). Turkey (***Meleagris gallopavo***) domestication likely occurred in two different regions of North America starting sometime around 2000 BP (Speller et al., 2010), and in the central Andes the beginnings of camelid

domestication occurred from around 6000 BP, followed by guinea pigs (***Cavia porcellus***) around 4500 BP (Pearsall, 2008; Wing, 1986). Little is known about the timing and location of Muscovy duck (***Cairinia moschata***) domestication, however it likely occurred somewhere in the tropical lowlands of South America (Stahl, 2005).

The domestication of an animal can be seen as denoting a transition of an animal species from 'nature' to 'captivity', although these two states sit at the extreme spectrums of the well-documented high variability within animal management or husbandry practices. Wild animals are known to inhabit wilderness space, semi-domesticated reserves and urban spaces where food provisioning occurs, whereas captive animals can range from the living conditions of lab mice to cattle left out to pasture (Carlstead, 1996; Price, 1999). Unfortunately, our approaches to understanding animal management practices are often too mired by an overt willingness to discriminate between 'wild' and 'domestic' species within zooarchaeological assemblages. This is problematic in regions where human-animal interactions may have been more nuanced and less clearly binarized than in Eurasia, such as the case for the Neotropics (Smith, 2001). Whether animals such as hutias were domesticated in the Caribbean islands might be too simplistic of a question, and too dualistic of a framing of Indigenous human-animal relations in its posturing of domesticated and wild animals as being on the extreme ends of a spectrum of human-animal interactions (Zeder, 2012, 2015). For many Amerindian communities the act of petkeeping (Erikson, 2000), environmental management practices that positively affect the flourishing of some native species over others (Balée et al., 2020; Linares, 1976; Smith, 2001), as well isotopic evidence of 'wild' animals consuming agricultural produce (Guiry et al., 2021; Sugiyama et al., 2020) strongly suggests that humans were interacting with animals in many parts of the Americas in ways that could be nestled somewhere within the spectrum of 'domestic' and 'wild'.

Ontological theories have attempted to explain why peoples in many parts of the Americas did not domesticate animals as commonly as in Eurasia. Some theories suggest that the ontologies of Amerindian cultures may have been functionally distinct from Western ontologies in how they hierarchically evaluated different species (Descola, 2013; Viveiros de Castro, 1998). According to anthropologist Phillipe Descola, who bases much of his schema off contemporary Amazonian cultures, Amerindians often take the cosmological stance that the internal 'spirits' of humans, animals, plants and some objects are metaphysically identical, with the only differences being our corporeal forms (Descola, 1986, 1998, 2013). This can be considered as an ontological monism that contrasts to Western ontological dualism in which 'nature' and 'culture' are divided into distinct categories, subscribing to the fact that even though we share biology with animals we are culturally and spiritually distinct (DiNovelli-Lang, 2013; Latour, 1993). Viveiros de Castro (2004) speaks of a "phenomenological unity" between beings in Amerindian cosmologies, in which although corporeally diverse all beings possess a generic soul and consider themselves persons while considering other entities as either prey, predators or spirits in what he coins "Amerindian perspectivism". It is these perspectives of spiritual equality between species that fosters human-animal relations that are governed by notions of reciprocity and egalitarianism, preventing people from assuming dominance over animal lifeways (Vivieros de Castro 1998; Descola 2013).

Amerindian perspectivism, and Descola's theories about an overarching Amerindian animist belief, have

been fairly critiqued for assuming a general totality and homogeneousness of Amerindian ontologies, perhaps overestimating cultural similarities between far-flung peoples spread across two continents (Halbmayer, 2012; Ramos, 2012). Additionally, instead of being an overarching Amerindian cosmology, the notion of metaphysical identicalness between humans and animals might be more manifest in hunter-gatherer cultures that relied minimally on domesticated species (Nadasdy, 2007). Laura Rival (2012) also questions whether all Amerindian ontologies are actually oppositional to Western natural sciences, and calls for more of a recognition of Indigenous ecological traditions and knowledge. Additionally, although clear historical, cultural and linguistic linkages between the Caribbean to the Amazonian lowlands are apparent (Rouse, 1992) we also have to be careful before assuming that Indigenous peoples living in the pre-AD 1492 Caribbean viewed most animals as consanguineous to themselves, as some contemporary Indigenous Amazonian cultures do.

