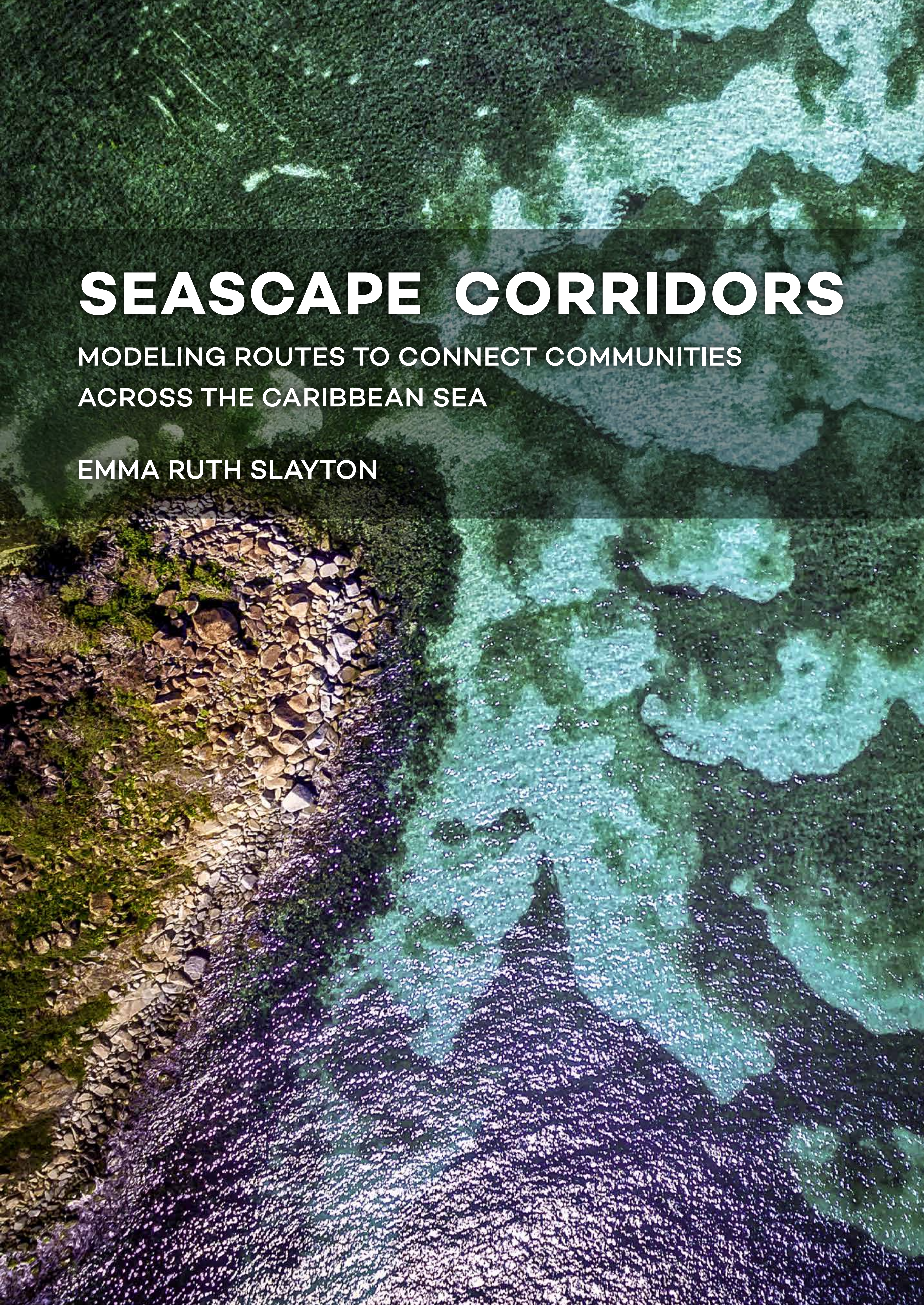
SEASCAPE CORRIDORS

MODELING ROUTES TO CONNECT COMMUNITIES ACROSS THE CARIBBEAN SEA

EMMA RUTH SLAYTON



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Sidestone Press

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Published by Sidestone Press, Leiden
www.sidestone.com

Imprint: Sidestone Press Dissertations

Lay-out & cover design: Sidestone Press
Photographs cover: beach with canoe Costa Rica; damedias | stock.adobe.com
Aerial view of Saint Martin Beach: Thierrydehove | dreamstime.com

ISBN 978-90-8890-577-3 (softcover)
ISBN 978-90-8890-578-0 (hardcover)
ISBN 978-90-8890-579-7 (PDF e-book)

This research has received funding from the Netherlands Organisation for Scientific Research (NWO); projectnumber 360-62-060.

This dissertation followed the Ethics code of Leiden University.

DOI dataset: https://doi.org/10.17026/dans-zfu-tscq
References to appendices in this work refer to the appendix for Slayton's PhD Dissertation, which can be found through the Leiden University Library.

“*Man, building this greatest and most personal of all tools, has in turn received a boat-shaped mind, and the boat, a man-shaped soul.*”

John Steinbeck, 1951

Contents

Acknowledgments

I would like to thank my supervisor Prof. Dr. Corinne Hofman. Without her guidance, I would not have been able to complete this work. I am grateful to the Netherlands Organization for Scientific Research (NWO) and the Island Networks Project for making this research possible.

I am especially thankful for the guidance of my co-supervisor Dr. Lewis Borck and for advice I received from Dr. Angus Mol, Dr. Andrzej Antczak, Dr. Arie Boomert, Dr. Jaime Pagán Jiménez, Dr. Marlena Antczak and Dr. Alexander Geurds. Maribel Adame Valero and Ilone de Vries-Lemaire who supported me through this process.

Jan Christoph Athenstädt (University of Konstanz) and Jan Hildenbrand, or as I like to refer to them *Jan2*, worked tirelessly on the route cost tool, and without them this research would not have been possible. A special thanks to Jan C. A. for checking my methods section to ensure the math was correct. I also appreciate the work of Dr. Viviana Amati (University of Konstanz) and Kirsten Ziesemer who helped me statistically analyze my results.

I owe a debt to Dr. Benoit Bérard (University of the Antilles and Guyane) for his help in understanding Caribbean canoe use. I am grateful for the support of the Karisko project and was very fortunate to work with several of the group's members, including Marcel Rapon, when I visited Martinique to take part in their canoe training exercises.

My officemate Floris Keehnen was, and is, amazing. As are the rest of my friends in the Netherlands: Felicia, Mariska, Roos, Phillipa, Jana, Eloise, Natalia, Eldris, Judith, Sam, Lou, Sony, Eduardo, Julian, Judith, Hayley, Katarina, Tom, Catarina, Marlieke, Andy, Jimmy, and Csilla. Thank you also to my friends outside the Netherlands: Nicola, Kathy, Liana, Katie, Kristin, Emily, Hannah, Julia, Patrick, and Sam. A special thanks to Alex who kept me sane and was the best travel buddy a woman could ask for. Also, to the Seattle-based brunch club who kept my spirits up on every trip home.

Thank you to my family in Florida, whom I love.

Most importantly, I would like to thank my parents. I am so grateful for everything you have done for me. Your investment in my education is a gift I can never repay. Your support has meant the world to me. I love you both.

1

Introduction

The sea has been a canvas for human mobility and interaction for thousands of years (*e.g.*, for the Caribbean, see Hofman and Bright 2010; for global examples, see Ammerman 2010; Anderson 2010; Broodbank 2002; Bednarik 2014; Irwin 2010; Irwin *et al.* 1990; O'Conner 2010). However, understanding what life would have been like at sea in the past is not an easy task. This is due in part to a lack of ethnographic or ethnohistoric records and to a dearth of material remains from seafaring. Yet we know sea travel happened due to the presence of archaeological materials on islands.

Researchers have tried many approaches to shed light on life and travel on the sea in the past. Initially, scholars discounted or undervalued the use of maritime spaces by past peoples. Seas were seen as blank spaces devoid of life rather than all-encompassing spaces in which all types of social connection and exchange took place (see McNiven 2008). Later, islands were approached as self-contained laboratories within the sea (*e.g.*, for early work on island laboratories as part of island biography theory, see MacArthur and Wilson 1967; see also Evans 1973, 1977; Fitzpatrick 2004; Fitzpatrick and Anderson 2008; Gosden 1999; Gosden and Pavlides 1994; Royle 2001; Terrell 1976, 2008). Peoples and objects came in and went out, but the islands were seen as entities onto themselves. These approaches do not provide a wholly representative view of how past peoples connected with islands, but only a limited framework for the interpretation of sea environments by modern archaeologists. For people in the pre-Columbian Caribbean, interacting with other groups on different islands was an important part of everyday life. Understanding how these interactions happened is essential to studying how past societies worked, how a community was formed, and how ideas and materials were transmitted. The current research adds to previous approaches to achieve a different perspective of sea travel in the Lesser Antilles.

This study, as part of the Netherlands Organization for Scientific Research (NWO) Island Networks Project (project number 360-62-060), aims to assess how archaeological sites from the Lesser Antilles might have been connected using computer modeling. Specifically, least-cost or optimal pathway travel corridors are generated from underlying environmental and archaeological data. Canoe routes likely influenced which communities were in contact with one another, where peoples settled, and how individuals, materials, and ideas moved through the islands (for examples of exchange patterns from the NWO Island Networks Project, see Breukel forthcoming; Laffoon *et al.* 2016; Mol *et al.* 2014; Hofman *et al.* forthcoming; Scott *et al.* in press). Alongside techniques like traditional ceramic analysis (*e.g.,* Boomert 1982; Hofman

1993), archaeometry analysis (*e.g.,* Jacobson forthcoming), lithic analysis and sourcing (*e.g.,* Knippenberg 2007), as well as isotopic research (*e.g.,* Laffoon *et al.* 2016), least-cost pathway modeling can point to possible inter-island connections. By modeling routes and analyzing the resulting canoe pathways, it is possible to propose corridors and patterns of movement through the Caribbean.

The dichotomy between day and night travel, as well as the shift in movement between settlements active in certain seasons or years, shaped the flow of peoples through the Caribbean. When people launched is an important aspect of how people used the sea. Route trajectories changed over time, both in terms of when in the day and year canoes set off and more broadly to match the shift in prominent or resource-focused settlement locations that arose in different archaeological periods. Shifting trends in current and wind probably affected how canoers moved between islands and further influenced how peoples, ideas, and materials interacted with one another. By analyzing these temporal and geographical patterns, the interconnection of separate island communities can be modeled and reconstructed.

Following from the earlier approaches, researchers have come to understand that seas facilitated and encouraged movement between specific islands and that this mobility was dependent upon the water's surface environment. Water acting as a facilitator for mobility has been adopted by archaeologists (*e.g.*, for Caribbean examples, see Boomert and Bright 2007; Hofman *et al.* 2007; for non-Caribbean examples, see Broodbank 1993, 2000; Irwin 1980, 1994; Terrell 1988). However, this view does not always represent the interaction between the sea's environmental factors in all their complexity and the human activity that would have taken place at sea. Like landscapes, whose hills and valleys influence how easy it is to travel across a region, the characteristics of the sea environment can impact the direction and difficulty of travel. The rhythms of currents and wind made voyaging between islands more complicated than is suggested by studies relying on Euclidean distances alone. These underlying environmental factors would have impacted the structure of inter-island networks and the social lives of seafarers in their vessels.

Canoes and a navigator's knowledge of routes ensured that people could move safely between islands with their material and their ideas. The knowledge of these routes was likely maintained by multiple canoers and shared between travelers, creating continually changing mental maps that gave navigators information about settlements along their journeys. Some aspects of these communal mental maps can be hypothesized by modeling the movements of peoples, not just to an island but also between islands. In turn, this information can suggest which areas were more connected to a broader mobility network and how site location was associated with possible travel routes.

It is likely that canoe pathways influenced several aspects of social life, including subsistence gathering and exchange of resources. Canoe transport corridors also affected how political ideas and ritual practices could spread among island communities. Evidence of these concepts and materials can be seen in several site assemblages. The presence of similar materials throughout the Caribbean archipelago (*e.g.,* Fitzpatrick 2013; Hofman and Hoogland 2003, 2011; Hofman *et al.* 2007, 2014; Knippenberg 2007; Rouse 1992) suggests that canoe routes across island passages reinforced bonds between seafarers separated by great distances. The inter-island exchange that existed in the region from the Archaic Age onwards fueled the use of specific lithic resources and influenced ceramic stylistic choices. In addition to these exchanges of materials and ideas, crews could procure seasonal products by traveling along routes with the knowledge that their navigation skills could lead them back to their starting point.

Archaeologists can use various sources of information to illuminate past seafaring practices. From a material point of view, island communities were linked through the transportation of objects and the sharing of stylistic elements. As a result, the archaeological record from island settlements can indicate which peoples were in contact with which areas. However, in this region the archaeological record has so far provided only general answers, rather than exact trajectories on where people moved. For example, the materials being exchanged between settlements can often be sourced to one island and the mechanizations behind moving that resource to other sites and islands explored (*e.g.,* Knippenberg 2007), but the difficulty inherent in moving people and materials cannot be fully uncovered based on the archaeological material alone (Davis 2000; Hofman and Hoogland 2003; Knippenberg 2007). Stylistic elements can show that several islands are tied together but cannot point to specific areas where the ideas or graphic themes were generated (*e.g.,* Boomert 2008; Hofman *et al.* 2007; Righter *et al.* 2004). Materials that are decorated in these characteristic styles were often produced locally in various locations (Hofman 1993), further obscuring how these stylistic elements were diffused throughout the Caribbean. To help reconstruct this pattern of mobility and exchange, direct archaeological evidence for sea travel would be highly beneficial. Unfortunately, the material evidence for early sea travel technology is limited due to taphonomic conditions. Seafaring technology, including canoes and canoe paddles, often degrades within sites due to the materials' organic make-up and the local soil composition. To bridge this gap in knowle.g., ethnographic, ethnohistoric, and experimental archeological research can provide some insights into how vessels were used and what the community atmosphere within canoes might have been.

Additional approaches are needed to investigate where vessels moved between islands in the seascape. Modeling potential routes is one way forward. Pathways generated through modeling can indicate the limits of voyage length and can give researchers an idea of what canoers would have needed to bring with them and how many crew members were required to complete a trip. Modeled pathways can also hypothesize the location of routes and the possible shape of a small portion of pre-Columbian mental maps. Modeling pathways between sites archaeologically thought to be engaged in inter-island interaction can strengthen our understanding of how communities on different islands might, or might not, have been connected.

Modeling multiple reciprocal routes can indicate possible areas where resources were gathered directly and what goods were imported and exported through indirect exchange processes. Least-cost canoe pathways, or computer-modeled routes that propose least energy paths based on the available environmental data, can also add a seasonal element to travel corridors. As canoe routes are modeled using shifting currents, groups of generated pathways can provide some insight into what portions of the year had a higher concentration of least-cost paths; this may indicate whether an annual advantage could have existed for real-world Amerindian canoers following similar travel corridors. The goal of the current study is to model these least-cost pathways to uncover the possible existence of there-and-back, or reciprocal, canoe voyages, and to assess how the location of generated least-cost canoe routes can add to our understanding of human mobility and the exchange of goods and ideas in the pre-Columbian Caribbean archipelago.

1.1 Objectives and Research Questions

The current research uses least-cost pathway analysis to propose possible pre-Columbian canoe routes in the Caribbean through the application of an isochrone model. Modeling canoe routes can be used to investigate how movement and mobility may have influenced the placement of settlements and the connections between them. Several key themes can be explored from the resulting routes, including the effects of seasonality on route construction, the relationship between modeled pathways and site placement, the navigation techniques observed in resulting routes, and how the connection between possible seafaring routes and the construction of communal mental maps can be evoked. These themes will be evaluated using archaeological analysis, experimental archaeology, historic accounts, and the application of isochrone least-cost pathway modeling.

In order to discuss sea routes between Lesser Antillean pre-Columbian Amerindian communities, I modeled least-cost canoe routes between archaeological sites that contain evidence of exchange with other island groups. To do this, I also evaluated the feasibility of using the isochrone tool developed in conjunction with this research (see Hildenbrand 2015; see also Chapter 4). Assessing the capabilities of the isochrone route tool to answer questions of inter-island interaction across three case studies can point to the tool's effectiveness in different environments and geographical settings, as well as provide valuable insights into mobility and exchange in pre-Columbian society.

In the mold of previous research that has sought to examine inter-island connections by evaluating the movement of materials, peoples, and ideas (*e.g.*, using lithic analysis, see Knippenberg 2007, using network theory, see Hofman *et al.* 2014; Mol 2014), I applied least-cost pathway techniques to evaluate the underlying mechanizations of movement between Amerindian communities in the pre-Columbian Caribbean. Modeling routes, and attempting to uncover the costs associated with canoeing between known settlements or resource areas, provides a baseline for how difficult it would have been for people to maintain social or political connections between islands. Beyond this functionalist understanding of movement costs this work seeks to demonstrate how computer models of cost-based sea travel enhance our understanding of connectivity amongst Amerindian island communities and can be mobilized to answer archaeological questions.

The aims of this work translate into the following research question: What are the mechanisms behind past inter-island connections in the pre-Columbian Caribbean archipelago?

The above primary question can be broken down into three sub-questions:

1. What are the possibilities or limitations for traveling between islands and how does this reflect seasonal variation?
2. How did people move between two distant islands? Did canoers follow indirect pathways to stop at intermediate islands, or were people more likely to move between islands without using stopover points?
3. How did sea pathways influence navigation and can computer generated routes reveal portions of ancient navigators' mental maps?

These questions will be explored over three different regional examples of inter-island mobility in the pre-Columbian Caribbean. Though these examples only give slices of the rich network of interaction that existed, they do provide three perspectives on which to ask and answer these questions. Regional boundaries for the following case studies include an evaluation of seasonal mobility through a small network of interconnected islands, between islands separated by large channels and connected through the archaeological record, as well as the possibilities of traveling from the mainland to the islands. Analysis of regions at different scales allows for an evaluation of where peoples may have needed to use indirect routes and stopover points and where indirect connections might have existed but were not used. In some sense, this method might be the only way to indicate the possibilities behind indirect connections, and what non-direct travel can tell us about mobility patterns seen in other works (see Knippenberg 2007; Mol 2014). The cost and trajectories of these routes can provide a baseline for understanding the spread of peoples, materials and ideas through the region, information that can then be used to support previous research on the social relationships in and beyond the Lesser Antilles.

1.2 The Model's Underpinnings

Generating least-cost, or optimal, canoe routes can enhance our understanding of past sea-based mobility and exchange networks. Although archaeological evidence of exchange and movement of materials exists, it is difficult to reconstruct the full range of human capability through an analysis of static objects. It must be noted that least-cost pathway methods cannot model in a vacuum, but rely on archaeological and environmental data. Pathway origin and termination points as well as the surface environment dictate the outcome of optimal routes. These factors are instrumental in connecting generated canoe travel corridors with the reality of the cultural landscape.

To map out these hypothetical routes I used an isochrone tool, a form of least-cost pathway construction that focuses on building routes by connecting movement across several time bands. To create the current portion of the surface upon which these pathways would be calculated, modern sea current data was used to represent past currents. This is consistent with other works that have generated seafaring routes (*e.g.*, Callaghan 2001; Davies and Bickler 2015; Montenegro *et al.* 2016). The data was collected in a way that allowed an assessment of seasonal trends, which added new information to the analysis of past inter-island interaction.

How humans interact in the canoe and a paddler's capabilities were particularly difficult to incorporate into the model. Limited research has been done on human capability in canoes within the field of archaeology using replica canoes (*e.g.*, Bérard *et al.* 2011, 2016; Horvath and Finney 1967; Pagán Jiménez 1988). Therefore, I used other ways to incorporate human constraints. The tool allows canoes to travel at a set speed, derived from experiential archaeology, which enabled the modeled routes to simulate vessels being propelled by canoers as well as water currents. The model avoids becoming purely environmentally deterministic through the addition of human influence on the routes.

Other factors that can inform on the human element prior to modeling are the historic accounts that mention peoples canoeing between islands in the Caribbean (*e.g.*, Benzoni 1857; Breton 1665-1666; de Oviedo y Valdés 1535; de Rochefort 1665; du Tertre 1667-71Layfield 1598). These accounts provide context for how vessels were used and some explanation of the navigation practices of pre-Columbian Amerindian canoers. Re-construction of seasonal rhythms of mobility, the total capacity of vessels, and how vessels were constructed provide the setting for canoe transport corridors. Ethnographic works (*e.g.,* Taylor 1938) also offer insights into canoe production and use that influence how we assess the viability of pathways returned by the model.

Using archaeological sites as origin and termination points incorporates activity areas into the earliest stage of route calculation. The use of archaeological sites ensures that routes being generated have some relationship to where goods from possible voyages are present, increasing the likelihood that modeled routes reflect pre-Columbian travel. As the placement of assemblages was tied to the location of nodes used as origin and termination points, archaeological sites were linked to a broader exchange network modeled here. Evaluating only the viability of canoe routes, the model treats all evidence equally and avoids weighting the evidence of one site over another. As a result, travel corridors are based on the cost or trajectory of the routes rather than the possible importance of any one resource or settlement to past Amerindian peoples. This may allow for new ways of thinking about connections between sites and islands that have been previously overlooked.

One assumption when modeling past possible travel corridors is that canoers may have sought out optimal, or least-cost, routes between origin and termination points. However, canoers would not have necessarily only followed the optimal routes modeled in the following case studies. In actuality, Amerindian canoe crews may have chosen to travel on non-optimal routes for a variety of social or cultural reasons. Canoers could also have turned back to shore if they observed the weather changing or if hostile elements were approaching their vessel. Crews might also have stopped mid-voyage to take advantage of fishing resources. While these factors cannot be included through the isochrone tool, they must be borne in mind in evaluating the results.

Still, this research shows that links between modeled routes and the location of in-between settlements suggest that these possible travel corridors may have been used by Amerindian canoers. Thus, the relationship of the location of sites not included in the route modeling data to the generated least-cost paths presents a possible solution to our inability to directly track the location of past canoe routes. When settlements occur along a modeled route, it increases the probability that this route may have been followed in the past (for an example of a land-based method of using sites along a pathway to statistically determine its viability, see Borck 2012). Calculating these canoe routes provides information that complements the available archaeological assemblages, especially considering the destructive effect of the sea on the archaeological remains of seafaring technology.

1.3 Outline of Chapters

I modeled possible canoe routes connecting sites on islands occupied between 2000 BC and AD 1600 over three case studies. Extending from the Archaic Age until after the arrival of Europeans in the region, I chose to focus on three temporal periods created for this work that demonstrated a number of inter-connected settlements as shown through the presence of similar materials or stylistic elements. These phases were the Archaic Age in the northern Lesser Antilles (2000 BC – AD 100), the Late Ceramic Age in the Greater Antilles and the northern Lesser Antilles (AD 1200 – 1500), and the Late Ceramic Age/early colonial period along the northeast coast of mainland

South America and the southern Lesser Antilles (AD 1250 – 1600). These time frames and geographic regions are used to focus modeling efforts on important archaeologically-attested exchange relationships that existed in the Lesser Antilles before and just after European arrival. These relationships include the movement of specific materials, such as Long Island flint through the northern Lesser Antilles (see Chapter 5), stylistic elements indicative of broader regional norms, such as so-called Taíno materials in the Greater Antilles (see Chapter 6), or Koriabo and Cayo ware from the mainland to the Windward Islands (see Chapter 7).

Before analyzing how route placements could be used to infer reciprocal voyages in the Caribbean, I examined the theory behind how people construct mental navigation maps. The theory regarding movement between two places within a landscape and seascape is discussed in Chapter 2, which also includes a discussion of wayfinding, or the processes of linking settlements and the landmarks or pathways between them (for examples of theory behind wayfinding, see Ingold 2000, 2009). It can reasonably be assumed that the Amerindian navigators were using navigation skills gained over their lifetimes through personal experience or shared knowledge to canoe between these known sites. Combined, these elements present a holistic comparison of archaeological material and modeled routes that can increase our understanding about past movement practices.

Chapter 3 explores the evidence for the use of canoes and what life might have been like for their crews. Experimental archaeological research has determined some of the limitations for long-distance paddling. These limitations set the baseline for the capability of canoers and canoe speed used within the model. Chapter 3 also includes a summary of the research that has been done to model land-based and sea-based least-cost pathways, which formed the methodological basis for the current study. Though sea-based movement is more complicated to calculate, the algorithms used within landscape modeling are not significantly different and it is only the underlying data that changes dramatically from terrestrial to oceanic voyaging. This chapter also details the work that has been done to model past canoeing and sailing routes to provide insights into how to approach sea modeling.

As there is currently no standard method for modeling sea-based pathways, a method was selected here based on previous work modeling modern seafaring (Hagiwara 1989; Hildenbrand 2015). I used an isochrone tool created by Hildenbrand (2015), as it can mimic seafaring choices by generating routes based on decisions of movement over bands of time. The tool enabled the construction of several routes across several periods of time, allowing for a qualitative approach to the seasonal analysis of routes. Examined in Chapter 4, Hildenbrand's isochrone route tool calculates the furthest distance possible to travel by canoe in any direction from an origin point in a set period. These time bands are repeated until the destination point is reached. The cost surface upon which canoe travel is modeled changes with each successive band. For example, a band in the middle of the journey would have a different cost surface when the canoe finally reached it than it would have when the canoe first started. This is because the ocean currents and winds are constantly changing, so the underlying cost surface needs to be similarly dynamic. Thus, this particular isochrone tool allows routes to reevaluate their heading based on optimal current, reflecting the possible choices real-world canoe crews who understood how to read waves to reorient themselves towards their goal over set time periods might have made, albeit at a resolution of approximately 30 minutes. As such, the Hildenbrand (2015) isochrone tool better reflects the dynamic and ever-changing nature of sea-based voyaging.

Not all modeled routes were evaluated in the analysis. This was necessary due to the number of routes returned for each travel corridor over the course of all years evaluated. For example, if one were to model outward routes from one node to 10 other sites over every possible time period (every three hours) for an entire year, 28,800 pathways would be returned. To limit the number of nodes included in this study I chose sites that were known to be in contact with one another and/or were suggested as key members of a broader inter-island exchange network. This ensures that the modeled routes were possible connections between these communities.

Settlements selected in each study were contemporaneous, based on the chronology documented in the site assemblages. However, this archaeologically-attested contemporaneity still contains many generations of human lives. Thus, for repeated travel at this low temporal resolution to be likely, mental maps must have remained somewhat consistent over several generations (see Callaghan 2003).

Chapters 5, 6, and 7 comprise the three case studies used to explore the research questions (see Figure 1). Chapter 5 applies the method to movement between sites

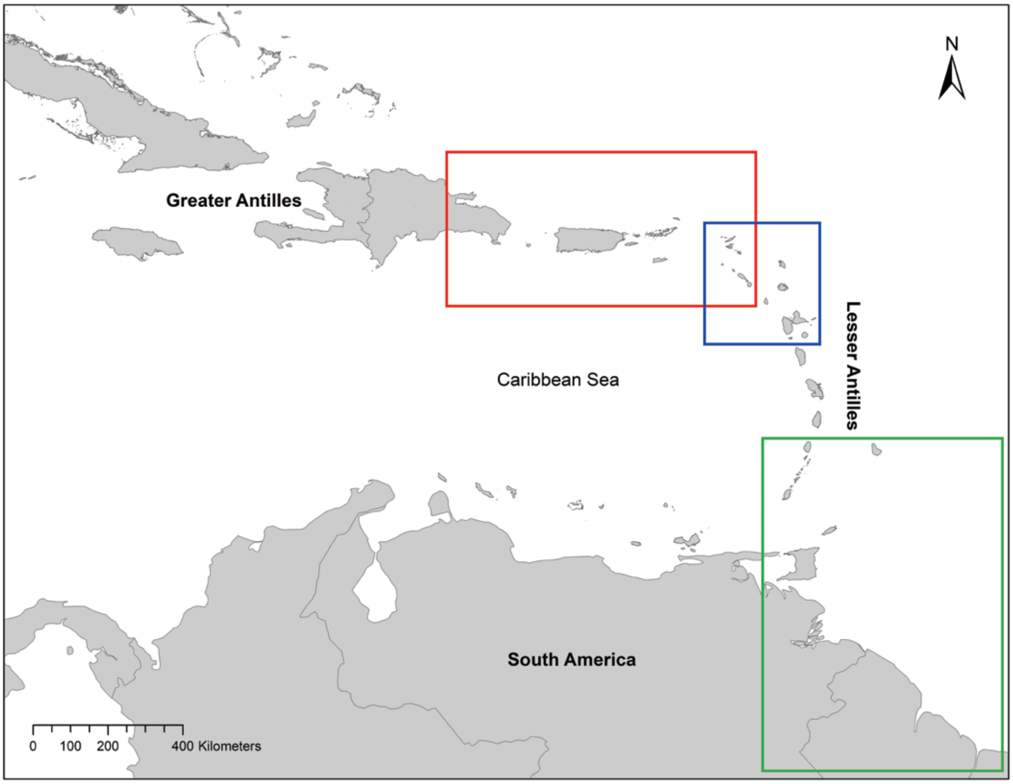


Figure 1: Map outlining the three case study regions. From left to right: the eastern Greater Antilles and the northern Lesser Antilles (Chapter 6), the northern Lesser Antilles (Chapter 5), mainland South America and the southern Lesser Antilles (Chapter 7).

in the Leeward Islands during the Archaic Age (2000 – 400 BC). This case study focuses on tracking the movement of Long Island flint around the northern Lesser Antilles (*e.g.*, Davis 2000; Hofman *et al.* 2014; Knippenberg 2007). Targeting movement between sites on several islands known to exchange this distinct lithic material can identify what places were more likely to be in direct contact due to the ease of travel between them. The routes modeled for this case study can also point towards instances of indirect exchange.

Chapter 6 applies the isochrone route tool to tracking movement between the Greater and the Lesser Antilles during the Late Ceramic Age (AD 1200 – 1500). This case study was chosen because although similar materials and stylistic motifs are found throughout the Greater Antilles, the Virgin Islands, and the Leeward Islands, it is difficult to determine how these elements were exported and imported (Hofman and Hoogland 2011; Keegan and Hofman 2017; Righter *et al.* 2004). The analysis focused on the difficulty of moving across the Mona Passage and Anegada Passage and whether any sites acted as key players within the cultural exchange between these island groups. The greater distances between islands in this case study enabled me to evaluate the tool's effectiveness over larger areas. It also permitted me to challenge the idea of seasonal travel corridors and assess how directionality affected route trajectories.

In Chapter 7 I used the tool to analyze canoe pathways during the Late Ceramic Age and early colonial period (AD 1400 – 1600) from the mainland to the Windward Islands. Connections between Koriabo ceramic communities on the mainland and Cayo ceramic communities on the islands are evident through analysis of archaeological assemblages in the region (*e.g.*, Boomert 2003; Hofman and Hoogland 2011). However, much like identifying how Greater Antillean materials were dispersed across the Anegada Passage, there is no clear idea of how Koriabo materials made their way into the Windward Islands. There is also no clear evidence of Koriabo or Cayo pottery on Trinidad and Tobago, the islands that lie between these areas. Evaluating how routes moved between the regions can indicate whether peoples traveled directly or indirectly between these two areas. This regional focus allowed me to look at routes where there were fewer options for crews to make stopovers due to the lack of in-between islands as well as social pressures that may have kept them away from some of the islands they would have passed. It also permitted me to evaluate how the tool responded to the stronger currents found in the channel between mainland South America and the Lesser Antilles.

Chapter 8 contains a discussion of the three case studies in Chapters 5, 6, and 7. This chapter compares the functioning of the route tool in different locations with different geographic factors and different timeframes, and what least-cost sea-based modeling can tell us about past sea movement in these distinct case studies. Findings include changes in the seasonality of route choice, possible connections between route trajectory and the location of sites, and a hypothesis on whether there is any insight into the existence of mental maps associated with the position of routes and how they relate to islands passed en route.

Through isochrone modeling using archaeological and environmental data, the current research identifies possible travel corridors for peoples moving through the islands of the Lesser Antilles and into the broader Caribbean region. Identifying possible routes between separate island communities engaged in exchanging objects around the region can help to identify the journey these peoples, materials, and ideas may have taken and/or possible centers of interaction. The trajectory of modeled routes can also be used to indicate where real-world canoers may have stopped during a voyage, suggesting new possibilities for inter-island connections. These connections can be extended to suggest links between sites over subsequent periods, showing the development of travel corridors and the persistence of a communal mental map that helped canoers retrace their paddling over generation.

In addition, I show the benefits of applying a least-cost pathway approach using Hildenbrand's (2015) isochrone tool to model past canoe routes in the Caribbean. This study does not seek to argue that the routes modeled were the only routes traveled, only to suggest that these may have been possibilities that were available to past peoples. Through comparisons with the archeological and historic evidence of how peoples moved through the region, route modeling can thus be used to supplement existing theories or point to new ways to think about mobility in the Caribbean.

Least-cost pathway modeling can provide key insights into there-and-back, or reciprocal, voyages. When banded together, the pathways modeled here suggest the location of canoe transport corridors that connected Amerindian islanders in the Caribbean. The physical trajectories of these routes are hard to determine only through the lenses of archaeology, history, or ethnography. Archaeological evidence can only illuminate part of the story of past mobility of peoples, materials, and ideas. Historic and ethnographic accounts can point to the general area of these routes, but are often records of later periods when canoeing populations may have used different routes to avoid or connect with Europeans in the region. Using computer modeling to recreate past mobility corridors can suggest who was in contact when and where. These pathways can even indicate indirect connections, central areas of inter-connection, and a connection between settlements and canoe travel corridors. By adding this type of route modeling to their toolbox, archaeologists can attain a more comprehensive image of mobility in the past.

2

Modeling Canoe Voyaging in Theory

This chapter explores the socialization of seascapes and the mental construction of navigation, or the existence of mental maps, which made sea-based travel corridors accessible. Seascapes can be defined as places imbued with cultural connections that are on the sea, in view of the sea, or in coastal areas bordering the sea (Cooney 2003; see also Crouch 2008). Seascapes are a cross between the conceptual and corporeal realities of everyday life. They represent an arena of interaction with the sea environment or between different cultural groups (*sensu* Cooney 2003: 326; Crouch 2008: 132-136), sea-centred material culture (*e.g.*, McNiven 2008: 154), and, in some cases, people and the 'spirit' world (*sensu* Cooney 2003: 324; Lewis 1994; McNiven 2003, 2008; for a broader discussion of water as spiritual metaphor, see Strang 2008b: 124). Seascapes can also be significant culturally (*e.g.,* McNiven 2003, 2008: 154) and for expressing group identity (*e.g.,* Cooney 2003: 323). Exploring these seascapes' physicality, or the physical space people use and move through, can assist in uncovering the relationship between the social, psychological, and physical use of the sea.

Because life at sea held a critical role within coastal mainland and island communities (Crouch 2008), canoeing technology in the Caribbean fostered robust inter-island exchange networks that are evident within the archaeological record (Bérard 2002). Yet, as noted by Callaghan (2013: 254), until recently the capabilities of past Caribbean seafarers have been underrepresented in archaeological research. The archaeological, ethnohistoric, and ethnographic records of canoe use in the Caribbean are essential to understanding the possibilities that seafaring offered. In addition to the different views of Caribbean seafarers as either expert navigators with effective technology or as simple canoers, there is also debate as to how they constructed their vessels and what technologies they used (see Frederick 2014; Honeychurch 1997a; Lewis 1994).

The technological limitations of canoe use revealed through ethnography, experiential, and experimental archaeology function as the basis for discussing constraints on voyages (for ethnographic, see Dodd 1972; Frederick 2014; Taylor 1938; for experimental and experiential, see Bérard *et al.* 2016; Billard *et al.* 2009; Horvath and Finney 1969). Experimental studies of canoe building and voyaging provide additional information on the possible use and utility of canoes to supplement these records (Billard *et al.* 2009, 2016). Ethnographic examples and comparisons can help to explain how people contextualized being on the sea (Crouch 2008: 134; Lewis 1994; Tingley 2016; see also examples in Ingold 2009). For example, the ways in which people 'read the waves' to understand current flow likely influenced their movement through and understanding of the sea (Lewis 1994; Tingley 2016). A canoer's view and feel of the surrounding environment provided clues on where the best direction for seafaring would be. These clues could be followed and linked to form optimal routes. We can also gain insight into how vessels may have been used by evaluating the capabilities, seaworthiness, or capacity for crew and cargo of the canoes themselves (*e.g.,* Billard *et al.* 2009; Taylor 1938). For example, planked vessels, or dugout canoes with additional siding added to extend the height of the vessel, would capsize less than those that had not had the canoe sides built up (Bérard personal communication 2014; Taylor 1938). Canoes that capsized less frequently had a greater chance of delivering their crew and cargo to their destination, supporting the continuation of existing systems of mobility in the islands.

In addition to these technological limitations, inter-island and intra-island settlement patterns, as well as the ability of canoers to reach certain destinations, may have been influenced by environmental factors. These factors include the outline of seascapes, the spaces where sea and land meet, the placement of coral reefs and sandbanks, tides, and the location of channels (Crouch 2008: 132). Other environmental factors such as current and wind also influenced the ability of canoers to reach certain destinations, as has been discussed in connection with modeling movement on seascapes (*e.g.,* Altes 2011; Callaghan 2001, 2003; Davies and Bickler 2015; Irwin *et al.* 1990; Slayton 2013). The likelihood of canoers having a successful voyage can be modeled by considering these environmental factors, as well as a crew's ability and paddling capacity (*e.g.*, Callaghan 2001, 2003). These limiting factors can be used as defining variables to create computer models of pre-Columbian sea routes. The application of these constraints will be discussed more extensively in the following chapter.

2.1 Seascapes as Spaces

Even though the sea makes up over 70 percent of the earth's surface, traditionally much of the discussion of lived spaces in archaeology has only concerned activities that would have taken place on land (McNiven 2008: 149). There has also been some discussion over the degree to which islands were isolated cultural entities (*sensu* Erlandson and Fitzpatrick 2006: 14-16; Evans 1977: 20,23; Fitzpatrick and Anderson 2008: 6-8; Vayda and Rappaport 1963). In the past, many archaeologists have considered islands to be isolated laboratories (for discussions of islands as laboratories as initially developed for island biographies, see MacArthur and Wilson 1967; for further discussion of islands as laboratories, see Boomert and Bright 2007; Broodbank 1999; Crouch 2008: 133; Evans 1973; Fitzpatrick and Anderson 2008: 5-8; Gosden and Pavlides, 1994; Terrell 2008), their cultural evolution linked to their relatively small size and surrounding water. In this view, island communities were not connected by the sea, but were rather bounded and constrained by it. Neglecting to acknowledge seascapes to the same degree as landscapes ignores the crucial role water played as a facilitator of social connection in past societies, globally and in the Caribbean (*sensu* for Caribbean examples, see Hofman *et al.* 2010; Torres and Rodríguez Ramos 2008; for non-Caribbean examples, see Crouch 2008; Broodbank 2000; Gosden and Pavlides 1994). As Gosden and Pavlides (1994: 170) put it "The sea is not necessarily either a bridge or a barrier: it is what people make it."

Only by considering the human understanding and use of the environment, not just the environment's effect on humanity, can we gain a more complete picture of these societies. The important role of the sea as a connector is one reason why explaining and analyzing seascapes is essential to understanding networks and connections between Amerindian islanders. Caribbean islands and their communities have increasingly been seen as highly connected, or engaged in complicated inter-island mobility systems (*e.g.*, Hofman *et al.* 2010; Torres and Rodríguez Ramos 2008). There is no question that many islands were linked through sea travel (*e.g.,* for the Caribbean, see Curet 2005; Hofman *et al.* 2006, 2010; Torres and Rodrígues Ramos 2008; for the Mediterranean, see Broodbank 2000; for the Pacific, see Terrell *et al.* 1997). Seafarers determined destinations for their canoe trips based on various factors that have been modeled, including site location, weather patterns, and the technological capabilities of the canoe (*e.g.*, Broodbank 2000; Callaghan 2001; Davies and Bickler 2015; Hofman *et al.* 2016; Montenegro *et al.* 2016; Slayton 2013). Canoers may also have had to plan voyages depending on shifts in the current or the weather, possibly stopping at an island for several days before they could launch again (*e.g.*, Broodbank 2000: 94). Voyages that were tied to specific environmental conditions may have altered relationships between seafarers and where they made port.

In landscape theory, corridors of movement are often connected to or around areas associated with specific "taskscapes." Ingold defines taskscape as "a pattern of activities collapsed into an array of features" (Ingold 1993: 162, 2000; see also Nyland 2017; Rajala and Mills 2017; Tilley 1994). Taskscapes can include areas of production, such as lithic collection or manufacture (*e.g.,* Nyland 2017; Rajala and Mills 2017), or a space in which ideas are transferred (Ingold 1993). Similarly, sea pathways (or corridors of movement) often link a series of sea-based activity areas, for example those associated with fishing grounds (Agouridis 1997: 13; Crouch 2008: 135; Lewis 1994; McNiven 2008: 152-154) or safe places to harbor (Agouridis 1997: 14). Lewis (1994) mentions Pacific seafarers mentally tying fishing grounds to the flight paths of birds and certain points within the seascape. Agouridis (1997) and Broodbank (2013) mention the physical placement of markers that can denote harbors, which also constitutes a social connection to a sea-based activity. Trowbridge (1913: 890) makes the argument that people's memory of distance places is not geographically exact. In this vein, the connection between known harbors on distant islands and the friendly communities that live there may provide deeper meaning to the seascape as you traverse it (Terrell and Welsch 1998). Places associated with navigation markers or activities may have been given names or positions within a cultural narrative (Broodbank 2013; McNiven 2008: 152-154). These pathways and connected activity areas form the broader continuous seascape. Selected and associated cultural areas within landscapes, and by extension seascapes, can provide information on a community's relationships with its environment and with other peoples, as humans spatially order their social world (*sensu* Casey 1996).

Casey (1996) also discussed the importance of movement through an area for constructing social space. For example, in ritual spaces individuals tend to move in set patterns established through learned tradition and bodily repetition (Casey 1996: 23). This is similar to theories explored by Ingold (1993, 2000, 2009, 2011) and Tilley (1994), who theorize the construction of social space as being tied to the body's movement through and interaction with a landscape. Here, either in the general world

(Ingold 2011) or through the Welsh mountains (Tilley 1994), the progression of an individual informs on how people established mental and physical relationships between physical landmarks. In this way, the continuation of cultural areas, or even the remembrance of certain social spaces, are key aspects of a community ordering its world and establishing set pathways of moving through it. Connecting social spaces with activities or navigation markers to create a spatially-ordered sphere can also be seen in works discussing seascapes (*e.g.,* Broodbank, 2013; Crouch 2008; Frake 1985; Terrell and Welsch 1998). For example, Crouch (2008: 133) discussed the position of the Tudu sandbank as a central point within the mental map of Torres Straight islanders, despite its small size and low prominence in the water.

The seascape theory used here is drawn from archaeological landscape theory (*sensu* Casey 1996; Ingold 1993, 2000, 2011; Tilley 1994) and previously developed seascape theory (*sensu* Boomert and Bright 2007; Cooney 2003; Crouch 2008; Gosden and Pavlides 1994; McNiven 2008; Terrell and Welsch 1998; Torres and Rodríguez Ramos 2008; Waldren 2002). However, the social rules applied to seascapes can be very different from those assigned to landscapes due to the somewhat static nature of the latter and the fluid nature of the former. As Cooney (2003: 325) put it, "Seeing and thinking of the sea as a seascape – countered, alive, rich in ecological diversity and in cosmological and religious significance, and ambiguity – provides a new perspective on how people in coastal regions actively create their identities, sense of place, and histories."

