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Canoe societies in the Caribbean: Ethnography, archaeology, and ecology of precolonial canoe manufacturing and voyaging

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A B S T R A C T

In the Caribbean, there is little direct evidence of canoes in the archaeological record, while inter-island connectivity is ubiquitous in archaeological explanations. This contradiction suggests that aspects of society related to canoe manufacturing and voyaging have tended to be under-represented in our interpretations. This paper aims to contribute to correcting this under-representation and highlight the canoe as the foundation of precolonial infrastructure by examining the ecology of canoe-specific resources using habitat suitability modeling along with diverse lines of evidence from archaeological findings, ethnohistoric accounts, and experimental ethnoarchaeology. The synthesis of these diverse lines of evidence leads to a discussion of some implications that may follow from adopting a more canoe-centric perspective on the archaeological record.

1. Introduction

In the insular Caribbean, there is little direct archaeological evidence for canoes (but see Cooper, 2007; Palmer, 1989). However, the construction and voyaging of canoes was directly responsible for supporting population dispersals into the Caribbean from South and Central America, continuing participation in interisland and mainland society, and all ensuing maritime adaptations. This contradiction may contribute to an under-representation of the processes surrounding the manufacturing and voyaging of canoes and their impact on the structure of settlement patterns, economic interactions, and socio-political configurations. Constellations of interrelated social realities were entangled in the manufacturing, maintaining, and voyaging of canoes (Moreau, 1991). These processes shaped the internal structure of communities, as well as the mode and manner of community interaction; and are embedded in conventional archaeological narratives in the Caribbean, particularly those that center on mobility and exchange. Beyond the obvious necessity of watercraft for interisland exchange and resource acquisition, examining social life from the perspective of a canoe infrastructure reveals that they were powerful structuring agents in maritime-focused societies, influencing cosmology, defining gender relations, supporting military campaigns, and requiring investments of communal labor. As a paramount organizing dimension of society, critical economic, sociopolitical, ritual, and symbolic associations were all implicated in the making and using of canoes.

As an early point of contact between European and Amerindian societies, Whitehead (1995a) describes the Caribbean region as the laboratory in which modern anthropology developed. However, the remarkably fragile archaeological record in many parts of the dynamic insular Antilles has been impacted severely due to high-energy weather systems, a lack of protective legislation, and the high coincidence of coastal archaeological sites and coastal development projects (Righter and Siegel, 2011). This can constrain the ability to answer questions related to canoe-related processes in precolonial contexts, as evident in the relative lack of indigenous canoes recovered in the Caribbean (compared to the remarkably preserved canoes from freshwater contexts in Florida and the Eastern Woodlands of North America (Newsom and Purdy, 1990; Ruhl and Purdy, 2005; Wheeler et al., 2003)). Given the size and prominence of the canoes reported throughout European conquest (e.g., Breton, 1665; Columbus, 1906; Du Tertre, 1667), along with insights from ethnographic research (Honychurch, 1997; Taylor, 1938), canoe manufacturing clearly represented an enormous investment of social labor. These communal projects likely involved kin and non-kin social groups, much like elaborate architectural projects elsewhere (Trigger, 1990), but without leaving equivalent traces in the archaeological record.

This paper will address these issues by integrating evidence from ethnography, historical accounts, archaeology, and ecological habitat suitability modeling to analyze the technical, sociopolitical, religious, and ceremonial aspects of canoe manufacturing and voyaging. A discussion of the ecology of trees that can and have been used to build canoes, as well as other resources involved in the production of canoes, is critical to understanding canoe manufacturing. Modeling the ecological variables associated with a canoe-based infrastructure opens

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avenues to evaluate otherwise invisible processes when investigating precolonial canoe societies in the Caribbean. Ethnoarchaeological research conducted with modern Kalinago canoe builders in Dominica augments the ecological analysis, and provides insight into ethnohistoric descriptions, leading to a holistic understanding of precolonial canoe manufacturing and voyaging. Finally, using Dominica as a case study, these analyses are applied to the interpretation of archaeological sites and settlement patterns. By synthesizing diverse sources of information in a theoretically grounded framework, this work is intended to have broad applicability to the study of coastal and insular regions worldwide, but primarily wherever watercraft played a vital role in structuring society.

2. Cultural and historical context of Caribbean canoes

> "The concept of the canoe comes out of the [Amazon] River and went up to the Islands."
> —Aragorn Dick-Read (Jarecki, 2000)

The movement of Arawakan speaking peoples over the last 5000–6000 years, and expansion from a heartland in the Amazon (Clement et al., 2015; Heckenberger and Neves, 2009; Hill and Santos-Granero, 2002; Hill, 2009, 2013; Lathrap, 1972), brought agricultural and ceramic-making villagers into the insular Caribbean (Fig. 1) by approximately 2500 years ago (Hofman et al., 2007, 2010, 2011; Hofman and Hoogland, 2011; Rouse, 1992; Shearn, 2018; Wilson, 2007). During the following centuries, insular populations continued adjusting from riverine to maritime lifeways and interacted in regional polities until the time of European arrival and eventual conquest. Evidence from archaeology (e.g., Heckenberger and Petersen, 1995), historical linguistics (e.g., Hoff, 1995), and genetics (e.g., Schroeder et al., 2018) converge to support the Arawakan Diaspora model of Ceramic Age Caribbean population movements, featuring continuous interaction between mainland and insular populations varying through time in nature, frequency, and direction. While it takes moments to describe this, population dispersals in the Caribbean happened over hundreds of years, over generations, and required the construction and voyaging of countless dugout canoes.

Following the chronology originally established by Rouse (1951, 1986, 1992) and refined by Petersen et al. (2004), the periods of Caribbean history are known widely as the Preceramic, or Archaic period (~4000/5000 BCE–400 BCE); the Early Ceramic Age A (400 BCE–CE 400); Early Ceramic Age B (CE 400–600/800); Late Ceramic Age A (CE 600/800–1200/1300); and Late Ceramic Age B (CE 1200/1300–1492). Following this precolonial period were successive European colonial exploits that can be further subdivided into early contact and exploration, leading up to permanent colonization efforts in CE 1625 (Hulme and Whitehead, 1992). A period of missionary-backed territorial expansion, erupting in open war and the forced migration of the Garifuna in CE 1790, left the Kalinago of Dominica as one of the few remaining Amerindian populations in the insular Caribbean who continue to manufacture traditional dugout canoes. Although the relationship between earlier Archaic settlers and later population dispersals into the Caribbean has undergone revision (Hofman et al., 2018), this paper is primarily concerned with the Ceramic Age and the maritime-adapted riparian agriculturalists who migrated into the Caribbean in dugout canoes, and whose descendants paddled out in very similar dugout canoes to traffic with Columbus and his fleet nearly two millennia later.

During the Early Ceramic Age, finely made stone beads and pendants as well as flaked and groundstone artifacts made from island-specific materials circulated over great distances, often allowing for provenance identifications (Cody, 1991, 1993; Knippenberg, 2006). The craft specialization exhibited by the bead manufacturing sites at Pearls on Grenada, Trants on Montserrat, Salt River on St. Croix, Sorce on Vieques, and Punta Candelero on Puerto Rico, presumably was

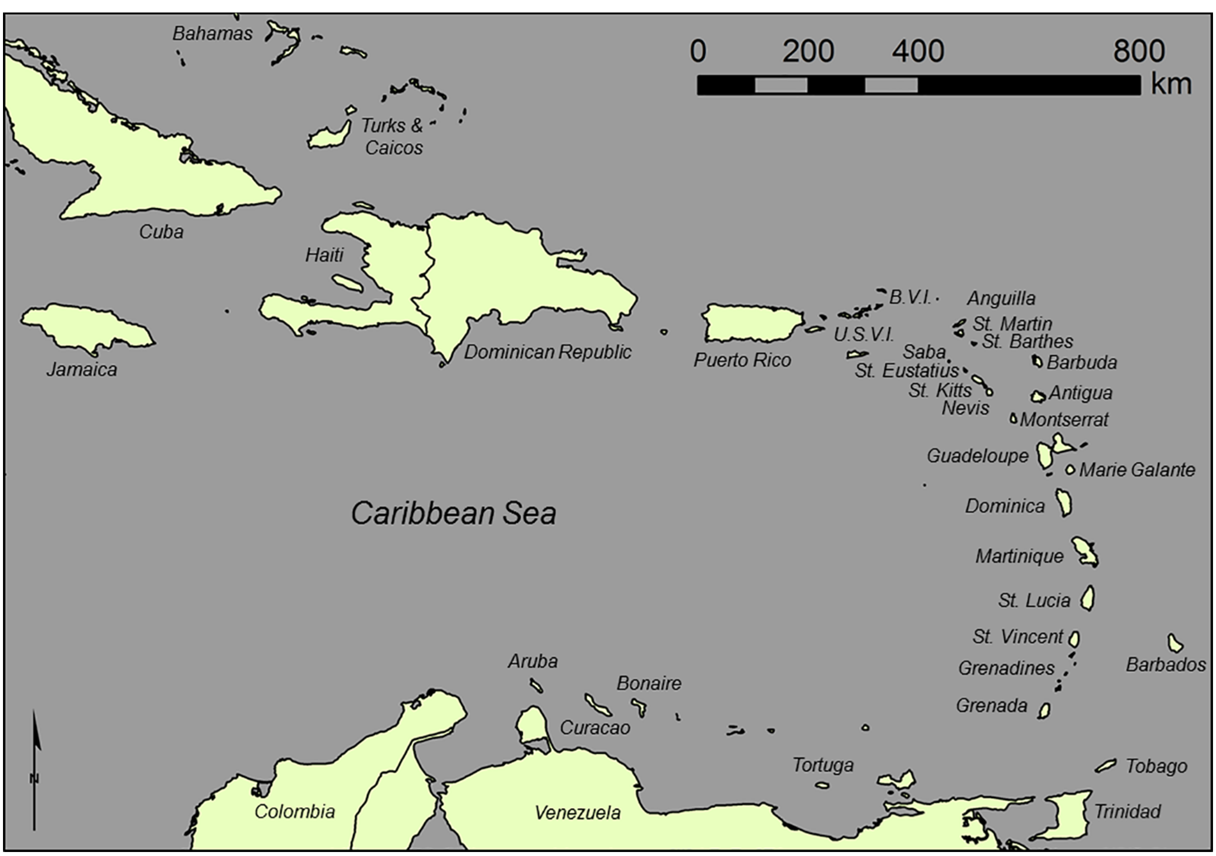

Fig. 1. Map of Caribbean Region.

supported by a corresponding specialization in the manufacturing of canoes. Preceramic and early Ceramic Age populations quickly identified and exploited high-quality chert from Antigua, which then circulated throughout the archipelago (Knippenberg, 2006). For example, Cherry et al. (2012) report that the Archaic period Upper Blakes site on Montserrat (ca. 2800–2600 cal BC) contained primarily Long Island Antiguan chert. Bartone and Crock (1991) report that at Trants, also on Montserrat and one of the earliest Ceramic Age sites in the Caribbean, over 80% of the 2347 lithic artifacts analyzed came from Antigua, with Antiguan chert recovered from even the deepest stratigraphic layers. On islands such as Anguilla, where exotic lithic material dominates archaeological assemblages (Crock, 2000), a reconstruction of exchange networks and the broader interisland sociopolitical contexts in which these industries existed presupposes an established framework of a canoe-based infrastructure (Crock and Petersen, 2004). Crock found that, by around AD 900, populations on Anguilla were four to eight times larger than on other nearby islands and were importing essential lithic resources (Knippenberg, 2006) and pottery containing aplastic temper of volcanic origin (Crock et al., 2008). All this commerce relied upon extensive canoe voyaging, but Anguilla and similar small limestone islands often lack the environmental conditions required (such as high elevations with developed soils and annual precipitation levels) to support the growth of trees used to manufacture canoes, suggesting that they were also dependent upon canoe-specific resources abroad.