Although providing some interesting hypotheticals to consider for interpreting how Indigenous peoples viewed animals, perspectival notions are often difficult to assess from the zooarchaeological record. There are exceptions, notably with animals such as dogs which likely held symbolic importance noteworthy in their common depiction in art and prevalence of ritual inhumations (Shev, 2018). Not to completely discount ontological theory regarding animism or perspectivism, but for animals such as hutia, which appear to have had more of a quotidian role as a food source and rarely appear to be depicted in material culture, assessing the perspectival qualities of this species for Indigenous people is difficult. However, in general traditional Indigenous ecological practices may have dictated educated by their ontologies, in particularly animist notions of reciprocity.

Given the bioarchaeological methodological approach of this dissertation, a theory embedded in the natural sciences that helps explains why people living in many parts of the Neotropics may not have needed to domesticate animals is better suited to my research aims. This theory can also be supported by empirical data, rather than philosophical discourse focused on generalizing the ontologies of distinct Indigenous cultures across the Americas.

1.7 Niche Construction Theory

Niche construction theory (NCT), which is a sub-branch of macroevolutionary theory, acknowledges the role organisms often have in changing environments around them to better suit their own needs for nutrition or shelter. These behaviours affect the constructions of ecological niches which can in turn affect evolutionary pressures on other species cohabiting the same manipulated environments (Odling-Smee et al., 1996). NCT is sometimes considered oppositional to many of the core tenets of human behavioural ecology (HBE) (Odling-Smee et al., 1996; Ready & Price, 2021). HBE approaches have instead traditionally focussed on predicting the behaviour of an organism when it faces a problem, such as acquiring sources of food or shelter, under the assumption that an animal will always act the most efficient way possible in order to achieve the greatest level of fitness possible (Winterhalder & Kennett, 2006). This optimization behaviour, in for example obtaining food by expending the least amount of energy possible, is the core tenet of optimal foraging theory (OFT) which falls under the conceptual umbrella

of HBE. OFT states that an organism will always consume the most efficient, higher-ranked food source, and whenever resources have been diminished due to overconsumption or ecological degradation, will then work its way down to lower-ranked foods according to their perceived energy cost-benefit ratios (MacArthur & Pianka, 1966; Pyke, 1984). OFT has been employed repeatedly to explain why the domestication of some taxa, generally considered to be lower-ranked such as cereals or some animals, occurred globally, and assumes that the choice to consume and eventually cultivate these lower-ranked foods is a direct response to resource depression (Piperno, 2006; Stiner, 2001; Winterhalder & Kennett, 2006).

Criticisms have been fairly levelled at optimization theories. This is partly due to a lack of support for model outcomes from empirical datasets that show that resource stress is not necessarily related to instances of incipient domestication in many circumstances (Smith, 2009, 2011; Zeder, 2012). There are also some conceptual flaws within its core tenets: that the net energy derived from a particular resource is the sole driving force behind their selection; that humans move randomly throughout a landscape; and that foragers are passive consumers and their behaviour is completely subject to adaptive pressures (Kennett & Winterhalder, 2006; Smith, 2009; Winterhalder & Goland, 1997; Winterhalder & Kennett, 2006). HBE approaches suffer from limitations of downplaying cultural transmission and viewing humans as rational beings only concerned with optimizing fitness, therefore behaving in a way which is purely responsive and adaptive to external pressures, such as resource depression. As an alternative, the use of NCT evolutionary models to explain human behaviour and environmental relations have become widely debated within archaeology in recent years (Laland & O'Brien, 2010; Scott-Phillips et al., 2014; B. Smith, 2015), although with only rare attempts to try and bridge some consilience between HBE and NCT approaches (see Ready & Price 2021).

HBE models do have merit, particularly when analysing phenomena at broader scales which call for some reductive generality, such as is the case for the study of human migrations over the longue durée. Their use in explaining the motivations and constraints behind the island-hopping migrations seen during the Ceramic Age of the Caribbean are particularly seductive due to their simplicity and workability with the archaeological data (see Giovas & Fitzpatrick 2014). However, acknowledging that human-caused environmental transformations such as slash-and-burn farming may influence the composition of faunal assemblages from archaeological sites cannot be overlooked. This is particularly the case given the palaeoenvironmental record that suggests that Indigenous peoples in the Caribbean were transforming vegetation communities in their land clearance practices (Bain et al., 2018; Castilla-Beltrán et al., 2018, 2020; Siegel et al., 2015) which likely applied adaptive pressures on animal species inhabiting these environments.