Sea voyages either around a specific island or between neighboring islands were likely a daily part of life for island communities. The use of seascapes must have helped shape these communities. Additionally, people living on small islands might need more interaction with off-island communities to supplement limited subsistence or material resources found around their habitation sites within their own landscapes (*e.g.*, Broodbank 2000; Crouch 2008; Gamble 2008). This could have led to the development of interconnection, focused on resource procurement or exchange relationships, between the various islands and communities within the Lesser Antilles (*e.g.,* Hofman *et al.* 2007, 2010). For example, Broodbank (2000: 91) describes the necessity for "ceaseless movement between individuals, communities and islands, simply in order to keep life going and information flowing in the Cyclades." It is likely that a similar situation existed amongst the small and neighboring islands of the Lesser Antilles.

In some cases, communities were connected more directly through seascapes than landscapes (Bérard 2002; Bright 2011; Cooper 2010; Rouse 1992). The preference for sea-based mobility can be seen in the high level of interaction between two islands on opposite sides of a channel (Bérard 2002; Bright 2011; Broodbank 2000; Rouse 1992). Sometimes Caribbean communities that inhabited the same island had equal opportunities to contact each other by sea or land, yet were often connected more directly through seascapes and settlement location was based on the efficiency and speed of water travel from that location (Cooper 2010). Cooper (2010) discussed movement around Cuba, both over its interior hills and exterior seascape. He puts forward the idea that many sites found within the archaeological record may have been closer, in terms of time cost, when traveling across seascapes rather than landscapes. In part, this was due to the superior speed of vessels in the water and the difficulty in covering Cuba's slopes by foot (Cooper 2010). Preference for movement by sea can also be considered valid for other Caribbean Islands that are also mountainous with small coastlines easy to traverse by canoe, such as Saba.

Reliance on a sea-based mental map of significant spaces would likely have been important amongst island-based communities (*sensu* Ingold 2000, 2009; McNiven 2008; Terrell and Welsch 1998). Mental maps can provide specific associations to the wide range of resources (Ingold 2009, 2011). This includes resources that can be found within the seascape, both above and below the sea's surface (McNiven 2008). The knowledge of landing locations and the logistics of sea travel contained in a mental map is related to a community's dependence on sea travel for survival (*e.g.,* Crouch 2008; Gosden and Pavlides 1994; Samson and Cooper 2015; for practical navigation, see Lewis 1994; as applied in wayfinding, see Ingold 2009, 2011). Seasonal availability of a place contained in a mental map could have further affected the social meanings people gave to it and could have created a schedule on which to visit it (*e.g.,* Callaghan 2003; Fitzpatrick 2014; Hofman *et al.* 2006, 2010). Because seasonally accessible resources can sometimes be the focus of site assemblages, for example mountain dwelling crabs and Audubon's Shearwater birds at the site of Plum Piece on Saba (Hofman and Hoogland 2003), these sites can demonstrate the importance of the seascape to the creation of a mental map.

2.2 Movement through Sea Spaces

Just as a landscape "exists by virtue of it being perceived, experienced, and contextualized" (Ashmore and Knapp 1999: 1), so too does a seascape. Landscapes and seascapes are three-dimensional spaces in which a human cognitive or 'experienced landscape' overlays topography (*sensu* for physiology, see Gibson 1979; Lynch 1960; Richards 1974, for mental map theory, see Ingold 2011; Richards 1974, for theory of movement, see Kirby 2009; Tilley 1994). Moreover, it has been argued that perception, or human experience, is irrevocably linked to movement (Gibson 1979; Ingold 2011: 11; Kirby 2009). Lynch (1960) address how an individual's perception of their environment can be influenced both by the landscape that surrounds them and information provided to them by the community on how to process these stimuli. In reference to the perception of reality through the context of maps, he states "As long as he can fit reality to the diagram, he has a clue to the relatedness of things" (Lynch 1960: 11). Repetition of movement may also allow for the establishment of context within a landscape or cityscape, and lead to the creation of localities that can provide context for travelers on how to move through a space (Lynch 1960). This may also have held true for Amerindian canoers who received instruction or input from more experienced navigators. As long as canoers could contextualize what they saw around them to what they knew of navigation, they could deal with paddling through different kinds of currents or landing on infrequently visited or unfamiliar shores. Richards (1974: 10) also refers to the ability of the individual to place themselves within a broader context without being able to physically see the entire trajectory of their path. This would have been key for Amerindian navigators to plan visits to other islands and the harbors on them that were out of their view.

Meaning is attached to pathways or environments through an individual's use of specific travel corridors (Gibson 1979; Ingold 2011; Kirby 2009). As Kirby (2009: 15) puts it, "memory is always influenced by spatial practice and spatial cues, and engagement in surroundings from embodied mnemonic interplay with characteristics of place in a community." This memory of places would have impacted the process of canoers through an environment and the construction of remembered places within landscapes or seascapes. Lowenthal makes the point that "What people perceive always pertains to the shared 'real' world" (Lowenthal 1961: 249); even in our remembering or dreams we source what we have seen to fill the spaces in our imagination. This shared real world would have informed the contextualization of individual and communal mental maps, as people could perceive and interpret the environment on a personal level and also have shared these thoughts with the community. In some respects, it is possible that navigation is one area where cognitive psychologists can study human thinking on movement and attachment to the environment.

Movement through landscape transforms topography from a surface on which culture occurs to a series of connected places where humans physically and mentally interact with their environment (*sensu* for cognitive physiology theory, see Gibson 1979; Lynch 1960; for mental map theory, see Ashmore and Knapp 1999; Ingold 2000, 2011; Richards 1974; for archaeological phenomenology theory, see Tilley 1994). Space is often seen as the container of movement (Shanks 1992) and provides a method for 'thinking' directionally and about mobility (Ingold 2000, 2009, 2011; Tilley 1994). More specifically, it allows for people to process their environment by moving through it. To some, movement exists in space while cultural affiliation dominates the places within spaces (Shanks 1992; Tilley 1994:36). Furthermore, instead of viewing islands as bounded by water it is possible to conceive of water as bounded by land. The blank space representing the sea on most maps hides a complex arrangement of both the physical realities of canoeing and the mental maps constructed around this activity. The straight lines used to draw connections on maps suggest simple relationships, which belie more complicated interactions dependent on social connections and environmental factors (*e.g.,* Broodbank 2000, 2013).

It is also possible to consider that mobility through space cannot be dissociated from place (Ingold 2009). All spaces, in fact, can be considered places with meaning assigned by those who pass through them (*sensu* Golledge 1992; Ingold 1993, 2009; McNiven 2008; Thomas 2006; Tilley 1994). Ingold (2011: 146) has also argued that there are no spaces within places, merely places experienced by wayfinders as they move through their environment. In this construction of reality, the primary container of being is a path rather than a fixed place (Ingold 2011: 12). In essence, space evolved in relationship to the community that moved through it. Landscapes, and the places that exist within them, can be considered as manmade areas (Jackson 1986). In this sense, where movement creates meaning, no space or landscape is devoid of cultural association (*sensu* Casey 2008; Ingold 2011).

Some researchers have applied the theory of phenomenology, or the understanding of the meaning of landscape through an individual's point of view (Tilley 1994, 2016: 25), to movement studies in order to fill in the gaps that exist in the ethnohistoric or ethnographic record and to better understand the construction of mental maps (*sensu* Husserl 1970, 2013; Llobera 1996). Husserl (1970), for example, studied how humans experience consciousness and interpret the world (see also Husserl 2013; Llobera 1996). Visual, physical, or mental comparisons with the past, when weighted against environmental change and cultural bias, can inform how we understand movement through a landscape (Tilley 1994) or seascape. Tilley (1994) famously applied this approach to the views from megalithic chamber tombs in the Black Mountains in Wales, connecting views of the mountains surrounding the tombs and the process of walking in the area to the construction of cultural perceptions. However, one should be careful not to rely completely on these methods, as there are many detractors to the phenomenological archaeological approach (see Fleming 1999). Still, phenomenological archaeological theory can help to align our perception of physical locations of archaeological evidence with progression along a path and to conceptualize how we think about traveling through an area.

Looking towards the past, it is possible to engage in a 'moving' dialogue with the landscape, which is known as pedestrian speech act (Tilley 1994: 30). In a pedestrian speech act, the individual walker reacts to the environment around them, interpreting pieces of the landscape as they come to pass in real time while holding onto preconceived views of what is passing. Walking through a landscape becomes a conversation between the observer and the environment (*sensu* Golledge 1992, 1999; Gibson 1979; Ingold 2011; Tilley 1994). Environmental conversations similar to pedestrian speech acts are possible on seascapes, if more complicated due to the fluidity of the surface. A path in a landscape can be followed directly, while a path through a seascape always requires some level of approximation of the necessary route because of the movable terrain (*e.g.,* Frake 1985; Gladwin 2009; Lewis 1994; Tingley 2016). As discussed by those who model routes through seascapes, the sea can be altered by several factors, such as tide and changing wave height, that can change on a daily or even hourly basis (Altes 2011; Callaghan 2001; Davies and Bickler 2015; Hofman *et al.* 2016; Slayton 2013). Traveling through seascapes provides a greater challe.g., as the seas are ever-changing and may not allow for consistency in retracing one's path due to seasonal variation in the currents.

Evaluating the development of a site by how it is viewed through time is intrinsic to the study of archaeology. A route's meaning and/or use influences and is influenced by the course of a path, as well as its beginning and end (*e.g.*, Surface-Evans and White 2012: 4). The location of sites or pathways can be the result of the presence or locations of older sites. This can lead to a sense of cultural continuity or persistent places (*e.g.,* Samson and Cooper 2015; Schlanger 1992; Terrell and Welsch 1998). While some parts of a landscape become observed through the progression of the observer down a path (Tilley 1994), other prominent points within the space may not yet have been revealed as the observer is not yet at a space from which they can be seen (Wheatley and Gillings 2000). For a person to progress successfully to a target along a preferred route, possessing a mental map is essential.

When approaching movement through space, one should look for how people would have approached seafaring on the sea, or evaluated the conditions for cognitive maps of the environment in which they were used (*sensu* Neisser 1976). This is due to the defined tasks and skill sets required by seafaring (*sensu* for cognitive maps, see Neisser 1976: 119-22; for cognitive seafaring maps, see Frake 1985: 255; Oatley 1977). In particular, challenges of being out of sight of land may have altered the processes of constructing cognitive maps (Oatley 1977: 583). In fact, Oatley (1977: 542) refers to the process by which sailors in Oceania think of themselves as moving through two frames of reference, past islands they cannot see and celestial bodies that are visible. The change in frame of reference may have sparked different traditions or techniques for marking places within the minds of seafarers.

The ability to create a mental construct of a place, and in turn associate other places with it, is a critically important aspect of navigation (*sensu* Golledge 1992, 1999; Ingold 2009, 2011; Tilley 1994). It is not necessary to be at or even in sight of a place to have that place in mind (*e.g.,* Frake 1985: 260; Gosden and Pavlides 1994; Samson and Cooper 2015; Tilley 1994). A mental order or progression of associated places can influence our cognitive view of traveling between two points (Golledge 1992, 1999; Ingold 2009, 2011; Tilley 1994). Navigation and mental ordering also include a process of separating out important areas or central places from the broader encompassing seascape within the total area existing in the mind of a person (*sensu* Ingold 1993, 2000, 2011; McNiven 2008; Tilley 1994). These associations or navigation markers can include places that one would pass when traveling to, from, or between sites (Tilley 1994). Navigation points can also include areas of the sea with shifting water color associated with changes in bathymetry, rocks protruding from the sea, or even known fishing grounds (Agouridis 1997; Lewis 1994).

Celestial bodies, such as the sun, moon, and stars, were also likely used by pre-Columbian navigators to mark the routes between islands or convenient landing points (*sensu* Lamarche 1993; Torres and Rodríguez Ramos 2008; for global examples, see Agouridis 1997; Bilić 2009; Dodd 1972; Lewis 1994; Oatley 1977). The stars and moon would have been especially valuable markers for those crews paddling at night, when other navigation points may have been obscured. As many routes through the Caribbean region required crews to travel for over 24 hours, celestial navigation techniques were probably in common use.

Less permanent phenomena are used by seafarers as well. Movable weather features, like clouds hovering over islands, can also act as navigation markers (Lewis 1994; Minnis *et al.* 1992). The presence of birds may also be considered a navigation tool, as the movement of birds could have been used by crews to identify fishing grounds or the location of islands (Lewis 1994).

When traveling between two points, social regulations, preferences, and associations enable the viewer to travel along the correct path safely if they have been introduced to the pathway by older navigators (*sensu* in reference to sea-based movement, see Broodbank 2000; Frake 1985; Golledge 1999; Gosden and Pavlides 1994; Tilley 1994). The process of traveling from one point to the next is central to landscape archaeology as "in the process of movement a landscape unfolds before the observer" (Tilley 1994: 31). This shared understanding connects the viewer to a material object and the position of that object within space. Allowances may be made for individual beliefs and associations within this construct because areas may bring up different connotations to different people (Fleming 1999, 2006; Johnston 1998). As Fleming (2005: 929) points out, one person's view of a prominent hill from a megalithic tomb is another's view of a prominent valley (see also Cummings and Whittle 2004: 61). Thus, there is a move beyond simple, objective recognition of space. Each space can have a different meaning or association for different individuals (Tilley 1994: 26). Just as modern-day sailors have differing opinions on the best points to anchor (*e.g.,* Bowditch 1995, 2002; Lewis 1994), Caribbean Amerindians likely had differing views on what were important places to which to navigate.

There are areas where movement occurs but little to no trace of human action or interaction remains. These transitional or border spaces, or "non-places" (*sensu* Agué 1995; Mans 2011; Nakamura 2013), are areas through which people regularly pass but which lack settlements (*e.g.*, Crouch 2008; Ingold 2009, 2011). The cultural significance of these transitional spaces can be difficult to discern from the archaeological record and are often obscured (Ingold 1993). The identification of these spaces is difficult, especially on the sea (McNiven 2008a; Terrell 1997). The placement of geographic features, which can be used to guide travellers through the sea, affects the boundaries of social spaces (*sensu* Darvill 2008; Zedeño 2008). These boundaries occur alongside areas whose existence is largely based in a perception of a wider encompassing landscape (David and Thomas 2008), effectively creating social and environmental barriers. The use of computer modeling may help us locate these boundaries, as will be demonstrated later in this work.

Additionally, the vessels that peoples used to move between places may also have affected the seafarers' perception of the environment. It has been argued that canoes themselves should be considered mobile sites (Crouch 2008). Within these vessels people engaged in social interaction, reprising their roles as social actors in land-based communities. Paddlers also ate and slept within canoes, allowing for the canoe to hold more meaning than just its economic or mobile functions (Crouch 2008). Peoples lived within the confines of these canoes, likely engaging in teaching navigation techniques. In some ways, this makes the mobile canoe a moving taskscape for educating canoers in seafaring knowledge. Though canoes as sites were limited in size, they can be considered of equal value to any campsite on a landscape in that they contained similar activities. The canoe also held individuals with possibly different skill sets, places within the community, and varying levels of seafaring knowledge (Crouch 2008). In association with the concept of wayfinding mentioned by Ingold (2000, 2011), canoes can also be a space in which these cultural activities are taught to younger generations, thus sustaining cultural ties and beliefs (*sensu* Terrell and Welsch 1998). Determining the shape of these in-canoe relationships is difficult because sea-based sites were mobile and are not generally present within the archaeological record. In this way, route modeling is one way to estimate the base needs of those in canoes. The time cost behind optimal voyaging routes generated by computer models can indicate what supplies, such as food or water, would have been necessary to sustain a crew for voyages of a specific length. These qualifiers are the first steps to identifying who and what could interact within the mobile site of a canoe.

2.3 Sea-based Mental Maps

Pathways offer a unique opportunity for archeological study. As discussed above, they represent the continuation of communal knowledge in the form of mental maps (*sensu* Golledge 1999; Ingold 1993, 2011; Tilley 1994, *e.g.*, Samson and Cooper 2015; Terrell and Welsch 1998). The way the body moved through a landscape can cause a link to form between memory and future actions, as expressed by Tolman's (Tolman 1948; Tolman *et al.* 1946) work with rats running through mazes. However, the way we remember places may change when they are not in view (Tilley 1994) or alter entirely through linguistic or cultural changes in society (Kirby 2009). Even how we adapt and view changing urban environments is tied to our previous experiences with city landscapes (Lynch 1960). Still, as long as we impose structures onto the physical world, our processes of moving through places we have learned in our private experience or public education can support the existence of mental maps (Lowenthal 1961).

These maps need not be physical manifestations of directions. Richards (1974: 9) states "that objective procedures for representing space, such as maps and charts, are valueless unless they are referred back to the individual and notions of direction." While the individual determines the context in which to interpret environmental stimuli, it is always through a frame of reference built from previous experience and the knowledge that has been communicated to them by others. In this case, information from others would not be physical paper maps or charts but communication from more experienced navigators.

Though focused on different regions, work by those referenced above could be applied to the development and maintenance of wayfinding maps in the Caribbean. Research by Frake (1985), Ingold (2000, 2009, 2011), Terrell and Welsch (1998), and Tilley (1994) suggests that humans almost assuredly constructed mental maps to order their world based on lived experiences of the individual that could be communicated to the group. Geography can play a role as an anchor for communal memories and shared associations (*e.g.,* Basso 1996; Schlanger 1992). If a place is returned to repeatedly over several decades, either by individuals or groups, the location can become rooted in the minds of a society (Golledge 1999; Ingold 1993; Terrell and Welsch 1998). This of course also applies to movement within seascapes, where many individuals within coastal groups likely had shared knowledge of cultural spaces (McNiven 2008; Strang 2008). Knowledge could then be passed down generationally from one navigator to the next (*sensu* Ingold 1993; Terrell 1997; Terrell and Welsch 1998; for a discussion of community practices, see also Wenger 1998). It is also possible that navigation mental maps could have been formed through community efforts at sea, resulting in something like a "joint enterprise" (Wenger 1998: 77), in which navigation processes are created by groups navigating together and making decisions as a team. The evolution of a seafaring mental map also reflects the generational and community-wide changes in inter-island mobility and exchange networks over time.

It can be challenging to understand how people constructed links between themselves and the fluidity of the sea's surface. Ashmore and Knapp (1999) argue that it is not only the construction of monuments that can define human alteration of topography but also the creation of trails and the views that are generated from them. Pathways, be they over land or through the sea, represent places meaningful in themselves or places from which meaningful features can be viewed (Gibson 1979; Golledge 1992; Ingold 2009, 2011). Gibson (1979: 174) refers to thinking of mental maps and the signposts that allow for navigators to follow them into two questions: "how could signals yield an experience of self-movement and an experience of the external world at the same time" and "how could signals have two meanings at once, a subjective meaning and an objective one." These questions should be considered in the progression along travel corridors established by individuals and maintained by generations. How would the meanings and uses of these routes change, and what connotations might be held within navigation markers altered over time (*e.g.,* Lewis 1994; McNiven 2008; Terrell 1997, for broader theory, see also Bradley 1993: 26; Ingold 1993; Knapp and Ashmore 1999). It is even possible in some cases that landmarks existed not only as cultural reminders but also as a reference to how these areas were used (Tilley 1994). These viewpoints can be linked with cultural ideologies that mark them as places that intersect with a group's mobile identity (Ingold 2000). This is especially significant for geographic navigation points woven into common mythology. This phenomenon is termed wayfinding and is related to concepts of cultural mobility and communal or social memory (Ingold 2000, 2011).

In using the term wayfinding, I also make connections with Ingold's (2011: 150) term "transport," or destination-oriented, movement. Although Ingold separates transport and wayfinding routes, I would argue that people moving between sites in canoes had to engage in basic concepts of wayfinding, such as learning from and interacting with others and the environment, despite being oriented towards a destination point. Navigation at sea may have involved active dialogues with the surrounding seascape, initiating connections with rest areas as they became necessary and following a set route when required. The constant demands of sea travel possibly remained in the minds of navigators, even when at their destinations, suggesting that, even when on directed routes, canoers were engaging in acts of wayfinding.

Individuals developing a personal mental wayfinding map would have learned places of import from experience at sea as well as from the stories, both real and mythic, from older navigators (Broodbank 2000: 23). As Ingold (2011: 161) puts it, "making their way from place to place in the company of others more knowledgeable than themselves, and hearing their stories, novices learn to connect the events and experiences of their own lives to the lives of their predecessors, recursively picking up the strands of these past lives in the process of spinning out their own." Like learning a language, acquiring navigational skills likely happened over time through associations with objects, environmental trends, and people, rather than solely through instruction (Ingold 2011: 162; Vološinov 1973: 81). These activities may not have been passed down explicitly, but through shared inter-generational activities and practices (Ingold 2011: 161; Vološinov 1973).

As referred to previously, one can posit that alongside these individual mental maps there existed a community or collective map (*sensu* Bradley 1993; Broodbank 2000: 22, 2013; Knapp and Ashmore 1999; Kuchler 1993; Oosten 1997: 152), maintained over generations (*sensu* Frake 1985: 268; Knapp and Ashmore 1999: 14; Schlanger 1992; Sherratt 1996: 146; Terrell and Welsch 1998) or shared across regions (*e.g.*, Samson and Cooper 2015). Each new mariner learned from his predecessors their stories of what worked and what did not, or which currents to follow and which waves to cut across (*e.g.*, Lewis 1994; for theory of navigation, see also Ingold 2011). This mental map could not survive in one individual. Instead, communal wayfinding maps perpetuated things learned in each successive generation, building in a knowledge of safe practices and social goals (*i.e.* resource collection).

There are many ways to uncover these mental maps. For example, identifying features or points are significant for marking navigational cues and physical boundaries (Bradley 1993; Broodbank 2013; Cooney 2003; Ingold 2009; Knapp and Ashmore 1999; McNiven 2008). Similarly, cultural associations or group connections, including the continued knowledge of the locations of far-off friendly sites, can be incorporated into the map as connections between communities on varying islands have "intergenerationally inherited friendships" (Terrell 1997; Terrell and Welsch 1998: 59). These sustained connections can be supported by ethnographic and historical accounts and can also be reflected in the archaeological record (Hofman *et al.* 2008b).

The bundling of modeled routes between island communities can suggest the location of canoe travel corridors and connected mental wayfinding points. If travel corridors evident from the modeled pathways were perhaps used by canoers, these routes may have been a part of the mental map of pre-Columbian navigators traveling through the Lesser Antilles. If these routes were used consistently, it is likely that nearby landscapes were linked to cultural memory to guide canoers along the route. The islands passed by these generated routes can suggest where researchers can look for deeper connections between seafarers and the coastlines they pass. Coastlines near these routes, and the areas visible from the suggested pathways, could have been areas used as wayfinding points within the Amerindian mental map.

Visibility is a large component of constructing a mental map. Although marked places are tied to specific topographical features or broader spaces, they can "move" with an individual through the space. While geographical features are physically static, they also become a portable entity within the viewer's mind (*sensu* Golledge 1999; Gibson 1979; Ingold 1993; Tilley 1994). Thus, landscape archaeologists must try to examine changes in topography alongside a space's cultural associations (Fleming 2006: 271). In addition to topographical changes over decades, annual alterations, such as the seasonally-dependent presence or absence of a river, need to be included in the mental map. Visibility is often examined in terms of lines of sight (*e.g.,* Llobera 1996; Wheatley and Gillings 2000). Lines of sight can also dictate and control how canoers related to their environment when out at sea. For example, canoers who could see patches of sea with birds swooping down to collect fish may have felt ownership over those fishing rights (*e.g.,* Lewis 1994). Canoers who were able to see landmarks from their vessels may also have felt a sense of ownership or social connection to those points. This has been hinted at in works like those done by Smith (2016), who generated least-cost seafaring routes modeled off the coast of Pembrokeshire in visual range of Iron Age promontory forts. He suggested that differences in the visual prominence of various types of promontory forts, as viewed from the sea, reflect a past coastal communities' engagement with wider Iron Age maritime trade networks.

In the past, visibility studies have focused on what could be seen from land, such as visible points on the same landmass, visible sections of another islands, or viewable areas of the sea. However, even when in view, the sea was typically discussed in terms of how it affected people on land (*e.g.,* de Ruiter forthcoming; Fisher *et al.* 1997; Fraser 1988). This focus on the sea from the land limits the full understanding of past human experiences, as people who intensively used seascapes likely tended to view them and landscapes from the perspective of the sea (Friedman *et al.* 2010; Torres and Rodríguez Ramos 2008). When looking at seascape viewsheds, it is important not only to consider the visual approach to the island but also "sea, horizon and sky" (Broodbank 2000: 23; Helms 1998: 24-28). Caribbean studies are beginning to focus on views from the sea to the land and including in the discussion how canoers could visual relate to their surroundings and travel to sites (*e.g.,* Brughmans *et al.* 2017; Friedman *et al.* 2010).

For seascapes, visibility is based in part on being able to see aspects of changing weather patterns, shifting currents, wave height, and the passing appearance and disappearance of islands with visible markers such as island peaks, beaches, harbors, as well as other visually prominent points (Crouch 2008; Friedman *et al.* 2009). Other movable markers, such as birds, clouds, and mangroves can also help to orient canoers at sea to the location of islands or specific ports (*sensu* Gladwin 2009; Lewis 1994). Canoers may also have been able to identify other vessels while paddling between islands. Thus, what is or can be viewed during the progression along a path becomes significant in constructing and maintaining mental maps.

As discussed above, following the movement of the viewer through these spaces is essential to understanding the progression of a mental wayfinding map along a route (Llobera 2000; for cognitive theory on visual perception, see also Gibson 1979). Not only the topography of a landscape but also the spot from which the landscape is viewed are susceptible to change (Fleming 2005, 2006; see also Friedman *et al.* 2010; for viewshed modeling from seascapes theory, see Torres and Rodríguez Ramos 2008). For example, a person sitting in a canoe will have a different view of the sea than someone standing, as can also be said of the cox and the paddlers (Friedman *et al.* 2010). While the physical capabilities of any one person may not necessarily have wide effect on the perception of the landscape for the whole group, it can influence individuals' access to specific pieces of the mental map and provide clues as to how that map was seen.

The concept of shared generational beliefs should therefore be approached carefully. For example, people reuse or replace monuments of past cultures or construct roads on top of existing trails (Gosden and Lock 2013), such as the Roman Appian Way (Povoledo 2008; Witcher 1998). Though such routes continue to be used, they are largely disassociated from their past cultural, if not physical, context. A clearer way to study pathways is to examine the movements passing through them as they can be a tie between peoples and several places. By investigating not only the chronological but also the spatial order of navigation points, changes in the use and perception of the landscape and its cultural associations can be judged (Schlanger 1992; Tilley 1994). For seascapes, these points can be extended to coastal sites or possible markers visible from the sea (Friedman *et al.* 2010; Torres and Rodríguez Ramos 2008). Changes in site locations can help to define changes in pathway structures and the mental map. As a result, the evolution of a seafaring mental map reflects the changes in inter-island mobility and exchange networks.

The theory of how people traversed through their environment is complicated by the possibility of several mental maps and navigation markers existing within one community (*sensu* Frake 1985; Ingold 2011). One constraint on accessing knowledge of a past landscape is a result of the temporal distance between modern communities and the cultural norms of past peoples. Individuals looking to canoe may have had their access to seascapes restricted (*e.g.*, Arnold 1997; Broodbank 2000, 2013; Gamble 2008), as one must possess a vessel like a canoe to travel over the sea. In some societies, ownership of the canoe was restricted to wealthy high-status individuals or those who had the technical knowledge to build a vessel (Arnold 1997; Broodbank 2000; Gamble 2008). Thus, ownership or knowledge of these mental maps could set one apart from the larger community (*sensu* wayfinding mobility theory, see Golledge 1999; Gould and White 1974; Ingold 1993; *e.g.*, for social hierarchy and canoe ownership, see Broodbank 2000, 2013; Cherry and Leppard 2015; Gamble 2008; Lewis 1994).

While discussing contemporary mental maps from the United States, Gould and White (1974) suggested that the mental maps of decision-makers, or those who have influence over the mobility of others, is a key aspect in the structuring community mental maps. Though they express this in regard to the freedom of mobility accessible to those in charge of large corporations and their ability to encourage the movement of their goods and the location of headquarters on a national or global scale, there are elements of this thinking that can be applied to the hierarchical structures of canoe use. Those who had control of the canoe would have felt the benefits of mobility in ways those denied access would not. Who had access to these canoes, and thus the sea and other islands, would have influenced both an individual's and the community's mental maps.

Navigators may have also held esteemed positions within seafaring societies. The dangers of seafaring likely elevated the reputations of individuals, which may have encouraged people to take up these skills to earn positions of importance within their communities (Broodbank 2001: 94). However, by conducting ethnographic research, the memorization of place ordering can be discussed on a regional basis (*e.g.,* for continuing work in the Pacific, see Gladwin 2009; Lewis 1994; for the Caribbean, see Lamarche 1993). By visiting research areas and speaking with local communities, archaeologists can access information stored in the social or geographic memory of the landscape. However, ethnographic efforts cannot cover all aspects of traveling practices, due to the broad subjects of research, the time depth of the records, the effects of colonization, and the change in cultural practices between 1492 and today.

2.4 Conclusion

The ways in which people move through seascapes affect not only the locations and associations of places, but the process of individuals interacting with one another and their environment. Peoples on paths categorized and memorized their environment when moving through it. The theory of movement and navigation helps to validate the use of least-cost sea-based pathways to connect archaeological materials, as without the knowledge of optimal routes there would be no assurance that peoples would have consistently used modeled travel corridors. Without the knowledge that people were remembering current flow and the location of past sites, modeling canoe routes between islands would be superfluous. Canoers would have communicated what they were seeing and how they were feeling moving through the sea as part of an organized social interaction. These interactions were contained in mobile sites (*i.e.* canoes) that encourage the exchange of seafaring knowledge between paddlers (Crouch 2008). By establishing a communal mental map, seafaring peoples populated the environment with places that could be remembered when not in sight and visited again and again. As such, the routes modeled for this work represent an additional way to discuss pre-Columbian Amerindian mental maps and travel corridors that helped to define the inter-personal and inter-island relationships in the Lesser Antilles.

3

Caribbean Canoes and Canoe Modeling

Archaeology, ethnography, ethnohistory, and experimental or experiential archaeology can provide some basis for understanding the physical links between Lesser Antillean Amerindian sites. This understanding can be enhanced through the computer modeling of least-cost sea-based pathways, which aim to calculate the optimal route between two locations (*sensu* Surface-Evans and White 2012:3). Mapping the physical relationship between archaeological sites can reveal trends in past human movement that are currently only partially uncovered by other lines of evidence. The routes these computer models create can help turn the Caribbean Sea from a blank space to a human environment rich with history, travel, and social meaning. Specifically, modeling can reveal the role movement across the sea may have played in linking specific communities and sites. It can also add to our understanding of possible mental maps (*sensu* for mental map theory outside anthropology, see Gould and White 1974; Lynch 1960; Richards 1974; for archaeology and anthropology, see Ingold 2000: 219-242, 2009, 2011: 141-153; Kirby 2009; Tilley 1994; Wiebe 1989; for geography, see Lowenthal 1961; for cognitive physiology, see Tolman 1948; Tolman *et al.* 1946; Trowbridge 1913; see Chapter 2) that seafaring peoples constructed, relied on, and shared.

Other researchers have also used least-cost pathway methods to construct models that hypothesize the existence of sea-based travel corridors. The variety of techniques used by different researchers demonstrates the fluidity of modeling least-cost corridors through the sea and the importance of linking generated routes to archaeology and ethnohistory. This chapter provides a brief overview of previous research in order to place the canoe routes generated by the isochrone model in a global seafaring computation context.

A discussion of what carried peoples between islands forms the base for our understanding of what sort of travel, and thus routes, were possible between the islands in the Lesser Antilles. The presence of Amerindian canoes has been documented through evidence of maritime activity and seafaring technology found in the archaeological record (Callaghan and Schwabe 2001; Ostapkowicz 1998). Ethnohistoric and ethnographic accounts also refer to canoes used by Caribbean Amerindian peoples. These works elucidate the function of the canoe by describing their shape and use (for ethnohistoric accounts, see Davies 1595; Drake 1585; Columbus 1493 cited in Hulme and Whitehead 1992; Layfield 1590 cited in Hulme and Whitehead 1992; Hulme and Whitehead 1992; Perry and Keith 1989; for ethnographic records, see Honeychurch 1997a; Taylor 1938). This functionality has been tested through experiential or experimental archaeology (Bérard *et al.* 2016). This knowledge provides a framework for assessing what routes returned by the model should be considered viable and representative of real-world seafaring practices. Archaeological findings underpinning the case studies will be detailed at the beginning of each chapter.

3.1 The Canoe as a Base for Modeling

To gain a better understanding of pre-Columbian seascapes it is important to discuss the canoes of the Amerindian wayfinders. The arrival of Europeans in the Caribbean, combined with a shift in maritime technology, altered the seafaring toolkit used in the region and there are few examples of pre-Columbian canoes that survive today (Callaghan and Schwabe 2001; Frederick 2014; Ostapkowicz 1998; Taylor 1938). Alongside archaeological evidence, reconstructing canoes (see Figures 2 and 3) and associated accoutrements can help to define what was possible when moving between the islands of the Lesser Antilles in the past.

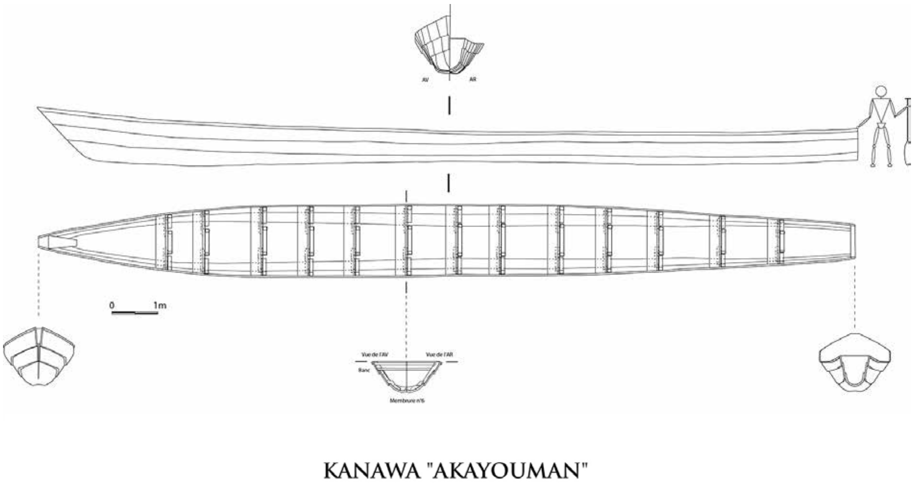


Figure 2: Drawing of Kanawa Akayouman, an experimental vessel used by the Karisko project (Bérard et al. 2016: figure 3; see below).

Figure 3: Image of Kanawa Akayouman in action (image Karisko) (Bérard et al. 2016: figure 6; see below).

Full reference figures 2 and 3: Bérard B., Billard J.-Y., L'Etang T., Lalubie G., Nicolizas C., Ramstein B. and Slayton E., 2016, « Approche expérimentale de la navigation précolombienne dans les Antilles », Journal de la Société des américanistes, 102 (2), pp. 171-204.

3.1.1 Canoes: What we Know

The relative absence of seafaring materials in assemblages makes it difficult for Caribbean archaeologists to identify the location of canoe travel corridors, where canoes were constructed, and when they were used (Callaghan 1999; Callaghan and Schwabe 2001; Ostapkowicz 1998). There are only a few whole or fragments of canoes recovered from the broader pre-Columbian Caribbean region (Callaghan and Schwabe 2001). Of those finds, many vessel remains are coastal canoes or river canoes from South America, Florida, Cuba, and the Bahamas, (Callaghan 1999, 2001; Cooper 2010; Granberry 1955; Keegan 1997; Lovén 1979; McGoun 1993, Palmer 1989; Ober 1894; Seidemann 2001). While these examples provide an approximation of what canoes in the Caribbean were like, it is difficult to rely on them as a complete representation of these vessels due to the fragmentary nature of the recovered canoe segments. Archeologists have drawn on examples from surrounding areas to analyze possible vessel types in the Caribbean to fill out the shape of pre-Columbian Caribbean canoes used for inter-island travel (Callaghan 1999; Seidemann 2001). However, Callaghan and Schwabe (2001) state that these canoe fragments do not wholly match those described by early chroniclers in the region (Fitzpatrick 2013: 109). As such, these fragments must be weighed against ethnohistoric and ethnographic accounts.

Though not directly connected with seafaring communities in the Lesser Antilles, it is possible that the style of canoe used by groups from the mainland Americas resembled types used by islanders. Canoes from Florida, like type 1a, are dugout canoes, or vessels made from one tree that have been hollowed out using fire, hot stones, and axes (Callaghan 1999; Honeychurch 1997a; Taylor 1938; see Figure 4). Callaghan (1999) has suggested that the early examples of canoes found in Florida exemplify expediently or rough-crafted canoes. The oldest example of this type of vessel is from DeLeon Springs and has a radiocarbon date ca. 4000 BC (Callaghan 1999: 13). Vessel like type 1a may be representative of canoes from across the Caribbean region dating to this period.

The Ye'Kwana style vessel, or type 1c, is produced by the Ye'Kwana peoples from the Upper Orinoco area in Venezuela (Callaghan 1999; see Figure 4). This style has been used by many groups from around "the State of Amazonas, south of Puerto Ayacucho" (Callaghan 1999: 15). This canoe is typically 5.6 meters or 18.4 feet in length (Callaghan 1999), which is half the size of some estimates for Pre-Columbian canoes in ethnohistoric sources (Peck 2002: 2). Vessel type 1c is comparable to another example from the Orinoco region, the type 1d or Warao type (see Figure 4). The Warao, whose name

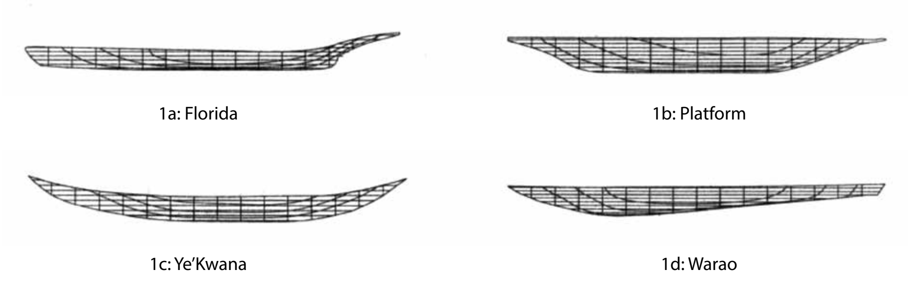


Figure 4: Image of canoe types from the Caribbean region, both the islands and the mainland (Callaghan 1999: figure 1, courtesy of the Northern Mariner).

Figure 5: Depiction of the Stargate Canoe recovered on South Andros Island, Bahamas (Callaghan 2001: figure 2. Image taken from Current Anthropology, 42(2), University of Chicago. Copyright 2001 by The Wenner-Gren Foundation for Anthropological Research. Ail rights reserved ooii-3204/2ooi/4202-ooo7).

translates as canoe people, were considered the best canoe builders in historic times (Callaghan 1999: 15). The Warao type is more maneuverable than the Ye'Kwana style, but has a smaller carrying capacity (Callaghan 1999). This may indicate the Warao type was preferred by peoples from the Orinoco traveling through the sea.

Vessel type 1b, or the Belize platform style, is found throughout Central America (Callaghan 1999). This vessel shape allows for stable travel with a large carrying capacity (Callaghan 1999). Type 1b most resembles historical accounts of the canoes used by Amerindian peoples and was likely similar to the kind encountered by Columbus (Callaghan 1999: 15). It, along with the Ye'Kwana type, resembles the Stargate Canoe found in the Bahamas more closely than types 1a and 1d (see Figures 4 and 5).

The Stargate Canoe, found in the Bahamas, demonstrates the rough shape of Amerindian pre-Columbian canoes (Fitzpatrick 2013; Ostapkowicz 1998) and was likely used for coastal travel as opposed to sea voyaging (Callaghan 2001; Callaghan and Schwabe 2001; see Figure 5). The Stargate Canoe is similar in design to those from the Upper Orinoco River basin, including modern examples made by the Ye'Kwana (Callaghan 2001; Fitzpatrick 2013).

In cases where segments of canoes are recovered from island sites, it is often not possible to discern the size or shape of the vessel. Two canoe fragments were found in the partially submerged site of Los Buchillones on Cuba (Cooper 2004: 94, 2008: 181; Fitzpatrick 2013: 109). Because the two pieces measure 1.5 m and 2 m, respectively, they do not provide a complete picture of what the canoe would have been like (Fitzpatrick 2013a). In this case, drawing from the ethnographic record (Callaghan 1999; 2001) and considering the stability of modern canoes over longer distances (Bérard *et al.* 2016) may prove useful in determining the capability of pre-Columbian Lesser Antillean canoes.

Due to the incomplete recovery of canoe vessels from the Caribbean, it is impossible to say how these vessels were made and if vessels were augmented with planks or outfitted to host sails. According to ethnographic and ethnohistoric accounts, all canoe vessels start as dugouts (see Fitzpatrick 2013; Honeychurch 1997a; McKusick 1960; Taylor 1938). Archaeologists have found evidence of tools, such as wedges, which could have been used to make planks for canoes (Breukel forthcoming). Although there is no evidence of planks themselves in the archaeological record (Fitzpatrick 2013: 116), there are ethnographic accounts that support the addition of planks or boards to the sides of vessel (du Tertre 1667; Fitzpatrick 2013a: 116; McKusick 1960; Taylor 1938: 142). Plank canoes, in which the hull of a dugout canoe is spread further outward and additional siding is added, are ideal for sea voyages (Arnold 1997). Building

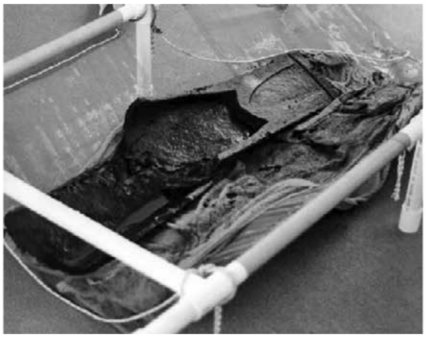


Figure 6: Remains of the Stargate Canoe recovered from South San Andros Island, The Bahamas (Image Richard Callaghan in Fitzpatrick 2013: figure 5).

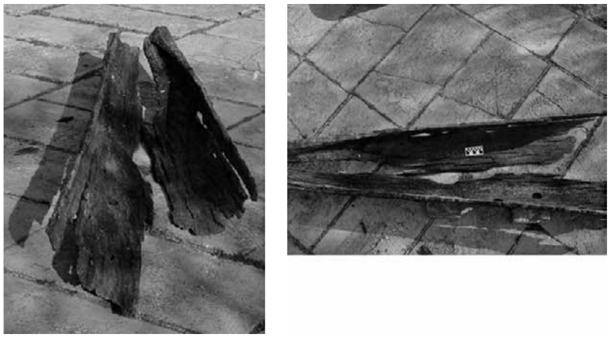


Figure 7: Image of Amerindian canoe fragments recovered from Los Buchillones, Cuba (Image Jago Cooper in Fitzpatrick 2013: Figures 3 and 4).