Indirect evidence indicates the centrality of seafaring canoes to the networked, highly dynamic social conditions of the Ceramic Age, and a canoe-based infrastructure is implicitly assumed to have existed in virtually all archaeological research in the Caribbean (e.g., Altes, 2011; Hofman et al., 2014; Laffoon and de Vos, 2011; Mol, 2007). Recently available isotopic data confirms what artifactual evidence for interisland interactivity had pointed to, that the circulation of objects implied the movement of people (Booden et al., 2008; Laffoon and de Vos, 2011). Additionally, an influx of South and Central American resources were introduced to the insular Caribbean in canoes during the Archaic and Ceramic Age (Hofman et al., 2018; Pagán-Jiménez, 2013), including numerous house garden trees such as sea grape (*Coccoloba* sp.), jagua (*Genipa americana*), and corozo palm (Arecaceae); cultivars such as maize (*Zea mays*), achiote (*Bixa orellena*), and common bean (*Phaseolus* sp.); root crops such as arrowroot (*Marantaceae* sp.), manioc (*Manihot esculenta*), and sweet potato (*Ipomoea batatas)* (Newsom, 1993, 2016; Pagán-Jiménez, 2013; Reid, 2018; Sauer, 1966); as well as several living faunal species such as agouti (*Dasyprocta* sp.), paca (*Agouti paca*), Curaçao deer (*Odocoileus gymnotus*), South American brocket (*Mazama gouazoubira*), and domesticated guinea pig (*Cavia porcellus*) (Giovas et al., 2012; Giovas, 2017, 2018; Haviser, 1987; Kimura et al., 2016). Beyond the role of transporting people and resources, indirect evidence for using canoes comes from zooarchaeological studies that indicate a dynamic maritime focus, transitioning from reef fish exploitation in the Early Ceramic Age to increasing reliance upon pelagic fish for later Ceramic Age societies throughout the Caribbean (Carder and Crock, 2012; Steadman and Jones, 2006; Watters, 1998; Wing and Reitz, 1982; Wing, 1994; Wing and Wing, 2001).

Numerous studies have focused more directly on canoes in the Caribbean, coinciding in the last two decades with a resurgence of indigenous canoe manufacturing in the Windward Islands (Honychurch, 1997). McKusick (1960) and Morice (1958) were among the first scholars to analyze Caribbean canoes in the 1950s and 1960s. Fitzpatrick (2013) and Bérard et al. (2016b) recently reviewed ethnohistoric accounts from the colonial encounter that contain kernels of insight into ways in which indigenous people made and used different types of watercraft. Fitzpatrick (2013) compared the voyaging capabilities of Ceramic Age canoes to seafaring vessels in the South Pacific, which often included both outriggers and sails to facilitate long-distance, open sea voyaging, whereas Caribbean canoes implemented different nautical technologies to traverse a different seascape. Bérard et al. (2016b) used ethnohistoric accounts to reconstruct essential aspects of canoe manufacturing processes and delineated three types of vessels that comprised the Kalinago "fleet" during the Colonial Period. The "flagship" of the Kalinago fleet, the *kanawa* represents the largest class of seafaring canoes, ranging from ~7.5 to 18 m (25–60 ft) in length and up. These were constructed by adding *bordage*, long planks attached to the sides of the dugout base to increase the freeboard, the height that the sides of canoe rise above the waterline (Bérard et al., 2016b). The French name for these complexly designed canoes was *pirogue*, which is likely a variant of *piragua*, a word the natives of Hispaniola and Cuba used for large canoes or warships (Arango, 1992). The smaller canoe, or *kuliala*, was generally between 3 and 5 m (10–16 ft) but included all canoes less than 7.5 m (25 ft) constructed entirely from a single dugout tree. These were not intended for open-sea voyaging and smaller vessels could be piloted by a single individual. Also documented were rafts, or *boúlali*, used only for near shore fishing. Bérard et al. (2016b:140) further concluded that the pirogues that were affixed with sails were not indigenous, but resulted from the rapid adoption of European sailing technology. In contrast, Moreau (1991) and Bérard et al. (2016b) argue that the early ethnohistoric accounts of pirogues support the precolonial antiquity of attaching *bordage* to a dugout base. This indigenous design element is what distinguished the larger pirogues from the smaller canoes by enhancing the ability to undertake open-sea voyages.

Additional avenues of research into Caribbean canoe voyaging utilize computer simulations and GIS modeling, such as those employed by Callaghan (1993, 1999, 2001) to evaluate the impacts of wind and currents on hypothesized routes of colonization from various mainland regions of the circum-Caribbean. Although no direct evidence exists about the watercraft utilized during the initial Archaic migrations into the Caribbean, computer simulations show that canoes could have accomplished colonization from any possible location, whereas rafts had a very low probability of making landfall without prior knowledge of the islands. Cooper (2010) used GIS tools to model routes connecting sites across the sea in the Greater Antilles, and Altes (2011) modeled ocean currents to assess the routes connecting Florida to the South American mainland. GIS modeling has also been used to evaluate possible sea routes connecting interisland sites by least-cost paths throughout the region (Slayton, 2018). Another use of computer modeling employed visibility studies to analyze a variety of contexts in Guadeloupe including viewsheds connecting sites to other sites, as well as to various canoe positions along the seascape (Brughmans et al., 2017). An analysis of faunal remains from sites together with underwater ecology and bathymetry was used to model the marine environments most readily exploitable to account for the faunal assemblages at archaeological sites in Anguilla (Crock et al., 2017). These studies hint at the importance of canoes, but a direct theoretical treatment of the role canoes played in establishing patterns of interaction is still needed to elucidate the role of canoes in the absence of direct archaeological evidence.

3. Canoe societies: Building theory around building canoes

> "Seacraft… are not just machines for crossing water. They are cultural objects as well. Access to them will determine the limits of experience for any islander, will establish channels of communication, will define isolation, and can also act as an instrument of power or coercion" (Broodbank, 2000:96).

The description of Ceramic Age people as *maritime societies*, while not inaccurate, is inadequate to capture the full scope of the labor investment, resource management, and plant-based ecological knowledge involved in the terrestrial process of manufacturing canoes. Describing these communities as *canoe societies* helps to correct this, but what would it mean to be a *canoe society*? Like describing the United States as a *car culture*, it has utility by highlighting the dominant feature of a societies' infrastructure, influencing all other aspects of social life. The extent to which the dominant mode of transportation determines access to resources and social status is an empirical question, and in certain societies, modes of transportation take on special significance. For example, in the United States, the organization of every settlement is dictated by networks of roads. The *need* to possess a car is perceived by many to be fundamental to American life, while both gender identity and social status are frequently associated symbolically with aspects of car ownership (Miller, 2001).

In anthropological and archaeological research, the term *'house society'* has been elevated from convenient label to theoretical framework by focusing on what the term offers; a processual rather than typological perspective on how architectural units served to organize *actual* societies. Certain societies were observed to organize production and politics in units defined as 'houses' in both etic and emic terms. These were cultural as well as architectural constructs that served to integrate and, at times, subvert rules of kinship and affinity, meaning that, in house societies, *'family'* could not be understood by the rules governing kinship or affinity alone (Gillespie, 2000; Lévi-Strauss, 1987; Lévi-Strauss, 1983). In the Caribbean, canoes likely served this structuring role in society, bridging kinship and affinal ties (e.g., sons-in-law working on their father-in-law's canoes) in a lifetime of constructing and voyaging canoes in specific social groups, making possible the interactions required for the biological, social, and material reproduction of society. Additional examples of watercraft playing a central role in the construction of social identities can be found in archaeological cases such as the Chumash of California (Arnold, 1995) and the Cyclades Islands in the Aegean Sea (Broodbank, 1989, 1993), as well as in modern fishing communities documented ethnographically in Venezuela (Wilbert, 1977), Martinique (Price, 1966), and New England (Miller and Van Maanen, 1982).

In developing an "archaeology of the sea" sensitive to the social implications of seacraft and potentially unrecoverable gaps in the terrestrial archaeological record, Broodbank (2000:34) argues that "models need to be built for how the sea was used, by whom, for what objectives, over what distance, at what cost, and how often." Similarly, in her investigation of Chumash canoe societies in California, Arnold (1995:744) outlines four conditions for identifying an increased importance of seacraft in structuring sociopolitical relations. The first is the capacity of the watercraft to support regular and distant movements of substantial cargo and/or passenger loads. The second is the degree to which difficulty and expense in building watercraft restrict who may make and own them. The third is the degree to which boats permit intensified exploitation of the society's most important food and non-food resources. Finally, she considers the degree to which owners of watercraft can become pivotal in their society's political economy by positioning themselves to broker information, highly ranked (elite) foods, trade goods, and/or access to the material symbols of wealth and status through watercraft use. According to Arnold (1995:734), "analyses must illuminate linkages between elites and producers of the [watercraft] technology, determine the spatial distribution of production, and establish who owned the technology and how it was used." Canoe societies in the Caribbean seem to satisfy these criteria, and the role of canoe building was integral to the negotiation of power relationships within communities while simultaneously structuring the avenues through which these relationships were experienced among regionally integrated communities. The building and voyaging of canoes linked people to a *particular kind* of interaction with each other and with the regional community (Harris, 2014:82). This interactivity was defined minimally by the labor relationships surrounding the construction and voyaging of canoes, practices through which community bonds and values were negotiated and reproduced among communities who worked together to build and voyage canoes, but also structured the experience of regional interactions, whether consisting of economic exchanges, marriage alliances, or violent raids. Only those who could successfully manage production and coordinate teams of paddlers were able to control theirs and others participation in such regional interactions (Bérard et al., 2016b).