There have been calls to unite theories from the biological sciences with anthropology to study the interplay between human culture and the environment under the umbrella term 'human ecodynamics' (Fitzhugh et al., 2019; Kirch, 2007). However, as clear definitions of 'human ecodynamics' and what is specifically entails beyond broad generalities are wanting, it does not appropriately act as an interpretative model per se (Holm, 2016). Rather, human ecodynamics better serves as a catchall term that

incorporates different theories within contemporary environmental archaeological approaches that are concerned with studying the causal relationship between change, or resiliency, in natural and cultural systems. As human ecodynamics can incorporate aspects of human behavioural ecology and niche construction as practitioners see fit, and has considerable overlap with human ecology in general, that term is therefore best used to describe a collection of approaches, rather than a defined theory or actionable practice (Fitzhugh et al., 2019). NCT is instead specifically tailored to examine the phenomena investigated in this research, in particularly the management of animals, garden hunting, and the interplay of these activities with other food production strategies. For this reason, have opted for more specificity in only naming niche construction theory as the main theoretical framework in this dissertation.

Humans are the global environmental niche constructors par excellence. We modify terrain and plant communities through a variety of methods, such as the burning of old-growth forest, the elimination of unproductive plant species, and the introduction and cultivation of useful plant species in newly cleared land (Boivin et al., 2016; Odling-Smee et al., 1996; Pagán Jiménez et al., 2005; Pagán-Jiménez et al., 2015; Smith, 2007, 2011; Zeder, 2015). These activities can form mosaics of plant communities comprised of untouched primary forest, horticultural areas containing nutritious plant species, and fallows consisting of secondary growth. The creation of horticultural plots by removing high-canopy flora can directly favour heliophilic plant species that may colonise fallows and forest edges, in turn attracting dietary generalists that tend to frequent and prefer a variety of habitats (Arce-Peña et al., 2019; Loiselle & Blake, 1992; Reitsma et al., 2001; Smith, 2005).

Animal species that may be attracted to these anthropogenic mosaic environments can provide a stable source of meat for peoples in areas located relatively close to humans, preventing the need to range far from settlements to find meat (Ramírez-Barajas & Calmé, 2015; Smith, 2011; Smith, 2005; Stahl, 2014). This phenomena is termed "garden hunting" and has been used to explain the composition of faunal assemblages with recognition of how human actions in creating mosaic vegetative niches also affects the kinds of animals that can be predated upon (Linares, 1976; Stahl, 2014). Garden hunting practices are well documented and supported by ethnographic evidence as being practiced in contemporary communities in the Neotropics, and for some peoples, such as the Buglé of Panama, around half of their meat comes from garden hunting (Loiselle & Blake, 1992; Smith, 2005).

Contrary to OFT models that explain human dietary choices, and the decision to domesticate plants and animals as being an adaptive response to resource depression and food scarcity, NCT theories suggest that humans will manipulate environments to bolster food security, directly by growing food crops, and indirectly by supporting and bolstering populations of animal species that may benefit from the growing of these crops. This can be considered as a form of 'management' of animal species (Zeder, 2015) and forms part of a stable and sustainable mixed economy termed by Smith (2001) as "low-level food production".

The archaeological evidence for widespread horticultural practices throughout the Caribbean islands during the Ceramic Age suggests that Indigenous peoples were low-level food producers performing

niche construction activities in a region known for its high taxonomic diversity in plant and animal life. The attraction of dietary and behavioural generalist animals that benefited from human ecosystem engineering, and a likely increasing dependence on these species as a stable food source, means that Indigenous peoples may have become more reliant on a mix of managed and free-living resources as human and 'wild' animal interactions increased (Zeder, 2012). Over time these resource management strategies would likely become refined with the transmission of traditional environmental practices across generations, leading to increased interactions and involvement of humans over animal lifeways (Smith, 2015), and serving as a possible pathway towards the eventual domestication of some animals (Zeder, 2012, 2015) .