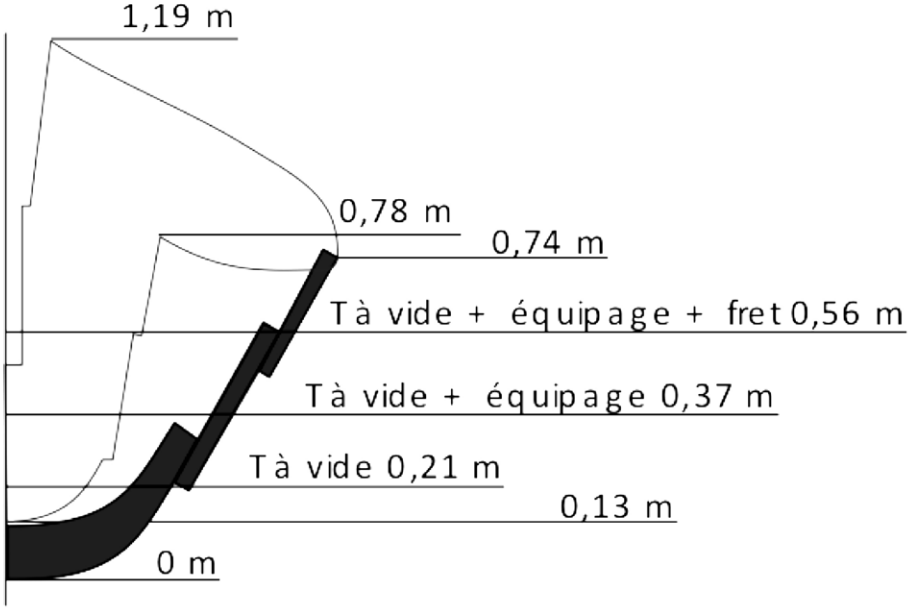


Figure 8: Depiction of planking style used on the Karisko project's Kanawa Akayouman (Bérard et al. 2016: figure 4. Bérard B., Billard J.-Y., L'Etang T., Lalubie G., Nicolizas C., Ramstein B. and Slayton E., 2016, « Approche expérimentale de la navigation précolombienne dans les Antilles », Journal de la Société des américanistes, 102 (2), pp. 171-204).

up the sides of the vessel protects both crew and cargo from rough seas (Bérard *et al.* 2016; McKusick 1960: 5; Honeychurch 1997a; Taylor 1938).

In drawings of these vessels composed by early chroniclers, the canoe seems to be of one piece, with no clear signs of planking (see Figures 9 and 10). This has inspired some to assume that there was no planking on these vessels (Frederick 2014). Modern reconstructions of canoes are made both with and without additional siding. Those without planking capsize frequently (Frederick 2014; Sardo personal communica-

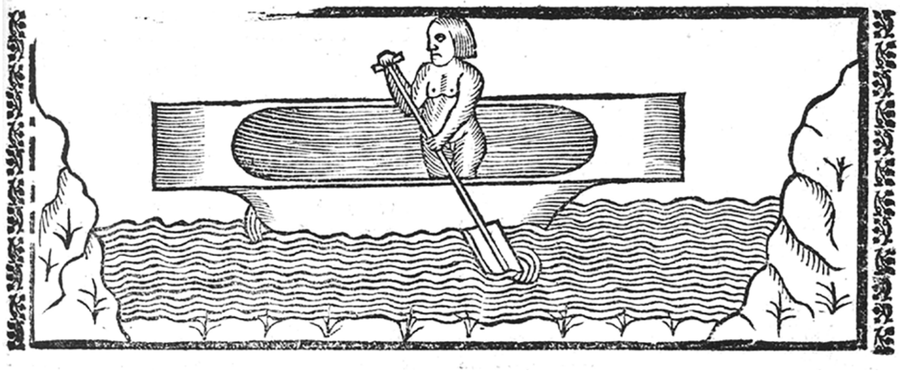


Figure 9: Print of a sole Amerindian in a canoe. Image by Gonzalo Fernández de Oviedo y Valdés (Fernández de Oviedo y Valdés and de Oviedo 1950).

tion 2016), which aligns with accounts of early chroniclers (Columbus 1493; Lovén 2010: 417). However, use of this technique in vessels constructed for the experimental canoeing group the Karisko project documents its success (see Bérard *et al.* 2016). It is a possible planking was used to shore up the sides of the vessel to help prevent capsizing (Taylor 1938). However, there is no way to confirm this technique was used by Lesser Antillean voyagers in the pre-Columbian era (Fitzpatrick 2013).

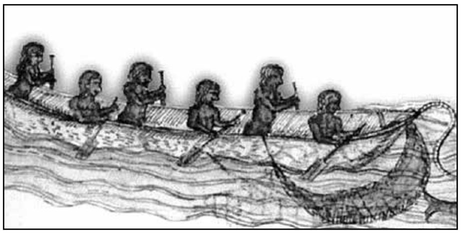
Because of the scarcity and fragmentary nature of canoes in the archaeological record, the ethnographic and early historic accounts that exist are extremely valuable. A review of text documents from the early colonial period shows that despite the variety of sources regarding early encounters in the Caribbean, there are only a few different descriptions of canoes. Columbus (1493) first describes canoes in this manner:

> "*They came to the ship in canoes, made of a single trunk of a tree, wrought in a wonderful manner considering the country; some of them large enough to contain forty or forty-five men, others of different sizes down to those fitted to hold but a single person. They rowed with an oar like a baker's peel, and wonderfully swift. If they happen to upset, they all jump into the sea, and swim till they have righted their canoe and emptied it with the calabashes they carry with them*." (Columbus 1493 cited in Hulme and Whitehead 1992: 13).

Another description of a canoe, or *canoa,* comes from Columbus's 1493 letter to the Spanish royals who sponsored his voyage:

> "*in all the islands they have very many canoes, which are like rowing 'fustes', some larger and some smaller, and some are greater than a 'fusta' with eighteen benches. They are not so broad, because they are made of a single log of wood, but a 'fusta' would not keep up with them in rowing, since their speed is incredible; and in these they navigate all the islands, which are innumerable, and carry their merchandise. I have seen some of these canoes with 70 or 80 men in it, each one with his paddle.*" (Columbus 1493 cited in Hulme and Whitehead 1992: 13).

Figure 10: Print of Taínos travelling in a canoe. The image is from the Historia general y natural de las Indias printed in 1535 and written by Drake (Berleant-Schiller 1998).



Columbus also suggested that he encountered a "handsome dugout or canoe, made of one timber as big as a fusta of twelve rowing benches" (Beckwith and Farina 1990: 133; Dunn and Kelley 1989: 187; Fitzpatrick 2013:115; Jane and Vigneras 1960: 78). Peck (2002: 2) has stated that a fusta fitting twenty-four rowers may have been forty feet long, if accounting for extra storage space at bow and stern (Fitzpatrick 2013: 116).

The majority of ethnographic sources written between 1492 and 1650 provide similar descriptions of canoe construction (Columbus 1493 cited in Hulme and Whitehead 1992; Davies 1595; Drake 1585; Perry and Keith 1989). This follows the scarce evidence of canoe building that supports dugouts being constructed from one log (Lovén 1935: 417). For example, Drake (1585) describes canoes as "hogges trowghe," referring to the hollow shape of animal troughs used in Europe during this period (Hulme and Whitehead 1992: 54). The fact that the canoe was made from a single log seemed to impress the Europeans (Davies 1595; Drake 1585 cited in Berleant-Schiller 1998; Hulme and Whitehead 1992). Information on the size of these canoes in the Caribbean is more prevalent in historic sources (*e.g.*, Columbus 1493 cited in Hulme and Whitehead 1992; Davies 1595; Layfield 1590 cited in Hulme and Whitehead 1992). Some reports even suggest that canoes could reach "ninety-six feet long and eight feet broad" (Berna´ldez, in Jane 1988, II: 124 cited in Fitzpatrick 2013:114; McKusick 1960: 7).

Like the style of construction, the size of the crew is often left to speculation in ethnohistoric reports. For example, Gonzalo Fernández de Oviedo y Valdés, in his work Historia general y natural de las Indias published in 1535, mentions the general size of the canoe before the arrival of Europeans and their introduction of sails, including how many could fit within one:

> "*I've seen them large enough to carry forty-five men, wide enough to hold a wine cask easily between the Carib Indian archers… Sometimes they paddle standing, at times sitting, and kneeling when they feel like it. Some of these canoes are so small that they hold no more than two or three Indians, others hold six, others ten, and on up.*" (de Oviedo y Valdés 1535).

Most records indicate the use of smaller vessels, with specific reference to vessels which hold between one and 30 people (Davies 1595; Fitzpatrick 2013; Hulme and Whitehead 1992; Peck 2002). However, canoes could be built to serve larger groups, for example the 80-person capacity canoes described by Columbus (Columbus 1493; Columbus 1493 cited in Hulme and Whitehead 1992), or canoes holding 100 to 150 people (Deagan and Cruxent 2002b; Fitzpatrick 2013; McKusick 1960; Rouse 1992; Stevens-Arroyo 1988). These large canoes would only have served very specific functions, such as cultural displays or as war canoes, and were likely little used (McKusick 1970).

The size of a canoe crew is likely related to whether it served an 'every-day' or small-crewed trade or fishing trip or a ceremonial voyage, which required more crew members to paddle the larger vessels. Dr. Chana (1494), the surgeon appointed to Columbus's fleet, states that once the fleet had cornered a group of four men, two women, and a boy in a canoe with the intent to take them prisoner. This excerpt highlights the skill of some Amerindian seafarers, as it describes how a small group of six, not including the child, was able to maneuver adequately enough to momentarily stave off an attack by several Spanish boats. The fact that women were a part of this small crew shows that there were opportunities for both men and women to use canoes and possibly learn the basic mechanics of seafaring.

The makeup of crews probably varied depending on the purpose of the voyage. For example, war parties likely consisted of only men, while migrating communities would have included women and children as well (Boomert and Bright 2007). There is evidence of young men being involved heavily in canoe voyages (Lai and Lovell 1992; Weston personal communication 2015). This heavy engagement was possibly part of their training and induction into the larger seafaring and wayfinding traditions (Golledge 1999; Krisel 2000; Lai and Lovell 1992; Weston personal communication 2015).

Changing the number of people in the vessel can affect the speed of a canoe (Bérard *et al.* 2016) and the ratio of male to female and adult to child paddlers can affect the energy outputs of the crew. Evidence of this physical activity can be seen on the upper arm bones of canoers' (Weston personal conversation 2015), where the intense routine of paddling lead to musculature that left stressors on the bone (Lai and Lovell 1992). These musculoskeletal markers indicate that a wide section of the community was involved in these practices and highlight the importance of seascapes within various Amerindian societies. Furthermore, they indicate that many canoers paddled frequently, perhaps to maintain social connections between communities spread throughout the Lesser Antilles. Skeletal remains are just one line of evidence that points to the necessity of exploring the intricacies that helped shaped these pathways.

3.1.2 Paddles and Propulsion

Canoeing required an intense physical effort by seafarers because these vessels were powered by paddling. No matter who was propelling the vessel forward, everyone used a paddle to do so. As mentioned earlier, Columbus describes these paddles as similar to "bakers peels" (Parry and Keith 1984: 30), or the wooden tools used to remove bread from brick ovens. These oars were "laid in banks" along each side of the canoe (Layfield 1590 cited in Hulme and Whitehead 1992: 59; Layfield 1598). The oars themselves are:

> "*made like a long battle doore, saving that their palmes are much longer than broade, growing into a sharpe point, with a rising in the middest of them a good way… The shankes of these oars are of equal bignesse, and at the top crosset, like a lame mans crutch. These they use always with both their hands, indirectly they find cause to steer this way and that.*" (Layfield 1590 cited in Hulme and Whitehead 1992: 59).

This description is useful as it hints at the layout of the canoe and how much space would have been taken up by each paddler to wield the oar properly.

Though canoe paddles do not offer much information on the nature of canoe construction, they can suggest how and where canoes were used. Paddles were first described by du Tertre (1667, see McKusick 1960: 6) as having "a handle like a spade, with a small crosspiece of wood across the top" and a "blade… 2.5 feet long" (Fitzpatrick 2013: 109). This shape has been supported by ethnographic accounts (Taylor 1938) and archaeological remains. Paddles were decorated in various styles, though following the same overall shape (Ostapkowicz 1998). It is also possible that the decorations on these paddles indicated the status or position of the paddle's owner (Ostapkowicz 1998:119). These designs largely go unmentioned by very early chroniclers, bringing into sharp relief the lack of detail pertaining to canoes in reports from early histories.

The number of paddles that have been found around the islands is of great value to the archaeological understanding of sailing (Ostapkowicz 1998). Canoe paddles have been found in the Bahamas (4), Cuba (2), Dominican Republic (1), Haiti (1), and Grand Turk (1) (Beeker and Foster 1997; Conrad *et al.* 2001: 10; de Booy 1913: 2-5; Fitzpatrick 2013: 109-111; Granberry 1955; Harrington 1915, 1921:208; Lovén 1935: 417-419, 2010: 417; Olsen 1974; Ostapkowicz 1998: 118-122). Many recovered paddles in archaeological contexts are only fragments of the whole (Conrad *et al.* 2001; Fitzpatrick 2013: 109; see Figure 11). As they were likely the only means of propulsion prior to the Spanish arrival in the region (Rouse 1992: 16), evaluating the effectiveness of these paddles is significant. Paddles and their design may have affected the speed at which people were able to travel and the seasonal capabilities of vessels.

Although the number of paddles, or paddle fragments, recovered limits our understanding of their function in the Caribbean, comparisons with other paddle types from around the world can contextualize how paddles were used. It is likely that the style of paddle differed depending on the use or type of canoe (Fitzpatrick 2013), be it for river or ocean travel, fishing or ceremonial use. These ocean-going paddles distinguish themselves from traditional river-based paddles due to their lancet shape, which allows for quick removal from the water and allows for crews to achieve greater speeds (Lovén 2010: 417-418). River paddles are often shorter and more suited to calmer currents (Fitzpatrick 2013).

Experimental archaeology teams, like the Karisko project, have recreated canoe paddles based on archaeological evidence, ethnohistoric accounts, and ethnographic reports (Bérard *et al.* 2016; see Figures 11 and 12). The performance of these paddles as a stand-in for pre-Columbian canoer speeds and capability can help to determine the capacity of modern canoers. As such, the performance of canoes and paddles highlights the possible speeds achieved by vessels. This is the basis for the speed settings for virtual vessels modeled within least-cost pathway programs.

Figure 11: Image of canoe paddle from Manantial de la Aleta. "Canoe paddle blade (PNE-01-A-0235). Length 51 cm. The blade is lancet-shaped; the pointed tip would have been to the left and the handle to the right" ((source: Conrad et al. 2001: Figure 21; courtesy of the Journal of Caribbean Archaeology).

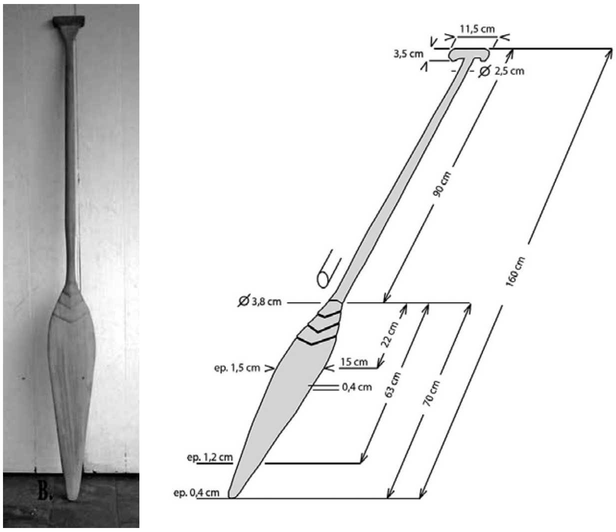


Figure 12: Modern reconstruction of Amerindian paddle for experimental use by the Karisko project (dessin B. Ramstein, cliché et DAO B. Bérard) (Bérard et al. 2016: figure 5. Bérard B., Billard J.-Y., L'Etang T., Lalubie G., Nicolizas C., Ramstein B. and Slayton E., 2016, « Approche expérimentale de la navigation précolombienne dans les Antilles », Journal de la Société des américanistes, 102 (2), pp. 171-204.).

Figure 13: Print of Amerindians leaving for the sea in a canoe. The image is from the Historia del Mondo Nuovo printed in 1565 and written by Girolamo Benzoni (Benzoni 1857).

Likely, early colonial representations of how individuals were spaced within the canoe do not reflect the actual relationships between the canoers or the canoers and the objects they were transporting. However, these images do provide some insight into how the vessels were propelled with paddles. Most images, like the one seen below (see Figure 13; see also Figures 9 and 10) show a series of paddlers resting towards the edge of the canoe with one set apart towards the back of the vessel. Canoers are often perched on the edges of the canoe near its rim (see Figure 13). From the drawing printed in 1565 by Benzoni (1857), we get some sense of how the canoe was propelled by forward-facing paddlers with an oarsman at the rear (see Figure 13). The placement of people in these images, as well as the designation of a rear oarsman, is consistent with the position of canoers within modern experimental voyages, like the Karisko project. Taking a seat near the rim of the vessel allows for easier mobility of the paddle and helps to balance the vessel (Bérard 2012).

3.1.3 To Sail or not to Sail

There is no archaeological evidence to suggest that any boat technology in the region of the Greater or the Lesser Antilles used the sail existed prior to European contact (Callaghan and Schwabe 2001; Fitzpatrick 2013b; Ostapkowicz 1998). There are conflicting historical reports as to whether sails were used in this time period (Callaghan 2011a; Fitzpatrick 2013a; McKusick 1960a; Seidemann 2001). For example, de Oviedo y Valdés (1478-1557) commented on the use of sails by Amerindians, specifically stating that "they sail (or navigate) with sails of cotton" (de Oviedo and de los Ríos 1851: 170-171; Edwards 1965; Thompson 1949: 71). However, de Oviedo y Valdés arrived more than twenty years after the islanders had seen the first Spanish ships with their sails (Edwards 1965: 352) and it is possible that he saw sails used by canoeing communities influenced by European arrival in the region.

There are some ethnographic sources that report that the sail was in use among native communities before the introduction of Europeans in the area (McKusick 1960). Honeychurch (1997a), however, postulates that it was not until the arrival of the Spanish and the adoption of aspects of their seafaring technology such as sails that Amerindian sailors were able to completely harness the wind, as the technological properties of the canoe prior to encounters with Europeans did not lend themselves to stabilizing a sail. Europeans introduced the sail either intentionally or by providing inspiration for copying almost immediately after Columbus's voyage to Hispaniola (McKusick 1960a). This technology, alongside material goods and stylistic elements, likely spread through the island networks by the Amerindians moving to the smaller islands at the turn of the sixteenth century (Holdren 1998; McKusick 1960a). The first recording of sails is from 1605 and the first mention of awnings is only slightly earlier in 1598. For example, John Stoneman (1625) recounts the story of how a Spanish priest, Friar Blasius's, introduced sails to the Amerindians of Dominica in 1605 (Edwards 1965; McKusick 1970; Fitzpatrick 2013). His story was recorded as follows:

> "*wee perceived in the cannoa a Friar, who cried aloud in the Latine tongue, saying O beseech, as you are Christians, for… I am a Preacher of the Word of G-d, A Friar of the Order of Franciscus in Sivill, by name Frair Blasius. And that he had been there sixteen moneths a Slave unto those Savages… We demanded of him then, how he got so much favour to preserve his life, his Brethren murthered: Hee answered, because hee did shew the Savages how to fit them Sayles for their Cannoas, and so to ease them of much labour often in rowing, which greatly pleased the Savages as appeared, for we saw them to use sayles in their Cannoas, which hathe not beene seene before.*" (Stoneman 1625: 4).

Some researchers have argued that the interpretations of descriptions of sails in historic material may not be tied to seafaring technology (Callaghan 2011a; Fitzpatrick 2013; McKusick 1960).

For example, Callaghan (2001) has suggested that the mention of sails could have referred to awnings. This is supported by the work of de las Casas (1875: 108-111), who records meeting canoes using awnings. Fitzpatrick (2013: 112) has suggested that the climate of the Caribbean may have supported the use of awnings or shelters on canoes to shade canoers. One chronicler, Dr. Layfield (1598), documented the use of a woven material, citing that material as "wicker" or "leaves" for use as awnings (Layfield 1590 cited in Hulme and Whitehead: 59). However, the passage that mentions the awnings does so in conjunction with the use of leaves to protect against rain, citing the awning as "a broad shield" to guard against the weather (Layfield 1590 cited in Hulme and Whitehead 1992: 59; Layfield 1598). This could mean that such items were not used as sails. It is of course also possible that the references to awnings could have also been about sails or a precursor to a sail.

Unfortunately, much like their canoe counterparts, whatever organic materials went into making awnings or sails were not preserved and no archaeological evidence has been found to support either claim (Honeychurch 1997a). The local materials that would have been used to make sails or awnings is unclear. As stated above, chroniclers recorded the use of cotton to make sails or awnings (de Las Casas' 1875: 108-111; de Oviedo y Valdés and de los Ríos 1851: 170-171). Stoneman's account of the Spanish friar from 1605 indicates that the Amerindians of Dominica got the material to make their sails from Spanish shipwrecks where "linen cloth and other merchandiser was cast on shoare" (McKusick 1970; Stoneman 1625: 4). Honeychurch (1997a) supposes that even if the Amerindians were making the cotton material required it would not have been in the quantity necessary to make a sail. Columbus may have also weighed in on this debate, noting one canoe had drawn up under a shelter or shed made of wood and covered with big palm leaves, so that "neither sun nor water could damage it" (Beckwith and Farina 1990: 133; Dunn and Kelley 1989: 187; Fitzpatrick 2013: 115; Jane and Vigneras 1960: 78).

This record indicates that while the adoption of sails was early, it may have required some mutual understanding and cooperative cultural transmission between the Spanish and the Amerindian canoe builders. It is also possible that the diffusion of knowledge concerning sails affected various groups of Amerindians at different rates. This may have affected the introduction of sails into the region.

The seafaring models calculated in the case studies do not use sail-based canoe travel and rely instead on paddling for motor activity. This is because the use of sails by Amerindian canoers throughout the Caribbean is not confirmable based on conflicting reports and possible observer misinterpretation. Until archaeological remains of sails are found, or stronger textual evidence emerges, I took the more conservative route of modeling based on motor activity that is confirmed.

3.2 Modeling Land and Sea Routes

Previous sea route models have focused on unidirectional drift colonization voyages (Altes 2011; Callaghan 2001). Drift voyages can refer to modeled least-cost routes that are undirected, where vessels move forward using current, wind, and in some cases a force equivalent to human paddling without aiming for a final destination. While this prior research explored the initial settlement in the Caribbean Islands (Altes 2011; Callaghan 2001), the current study aims to assess possible later routes. The routes representing possible reciprocal sea movement will be hypothesized and analyzed in the case study chapters (see Chapters 5, 6, and 7).

3.2.1 The Origins of Optimal Modeling Methods

Applying GIS-based methods to archaeological research questions connects a "spatial understanding" with "natural and anthropomorphic phenomena" (Conolly and Lake 2006), for example, the changing spatial positions of an individual affect how they perceive their environment (Ingold 2000; Tilley 1994). How someone interacts with their environment can be affected by their position within it (see Chapter 2). If they perceive a hill to be too hard to climb, their understanding of how much energy it takes to travel up it or around it may impact their path between two locations. Thus, the cost of movement in energy (*i.e.* calories) or time can also influence route choices (*e.g.*, Bell and Lock 2000; Bell *et al.* 2002; Herzog 2013; Llobera 2000; Surface-Evans and White 2012; Tobler 1993; van Leusen 1999). Surface-Evans and White (2012: 2) crafted a fitting description of least-cost pathways when they referred to them as "a means of reconstructing extinct connections between peoples and places, connections that are at the heart of many complex social, political, and economic questions of interest to archaeologists." In least-cost pathway models, humans possess knowledge of the wider landscape and will choose to travel on an optimal path (Surface-Evans and White 2012). Least-cost pathway analysis assumes that humans will want to economize their movements to fit with the principle of least effort (Kingsley 1949; Surface-Evans and White 2012). For example, works by Bell and Lock (2000) on an Oxfordshire Ridgeway in England, Herzog (2013) on the Nutschied Ridgeway in Germany, and Llobera (2000) on an area of the Yorkshire Wolds all approach the creation of least-cost pathways using calculations to suppose the cost in energy of traversing different slope gradients, with preference given to walking over low angles of slope.

Initial tests into modeling human movement across the landscape were developed as early as the 1950's (Imhof 1950). Using algorithms to model movement across a landscape was widely adopted in mobility research in archaeology (see Bell and Lock 2000; Borck 2012; Carballo and Pluckhahn 2007; Conolly and Lake 2006; Kantner 2012; Llobera 2000; Lock and Pouncett 2010; Marble 1996; Surface-Evans and White 2012; Tobler 1993; van Leusen 1999; Wheatley and Gillings 2002; White and Surface-Evans 2012). In most approaches to spatial analysis cost surfaces are generated to determine the difficulty of movement through landscapes (*e.g.*, Surface-Evans and White 2012: 5). Cost, or friction, surfaces usually refer to a gridded raster surface used to determine the cost of movement across an area (Surface-Evans and White 2012: 3). These can then be translated into least-cost pathways that detail how difficult it is to move from point A to point B in a certain region with certain parameters or defining factors.

These cost surfaces are based on Digital Elevation Models (DEM) (Conolly and Lake 2006; Tobler 1993; Wheatley and Gillings 2002). DEM's contain information on elevation and slope (Herzog and Posluschny 2011: 238-240). These factors commonly form the base of least-cost pathway analysis (Herzog 2010). The general search for pathways can be calculated in different ways depending on whether the goal of the program is to search all cells within a cost surface for the best path or to zoom in on least-cost pathway steps in stages (Kantner 2012; Lock and Pouncett 2010; Surface-Evans and White 2012: 3-4).

There are two main algorithms that dictate path selection that have been used in archaeology, Dijkstra's algorithm and A*algorithm (Surface-Evans and White 2012).

Proposed by Dutch computer scientist Edgar Dijkstra in 1959, Dijkstra's algorithm is designed to identify the lowest cost path between an origin point and every other point within a grid (Herzog and Posluschny 2011: 237; Surface-Evans and White 2012). Most archaeologists use this method, as it is included in most standard GIS software packages, either fully or partially in the calculation of least cost (Herzog 2014; Herzog and Posluschny 2011). Engineered by Hart, Nilsson, and Raphael in 1968, the A* algorithm is an adaption of Dijkstra's algorithm and implements a distance-plus-cost heuristic function to define its search for which points to pass through when creating a least-cost pathway (Surface-Evans and White 2012: 4). Programs using the A* algorithm begin by following the direction of the path with the known least cost. If it encounters a different path with a least cost it can switch to that route, and so on until the destination point is reached (Surface-Evans and White 2012). Though it has potential for use by archaeologists (*e.g.*, Livingood 2012), the A* algorithm has not been used widely within archaeological research (Surface-Evans and White 2012). Most of the land- and sea-based works discussed here use the Dijkstra algorithm, due to the its inclusion in most GIS software packages and shorter run time (Cormen *et al.* 2001; Herzog 2014; Surface-Evans and White 2012: 4). The current study applies the A* algorithm to the analysis of least-cost pathways to function within an isochrone model.

Many analyses of movement between sites and across different terrains have relied on cost-surface analysis, in the style of Dijkstra's work (*e.g.*, Gaffney & Stančič 1991; Tobler 1993). Movement between two points is assigned a cost relating to the degree of slope and distance crossed using an algorithm set by the archaeologist or the GIS program. The cost to travel across a slope can be expressed as:

$$mass \times gravity \times height\ ascended$$

The ratio between the two changes in potential energy is equal to "*Mgyi* : *Mgyz*" (Bell and Lock 2000:88). The change in potential energy is based on to the change in elevation, as gravity forces and the mass of the individual are assumed to be unchanging (Bell and Lock 2000). The equation $\tan \theta_1 : \tan \theta_2$ expresses the change in angle of an individual moving up, down, or across slope (Bell and Lock 2000).

Most cost surface methods use walking as the mode of transport (*e.g.,* Bell and Lock 2000; Kondo and Seino 2011; Lock and Pouncett 2009; Minetti et. al. 2002; Tobler 1993; van Leusen 2002), and most of the algorithms that calculate movement over a landscape rely on equations like Bell and Lock's (2000) to calculate movement. Researchers have approached movement across a landscape through a cost surface that represents a cost in either time or energy to the walker. Unfortunately, the methods that calculate either time cost or energy cost can return very different results for the same data set (Kantner 2012). For example, in cases where energy cost is prioritized, routes seeking slopes with less steep angles can be lengthy (Rademaker *et al.* 2012). Calculating shorter time paths may not favor easier slopes in the same way. These differences can affect how archaeologists evaluate pathway connections between past communities (Surface-Evans and White 2012). Because it is impossible to say whether groups prioritized optimal least-cost time or energy routes, the decision to use either method is left in the hands of researchers.

The earliest algorithms to calculate movement included slope as a factor. Imhof (1950) developed the following equation to calculate the cost of walking across a landscape for the Swedish military (Kantner 2012):

$$V = 6e^{-3.5|S+.05|}$$

Where V is walking velocity in km/hr, e is the base of natural logarithms, and S is the slope measured in vertical change over horizontal distance.

In this equation, the walking velocity across a landscape is directly based on slope. Tobler (1993) adapted Imhoff's (1950) equation for his hiker's walking calculation that has become a staple in archaeological least-cost pathway analyses (*e.g.,* Borck 2012; Gorenflo and Bell 1991; Kantner 1997, 2012; Livingood *et al.* 2012). Tobler's (1993) hiking equation is:

$$S = {}^{dh}/_{dx} = \tan\theta$$

$$W = \left(6exp\left(-3.5 \times abs(S + 0.05)\right)\right)$$

$$Travel\, Time = {}^{D}/_{W}$$

Where *W* is walking velocity (km/hr) for each cell, D is the distance across each cell, and S is the slope of that cell.

Both equations produce a cost to the traveler in km/hr . The returned costs for these equations help to establish both the optimal route mapped on the landscape and the cost in time to complete this pathway. Knowledge about route length would have been invaluable to past travelers because it would help them plan for what journeys were advisable and what supplies they would need to bring with them to sustain them throughout their journey.

Other calculations look to determine exactly what those supply needs would be. These algorithms calculate optimal routes by evaluating pathways with the least-cost in caloric expenditure to the traveler. Duggan and Haisman (1992) developed an equation for calculating movement across slopes in terms of energy expenditure based on research by Pandolf and colleagues (1977). Pandolf *et al.* (1977) based their research on direct observation of human movement in a laboratory (Kantner 2012). The algorithm created by Duggan and Haisman (1992) is:

$$M = 1.5W + 2.0(W + L)\left(\frac{L}{W}\right)^2 + n(W + L)(1.5V^2 + 0.35VS)$$

Where M is used energy or metabolic rate in watts (kilojoules/minute), W is the walker's weight in kilograms, L is weight of carried items in kilograms, is terrain factor, is speed of walking, and is slope.

Van Leuven (2002) updated Pandolf *et al.*'s (1977) and Marble's (1996) equation by adding a factor, S+6, so that the lowest cost values for terrain are slopes of 6 percent going downhill. Other studies by Santee *et al.* (2001), Kramer (2010), and Rademaker *et al.* (2012) have also explored how Pandolf *et al.*'s (1977) algorithm can be applied to archaeology (Kantner 2012). Other equations that aim to identify the cost in energy expended when crossing terrain to determine a least-cost path can be found in the broader cost path and human biology literature (*e.g.,* Brannan 1992; Ericson and Goldstein 1980; Hare 2004; Herhahn and Hill 1998; Kramer 2010; Kantner 2012; Llobera and Sluckin 2007). Many researchers avoid using energy-focused algorithms due to the number of variables, not all of which can be known (Kantner 2012).

Once the time cost or energy cost surface values have been determined and assigned to all cells within a grid, they can be used to create least-cost paths in GIS software packages. Within GIS programs such as ArcMap and QGIS, this grid is referred to as a raster. Raster grids are a series of geospatially linked squares, or cells, that are assigned values. In least-cost pathway analysis, these values express how difficult it would be for an individual to cross that cell. Traveling from one cell to another is directly related to the ease of moving between raster cells (Llobera 2000). Routes are calculated by evaluating which raster cells have a lower cost than their neighbors within the base grid. Travelers are more likely to pass through areas of high accessibility, reflected in movement through lower cost cells within the raster (Helbing *et al.* 1997).

Raster cells between the origin and termination points are selected based on choosing the overall least-cost route either by evaluating the entire cost surface or by selecting progression to the least-cost square cell by cell (Bell and Lock 2000; Llobera 2000; Tobler 1993; van Leuven 2002). This can be an important point of distinction for those modeling human behavior, as the former choice will represent trips done by people with knowledge of the whole region and the latter may generate routes as if travelers do not know the area. If the cells between two points have an equal cost, the route between them will appear as a straight line. If these cells do not have equal cost values, routes will appear to follow topographic features, or in the case of seascape modeling, currents or winds. An example of the trajectory of these two possible types of least-cost paths can be seen below (Figures 14 A and B ; see also Surface-Evans and White 2012: Figure 1.1 and 1.2).

The way in which modeled routes pass through cells can influence pathways resulting from a cost surface. Least-cost pathway modeling can either be isotropic,

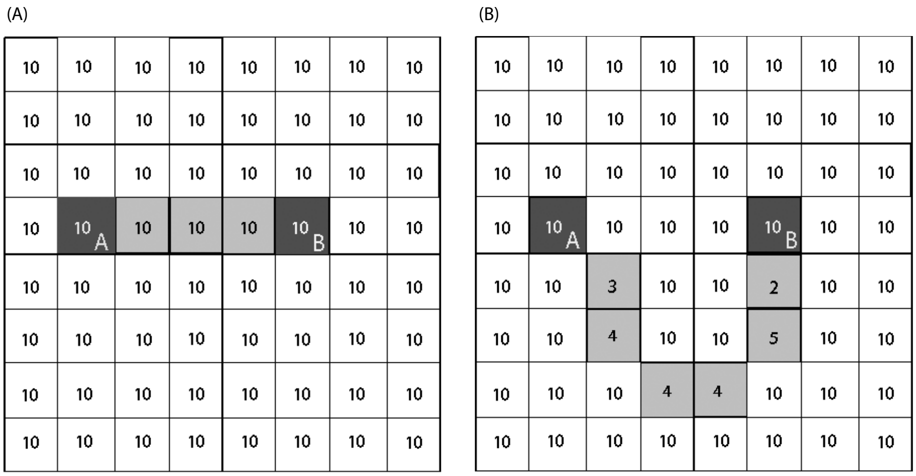


Figure 14: (A: left) shows movement across a landscape where all cells have a uniform cost. (B: right) shows movement through a landscape where all cells do not have uniform costs (adapted from Surface-Evans and White 2012: Figure 1.1 and 1.2).

where routes to and from the origin point return an equal cost, or anisotropic, where the cost is different depending the direction the individual is traveling (Conolly and Lake 2006:215; Wheatley and Gillings 2002: 152-153). Both methods are used in archaeological approaches to least-cost pathways (Kantner 2012). Many archaeologists have moved towards assessing movement using Tobler's (1993) algorithm, which allows for anisotropic calculations (*e.g.,* Borck 2012; Kantner 1997, 2012; Marble 1996; Taliaferro *et al.* 2010; White 2012). For example, anisotropic movement would assume that communities living at the base of a hill would have a more difficult time visiting their neighbors living on the ridge than vice versa. Movement with or against slope can drain the energy levels of individuals at different rates (Wheatley and Gillings 2002). This cost difference probably affected where and in what direction past peoples moved. These considerations of movement with or against slope also need to consider the totality of the trip, meaning there-and-back journeys. The total cost of a trip may change when comparing the combined costs of reciprocal travel.

However, there is no guarantee that the difficulty in crossing up or down a slope would be viewed as disadvantageous by the peoples using these routes in earlier periods. Other factors besides the environment can weigh more heavily on landscape movement decisions. It is also true that some anisotropic calculations may not be viable because individuals carrying heavy loads may have spent the same time traveling down a steep slope as they would have moving upslope (Kantner 2012; Marble 1996; Wheatley and Gillings 2002: Figure 7.4). Anisotropic modeling, however, is essential when evaluating sea-based routes due to the strength of current force which can ease or inhibit canoe travel depending on the direction the vessel is headed.

Modeled least-cost pathways indicate hypothetical routes. Moreover, resulting pathways represent only a possible movement between two points and are not an absolute value of cost (Harris 2000). Pathways generated between archaeological sites or assemblages can help confirm or disprove archaeological hypotheses. In some cases, routes linking archaeological materials give rise to new questions concerning past interconnection. However, modeled routes are only one source of information for archaeological research, and should not be taken as the sole justification for a hypothesis, as least-cost pathways can be spatially or topographically deterministic (Harris 2000). Models can also undervalue, or completely miss, cultural or social norms that would have dictated travelers go another route. These factors can be acknowledged before analysis of routes, including sea voyages, even if not directly included in the model.

3.2.2 Previous Attempts to Model Sea Routes

Though the material and cultural exchange that resulted from voyages through the Lesser Antilles has been well documented (*sensu* Hofman *et al.* 2007, 2010; Hoogland and Hofman 2008), analyzing physical remains of inter-island exchange is only one avenue for research. Researchers have recently begun to consider seascapes as a surface for modeling past movement, which will allow them to approach the sea as a lived space and not only a platform for the exchange of materials.

The sea is a prime example of a diverse environment with an intricate surface on which movement occurs. Therefore, the sea should be viewed as a complex entity, rather than an empty space to be ignored or easily crossed (Broodbank 2002). To presume that movement through the dynamic sea environment is uniform ignores the many variables involved (Llobera 2000: 88). Variables such as wind, current, and speed of the vessel can influence the trajectory of a vessel and may have forced least-cost pathways to run in a specific direction or real-world canoe crews to choose one travel corridor over another.

Researchers who have modeled sea routes have typically generated a route time cost rather than an energy cost (*e.g.,* Altes 2011; Arcenas 2015; Callaghan 2003; Cooper 2010; Irwin *et al.* 1991; Leidwanger 2011; Slayton 2013). In order to do this, they have relied on various sources and forms of environmental data and have chosen to use different methods for translating that environmental data into cost surface, or friction surface, proxies (see Table 1). These sources were typically produced by government agencies, such as the United States Navy or the National Oceanographic Atmospheric Administration (NOAA) (Callaghan 2003; Davies and Bickler 2015; Slayton 2013). Due to the fragmented nature of data collection by these agencies, and sometimes different projects within the same agency, researchers rely on data sets with different cell resolutions and data (see Table 1).

Perhaps in response to these different data sets and the desire to model different types of voyaging, each researcher has developed their own approach to this method (*e.g.,* Callaghan 2003; Davies and Bickler 2015; Irwin *et al.* 1991; Montenegro *et al.* 2016). Some researchers rely on preexisting land-based tool kits in programs like ArcGIS (*e.g.,* Altes 2011; Gustas and Supernant 2016), while others rely on programs they have developed themselves. These various methods each offer unique perspectives on the possible past actions of navigators in different environments around the globe.

The method of modeling sea-based routes using computer processing and GIS-referenced data sets was first applied to island connections in the Pacific. Levison *et al.* (1973) carried out this pioneering work, which modeled sailing and colonization patterns. Later works, such as that by Irwin *et al.* (1991), further developed route modeling techniques to study colonization patterns and also focused on long voyages that were aimed at making landfall (Irwin *et al.* 1991). The genesis of these earlier works coincides with the development of the land-based least-cost pathway models we would recognize today.

In the decades following the publication of these works, many methodologies focused on adapting theories from landscape least-cost pathway analysis (see Table 1). In the Pacific, there have been several works that have built on the initial explorations of Levison *et al.* (1973) and Irwin *et al.* (1991) (*e.g.*, Avis *et al.* 2007; Callaghan 2003; Davies and Bickler 2013, 2015, Di Piazza *et al.* 2007; Evans 2008; Fitzpatrick and Callaghan 2013; Montenegro *et al.* 2006, 2007). Studies applying least-cost pathway theory to sea routes include efforts to model movement through the northwest coast of Canada and the United States (Gustas 2017; Gustas and Supernant 2016; Safi *et al.* 2016). Other works focus on modeling the movement of sailing vessels (Arcenas 2015; Leidwanger 2013) and the difficulty of bringing them into port (Safadi 2016) in the Mediterranean. There have been several studies which focus on retracing canoe movement through the Caribbean and in Lake Nicaragua (Altes 2012; Benfer 2017, 2018; Callaghan 2001; Cooper 2010). Recent studies have focused on visibility from the sea or sea routes (Brughmans 2017; Callaghan 2008; Friedman *et al.* 2009; Smith 2016; see Appendix A).[1]

1 References to an appendix in this work refer to the appendix for Slayton's PhD Dissertation Appendix, which can be found through the Leiden University Library, DOI: https://doi.org/10.17026/dans-zfu-tscq.

Year	Authors	Region	Wind Data	Res.	Current Data	Res	Type of Movement
1973	Levison, Ward, and Webb	Pacific (South)	Quarterly Surface Current Charts, Marine Division, British Meteo. Office, 1947, 1956	5 °, monthly averages	Quarterly Surface Current Charts, Marine Division, British Meteo. Office	5 °, monthly averages	Drift
1985	Wild	Sunda-Sahul	NA	NA		Reconstructed coastline	Drift
1990	Callaghan	Caribbean	Marine Climate Atlas of the World, U.S. Navy, 1995	1 °	Marine Climate Atlas of the World, U.S. Navy, 1995	1 °	Drift
1990	Irwin, Bickler, and Quirke	Pacific	Quarterly Surface Current Charts, Marine Division, British Meteo. Office, 1947, 1956	5 °, monthly averages	NA	NA	Directed
1995	Callaghan	Caribbean	Marine Climate Atlas of the World, U.S. Navy, 1995	1 °	Marine Climate Atlas of the World, U.S. Navy, 1995	1 °	Drift
1999	Callaghan	Caribbean	Marine Climate Atlas of the World, U.S. Navy, 1995	1 °	Marine Climate Atlas of the World, U.S. Navy, 1995	1 °	Drift
2001	Callaghan	Caribbean	Marine Climate Atlas of the World, U.S. Navy, 1995	1 °	Marine Climate Atlas of the World, U.S. Navy, 1995	1 °	Drift
2003	Callaghan	Pacific (North)	Marine Climate Atlas of the World, U.S. Navy, 1995	1 °	Marine Climate Atlas of the World, U.S. Navy, 1995	1 °	Drift
2003	Callaghan	South American West Coast	Marine Climate Atlas of the World, U.S. Navy, 1995	1 °	Marine Climate Atlas of the World, U.S. Navy, 1995	1 °	Drift
2005	Rahn	Orkney Islands	None	NA	None	NA	Directed
2006	Montenegro, Callaghan, and Fitzpatrick	Atlantic and Pacific	NCEP/NCAR reanalysis project, Kalnay *et al.* (1996)	1.9 ° 2° resolution daily	ECCO (MITgem)	1° at high latitudes, 1°*0.3° in tropics, 10-day averages	Drift, paddle drift
2007	Avis, Montenegro, and Weaver	Pacific (Western)	NCEP/NCAR reanalysis project, Kalnay *et al.* (1996)	1.9 ° 2° resolution daily	ECCO (MITgem)	1° at high latitudes, 1°*0.3° in tropics, 10-day averages	Drift
2007	Di Piazza, Di Piazza, and Pearthree	Pacific	Laboratoire d'Océanographie Dynamique et de Climatologie	1991-1999 1° grid; weekly summaries	NA	NA	Directed

Table 1 (continued on next page): Table showing existing seafaring modeling and simulations (Updated from Davies and Bickler 2015: Table 1).