Processes involved in canoe building and voyaging involve potentially diverse kinds of social relationships in terms of group identity, the teams of builders and paddlers working together; gender identity, the male domination over canoe making, voyaging, and raiding, along with the rites of passage implied in the transmission of esoteric knowledge in male-gendered spaces, and even a male-dialect, apart from women; and captainship, the control over when a canoe is made and launched, along with the political and material capital required to marshal and sponsor communal labor. Canoes as cultural objects achieved an elevated significance as the materialization of these overlapping modalities. A straightforward relationship among group identity, canoe ownership, canoe captainship, and the elite sponsorship required to support the production of canoes should not be assumed, but these relationships require investigation.

As noted by Wilson (1986), the class of large elaborate seafaring canoes are widely viewed in ethnohistoric accounts as symbols of status and rank. Such colonial accounts lead practically to the hypothesis that control over canoe manufacturing and captaining interisland voyages, while promoting community integration, supported sociopolitical rivalry and inter-community conflict in the negotiation of regional status hierarchies. Du Tertre (1667:32)—a French missionary who resided in Guadeloupe on and off between 1640 and 1657—remarked on the sociopolitical nature of canoe navigation: "the one who assumes the responsibility for a trip is called a captain, and he commands the pirogue. He gives orders for everything necessary for the embarkation, although he is not more highly considered by the others because of his role." The term *Oúboutou* comes from Breton's dictionary and signifies the *captain* of a canoe (Breton, 1665:417). In the Greater Antilles, Columbus linked canoe ownership more tightly to political identity and power, noting that Caciques in Jamaica each possessed their own great canoe, specifically for their service, which was a source of pride and prestige ([Bernáldez, 1869] Columbus, 2016:124). These accounts describe the relationship between canoes, paddling teams, and captainship, providing an interpretation of the social significance of canoes filtered through the colonial view of events. Regardless of the accuracy of colonial accounts, the construction and voyaging of canoes, along with the resource management and coordination involved, requiring the elite-sponsored mobilization of communal labor to construct and crew large vessels. In the Lesser Antilles, communal labor projects such as ceremonial plazas are rare (Torres et al., 2014; Curet, 2003), but canoe making represents a similar public project requiring substantial investments of labor. Canoes functioned as instruments of mediation within and between communities, and the elites who sponsored their manufacture and captained their voyages as agents of mediation (Trouillot, 1988), controlling the avenues through which communities interacted, and the means of community integration, permitting regional systems of resource acquisition, exchange, intermarriage, and warfare.

There is ethnohistoric and ethnographic evidence in the circum-Caribbean for a highly gendered division of labor, a gendered separation of space in the built environment, along with distinct modes of speech for males and females. The male register of this Arawakan language was used to discuss politics, plan raids, and facilitate inter-island exchanges, all of which connect the male dialect to canoes (Cody, 1995; Hoff, 1995; Holdren, 1998; Whitehead, 1995b). The social lives of the individuals linked as paddlers and as military compatriots became connected to the social life of the canoe, and the social organization of canoe manufacturing and voyaging were pillars of society at large. The sets of practices surrounding canoes serve to relate social organization at the smallest scales (i.e., one group of people building a canoe) to the grandest scales (i.e., entire communities intertwined across vast distances in complex social networks). Given the likelihood that the organization of these networks required exogamous marriage alliances among regional allies (Wilson, 1986) as well as enemies conquered in inter-island raids (Cody, 1995), the biological reproduction of society rested upon the success of canoe voyages.

The system of exogamous marriage was referenced in a body of myths recorded ethnographically and historically from the region that situate the acquisition of suitable marriage partners within the narrative context of a canoe journey (Pané, 1999; Stevens-Arroyo, 2006). Lévi-Strauss (1990) identified two categories of canoe trips, vertical and horizontal, which appear repeatedly in a suite of structurally related South American myths. The vertical canoe trips in which celestial entities such as the sun and moon voyage between the heavens and earth tend to represent the juxtaposition between the cosmos and the worldly plane, between the sacred and the profane, and between mythological cosmic time and mundane earthly time. The horizontal canoe journeys set entirely in the worldly plane tended to represent sociological principles and kinship logic through a geographic analogy, functioning in myths to "remove the hero from the too-close woman…, or to bring him closer to the remote woman…, or to do both at the same time" (Lévi-Strauss, 1990:153). This linkage among canoes, exogamous marriage, mythology, and cosmology, represents a cluster of integrated cultural ideals materialized in, and reinforced by, the manufacturing and voyaging of canoes.

To develop a holistic perspective on canoe societies in the Caribbean, sources of cultural preference such as those found in religion and mythology must be considered in tandem with ecological and archaeological evidence. The goal here is to synthesize the sociopolitical dynamics, technical procedures, religious significance, and environmental variables involved in canoe manufacturing to propose new ways of looking at familiar archaeological patterns through the lens of canoes. However, the environment did not consist of randomly distributed natural resources, but rather was shaped by millennia of anthropogenic impacts (Cartwright, 2018) and perceived in mythical terms. The environment cannot be reduced to a map of resources; it was a sacred geography in which certain locales and specifically gendered activities were imbued with special meaning through the coalescence of social, political, economic, and religious significance.

4. Mapping canoe resources

Conventional geographies tend to classify continental islands of the southern Caribbean together, the Lesser Antilles are often divided into the Windward and Leeward Islands, and the Bahamian archipelago as a group situated to the north of the Greater Antilles. This regional grouping of the islands masks a complex distribution of varied biomes ranging from the extremes of aridity and heat on the sun-blasted karst landscape of the limestone islands to the eternally drenched and often cloud-covered elfin rainforests of the volcanic islands (Fitzpatrick, 2015). In some cases, both extremes can be found on a single island. The ecological diversity and patchiness of the Caribbean region are critical for understanding the types of environments that support, or fail to support, the resources required to build canoes. Ecological niche models for a variety of potential canoe trees were developed to evaluate this variability. These models are intended to augment archaeological analyses of interisland interactivity by contextualizing networks of connectivity within the constraints and affordances of the complex and variegated island setting with respect to canoe-specific resources. The massive trees required to manufacture seafaring dugout canoes thrive in a restricted range of habitats in the Caribbean, but canoes are assumed to be ubiquitous across the islands. This juxtaposition raises the possibility that canoes themselves were the objects of exchange, acquired through interisland alliances, or constructed during voyages to other islands (Southey, 1827:110).

Habitat suitability modeling, known variously as ecological niche models (ENM) and species distribution models (SDM), is a method used commonly in ecological sciences, and open-source tools have become widely available to conduct these analyses (Ghisla et al., 2012). For this study, models were constructed in the open-source software package MaxEnt (Phillips et al., 2018), utilizing the Maximum Entropy method, which was selected due to its suitability for presence-only species occurrence data. The analysis compares the known occurrence locations of a species to a set of environmental variables to determine which variables contribute significantly to the observed species distribution. MaxEnt works by "[minimizing] the relative entropy between two probability densities (one estimated from the presence data and one, from the landscape) defined in covariate space" (Elith et al., 2011:43). A suitability index between 0.0 and 1.0 is then projected across a geographic range to predict potentially suitable habitats for the species in question. ArcGIS and SDMtoolbox (Brown et al., 2017) were used to prepare the data by spatially rarifying occurrences, analyzing climatic variables for spatial correlation, and conducting principal component analysis to estimate climate heterogeneity, one of the inputs employed in MaxEnt calculations. Climate data (19 bioclimatic variables at 30-arcsecond resolution) was obtained from WorldClim version 2 (Fick and Hijmans, 2017). The bioclimatic variables were derived from data recorded between 1970 and 2000 and may not be reflective of climatic variation in the intervening millennia but are assumed to be near enough to develop coarse-grained representative models. These were tested for strong spatial correlation using SDMtoolbox, and nine non-correlated variables were selected for inclusion in the model: annual mean temperature, mean diurnal range, temperature seasonality, annual temperature range, annual precipitation, precipitation seasonality, precipitation of driest quarter, precipitation of warmest quarter, and precipitation of coldest quarter. Occurrence data obtained from the Global Biodiversity Information Facility was spatially rarified to reduce sampling bias. The ENM results for the most relevant species are presented below along with a discussion of their physical properties, environmental requirements, and cultural significance (Fig. 2).

4.1. Canoe trees

> "Near one river they saw a canoe dug out of a single tree, 95 *palmos* long [~70 ft], and capable of carrying 150 persons. It was most beautiful… It is no wonder for there are in that island very thick and very long and tall fragrant red cedars and commonly all their canoes are made from these valuable trees."
>
> —Las Casas' comment on Columbus' journal entry (Columbus, 1906:162)

The attributes that characterize a *good* canoe tree are its height (specifically the interval that is straight and clear of limbs) and diameter potential; density, which effects workability and durability; resistance to marine borers (mollusks and crustaceans that eat and bore into wood); but also esoteric qualities such as mythological significance and the ability to dance in the breeze (Saunders and Gray, 1996). Mahoganies (Meliaceae) such as *Swietenia mahagoni* and *Cedrela odorata* (see Table 1), along with the Mallow family (Malvaceae) such as *Ceiba pentandra*, would all be suitable for canoe manufacture (Fitzpatrick, 2013). In Dominica, modern Kalinago utilize the gommier (*Dacryodes excelsa*) from the Bursera family (Burseraceae) to manufacture canoes. This was the primary tree that was exploited for canoes in the early 20th century in Dominica (Taylor, 1938) and a fragment of a gommier canoe that washed on the shore of Mona Island was observed in 1953 (Little and Wadsworth, 1964).

Gommier derives its name from the gum-like amber copal it produces, which is common to many trees of the Bursera family and has been "widely employed for torches, as incense in religious ceremonies, to calk boats, and for medicinal purposes" (Little and Wadsworth, 1964:238). The canoe calk was made by boiling the copal from the gommier tree together with shark oil and mixing with dry cotton lint or plantain straw (Taylor, 1938:136, 142). Gommier grows close to 40 m in height, but only under specific ecological conditions, thriving on the slopes and ridgetops of highland rainforest environments (Basnet, 1992; Longwood, 1971). South of Puerto Rico (where the tree is known as tabonuco), gommier can only be found growing on eight islands in the Lesser Antilles: St. Kitts, Montserrat, Guadeloupe, Dominica,