This dissertation seeks to answer whether Indigenous peoples in the Caribbean were managing certain animals prior to the tragic and dramatic post-AD 1492 demise of their cultures and cessation of their environmental management strategies. This assessment focusses mainly on hutias which are the primary candidate for having been managed by Indigenous peoples, but also examines the dietary and mobility entanglements between humans and dogs as a known domestic animal which can be used as a proxy demonstrating how a domestic diet should look isotopically. I seek to establish whether human niche construction activities such as land clearance and slash-and-burn horticulture, and whether garden hunting, or even a more direct form of animal husbandry, were part of Indigenous environmental management strategies in the Greater Antilles. To do this I have employed stable isotope analysis to reconstruct the diets of animals and conducted zooarchaeological analysis of fauna from two case studies from Late Ceramic Age sites in Hispaniola and Jamaica.

1.8 Isotopic extraction and analysis methods

As this dissertation is comprised of five peer-reviewed articles that often refer to previous publications for the laboratory methods employed, I will now briefly outline the isotopic extraction and analyses protocols used in my research. These methods remained the same for all the isotopic case studies that comprise this dissertation, so if they are omitted in the following chapters this serves as a reference point for the reader.

The protocol for tooth enamel extraction is slightly modified from the protocol outlined by Bocherens et al. (2011). All samples were cleaned with water and dried before extraction was conducted. Enamel was drilled from teeth using a hand-held diamond tipped Dremel drill and placed into miniature polyethylene test tubes. To remove unwanted organic contaminants, 1mL of 2-3% NaOCl solution was added, samples were then vortexed and left at room temperature for 20-24 hours. This solution was then removed with a sterile pipette and samples were washed with 1mL of deionised water, centrifuged, and then the water was removed. This step was repeated three times to ensure no NaOCl remained. To remove unwanted carbonate pollutants, 1mL of 1M acetic acid-CA buffer (pH 4.75) was added to each sample and then left for 20-24 hours. This solution was then removed, and samples were subsequently cleaned again by adding deionised water, centrifuging the samples, and removing the solution, repeating

this thrice. Samples were placed to dry overnight in an oven set at 60°C with their caps open. After drying, a minimum sample weight of 0.3mg of each sample was weighed and transferred to glass vials. Samples were submitted to the Stable Isotope Lab, Department of Earth Sciences, Vrije Universiteit (VU) Amsterdam and measured with a Finnigan DeltaPlus Isotope Mass Spectrometer after reaction with H_3PO_4 [100%], with the isolation of produced CO_2 using a Gasbench II universal automated interface.

The bone collagen extraction procedure follows the protocol stated in Müldner and Richards (2005). Bone samples were crushed using a mortar and pestle into small fragments which were added to sterile, labelled test tubes. Approximately 9-10mL of 0.6M HCl solution was added to cover each sample, after which samples were vortex and then placed in a refrigerator at 4°C for 48 hours. The acid solution was then removed and refreshed, and this step was repeated until bone material was sufficiently demineralised and no noticeable reaction in the form of bubbling could be seen. After demineralization, samples were rinsed in deionised water, centrifuged, and then water was removed. This step was repeated three times to ensure no HCl solution remained in the test tubes. To remove any unwanted humic acids, 10mL of 0.125M NaOH was added, and samples were left to sit at room temperature for a maximum of 20 hours, after which they were again rinsed with deionised water, centrifuged, and decanted three times. To gelatinise the samples 9mL of 0.001M HCl (pH 3) was added, and the samples were left in an oven for 48 hours set at 80°C. Ezee filters were then used to separate the gelatinised samples from any remaining solid particulates, and the remaining collagen was then poured into pre-weighed and labelled test tubes. Samples were then frozen overnight before being lyophilised for 48 hours. Approximately 0.5mg of pure collagen was weighed from each sample and inserted into tin packets and submitted to the Stable Isotope Lab at VU Amsterdam. Samples were measured with a ThermoQuest IRMS Delta XP plus interfaced with a Flash elemental analyser.

Carbon ($\delta^{13}C$), oxygen ($\delta^{18}O$), and nitrogen ($\delta^{15}N$) isotope values are reported in delta (δ) as parts per thousand (‰). Carbon and oxygen isotope ratio values are determined relative to the international PDB (Pee Dee Belemnite) standard, and nitrogen isotope ratio values relative to the international N_{air} standard.

1.9 Dissertation structure and chapter summaries

The broad aim of this research is to assess the functioning of human-animal relations in the Caribbean prior to the arrival of Europeans in the Americas. To do this, this research is structured initially in broad strokes and moves towards a higher degree of specificity by looking at interactions between humans and certain animals at select case study sites.