Year	Authors	Region	Wind Data	Res.	Current Data	Res	Type of Movement
2007	Callaghan and Bray	Caribbean coastal area	Marine Climatic Atlas of the World, U.S. Navy, 1995	1°	Marine Climatic Atlas of the World, U.S. Navy, 1995	1°	Drift
2008	Callaghan	Caribbean	Marine Climatic Atlas of the World, U.S. Navy, 1995	1°	Marine Climatic Atlas of the World, U.S. Navy, 1995	1°	Drift
2008	Fitzpatrick and Callaghan	Indian Ocean	Marine Climatic Atlas of the World, U.S. Navy, 1995	1°	Marine Climatic Atlas of the World, U.S. Navy, 1995	1°	Drift
2008	Evans	Pacific	SSM/I with ECMWF blended by NASA (DAO)	2.5° 2. 6° hourly	NA	NA	Directed
2008	Indruszewski and Barton	Baltic Sea	Wind data encountered during experimental voyage of Ottar (2004)	10° 10°	NA	NA	Directed
2008	Montenegro, Avis, and Weaver	Pacific	NCEP/NCAR reanalysis project, Kalnay *et al.* (1996)	1.9 ° 2° resolution daily	ECCO (MITgem) 1993-2005	1° at high latitudes, 1°*0.5 between 12° and 20°, 1°*0.3° in tropics, 10-day averages	Drift
2010	Cooper	Caribbean	None	NA	Data from experiential canoe trip from Cayo Hijo de Guillermo Este and Los Buchillones, (Callaghan 2001, Callaghan 2006; Callaghan and Bray 2007).	NA	Time Banded/ Isochrone
2011	Callaghan	Caribbean	Marine Climatic Atlas of the World, U.S. Navy, 1995	1°	Marine Climatic Atlas of the World, U.S. Navy, 1995	1°	Drift
2012	Altes	Caribbean	Marine Climatic Atlas of the World, U.S. Navy, 1995	1°	Marine Climatic Atlas of the World, U.S. Navy, 1995	1°	Drift
2013	Leidwanger	Mediterranean	www.windfinder.com, Wind and Wave Atlas of the Mediterranean Sea 2004	0.5° -1 °	Wind and Wave Atlas of the Mediterranean Sea 2004	0.5° -1 °	Time banded
2013	Fitzpatrick and Callaghan	Pacific (Western)	Marine Climatic Atlas of the World, U.S. Navy, 1995	1°	Marine Climatic Atlas of the World, U.S. Navy, 1995	1°	Drift
2013	Davies and Bickler	Global	NOAA Blended Sea Winds (Zhang *et al.* 2006)	0.25°	NOAA Ocean Surface Currents Analyses – Real time (OSCAR)	0.33°	Directed, Drift
2013	Slayton	Caribbean, Mediterranean	None	NA	NOAA Global Drifter program, 2010-2015	5°, 3 hourly	Directed

Table 1 (continued).

Year	Authors	Region	Wind Data	Res.	Current Data	Res	Type of Movement
2014	Bar-Yosef Mayer, Kahanov, Roskin, and Gildor	Mediterranean	Mediterranean Pilot 1988, Weather and the Mediterranean 1964	NA	Mediterranean Pilot 1988	NA	Drift
2014	Leidwanger	Mediterranean	www.windfinder.com, Wind and Wave Atlas of the Mediterranean Sea 2004	0.5° -1 °	Wind and Wave Atlas of the Mediterranean Sea 2004	0.5° -1°	Time banded/ Isochrone
2014	Montenegro, Callaghan, and Fitzpatrick	Pacific	Marine Climatic Atlas of the World, U.S. Navy, 1995, ERA Interim Reanalysis developed by the European Centre for Medium-Range Weather Forecasts	1°, 1° between 1979 and 2011, 6 hour intervals	Marine Climatic Atlas of the World, U.S. Navy, 1995	1°	Downwind or Directed
2015	Arcenas	Mediterranean	United States Imagery and Mapping Agency	5°	NA	NA	Directed
2015	Callaghan	Mid-Atlantic	Marine Climatic Atlas of the World, U.S. Navy, 1995	1°	Marine Climatic Atlas of the World, U.S. Navy, 1995	1°	Drift
2016	Safi, Dolan, and White	Salish Sea	None	NA	NA	NA	Directed
2016	Montenegro, Callaghan, and Fitzpatrick	Pacific	Marine Climatic Atlas of the World, U.S. Navy, 1995	1°	Marine Climatic Atlas of the World, U.S. Navy, 1995	1°	Directed
2016	Smith	Irish Sea / Celtic Sea	None	NA	Coastal Flooding by Extreme Events (CoFEE) Model	0.0185°	Directed
2017	Gustas and Supernant	Pacific Northwest Coast	None	NA	None	NA	Directed
2017	Baumann	Mediterranean	Modern Era-Retrospective Analysis for Research and Applications (MEERA) 100 m layer from the Global Wind Atlas	0.001°	None	NA	Directed

Table 1 (continued).

These researchers approached the modeling of routes differently, using several forms of environmental data and methodology. Many of these methods are limited by their reliance on licensed modeling software, the spatial extent of the study region, modern coastal boundaries, restricted vessel or navigation options, ability to represent only directed or drift voyages, deterministic or problematic environmental data (Davies and Bickler 2015), and a reliance on modern environmental data. Due to the availability of modern environmental datasets the resolution of data is different for models focusing on wind- or current-powered vessels (see Table 1). As such, it is difficult to categorize these works into methodological subsets. Though I will not give a detailed overview of all works referenced in Table 1, I will break the various methods used by these researchers into the type of pathways they generated.

Many approaches to modeling routes in the Pacific use programs that have been specially built to model sea-based pathways (Callaghan and Fitzpatrick 2013; Davies and Bickler 2015; Irwin *et al.* 1991; Montenegro *et al.* 2016). Pacific models have focused on directed sailing aimed at uncovering colonization routes and based on the assumption of prior knowledge of island location. Though different from modeling drift voyages, which make no assumption of prior knowle.g., these Pacific models are similar to the method used in this study, as many of those are centred on directed routes towards islands (*e.g.,* Davies and Bickler 2013, 2015; Di Piazza *et al.* 2007; Evans 2008; Irwin *et al.* 1991; Montenegro *et al.* 2016). Whether a voyage is directed or a drift voyage affects the level of human influence found in the model.

Researchers modeling Pacific and Mediterranean seafaring focused on vessels with sails. As such, they favoured wind data more heavily than current data for the creation of the friction or cost surface equivalent (Arcenas 2015; Irwin *et al.* 1991; Leidwanger 2013; Levison *et al.* 1973). Vessels in some Pacific models (Davies and Bickler 2015; Irwin *et al.* 1991) could tack, *i.e.* seek the best wind conditions available to reach optimal speed. Human decision-making was also a part of these models. Voyagers had the option of turning around for home after 20 days at sea if no islands were encountered (Irwin *et al.* 1991) or could set new headings after other set times (Davies and Bickler 2015). Though the navigator's ability to choose vessel heading was limited, the ability of vessels to change direction enables these methods to inject a human element not found in programs where vessels cannot tack (Callaghan and Fitzpatrick 2013; Montenegro *et al.* 2016; Slayton 2013). Because these wind friction surfaces were regenerated at the start of every new day (Davies and Bickler 2015; Irwin *et al.* 1991), the model allowed for some variability in sailing conditions. Turning around or tacking with the wind would have been vital considerations for sailors traveling over the longer periods and distances in the Pacific.

Montenegro, Callaghan, and Fitzpatrick (2016) built on this theory by allowing for routes to be based on short hops. In this case, modeled sailing vessels sought out the shortest distance to landfall with nearby islands while progressing to their final destination. Here, modeled decision making is geared towards identifying corridors of 'shortest routes between coastlines' that may have impacted larger trips. In cases where researchers look to model shorter distances, as is the case the current work, the need for fine grained resolution of environmental data is necessary. Early modeling efforts in the Pacific typically had a lower resolution for environmental data, because of the larger cell size at which the data was collected, than what has been used in the past two decades (Davies and Bickler 2015). As a result, researchers were not able to evaluate how the change in wind affected vessels as frequently (see Table 1). For example, Irwin's *et al.* (1991) original model used a friction surface with a cell size of 5° squares based on wind data for the months of July and January. In later works, Davies and Bickler (2015) ran models with a resolution of 0.25° for wind and 0.33° for current. This greatly increased the accuracy of the underlying cost surface.

As in the Pacific examples, researchers modeling sea routes in the Mediterranean have focused on seafarers using sailing vessels. This requires models to prioritize wind data over current data, which is shown in works by Arcenas (2015) and Leidwanger (2013). However, researchers evaluating mobility in the region have approached modeling these sailing routes using different methods. Arcenas (2015), who developed the seafaring model used by the ORBIS program, takes a more traditional least-cost pathway friction surface approach. This surface is limited to directional travel across set lines between port cities. The seasonal variation in cost to these lines is the only change in travel cost represented. To model routes along these set lines Arcenas (2015) used the equation:

$$T = \frac{F1(Vwind)}{F2(Vwind)}$$

where F1 (Vwind) is distance and F2 (Vwind) is the average velocity of travel time.

The original equation was adapted for use within the computer modeling framework used by the broader ORBIS program, and F2 (Vwind) was simplified to make use of wind-roses or speed-roses (Arcenas 2015). The simplification of F2 (Vwind) weakened the freedom of the vessels to choose an independent least-cost route. The resolution of Arcenas's model was set at a cell size of 5° squares and the wind data was averaged month by month. The larger cell size is problematic for accurately modeling routes, as the Mediterranean would contain only a handful of cells. The small number of cells is likely responsible for the rigidity of routes along the set grid of pathways between ports (Davis and Bickler 2015; Irwin *et al.* 1991).

Other methods of modeling sea routes focus on canoes, which were influenced more by current than by wind. This change is seen in Richard Callaghan's work in the Caribbean. Like his research in the Pacific, Callaghan modeled drift voyages. Callaghan relied on environmental data obtained from American Navy pilot charts (Defense Mapping Agency Hydrological Topographic Center 1982) and the United States Navy Climatic Atlas (United States Navy 1995), which has a resolution of 1° or 2° squares (Callaghan 2001, 2003). These grid sizes matched the needs of Callaghan's focus on connections from the mainland to the Antilles (Callaghan 2001). Callaghan's research in the Caribbean also explores how the use of different vessels would have affected a voyage's time costs (Callaghan 2001).

Although the vessel and environmental types in Callaghan's early work differ from earlier Pacific examples, such as Irwin, Bickler, and Quirke (1991), the method of environmental data being randomly selected at the start of every 'day' within the model is similar. Thus, the environmental data used as the base for these routes are static, not sequential. This tactic may be better applied to deeper time depths or greater modeling distances or coarser resolution of environmental data, where the random generation of currents may result in similar returns based on sequential environmental data. This method can also be said to apply to other researchers' work, where the data collected is calculated to form averaged isochrone models.

Unlike the previous examples where researchers modeled routes, Leidwanger (2013, 2014) and Cooper (2010) marked movement in bands of time. In studying the Mediterranean, Leidwanger (2013) created maps that showcased the length of voyages from to an origin point to all sections of coastline within the study area. He adapted wind data to a series of vectors that were then made into a raster grid and analyzed using ArcGIS (Leidwanger 2013, 2014). Leidwanger (2013) supported his use of environmental constraints with information on experimental voyages conducted in a replica of a Greek sailing vessel, modeled after a ship found in Cyprus dating to 300 BC. The vessel's sailing capabilities were based on physically observed data from the ship's performance. Though wind data was not the only environmental factor considered, the weights used to establish a cost surface were not fully articulated in the article.

Computer modeling of sea-based routes is a relatively new approach to studying connections between island communities in the Caribbean. Attempts to model movement through the Caribbean have general taken two approaches, either looking at the general difficulty to movement (Cooper 2010) or analyzing the likelihood of undirected movement across larger expanses of sea (Altes 2011; Callaghan 1999, 2001, 2003, 2008). Caribbean researchers have mostly focused on drift voyages (*e.g.*, Montenegro *et al.* 2006; Avis *et al.* 2007). For example, Altes (2011), who modeled colonization routes in the Caribbean, used ArcMap to run analyses of sea-based cost-surfaces, with the intent of creating pathways from South America to Florida. The cost surface resolution cell size for this model was 1° (Altes 2011). The force of the current applied in Altes's model is not specified and no wind information was added to the model. Like the model used in the present work, Altes (2011: 115) also made a point of leaving space for islands within the surface to avoid least-cost routes running through them. This is not typically discussed in other works referred to in the Table 1. The current redirect influences the vessel every 27 km within the cost surface (Altes 2011). This isodistance method, which calculates cost over set distances, is like the isochrone method used in the current study. The pathways generated in Altes's (2011) study conformed to those produced in undirected drift models.

Cooper (2010) created an anisotropic cost surface in ArcGIS to compare movement around Cuba. He combined landscape and seascape, which he termed islandscape (Cooper 2010). Results from Cooper's modeled time fronts highlighted the greater efficiency of utilizing coastal waters to move materials and peoples. Though he did reference the use of a cost surface for sea areas, Cooper (2010) did not provide explicit information on the nature of the associated water friction layer. He stated that the surface was derived from digitized water maps and interviews with local fisherman (Cooper 2010: 30). How this data would relate to current flow is unclear. However, the focus on travel time instead of physical cost in his research is consistent with the isochrone method used in the present study.

Altes and Cooper established the possibility using computer modeling to test for seafaring links in the region. Though typically focusing on broader success rates of voyaging between two areas, these works help to identify possible canoe travel corridors for colonial seafaring (Altes 2011; Callaghan 1999, 2001, 2003, 2008). These modeled pathways suggest the level of Amerindian canoers' capability to overcome the challenges of canoeing over long distances and for extended periods, indicating the skill and perseverance of pre-Columbian canoers. These efforts form the base for future modeling efforts, including those looking to establish possible corridors of movement between islands in the Caribbean.

3.2.3 Incorporating Archaeological Evidence

A human, or non-environmental, element was included in the setup of routes modeled for this study to ensure that pathways reflect these factors. Using known archaeological sites as the origin and termination points of pathways links the model to human action. The model further reflects human influence by assuming canoers knew various site locations, similar to the way sites are treated within a landscape (*e.g.*, Bell and Lock 2000, Llobera 2000; Surface-Evans and White 2012). However, many sites involved in the Lesser Antillean Archaic Age, Ceramic Age, and early colonial period inter-island exchange networks are unknown, as not all surfaces in the region have been surveyed. Environmental incidents, such as landslides, coastal erosion, and sea level rise have also obscured the location of sites (Bright 2011; Cooper 2010, 2012, 2013; Cooper and Peros 2010; Glassow *et al.* 1988; Hofman and Hoogland 2015; Siegel *et al.* 2015; Wilson 1989). Inclusion of missing sites as origin and termination points would increase the accuracy of suggested least-cost pathway networks and could impact how canoe routes between islands are analyzed (Bright 2011; Johnston 2002). However, this work only focuses on known sites in order to fit within the NWO Island Networks Project. A review of published archaeological evidence, including work done as a part of the NWO Island Network Project (Breukel forthcoming; Hofman *et al.* forthcoming; Laffoon *et al.* 2016; Mol *et al.* 2014; Scott *et al.* in press), particularly the existence of sites, informed the placement of nodes for this study.

Evidence of exchange can support inter-island movement (Hofman and Hoogland 2011; Hofman *et al.* 2008a, 2008b, forthcoming). The placement of archaeological sites can show the basic structure of canoe travel corridors that linked neighboring islands. Connections between site placement and the location of canoe mobility corridors has been discussed in other works (*sensu* Hofman and Hoogland 2004; Hofman *et al.* 2006, 2007; Rouse 1986, 1992), though without identifying the specific layout or base cost to these connections. Materials in assemblages can show how seafaring peoples living on islands across a channel from one another were linked. Similar materials found on opposite sides of a channel have demonstrated that communities canoeing between islands were sometimes better connected than communities on the same island, or even that coastal communities were better connected than inland sites (Bright 2011; Hofman *et al.* 2007; Rouse 1992). The presence of these materials can inform on the mechanisms of the mobility of peoples, goods, and ideas between islands.

Cross-channel connections and the transportation of materials between islands indicate that island Amerindian communities were oriented towards the sea and maritime connections (Bright 2011). Amerindian peoples' probable focus on maritime activity highlights how vital canoes were to these communities. Canoes would have been integral to social life as they were used to connect communities with other peoples and materials. The archaeological material underpinning each regional example of reciprocal canoe routes tied to Amerindian mobility through the Lesser Antilles will be discussed at the beginning of each case study chapter.

3.3 Conclusion

Combining archaeology, historical accounts, and experimental or experiential archaeology provide a strong background for the application and analysis of computer-modeled canoe routes through the Lesser Antilles in the Archaic Age, the Ceramic Age, and the early colonial period. This is particularly true for social aspects, which are essential to supplement the largely environmentally-driven nature of computer modeling. Canoers were motivated not only by ease of movement but also by the need to sustain and maintain community ties and connections with allies or family on other islands and the exchange or movement of materials.

Analysis of modeled least-cost pathways must also include consideration of the possible social motivations of canoe crews and navigators. These motivations are suggested through the archaeological record and ethnographic accounts, like those that express the technology and capability of sea vessels. Combined with theoretical approaches to understanding movement and the construction of mental maps (*sensu* Ingold 2000, 2011; Lynch 1960; Richards 1974; Tilley 1994; Trowbridge 1913; Wiebe 1989), the physical and psychological nature of seafaring can be weighed against the results of computer modeling. Ideas of how people remember past routes can support the re-use or maintenance of inter-island routes constructed by computer models. The integration of hypothetical physical routes and mental routes may point towards new understandings of social motivations and the actions of canoers.

Experiential voyages, like those conducted by the Karisko project (Bérard *et al.* 2016), can help to enhance our understanding of the human experience in canoes, the capability of voyagers, and how crew members relate to one another. These social functions may impact several aspects of voyaging, and should be included in modeling hypothetical routes, in terms or finding rest periods and stopover places for voyagers. These factors can help to identify where peoples may have wanted to travel and can support or contradict generated least-cost paths, which can be used to discuss what is possible and form a base on which ideas of voyaging and the creation of navigation maps can be placed.

Least-cost pathway analysis, social preferences for voyaging, and the historical record can provide additional methods to analyze archaeological evidence of inter-island interaction. Though cost-benefit analysis may not return definitive routes used in the past, they are one way to bolster or critique archaeological arguments by suggesting the possible layout of past movement. It is also possible that peoples would have chosen not to travel by the most direct or optimal route (Surface-Evans and White 2012). However, sea-based least-cost paths are one of the few ways to recreate past movement between islands, an aspect of Caribbean life that is obscured by the nature of the archaeological record of coastal environments and the relative absence of evidence of seafaring technology from sites.

Sea-based least-cost pathways can explore possible routes of connection through the modeling of reciprocal voyages under finer-grained cost surface resolution than has been used in the past. Some earlier studies in the Caribbean region applied modeling to drift voyages, which removed some of the human element from the results while more accurately suggesting colonization routes. The model developed for this work creates directed voyages that, while limited in terms of how they connect seafarers and sites, in a small way reconstruct the possible mental maps of past sailors and canoers. The specifics of this method and the base it runs on are detailed in the next chapter.

4

Modeling Reciprocal Voyages

This research seeks to explore how reciprocal voyages may have influenced inter-island mobility networks in the Caribbean, which requires consideration of multiple factors. First, these modeled pathways are based on environmental factors and constraints, such as current and wind. Second, routes are influenced through the origin and termination points, which are tied to the archaeological record and, as a result, past inter-island networks. Setting known sites as origin and termination points not only makes the routes directed but also ties these routes to real inter-island interactions. Third, the model sets a canoe speed for the vessel. Canoe speed was based on experimental and experiential canoeing voyages and set at three knots (Bérard *et al.* 2011, 2016). Routes returned by the model are thus not entirely dependent on environmental data alone, and are shaped through the speed of the canoe and the path's destination.

Landscape least-cost pathway analysis discussed in the last chapter is primarily based on static values and is not easily adapted to modeling sea routes because least-cost pathway sea-based models deal with moving or changing surfaces and needs. The model presented in this study expands on the traditional platforms to discuss movement over currents. I worked with Jan Hildenbrand and Jan Athenstädt from the University of Konstanz to build an isochrone model capable of dealing with current velocities (Athenstädt forthcoming; Hildenbrand 2015). Isochrone modeling refers to the process of suggesting the duration and layout of routes between two locations based on calculating the distance covered over several time segments (time fronts) toward the destination point. This isochrone tool was coded in Java and has an easy-to-

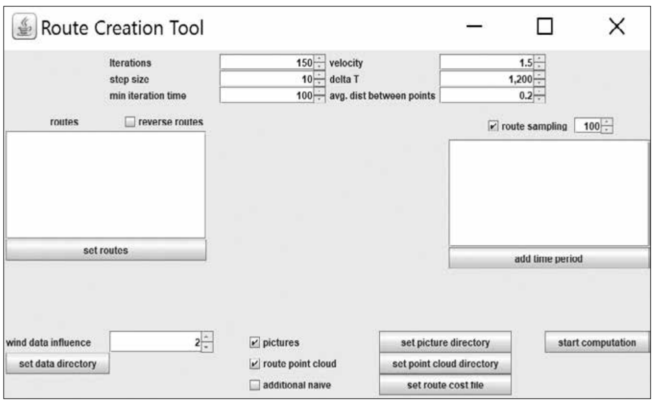


Figure 15: The model user interface into which the parameters are placed. The values present for each setting reflect the automated values present when the program is opened.

use user interface (Hildenbrand 2015; see Figure 15). The program uses a grid system of environmental data – namely wind and current. The underlying calculations used in these methods can calculate velocity and drift, unlike land-based cost surface analyses (Higawara 1989; Hildenbrand 2015). However, this model does operate on the same basic principles as other least-cost pathway models, as a time cost is calculated.

4.1 The Influence of Current and Wind

The most important environmental factors contributing to patterns of movement through the Caribbean Sea are current and wind. Current has the strongest effect on the direction of each modeled canoe voyage due to the impact it has on the vessel in the water. Current is a constant force that prevents any vessel from remaining stationary (*sensu* Bérard *et al.* 2011; Bérard personal communication 2014). The current continually pushes vessels in various directions. This push can either aid or disadvantage a canoe crew's journey, depending on the direction they wish to travel (*i.e.* with or against the current). Current influences the ability of peoples to connect with one another (*e.g.,* Callaghan 2001, 2003; Davies and Bickler 2015). Strong ocean currents could have prevented or promoted movement between certain communities connected through current flow and changing navigation strategies that may have influenced community links. These strong currents may have influenced the construction of seasonal strategies, depending on the location of the travel corridor.

It is also possible that the repetitive push of currents could affect the construction of a mental map. Previous research in cognitive science (Tolman 1948; Tolman *et al.* 1946), anthropology or archaeology (Kirby 2009; Tilley 1994), geography (Lowenthal 1961; Richards 1974), and the constructing of urban environments (Lynch 1960) supports the influence of continued pathway use on the development of mental navigation maps (for additional discussion on mental maps, see Chapter 2). Mental maps may have been used by Amerindian communities, as indicated through relationships between archaeological finds on islands in the Caribbean and the position of modeled canoe routes. Current movement can also direct least-cost routes, and by extension any canoe crews that might have followed them, towards certain areas increasing the likelihood that those movement corridors would be remembered and included in a wayfinding map of the region. Several hypothetical canoe routes constructed for this work suggest a link between site placement and least-cost canoe pathways, indicating some affiliation between trajectory and memory.

The time periods discussed in this study, beginning around 2000 BC in the Archaic Age and ending in AD 1600 during the early colonial period, fall after the large sea level rise that obscured the many small islands between the Greater Antilles and mainland South America (Cooper and Peros 2010). Currents encountered by Amerindians after this sea rise period can be comparable to currents recorded in the modern era (Callaghan 2001). Current flow has remained relatively level over the past one thousand years due to the consistency of the bathymetry (*i.e.* topography) of the sea floor. Sea levels have not yet risen to heights that would preclude the use of modern currents as the base for the model's cost-surface (Callaghan 2001: 309). Thus, for this study I have assumed that modern observations of current can be used to represent prehistoric sea conditions.

I took data on sea currents from the National Oceanic Atmospheric Administration (NOAA) and the AmSeas3D project. The AmSeas3D project collects data on surface currents around the Caribbean region. AmSeas3D data is spread over the Caribbean in 0.033 grids, or roughly 3.7 km separation between collected data points. This is a relatively high resolution for seascape-based cost surfaces, which have ranged from 5 degrees (roughly 550 km) to 0.25 degrees (roughly 27 km) in other works (Davies and Bickler 2015; Irwin *et al.* 1991; see Chapter 3 Table 1). AmSeas3D data include longitude, latitude, eastward velocity, northward velocity, and time-specific coordinates in the region. The two velocity readings can be used to calculate velocity vectors for current movement. Current data was collected in three-hour intervals. This allows multiple samplings of current data over the course of a day and a year. Linear interpretation is used to interpolate the force and direction of the current when calculating steps along the isochrone route for modeled pathways that launched inside these three-hour intervals (Hildenbrand 2015: 26). The AmSeas3D project has collected data from 2010 to the present and this study uses data collected from 2011 to 2014. It is difficult to exactly replicate cost values that were reflective of the real conditions faced by early seafarers without using modern records. In the future, it may even be possible to use data generated to reflect past currents directly, and to evaluate whether these data differed significantly from modern data.

Current can also affect route layout, or the trajectory of individual hypothesized canoe pathways generate by the isochrone tool. Estimating the length and trajectory of a journey partly depends on counteracting the side, front, or back push of the current on the vessel. This includes the influence of drift, or the current's impact on the canoe when at rest. Drift affects any canoe in a resting position at sea and the continual push of the current ensures that even when paddlers are at rest the vessels are in motion. Furthermore, paddlers cannot stay still, as ceasing to paddle means risking capsizing.

Experimental voyages conducted by Benoit Bérard and the Karisko project detail the difficulty of canoes staying upright in strong currents (Bérard *et al.* 2016). Karisko is a Martinique association that organizes experiential canoe voyages. Many of Karisko's routes were designed to take advantage of the current's push on the vessel, which had a significant effect on the drift of the vessel towards the destination point (Bérard *et al.* 2016; Bérard personal communication 2015). The current's push, which encourages a trend toward curved trajectories, is reflected in the routes modeled here. The current's influence on both the experiential and the modeled routes suggests that canoe travel corridors were in part constructed around current flow.

Wind also influenced canoe movement. Wind patterning has also remained consistent enough to use modern data for this type of model (Indruszewski and Barton 2008; Murray 1987). Wind data was taken from the Global Forecast System (GFS)[2] produced by the National Center for Environmental Prediction. The GFS has a resolution of 0.28 degrees, or roughly 28 km, grid cell size. This is coarser than for the AmSeas3D data set. As wind is not as heavily weighted within the model and is also interpolated alongside the current data, I assume a resolution for the wind data essentially equal to that of current. Like the AmSeas3D data set, the GFS data is also collected in three-hour intervals.

2 Data from the Global Forecast System (GFS) was accessed through: https://www.ncdc.noaa.gov/data-access/model-data/model-datasets/global-forcast-system-gfs.

Wind plays a role in the minute-by-minute ease of travel of a voyage. Wind not only affects surface currents but provides an additional force working with or against a vessel, as it helps to shape surface currents, wave height, and drag on the vessel and the canoe crew (Bérard *et al.* 2011, 2016; Billard *et al.* 2009). Wind also affects wave height, which impacts a canoer's ability to paddle. High winds can result in tall waves. Tall waves slow down the canoe as they make it difficult for canoers to connect their paddles with the water in a uniform pattern. I personally encountered this problem when working with the Karisko project for three short experiential canoe voyages. I often found it difficult to push the blade of my paddle into the water to help push the canoe forward. This led me to strain my arms and an acceleration of physical exhaustion. Unfortunately, without complete access to a hydrodynamic (Bérard *et al.* 2011) model, it was not possible to directly calculate the influence of wave height and direction on the vessel.

In some cases, wind can signal the arrival of storms, which would have likely influenced a crew's decision to go out to sea. We were not able to account for storms in our model due to the inconsistency and high variability of storms within the underlying wind dataset. The snapshot nature of the current and wind data collected also made it difficult to pinpoint consistency of current or wind flow through the Lesser Antilles. In the future, it may be possible to see storm activity in abnormal pathway results by checking routes with atypical time costs against recorded weather events. Using all available environmental data, it is possible to represent an accurate approximation of optimal canoeing practices. Simulating possible least-cost paths at multiple points can suggest certain times when routes were more difficult or costly than those faced by real-world canoers, who may have chosen to either not set out or to paddle to shore under such conditions.

These environmental constraints are combined into one surface, on which current and wind information is georeferenced to longitude and latitude coordinates. In general, a map projection affects the consideration of origin and termination points, with affixed longitude and latitude, that are placed within a grid that fits earth's surface. The map projection, or the association of environmental data with the grid, is spaced evenly when the data is collected near the equator, where degrees of longitude and latitude are relatively equivalent (Conolly and Lake 2006). As grid surfaces move further away from the equator, the shape or projection of grid cells shifts to accommodate the underlying sphere of the earth. Plotting the shortest direct path between two points, without influence from environmental data, on a Mercator projection returns a curved and not a straight line (Hildenbrand 2015: 7). Hagiwara (1989) relied on great circle calculations, used to determine the distance between two points on a sphere (Gade 2010), to ensure that the calculation of a path reflected a straight path over long distances. However, because of the Caribbean's position near the equator, which minimizes distortion due to the earth's shape, a Euclidian distance measure was used. Here, the Euclidean distance measure refers to a calculation of straight-line distances (Deza and Deza 2009). Hildenbrand's (2015) tool better fits a Euclidean distance measure as it uses a smaller step size that represents changes in canoe headings dictated by hypothetical Amerindian mental maps.

As stated earlier, because canoes of this region did not operate on sail power until after the arrival of Europeans, wind may not have had as great an effect on canoe voyages as it had on the European sailing vessels. As a result, current would have had a relatively much greater effect on Amerindian paddled canoes. Therefore, I decided to weight current more heavily than wind. The projected wind and current data can be added together and given different weights within the tool (see Figure 15). This allows the cost surface used as the base for modeled canoe routes to reflect the percentage of influence each environmental factor had on the canoe.

Hildenbrand's tool allows for the current and wind cost surfaces to be updated at multiple stages along the isochrone route. The cost surfaces used here reflect the reality of current and tidal change over a 24-hour period. For this research, data was sampled every 3 hours to reflect the collection rates of the NOAA AmSeas3D project. However, this sampling rate can be changed to reflect whatever environmental data is used. This is because the resolution of this change is controlled by the time step, iteration settings, and route sampling settings of the model (see Figure 15). The model can also interpolate cost surfaces reflecting the change in current between current and wind datasets.

4.2 Adding a Human Element

The distances between islands in the Caribbean suggest that canoers could manage around time constraints for voyages, such as when crews became too tired. Tactics to counter these constraints include island hopping and paddling in shifts, as Callaghan and Bray (2007) have suggested. Stopover areas, where a crew could land along a coastline and rest, represent a way for crews to recharge mid-voyage. Stopover areas can be identified from pathways that go past other islands between the origin and termination points. These islands indicate the probable rest points in the journey. Whether voyagers needed to rest can be connected with the distance or time cost of a route and the position of an island.

To determine which modeled routes fit more closely to reality, I evaluated the influence that crew capability, or a canoer's physical ability, would have on the success of trips depending on a voyage's length. Determining crew capability requires a consideration of caloric (energy) loss involved in canoeing. A small number of studies have delved into the effects of canoeing on the human body. Sports medicine researchers, including García-Pallarés and Izquierdo (2011), Shephard (1987), and Tesch *et al.* (1976), have run tests on the performance of professional and semi-professional canoers. This research shows that the stress on the body from canoeing is like other sports, for example rowing or running (García-Pallarés and Izquierdo 2011; Shephard 1987; Tesch *et al.* 1976). This indicates that general considerations for how long people can canoe may be taken from similar calculations for modern day rowing or paddling studies.

Horvath and Finney (1969) conducted a short study on the capability of paddlers in a double-hulled canoe off the coast of Hawaii. Their tests found rowers could constantly paddle for eight hours and, when the canoe achieved an average speed of 3.16 knots (or 5.85232 km) per hour, an average of 369 calories were expended per canoer per hour, or roughly 2960 calories were consumed by an individual for one eight-hour voyage when the seas were fairly calm (Horvath and Finney 1969: 271). The total energy expenditure for all individuals must fall "below 35 percent of the maximum oxygen uptake" for the crew to maintain that speed. Roughly, this means that crews cannot always travel at maximum speed or they would not be able to paddle over longer periods. However, the challenge of paddling on the open sea often led to a fluctuation in these energy expenditure levels among the canoers. Energy expenditure is dependent on sea conditions, such as current and wind speeds, as well as individual responsibility or activity during a specific period (Horvath and Finney 1969).

More recent experiential canoe voyages conducted by the Karisko project (Bérard *et al.* 2016) found that even canoers who received only a few hours of training could maintain enough energy to successfully complete at least six hours of voyaging on semi-rough seas (Bérard *et al.* 2016; Bérard personal communication 2014). According to Bérard, it is possible to have a journey last up to 12 hours under typical conditions. These voyages, however, result in heavy fatigue after the eight-hour mark. This is consistent with Horvath and Finney's (1969) findings that suggest fatigue may set in before the eight-hour mark.

In 2014 as part of my work with the Karisko project I ran heart rate monitor measurements during a two-hour canoe excursion. I had two paddlers (paddler 1 and paddler 2) out of a 23-person crew wear heart rate monitors[3] as we crossed the Fort De France Bay in Martinique (see Figure 16). The weather conditions during this canoe run were considered 'normal' for the area, *i.e.* calm seas (Bérard personal communication 2014). Paddlers 1 and 2 showed an average heart rate of 89 BMP when moving at a speed of 2 knots or 3.8 km/hr. These paddlers were physically fit middle-age individuals, who exercised daily and regularly trained in a canoe with the Karisko team. The number of calories burned was calculated by taking the average weight of the canoers and applying the Wahoo Fitness App's calorie equation:

$$CalorieBurnRate = \frac{abs\big((0.6309 \times newHeartrate) + (0.09036 \times weightinPounds) + (0.0217 \times userAge) - 55.0969\big)}{4.184}$$

It is also possible to assess the theoretical capability of canoers by determining the ability of people to paddle an average distance per hour while expending a set level of energy. As there is no way to currently calculate the energy cost faced by canoers within the isochrone tool, these considerations of human capability and voyage length must be included after the routes are generated.

Due to the inclusion of several channels that surpassed normal distance covered by modern experimental voyages in the following case studies, a new way of determining the maximum length of a canoe voyage was considered. Pre-Columbian voyages modeled in this work often exceeded the six-hour voyage average and 12-hour limit discussed by Bérard (Bérard *et al.* 2016; Bérard personal communication 2014), as well as the eight-hour voyage set by Horvath and Finney (1969). Perhaps, as suggested by Callaghan (2001), these timetables could be extended by canoers taking shifts. There are various arguments for taking shifts in canoes, or calculating an overall 'safety' level for being near an island and the ability to take rest breaks on a beach (Callaghan 2001; Torres and Rodríguez Ramos 2008). Callaghan and Bray (2007) discuss the possibility of utilizing shifts of eight hours when calculating drift voyages, when canoes are not

3 Wahoo Fitness App and Ticker X heart rate monitors.

directed towards a termination point, from South America to the Greater Antilles. For these voyages four paddlers out of a crew of eight would paddle while the others rested. The shifts where canoers would paddle or rest likely changed between voyages, including the duration and timing of breaks. As any break in paddling can lead to capsizing the canoe (Bérard personal communication 2015), the 'working' paddlers would be required to paddle constantly. Likely, the canoeing in shifts theorized in sea-based least-cost pathway models reflect the reality of early voyages. However, there is limited ethnographic information on the use of canoes in the region and there is no information on the process of taking shifts. Therefore, the use of a shift system by canoers must be based on estimations when modeling least-cost routes, in this and other studies. These hypotheses about shift changes are typically calculated after the model has run, comparing route length with theorized size of the canoes crew (*e.g.*, Callaghan 2001).

It is possible that a voyage could exceed 12 hours due to time requirements of crossing some of the larger channels between islands in the Lesser Antilles. The speed of the

Figure 16: Route map of canoe heart monitor test run by author in bay of Fort De France, Martinique, from Pointe Du Bout to Fort Saint Louis, using the app Wahoo Fitness.

crew could fluctuate depending on the total length of the voyage. In these cases, one could consider adjusting for slower speed after the 8-hour mark to take into account a fatigued crew. With a 12-hour voyage, it is likely that a combination of eight hours of traveling at three knots and four hours of traveling at two knots could together represent a possible average speed. This corresponds to a hypothetical maximum distance across the Anegada Passage of roughly 59 km total distance when adjusting for a fatigued crew, and 66 km for a crew that theoretically manages to paddle at full speed for the entire 12 hours using the equation:

$$(MaximumCanoeSpeed \times TimePaddled) + (MinimumCanoeSpeed \times TimePaddled)$$

Or

$$(5.56km/hr \times TimePaddled) + (3.7km/hr \times TimePaddled)$$

Though these calculations can provide a baseline (*e.g.*, Horvath and Finney 1969), it is likely that many trips between islands involved longer distances and paddling times. These distances could take longer when working against the current or in poor weather. In this regard, it may be feasible to consider that crews took staggered or shorter breaks to extend their paddling capabilities. In this sense, no true maximum time of a voyage can be established. Pathways that pass by island coastlines should be assessed for their potential as rest areas that could extend the length of canoe voyages between islands.

By evaluating where routes passed by islands and the difficulty in completing the entire route, it may be possible to identify where stopover points along least-cost routes may have been desired or necessary, and thus possibly used as waypoints by Amerindian crews. For this work, I have discounted optimal routes that have higher route times than others, particularly those that exceed the average route time by over 15 hours. This process is done after the canoe routes have been modeled using the isochrone tool, detailed later in this chapter. By assessing the trajectory and the time costs of routes, it may be possible to determine if a crew of average size, between one and 30 people (Davies 1595; Fitzpatrick 2013; Hulme and Whitehead 1992; Peck 2002), would have been capable of making a journey if the crew was able to work in shifts (*e.g.*, Callaghan 2001).

4.3 Evaluating Currents

At my request for additional ways to evaluate seasonal trends, Jan Christoph Athenstädt from the University of Konstanz developed a program to assess the strength of the current at any given point in the region (Athenstädt forthcoming). Like the isochrone route tool discussed below, the current tool evaluates current data collected by NOAA's AmSeas3D project. The current tool details the direction and force of the current at three-hour intervals from the years 2010 to 2016. This is like the method of sampling for the route-cost tool used in this work. This ensures any evaluation run through the online interface will match the environmental factors influencing the route-cost tool.

Using the current tool, I produced a series of graphs that plot the strength of the current against the time it occurs (Athenstädt forthcoming). Each graph is accompanied by a color wheel that ties color to direction to visualize the analysis. In these graphs, colored dots correspond to the direction the current was heading at every data collection time. The 'standard direction' of the current for the northern Lesser Antilles is due north, which is represented by grey in the color wheel. Movement away from the standard direction "to port," or counter-clockwise, is indicated by a red dot (Athenstädt forthcoming). A green dot refers to "starboard" movement or a clockwise shift away from the standard direction. Current averages are measured to determine if trends in the data were periodic. A quadratic function was fitted to all modeled points, using interval length of one to 30 days, or eight to 240 data points (Athenstädt forthcoming). A linear regression was then run in all intervals averaging the r^2. The average of these r^2 values should "be significantly lower if there is a periodicity" (Athenstädt forthcoming).

The current tool returns graphs with current values displayed by year in three-month intervals. Time is plotted on the X axis while current strength is plotted on the Y axis (Athenstädt forthcoming). Each interval is accompanied by a direction-wheel alongside longitude and latitude information for the point surveyed. I wanted to evaluate how time connected to current-force data averaged out over the year to compare these values seasonally. This would make seasonal trends apparent. As the tool also allows time information from these data points to be averaged, seasonal variability can be checked by using the current tool to create a running average for two period types, 15 and 30 days. The force of current is determined by averaging the strength of all data points within these time frames. Current direction was calculated by separately averaging the northerly and easterly vector component (Athenstädt forthcoming). These averages are represented in several bands corresponding to a year. The graphs created through this tool assess and visualize how currents fluctuated annually.

These current values can indicate what times of year should be evaluated using Hildenbrand's isochrone tool. Depending on the consistency of current velocity over several years, comparing the force and direction on current at several points within the case study could indicate those regions that were accessible throughout an annual canoeing cycle. This assessment ensures a more targeted approach to uncovering canoe travel corridors can be taken with the isochrone model.

4.4 Isochrone Modeling

As stated above, isochrone modeling is a method used to calculate the optimal path between two points by linking a series of time fronts. These time fronts, which showcase movement from one point over the same period in all directions, can be linked to form a continuous route. The isochrone method, as first proposed by Richard W. James (James 1957), creates a sequence of time fronts in which each new time front is based on how far an object can move from a start point in the repeated period. In this sense, it approaches a ship's movements as a "discrete optimization problem" (Hagiwara 1989: 17; see Figure 18). Vessel movement is charted in sections rather than as a continuous path, as shown by continuous optimization routes (see Figure 17). However, the isochrone method itself was not adaptable for computerization. This led Hagiwara to improve the method so it could be used for computational analysis. Hagiwara (1989) dubbed this the 'modified isochrone method'. Hagiwara (Hagiwara 1989: iii), working on ship routing logistics, developed the modified isochrone method as a weather routing tool that provided accurate information on a "(sub) optimum ocean-crossing route" to captains of small wind and motor-powered vessels.

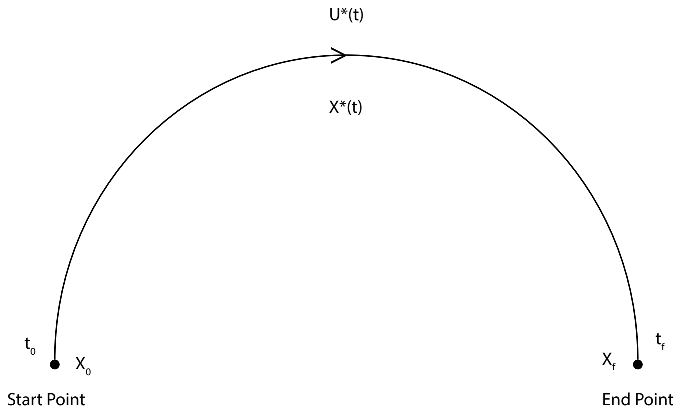


Figure 17 The formulation of ship routing as a continuous optimization problem (above figure modified from Hagiwara 1989: Figure 2.1; see Appendix A). In this method "a ship's position vector is: X = [∅ λ]^T , where ∅ : latitude, λ : longitude. A ship's control vector is: U = ⟦[θ n]⟧^T, where θ : ship's heading, n: number of propeller revolutions" (Hagiwara 1989: 12).

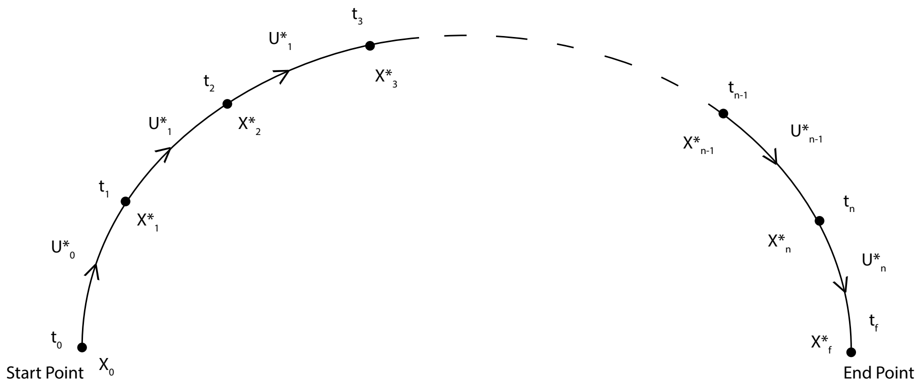


Figure 18: Formulation of ship routing as a discrete optimization problem (Modified example of a formulation for ship routing as a discrete optimization problem as seen in Hagiwara 1989: Figure 2.2; see Appendix A).