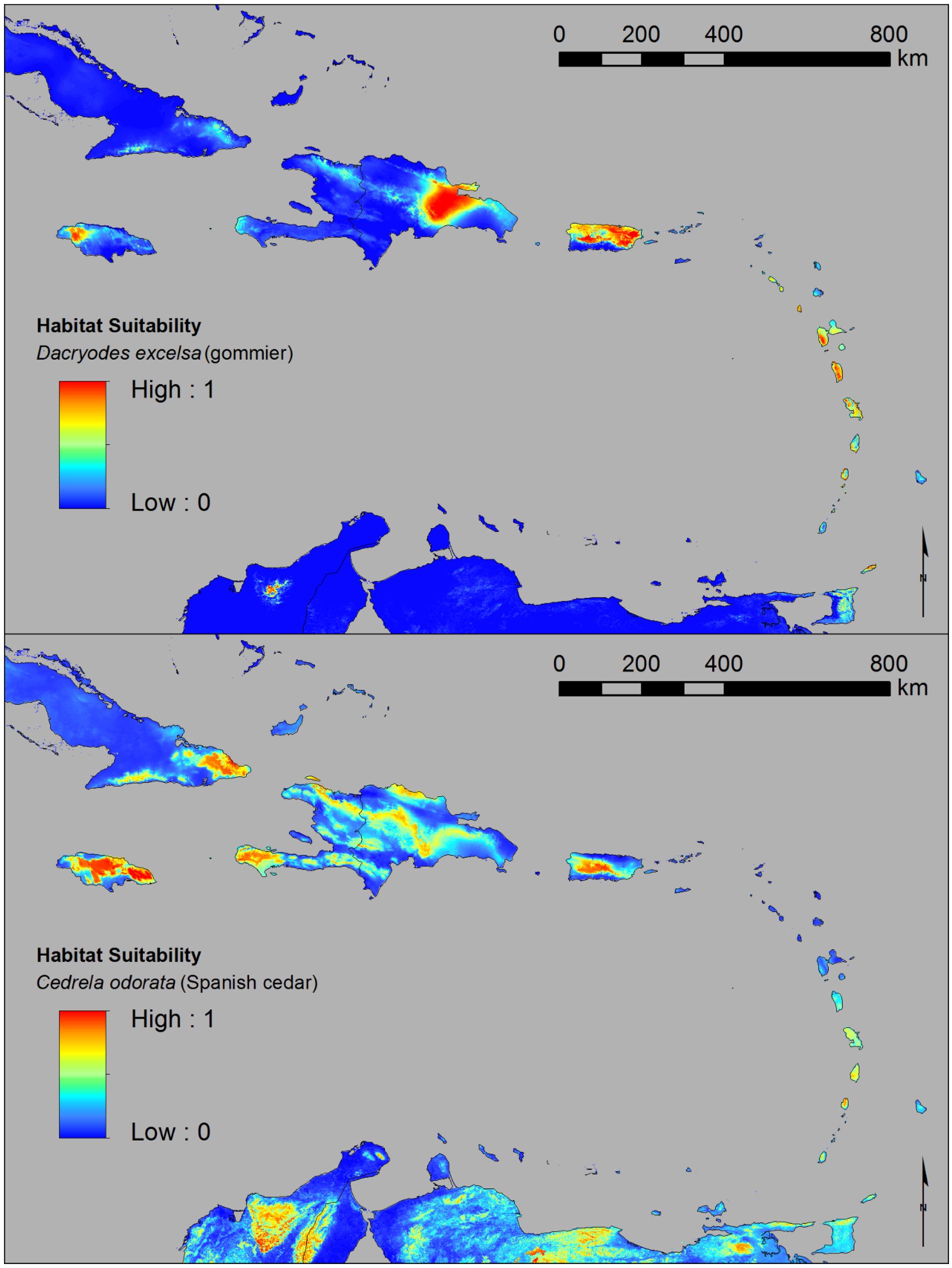

Fig. 2. Ecological Niche Models for two of the most typical canoe trees, *Dacryodes excelsa* (gommier) and *Cedrela odorata* (Spanish cedar).

Martinique, St. Lucia, St. Vincent, and Grenada (Lugo and Wadsworth, 1990). Furthermore, the presence of gommier stabilizes rainforest structure, providing resilience to hurricanes and heavy rainfall, and giving rise to semi-permanent gommier patches on these islands (Lugo et al., 1981). Gommier exhibits a low resistance to marine borers (Longwood, 1971), so the durability of canoes manufactured from gommier may have been enhanced by the application of a waterproof coating. The conditions that foster the growth of these massive trees are rarely found in the mostly low-elevation limestone islands of the Bahamas and Leeward Islands. During the early Colonial Period, it was noted that residents of the arid island of Santa Cruz (St. Croix) would travel to Puerto Rico, where the wetter, high-elevation biomes provided habitats suitable for canoe trees (Cody, 1995; Southey, 1827:110).

Cedrela odorata, commonly known as Spanish or red cedar, belongs to the mahogany family and grows in the forests of the tropics and subtropics in well-drained soils. *Cedrela odorata* is referred to in Kalinago as *ouboüeri* and is known from ethnohistoric accounts to be used to manufacture canoes (Bérard et al., 2016b; Breton, 1665; Columbus, 1992; Moreau, 1991; Taylor, 1938). A fragment of a cedar canoe was recovered in association with burials in a cave context in Jamaica (Flower, 1895), and a cedar paddle was recovered from Mores Island in the Bahamas (de Booy, 1913). The ENM for *Cedrela odorata* shows that suitable habitats exist throughout the Windward Islands and in a patchy distribution throughout the Greater Antilles, but that the Leeward Islands and the Bahamas, as well as much of central and western Cuba lack suitable habitats (Fig. 2). These results suggest that the cedar paddle and canoe fragment recovered in the Bahamas may have originated elsewhere, such as Hispaniola or eastern Cuba. Taylor (1938) and Morice (1958) suggest that *Cedrela odorata* was used more commonly during precolonial and protohistoric periods, but that gommier has replaced cedar as the tree of choice for canoe manufacturing in the Caribbean. This diachronic pattern may be attributable to either changes in the distribution and availability of these trees (i.e., overharvesting), or to the increased harvestability of gommier with the addition European technologies.

Ceiba pentandra, known commonly as kapok or silk-cotton tree,

Table 1
Growth characteristics of trees possibly used for canoe manufacture in the Caribbean (Burns and Honkala, 1990; Chudnoff, 1984; Little and Wadsworth, 1964; Longwood, 1971; Orwa et al., 2009).

Species	Common Name	Elevation (m)	Precipitation Range (mm/yr)	Temperature Range (°C)	Max. Height (m)	Max. Diameter (cm)	Bending Strength (psi)*	Specific Gravity
Dacryodes excelsa	gommier, tabonuco	200–900	2000–4000	21–25	40	180	13.030	0.53
Cedrela odorata	Spanish cedar, red cedar	–	1200–2400	23–26	40	250	11.530	0.45
Ceiba pentandra	kapok, silk-cotton	0–900	750–3000	18–38	70	250	4.330	0.23
Swietenia mahagoni	West Indian mahogany, caoba	0–1500	750–2500	20–28	30+	60	11.590	0.7–0.8
Hymenaea courbaril	algarrobo, West Indian locust	Ridges, high slopes	850–2500	–	40	150	19.400	0.7
Tabebuia heterophylla	white cedar, roble	–	1000–2500	16–31	18	60	13.780	0.58
Calophyllum brasiliense	Santa Maria	0–150	1500–2500	~25	25**	180	14.640	0.55
Talipariti tiliaceum	sea hibiscus, mahoe	0–800	900–2500	24–41	10	15	–	0.6

* Based on 2 in standard, measured at 12% moisture content (Chudnoff, 1984).
** Santa Maria can achieve heights of 45 m, but with the extensive canopy, generally only ~25 m of the bole is usable.

ranks alongside gommier as among the tallest trees that grow in the Caribbean (Little and Wadsworth, 1964). In the Windward Islands, gommier is currently favored for canoe manufacture, but some report that in the Greater Antilles, *Ceiba pentandra*, the national tree of Puerto Rico, was used to make larger canoes (Little and Wadsworth, 1964; Morice, 1958; Sauer, 1966). Ceiba trees grow massive straight boles that seem ideal for canoe manufacture and are supported by sprawling buttresses at the base. They require deep soils and can thrive in both moist and dry forests. Although ceiba achieves some of the grandest heights of any tree in the Antilles, it is a low-density wood with thin-walled fibers, low bending strength, and poor resistance to marine borers, so additional framing and surface treatments may have been required for the manufacture of ceiba canoes.

Ceiba pentandra is a spiritually significant tree in Caribbean religions and was identified by Saunders and Gray (1996) as a wood used to make *zemí* idols in Jamaica. Hodge and Taylor (1957) note that *Ceiba pentandra* is believed by the Kalinago to house spirits that would become angered if disturbed. Taboos were observed when dealing with this tree, but when the tree sheds from March to May, the spirits are thought to be absent, and it can be felled safely during this period. Similar attitudes toward *Ceiba pentandra* seem to be typical across Amazonian and circum-Caribbean belief systems, perhaps due to its characteristic barbed appearance, equating its spikes to magical darts employed by shamans (Peter G. Roe, personal communication, 2019). For example, the Shipibo view it as the “world tree,” granting it a similar reverence that Catholics have for cathedrals (Roe, 1982; Peter G. Roe, personal communication, 2019; Saunders and Gray, 1996). These factors, along with its inferior strength characteristics and low specific gravity (Table 1), reduce the likelihood that this tree would be used to build canoes.

Hymenaea courbaril (algarrobo, West Indian locust) belongs to the Fabaceae or Leguminosae family and is notable for producing a thick bark that is used widely for the manufacture of river canoes in South America (Lévi-Strauss, 1990; Little and Wadsworth, 1964). The tree is called *Darina* in some Arawakan languages (Bennett, 1994), which is reminiscent of the word *Dauarani*, the “Mother of the Forest” in Warao mythology, who must be appeased by a master canoe builder before the tree is cut (Wilbert, 1977). A gum-like resin known as South American copal is extracted from *Hymenaea courbaril* (Chudnoff, 1984; Little and Wadsworth, 1964) and used as a sealant for waterproofing and protecting canoes (Wilbert, 1977). The tree grows in similar environments to gommier, but with less restrictive ecological constraints, leading to a broader distribution (Longwood, 1971). Although it does not tend to grow to the stature necessary to make seafaring canoes, it may be suitable for smaller fishing or short-range watercraft.

Other species with potential for the construction of canoes were evaluated, including *Swietenia mahagoni* (West Indian mahogany, caoba), *Calophyllum brasiliense* var. *antillanum* (Santa Maria, West Indian laurel), and *Tabebuia heterophylla* (white cedar, roble) (see Table 1). These would have been suitable for constructing smaller canoes intended for one or two paddlers, but not likely to have been used to build the larger pirogues and seafaring canoes (Weaver, 1990). For example, South American groups used *Swietenia mahagoni* as a favored wood for smaller riverine canoes (Lévi-Strauss, 1990). Owing to its density, reflected in high specific gravity (Table 1), *Swietenia mahagoni* would have been difficult to shape into massive canoes but would make an excellent resource for paddles, as evidenced by the specimen recovered from a cave on Mores Island in the Bahamas (Ostapkowicz et al., 2012). *Calophyllum* is also reported as a wood with mythological significance used to manufacture paddles in South America (Honychurch, 1997).

4.2. Other canoe related resources

> “It is to obtain cotton that leads them to fish at the Saints or to catch crabs at Marie-Galante, for they make clearings in those places to

grow cotton. You see very few Caribs who do not always carry a small roll of cotton in their baskets" (Breton, 1665:28).