We begin with a broad isotopic and osteometric investigation across both Greater and Lesser Antilles of the most ubiquitously found domesticated animal in the region, dogs, and finish with a more narrowed focus on the zooarchaeological and isotopic evidence for the management of two different species of hutias which have long been theorized to have been undergoing nascent domestication (Carlson, 2012; Carlson & Steadman, 2009; Wing, 2008, 2012). This dissertation entails isotopic studies of palaeodiets of animals recovered from several precolumbian archaeological sites located in the insular Caribbean, as

well as zooarchaeological and isotopic investigation case studies from two contemporaneously occupied Late Ceramic Age case study sites, El Flaco (AD 990 – 1450) in the northwestern Dominican Republic, and White Marl (AD 900 – 1500) in southern Jamaica. This volume includes seven chapters: this introduction, five chapters entailing the case studies that comprise the body of this dissertation, and Chapter Seven which serves as the final chapter and entails a synthesis of the precursor chapters, provides answers to the research questions, discusses the scope for future research, and contributes some concluding remarks.

Chapter Two: An Isotopic and Morphometric Examination of Island Dogs (Canis familiaris): Comparing Dietary and Mobility Patterns in the Precolumbian Caribbean. This dissertation begins with an isotopic and morphometric assessment of dogs from 16 precolumbian sites of both Early and Late Ceramic Age contexts on the islands of Cuba, Dominican Republic, Puerto Rico, Saint Martin, Guadeloupe, Barbados and Grenada. Chapter Two examines whether there are distinctions in morphology and diets of dogs across space and time in the insular Caribbean, partially aiming to assess whether the canine surrogacy approach (Guiry, 2012) has merit for the region. We compare the diets of dogs from both enamel isotope values (n=81) of carbon ($\delta^{13}C_{en}$), and mobility according to their designation as being reared local or nonlocal to their site of recovery as dictated by their strontium ($^{87}Sr/^{86}Sr$) values. Previous studies of precolumbian Caribbean dog diets and mobility have been conducted by studying enamel isotope values (see Laffoon et al. 2019, 2015), however this is the first study to also incorporate both enamel and collagen values (n=21) of carbon ($\delta^{13}C_{co}$) and nitrogen ($\delta^{15}N$). It also includes a morphometric assessment of two dogs from the site of El Flaco which adds to previous withers height estimations of buried dogs from the Caribbean (see Grouard, Perdikaris, & Debue 2013). We compared five different parameters to assess if there were discernable differences in the isotopic values of dogs which might indicate differences in how they were treated by humans. These parameters are according to whether they were buried or not, their relative antiquity, their location within the Caribbean, whether they were local or nonlocal, and whether they were modified or unmodified bones. This chapter also introduces the use of isotopic dietary mixing models, Food Reconstruction Using Isotopic Transfer Signals (FRUITS) (Fernandes et al., 2014), which was utilized to quantify the relative contribution percentages of C_3 plants, C_4/CAM plants, land animals and marine animals to the diets of four dogs that were found buried at the sites of Morel (n=2) and Cathédrale de Basse-Terre (n=1) in Guadeloupe, and from El Flaco (n=1) in the Dominican Republic.

As this chapter was published as a short report in Latin American Antiquity, the accompanying supplementary information provides a more detailed overview of the cultural history of human-dog relations in the Caribbean and surrounding South American lowlands than could not fit into the published manuscript. The supplementary document also provides the methodology for both withers height estimations of dogs, and FRUITS. This chapter broadly examines temporal and geographic patterns of dog diets and mobility in the precolumbian Caribbean to assess the closest and most commensal relationships Indigenous peoples had with any animal, providing us with an isotopic baseline to enable us to assess human dietary entanglements with other animals that were not domesticated. This chapter also introduces some of the methods which are employed in later chapters, such as morphometric reconstructions of animal

body sizes using regression formulae, isotopic analysis, and FRUITS.