Hagiwara's (1989) modified isochrone method involves creating new iterations of isochrones from each point along the journey (see Figure 19). At the start, a series of rays is produced from the origin point. Within these rays the furthest point that can be reached by Euclidean distance standards is selected as the next point from which to model an isochrone ray. These next generation points are linked to create a time front showing the farthest possible movement from the origin point during a set time in every direction (Hagiwara 1989; see Figures 19 and 20, Appendix A). This process of creating rays and then determining new points is repeated for every time front until all possible outcomes have been explored (Hagiwara 1989; Hildenbrand 2015). These time steps create an image of continuous movement of a vessel over designated periods. While a canoe's speed during these time steps remains constant, the resulting velocity of the boat does not, as it is a combination of current velocity with the vessel's velocity.

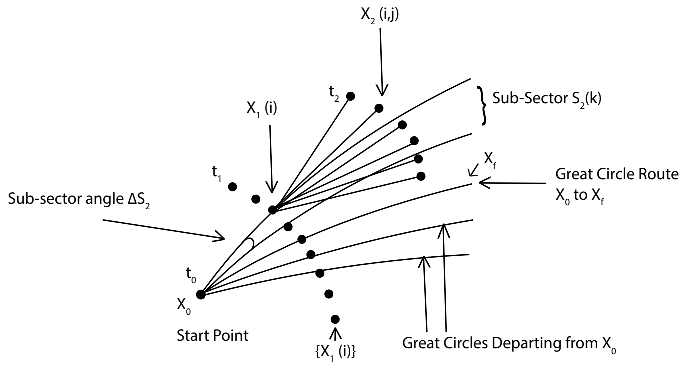


Figure 19: Modified from Hagiwara (1989) figure 2.3, Calculation of isochrone $\{X_2(k)\}$ at time t_2.

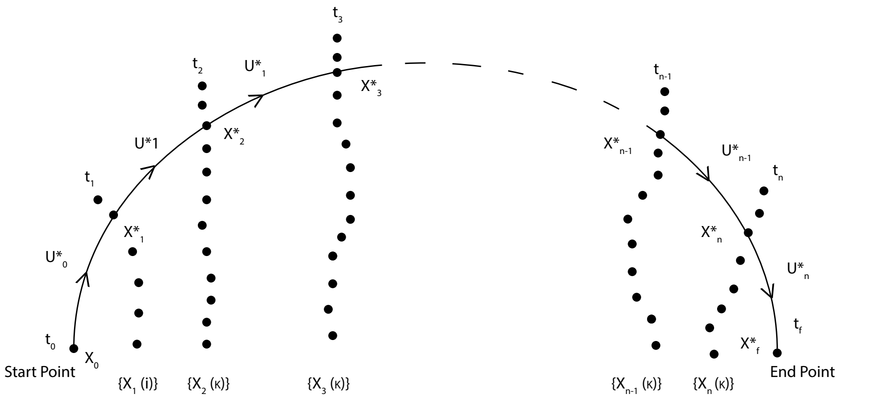


Figure 20: Modified from Hagiwara (1989) figure 2.4, showing the determination of minimum time cost fronts for routes by tracing points within the modeled isochrones.

Much like least-cost pathway analysis, the choices of joining time fronts in Hildenbrand's isochrone tool are governed by locally optimal decision-making strategies (Hildenbrand 2015). Here, 'locally optimal' refers to the tool making decisions about which direction to travel by comparing the cost of traveling in every direction from a central point and choosing the fastest heading (Bell and Lock 2000). All calculations in the model are made from one grid cell to the next (*e.g.,* Bell and Lock 2000; Conolly and Lake 2006; Wheatley and Gillings 2002), or one step between one isochrone ring (Hildenbrand 2015), or time front ring, and the next. As the routes are determined in time fronts, the evaluation of movement across the region is determined through the combination of many lengths of route. In this way, these models simulate how virtual routes mimic canoers re-evaluating their vessel's position and heading several times throughout a voyage.

In this model routes adjust position to take better advantage of changing currents (Hildenbrand 2015). Approaching sea voyages as steps also allows the model to more accurately update the underlying current and wind cost surface to reflect changing environmental factors. Updating environmental factors and taking voyages in segments is consistent with other sea-based route modeling methods (*e.g.*, Davies and Bickler 2015; Montenegro *et al.* 2016). Using time steps, pathways can reorient or change heading direction during a voyage to take advantage of optimal currents. In some ways, the possible human choices made by navigators to make use of better currents is reflected.

Though this method mimics real-world navigation techniques of re-evaluating direction, the resolution of time fronts may constrain the ability of routes to change heading independent of the isochrone steps. The area covered by isochrone steps inhibits voyages differently depending on the distance between the origin and termination points. This may be a larger issue for routes modeled between neighboring islands separated by small channels. However, the distances covered by many of the routes generated for this work minimize the smoothing of the cost surface to match isochrone steps. As some of these routes cover over 30 km, they provide many opportunities to have multiple isochrone steps. Furthermore, the distance between isochrone steps can be altered within the model, allowing for a finer resolution when necessary.

When determining what kind of model to use to calculate the true cost in movement between two points for this study, it was essential to choose a method that factored in the cost surface on which hypothetical canoes moved. Depending on their heading, canoes could travel various distances from the origin point to work with or against the underlying environment cost surface. The tool makes cost calculations based on friction surfaces derived from wind and current patterns. To counteract the current's direction and velocity to not be taken off course, crews sometimes had to move against the current in order to maintain course towards the termination point (Hildenbrand 2015; see Figures 21 and 22).

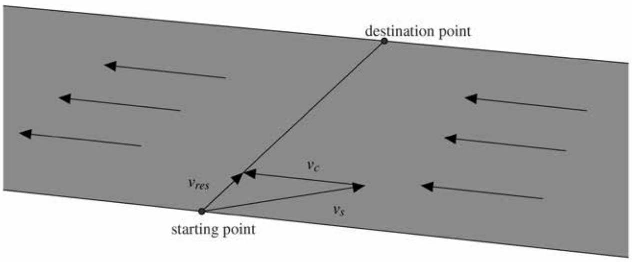


Figure 21: The direction of movement through current, where v_s is the direction of movement against the current, v_c, with the resulting direction of v_{res} (Hildenbrand 2015: Figure 2.1).

$$|\overrightarrow{v_{res}}| = \frac{\vec{c} \times \overrightarrow{p_1p_2}}{\overrightarrow{p_1p_2}} \pm \sqrt{|\overrightarrow{v}|^2 - |\overrightarrow{c}|^2 + \frac{(\vec{c} \times \overrightarrow{p_1p_2})^2}{|\overrightarrow{p_1p_2}|^2}}$$

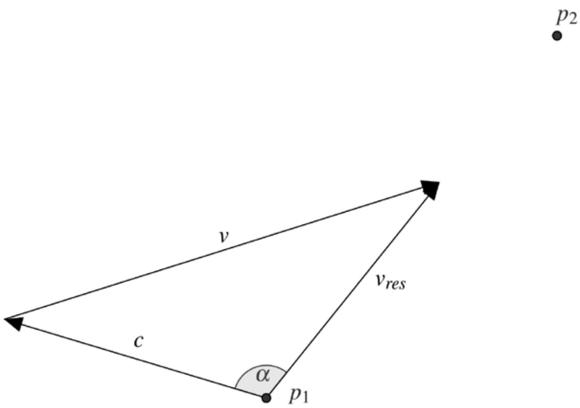


Figure 22: The equation used to determine the resulting velocity, where v= velocity of the canoe, C= current velocity, p1 = the start point and p2 = the end point (Hildenbrand 2015: Figure 2.2).

The resulting pathway can be considered the vector sum of the velocity and direction of the current and the velocity and direction of the canoe (Hildenbrand 2015; see Figure 22). For the tool's settings, it was assumed that the speed of the canoe is an equivalent influence or force value to the underlying environmental factors (Hildenbrand 2015). These routes confirm that Euclidean distance methods rarely capture the true restrictions met by travelers when crossing the distance between two points. Moving with or against currents can affect the distance achieved between isochrones in much the same way moving up and down a slope affects the difficulty of traveling over a raster-based cost surface (Bell and Lock 2000). To work with the current, canoers moving from site A to site B and then back from site B to A likely followed different routes. Including these factors enables the model to evaluate anisotropic movement between island sites.

Sectors, the area of the cost surface evaluated, are created for each time front to reduce the model's runtimes. These sectors are set so that from the central point time fronts are built in over a set degree from the node. The creation and positioning of sectors along isochrones is dynamic (Hagiwara 1989; Hildenbrand 2015; see Appendix A). The average distance between sectors is set as "greater than the iteration of ΔT times the speed," with ΔT being the time step (Hildenbrand 2015: 7). To create a default sector size d_p at the point farthest from the departure point d_{cmax} the angle separating every sector ω is calculated as (Hildenbrand 2015: 8):

$$\omega = 2 \times \arctan\left(\frac{d_p}{2 \times d_{c_{max}}}\right)$$

To increase the route tool's precision, smaller steps were created between each newly modeled isochrone point (Hildenbrand 2015). As each new route segment would be generated in the same sector consecutively they would then resemble straight lines. In addition to the modifications made to the isochrone method for this computer model, island placement needed to be evaluated. Sometimes there is an island located between the origin and termination points that could block the execution of a route. These islands needed to be clipped out of the underlying environmental surface to prevent modeled least-cost routes running through an island (*e.g.,* Altes 2011; Slayton 2013). The shape of smaller islands was difficult to clip and in some cases resulted in pathways running through the coastline of an island. However, the partial failure of the island clip did not influence the majority of the hypothetical routes retuned by the isochrone tool.

The need to clip islands creates an issue within traditional isochrone methods, as there were restrictions with modeling towards a termination point on the opposite side of an island being approached. Island placement is not addressed in Hagiwara's (1989: 32) isochrone method, which has a fixed number of rays constructed per isochrone. To respond to this issue, Hildenbrand's tool "takes the angle between the right neighbor, the current point on the isochrone and the left neighbor, and constructs rays with a global constant step size so that the maximum number of rays fit in between the two neighbors" (Hildenbrand 2015: 10). To construct these additional rays moving around coastlines the angle β between the right neighbor and the left neighbor of the central point is calculated, or angle $\beta = \angle P_{rm} P_c P_{ln}$, where P_{rn} is the right neighbor, P_{ln} is the left neighbor, and P_c is the central point (Hildenbrand 2015: 10). The number or rays np_c can be calculated from the global constant step and the quotient of (Hildenbrand 2015):

$$np_c = \left\lfloor \frac{\beta}{\gamma} \right\rfloor$$

The rays are constructed in a way that angle between and the last ray is equal to the angle and the first ray (Hildenbrand 2015; Figure 23):

$$\alpha_r = \alpha_l = \frac{\beta - \left\lfloor \frac{\beta}{\gamma} \right\rfloor \times \gamma}{2}$$

To calculate the angle β of the model offsets angles α_s and α_e for the end and beginning of the isochrone paths (Hildenbrand 2015). These steps help to generate isochrone routes that can hypothesize pathways doubling back on themselves to reach sites on the opposite side of an island. Removing the islands from the cost surface enabled these neighbor-aware ray-constructed isochrone routes to travel around instead of through islands. This process allows for routes to pass around islands in a realistic manner.

The model is also capable of distinguishing loops, or sections of the pathway that turn back on themselves within routes and eliminating them (Hildenbrand 2015). This allows for a more accurate display of possible route locations. It also removes incorrect time cost as it prevents the addition of an extended route segment to a time front.

For the tool to function the following parameters need to be set:

> “ • the start angle α_s, the direction in which the first rays are always constructed
> • the end angle α_e, the direction in which the last rays are constructed
> • the step size γ , the angle between two rays
> • the average point distance d_p, the sector size or the preferred distance between two points on the isochrone
> • the iteration time ΔT, the time, which is added between each iteration or each isochrone
> • the mini-iteration time $t_{\min}$, , the time for each mini-step in the computation of the new isochrone
> • the departure point p_0
> • the maximum number of iterations n , the algorithm must terminate somehow, one way is to limit the number of isochrones.
> • the constant speed v, the propelling velocity of the vessel.”
>
> (Hildenbrand 2015: 8-9).

Once these cost surfaces are combined and the parameters set, the model can begin to calculate pathways. Pathways are represented as a ‘line’ on a map of the Caribbean and a series of x and y coordinates (see Figures 26 and 27). Both outputs are tied to the positions on the isochrone time fronts connected with the optimal route. In cases where the whole route is not displayed on the provided map, the x and y coordinates are uploaded into ArcGIS 10.2 and turned into polylines using the point-to-line tool as a part of the conversion tool kit (ESRI 2013).

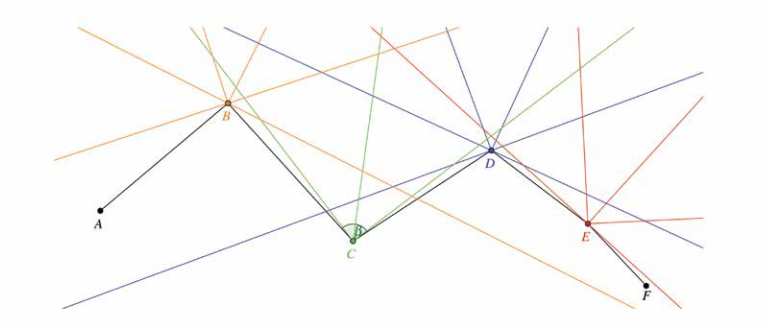


Figure 23: New neighbor ray construction with step size 45° (Hildenbrand 2015: Figure 2.6).

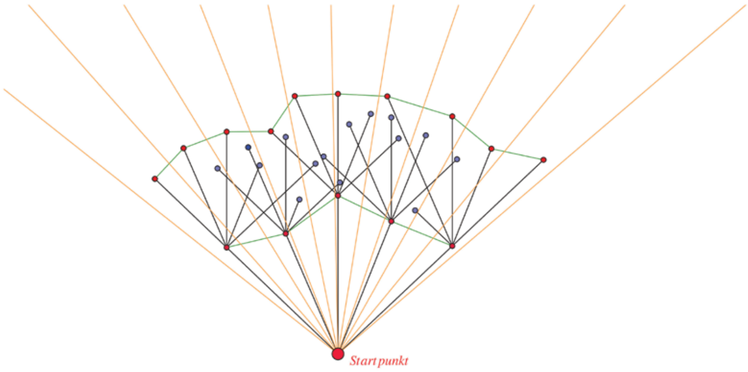


Figure 24: "Example for the modified isochrone method. The red points are on a (green) isochrone. The orange lines bind the sectors. The blue points are filtered out as they are not the farthest away from the departure point in their sector" (Hildenbrand 2015: Figure 2.3).

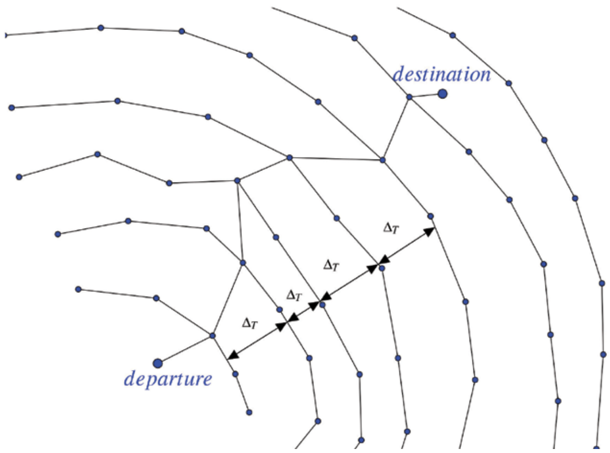


Figure 25: "The (modified) isochrone method, with the time fronts (=isochrones) seconds apart" (Hildenbrand 2015: Figure 1.1).

Figure 26: Example of line representing a hypothetical canoe route generated by the isochrone model route tool from Dominican Republic to Puerto Rico (0-1_2012-04-01T03_00).

-63.217	17.633	-65.748	18.069	2012-04-01T00:00	isochrone	160948.669	44.7079636
-63.153	18.175	-65.748	18.069	2012-04-01T00:00	isochrone	168225.045	46.7291792
-63.115	18.171	-65.748	18.069	2012-04-01T00:00	isochrone	170920.997	47.4780546
-63.06	18.105	-65.748	18.069	2012-04-01T00:00	isochrone	176158.659	48.9329608
-64.759	17.783	-65.748	18.069	2012-04-01T00:00	isochrone	66126.2064	18.3683907

Figure 27: Example of.CSV file depicting X and Y coordinates for the Origin point, X and Y coordinates for the termination point, the day and time the canoe was 'launched' by the model, isochrone, the time cost of the voyage in seconds, and the time cost of the voyage in hours.

The location and layout of these routes can then be compared to the time cost data returned by the tool. The time cost data is returned as a.CSV (comma separated value) file at the end of the tool's run. The final cost in time (in seconds and hours) is given alongside the origin and termination points as well as the time and date when the canoe was 'launched' (see Figure 27). Time costs returned for time steps can indicate what effect the time step parameter had on the model's output. Comparing start times and route costs can expand upon how launch times may have influenced canoe voyages.

Connecting routes to the archaeological record through the inclusion of site-based origin and termination points allows for the model to represent past mobility patterns that could possibly have been tied to the exchange of materials. Directed least-cost sea-based pathways can be used to evaluate reciprocated ties between Amerindian peoples in the Lesser Antilles from the Archaic Age to the Late Ceramic Age/early colonial period. Hildenbrand's recently developed isochrone tool, used here, stands as one effort to explore reciprocal there-and-back voyaging using computer models. Even if the resulting routes do not represent actual paths used by Amerindian seafarers, they are a close equivalent, representing a best guess of possible optimal routes. There is currently no way to confirm if these exact travel corridors were used. However, modeled routes can indicate where to look for interaction points between separate island communities, as shown in all three case studies discussed in the following chapters (see Chapters 5, 6, and 7). These interaction types include indications of areas where multiple communities may have interacted and/or canoe crews sought to rest.

5

Routes Between Neighboring Islands

Connecting Partners in the Long Island Lithic Exchange Network

This chapter encompasses the first case study, which deals with Archaic Age communities in the northern Lesser Antilles. Sites were selected based on their connection with materials known to be exchanged widely in the region, primarily Long Island flint (Davis 2000; Hofman *et al.* 2014; Keegan and Hofman 2017; Knippenberg 2007; Knippenberg and Zijlstra 2008; van Gijn 1993; Verpoorte 1993). These sites all date between 2000 BC and AD 100 (Hofman *et al.* 2007; Keegan and Hofman 2017). Least-cost pathways from a set list of Leeward Islands sites occupied in the Archaic Age were constructed and evaluated. Emphasis will be placed on the interconnection between the Leeward Islands as evidenced by lithic exchange visible in shared lithic material within site assemblages.

Archaic Age occupation of the northern Lesser Antilles, referring here to the group of islands from Anguilla to Antigua (see Figure 28), coincided with the accumulation of knowledge regarding sea conditions and currents (*sensu* Lewis 1994; Tingley 2016) and the probable existence of an inter-island wayfinding mental map (*sensu* Crouch 2008; McNiven 2008; Terrell and Welsch 1998). Routes were modelled on the assumption that this accumulated knowledge supported canoers moving between several sites. The underpinning of these routes was the maintained knowledge of seafaring patterns in the region, described earlier in this work (see Chapter 2). Knowledge of canoe travel corridors between these islands may have influenced social networks and types of interaction in later periods.

Choosing sites that were used across the Archaic Age allows for the discussion of a broader range of sites and a larger network, rather than looking only at sites that were continuously used. The routes between these sites can be hypothesized to reflect those that may have existed in the minds of seafarers during this period and in this region. These routes imply the extension of wayfinding traditions, or the communication of known sea routes between community members. Measuring the hypothetical cost of travel between these places and evaluating the cost of visiting some sites on the way to others can help to judge the feasibility of connections between sites and the layout of mobility networks in the Lesser Antilles. The isochrone

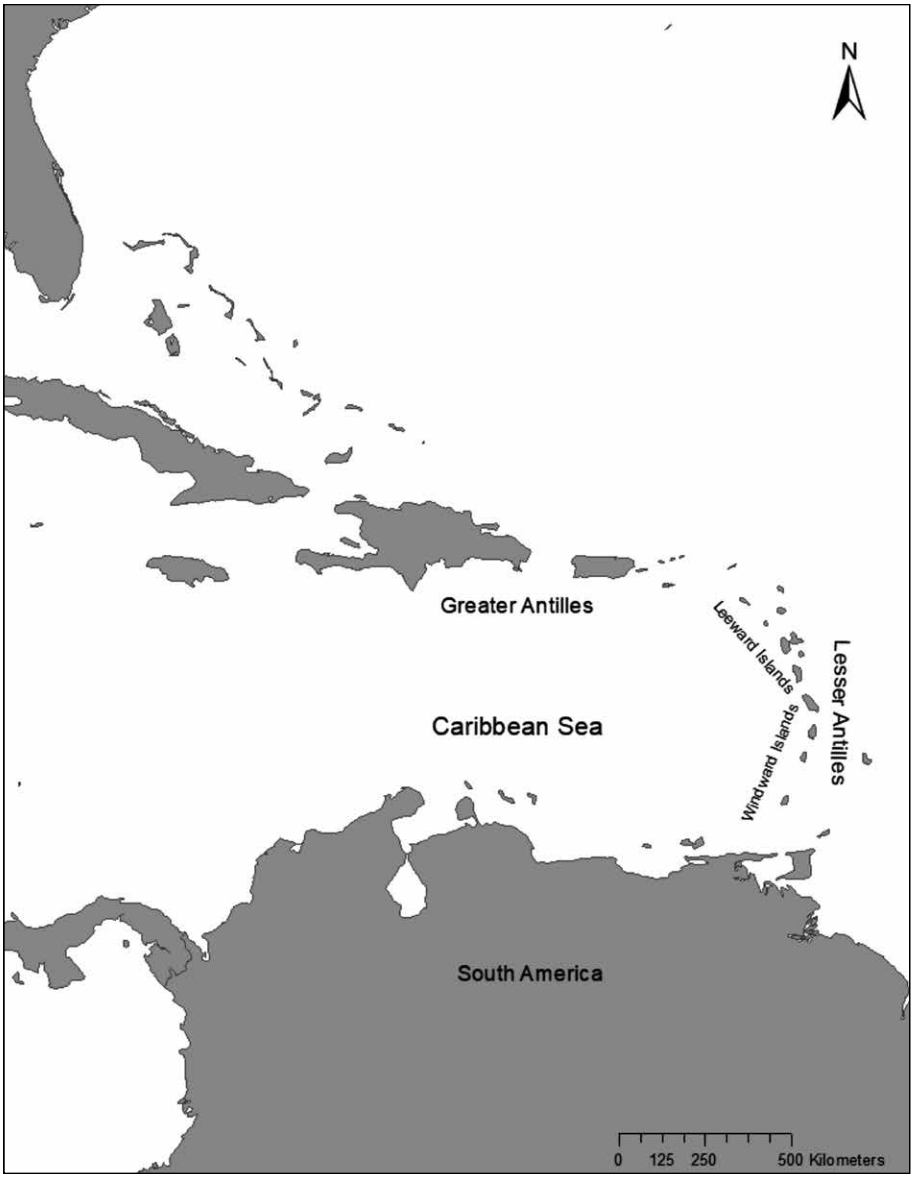


Figure 28: Map of the broader Insular Caribbean region.

model assumes a standard of seafaring existed that supported back and forth travel between the same groups of sites, facilitating the spread of island-associated peoples, materials, and ideas.

Much of the evidence for early connections between sites comes from lithic materials, particularly flint objects. The presence of flint at all the sites used for this case study suggests that there was a cultural tie between this material and Archaic Age Amerindians of the region (Hofman *et al.* 2014; Knippenberg 2007). The spread of Long Island flint is a fitting base for modeling least-cost isochrone pathways to analyse inter-island interconnection.

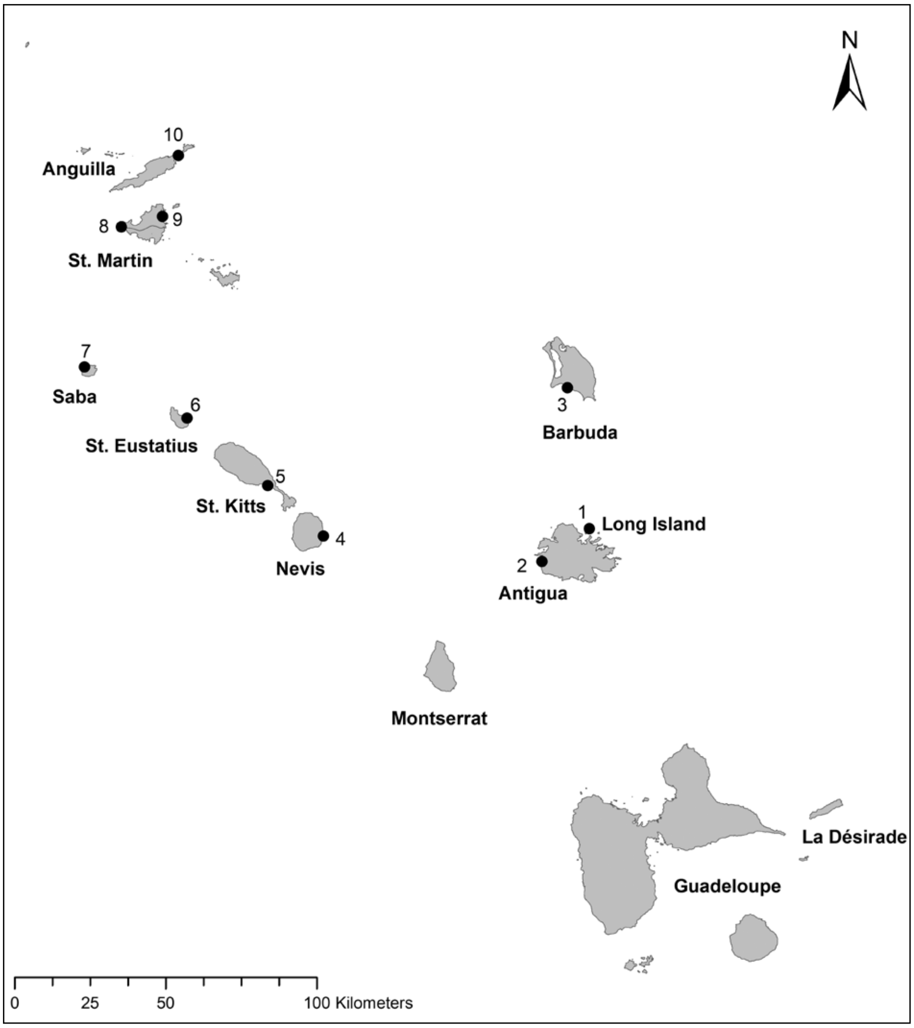


Figure 29: Map of the case study area (Leeward Islands) with the islands labeled. Sites numbered (from southeast to northwest), 1: Flinty Bay on Long Island, 2: Jolly Beach on Antigua, 3: River Site on Barbuda, 4: Hitchman's Shell Heap on Nevis, 5: Sugar Factory Pier on St. Kitts, 6: Corre Corre Bay on St. Eustatius, 7: Plum Piece on Saba, 8: Baie Orientale on St. Martin, 9: Norman Estate on St. Martin, and 10: White Head's Bluff on Anguilla.

It is important to note how infrequently flint is naturally found in the Leeward Islands (van Gijn 1993). As there are already multiple explanations for the formation of the Lesser Antillean island arc within the archaeological literature (Davis 2000; Hofman and Hoogland 1999; Knippenberg 2007; Sealley 1992), the geological forces behind the creation of these flint sources will not be discussed here. There are no known flint sources on Martinique, Guadeloupe, Dominica, Barbuda, St. Martin, or Montserrat (Christman 1953; Knippenberg 1999, 2007; Pinchon 1952; van Gijn 1993; Watters 1980). Although small nodules can be found on St. Kitts and St. Eustatius, these nodules do not seem to have been widely used by Amerindian peoples (van Gijn 1993: 183).

As a result, Antigua and the adjacent Long Island are the prime examples of where flint sources can be found, collected, and used (Davis 2000; Knippenberg 2007).

As two of the few sources of raw flint, Antigua and Long Island became integral to the inter-island exchange network that formed around 2000 BC (Davis 2000; Hofman and Hoogland 2004; Hofman *et al.* 2014). The specific patterns of use of Long Island flint hint at it being a prized resource produced specifically for export (Davis 2000; Knippenberg 2001; van Gijn 1996). Examples of these lithic materials are compelling evidence for connections between communities on Long Island and neighboring islands (Davis 2000; Hofman and Hoogland 2003; Knippenberg 2007; van Gijn 1993). The presence of Long Island flint at various sites hints at groups having direct access to the flint resource, or obtaining it through down-the-line exchange where an object may be procured through a third party (Knippenberg 2007; van Gijn 1993).

As such, Long Island plays a vital role in this case study as a destination of canoe travel corridors (de Mille 2001; Hofman and Hoogland 2003; Knippenberg 2007). Flinty Bay on Long Island was possibly used as a production and export site for flint to all other islands in the case study. Evidenced by the worked flint remains, much of the processing work to pre-form the flint into blades was done before transport during the Archaic Age (Davis 2000; Knippenberg 2007). The desire of Amerindian knappers to pre-work nodules before transport could be due to the distance between the sites and the source of the flint (Bérard 2013; Hofman and Hoogland 2003; Knippenberg 1995). Crews likely also wanted to keep cargo weight at manageable levels, which could be achieved by working flint prior to transport (Bérard 2013; Hofman and Hoogland 2003; Knippenberg 1995). No consistent analytical archaeological method can be used to classify or tie any cultural sequence to the flakes and ground stones found within Archaic Age sites (Davis 2000; Knippenberg 2001, 2007). However, the regularity in the stages of production found at different sites, as well as the artifacts' common origin, link Long Island-sourced lithic assemblages. Even though flint has also been found in Puerto Rico (Hofman *et al.* 2014), direct connections between the Greater and the Lesser Antilles is not discussed in this chapter. Instead, this case study seeks to evaluate connections between islands in direct range of Long Island. These will be evaluated for possible ties to the micro-regional flint exchange of the northern Lesser Antilles.

5.1 Some Islands and Sites

A typological comparison of Archaic Age sites from around the northern Lesser Antilles demonstrated several similarities between site types, use, and assemblage (Davis 2000; de Mille 2001; Hofman and Hoogland 2003, 2006). To evaluate how the modeling of least-cost routes can determine seasonal variance in the possible canoeing networks of a small island cluster, I chose to focus solely on the northern Leeward Islands. Though not discussed in this chapter, parallels can be seen in sites reaching from the Virgin Islands, specifically Krum Bay on St. Thomas to Pointe de Pies on Guadeloupe (Hofman and Hoogland 2003; Lundberg 1989). It is possible that seasonal rhythm of mobility also influenced connections to Guadeloupe, as suggested by least-cost routes modeled for this work, as well as the Virgin Islands. In the future, additional routes to Archaic Age sites to the west and south of the northern Leeward Islands can be modeled to build on the evaluation of mobility networks in this period.

Site	Date	Sample Type	Reference
Flinty Bay	Pre-ceramic (no radiocarbon dates)		Davis 1974; Knippenberg and Zijlstra 2008; Nicholson 1976; Rouse 1999; van Gijn 1993; Verpoorte 1993
Jolly Beach	4225 to 4095 BP	Charcoal	Davis 1982, 2000; Hofman *et al.* 2007; Nodine 1990; Olsen 1976
Plum Piece	3825 to 3470 BP	Land Crab	Hofman and Hoogland 2003; Hofman *et al.* 2006
Norman Estate	4380 to 3960 BP	Shell	Hofman *et al.* 2007; Knippenberg 1999; Nokkert *et al.* 1995
Etang Rouge	4950 to 2750 BP (1495 to 1400 BP)	Shell	Bonnissent 2003; Hofman *et al.* 2006
Baie Orientale	2750 to 1850 BP	Shell	Haviser 1999; Knippenberg 1999, 2004
White Heads Bluff	3365 to 3255 BP	Shell	Crock *et al.* 1995; Hofman *et al.* 2007
Corre Corre Bay	2360 to 2158 BP	Shell	Keegan and Hofman 2017; Versteeg 2000; Versteeg *et al.* 1993
Sugar Factory Pier	4100 and 2175 BP	Shell	Armstrong 1978; Goodwin 1978; Keegan and Hofman 2017
River Site	3875 to 3515 BP	Shell	Hofman *et al.* 2007; Watters *et al.* 1992

Table 2: Table showing date ranges for sites used as nodes in this case study.

Archaeological remains of resources found at these sites indicate a reliance on seasonal activities. These seasonal resources can include marine substance or land-based foodstuffs and materials (Hofman and Hoogland 2003; Keegan and Hofman 2017). The Archaic Age peoples from the northern Lesser Antillean region are assumed to have been non-sedentary foragers (Hofman *et al.* 2006; Keegan 1994; Keegan and Hofman 2017). Sites on these islands likely functioned as a part of a larger seasonal network of complementary settlements or camps (Hofman *et al.* 2006, 2014; Knippenberg 2007). Seasonal rhythms that may have enabled Amerindian peoples to visit multiple islands and establish temporary camps to make use of materials were dictated by both weather patterns and the availability of specific resources (Hofman *et al.* 2006). As indicated by their focus on marine substance and placement near the coast, Archaic Age sites in the Lesser Antilles served seasonal functions.

The sites discussed below span almost the entirety of the Archaic Age period. The following list of islands and sites will be considered in this work, though some as a by-product of route trajectory and not as origin and termination points. Flinty Bay on Long Island, Jolly Beach on Antigua, Plum Piece on Saba, Norman Estate on St. Martin, and Whitehead's Bluff on Anguilla date between 3200 to 2000 BC (Haviser 1991; Hofman *et al.* 2007; Hofman and Hoogland 1999, 2006; Knippenberg 1999, 2001, 2004, 2007; Ramos 2011; see Table 2). Later sites, ranging from 2000 to 800 BC, such as Corre Corre Bay on St. Eustatius, Sugar Factory Pier on St. Kitts, and River Site on Barbuda, represent an influx of peoples into the region (de Jong 1947; Hofman *et al.* 2007, 2014; Versteeg *et al.* 1993; Walker 1980; Watters 1980; see Table 2). Examples such as Baie Orientale on St. Martin (800 BC – AD 100), meanwhile, show an increase in specialisation of tool workshops alongside a decrease in Archaic Age sites around the northern Lesser Antilles (Bonnissent 2008; Bonnissent *et al.* 2016; Haviser 1999; Knippenberg 1999, 2004). Sites like Trants on Montserrat also appear, marking the introduction of Early Ceramic Age communities in the region (Hofman *et al.* 2014; Watters 1980).

These sites may not have all been in use at the same time. Still, it is possible that a mental map (*sensu* Agouridis 1997; Ingold 2009; Lewis 1994; Tilley 1994), which allowed canoers to move between sites seasonally, helped them to return to islands decade after decade. Routes with similar trajectories formed canoe corridors of movement and allow for research to analyze the consistency of connections between islands in the Lesser Antilles Sites from these islands will be briefly discussed to highlight the commonality between the sites and islands used for this case study. A comparison of the sites will demonstrate how modeling routes between Archaic Age sites in the northern Lesser Antilles is beneficial to the study of the mobility of peoples, materials, and ideas.

5.1.1 Antigua and Long Island

Contact with the island of Antigua was likely driven by the regional need for flint. Flint nodules protrude from the limestone in the northeastern areas of the island, which is similar to the environment enjoyed by the Long Island flint sourcing sites like Flinty Bay (Davis 2000: 93). These islands possess the only known places within the Lesser Antillean arc where during the islands' formation "old sea-bottoms" rose to the surface providing access to this quantity of workable flint (van Gijn 1993: 186). Most of Antigua's sites are centered along the northeastern coast (Davis 2000; Knippenberg 1995, 2006; Stokes 1991) and would have had relatively easy access to Long Island. The northeastern coast of Antigua provides a clearer geographic and visual link and a sense of proximity control over the smaller island (Davis 2000). These visual ties could have driven connection between communities on Long Island and Antigua. It may also have encouraged people from Antigua to interact with canoers they could see landing on Long Island for flint.

Communities from many of the surrounding islands were probably in direct contact with Antigua and Long Island, suggesting that these islands would have a high number of sites. Archaic Age sites on Antigua are typically comprised of shell middens (Rouse 1992; van Gijn 1993). These sites and shell middens are consistently placed in areas where the offshore water is shallow as it transitions into the sea (Davis 1982). This placement would have made it easier to moor canoes safely. The position of sites near the coast likely resulted from the preference of Antiguan Archaic Age peoples for water access for transportation purposes (Davis 2000). The placement of nodes for this case study can be linked to this preference for sea access.

Long Island itself was heavily used as a primary source for flint. Long Island's archaeological flint deposits are so dense that determining where a cultural scatter begins and ends can be difficult (van Gijn 1993: 188). To further obscure the image, agriculture and land use disturbance likely altered the position of flint nodules since the historic period (Knippenberg 2001). The abundant presence of flint on Long Island in some ways negates the disruption of the surface finds by modern peoples. At the site of Flinty Bay, for example, Davis (2000:13) found thousands of examples of worked flint. These pieces were crafted from nodules that eroded from limestone outcroppings near the water (Davis 2000). The number of worked pieces combined with the abundant availability of the raw product indicates that the activity at Flinty Bay centered on the "collection and primary production" of flint (van Gijn 1993: 193). Additional emphasis was put on turning out high quality cores from the collected nodules. The presence of primary and secondary blades and the near absence of any retouched tools or blade cores in Long Island assemblages suggests that blade cores were "pre-worked" on the island before export (Knippenberg 1999, 2001: 91).

Another example of an Archaic Age flint-focused site is Jolly Beach on the western coast of Antigua. Davis (2000: 26) found that more than 99% of the assemblage at this site was made up of flaked stone, most of which was flint. The resulting flakes and tools are like those found within sites on Long Island and suggest that these two areas shared the same toolkit (Davis 2000: 45). Van Gijn (1993: 194) argues that sites like this on Antigua likely served as the dwelling places for those who sourced and processed flint on Long Island.

These peoples from Antigua worked the flint before taking it off Long Island. Often peoples preferred to take perfect lithic cores from Long Island sites (Knippenberg 2001). This made the flint 'lighter' for travel to nearby habitation areas where the flint cores could be worked further (Knippenberg 2007; van Gijn 1993). Minimizing weight was essential for efficient long-distance transport of flint between Archaic Age settlements (Knippenberg 2001). The need to transport people and subsistence items alongside flint could have further compounded this concern. However, not all nodules were fully processed by the Amerindian knappers before leaving the island. Evidence for flint knapping has been found on other islands in the northern Lesser Antilles (Hofman *et al.* 2006; Knippenberg 2007). It could be that pre-worked blades provided necessary ballast for the canoe. This would have made it easier to keep the canoe level in the water and prevent the boats from capsizing during the transportation of flint (Bérard 2013).

5.1.2 Anguilla

Whitehead's Bluff on Anguilla dates to around the same period as the sites of Jolly Beach on Antigua, although it has a slightly later date (around 1000 BC) (Crock *et al.* 1995; Keegan and Hofman 2017; Knippenberg 1999). Like the other sites, Whitehead's Bluff shows a marine orientation and examples of Long Island flint that arrived on the island pre-worked, as is the case with other sites dating to this period (Crock *et al.* 1995; Hofman and Hoogland 2003).

The examples of flint found at Whitehead's Bluff differ from Jolly Beach as "only one blade and some cores with traces of blade production were found" amidst a significant number of flakes and flake cores (Crock *et al.* 1995; Knippenberg 1999: 43). This is due to the distance between the two islands, or the distance between the assemblage and the source. The exotic nature of this material could account for the thorough use of these flakes (Crock *et al.* 1995; Knippenberg 1999). Amerindian peoples had to make more frugal and full use of the limited resource once it reached Anguilla (Hofman and Hoogland 2003; Knippenberg 1995). This effort to make optimal use of Long Island flint is also seen in the treatment of blades imported to the other sites in the area, for example Norman Estate (Knippenberg 2007). The commonality in blade transport, manufacture, and use highlights the shared practices involved in the export and import of Long Island flint.

Much like other settlements in the region, Whitehead's Bluff was probably a seasonal encampment (Crock and Petersen 1999; Hofman and Hoogland 2003). The site's location and comparatively small size suggest its placement was centered on access to marine resources (Hofman and Hoogland 2006: 148). It is also possible that this site was used as a connection point between movement to and from St. Martin. Testing the location of hypothetical least-cost paths may show how movement through Anguilla was connected to other sites.

5.1.3 St. Martin

Flint types found on St. Martin are both Long Island flint specimens and a second likely non-local flint (Knippenberg 1999). Secondary working is infrequently observed on flint pieces found at Archaic Age sites (Knippenberg 1999: 44). However, some flint pieces in assemblages show signs of re-chipping and shaping, representing both an increase in the initial effort in constructing the tool and in its durability (Knippenberg 2007). This re-working of flint pieces is consistent with how Long Island blades were prepared for transport. The further reduction done on-site could confirm the transportation of partially processed lithic tools from Long Island (Knippenberg 2007). As mentioned earlier, this points to these materials being part of the ballast for canoe voyages heading north or west.

The sites of Etang Rouge, Norman Estate, Pont de Sandy Ground, Baie Nettle, Trou David, Lot 73, Salines d'Orient, Belle Créole, Pointe du Bluff, Baie Longue 2, Hope Hill, and Baie Orientale on St. Martin are contemporary with Jolly Beach (Bonnissent 2013a, 2013b; Bonnissent *et al.* 2016: Figure 3; Davis 1982; Keegan and Hofman 2017). I have chosen to focus on Etang Rouge and Norman Estate to limit the tested connections to St. Martin, as settlements on this island's coastline were often clustered on the northwest or east side of the island and their assemblages establish ties between St. Martin and Long Island. Movement between these two areas and other islands within this case study can suggest routes headed from and to nodes placed at on either side of the island. Although it is not the earliest example of Archaic Age occupation, Norman Estate, where flint was also further worked (Bonnissent 2011; Knippenberg 1999: 38-40), was one of the first sites dating to this period discovered on the island (Hofman and Hoogland 1999; Keegan and Hofman 2017). Etang Rouge is one of the earliest sites known in St. Martin (Bonnissent 2008). It was occupied from 3000 to 800 BC (Bonnissent 2003, 2013; Keegan and Hofman 2017). Like the nearby site of Plum Piece on Saba, the assemblages contain an abundance of non-local flint types. The absence of unworked nodules at Etang Rouge is consistent with flint remains from Saba (Bonnissent 2013).

5.1.4 Saba

The site of Plum Piece on Saba also contains pieces of Long Island flint, most of which were "un-retouched whole flakes" (Hofman and Hoogland 2003: 18). However, blade production at Plum Piece may have been limited (Hofman and Hoogland 2003). This ties into the hypothesis that partially pre-formed blades were exported from sites like Flinty Bay to those like Jolly Beach before being distributed throughout the region. The inhabitants of Plum Piece either procured the material and transported it to Saba or were the recipients of these modified pieces. The absence of nodules at this site suggests they were received from other places within the network as well (Hofman and Hoogland 2003). This indicates that like Flinty Bay and Jolly Beach, Plum Piece was a node within the larger lithic exchange network (Hofman and Hoogland 2003; Knippenberg 2007). The amount of imported and worked Long Island flint present at the site is a strong argument for its inclusion within the Archaic Age lithic network.

The archaeological assemblage of Plum Piece also provides information on community life besides the movement of flint. Seasonal divisions of life at Plum Piece can help to explain the purpose of the site located away from Long Island but still under its influence. The collection of specific types of marine and terrestrial resources provides one argument for seasonal habitation of these islands (Hofman and Hoogland 2003). The seasonal diet for Amerindians at Plum Piece consisted partially of conch, including *Lobatus gigas* or queen conch. People likely extracted and processed the meat from these mollusks on the beach, perhaps near canoe landing sites (Hofman and Hoogland 2003). The site's focus on crab and bird populations also suggests a seasonal component to the occupation of the island. The most common type of bird remains found at Plum Piece are classified as Audubon's Shearwater (*Puffinus lherminieri iherminierii*) (Hofman and Hoogland 2003). These birds commonly roost on the island between February and July (Hofman and Hoogland 2003: 17; Hofman *et al.* 2006).