In addition to trees used for dugouts, several other resources were involved in the construction of canoes. Cotton (*Gossypium hirsutum*) was one such essential resource and is one of the most frequently commented upon indigenous resources in European ethnohistories (e.g., Breton, 1665; Columbus, 1992; Du Tertre, 1667). Cotton is intricately linked to canoe infrastructures as a critical resource for cordage to fasten the *bordage* on a pirogue, to make nets used in fishing, to mount anchors to canoes, and for hammocks brought on canoe trips to facilitate multi-day voyages. Cotton was also used to manufacture religious idols (Ostapkowicz and Newsom, 2012), and the ubiquity of spindle whorls in excavations across the region support the widespread importance of cotton (Davis, 2011; Keegan, 2001; Olazagasti, 1997; Torres and Carlson, 2011). It was reportedly common practice for the average person to carry bolls of cotton on their person the way many people today carry car keys or phones (Breton, 1665). One account suggests that such cordage could be used to coordinate production and voyage schedules. The technique requires all members of a party to tie a series of knots in some personal cordage equal to the number of days before the proscribed event, and then untie one knot a day until the last signified the arrival of the prearranged date ([Sieur de la Borde, 1674] Hulme and Whitehead, 1992:141).

Cotton is notoriously xerophytic and salt-tolerant, thriving in arid to semiarid environments that receive elevated levels of sunlight and surviving erratic levels of rainfall (Oluoch et al., 2016; Stephens, 1965; Wendel and Grover, 2015). Using the same bioclimatic variables used to model canoe trees, and following d'Eeckenbrugge and Lacape (2014), an ENM was constructed using occurrence data for *Gossypium hirsutum* (Fig. 3). The ENM revealed an inverse distribution of suitable habitats from the ENM for gommier and red cedar. Cotton thrives on the coasts of Jamaica and Puerto Rico, in the Leeward Islands and Bahamas, but the rainforest biomes of the Windward Islands and Greater Antillean highlands provide less suitable habitats. This explains the ethnohistoric accounts that document residents of Dominica cultivating and harvesting cotton on Marie Galante (Breton, 1665; Hulme and Whitehead, 1992:56).

Talipariti tiliaceum (*Hibiscus tiliaceus*, mahoe, or sea hibiscus) would not have been used as a dugout, but had several potential applications to the construction of canoes, including extracting its fibers for use as a caulking agent much like oakum, for making cordage to attach an anchor, and for lumber to build parts of the canoe hardware. In Jamaica, the wood of this small tree was also used in the manufacture of wooden religious idols known as *zemís* (Ostapkowicz et al., 2012; Saunders and Gray, 1996). *Talipariti tiliaceum* grows in coastal and lower elevation biomes to heights of only about 4 to 10 m, and about 15 cm in diameter. It has a tolerance to drought, salty soils, and salt wind, allowing it to flourish in coastal locations that also foster the growth of cotton. *Talipariti tiliaceum* conformed to a similar pattern as cotton, though appears to be less restrictive in the distribution of suitable habitats, some notable exceptions being southern Puerto Rico, Central Hispaniola, and the Turks and Caicos (Fig. 3). Islands such as Dominica and Guadeloupe that rank high in suitability for canoe trees tend to rank poorly for cotton and hibiscus, lending further support to the pan-regionality of resource acquisition.

5. Ethnoarchaeology and experimental studies

"Twenty-seven men and women are preparing to cross the Dominica Channel, an arm of the sea separating Martinique from its neighbor located 23 nautical miles further north. For the first time in three hundred years, they will make this paddle on a *kanawa*, a mono-hulled dugout canoe almost 18 m long" (translated by author from Bérard et al., 2016a:172).

Observations on Amerindian canoe manufacturing and voyaging have been the focus of experimental and ethnoarchaeological studies deriving information from modern canoe voyages to help make inferences about precolonial canoe voyaging (but see Cherry and Leppard (2015) for limitations with applying ethnographic analogy and experimental nautical voyaging to ancient contexts). When used judiciously with supporting evidence from archaeology or ethnohistoric documents, ethnoarchaeological observation can contribute to the reconstruction and understanding of precolonial canoe-building societies throughout the Caribbean. The closeness between linguistically and culturally related insular and mainland communities expressed in the precolonial ethnic plurality proposed by Whitehead (1995b) provides an analytical justification for comparing European ethnohistoric accounts from the West Indies with homologous ethnographic research in South America.

Karisko is a collaborative French and Kalinago canoe association that has organized expeditions described by Bérard et al. (2016), most notably the 2008 voyages of the 17.5 m (57 ft) Guyanese constructed canoe called *Akayouman*. The international team of paddlers trained and took *Akayouman* on several interisland voyages in the southern Leeward and northern Windward Islands, collecting data on several aspects of canoe voyaging including hydrostatic displacement, the effects of the number of paddlers on velocity, and the average speeds for distances covered (Billard et al., 2009). These voyages echoed previous indigenous canoe revitalization projects. In the late 1980s, Cuban archaeologist Antonio Núñez Jiménez conducted a year-long voyage that included the construction of five canoes in the upper Orinoco using traditional techniques (Jiménez and Márquez, 1993). The team included archaeologists, geographers, biologists, and artists who voyaged from the Amazon to the Bahamas stopping at numerous islands along the way. The goals of the experimental project were to research indigenous migrations into the islands as well as to reignite international collaboration between insular and mainland groups. In a similar spirit, Jacob Fredrick and master boat builder Etienne "Chalo" Charles of the Kalinago Territory in Dominica, along with amateur anthropologist Aragorn Dick-Read, constructed *Gli-Gli* in 1994, an approximately 10.5 m (35 ft) dugout canoe that they voyaged from Dominica to Guyana and back (Dick-Read, 1997). The BBC produced film "Quest of the Carib Canoe" (Jarecki, 2000) documented the construction and voyage of the canoe, which also reignited connections between insular and mainland Amerindian groups. The builders of Gli-Gli used several traditional methods and ancient esoteric knowledge, but eschewed others in order to utilize modern technology. They used chainsaws in the felling of the tree and initial shaping of the canoe, whereas precolonial canoe makers would have used fire successively in conjunction with stone or shell axes to accomplish these tasks (Morice, 1958). Furthermore, a sail was added to augment the canoes' seafaring capability, a non-traditional technology most likely introduced in the Caribbean by Europeans during early colonial encounters (Fitzpatrick, 2013; McKusick, 1960; Moreau, 1991).

Over the last decade, the Kalinago people have renewed their interest in manufacturing traditional dugout canoes for interisland transportation. Honychurch (1997:87) argues that the resurgence of canoe making holds especially significant ties to traditional techniques because the community "identifies the canoe as more than simply a practical seagoing vessel, for the survival of its form and its cultural associations through time now also signify the survival of the people associated with its production." Smaller dugout canoes for offshore fishing and around-island transportation have been in production continuously from colonial times (Honychurch, 1997; Morice, 1958). In the 1994 census of vessel types for Dominica, the 474 dugout canoes outnumbered the 366 board and rib-framed "keelboats" (Honychurch, 1997:98). However, larger canoes for interisland travel on the open seas require a more substantial investment of time, organized labor, and resources, while simultaneously representing the type of interisland mobility most commonly replaced by sailing vessels and later, motorized watercraft.

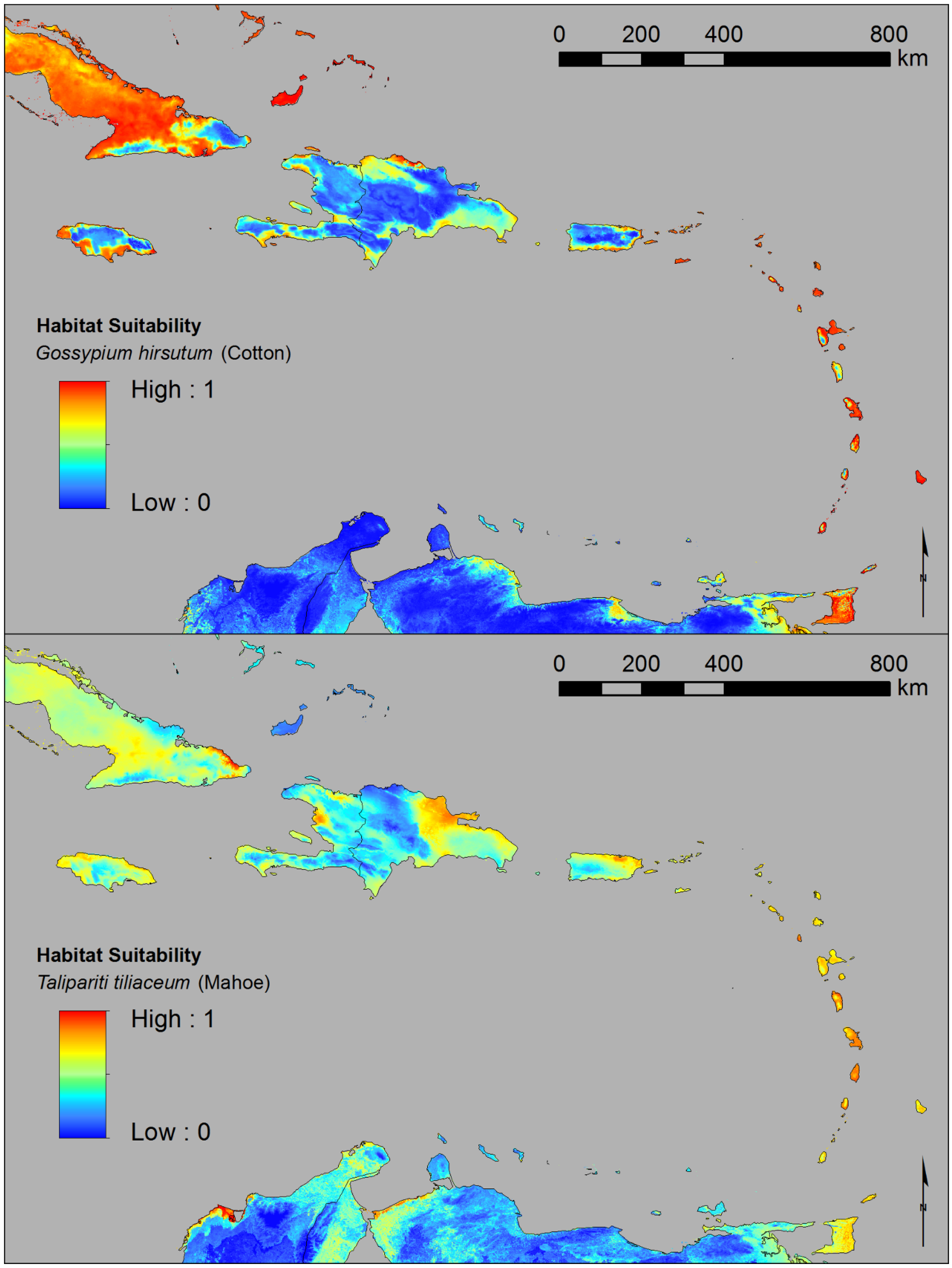

Fig. 3. Ecological Niche Models for other canoe building materials, *Gossypium hirsutum* (cotton) and *Talipariti tiliaceum* (sea hibiscus).