Chapter Three: Coastal-Hinterland Exchange and Garden Hunting Practices Prior to the European Invasion of Hispaniola

This chapter departs from a focus on the isotopic analysis of human-animal interactions, and instead entails a qualitative zooarchaeological analysis of material recovered from the site of El Flaco, excavated between 2013-2016 as part of the ERC-Synergy project, NEXUS-1492. This study entails the qualitative investigation of vertebrate and invertebrate remains recovered from three archaeological units at the site from two earthen mounds: Unit 71 and 72 which were located in an artificial mound immediately to the west of identified housing units, and Unit 69, an earthen mound in the southern part of the excavation area which also contained human burials and an interred dog skull and pelvic bones (Hofman & Hoogland 2015; Keegan & Hofman 2017; Pagán-Jiménez et al. 2020; Shev 2018). All marine invertebrates were identified and quantified during excavation, and all vertebrates were identified with the assistance of Juan N. Almonte Milan, the curator of the vertebrate fossil collection at the Museo de Historia Natural 'Prof. Eugenio de Jesús Marcano' in Santo Domingo. Some of the material identified was analysed isotopically and the results of which are listed in the subsequent chapters. This chapter also includes three new radiocarbon dates and a diachronic study of faunal exploitation from Units 71 and 72 spanning approximately from cal. AD 1278-1401 (median dates).

To contextualize the findings and provide interpretations of the composition of the faunal assemblage, palaeoenvironmental studies from close to the site (Castilla-Beltrán et al., 2018, 2020; Hooghiemstra et al., 2018) and paleoethnobotanical data from the site itself (Pagán-Jiménez et al. 2020) were considered to establish the degree of human impact on the environment due to agricultural practices. Additionally, information was compiled regarding the marine biomes existing close to the site, albeit approximately 20km to the north and west of the settlement beyond the Cordillera Septentrional, which likely acted as formidable barrier restricting ease of access to these coastal resources. This chapter provides new last occurrence dates for some extinct taxa, speculates as to whether resource exchange between this hinterland site and coastal communities was occurring, and theorizes about how the composition of the faunal assemblage, in particularly the high abundance of hutia, would have been impacted by niche construction activities such as slash-and-burn farming, and how the faunal assemblage could reflect garden hunting practices.

Chapter Four: Human and hutia (Isolobodon portoricensis) interactions in pre-Columbian Hispaniola: The isotopic and morphological evidence

The fourth chapter continues with a combination of morphometric and isotopic investigations, examining several endemic animals found at archaeological sites located in the modern-day Dominican Republic to assess if there existed similarities in dietary isotope values with humans and dogs recovered from the site of El Flaco. Bone collagen values of carbon ($\delta^{13}C_{co}$) and nitrogen ($\delta^{15}N$) from seven species across four sites were examined, including from El Flaco (cal. AD 990 – 1452) and El Carril (cal. AD 1030-1520) which are both located in the southern foothills of the Cordillera Septentrional in the northwest, El Cabo de San Rafael (cal. 604-1504) situated along the southeastern coast, and the earlier

dating site of La Entrada (ca. cal. AD 840-900) located along the northern coast. The species examined include edible rat (***Brotomys*** sp.), montane hutia (***Isolobodon montanus***), rhinoceros iguana (***Cylclura cornuta***), Antillean freshwater slider (***Trachemys stejnegeri***), Hispaniolan hutia (***Plagiodontia aedium***) and Puerto Rican hutia (***Isolobodon portoricensis***). One guinea pig (***Cavia porcellus***) mandible was also analyzed, which is one of only four examples of this domesticated animal ever recovered from precolumbian contexts in Hispaniola (LeFebvre & deFrance, 2014). Although only ***Isolobodon portoricensis*** is theorized to have been managed, the inclusion of other mostly herbivorous endemic animals serves in providing isotopic proxies for what a 'wild' diet not directly influenced by humans should look like. All samples were compared to human and dog collagen values from El Flaco that are listed in Chapter Two. A morphometric study of 230 ***I. porotoricensis*** mandibles from El Flaco was also conducted, allowing the body mass of these individuals to be estimated and provide general indications as to their mortality ages, however the relationship between body size and age of this species is unknown due to its extinct status. Chapter Four consists of the first isotopic assessment of human-hutia interactions in Hispaniola and speculates about the form of these interactions.