The Audubon's Shearwater's roosting period could indicate which months to closely study when comparing seasonal routes to and from Saba. Routes that followed the flight paths of birds could indicate that people were interested in subsistence collection. Routes that also pass by other islands indicate routes where people may have wanted to connect with seasonal resources or peoples on neighboring islands. A comparison of different travel routes and rhythms in February to July and other parts of the year can indicate what routes were used for convenience, for external social reasons, or for the collection of subsistence resources.

Audubon's Shearwater could also have been used as a part of navigation practices or a mental map. Audubon's Shearwater fish by diving from the air towards their prey (Nellis 2001). Amerindian seafarers could have followed the flight and fishing patterns of these birds out to sea to seek out fish (*e.g.*, Lewis 1994). Evaluating whether canoe routes pass near or over areas with higher densities of fish schools could indicate a connection between gathering marine resources and travel. This includes routes through areas like the Saba Bank, which may have been a resource collection area connected to the site of Plum Piece (Hofman and Hoogland 2003). However, this technique may have been minimally used with other species due to some birds' preference for night fishing (Nellis 2001).

The stratigraphy of the site with seasonal materials accumulated during different stages of deposition within larger refuse middens and caches of conch adzes suggests that Plum Piece may have been used, abandoned, and reoccupied several times during the its lifespan (Hofman and Hoogland 2006: 154). This continual occupation and abandonment of a site indicates that peoples inhabiting it knew both the site's location and enough navigation to maneuver to it multiple times. These seasonal occupations show that Archaic Age Amerindian peoples were competent canoers with transferable knowledge of seafaring practices and technology. Amerindian canoers might also have had a shared mental map with the locations of sites like Plum Piece on Saba and Flinty Bay on Long Island (*sensu* Agouridis 1997; Crouch 2008; Lewis 1994; McNiven 2008; Terrell and Welsch 1998), which would have allowed these seafarers to travel between sites on different islands during the optimal season.

Plum Piece may have served more than one role within the Archaic Age Amerindian canoeing community due to its position inland. It is located high in the hills on Saba (Hofman and Hoogland 2003). Amerindians who camped there had access to wood that could be used to build vessels and likely used this seasonal campsite as a base for canoe construction (Hofman and Hoogland 2003). Further research is needed to evaluate if the February to July seasonal period coincides with the time of year when trees were cut down and made into canoes.

5.1.5 St. Eustatius

The site of Corre Corre Bay on St. Eustatius ascribes to the pattern of other Archaic Age sites in the region. Hofman and Hoogland (2006) determined that Corre Corre Bay on St. Eustatius was contemporaneous with other Archaic Age sites in the region due to the similarity of the assemblage. Radiocarbon dates for Corre Corre Bay indicate it was in use around 900 BC (see also Versteeg *et al.* 1993). The location of the site suggests it is a good candidate for comparisons with other northern Lesser Antillean Archaic Age sites. Corre Corre Bay is positioned on the southeastern coastal area of the island (Haviser 1985). It is more difficult for canoers to land near the site, as it is located on the part of the island that receives heavy winds and waves. However, it is positioned to take advantage of canoe travel corridors. This offers an opportunity to relate site position to the routes between two other islands, tying site placement to inter-island travel.

There was a prevalence of marine remains in the site's assemblage. Much of the marine focus of this site was on conch and *Cittarium pica* (West Indian top-shell) (Morsink *et al.* 2013). The presence of these marine materials suggests Amerindian peoples on St. Eustatius were more interested in coastal resources. This focus was possibly tied to the method of accessing sites in Corre Corre Bay, where canoes moved into the bay on calmer days for short-term visits (Morsink *et al.* 2013).

Long Island flint was also found in the area around Corre Corre Bay (Haviser 1985). These flint objects may have been used to cut mollusks from their shells, linking the lithic presence to the marine focus of the site (Morsink *et al.* 2013). The presence of flint demonstrates the connection between St. Eustatius and the inter-regional network of exchange tying the islands of the northern Lesser Antilles together.

5.1.6 St. Kitts

Two Archaic Age shell middens make up the site of Sugar Factory Pier on the island of St. Kitts (Armstrong 1979; Goodwin 1978) and indicate that the site was used between 2100 and 200 BC (Goodwin 1978). The long-term use of both middens supports the existence of a strong link within a community shared, or individually referenced, mental map used by Amerindian navigators, a map that could lead them to return to 'known' areas over long time spans (*sensu* Schlanger 1992; Terrell and Welsch 1998; Terrell *et al.* 1997; Tilley 1994). Both middens are predominantly comprised of marine shells. However, the shells were mostly the remains of clams instead of conch that is found at most other sites dating to the Archaic Age (Goodwin 1978). Though this site may have looked more towards coastal resources, as no pelagic fish bones were found in either deposit, the site's marine focus is still consistent with the other sites used for this case study (Goodwin 1978; Versteeg *et al.* 1993).

There is no strong evidence of a lithic tradition visible at Sugar Factory Pier (Goodwin 1978). The presence of one large chert blade found in the older midden is the best support for including this site in a broader inter-island network, especially as there are no chert outcrops on the island (Goodwin 1978: 7). The chert's presence indicates importation from another island (Walker 1980), perhaps as a part of the chain of seasonal movement that connected Antigua to Saba. Though there is not enough evidence at the site to determine if Sugar Factory Pier was a seasonal encampment or whether it was only used for a short period, it is worthwhile to include its presence within the model to evaluate its potential as a stopover point on routes between other islands. The placement of Sugar Factory Pier should be checked against routes to and from other islands to confirm its possible inclusion in a navigator's wayfinding map.

5.1.7 Nevis

The assemblage at Hitchman's Shell Heap on Nevis has a marine focus, with coastal scatters consisting of fish bones and mollusk shell remains, including conch (Wilson 1991). Fish bones found at the site came from reef fish, such as grouper and parrotfish, and pelagic fish, such as barracuda. As is the case with other Amerindian Archaic Age sites in the region, the presence of deep-sea fish links this site with canoe use. Like the diets of communities inhabiting Plum Piece on Saba, land crabs were also part of the subsistence pattern of Amerindians living at Hitchman's Shell Heap (Versteeg *et al.* 1993; Wilson 1991). Lithic tools were recovered from the site (Wilson 1991), indicating people at Hitchman's Shell Heap also engaged in the movement or exchange of stone tools. These factors indicate that the site of Hitchman's Shell Heap merits inclusion in this case study.

5.1.8 Barbuda

Barbuda's River Site is located on the south coast of the island. It faces both Antigua and Long Island, both of which are located roughly 60 km south across the channel. River Site lies adjacent to the coast and follows the marine influence present at other Archaic Age sites in the region (Nicholson 1994; Watters *et al.* 1992). The site is also physically close to other Archaic Age sites on the island, most of which are near the large shell midden called the Strombus Line (Rousseau *et al.* 2017). This geographic placement mirrors that of the other sites mentioned above in its location near the coast and its potential for connections to canoe travel corridors or its possible position in communal or individual mental wayfinding maps.

Like Plum Piece (Hofman and Hoogland 2003), remains of shell tools made from *Lobatus gigas* were found within the River Site (Watters *et al.* 1992). Piles of *Strombus gigas* were recovered near the site along the coast (Watters *et al.* 1992). Like the site of Corre Corre Bay, evidence of *Cittarium pica* was also found within the site. Two shell celts, or Archaic Age tools, from the site were dated to between 1700 and 1875 BC (Watters *et al.* 1992). Unlike earlier assumptions that the River Site was merely a mollusk collection point for Ceramic Age communities (Watters 1980), this suggests that the site falls within the Archaic Age (Watters *et al.* 1992). The lack of ceramic material at the site also indicates the site belongs to the Archaic Age. This allows it to be used as an origin and termination point for routes modelled here.

5.1.9 Montserrat

There is one proposed Archaic Age site on the island of Montserrat. Lithic materials at the Upper Blake site are consistent with those found at other sites discussed in this case study (Cherry *et al.* 2012). Though no dates have been returned for this site, archaeologists were able to place the characteristics of the lithic materials to ca. 4000 and 2500 BP (Cherry *et al.* 2012). The site on Upper Blake is located away from the coast at an altitude of about 1000 feet (Cherry *et al.* 2012). This makes Upper Blake's placement similar to that of Plum Piece on Saba, which is at an altitude of about 1300 feet (Hofman and Hoogland 2003).

Though not an Archaic Age site, it is important to briefly mention Trants, as many pathways modeled for this work pass by the island. Trants sprung up in the transition between the Archaic Age and the Ceramic Age (Cherry *et al.* 2012; Hofman *et al.* 2014). It served as a production site for microlapidary objects (Crock and Bartone 1998; Watters 1997). Amerindians from Antigua and Montserrat may have maintained either direct or indirect relationships into this period, as indicated by the Antiguan-sourced carnelian artifacts found within Trants assemblages (Hofman *et al.* 2007; Murphy *et al.* 2000). The strong bonds between this island and others from this region suggest that there may be more to explore in terms of mobility and exchange in the southwest portion of the case study region (Slayton *et al.* 2014). Though not included as an origin point, the relation of these sites to the pathways modelled between nodes used for this work could indicate a connection between route and site placement.

5.2 Modeling Interpretations

The sites discussed above were used as origin points for least-cost pathway modeling. Tying origin points to sites with Long Island flint linked the computer-modeled routes to reality. Islands will be evaluated both on an individual and interconnected basis. The specific nodes will be connected and the direction of travel discussed.

The potential length of voyages in the northern Lesser Antilles can be compared against those hypothesized for early colonization paths across the Caribbean Sea, for example those proposed by Callaghan (2001), Altes (2012), or Rouse (1992). The layout of the Lesser Antilles meant canoers did not have to travel as far as those colonization routes and offered shorter trips depending on the season. In comparison to colonization routes that could last over five days (Callaghan 2001), maximum travel times in the northern Lesser Antilles of one and a half days seems like an easily feasible goal. As these communities were making trips between neighboring islands regularly, canoers would be aware of the risks and rewards of longer journeys. These shorter routes relate to the canoers' possible preference for optimal pathways, if indeed crews followed similar travel corridors. These pathways might represent possible recurring avenues of movement learned over several trips, like remembering how certain currents affected moving through an area. Canoers or navigators remembering currents or travel corridors is consistent with Ingold's (2011) suppositions about the development of mental maps based on both on an individual's past trips.

The availability of resources is another way to gauge the optimal season for departure. An example of how the change in seasonal resources might affect the launch times of canoes is the access to flocks of birds. As mentioned above, birds can serve as food directly, or as an indicator for the location of fish schools (Lewis 1994). Birds, like humans, have preferred daily rhythms and season-specific activities (Cowx 2008). The presence or absence of birds perhaps motivated canoers to head out during different seasons (Lewis 1994). For example, the presence of the Audubon's shearwater on Saba during the February to July season possibly influenced the travel of canoers (Hofman and Hoogland 2003). Different optimal departure times exist for optimal routes from Saba to Long Island in this period. Further evaluation of currents coinciding with migration patterns of several bird species out to sea over the Saba Bank or the west coast of Saba is necessary to confirm this hypothesis.

5.2.1 Route Costs

Testing the possibilities of movement between islands relies on an understanding of how difficult it would have been to connect with communities on neighboring islands. For this study, the difficulty of canoeing between sites is measured through the time it takes to complete a journey from origin point to termination point. To determine these costs, I use two methods. First, I determine how the underlying current might affect movement through the region. Second, I use the isochrone route tool (see Chapter 4), which models an optimal canoe route by calculating which direction of travel results in the lowest time cost over several time fronts. Comparing the cost to Amerindian seafarers of different routes can also hint at what routes returned by the model were more likely used. Together these runs help to evaluate of current strength and route cost can suggest seasonal canoeing periods.

5.2.1.1 Currents and Seasonality

Route modeling done for this work is meant to reflect real currents and hypothetical routes used by Amerindian navigators, possibly relating to the existence of a communal mental map. During the prospective phase of this study it became apparent that checking for differences in the current shifts prior to modeling was appropriate when discussing seasonality. Data on modern currents can point to seasonal trends that must be taken into account when modeling the isochrone routes. Evaluating current data before modeling allows for the months associated with sailing seasons to be given more attention. To look for these canoeing seasons I evaluated information on current prior to its inclusion in the model. Two methods were used to evaluate the difference in current force over the year. One focused on analyzing the currents themselves. The second compared the results of a single 'test route' over several months to check for seasonal fluctuations in time cost.

Three points were sampled for evaluation using the current tool (see Chapter 4). The northernmost point was placed near St. Martin and the southernmost point below Antigua (see Figures 30, 32, and 34). I selected areas in or near island channels and near areas of route-heavy activity. Channels typically have currents with higher associated forces moving through them, because in areas of sea with few islands there is nothing to slow currents down and cause drag (Bowditch 2002). I placed two points in an island channel to evaluate how routes might overcome areas of higher current intensity. I also wanted to check one area of higher concentration of travel. The space in the middle of the northern Lesser Antillean island cluster, as represented by the chosen Point 1, likely had many canoes passing through it annually. All points are located between several islands of comparative assemblages and sizable occupation during the Archaic Age.

Point 1 (17.30, -62.38) corresponds to a location in the middle portion of the northern Antillean island cluster (see Figure 30). Current at this point pushed to the northwest. The force direction shifted during the fall months, or September to October towards the northeast when calculating the average over 30 days. When calculating the average over 15 days, currents shifted towards the northeast from the latter part of September to the beginning of October (see Figure 31). There is also a period between September and May where the current pushes out to the southwest. However, these aberrations were short, and likely would not have prevented canoers from connecting with other islands during most of the year (see Figure 31).

Figure 30: Point 1 sampled by the current tool.

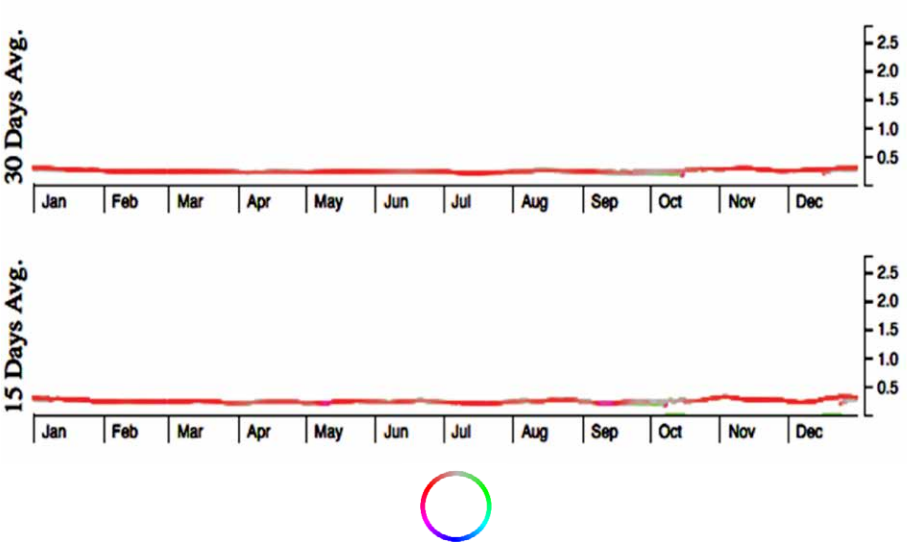


Figure 31: 15- and 30-day averages for current strength and direction between 2010 and 2016 for Point 1. The color wheel below indicates the standard direction, north, in grey. Deviations from this are depicted by the color tied to the direction on the wheel.

Seasonal interpretations may be limited when looking at the force behind the currents at Point 1. Though the direction is important, the overall force may be so similar throughout the year that these values do not reflect an overarching seasonal narrative that can be applied to voyaging. This is reflected in the averaged data graphs where current force remains within the band of 0 to 0.5 knots (see Figure 31).

Point 2 (16.7, -61.61) samples an area south of Antigua, north of Guadeloupe, and east of Montserrat (see Figure 32). This area was chosen because in early runs of the model some routes that should have gone directly north instead came south towards this area. The resulting current data for this point is more erratic than Point 1, probably because of its position in the center of an unprotected channel. There was a wider spread of force bearings in July and September 2013 to 2016 (see Figure 33).

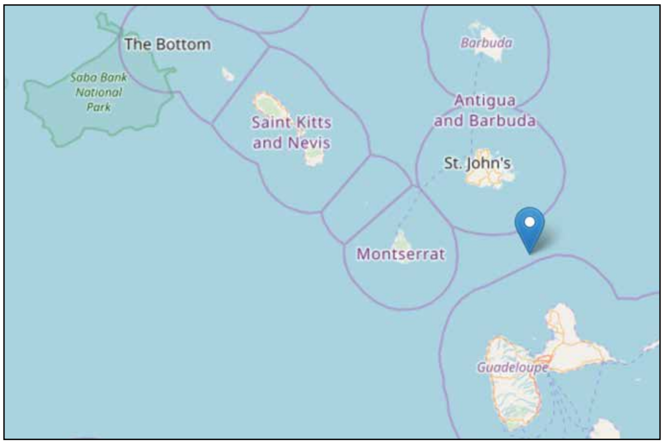


Figure 32: Point 2 sampled by the current tool.

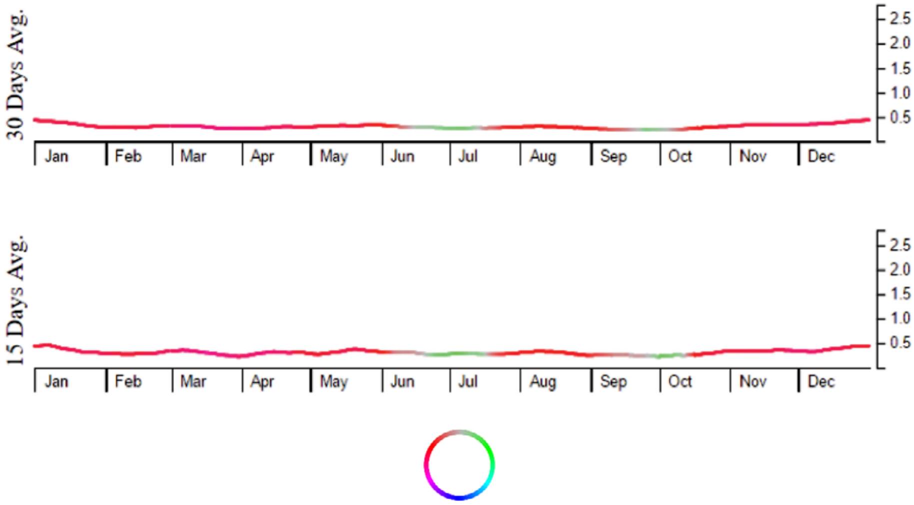


Figure 33: 15- and 30-day averages for current strength and direction between 2010 and 2016 for Point 2. The color wheel below the map indicates the standard direction, north, in grey. Deviations from this are depicted by the color tied to the direction on the wheel.

Together with the data from Point 1, this could indicate that September was a particularly difficult month for travel.

Point 3 (17.83, -63.16) lies at the northern end of the case study region. Located between St. Martin and Saba, I chose to place a point here to assess current movement through an additional channel in this region (see Figure 34). Data returned for Point 3 has a higher discrepancy in current averages between years than is apparent in the values returned for the other two points. The bands representing the current averages in Figure 35 show current force was more variable at this location. These bands also indicate that force values for Point 3 had a slightly higher average than currents at other points, especially in December (see Figure 35). However, these values are still low enough that any influence of seasonal values was limited.

Figure 34: Point 3 sampled by the current tool.

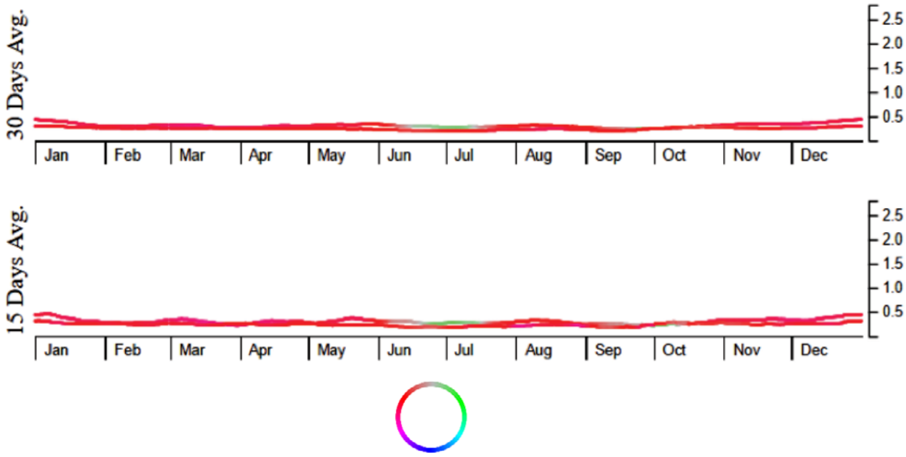


Figure 35: 15- and 30-day averages for current strength and direction between 2010 and 2016 for Point 3. The color wheel below the map indicates the standard direction, north, in grey. Deviations from this are depicted by the color tied to the direction on the wheel.

Direction values for travel periods at Point 3 also differ from the previous examples. June and July are the best months to travel to the northeast from this point. This suggests that people wanting to canoe southeast from this area should leave earlier in the year than those living further south. When one looks at the year's data without averaging, it appears that September was also a good period to travel east. The results from the tool suggest that when arriving at Point 3 it is best to find land quickly or the current may take the crew further out to sea.

The window of opportunity when the currents are moving east is small, in some cases only a month (see Figures 31 and 33). However, it would have allowed any real-world canoers that followed travel corridors close to these route trajectories to travel in different directions. The shift in current force from the northwest to the northeast during June and July could have allowed people to carry out voyages that were inadvisable at other times of year. Changes in current heading had larger implications for

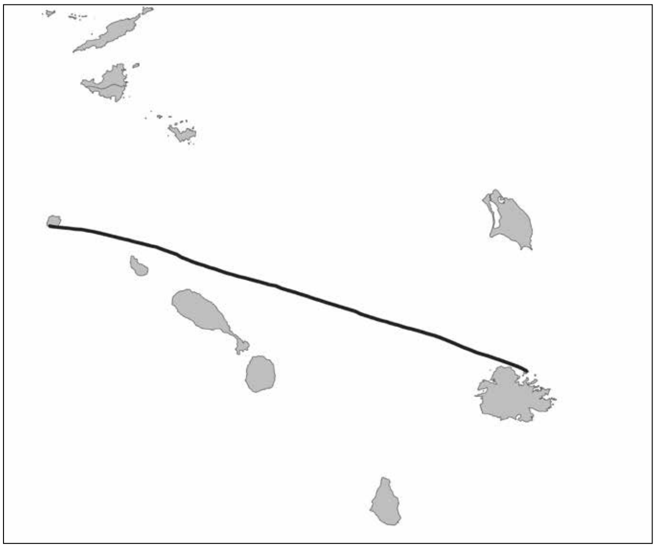


Figure 36: Pathway of the route (indicated in black) evaluating the current's effect on route placement using the least-cost isochrone tool developed for this model.

the direction of least-cost travel, or more specifically whether crews that might have followed along these travel corridors went directly to an island or undertook return voyages. These shifting canoeing periods called for seasonal visiting. For example, seafarers might have left from Saba in June to take advantage of the current pushing east. They could then return in August when the currents once again moved towards the west (see Figure 33). Staggering the direction of travel through the year to fit seasonal parameters may have pushed these communities to travel east in September and return in November (see Figure 31).

I wanted to ensure that the underlying current was reflected in the results of the model. If modeled routes closely related to the averages expressed by the current tool it could mean that years evaluated using the tool can stand in for longer periods of time and that the model reflects real world conditions. The route connecting Long Island to Saba was chosen to check against the results of the current tool to propose base seasonal values for this region (see Figure 36). I ran the isochrone tool for the route from the years 2010 to 2015 with runs beginning every three hours.

The time cost results from this group of runs showed no broad variance in the returned values for several runs of this pathway. The differences in the time costs amounted to an average of zero to five hours. These returns suggest that most trips were within the realm of human capability and of a similar difficulty level. No season stood out as the clear choice for canoe trips. This is reflected in the tables below, all of which demonstrate the resulting route costs return values within the same period.

A series of boxplots was generated to further evaluate how these routes varied over several years. All boxplots represent one month and the time costs of routes from each day within that period (see Appendix B). When looking at the boxplot graphs in sequence it is easy to see slight trends of current flowing between months within a year, though this is likely due to the range in time values observed throughout each day. When regarding the test route using the isochrone tool, there is no disruption in the current flow between modeled periods. This is consistent with the assumption that the model reflects real world values.

In the January boxplot, route time costs more closely correspond to one another than in graphs from other months (see Appendix B). Route time costs from February and March also keep to a time band of between 25 and 30 hours (see Appendix B). Returns for April have a similar spread but keep to between 25 and 33 hours (see Appendix B). As route time costs remain more consistent these months are more reliable for further analysis. Voyaging may also have been safer for crews in these months. Canoers that may have followed pathways similar to the ones suggested here and set off in these periods would have had a more reliable sense of the voyage's expected length. Conversely, time costs returned for August, September, and October were less consistent (see Appendix B). These months were less likely to be used for travel.

These boxplots demonstrate that many of the routes returned for the test run finished within five hours of one another across all seasons. As a result, no month is observably optimal for canoeing based on the similarity of time cost returns. It may be that longer routes were avoided by the Amerindian navigators. The difference of five hours does suggest that these journeys would have been less attractive to crews. Five hours is close to the time cost necessary to travel across an island channel. For example, it takes roughly six and one-half hours to canoe between Martinique and St Lucia (Bérard personal communication 2014).

Extreme differences in time costs were returned in some cases and routes that exceed a month's average time cost were not considered truly optimal possible routes and have been excluded from analysis of route costs. For example, there was an extreme return of over 36 hours for one route's time cost in July. This is over 10 hours longer than the mean time cost for the month before (see Appendix B). This route also exceeds the daily allotment of canoeing by an individual crewmember, in accordance with Callaghan's theory of route shifts lasting eight hours (Callaghan 2001). This canoe pathway likely coincided with an extreme weather event and can be seen as an outlier in the data and thus excluded from consideration. As mentioned previously (see Chapter 4), the isochrone tool cannot account for extreme weather events and instead returns an optimal route for whatever current data is inputted into it.

Testing the possibilities of movement through the northern Lesser Antilles with this trial run defined the appropriate factors to include for evaluation of canoe pathway route costs. Looking towards the seasonal fluctuation apparent in other routes may point to canoeing trends or optimal seafaring seasons. However, the currents are relatively stable. This is demonstrated both by the returns of the current tool and the test route run between Long Island and Saba. In the next section, I will explore if pathways modeled between other sites display similar seasonal averages, or lack thereof, for route costs.

5.2.1.2 Route time costs

One advantage to approaching connections in the Archaic Age northern Lesser Antilles with route modeling is the sheer number of canoe pathways returned. However, this can also lead to an overabundance of results. The large number of results makes it difficult to properly analyze the connections shown by these routes. As the model samples the sea current data set every three hours, there are eight cost values returned for every day of the month for each route. This number is then multiplied by every year where routes could be run. As there is also no one month that contains all the positive (or shortest) or all the negative (or longest) routes I have selected several times of year for targeted analysis.

5.2.1.3 Seasonal Averages

The best origin point to start analysis of seasonal periods is Long Island's Flinty Bay. As Long Island flint is the binder used to connect all the nodes within this study, it seems appropriate that it should be a part of a seasonal approach. However, as Long Island's Flinty Bay lies close to Antigua, some of the analysis provided here will deal with both.

Movement from Flinty Bay to other sites has a lower general associated cost than canoe routes from the site of Jolly Beach on the west coast of Antigua. Time costs in June and August are still within a three-hour margin of each other and these months represent an optimal canoeing period. Comparatively, the highest minimum value for a least-cost route comes in at 10 hours for a pathway in December. When travelling from Flinty Bay to Jolly Beach it is better to travel in January and April where the average time costs are between four and one-half and six hours. However, most routes have a cost of between four and one-half and nine hours. These low costs demonstrate the distance between Jolly Beach and Flinty Bay may have been relatively easy for those crews that moved along the same corridors as the routes model here. The ease of movement between these two sites supports that archaeological evidence that this link was a cornerstone of the flint exchange (see Davis 2000).

After modeling movement between Long Island and Antigua, which were geographically the closest of all case study nodes, I computed connections towards other sites. Each route corridor has a different average time cost associated with it, though these route times do not diverge widely from one another. For example, the mean time costs returned are very like one another when looking at movement from Long Island to Saba in January and July (see Tables 3 and 4). This is true both between months and for different departure times evaluated in the same month. The average standard deviation for routes moving between Long Island and Saba is 4.34 in January and 5.3 in July, which is higher than the standard deviation for routes connecting Saba to Long Island (see Tables 3 and 4; Appendix B) The difference in standard deviation could also indicate that movement in January was more predictable than movement in July. Navigators likely preferred predictable travel and may have preferred traveling during the winter month.

	Min.	Median	Max.	Mean	standard	missingAbs	missingPerc
0:00	25.4	27.96	39.11	29.46	3.838289	7	22.58065
3:00	26.02	27.59	50.88	31.42	7.515236	5	16.12903
6:00	25.08	27.42	40.54	28.23	3.74079	8	25.80645
9:00	25.51	27.72	44.03	29.72	5.088017	7	22.58065
12:00	25.45	27.54	44.69	29.91	5.451259	8	25.80645
15:00	25.52	28.07	51.71	31.16	6.322937	6	19.35484
18:00	25.39	27.47	40.05	28.16	3.013735	8	25.80645
21:00	25.22	27.57	43.42	29.21	4.869163	8	25.80645

Table 3: Long Island to Saba least-cost route values for January. Columns from left to right: Minimum Time Cost, Median Time Cost, Maximum Time Cost, Mean Time Cost, Standard Deviation, Number of Missing Routes (or routes that did not complete), Percentage of Missing Routes (or routes that did not complete). Time value is represented in hours. Rows represent time of day the canoe launched.

	Min.	Median	Max.	Mean	standard	missingAbs	missingPerc
0:00	24.87	27.39	43.36	30.32	5.923895	12	38.70968
3:00	24.78	27.31	52.12	30.56	6.79233	7	22.58065
6:00	24.52	28.52	50.01	31.77	6.248519	6	19.35484
9:00	25.43	27.44	39.37	29.31	4.60132	8	25.80645
12:00	24.02	26.98	43.24	29.63	5.926337	13	41.93548
15:00	25.6	27.37	38.38	29.03	4.428893	12	38.70968
18:00	24.77	27.21	49.91	31.38	7.833633	9	29.03226
21:00	24.73	27.08	46.53	29.72	5.87873	5	16.12903

Table 4: Long Island to Saba least-cost route values for July. Columns from left to right: Minimum Time Cost, Median Time Cost, Maximum Time Cost, Mean Time Cost, Standard Deviation, Number of Missing Routes (or routes that did not complete), Percentage of Missing Routes (or routes that did not complete). Time value is represented in hours. Rows represent time of day the canoe launched.

	Min.	Median	Max.	Mean	standard	missingAbs	missingPerc
0:00	34.03	38.33	43.38	38.42	1.75881	2	3.225806
3:00	34.68	38.05	42.11	38.08	1.89476	4	6.451613
6:00	34.5	37.94	41.85	37.7	1.831388	1	1.612903
9:00	34.7	38.08	41.45	38.2	1.827556	3	4.83871
12:00	34.76	38.91	42.08	38.78	1.727511	2	3.225806
15:00	33.39	39.23	48.39	38.94	2.177015	2	3.225806
18:00	32.51	38.75	42.01	38.4	1.930089	3	4.83871
21:00	33.49	38.29	43.13	38.42	1.724355	2	3.225806

Table 5: Saba to Long Island least-cost route values for January. Columns from left to right: Minimum Time Cost, Median Time Cost, Maximum Time Cost, Mean Time Cost, Standard Deviation, Number of Missing Routes (or routes that did not complete), Percentage of Missing Routes (or routes that did not complete). Time value is represented in hours. Rows represent time of day the canoe launched.

	Min.	Median	Max.	Mean	standard	missingAbs	missingPerc
0:00	34.72	38.36	41.51	38.26	1.40164	1	1.612903
3:00	35.08	38.1	41.69	38.08	1.65805	1	1.612903
6:00	34.36	37.43	41.37	37.67	1.791822	1	1.612903
9:00	34.32	37.88	40.62	37.62	1.526579	3	4.83871
12:00	34.18	37.26	39.82	37.43	1.203651	4	6.451613
15:00	34.11	37.01	42.4	37.18	1.564748	5	8.064516
18:00	33.78	37.66	42.15	37.32	2.134544	33.78	54.48387
21:00	34.08	38.7	44.53	38.02	2.145172	1	1.612903

Table 6: Saba to Long Island least-cost route values for July. Columns from left to right: Minimum Time Cost, Median Time Cost, Maximum Time Cost, Mean Time Cost, Standard Deviation, Number of Missing Routes (or routes that did not complete), Percentage of Missing Routes (or routes that did not complete). Time value is represented in hours. Rows represent time of day the canoe launched.

In comparison, standard deviation values for movement from Plum Piece to Flinty Bay reflect the lower variation in time costs. The standard deviation for this route averages to between one and two when compared against all months (see Tables 5 and 6; Appendix B). This indicates that movement from Plum Piece to Flinty Bay was more reliable than traveling in the opposite direction. With a smaller and more stable range of time costs any real-world canoers that followed routes similar to the ones generated would have had a better idea of what supplies might be necessary for the standard time of the voyage.

Comparing the time costs of these routes between Long Island and Saba suggest that movement from the east was easier. As demonstrated by tests run with the current tool, these eastward routes fit with the strong current moving east to west in this region (see Figures 31, 33, and 35). It takes on average 29.5 hours to canoe from Long Island to Saba in January (see Appendix B). In contrast, it takes an average of 38 hours to make the reciprocal crossing. Similarly, the annual cost for moving between Jolly Beach and Saba in January is around 37 hours with a reciprocal cost of 26.5 hours (see Appendix B). Movement from Jolly Beach in July runs towards the limits established for this case study. Canoers may have chosen to stop after 50 hours to comply with the human physical cap equivalent to the channel crossing of the Anegada Passage. These time costs suggest that voyagers would have preferred heading west so that the current from the east could push them forward. Use of this technique resulted in shorter route times.

A difference of around 10 hours has implications for how much planning is needed for a voyage (Bérard personal communication 2014; Billard *et al.* 2009). Crews would have to adapt their plans based on the amount of food supplies needed, the number of paddlers supplying propulsion, and, depending on what time the canoe left harbor, if the journey would end at night or during the day. These considerations may have led navigators to favor stopping at in-between islands when traveling east to west. When evaluating movement from Saba to Long Island, canoers could have followed along the coast of St. Kitts to take advantage of stopovers to rest. Movement between Long Island and Antigua as well as Long Island and Saba set the trend for movement east and west in the northern Lesser Antilles.

North to south movement also remains largely consistent. There is some variation in route time costs depending on whether least-cost routes ran slightly to the west or east of the origin point before heading south or north to the termination point. For example, routes from Long Island typically arced to the west before heading north into Barbuda's western coast (see Appendix B). Routes charting the reciprocal voyage often arced to the east before connecting with Long Island (see Appendix B). Pathways originating from River Site on Barbuda towards all other end points seem to be consistent in terms of time cost over all months (see Appendix B). The shortest routes heading to Flinty Bay averaged six to 11 hours no matter the time of day or year (see Appendix B). Reciprocated journeys from Long Island average between seven and one-half to eight hours (see Tables 5 and 6; see Appendix B). This slight change in route time cost could be connected to the arc of the pathway heading with the current when routes moved north and against the current when moving south.

This can be compared to travelling from Long Island to the furthest point from it, White Head's Bluff on Anguilla. October is the fastest month for travel with a range of cost times for routes of 22 to 50 hours and an average voyage of 30 hours (see Appendix B). These time costs are different from those produced for the other months.

For example, January routes range from 29 hours to 50 hours (see Appendix B). Despite the average journey times for these months being similar, the standard deviation of route variance also fluctuates between a 4.5 standard deviation in January and a 5.5 standard deviation in July. The lower standard deviation in January suggests that any actual canoers that may have followed similar routes in winter months were more likely to know the time cost associated with travel than in summer months. This could indicate that the summer season, or the period from April to July, was not the best for voyaging north due to uncertain route times.

However, there are some cases of 'optimal' routes with time costs up to 45 hours, for example, routes travelling across the Anegada Passage, and some routes heading from Long Island to Saba (Table 3 and 4; see Appendix B). These costlier routes between Long Island and Saba likely corresponded to voyages with loops (see Chapter 4). Their time costs can be discounted as they do not hold to the spirit of least-cost pathway analysis and it is possible that canoes with strong navigators may have been able to avoid becoming stuck in these loops by making a choice to head in a non-optimal direction at a key point within the journey. Routes that had a true higher cost were typically associated with movement from Barbuda to Saba (see Appendix B). This is consistent with these islands occupying the furthest east and west points within the case study.

5.2.1.4 Direct and Suggested 'Indirect' Travel

Many of the times returned for the direct movement between two sites, such as Saba and Antigua, indirectly support the theory of connections between multiple islands. These routes together represent a total time cost of over 50 hours. This is a greater time cost than what may have been acceptable to Amerindian seafarers. If a crew chose a bad time to leave, one leg of the voyage from Saba to Antigua could be 52 hours (see Appendix B). Even though routes between Saba and Long Island take on average 38 hours, the time cost still pushes the limits of what humans would find comfortable (see Appendix B). Previous water modelers (Altes 2012; Callaghan 2001) and exertional projects (Bérard *et al.* 2011, 2016; Bottome personal communication 2017) have suggested trips of this duration were possible. However, actual canoers likely did not prefer routes similar to these least-cost pathways. Stopover points probably played a role in alleviating the crew's physical and mental stress.

Time costs overall remain relatively consistent. The evenness of the time cost returns indicates that there may not be a clear-cut canoeing season in this portion of the Caribbean based on route cost alone. I will now turn towards a discussion of route placement to determine if canoeing seasons existed. Unlike time costs, route layouts show the physical relationship between canoe pathways and the broader world. These routes should be able to add to our understanding of the 'when' of seafaring during the Archaic Age.

5.2.2 Route Trajectories

The time cost and trajectory of routes are linked. Route trajectory is determined by the underlying costs to movement. Because the returned time costs for the optimal routes produced by the isochrone tool are similar, the route trajectories returned by the model indicate possible connections contained in a mental navigation map. As a result, these modeled routes possibly suggest that past real-world canoers may have had the opportunity to prioritize social and economic factors when choosing to paddle between islands. To explore the hypothetical connections open to Lesser Antillean canoers, I have chosen to evaluate route trajectory through the seasonal breakdown used to study Caribbean seafaring routes in the past (Callaghan 2001; Hofman *et al.* forthcoming; Slayton 2013). These seasons were chosen for their even spread across the year and their relationship to modern sailing seasons (Callaghan 2001). Routes were evaluated for January, April, July, and October.

As I began to evaluate the routes discussed in the last section, it became clear that determining how close a route passing by an island had to come to the coastline to have stopover potential was important. Torres and Rodríguez Ramos (2008) determined that landing would be a certainty at five km from the coastline. This distance covers many examples returned by the model, in particular those routes that make physical contact with coastlines. Torres and Rodríguez Ramos (2008) also suggest that once an island is in sight landing on its coastline could be a foregone conclusion. Based on the understanding that canoe navigators would have had the wayfinding knowledge necessary to connect with the coast, I assume that crews moving within five km from the coastline would have been able to make landfall. This ties with the existence of mental maps, which rely on visual cues to build navigation markers.

Connections between visual perception and mobility through a space has been discussed by Gibson (1979). He states that "all optical flow vanishes at the horizon and at the two centers that specify going toward and coming from" (Gibson 1979: 174), which has interesting implications for sea travel. When traveling on a surface that vanishes directly into the relatively flat plan of the sea's surface, it is possible that the elements protruding in the line of sight along the lane of travel going towards and coming from a point would appear prominently. These prominent points that occur near travel corridors would have made convenient route markers for generations of travelers. For example, Frake (1985) discusses the continual use of navigation markers as a base for generations of medieval seafarers being able to find their way, connecting visual cues to longstanding seafaring routes. Just as the position of coastlines off travel corridors in Europe might have acted as visual markers, so too would Caribbean islands for Amerindian canoers.

The routes generated here can be related not only to the origin and termination points of pathways but to the sites they pass by as well. Even if routes move directly towards the destination point along the shortest path, how routes are laid out and the existence of possible stopover areas can suggest either alternative direct or indirect connections. This is demonstrated through the relationship of the Sugar Factory Pier site on St. Kitts to canoe routes running to and from Saba. Finding possible evidence of connections between sites on neighboring islands in the Lesser Antilles can identify who may have been in contact even if the connection is only minimally evidenced by archaeological remains.

The opportunity to evaluate how route layout may have influenced the structure of mobility and exchange networks is one advantage of sea-based least-cost pathway modeling. This section will also evaluate some choice routes that went 'off course.' Some of these off-course routes passed by other islands or ran far into the sea away from the destination point, leading to a phenomenon I am calling 'indirect routes.'

Indirect routes are interesting for this work as they can indicate the location of possible stopover points. Many of the exaggerated route times coincide with indirect routes. This analysis can indicate the location of navigation corridors used in this period and into the Ceramic Age. Connecting known sites with modeled least-cost canoe pathways highlights the possible relationship between seascapes, navigation along known corridors of movement, and Amerindian canoe crews.

5.2.2.1 Island Layout

To understand how pathways were laid out between islands it is necessary to discuss the geographic placement of the islands within the northern Lesser Antilles, which are shaped almost in a cluster or ring (see Figure 29). Though pathways would often run through the center of the island cluster, many steer closer to neighboring islands that come between the origin and termination points.

In some cases, pathways between two islands come in proximity to or contact with a third island in the cluster. Canoers who passed by in-between islands may have been able to connect with those islands physically due to the high levels of visibility from canoes to the islands. Many islands are inter-visible or become visible from the center of a channel. Canoeing between these islands' visual spheres would have made paddling from island to island intuitive or linked to a community navigation mental map. The visual link between islands in the region would have allowed for a strong backdrop for wayfinding points. Though some canoe crews may have chosen to not follow along the least-cost corridors modeled in this work, subject to a voyage's time cost, the visual links between islands would have been accessible in all seasons.

There was probably a seasonal component to when people canoed between two islands, here referred to as islands 'A' and 'B'. Canoers may have waited for optimal currents to help push them towards their intended destination. This can be seen in voyages where one route passes by a third island when moving between points 'A' and 'B' (*e.g.*, routes Flinty Bay to Jolly Beach reaching St. Kitts; see Appendix B). It is possible that people canoeing along these routes were more focused on stopping at this in-between island. These islands and sites represent stopgaps for those routes veering off course. Montserrat, for example, is visited several times by routes heading towards sites on the northern islands of Saba, St. Kitts, St. Martin, and Barbuda from Flinty Bay and Jolly Beach. Even when routes were ultimately headed towards the north, the currents sometimes took them south first. Montserrat provides a convenient, or life-saving, stopping point for those voyages that were pushed off course by strong currents. The patterns observed in pathways going to one island and stopping or connecting with a site on another hint that accidental voyages resulted in new sites. These sites were possibly incorporated into the yearly mobility cycle and eventually the Amerindian shared navigation map of the northern Lesser Antilles.

The route trajectories mentioned below relate to the time costs discussed in the previous section. As with the multitude of time cost results, due to the sheer number of routes evaluated only a few images will be put in text (see Appendix B). These maps exemplify the key aspects of normal and atypical routes through the northern Lesser Antilles.