In 2009, and again between 2012 and 2013, observations and interviews were conducted by the author during the construction process of two different dugout canoes (Fig. 4). In 2009, a 5.5 m (18 ft) canoe was constructed from a gommier tree in Boetica, the small mountain village north of the archaeological study area in Delices (Shearn, 2014) (Fig. 4). This canoe typified the near-coast small fishing vessel, lacking *bordage* and unsuited for open sea voyages. In contrast, between 2012 and 2013, a Kalinago team constructed a larger 11.5 m (38 ft) long seafaring canoe intended for associates in Guadeloupe. Informal interviews with the builders conducted during various stages of the months-long production process helped to develop insights into the relationships among Kalinago settlement, mobility, and the technical processes involved in making a seafaring canoe.

The topics discussed by informants included the processes involved in manufacturing a seafaring dugout canoe from start to finish, including how to select the right tree and rough estimates of the labor involved; innovations in modern dugout canoe manufacturing that were not representative of traditional techniques; aspects of paddling and voyaging, including the mechanics of how to take breaks while at sea; and a discussion of previous routes traversed and possible distances traversable, as well as some of the dangers associated with open-sea canoe travel. Several members of the team working on the 2012 canoe had participated in the Karisko voyages of *Akayouman* and offered insight into the differences between Guyanese and Kalinago pirogue construction. The Guyanese boat builders, being accustomed to building smaller river dugouts, had constructed *Akayouman* as if from two halves joined down the center making it narrower, with an angular keel. The Kalinago canoe, constructed from a single dugout log with *bordage* attached to the sides, featured a flatter keel, providing greater stability at sea.

The process of cutting and initially shaping the tree into a canoe preform, with the assistance of chainsaws and steel axes, took approximately 30 days. During this time, the primary group making the canoe was camping in the highland rainforest, with some volunteers coming and going. In order to move the partially hollowed tree from the forest to the coast between 12 and 30 laborers per day worked together

Fig. 4. Images of two canoes at various stages of Phase III processing and finishing (photos taken by the author 2009–2013).

for six days to bring the preform to the nearest road, at which point a truck was employed to carry the early-stage canoe the rest of the way to Kalinago Territory for completion. Then months were spent finishing the rest of the construction procedures. Without the assistance of motorized vehicles, chainsaws, and metal tools, according to experimental findings, this process would have taken considerably more effort (Saraydar and Shimada, 1971) and a longer time to fell the tree depending on the species' size and hardness (Mathieu and Meyer, 1997).

6. Discussion of canoe manufacture and voyaging

> "When a pirogue is made people are asked to help drag it down from the mountain to the sea. They are invited to the feast which follows. In this country, if there is no feast, there is no work party" (Breton, 1665:11).

A canoe lives on the sea, but it is born in the bush. The production processes involved in manufacturing a seaworthy canoe are not readily apparent in the archaeological record, but the activities occupied a substantial investment of a communities' social labor (Du Tertre, 1667; Moreau, 1991). Moreover, this labor investment required extended trips into the forested highlands, away from permanently settled coastal villages more commonly documented in archaeological surveys (Bradford, 2001; de Waal, 2009; Shearn, 2014). Ethnohistoric passages highlight the communal labor and the commingling of social, political, and economic forces in ritualized ceremonial practices accompanying work parties and major milestones in the lifecycle of the canoe (Bérard et al., 2016b; Moreau, 1991). Du Tertre (1667:18) reports that prior to the introduction of European technologies, it took months and sometimes years to manufacture a canoe, although the underlying technical procedures for several aspects of the production process remain similar to the techniques still used by Kalinago canoe builders in Dominica. A departure from traditional techniques came with the introduction of European steel when the use of, at first, axes, and later, chainsaws, reduced the amount of time taken to fell and shape the tree. Another modern innovation is the substitution of nails for cordage to attach the *bordage* and the ribbing. Finally, whereas today, women are directly involved in canoe production, there are indications that precolonial canoe manufacture was work done strictly by men (Du Tertre, 1667:32).

Echoing Breton (1665), Du Tertre (1667:24) comments that in Dominica they would "hold drinking parties when they want to put a canoe to sea after it is newly built in the mountains. They call in all their neighbors who work for several hours and drink for the rest of the day." Honychurch (1997) identifies the beverage consumed at these work parties as *ouicou*, a fermented manioc wine manufactured by women. In Guyana, a similar beverage, known there as *paiwari*, is still produced by chewing and spitting manioc into a large earthenware jar to ferment, a process stimulated by the enzymes in saliva. Honychurch (1997:93) suggested that "the gathering of food and the long period required for the processing of *ouicou* was evidence also of prolonged commitment to the canoe leader by other groups of specialists." This inference indicates the degree to which canoe manufacturing impinged upon other seemingly unrelated tasks such as farming, fermenting, and surplus management.

6.1. Outline of production process

Bérard et al. (2016b) offered a reconstruction of the *chaîne opératoire* for Kalinago canoe manufacturing based on 16th and 17th-century ethnohistoric accounts and augmented by ethnoarchaeological data. That model consisted of ten steps, expanding the scope to include not only the technological operations that turn raw materials into usable products, but also the social, political, and religious operations. Honychurch (1997) describes the same process in four stages, and Wilbert (1977) outlines the Warao construction process in three stages. Table 2 shows a synthesis of these models organized into three phases, augmented by the data gathered from informants on Dominica. Whereas Bérard treats both technical and ritual procedures as individual steps, here they are organized into three phases based upon the different locations involved in the production, and the movements of the canoe. Each of the three phases is subdivided into the various technical, ritual, and sociopolitical aspects of the relevant production process.

The initial phase of canoe construction takes place in the highlands and consists of transforming the live gommier tree into the preform of a canoe. A critical and easily overlooked aspect of this is selecting the right tree. Not only does the tree have to have the proper height and width dimensions, but it must also be situated in an area that is accessible and, more importantly, amenable for transportation of the canoe preform to the sea. The sap of the gommier tree fluctuates with the phases of the moon, filling the tree when the moon is full, and reaching a low point with a new moon (Honychurch, 1997:90–91; Taylor, 1938:141). The initial cutting of the tree was traditionally timed with the arrival of the new moon when the sap was low, and the wood dry, to avoid infestation from mold and insects (Morice, 1958). This cosmological association between lunar phases and boat building is reinforced by numerous Circum-Caribbean myths (Lévi-Strauss, 1990; Stevens-Arroyo, 2006) linking the canoe to celestial bodies, specifically the sun and moon, who were believed to traverse the sky in canoes.

Phase I in the construction process of the 2012 canoe lasted over thirty days, during which the crew of between six and 14 people

Table 2
Phases of the production process, with adaptations from Bérard et al. (2016b) and Honychurch (1997).

Phase	Place	Personnel	Aspects of Manufacture			Resources
			Mythico-Ritual	Sociopolitical	Technical	
I	Forest	Specialist	Tree selection, initiation	Agreement	Establish camp	Canoe tree
	Village	Entire village	Opening *Caouynage*	Recruitment		Housing, subsistence +
	↓ Forest	Specialist, build crew$_1$, occasional provisioning	Tobacco mediates supernatural forces; mythical association of canoe, gourd, and maraca.	Enculturation	Tree felling (new moon)	Stone or shell axes, fire, labor
					Shaping the preform: i. excavating trunk ii. external shaping	Palm frond
II	Forest ↓	Specialist, move crew	*Caouynage* ↓	Recruitment	Moving the Preform	Subsistence + libation + Cordage, labor
	Coast/ Village	Entire village	*Caouynage*	Agreement, incorporation	Secure needed resources	Subsistence +, libation +
		Specialist, build crew$_2$		Enculturation	Opening the preform	Stones, water, fire
III	Coast/ Village ↓	Various specialists, build crew$_2$	Decorations adorning the canoe would be added, possible celestial and/or mythical associations	Enculturation	Reinforcement: i. bordage ii. ribs and front piece iii. water-proofing	Alternate lumber Mahoe, cordage, resin
	Sea	Captain, launch crew	Closing *Caouynage*	Rites of passage	Hauling and launching	Labor, subsistence +, libation +
		Entire village	(Baptism)			

+ indicates that surplus is required.

camped in the rainforest, felling the gommier tree and then removing most of the excess wood to reveal the initial shape of the canoe. In both ethnohistoric accounts (Bérard et al., 2016b; Morice, 1958) and modern canoe construction projects (Jarecki, 2000), temporary camps were established in the forest to house the workers and to protect their tools from rain during this phase. This initial shaping was performed *in situ* because it would be far too difficult to transport the entire tree trunk to the coast, but the entire canoe is not manufactured in the forest. A preform is shaped first with a chainsaw, and then by alternating use of fire and excavation of charred wood such that the majority of what must be 'dug out' can be accomplished before moving it (Honychurch, 1997; Morice, 1958; Taylor, 1938). Some excess wood is left, maintaining the strength of the preform to ensure sturdiness during transportation because dragging it from the mountains to the coast during Phase II can be a risky procedure.

As Honychurch (1997:94) explains, "the Creole language term adopted by the Caribs to describe the activity of 'digging out' is *fouyé* from the French word *fouiller*, however in its Creole usage it implies not just the action of digging but the entire shaping of the carved hull." Precise knowledge is required about the dimensions of the curves employed to shape the unruly bole of a felled tree into a finely balanced seafaring canoe. In 1994, Chalo, the boatbuilder who engineered *Gli-Gli*, used the curvature of a palm frond to sketch out the desired measurements for the preform, a secret and ancient technique that was handed down and carefully guarded, but graciously shared by Chalo (Jarecki, 2000). This focus on secrecy and ancient esoteric knowledge is reminiscent of 17th century accounts of Kalinago boat builders (Honychurch, 1997) and of the modern Warao canoe builders on the Orinoco Delta (Wilbert, 1977:24).

Once the preform has been sufficiently reduced, Phase II requires moving the preform to the coast to receive a set of finishing procedures to make the canoe seaworthy. Moving the preform is a high-stress, high-risk maneuver requiring more labor over a shorter period to achieve than the operations of Phase I or Phase III. A work party, or *caouynage*, encouraged cooperation at this stage (Bérard et al., 2016b). Honychurch (1997) documents that under certain conditions, as many as eight of these work parties have been required to move canoes over steep terrain. Kalinago informants recounted that during this stage in 2012, the preform unintentionally slipped down a ravine, highlighting the need to account for the intervening topography when selecting a tree. After stalling the process for two days, they were able to recruit the help necessary to lift the preform out of the ravine, but with great difficulty. In total, they reported that it took about 45 people (12 to 30 per day) over six days to haul the preform from the forest to the road, where they transported it the rest of the way by truck and trailer. In the past, it would have taken longer to traverse the distance from the highland Phase I location to the Phase III coastal location without the assistance of automobiles, but riverine systems may have been utilized to aid in transporting the preform during Phase II.