Chapter Five: Palaeodietary reconstruction of endemic rodents from the precolumbian Dominican Republic: discriminating between wild feeding behaviour from diets linked to human niche construction activities

This chapter studies an extra 31 enamel carbon ($\delta^{13}C_{en}$) values from El Flaco, El Carril and La Entrada of many of the same individual animals from which collagen isotopes were analysed in Chapter Four. We once again employ FRUITS, the isotopic dietary mixing model that was introduced in Chapter Two, to assess the relative contributions of different dietary sources. Enamel and collagen dietary isotope values are compared for four species: ***Brotomys*** sp. (n=5), ***Plagiodontia aedium*** (n=1), ***Cavia porcellus*** (n=1), and ***Isolobodon portoricensis*** (n=24). The gathering of three different isotopic proxies facilitated the input of this data into FRUITS which generated a probabilistic estimation of the percentage contribution of dietary sources to the whole diet of an organism. To enable this, an isotopic 'foodweb' for the Caribbean region was utilized as a regional baseline, with isotopic values for plants and animals from the Caribbean region being incorporated from a variety of sources (Keegan & DeNiro, 1988; Pestle, 2010; Schwarcz et al., 1985; Stokes, 2008; von Fischer & Tieszen, 1995), but altered to reflect the plant species only existing on Hispaniola. From our understanding of their dietary behaviors, hutias and all other analyzed rodents being predominantly herbivorous, all isotopic values pertaining to animal tissues were removed from the isotopic foodweb database. As the established isotopic foodweb only contains domestic species, an additional 79 wild C_3 plant and 40 wild C_4/CAM plant species' isotopic values were included. This allowed us to distinguish between 'wild' and 'domestic' plant food sources, which is a novel application for FRUITS.

We ran three different models: a 2-source model comparing all C_3 versus C_4/CAM plant contributions; a 3-source model comparing C_3, wild C_4/CAM and domestic (maize) C_4/CAM plant contributions and a 4-source model comparing wild C_3, domestic C_3, wild C_4/CAM, and domestic (maize) C_4/CAM plant contributions. Each of these models provides different estimations of source contributions, however all suggest that certain individual hutias likely consumed considerable quantities of domestic C_4/

CAM plants which was most probably maize. This chapter also provides a direct comparison between the outputs of all four models for the guinea pig, the only domesticated animal in this FRUITS study, and one ***Isolobodon portoricensis*** that had particularly elevated carbon values beyond expectation of its natural diet.

Chapter Six: Zooarchaeological and Isotopic Findings from White Marl, Jamaica: Insights on Indigenous Human-Animal Interactions and Evidence for the Management of Jamaican hutias

The final case study again incorporates a zooarchaeological study alongside isotopic analysis to assess whether the management of Jamaican hutias (***Geocapromys brownii***) was occurring at the site of White Marl. This chapter is the result of a collaboration between the University of West Indies (UWI), Mona and Leiden University, in which faunal material was analysed from contexts relating to a human burial recovered during rescue excavations conducted in 2018. Fauna was qualitatively analysed from one excavation unit (U2.12.NE) and was identified with the aid of an in-house reference collection at UWI Mona, while the tooth row lengths of hutia mandibles (n=118) from another two surrounding units were measured in order to estimate their body masses and mortality ages at death (Hopkins, 2008; Wilkins, 2001). This was done to construct a mortality profile that can elucidate modes of human predation or husbandry that affected this hutia population. In addition, isotopic analysis of tooth enamel and bone collagen was conducted on 11 individual mandibles, the results of which were compared to three previously published isotopic values from humans buried at the site (Mickleburgh et al., 2019).

This chapter compares the isotopic values of hutias and humans and speculates about the degrees of commensalism exhibited at the site, examines the whole faunal composition, and by providing three new radiocarbon dates from deposits overlying the human burial, examines the changing modes of faunal exploitation over a period of roughly 150 years. This chapter also provides evidence that might suggest some form of management of hutia was occurring in highlighting examples of healed bone pathologies, examining dietary isotope similarities between humans and hutias, and illustrating a hutia mortality profile comprised mostly of prime-age individuals that is not reminiscent of modern-day trapping activities employed by Jamaican hunters.

The final chapter, ***Chapter Seven: Synthesis and concluding remarks***, provides a discussion of the crucial findings of each chapter and contributes some overarching conclusionary statements regarding the functioning of human-animal relations in the precolumbian Caribbean as evidenced from the case studies. This chapter discusses the minutiae of how isotopic analyses and zooarchaeological approaches can be used in tandem to explore human-animal interactions in the past. It also provides discussion on how these interactions may have been dictated by human niche construction practices and speculates as to how Amerindian ontologies may relate to these practices observed in the archaeological record. This chapter culminates in providing scope for future studies using these techniques, elucidating research directions for examining human-animal interactions broadly, and pre-1492 animal management practices in the Caribbean more specifically.

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