5.2.2.2 Failed Routes and Navigation Challenges

Certain routes can be discarded in the pursuit of uncovering optimal canoe pathways due to their atypical placement. For example, some routes from Flinty Bay to Plum Piece looped around the island of Antigua to achieve the 'least-cost' route. Because the majority of these looped routes show that pathways departing from Flinty Bay were more likely to have moved directly away from land or run slightly west along the coast before heading out to sea, these pathways can be rejected (see Figure 37; Appendix B). This 'logical' trend is reflected in most routes from Flinty Bay to Jolly Beach over all seasons. I had to consider how these looping pathways affected what

Figure 37: An example of a route with loop. The route is from Long Island to Saba, launched at 3am on the 1st of October 2013, Route: 0-2_2013-10-24T09.

least-cost routes crews might have chosen to follow, if they followed any, if the currents along a pathway forced them away from their goal. There must have been some instances when canoers were caught unaware, especially if they were unfamiliar with the environment or misread the signs of the currents. These cases cannot be measured by least-cost pathway routes. A canoe crew's reaction to these unusual circumstances falls outside the current research.

Some routes between Flinty Bay and Jolly Beach can be discounted as they show the island being circled more than once before landfall is made (*e.g.*, route 0-2_2013-10-24T09). This is an indication of canoers that may have traveled along similar trajectories were unable to make landfall at a certain point due to strong currents. Plausibly there would have been a better way to deal with this issue. For example, crews could have chosen to either wait for a better time to launch or they could have canoed along the coastline until they could make landfall.

There are a few examples of routes that likely were not used either because they push too far off the typical path between origin and termination points or because they contain loops that add unnecessary time to the route cost. The trajectories in route 0-2_2013-09-24T21 and route 0-2_2013-10-19T15 run so far into the Caribbean Sea that actual Amerindian canoers who wanted to travel along similar corridors would have tried to circumvent these currents at all costs, even by staying at home if necessary. However, in terms of the successful implementation of the isochrone tool to the analysis, the model deals well with projecting routes for when currents surprised canoers. That these routes were still able to complete shows that possibilities of voyages to overcome obstacles at sea.

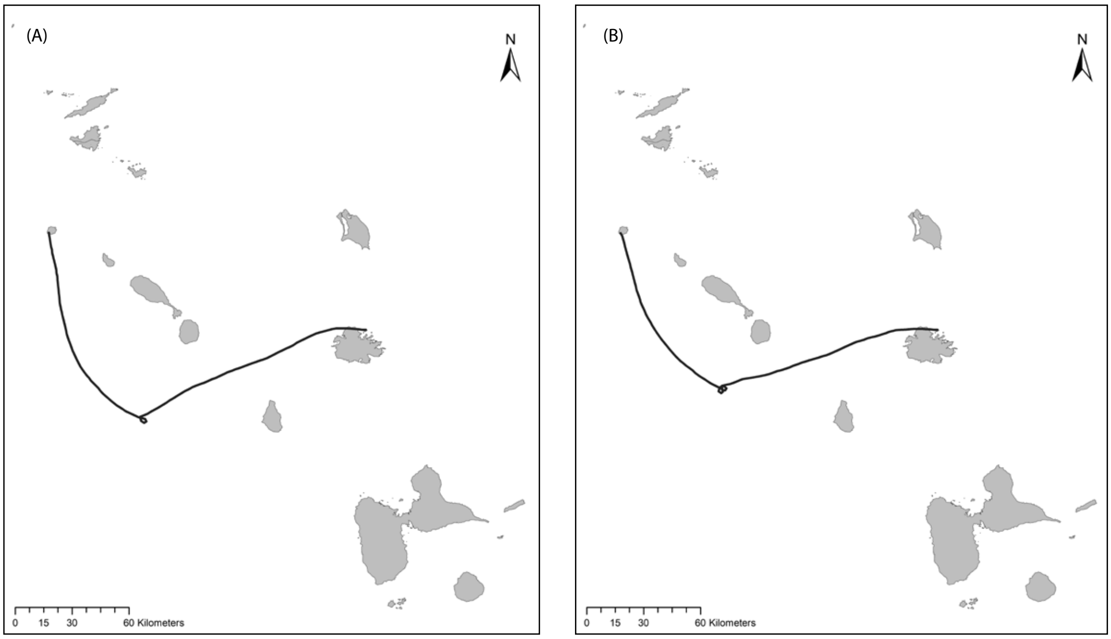


Figure 38: Examples of routes running past islands into the Caribbean Sea. (A): The route is from Long Island to Saba, launched at 9pm on the 24th of September 2013, Route 0-2_2013-09-24T21, and (B): The route is from Long Island to Saba, launched at 3pm on the 19th of October 2013, Route 0-2_2013-10-19T15.

Loops that occur in routes add unnecessary time and danger to any voyage. They show the inability of a crew to move directly towards their goal. Despite the inclusion of an anti-loop calculation in the underpinnings of the model (see Chapter 4), loops still appear in some routes (*e.g.*, route 0-3_2013-11-17T15, route 0-2_2013-05-28T9). As both the layouts and the time costs are inaccurate, these routes can also be discounted. Other routes, like route 1-0_2013-0121T18, show movement that laps back onto itself so often it would be problematic to consider it a representation of a route which would be chosen and navigated by humans. Pathways that double back onto themselves are illogical for two reasons: first, there may not have been a reason to turn back. As each modeled route constantly looks for the optimal route, it is unable to discern where actual canoers may have waited for better currents or pushed forward to reap long term benefits; second, because there is a cost associated with continually turning to face the brunt of the current. This can be compared to instances when the model could not generate a route, signifying

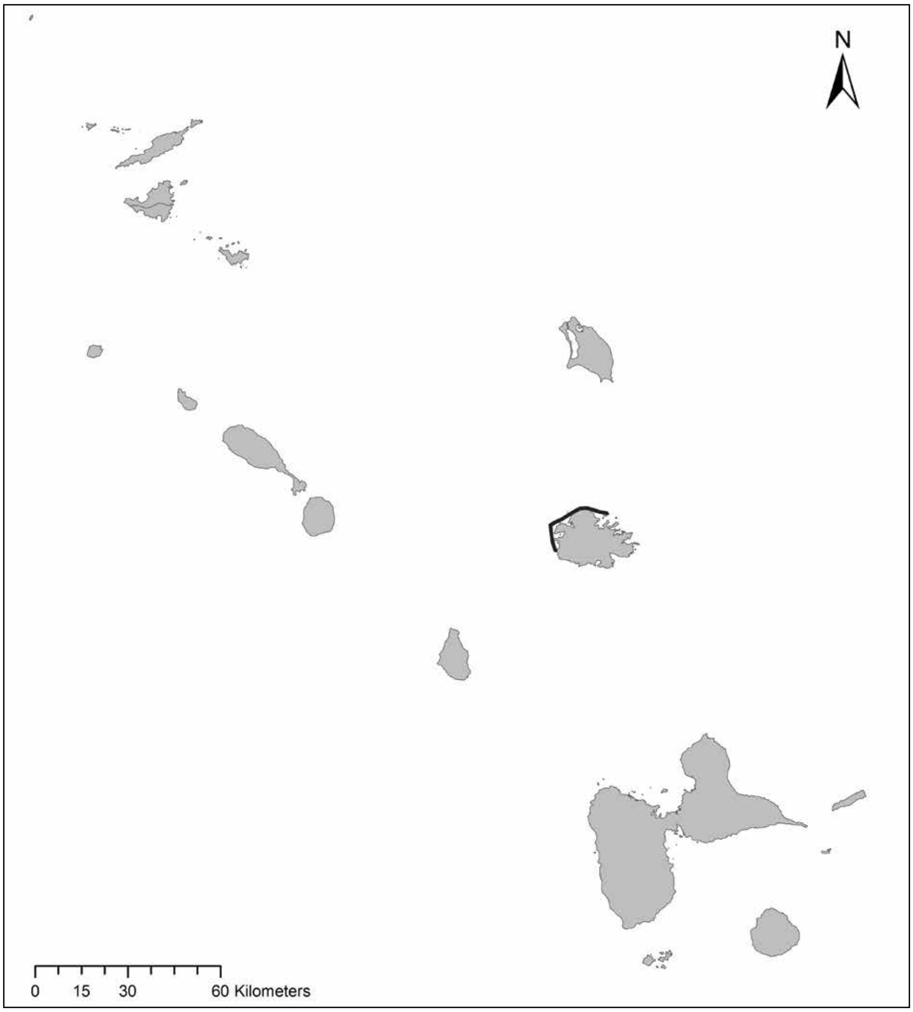


Figure 39: Example of typical route from Flinty Bay, Long Island to Jolly Beach, Antigua. The route launched was launched at 3 am on the 30th of March 2011, Route: 0-1_2011-03-30T03.

the current was too powerful to be overcome and successful voyaging was impossible. Assuming that most of these canoers were expert or at least adequate navigators, it stands to reason that steps were taken to prevent this outcome.

5.2.2.3 Flinty Bay and Jolly Beach

The first pathway layout I will examine is the reciprocal route between Flinty Bay and Jolly Beach (see Figure 39). As discussed in the archaeological background above, Flinty Bay served as a major source of flint for the Archaic Age communities in the northern Lesser Antilles. Jolly Beach and Flinty Bay were connected through exchange or direct contact evidenced by the lithic materials sourced from the smaller island (Davis 2000; Knippenberg 2007). These flint nodules were refined at Jolly Beach, possibly before export to other islands (van Gijn 1993). The close working relationship between these two

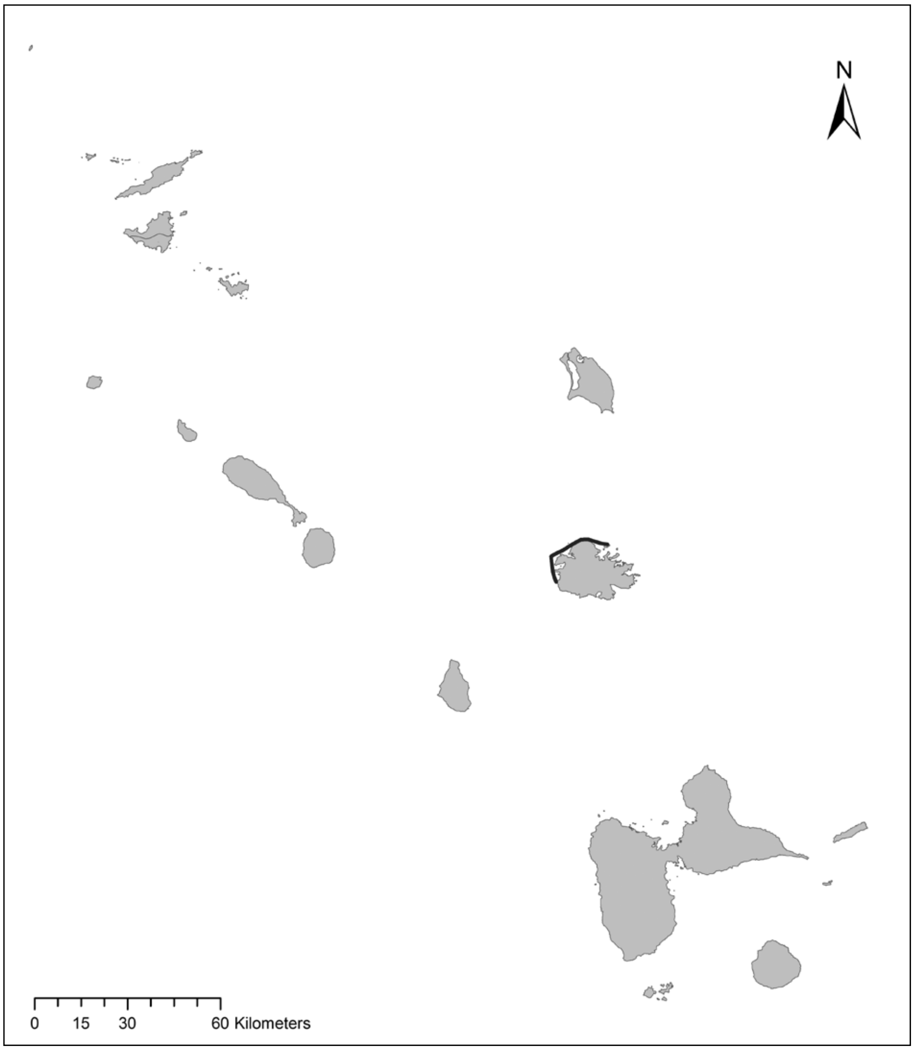


Figure 39: Example of typical route from Flinty Bay, Long Island to Jolly Beach, Antigua. The route launched was launched at 3 am on the 30th of March 2011, Route: 0-1_2011-03-30T03.

sites is mirrored in their assemblages, particularly in the transportation and modification of flint nodules. It is clear that Amerindian peoples traveled between these two sites.

Testing movement along this route will show how currents influenced pathways with the shortest Euclidean distance connection in this case study. A few months will be selected to stand for broader annual trends, as the evaluation of route time cost showed there was limited variation through the year. Some months had routes with more consistent layouts than others did. For example, the travel corridor between Flinty Bay and Jolly Beach is more stable in January than in April. Canoe movement in these months can be compared against variations throughout the year. These variations can mark those months that have semi-stable indirect routes that pass by a third site when moving between Flinty Bay and Jolly Beach.

How does this movement past other islands compare with typical corridors between Long Island and Antigua? Routes between Flinty Bay and Jolly Beach in March show little deviation from the typical least-cost pathway along the north coast of Antigua (see Figure 39; Appendix B). Over 92 percent of routes stay above the island of Antigua and close to its coastline in 2011 and 2013 (see Appendix B). In March 2011 only two routes come close to meeting another island pathway. For example, route 0-1_2011-03-06T21 heads west of Antigua to make contact with St. Kitts (see Figures 40 A and B). This trend continues in 2012, with 88 percent of routes staying above the island. In 2013 only a few routes veer away from Antigua when making a run between Long Island and Jolly Beach. Two routes pass by the north coast of Montserrat (*e.g.*, route 0-1_2013-3_09T12). More routes pass by St. Kitts (*e.g.*, route 0-1_2013-03-14T00, route 0-1_2013-18T3). Though possessing indirect routes, March represents one of the most stable periods for canoe travel and links St. Kitts to for reciprocated movement from Jolly Beach to Flinty Bay.

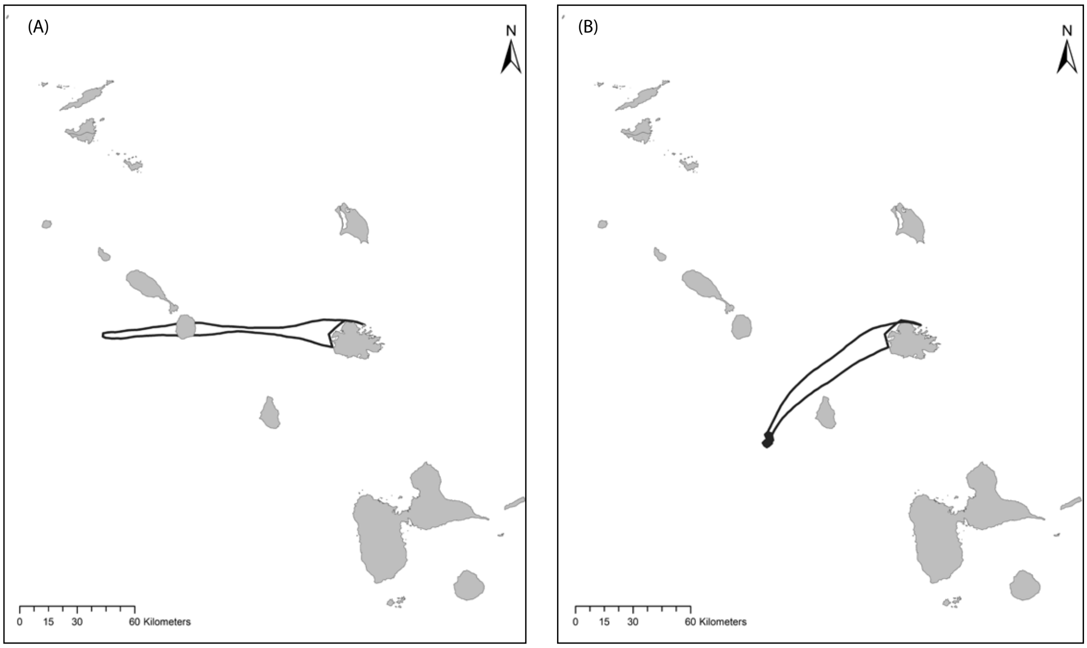


Figure 40: Routes from Flinty Bay, Long Island to Jolly Beach, Antigua that make contact with both St. Kitts and Montserrat. (A): The route launched was launched at 12pm on the 6th of March 2011, Route: 0-1_2011-03-06T21, and (B): The route launched was launched at 12pm on the 9th of March 2013, Route: 0-1_2013-3_09T12.

Many routes from Flinty Bay to Jolly Beach run into the center of the island cluster and parallel to St. Kitts (see Appendix B). Depending on the proximity of the route to the island, sightlines towards St. Kitts may have aided passing canoers. Views of the island would have given these voyagers a feeling of relative safety. There are some modeled pathways that pass very close to the island. Many simulated canoe paths even passed within five km of the coastline (see Figure 40; Appendix B). Applying the theory from Torres and Rodriguez Ramos (2008), if crews did undertake the least-cost routes modeled here they would have been able to make landfall. Amerindian seafarers on this route possessed waypoints for navigation and paddlers may have known there was a nearby island where they could rest.

Other indirect routes in March indicate movement from Long Island towards Jolly Beach could have travelled south away from Antigua. Canoe pathways that pushed south of Long Island and Antigua sometimes ran parallel to the east coast of Guadeloupe. Other exceptions to direct routes returned by the model follow the second example of an indirect route from March 2011. The route 01_2011-03_20T12 heads south of Long Island and almost connects with the island La Désirade off the east coast of Guadeloupe (see Figure 41 A). There is also route 01_2012-03-13T12 that runs first by Pointe de la Grande Vigie at the northern end of Guadeloupe before heading east to Montserrat and then north to Jolly Beach (see Figure 41 B). This is one of the only routes in the study that reaches Guadeloupe and Montserrat on the same journey. Four other routes connect with Guadeloupe around Moule (route 0-1_2013-3-14T18), Le Désirade (route 0-1_2013-3-21T21, 0-1_2013-3-23T9), and the island

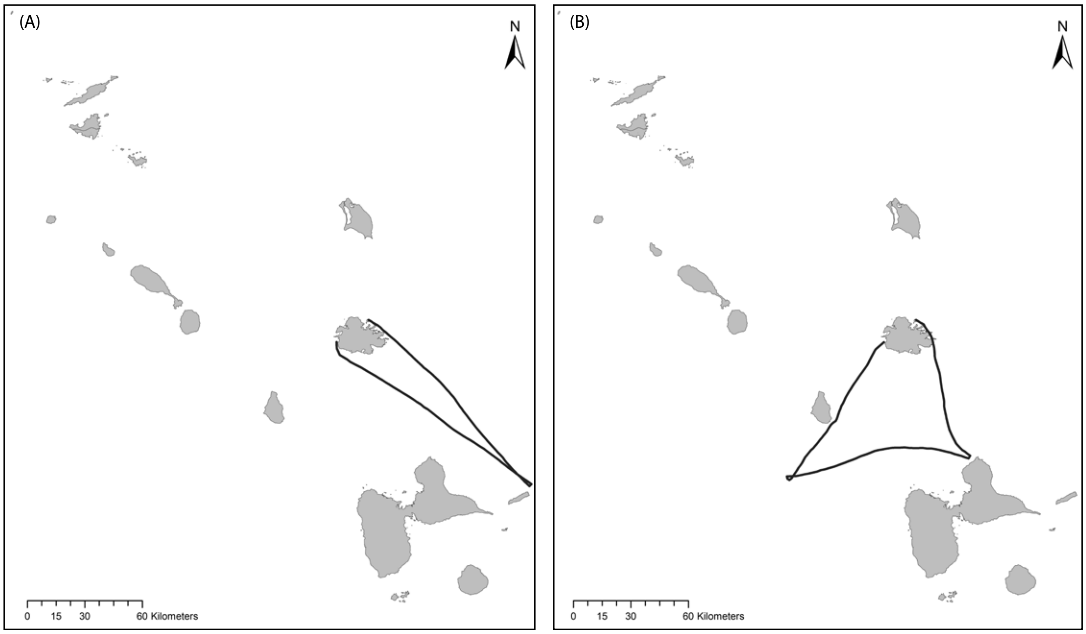


Figure 41: Routes from Flinty Bay, Long Island to Jolly Beach, Antigua that move towards La Désirade or Guadeloupe and Montserrat. (A): The route launched was launched at 3pm on the 31st of March 2011, Route: 0-1_2011-03_20T12, and (B): The route launched was launched at 12pm on the 13th of March 2012, Route: 01_2012-03-13T12.

of Fajou (route 0-1_2013-3-16T0). Possible real-world canoe crews following the same trajectory as these least-cost routes, *i.e.* those that were pushed this far south, may have decided to stop along the coast of Guadeloupe or La Désirade. This travel processes may link to the materials found on the Island of La Désirade that tie more closely to the northern Lesser Antilles than materials on Guadeloupe.

In keeping with trends observed in March, routes typically follow the coast of Antigua conforming to the logical least-cost pathway in May. Indirect routes in May sometimes go down towards Guadeloupe (*e.g.*, route 0-1_2011-05-12T15, route 0-1_2013_05_08T15, route 0-1_2013-05-14T9, and route 0-1_2013_05-21T18), Montserrat (*e.g.*, route 0-1_2011-05-17T06), and St. Kitts (*e.g.*, route 0-1_2011-05-14_00, route 0-1_2013-05-09T6). Canoe routes that veer off course in May are like those observed in April (see Appendix B). With more routes heading widely off course than in 2011 and 2012 combined, pathways from May 2013 are particularly indirect. Unlike in other months, pathways do not extend towards Barbuda. This could indicate that connections between Flinty Bay and Barbuda were less common during this time of year. This may have influenced annual trends of interaction between peoples to the south and west of Long Island and those to the north.

Differentiation between spring and winter travel can also extend to route differenced in autumn. Like in winter and spring, many autumn routes also pass by in-between islands. Extreme indirect routes in September include pathways passing by or running into St. Kitts (*e.g.*, route 0-1_2011-9-7T12, route 0-1_2011-9-18T18, route 0-1_2011-9-25T6, 27T3, route 0-1_2012-9-15T12, and route 0-1_2012-9-28T3). The latter two of these routes (*e.g.*, route 0-1_2012-9-15T12 and route 0-1_2012-9-28T3) also pass closer to Montserrat. Other routes connect with (*e.g.*, route 0-1_2011-9-20T21) or circle (*e.g.*, route 0-1_2012-9-16T09) the island. Most September deviations in routes occur to the south, pushing towards Guadeloupe. Three notable cases are route 0-1_2011-9-16T18 and route 0-1_2012-09-29T03, which meet the northern coast of La Désirade, and route 0-1_2011-9-08T21, which moves towards Anse à La Gourde on the northeast coast of Grande Terre, Guadeloupe (see Figures 43 A, B, and C). Again, these routes could indicate seasonal push for Amerindian canoers to travel towards certain islands, where they might engage in exchange or resource collection.

Compared to other months, the most unique aspect of the September routes is the frequency of movement north to Barbuda when traveling from Flinty Bay towards Jolly Beach. Route 0-1_2011-9-26-T21 comes close to connecting with the western extreme of the island, consistent with the placement of Barbuda's River Site (see Figure 43). This route, and a few others noted in September, push north towards St. Martin (*e.g.*, route 0-1_2012-9-23T00). Pathways heading in this direction fit the trend of movement further north that occur when moving from Flinty Bay to other sites in the autumn season. This may suggest that communities on Barbuda were more engaged with the wider exchange network in Autumn, perhaps curtailing the availability of certain resources.

In October, routes also tend to stay closer to Antigua. It appears that after March, October is the month with the least number of 'off-course' voyages. However, there are still the occasional routes that meet St. Kitts (*e.g.*, route 0-1_2012-10_06T21, route 0-1_2013-10T15, and route 0-1_2013-10-01T18).

The modeled runs show routes infrequently pushing towards, or connecting with, La Désirade (*e.g.*, route 01_2012-10_31T15 and route 0-1_2013-10-11T00). Modeling in the month of October was hindered by the inability of currents from 2011 to be included in the model due to their absence from NOAA files. As a result, these assumptions of October's seasonal makeup may need further support from future modeling efforts.

November has similar route trajectories to October. The similarities in route layout between the two months indicate that they may have formed a 'sailing season'.

Figure 42: Routes from Long Island to Antigua that make physical contact (or come close) with the coast of La Désirade. (A): The route launched was launched at 6pm on the 16th of September 2011, Route: 0-1_2011-09-16T18, (B): The route launched was launched at 3am of the 29th of September, 2012, Route: 0-1_2012-09-29T03, and (C): The route launched was launched at 9pm on the 8th of September, 2011, Route: 0-1_2011-09-08T21.

November also has some routes that head towards Guadeloupe and La Désirade (*e.g.*, route 0-1_2011-11-6T21, route 0-1_2011-11-11T9, route 0-1_2012-11-10T9, route 0-1_2012-11-11T21, route 0-1_2012-11-13T3, route 0-1_2012-11-21T00, and route 0-1_2013-11-20T18). The November routes that head southeast of Antigua predominantly occur in 2011. Conversely, November 2013 has more routes that run north before reconnecting with Antigua (*e.g.*, route 0-1_2013-11-18T03). These routes include more pathways that run into the east-central coast of St. Kitts (*e.g.*, route 0-1_2013-11-26T21). Routes running to the east suggest a level of non-conformity to the broader cycle during 2013. Conforming to this sailing season, travel from Long Island this far east occurs less frequently than in other months.

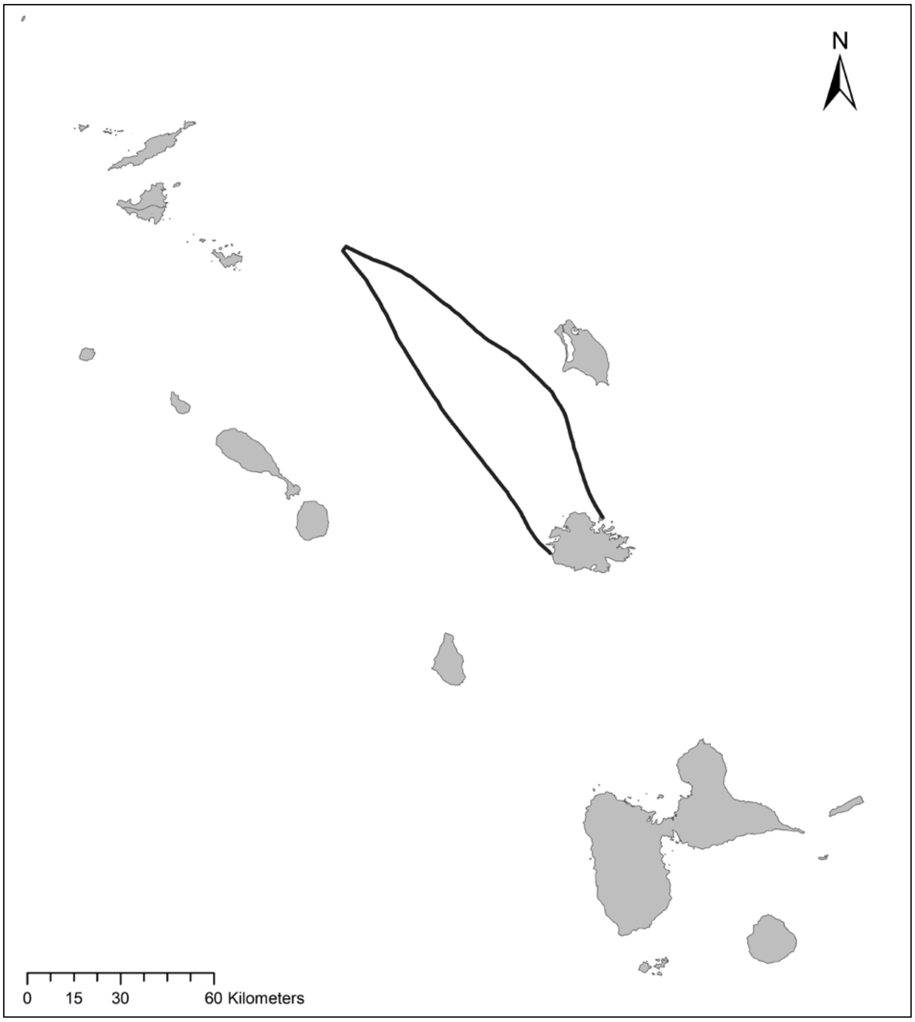


Figure 43: Route from Long Island to Antigua that runs past Barbuda. The route launched was launched at 9pm on the 26th of September 2011, Route 0-1_2011-09-26-T21.

5.2.2.4 Jolly Beach to Flinty Bay

The typical least-cost corridor that connects Jolly Beach and Flinty Bay is almost a mirror image of those modeled for travel from Flinty Bay to Jolly Beach. Most direct least-cost routes between these sites accrue a similar time cost over all seasons. Pathways modeled for this section represent hypothetical reciprocal routes to those from Flinty Bay to Jolly Beach and the seasonal similarities between time costs and route placement continue to indicate that real-world canoers traveling similar sea corridors may not have been obliged to travel in specific months. These routes further suggest that seasonality was not a major factor when undertaking direct routes between these sites.

These direct routes between Long Island and Antigua also suggest that there was a level of familiarity when traveling along the coastline in both directions. Coastal areas of Antigua have corresponding Archaic Age sites that could have acted as breaks between Flinty Bay and Jolly Beach (Davis 2000). These sites also confirm the consistency of this route-corridor.

Routes running the reciprocated corridor from Jolly Beach to Flinty Bay also encountered extreme currents that would lead them into indirect routes. Routes headed east on these routes often traveled north to meet Barbuda (*e.g.*, route 1-0_2013-04-13T21; see Figures 44 A and B). In some cases, routes from Antigua even looped up over the northern island before returning south to Long Island (*e.g.*, route 1-0_2013-04-21T00; Figure 44 B). Unlike for voyages that originated in Flinty Bay, least-cost routes run in this direction were more likely to head past the east coast of Barbuda. Archaic Age sites have yet to be found around the points of pathway contact with this section of Barbuda's coast. To confirm if these routes resulted in any stopover points, more research into the placement of Archaic Age sites along the east coast of Barbuda is

Figure 44: Routes from Antigua to Long Island that move by Barbuda. (A): The route launched was launched at 9pm on the 13th of April 2013, Route: 1-0_2013-04-13T21, and (B): The route launched was launched at 12am on the 21st of April 2013, Route: 1-0_2013-04-21T00.

necessary to match the work that has been done on the west coast near the River Site and the Strombus Line (Rousseau *et al.* 2017; Watters *et al.* 1992).

Canoes could also be pushed further east when leaving Jolly Beach. Canoes that ran towards St. Kitts when traveling between Jolly Beach and Flinty Bay move one of two ways. Routes either went to the south of the island, where they may also pass close to Montserrat, or up the eastern coast (see Appendix B). Routes typically approached the island from the southeast, which fits with the direction of travel out of Antigua. Some pathways start with the canoe moving more to the north and then turning left into the eastern coast of St. Kitts (see Appendix B). This corresponds to the northwestern push of the current common throughout the year (see Figure 35). The points of contact between routes running away from Antigua and the coastline of St. Kitts can stand as approximations for stopover points over the entire year. Many of these routes touch either the center or southern extremity of the island. The sections of coastline these indirect routes pass would be areas to further survey for archaeological materials or sites.

Modeled routes were sometimes pushed towards Monserrat in April (*e.g.*, route 1-0_2013-04-25T15). As was the case with trips that run north towards Barbuda, these Monserrat routes loop around the island before heading north back towards Antigua. Pathways like these were probably not used by Amerindian canoers. Routes leaving Jolly Beach would need to head west before heading east to make this connection possible. I find it hard to believe that this additional effort, reflected in the time cost for this route (see Appendix B), would have been worth the expense if the only goal of the crew was to reach Flinty Bay. Pathways that reach Monserrat in January are less likely to connect with the south side the island. Instead, they connect with the northeastern coast (*e.g.*, route 1-0_2013-01-13T6). This could indicate that Archaic Age communities had seasonal encampments in this area during the winter season.

This trend could demonstrate the engagement of Monserrat in the broader network of lithic exchange and mobility around the northern Lesser Antilles. The transitional Archaic Age to Early Ceramic Age site of Trants on Monserrat also lies along these looped routes, suggesting it connected with peoples canoeing through this travel corridor. Although pathways occasionally pass on the south side of the Antigua (*e.g.*, route 1-0_2013-01-17T18), they never head south towards Guadeloupe. The movement of crews along these modeled least coast routes, if they were actually followed by canoers, around Antigua and Monserrat indicates that the emphasis of movement passed these islands perhaps connected with Long Island. These connections may have been direct or indirect, dependent of the engagement of peoples from Monserrat with the other islands in the northern Lesser Antilles. This possibility can be further tested in future by modeling least-cost routes from Monserrat outwards and comparing the results against archaeology from that island.

As the most routes heading out from Jolly Beach traveled north east, voyages very rarely go towards St. Kitts (*e.g.*, route 1-0_2013-04-27T3). In some cases, routes first connect with Montserrat before heading north to St. Kitts (*e.g.*, route 1-0-2011-07-12T15). Pathways running in this direction do not pass by the western side of the island near the site of Sugar Factory Pier. Routes meet the southeastern coast of St. Kitts before heading west again. The route leaving Jolly Beach at 3 pm on July 12, 2011 runs into Monserrat and St. Kitts before heading north to run parallel to Barbuda (see Figure 45). This route demonstrates the possible interconnectivity between communities on these islands. That the route connects with all four islands in the same period suggests that a navigator's mental map would have to include all islands to make full use of the connecting sea (*sensu* Terrell and Welsch 1998; Tilley 1994). The steps to this route show that sometimes thinking about a short direct route may have entailed planning a long circuitous multi-site voyage.

Long Island's position within the northern Lesser Antillean arc may have supported its role as a connection point for Amerindian peoples throughout the region. Many routes from this site are indirect routes. These routes show a trend for least-cost pathways to group into corridors, offering some consistency to movement in this direction. In reality, canoers paddling towards Long Island possibly knew they might also be catching up with their neighbors on the return journey due to the current pushing their vessel towards another island. The inhabitants of Jolly Beach may

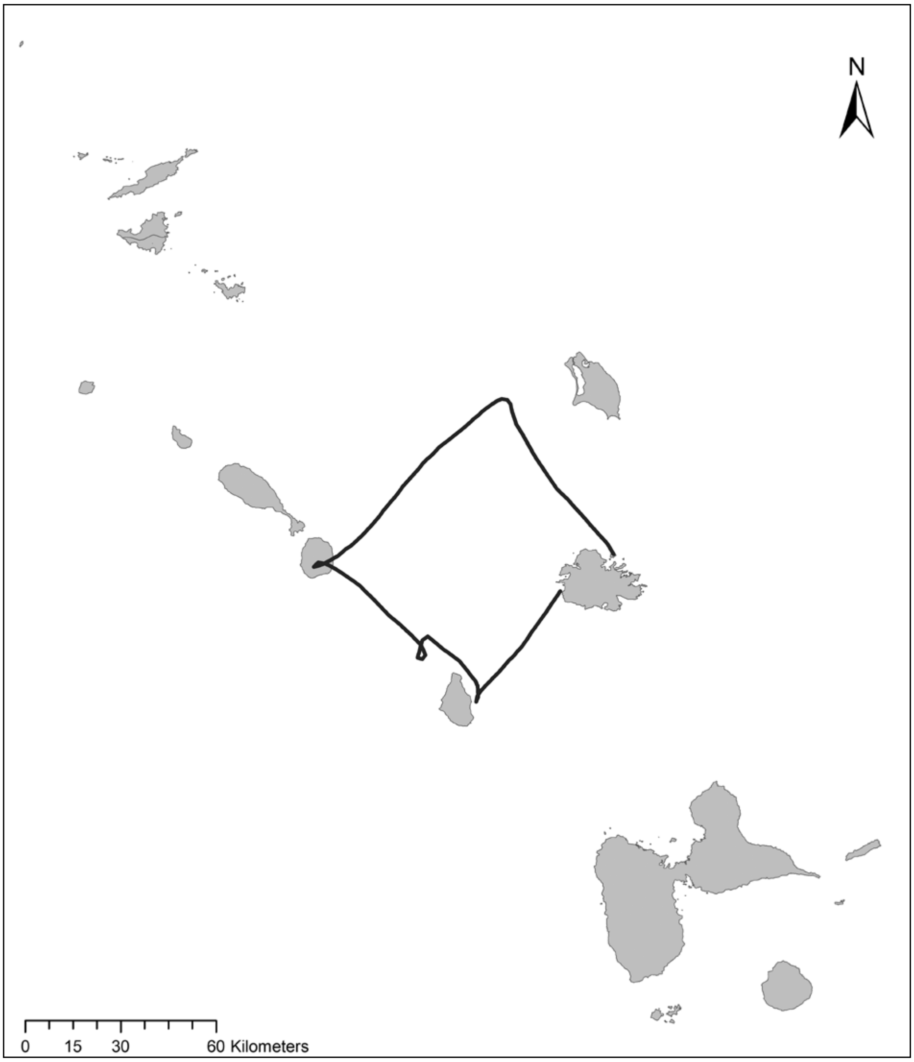


Figure 45: Route showing movement passed Montserrat, the site of Hitchman's Shell Heap on Nevis, and Barbuda. The route launched was launched at 3pm on the 12th of July 2011, Route: 1-0_2011-07-12T15.

have been less interconnected to the northwest islands in the region. Instead, communities at this site may have played a key role in connecting peoples on Monserrat to the lithic exchange network.

5.2.2.5 Long Island and Saba

To fully place Long Island within the broader inter-island network that connected Archaic Age communities in the Lesser Antilles, it is vital to model routes from Flinty Bay to other sites. Plum Piece on Saba and the nearby site of Fort Bay were identified early in this study as key nodes within the patchwork of interconnected sites. While these sites were not fully contemporaneous, dates from Plum Piece and Fort Bay do overlap at some points (Hofman and Hoogland 2016; Hofman *et al.* 2003). As Fort Bay postdates Plum Piece (Hofman and Hoogland 2016), it is possible that communities inhabiting the later site knew of the landing places near the former. The inclusion of Fort Bay allowed a wider array of comparable routes. Any effect of the distance between Plum Piece and Fort Bay is minimized by the fact that it would be very easy to canoe between these two points. As a result, physical, and possible mental, connections between these sites and the routes to both sites from Long Island will be reviewed here. When looking at the reciprocal component of this route, only pathways from Plum Piece will be evaluated. This tactic fits within the concept that routes leave one harbor but approach destinations from several avenues. During all seasons routes from Flinty Bay to Plum Piece generally go through the center of the northern Antillean island cluster. Pathways passing through the center of the cluster coincide with the persistent push of the current directly across the expanse between Long Island and Saba. These

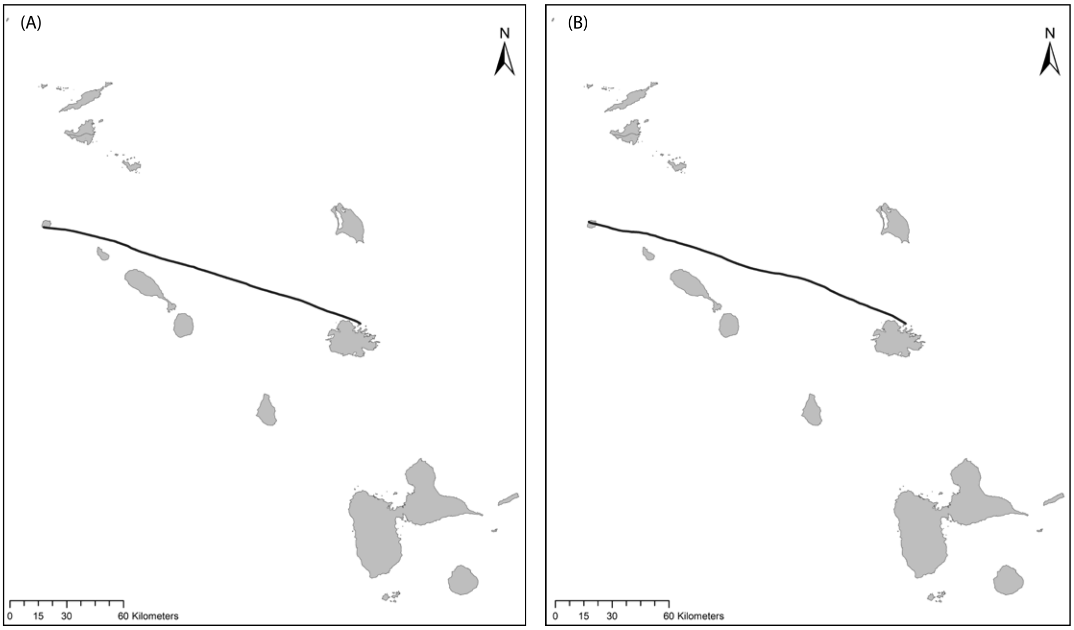


Figure 46: Routes showing direct routes from Long Island to Saba, (A): The route launched was launched at 9am on the 15th of February 2012, Route: 0-2_2012-02-15T09 and, (B): The route launched was launched at 6pm on the 8th of March 2013, Route: 0-2_2013-03-08T18.

routes form a corridor of movement between the two islands (*e.g.*, Bell and Lock 2000; Surface-Evans 2012). The best examples of following the expected straight-across corridor are seen in December, January, and February (*e.g.*, route 0-2_2012-02-15T09, route 0-2_2013-03-08T18; see Figures 46 A and B).

Any divergence from this corridor highlights the basis for connections between Flinty Bay and other sites. It can point to stopover islands or sites engaged with indirect or stopover exchange along this route. The number of indirect routes likely results from the presence of the strong current observed in the analysis of movement to and from Saba. Saba is both the most western point physically from Long Island and the point requiring the most in-between stops. Movement from Long Island to sites on the western end of the island cluster, like Plum Piece, leads to more indirect routes. It may be that Saba connects other sites to Long Island because travel to Plum Piece required the most stopovers.

In most months, these indirect corridors frequently push to the limits of the channel and come into contact with St. Kitts (see Appendix B). Some routes from Flinty Bay run along the north coast of St. Kitts before running into the Saba Bank on their way to Saba (*e.g.*, route 0-2_2012-01-09T6, route 0-2_2011-3_23T15, route 0-2_2012-5-7T3, route 0-2_2012-05-21T9, route 0-2_2012-08-11T03, and route 0-2_2012-11-21T21_00). Fishing in the Saba Bank was likely associated with travel between St. Kitts and Saba.