With the canoe closer to the shore and the home villages of the work team, Phase III consists of several months of work forming the canoe and preparing it to be seaworthy. The process starts with digging out the remainder of the bulk that was left to protect the preform during transportation. The hull is then put upright by supporting it with timbers and loaded with stones and water for at least two weeks as ever longer timbers are inserted into the frame forcing it to expand in width. Fires lit on both sides heat and soften the wood, helping the hull to expand further, while water is splashed continuously to prevent it from catching fire. This process—the final stage of expanding the dugout hull of the canoe—was identical for the small 2009 canoe and the larger 2012 canoe (Fig. 4), as well as several other documented examples (Honychurch, 1997, 2011).

During these weeks, or before, other parts of the canoe hardware are constructed, including the *bordage*, ribs, benches, and paddles. After the dugout portion of the canoe has been fully expanded, these other pieces of hardware are attached. The Kalinago canoe builders in 2012 used resin from the gommier tree to patch holes and seal cracks in the canoe to make the hull watertight (visible in Fig. 4). A shark oil and resin mixture had been observed being used for this purpose (Taylor, 1938), as well as *Talipariti tiliaceum* (Little and Wadsworth, 1964), which could be peeled and crushed with stones to produce a resinous caulking agent describe by Breton (1665:164) as similar to oakum. Breton (1665:185) described a black tar made from the resin of the chibou tree (*Bursera simaruba*) that is sometimes used to coat the entire body of the canoe, presumably to enhance water resistance. Larger pirogues would have required additional reinforcement, especially if softer woods such as *Ceiba pentandra* were employed. The ribs would likely have been constructed from stronger, denser woods, such as *Tabebuia heterophylla*, which was observed being used for this purpose by Breton (1665:125).

6.2. Ritual and ceremony

> "Even in recent times no *Carib* would cut a tree for a canoe or a bow without first making an offering to the spirit inside" (Métraux, 1949:578).

The construction of canoes was not just one of many equivalent economic tasks; a sterile technical process enabling the exploitation of marine resources, exotic materials, and trade goods. It was a symbolically and ritually charged process that enabled vital connectivity to a social field that was very much alive in the minds of the canoe builders and voyagers. Ethnohistoric accounts indicate that manufacturing and voyaging canoes carried not only great social and political importance, but also great mythological and cosmic significance (Pané, 1999; Stevens-Arroyo, 2006). Activities surrounding aspects of canoe construction and use would have been characterized by religious and spiritual concerns interwoven with technical ones.

In Venezuela, Wilbert (1977:31) describes the religious significance of tree felling during which the skillful canoe-maker navigates the dangerous activity "by carefully observing the prescribed taboos and by propitiating [*Dauarani*] with generous gifts of moriche sago and tobacco smoke." Beyond their technical expertise, master Warao canoe builders, *moyomutuma,* were often high-status religious specialists for whom initiation and training was a matter of considerable importance (Wilbert, 1976, 1977). The Warao *moyomutuma,* or a priest-shaman he engages, must communicate with the spirit in the tree, a daughter of *Dauarani*, "Mother of the Forest," who must consent to 'release' the tree before it can be cut (Wilbert, 1977). Activities perceived by westerners as purely economic were perceived in mythico-religious terms and the interplay of ritual, social, and technical considerations that a master canoe builder must balance to successfully build a canoe were argued to ensure the successful reproduction of society (Wilbert, 1977).

The ethnographic description of Warao canoe making parallels patterns of canoe manufacture in the insular Caribbean that can be gleaned from ethnohistoric accounts, as well as to rituals relating to the manufacture of wooden *zemís* (Pané, 1999; Saunders and Gray, 1996), religious idols used by groups in the Greater and Lesser Antilles in the centuries before European arrival. An observation made by Pané (1999:25-26) recounts the way the spirit of a tree calls out to become a *zemí*, and when a commoner happens upon one such tree, they seek out the ritual specialist to mediate with the spirit and initiate the process of transforming the tree into a *zemí*. Analysis of wooden *zemís* from Jamaica preserved from the Protohistoric Period reveals that several were made from the same trees used to manufacture canoes (Ostapkowicz et al., 2012; Saunders and Gray, 1996). A similar supernatural association was likely involved in tree selection for Caribbean canoes (Hodge and Taylor, 1957), implying that initiating the construction of a canoe had ritual and religious meaning.

An interesting question emerges from these examples of communication with tree spirits. Does the canoe builder select the tree, or does the tree select the canoe builder? For precolonial boatbuilders, both may have been true; the tree must display the conditions of being amenable to canoe manufacture, but for these natural signs to be interpreted within a supernatural framework is consistent with models of precolonial cosmology (Stevens-Arroyo, 2006). It then rests on the canoe builder to convince the rest of society to agree that the tree is ready and that the time is right to construct a canoe, for the sponsor of the manufacturing process will have to marshal the support of virtually the entire community to construct a sizeable seafaring canoe successfully. The social and religious significance of these practices is further cemented in the ritualized *caouynage* ceremonies, and the feasting that would occur when a canoe is completed and *baptized* in a ritual of intensification that marks the end of the construction process and the beginning of the future life for the canoe on the sea (Bérard et al., 2016b; Moreau, 1991). A final consideration in the life cycle of a canoe is the disposal method when it is no longer a viable watercraft. Given that the stargate canoe from the Bahamas (Palmer, 1989) and the canoe fragment from Jamaica (Flower, 1895) were recovered in burial contexts, together with ethnographic examples of individuals buried in canoes (Lévi-Strauss, 1990), purposeful, ritualized burial may have been common.

6.3. Mechanics and logistics of voyaging

> "It does not matter if their canoe capsizes for they know how to right it very easily and get inside it again" (Bouton, 1640:7).

Preparing a canoe for open-sea voyaging carries with it design considerations during the manufacturing process, but also requires social capital to recruit a team of paddlers, political capital to plan the voyage, and the technical skills for paddling safely through rough seas, a capability regularly admired by early Spanish commentators (Sauer, 1966). Informants described how the crew must paddle together as one, and each team has someone in charge of synchronizing the paddling. When voyaging on open seas, the most immediate navigational consideration is the orientation of the canoe to the waves and currents. Each rise and lull of the sea must be navigated purposefully to prevent water from entering the canoe or the canoe tipping over. As one worker on the 2012 Kalinago canoe put it, "in the sea, you have to know the *technique* of the sea." This technique is to take waves straight on, not to try to go sideways around them. This requires constant forward momentum from the paddling team, meaning that at no time can the entire team stop to take a break. The principal advantage that outriggers offered canoes in the South Pacific was stability, affording opportunities for paddlers to rest, and even sleep on board (Fitzpatrick, 2013). In the Caribbean, a dugout canoe must maintain its momentum to achieve stability. On long journeys, paddlers will alternate taking breaks from paddling, such that forward momentum is consistent. Two paddlers may stop paddling, rest, eat, drink, and when they are ready to paddle again, the next two paddlers take their break. While nothing precludes this technique from extending into multi-day voyages, in recent times such overnight voyages have only been attempted with the aid of sails and motorized support ships.

Columbus noted the rapidity with which news traveled between islands (1992:143,150), on the superb level of navigational and seafaring skills (1992:151,172), but mostly on the size and magnificence of large canoes and the commonality of smaller ones (1992:95,128–130). The speed of indigenous canoe travel and the range that native canoe paddlers were able to traverse in various conditions was documented by Du Tertre (1667). His estimate of ten to twelve leagues (~35–40 km) per day in the face of contrary winds was intended to correct a previous statement by Rochefort who undersold the voyaging capabilities of Caribbean canoes calculating a figure of about one league per day directly into the wind. Du Tertre (1667) went on to elaborate on the difference between European and Native paddling techniques, the latter of which face forward and push the water behind when paddling.

Participants in previous Karisko voyages discussed hypothetical distances that precolonial paddlers could travel, as well as more specific accounts of how far and how fast modern paddling teams had traveled in dugout canoes. Average speeds for modern voyages were measured to between 3 and 3.2 knots by Billard et al. (2009), and with favorable conditions, paddlers traversed the approximately 45 km voyage from Martinique to Dominica in less than seven hours. Reconciling these figures with ethnohistoric accounts indicates that veteran paddlers during the Colonial Period could traverse in adverse conditions approximately the distance modern paddling teams accomplished in favorable conditions. Therefore, given favorable conditions, veteran paddlers in antiquity likely covered greater distances and, as reported during European conquest, routinely embarked on voyages that covered 650–975 km over multiple days (Breton, 1665; Du Tertre, 1667).

6.4. Navigation and scheduling

There are a wide array of climatological concerns and esoteric knowledge involved in timing, navigating, and organizing voyages. Navigation was a critical skill for open-sea voyaging, but ideas about navigation would have had to consider far more than just the winds and currents; a host of other factors, whether sociological, political, astronomical, or mythological, would have contributed to the planning of routes and navigation. One poignant example comes from the 1674 account of Sieur de la Borde (Hulme and Whitehead, 1992:151), who observed that in their voyages, indigenous paddlers would stop at certain spots in the sea to provide offerings to ancestor spirits whose 'houses' were in those specific locations, having died at sea. Sullivan (1981) presents a convincing argument that stone alignments identified at MC-6 on Middle Caicos represent a navigational chart mapping out canoe routes between the specialized salt exploitation center and the residential, sociopolitical center of Chiefdoms in Hispaniola. However, Columbus (2016:10) seems to have encountered many individuals who knew navigational routes implicitly or could use the stars to navigate (1906:408).

The testimony of Louisa de Navarrete taken in 1580 by Bernáldez de Quiroz, the Spanish Procurator General of Puerto Rico, reveals further insights into typical navigational patterns during the early Colonial Period (Hulme and Whitehead, 1992:38-44). Louisa de Navarrete had been kidnapped by Kalinago of Dominica in 1576 during a raid on Puerto Rico but managed to escape when she was taken along for another raid in 1580. She testified that her captors in Dominica conducted these raids annually, that raids coordinated residents of multiple islands, and, in this case, involved 15 canoes, organized into three fleets of five. This account provides added details to Bretons (1665:13) note that when they go to war, they "make great preparations, assembling many pirogues and canoes. They only take one woman into each boat to comb their hair and paint them, as well as to prepare their food." Elsewhere, he elaborated that "they leave from Dominica in eight or ten pirogues armed in their fashion for war; they take along women only to cook and serve them, and leave them on some islet while they go to the encounter" (Breton and la Paix, 1929:23). Navarrete's testimony described a direct paddle from Dominica to an island near to Puerto Rico, perhaps St. Croix or Vieques. After leaving the women at a rendezvous location, they divided into three groups to conduct their raids and then returned to Dominica via a different route, stopping at several islands along the way to divide the captives and the spoils of war, presumably among groups who contributed to the raid. This pattern is consistent with the prevailing winds and currents in the Caribbean Sea that make east to west journeys more favorable than the reverse (Altes, 2011), a fact much lamented earlier by Columbus (1906:162-163,408). Navarrete's testimony was taken shortly after her capture in October, which suggests that the timing of the raid coincided with the end of the hurricane season, when currents would have been favorable for the approximately 450 km voyage from Dominica to St. Croix, a mere 100 km off the coast of Puerto Rico. The intercommunal coordination described in these accounts, along with the routinized, if not ritualized nature of the enterprise, reveal the degree to which interisland integration was supported by a canoe infrastructure.

Following Stevens-Arroyo's (2006:181) reconstructed calendar of mythological, astronomical, and ecological scheduling, one can develop models for the seasonality of canoe manufacture and travel that are also rooted in the indigenous cosmology and embodied in myths focusing on canoe journeys. In chapter V of Pané's (1999) account, he relates the myth that Stevens-Arroyo calls *The Betrayal of Anacacuya* in which the Cacique and his brother-in-law Guahayona take a canoe trip, but the Cacique is betrayed and thrown overboard by Guahayona. By drowning in the sea, Anacacuya took his place in the heavens as a star in Orion's Belt, the procession of which was used both for maintaining an annual calendar and for navigation at sea. This relationship between the stars in the sky, their reflection in the sea, and a mythology that connects the two through canoe journey narratives, serves to reinforce the use of specific astronomical observations for navigation and climate forecasting (Rodriguez, 2013). Thus, when Orion first appears in late July, it coincides with the onset of hurricane season, a potentially dangerous time for canoe voyages and fishing, but perhaps a safer time to take refuge in the highlands and begin working on canoes for the next dry season (Stevens-Arroyo, 2006). The timing of the 1580 raid on Puerto Rico launched from Dominica supports the notion that the months leading up to October were spent working on and repairing canoes in preparation for annual raids (Hulme and Whitehead, 1992:38–44). As Orion reaches its zenith in mid-September, it signals that hurricane season is at its most dangerous, beginning to return to more favorable conditions in October and November. Winter is the dry season when ocean travel is favorable, and fishing is more productive, but as winter turns to spring, shellfish become dangerous to eat, and seas become more turbulent, leading from another period of canoe voyaging to a period of focus on agricultural production and canoe manufacturing.

7. Toward an archaeology of canoe societies

Despite overwhelming agreement that the interconnectedness between islands was typical of precolonial societies in the Caribbean, the ecology of canoe manufacturing is not regularly factored into archaeological syntheses and settlement pattern studies. Furthermore, the historical preference for excavating coastal sites conflicts with the relatively restricted highland distribution of biomes capable of supporting the largest canoe trees. The map in Fig. 5 shows the relationship of known sites in Dominica to the suitable gommier habitats. Also shown in the map are the approximate locations for the collection of stone axes in the Dominica Museum (Petitjean Roget, 1978), all of which were spot finds recovered within prime gommier zones, far from excavated sites along the coast. Future excavation in these highland regions attempting to link the isolated spot finds to temporary or semi-permanent

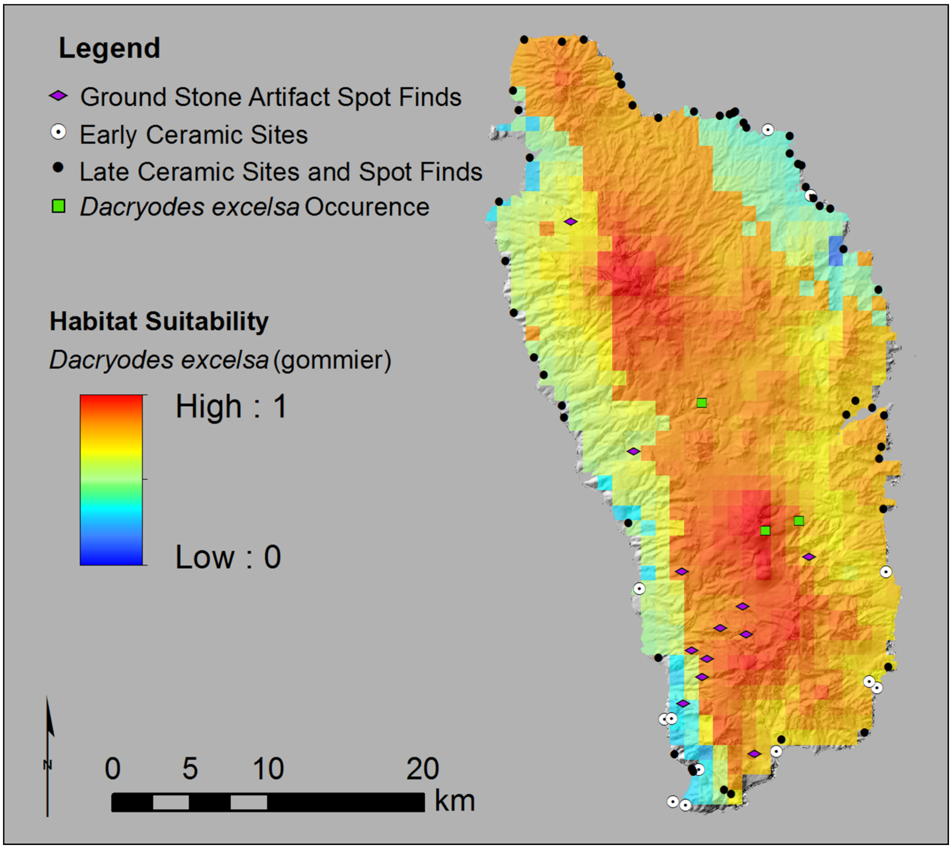

Fig. 5. Ecological Niche Model for *Dacryodes excelsa* (gommier) in Dominica showing known sites and spot finds (Honychurch, 2011; Petitjean Roget, 1978).

work camps would represent a major step toward developing an archaeology of canoes.

The model of the canoe production outlined above provides an explanation for one of the outstanding questions to emerge from European ethnohistoric accounts, the apparent gendered language dimorphism that characterized Amerindian groups in the Lesser Antilles during the Protohistoric and early Colonial Periods. During European conquest the Kalinago were characterized by a marked division of labor, wherein men and women not only participated in distinct socioeconomic spheres, but maintained entirely distinct languages and vocabularies, such that the men possessed a secondary pidgin language to which women and young boys did not have access (Hoff, 1995; Taylor and Rouse, 1955; Taylor and Hoff, 1980). The social relations of canoe production can help to explain this pattern by contextualizing gender relations as rooted in daily practice and seasonal cycles of canoe building and voyaging. It follows that the process of making canoes involved important rites of passage, training in the technical and ritual procedures of canoe making that formed a critical component in the organization, and reproduction of canoe societies. The construction of canoes required large groups of men to remove themselves from the village and establish temporary or semi-permanent camps in the forest, providing the time away from women when the men's speech would be used openly, passed on to the next generation of young men, and solidified during canoe voyages abroad where it served as a pan-Caribbean *lingua franca*. The observation that jaguar skin was worn as a status symbol, indicating having visited South America (Breton, 1665:100), exemplifies how social identity formation and coming of age were connected with canoe voyaging.

Considering canoes as a structuring agent in archaeological patterns opens avenues for investigating gender identity formation in the archaeological record. The bimodality of labor and language suggests that the very settlements and activity areas typically investigated archaeologically represent largely gendered spaces. This view calls into serious question the usefulness of decorative style as a means of ethnic or temporal classification, as any variation between sites could reflect contemporaneous differences in gendered tasks. The identification of canoe manufacturing sites holds the promise of adding a vital dimension to the analysis of settlement patterns in the Caribbean. Far more than mere activity areas, or production zones, these were ceremonial sites where important sociopolitical and religious rituals necessary for the reproduction of society converged on the construction of canoes. Suitable habitat zones where canoe trees were harvested must be connected to the coast by paths to transport canoe preforms. Presumably, the closest path to any suitable river would make this trip more manageable if rivers were used to transport canoe preforms. This feature of the workflow process could become especially useful to an archaeological methodology sensitive to such features of connectivity. The notion that feasting often involving libation was a regular feature of communal labor efforts is not contentious, although direct evidence in the form of archaeological patterning is challenging to identify. In Dominica, decorated wares and serving vessels were generally more common at coastal sites than at sites slightly removed from the coast, although no truly highland sites were investigated (Shearn, 2014). This pattern was similar in various regions of Dominica, and the differences in pottery among sites could be explained by the labor processes and sponsored feasting involved in canoe construction, as opposed to indicating different periods of occupation or ethnic identity. The undecorated pottery at non-coastal sites was argued to be reflective of agricultural production and domestic tasks, whereas the more ornate serving vessels along the coast were argued to reflect feasting, such as the ceremonies that take place when a canoe is "baptized" after being brought from the highlands, or before mounting a canoe voyage (Shearn, 2014). What remains is to identify the highland sites where canoe manufacturing camps were established, and canoe trees were harvested and processed. An avenue for future research would be to connect known sites to high probability gommier patches using GIS tools such as least-cost-path modeling to seek out possible canoe manufacturing sites.

8. Concluding remarks

The integrative approach laid out in this article offers an avenue for augmenting the archaeological record in the Caribbean by considering the ecology of canoe resources and the theoretical implications of ethnohistoric and ethnographic observations on canoe manufacturing and voyaging. Canoe-based mobility and infrastructure permitted the integration of communities across the Caribbean; and the social organization involved in the manufacture and voyaging of canoes created the framework for how regionally oriented communities experienced interactivity. Canoe construction processes produced, and reinforced social relationships, and this likely included the instruction of future generations of canoe builders and the bonding of affinal kin. These aspects of group identity formation became materialized in the canoes as cultural objects, elevating their significance above simple transportation technology. The labor investment, management practices, and economic redistribution implied in canoe craft specialization represent a *particular kind* of complex organization underwriting systems of regional integration supported by canoe building and voyaging, motivated by elites who could marshal the specialized labor and resources necessary to achieve their goals. This included provisioning the food and beverage necessary to sponsor the work parties for moving the canoes, and the surplus domestic production required to support the specialists and the paddlers while they were building and voyaging. Making, maintaining, and using canoes represented sets of practices that were daily realities for members of society, with religious and social significance, structuring community relations and settlement patterns. Despite any lack of direct evidence, the social implications of seacraft should hold as much importance as agriculture, house construction, fishing, exchange, or any other aspect of the archaeological record in the investigation of canoe societies in the Caribbean.

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Statement of Informed Consent

Ethnoarchaeological research was conducted following the American Anthropological Association Code of Ethics. All individuals who provided information and whose products were photographed for research provided informed consent prior to the initiation of research, and an extensive dialogue about the nature of the study was held prior to all interviews and photographs. All participants were informed about the goals of the research and the intent to publish and publicize the information provided and were assured that all photographs and video footage would only be used for non-profit, non-commercial, and educational purposes. They continued to provide consent throughout the project, and after its conclusion while planning for future research endeavors. In order to respect and protect their security and confidentiality, I have kept their identities anonymous.

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