St. Kitts is also connected directly to the routes from Saba to Long Island and Long Island to Saba. While the eastern side of St. Kitts is often passed via indirect routes to and from Saba, as is the case with many runs from Flinty Bay to Jolly Beach, many pathways would head up the western coast of St. Kitts passing along the northern coast

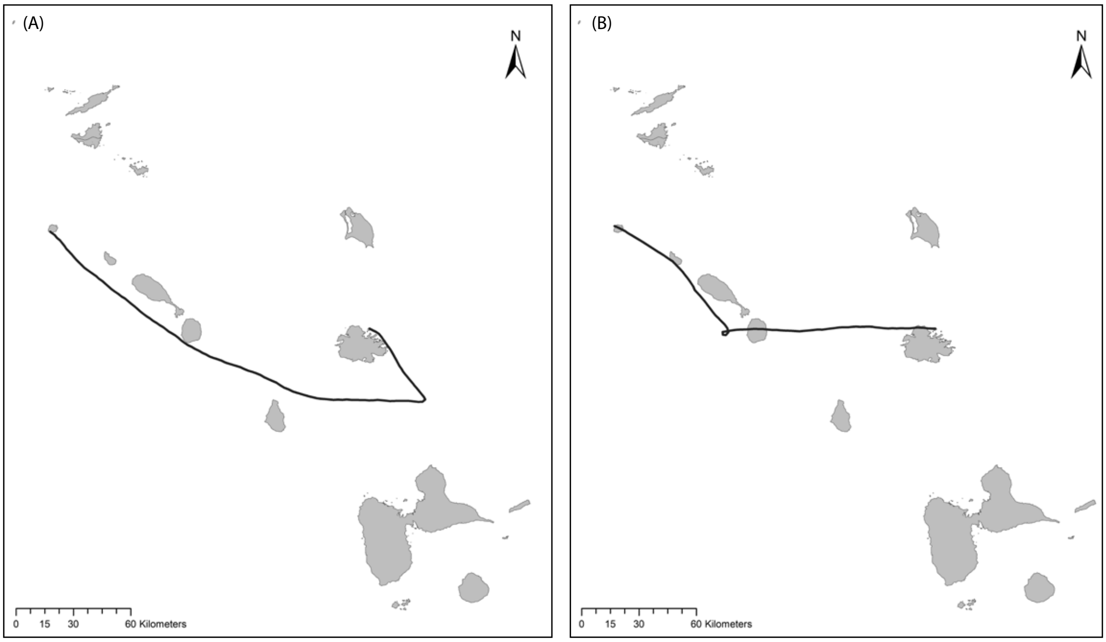


Figure 47: Canoe routes from Long Island to Saba that pass by the site Sugar Factory Pier on St. Kitts. (A): The route launched was launched at 6am on the 27th of May 2012, Route: 0-2_2012-05-27T06, and (B): The route launched was launched at 6am on the 5th of September 2013, Route: 0-3_2013-09-5T03.

of Nevis. Moving along the western edge of St. Kitts also ensures that routes went past the site of Sugar Factory Pier. These routes thereby establish that the site of Sugar Factory Pier on the west coast of St. Kitts is connected into a broader exchange network (*e.g.*, route 0-2_2012-05-27T06, and route 0-3_2013-09-05T03; see Figures 47 A and B). Routes from Long Island to Saba had a higher probability of passing by the west side of St. Kitts and Nevis in December (*e.g.*, route 0-2_2013-12-02T15). Most December routes that run through this layout occur in 2013. The modeled routes from December also showed a tendency for canoe routes to cross by the north coast of Nevis and the west coast of St. Kitts (*e.g.*, route 0-2_2013-03T18).

However, there are indirect routes that run towards the extent of the central space between the islands in the winter season that are not observed in other months. This includes movement around the north coast of Anguilla past the site of White Heads Bluff (*e.g.*, route 0-2_2012-12-05T6, route 0-2-2012-12-05T18, and route 0-2_2012-12-29T21). Canoe pathways rarely pass by this site in other seasons. In fact, it occurs in less than 20 routes modeled for the entire case study. Routes in December also pass by the underside of Anguilla and the north and east coast of St. Martin (*e.g.*, route 0-2_2012-12-19T0). Other pathways demonstrate the canoe routes' connection with the south side of St. Martin, most notably near Baie Orientale (*e.g.*, route 0-2_2013-12-17T03).

When modeled canoe routes head towards Saba from Long Island they sometimes pass the western side of Nevis (*e.g.*, route 0-2_2012-05-27T3, route 0-2_2012-12-04T3). However, Hitchman's Shell Heap, located on the eastern side of Nevis, is currently the only site on the island that dates to the Archaic Age (Wilson *et al.* 1991). The fact that many sites elsewhere in the region lie off constructed canoe routes indicates there may have been Archaic Age sites or rest areas on both sides of the island. Real-world canoers who may have been following similar routes moving past the island were under no obligation to stop, suggesting that stopover locations indicated by these possible routes are also hypothetical. More research should be done on Nevis to investigate if there is a site that corresponds to the layout of these routes. It is possible that there is a site on the island that has a comparable placement or that played a similar role to Sugar Factory Pier on St. Kitts as a possible connection point for the distribution of materials and rest area for canoe crews.

Least-cost route travel corridors that move further north into the middle of the northern Lesser Antillean island cluster often pass by the islands to the north when crossing from Long Island to Saba. In fact, all months have routes that move further north into the channel (see Appendix B). These routes sometimes headed by the eastern side of St. Eustatius when moving between Flinty Bay and Plum Piece (*e.g.*, route 0-2_2011-09-13T09, route 0-2_2013-10-18T6, route 02_2011-11-15T00, and route 0-2_2012-04-03T06). The western side of the island is also passed (*e.g.*, route 0-2_2012-9-4T12, route 0-2_2012-09-04T18, route 0-2_2013-10-16T12, and route 0-2_2011-05-01T0). Movement north towards St. Martin is most notable in April and August, and least in February (see Appendix B).

Canoe routes modeled in March, April, and May were more consistent. Many modeled pathways from Long Island head north of Saba before meeting Plum Piece (see Appendix B). Routes during this period sometimes connect with the eastern edge of St. Martin (*e.g.*, route 0-2_2011-05-11T18, route 0-2_2012-05-19T12, and route 0-2_2013-5-21T18) or with the island's southern coastline (*e.g.*, route

0-2_2012-04-18T21, route 0-2_2012-05-25T6, route 0-2_2013-5-27T15, and route 0-2_2013-5-30T15). In rare instances, these routes run along the entire north coast of the island (*e.g.*, route 0-2_2012-04-26_T3). Additional pathways merely move towards St. Martin (*e.g.*, route 0-2_2012-05-12T21, route 0-3_2012-05-12T21) or pass directly by its east coast (*e.g.*, route 0-2_2012-05-15T21, route 0-2_2013-05-14T9). On some occasions, the routes traveling between Long Island and Saba detoured past the coast opposite the site of White Head's Bluff on Anguilla (*e.g.*, route 0-2_2011-03-24T6, route 0-2_2011-03-24T18, route 0-2_2011-03-27T3, route 0-2_2012-04-27T3, route 0-2_2013-05-23T21, and route 0-2_2013-05-31T21). In very few cases, pathways run right by the site (*e.g.*, route 0-1_2012-04-22T9). As with St. Kitts, the removal of the island from the cost surface is not fully functional in these images, and these later routes may not be wholly accurate. Routes also connect with the island of La Désirade in a similar fashion to indirect routes from Flinty Bay to Jolly Beach (*e.g.*, route 0-1_2013-05-05T12).

Pathways heading north from Long Island had a greater chance of meeting with the coastlines of different islands than routes leaving Antigua, though which coastlines they encountered varied depending on the canoe season in which they were run. In September, October, and November optimal routes heading from Long Island to Saba tended to move north towards St. Martin (*e.g.*, route 0-2_2013-10-20T03, route 0-2_2011-11-23T00, and route 0-2_11-14T12). Three routes in November even meet the east coast of St. Martin near the site of Etang Rouge and Norman Estate (*e.g.*, route 0-3_2012-11-01T21, route 0-2_2013-11-9T21; route 0-2_2013-11-19T09; see Figures 48 A, B, and C). Other canoe routes during November head up to Baie Orientale before turning south towards Saba (*e.g.*, route 0-2_2013-11-19T9; see Figure 48 C). One pathway connects with the south end of Anguilla (*e.g.*, route 0-3_2012-11-01T21). Sometimes northerly run routes originating at Long Island pass close to Barbuda and pathways close to Barbuda typically fall near the River Site (*e.g.,* route 0-2_2012-08-23T0, route 0-2_2012-11-10-10T9, and route 0-2_2012-08-20T12).

Reminiscent of travel in the winter season, routes heading east from Saba to Long Island in March ran through the center of the northern Antillean island cluster (*e.g.*, route 0-3_2011-04-14T15). Routes rarely extended north of Barbuda's latitude, though some passed by the island of St. Eustatius where the current had them keeping a southeastern trajectory. A few pathways run along the south coast of the island (*e.g.*, route 0-2_2011-04-15T21). Other routes towards Saba also moved east, before traveling under Antigua, past Jolly Beach, before reaching their destination (*e.g.*, route 0-3_2013-10-01T09, route 0-2_2012-11-07T03).

Even when moving between Flinty Bay and other nodes, a preference for Saban connections is sometimes shown in a route's trajectory. When traveling to Nevis from Long Island in April several canoe routes overshoot their destination and bypass, or loop, around Saba (*e.g.*, route 0-9_2012-04-01T18, route 0-9_2012-04-03T21). Overlap with the Saba Bank is also observed in a few of these routes (*e.g.*, route 0-9_2012-04-05T12, route 0-9_2012-04-07T0). A crew's access to the fishing resources around the Saba Bank could have made pathways like these preferable. Routes that run through the Saba Bank mirror connections between Nevis and Saba that occur for routes heading from Flinty Bay to Plum Piece. The hypothetical pathways suggest a deeper connection between these three islands.

The layouts of these least-cost routes indicate that crews looking to engage in lithic exchange with Long Island could have structured their journey to benefit from seasonal advantages or the direction of current flow. Connections between canoe routes and the islands of Nevis and St. Kitts strongly suggest that these northeastern sections of coastline may have been utilized as stopover points by crews that could have followed routes similar to the least-cost pathways modeled towards Saba. In fact, though not viewed as a major player in the regional exchange of Long Island flint, the tendency of these routes to run past St. Kitts and Nevis suggests these islands should be further explored.

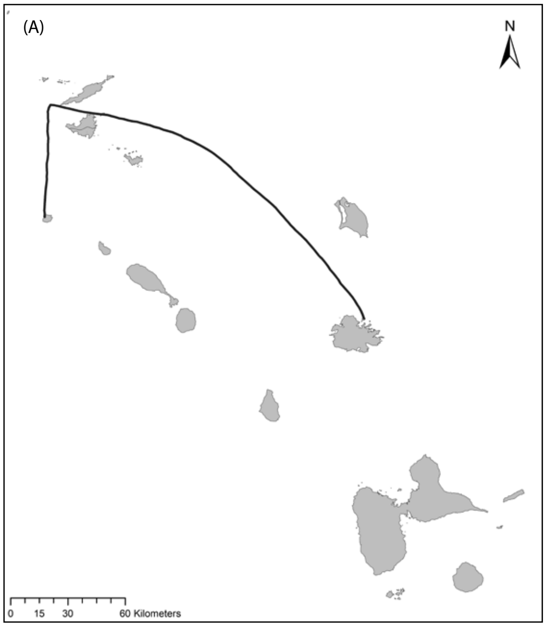
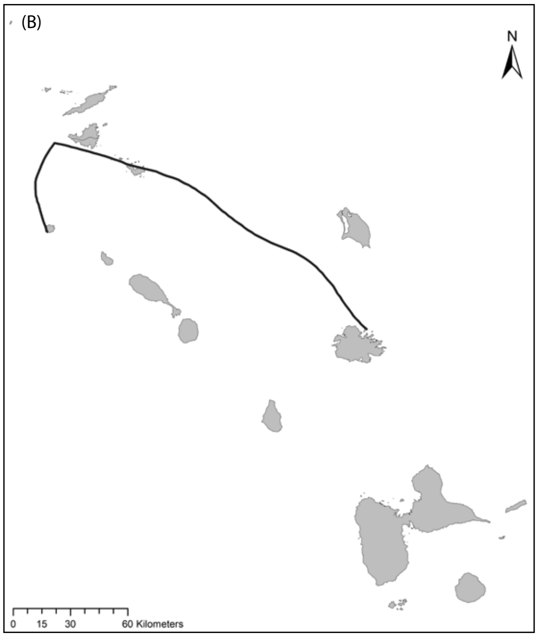
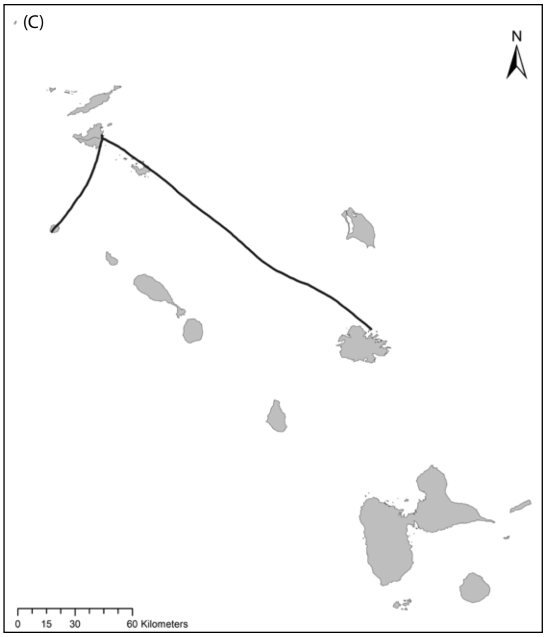


Figure 48: Movement from Long Island to Saba that passes by the St. Martin sites of Etang Rouge, Norman Estate, and Baie Orientale. (A): The route launched was launched at 9pm on the 1st of November 2012, Route: 0-3_2012-11-01T21, (B): The route launched was launched at 9pm on the 9th of November 2013, Route: 0-2_2013-11-09T21, and (C): The route launched was launched at 9am on the 19th of November 2013, Route: 0-2_2013-11-19T09.





This is also the case for St. Eustatius. In fact, many of the routes that pass by this island on their way to Plum Piece go directly past the site of Corre Corre Bay. The location of Corre Corre Bay could have been selected to take advantage of the Long Island to Saba route, either in terms of access or visual and physical relationships. Visual connections from and to passing canoes may have connected peoples living at this settlement to the broader rhythms of exchange or seasonal mobility that moved through the region. It is also possible that these visual connections translated into a form of influence over these travel corridors. If these modeled pathways were in use, canoers passing between Saba and Long Island may have been tied more closely to peoples living on St. Eustatius with whom they were in direct visual contact. This is juxtaposed to relationships with other island communities, like on Anguilla and Barbuda, with which there was no direct visual contact.

Similarly, routes traveling on this path would not have had to deviate much to reach the island, unlike routes from St. Martin or Anguilla. The cost of moving past this island is not widely different from passing further north in the channel. Further evaluation of the materials found in the assemblages at Corre Corre Bay and Plum Piece could tell us whether these islands are more closely linked than others in the region. More research into potential sites on the southern coast of St. Eustatius should be carried out to determine if there are any Archaic Age sites that could connect both with movement from Plum Piece and Long Island. An analysis of the assemblages of these south coast sites could also be compared with those from Corre Corre Bay to further connect this site with regional exchange.

The sheer number of indirect routes that run past Anguilla and St. Martin demonstrates that the sites of White Head's Bluff, Baie Oriental, and Norman Estate could be tied to communities on Saba. Future research along the edges of coastline passed by routes modeled here may determine if there are any Archaic Age sites that have as yet not been uncovered. Furthermore, comparisons of assemblages from these sites could enable us to see if there are any materials that indicate a strong outward connection with island communities to the west.

Seasonality is visible in route layouts between Long Island and Plum Piece. The best time for traveling directly, with the least indirect routes, is in winter between December and February. The best time to take advantage of indirect routes is between April and July. The dichotomy between January and April suggests that comparing these periods can be used to assess the possibility of traditional views of sailing months. In keeping with themes established in earlier research (Callaghan 1999; Hofman *et al.* forthcoming; Slayton 2013), the remaining routes analyzed for this study will be run in January, April, July, and October.

5.2.2.6 Flinty Bay and Other Sites

This is not to say that Plum Piece is the only site on the edge of the northern Lesser Antillean cluster that encourages stopover points or indirect and stopover connections. As mentioned above, the distances between Long Island and Saba to the east are matched by travel from Long Island to islands in the north. Crews navigating these optimal routes, or pathways with similar trajectories, traveling north may also have prioritized pathways with stopover potential. Routes between Long Island and the site of Baie

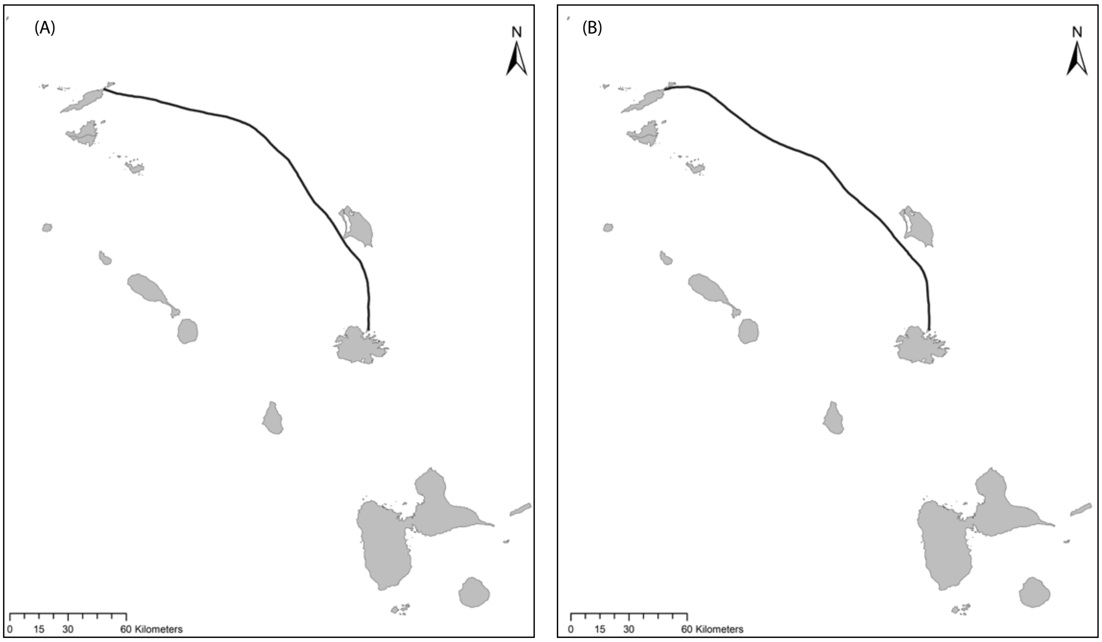


Figure 49: Routes from Long Island to Anguilla that pass by Barbuda and the River Site. (A): The route launched was launched at 12am on the 3rd of April 2013, Route: 0-4_2013-04-03T00 and (B): The route launched was launched at 3pm on the 27th of April 2013, Route: 0-4_2013-04-27T15.

Orientale on St. Martin often went past Barbuda (*e.g.*, route 0-8_2013-04-11T18). Barbuda's River Site may have provided a convenient stopping place.

Barbuda could also act as a stopover on least-cost routes between Flinty Bay and White Head's Bluff. Pathways running from Long Island to Anguilla sometimes went by Barbuda's River Site as well (*e.g.*, route 0-4_2013-04-3T0, route 0-4_2013-04-27T15; see Figures 49 A and B). Voyages from White Head's Bluff to Jolly Beach on Antigua arc sharply just below the site (*e.g.*, route 1-0_2012-01-01T15). Barbuda is passed more often when Flinty Bay is the start point. This is congruent with Long Island's position almost directly south of the River Site.

Many of these routes' arcs comply with the common-sense curved or 'banana' technique used by experimental canoers (Bérard personal communication 2014). Currents running through this area may have influenced the modeled routes' outcome and may reflect the canoer's 'choice' to pivot in this location. The change in the arc or pivot-position to above or below Barbuda shows the seasonal influence on moving from Anguilla to Long Island and vice versa. Pivots above the island occur in October and below in January. Curving east away from St. Martin, the route only turns west when parallel with the island. Thus, if actual canoers were following similar routes, the current may have done most of the work for the crews at the end of this voyage (*e.g.*, route 0-8_2013-04-11T18). Other routes to Baie Orientale are pushed further to the west before redirecting towards the site, which would have made connecting with St. Martin more difficult.

Some modeled routes suggest that site location was tied to Amerindian sea travel corridors. For example, routes moving from Flinty Bay on Long Island to Sugar Factory Pier on St. Kitts sometimes traveled past Barbuda (*e.g.*, route 0-10_2013-04-11T03, route 0-10-2013-04-11T9). These pathways either directly connect with the island or sweep past its southern coast. Though they make landfall near Coco Point on Barbuda, the routes turn back towards St. Kitts once they pass near the River Site. Canoers may have stopped here if they needed a rest or more supplies. The River Site is well placed to take advantage of these routes alongside the pathways from Flinty Bay to Plum Piece mentioned above.

Routes from Flinty Bay to Sugar Factory Pier link Long Island and Barbuda in ways that pathways to Plum Piece do not and highlight the possibility of a connection between Barbuda and St. Kitts. More research into the archaeological material collected at sites from both islands is necessary for this theory to be confirmed. Several least-cost pathways towards St. Kitts went past Montserrat (*e.g.*, route 0-10_2013-04-22T0; see Appendix B). These routes passing in-between islands indicate that movement away from Long Island fostered indirect or stopover exchange between several sites in the archipelago. Connections with these islands also hint at the importance of stopover points along routes.

Though a logical aspect of canoe voyaging, the stopover phenomenon played a larger role than expected within the analysis of these modeled routes. These in-between, indirect, or stopover connections could have extended to routes to and from Antigua's west coast. As mentioned above, when moving towards Jolly Beach from Long Island there is a higher chance of moving towards St. Kitts in January (*e.g.*, route 1-0_2012-12-27T09). Movement from the north of the northern Lesser Antilles island cluster, particularly Anguilla, in July and October shows a higher chance of passing by the east side of St. Kitts and Nevis and making contact with the coastline near the site of Hitchman's Shell Heap on Nevis (*e.g.*, route 1-2_2012-10-12T9). Movement from Long Island in these autumn months is more direct, with few arcing routes. As such, where and when the voyage terminates can influence what islands a canoe crew passes on the way to their final destination. Likely these factors had implications for the structure of Amerindian navigation maps.

5.2.2.7 Saba and Anguilla

It is possible that crews traveled between islands without moving to or connecting with Long Island. Canoers could have been looking to exchange flint as a part of the short-hop process, or seeking out seasonal resources available by taking advantage of travel corridors passing by the coastlines of other islands. Amerindian navigators would have been versed in how to move between these islands as well, if only to recalibrate direction after resting at a stopover point. Routes leaving from and arriving at Saba can provide examples of connections between islands in the northern Lesser Antilles that did not run through Long Island.

Least-cost routes from Plum Piece to White Heads Bluff typically sweep along the coastline of St. Martin. Pathways making the reciprocated journey follow the same trend. This is in keeping with the common-sense sailing technique of prioritizing movement along an island's coastline. These routes reflect that real-world canoers traveling from Saba to Anguilla may have had the opportunity to choose to move to the right or left side of St. Martin when making this trip (see Appendix B). Some of the pathways run next to Etang Rouge, close to Norman Estate, or pass by the site of

Baie Orientale (see Appendix B), linking the routes to known Archaic Age sites. (see Appendix B). Modeled canoe routes running past these sites suggest that these areas had stopover potential. It is also possible that these sites were founded in these locations to take advantage of existing routes between Saba and Anguilla.

As reciprocal connections from Whitehead's Bluff to Plum Piece always include St. Martin, it is possible that the island acted as a broker for interaction between communities on Anguilla and Saba. The placement of Norman Estate and Baie Orientale further indicate the sites could have exerted influence over canoers following similar routes passed St. Martin to those least-cost pathways seen here. How this possible influence manifested itself is unclear. Genesis of these communities could have centered on wanting to be a part of the network or to influence use of these pathways.

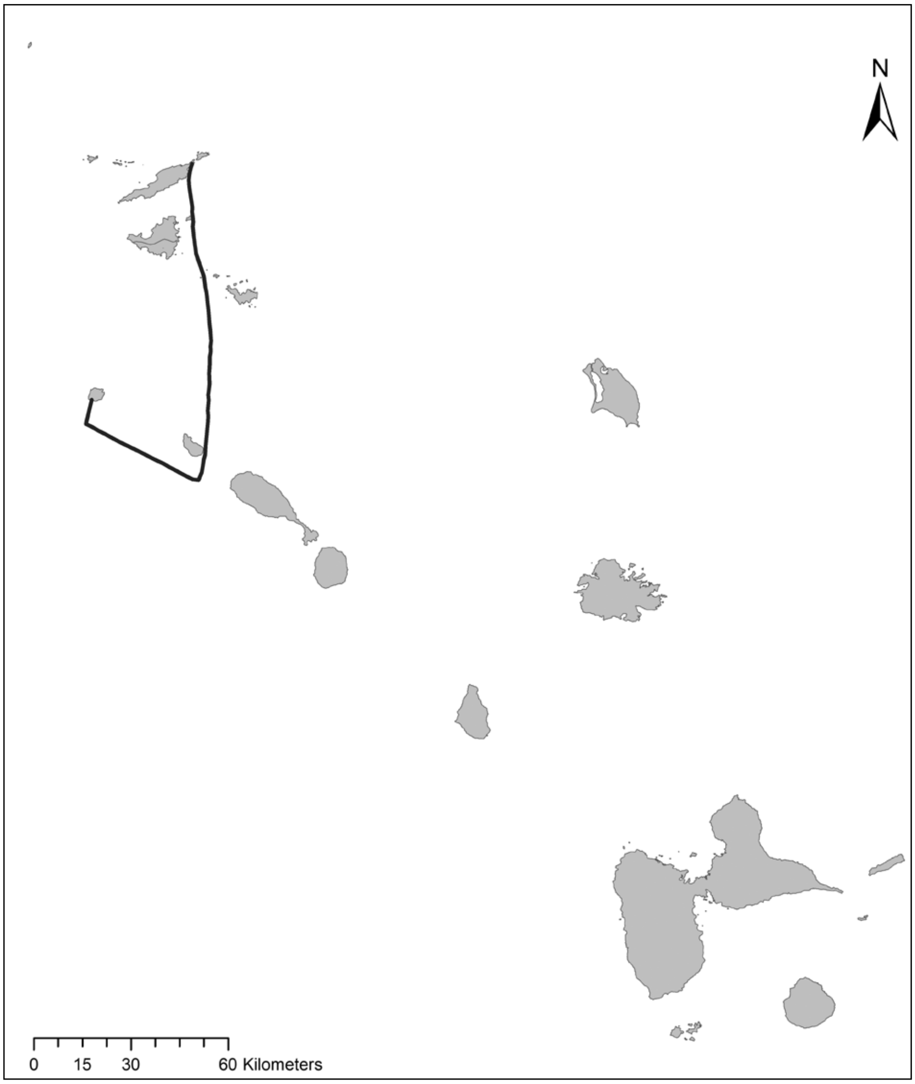


Figure 50: Routes from Anguilla to Saba that pass by the island of St. Eustatius. (A): The route launched was launched at 9am on the 14th of October 2012, Route: 1-3_2012-10-14T09.

When moving from Anguilla to Saba, routes sometimes loop past Corre Corre Bay on the far side of St. Eustatius (*e.g.*, route 1-3_2012-10-14T9, route 1-3_2012-10-16T3; see Figures 50 A and B). Similar routes from White Head's Bluff on Anguilla pivot north of Corre Corre Bay before heading west to Saba (*e.g.*, route 1-3_2013-07_15T6). This tendency shows another reciprocal connection between Anguilla, St. Eustatius, and Saba. It is possible that movement to and from Anguilla also marked it as a connection point for communities traveling around the northern Lesser Antilles. More work should be done to examine archaeological and modeled route connections between Anguilla, St. Eustatius, St. Martin, and Saba to determine if the specifics of these island links can be uncovered.

5.2.2.8 Visiting Saba through Other Islands

Plum Piece on Saba has been proposed as a major player in the lithic exchange network of the northern Lesser Antilles (Hofman *et al.* 2006, forthcoming). Its placement close to the Saba Bank and its role as a possible canoe producer make it a key figure for analysis in the current research. Its distance from the pivotal site of Flinty Bay makes Plum Piece a contender for supporting additional or indirect links to other islands, as discussed above.

It has been suggested that canoers leaving Long Island may have headed for Anguilla or St. Martin before turning to visit Saba (Hofman *et al.* forthcoming). These possible side connections are supported by the modeled routes discussed in the previous two sections. Routes that optimize multiple connections include pathways generated for several seasons (in March routes, *e.g.*, route 0-2_2011-03-19T21, route 0-2_2011-03-21T12, route 0-2_2011-03-23T03; in May route 0-2_2012-05-02T14, and route 0-2_2012-05-19T12; in September routes, *e.g.*, route 0-2_2011-09-8T21_00, route 0-2_2011-09-09T12, route 0-2_2011-09-20T15, and route 0-3_2011-09-09T12; in November routes, *e.g.*, route 0-2_2011-11-01T03; see Figures 51 A, B, C, and D). These pathways head north before arcing alongside the north coast of St. Martin, past the sites of Norman Estate and Baie Orientale, before heading south to Saba. Routes from Long Island to Saba that pass through the islands in the north of the cluster suggest that under the right current conditions Anguilla would also have been an important locus in an extended circular multi-seasonal route. The November pathways (*e.g.*, route 0-2_2011-11-26T12, route 0-3_2011-11_01T3, and route 0-2_2012-11-01T21) demonstrate this, as the routes run into the south side of the island.

Amerindian navigators almost certainly knew of these routes and could have used them as links between Long Island and Saba. These extended multi-island routes probably affected the distribution of materials found between Long Island, St. Martin, and Saba (Knippenberg 2007). The presence of worked cores that reached Saba may have passed through other islands first, expanding the area in which flint that reached Plum Piece may have been knapped (Hofman 2003). The routes that run north from Flinty Bay also hint at Barbuda's River Site as a stopover point in these multi-stop multi-seasonal routes.

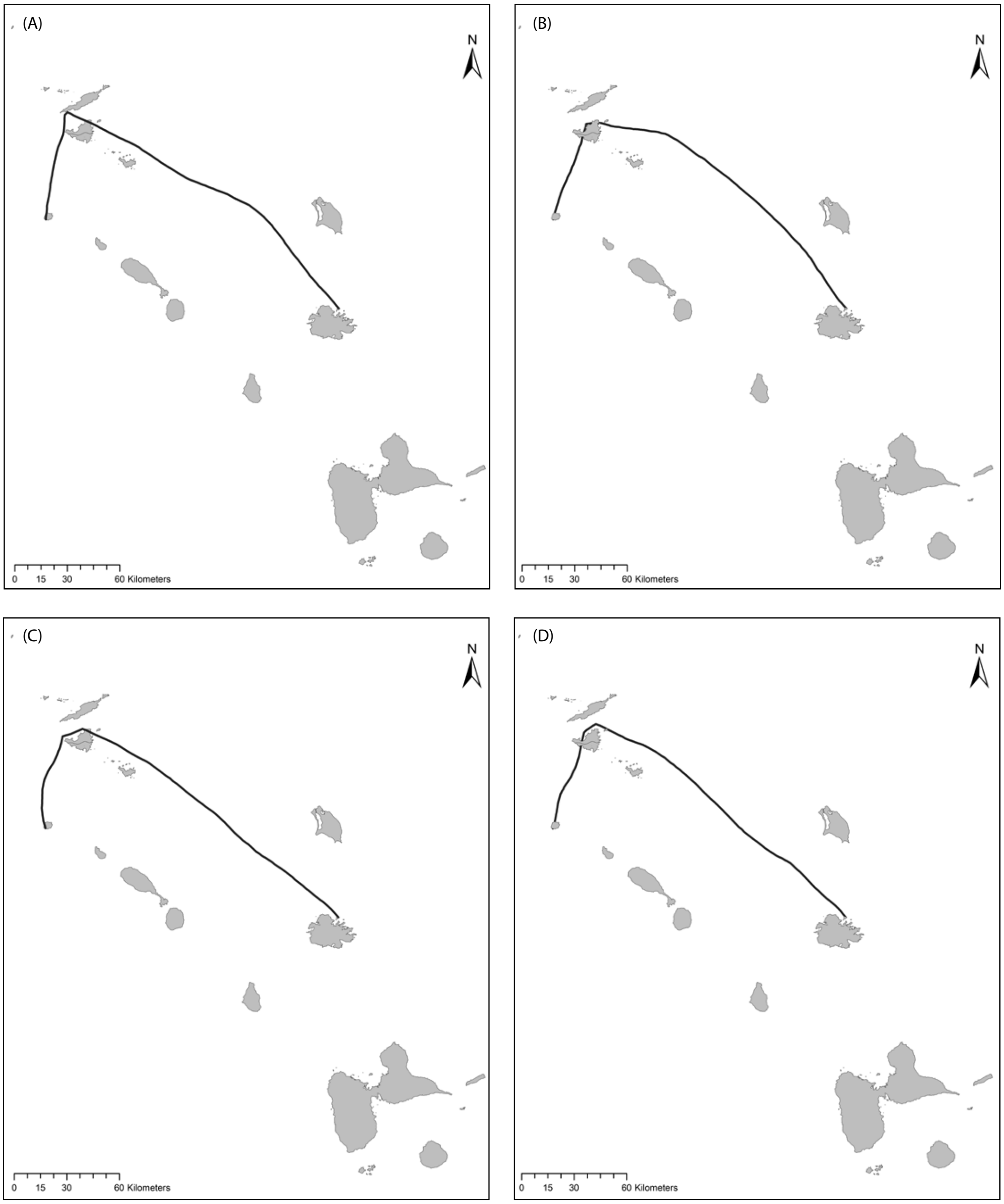


Figure 51: Routes from Long Island to Saba that pass by Anguilla and St. Martin. (A): The route launched was launched at 12pm on the 21st of March 2011, Route: 0-2_2011-03-21T12, (B): The route launched was launched at 12pm on the 19th of May 2012, Route: 0-2_2012-05-19T12, (C): The route launched was launched at 12pm on the 9th of September 2011, Route: 0-2_2011-09-09T12, and (D): The route launched was launched at 3am on the 1st of November 2011, Route: 0-2_2011-11-01T03.

5.2.2.9 Guadeloupe

Although not initially included in this case study, the generated models show that the islands of Guadeloupe and La Désirade seem to be heavily connected to communities traveling to and from Flinty Bay. Known Archaic Age sites on and around Guadeloupe are clustered towards the bottom half of the big island and the small islands that lie directly south (Beets *et al.* 2006; Hofman *et al.* 2014; Keegan and Hofman 2017), including the sites of Pointe des Pies and Anse à La Gourde as well as the island of La Désirade (see Figures 42 A, B, and C; Appendix B). Later sites like Anse à La Gourde on the tip of Pointe des Chateaux and those found on La Désirade dating to the Ceramic Age suggest that connections between Antigua and Guadeloupe began in earlier periods (Beets *et al.* 2006; de Waal 2006, 2014; Hofman *et al.* 2007; Hofman and Hoogland 2011; Knippenberg 2007).

Flint from Long Island and greenstone from St Martin crossed these waters to Guadeloupe, supporting the existence of earlier connections (Bonnissent 2013; de Waal 2006; Hofman and Hoogland 2011; Knippenberg 2007). The routes mentioned above suggest that the coastlines around Guadeloupe and La Désirade could hold more evidence of Archaic Age settlements, information which is valuable to archaeologists seeking to explore this region. Pathways between Archaic Age sites that pass these islands suggest the placement of the later sites. Amerindian seafarers moving to and from Flinty Bay on Long Island could have learned of these convenient stopping points through canoeing misadventures and thereby included them in a navigational mental map. The occupation of these sites following the Archaic Age could be signs of their inclusion in the mental wayfinding map of northern Lesser Antillean canoers.

5.2.2.10 Realistic Navigation

Many of the routes produced by the model display elements of real-world sailing techniques fitting with practices used by small vessels in the northern Lesser Antilles, confirming the validity of using this least-cost approach. For example, modelled routes seem to favor passing island coastlines when possible. Movement along the western coast of islands in the northern Lesser Antilles fits with sailing techniques that dictate taking shelter behind an island when possible.

Some crews may have chosen to use passing island coastlines to their advantage. Modeled journeys from the St Kitts' site of Sugar Factory Pier began by hugging the coast going north. These routes remain protected against the currents and winds passing through the channel. Tactics like this are in line with modern seafaring techniques (Bérard personal communication 2014; Billard *et al.* 2009). However, in some cases (St. Kitts route 1-2-2011-01-05T14_24), modeled routes from St. Kitts suggest that canoes would have moved west in the Caribbean Sea before turning around and heading north over the island to reach Long Island, which may have affected the level of protection offered by the coastline of St. Kitts.

As mentioned above, it is important to highlight the curved route, or banana effect, when discussing common-sense sailing techniques (Bérard personal communication 2014). Curves or arcs appear in many of the modeled pathways. Canoeing into the current at the beginning of a trip pushes the vessel towards the coastline of the destination island. This would allow canoe crews to avoid having to fight against the current when the paddlers would have been most tired. It is a common technique applied in experimental voyages (Bérard personal communication 2014). Movement in this fashion allows the current to push the seafarer into the site at the end of a run, saving the crew's energy for the channel crossing. Curved routes also make voyages safer. They ensure the vessel is being pushed in the direction of land. The presence of arcs within canoe pathways legitimizes the validity of these routes. One conflicting example of this phenomenon within the model is in reciprocal travel from Long Island to Barbuda. As observed in route LI 0-12-2011-01-04T19-12, route LI 1-2-2011-10-06T19_12, and route LI 1-2-2011-01-06T09_36, the movement towards Barbuda shows a curve into the current. However, the majority of pathways to Long Island show a curve with the current. The safer option for any actual crews attempting similar voyages would be from travel Long Island to Barbuda as movement with the current taxes canoers' strength less.

Pathways towards and away from Barbuda provide an exception to this rule, as they seem to follow a straighter, more Euclidean, route through the center of the channel. This is because the model aligns with the current moving west past the northern Lesser Antilles (see Figure 31). When moving into the current, or towards Barbuda, the route bows south. When moving with the current, or away from Barbuda, the routes tend to arc in the north. Like arcs that connect Barbuda to Long island, the shape largely depends on whether the terminal point is found to the north or south. This pattern of the apex of the route arc being on the west side when travelling south and to the east when travelling north is also apparent when looking at canoe pathways to and from Long Island's Flinty Bay and White Head's Bluff on Anguilla. The trend also emerges in pathways from Long Island to St Martin. These routes are bowed with the arc to the right towards Barbuda (Antigua route 0-6-2011-28T14_24). Routes closest to Barbuda when moving from Long Island to Anguilla (Antigua route 0-4-2011-01-06T09_36).

When observing the path's curve towards Barbuda in the spring season, the pathway typically goes to the right or left of a straight line between the start and end points. Broad-scale bowed routes can be seen in route 0-2_2011-9-8T21 and route 0-2_2012-9-02T03 that connect Flinty Bay, Long Island to Plum Piece, Saba. These routes parallel Barbuda before heading west and pushing into Saba's eastern coast (see Figure 49; Appendix B). The position of the outermost point of the curve varies; if these right or left arcs occurred sporadically for any real-world voyages there was a greater risk to canoers. Amerindians paddling these canoes could not rely on the consistency of the current's flow. This reduced consistency would have lowered the ability of the crew to carry out a successful voyage.

The placement of arcs along these routes in the models represents a real-time reaction to the current. However, crews that wanted to cross the distance from Saba to Long Island also had to plan whether they would arc to the north or the south ahead of time. The model's approach to analyzing multiple routes across the same surface and selecting the least-cost route could represent canoers knowledge of where it was beneficial to push against the current and where it was better to let the current push the boat. More research needs to be done in comparing these bowed routes to real-world navigation strategies.

As I evaluated route trajectories it became clear that current force can push in the same direction for short periods. Here, though the pathways arcs may not terminate at the same location, the current force direction can be consistently seen. Thus, when looking at routes that make landfall or arc in the same general area, times can be viewed as a micro-seasonal sailing period. Similar trajectories of extreme routes between Flinty Bay and Jolly Beach were noted for several micro-seasonal periods. Lasting anywhere from six hours to two days, these periods reflect what are likely to be prolonged weather events. Micro-seasonal periods also suggest that opportunities would be present for long-distance travel between two islands at various points during the year. I assume that the navigational prowess and knowledge of Amerindian canoers would have allowed crews to take advantage of these opportunities, which can be observed in some of the least-cost routes modeled for this case study (*e.g.*, route 0-1_2013-10-01T15 to route 0-1_2013-10-01T21).

Micro-seasonal periods could facilitate voyages, as they may have enabled crews to read periods of wave movement and more accurately follow a wayfinding map. These periods in part result from consistency in indirect routes. One example of this type of stabilized route trajectory and seasonal push is seen when moving from Flinty Bay to Plum Piece. Here, routes between these islands pass along the western side of St. Kitts leaving between 3 am and 6 am on the May 27, 2012. Another instance of this indirect-route stabilization comes from routes modeled on May 2 leaving between 6 am to 3 pm. These routes from Long Island to Saba pass by St. Martin. This represents nine hours of consistent movement north away from the target towards other sites in the case study. However, routes modeled over this micro-season do not connect with St. Martin in the same way. The pathways hit the southeastern coast (*e.g.*, route 0-3_2012-05-02T09), the southwestern coast (*e.g.*, route 0-3_2012-05-02T12), and travel over the northern side of the island past the sites of Norman Estate and Baie Orientale (*e.g.*, route 0-3_2012-05-02T6, route 0-3_2012-05-02T15). These links could have been noticed by past canoers and used by navigators to determine what currents should be followed to reach what islands.

Micro-seasonal consistency can also be seen in an example of movement linking Long Island and St. Kitts from April 10 at 9 pm to 12 pm on April 11 (*e.g.*, route 0-10_2013-04-10T21 to route 0-10-2013-04-11T12). Between these times all routes are pushed north towards the coastline of Barbuda. Only two runs from this stretch come close to Barbuda. This again suggests that Amerindian canoers could have relied on these persistent currents to reach Barbuda during this period. Navigators with prior knowledge could use these micro-seasons to plan connections between sites. It could also be that canoers were able to read the current well enough to recognize when these short windows of opportunity arose.

The progression of current strength is seen in the comparison of a string of routes. For example, the arc of routes from Flinty Bay to Jolly Beach from March 26 at 3 pm to 9 pm moves further away from Antigua at every time step (*e.g.*, route 01_2013-3-26T15 to route 0-1_2013-26T21). As the strength of the current increases and routes are pushed farther out to sea, adept crews following similar routes would have been able to read the signs and choose to wait until they could pass the island. It is assumed that knowledgeable navigators would be able to avoid being swept out to sea. In choosing and analyzing least-cost routes these aberrant pathways can be ignored.

5.3 Conclusion

Both in the Caribbean and on other global waterscapes, there is a lot left to consider as to the 'when', 'how', and 'where' of connections between island seafaring communities. Instead, I focused on initial exploration, such as whether the regularity of canoe routes could have influenced social connection between islands of the northern Lesser Antilles. When Archaic Age communities had access to certain resources, or resources became available, seasonality could also have influenced what routes canoers took in addition to when and where they chose to travel. If each site is treated as if its inhabitants were part of separate groups, the issue of movement and connection between these sites is complicated.

Judging the consistency of travel over the same month during different years proved more challenging than initially expected. When I began this research, I worked from the assumption that the seasons would line up easily into best and worst travel periods. This has not been the case. In fact, there are parallels between seasonal periods. The consistency in these values is enough to suggest a loosely-linked sailing season, but the results are not conclusive. This can also be said for the variance between launching at different times of year. There is only a slight relationship between launch times, route cost, and route placement.

The largely seasonal nature of site use in this region and time suggests groups made use of the sites mentioned above at different times of year. That movement to and from Long Island was easier from different sites at various times of year could indicate that a system was in place for communities from each site to collect flint seasonally. It is also possible that Amerindian communities were maintained by an extended seasonal circle of movement around the northern Lesser Antilles. To my knowledge there has been no substantial work to organize the seasonal movement of Archaic Age peoples between various islands in such a way as proposed here. Once a larger number of zooarchaeological and archaeobotanical seasonal studies have been executed in the region, it would be useful to return to this analysis and compare results.

Many sites appear prominent within the inter-island network of Long Island lithic exchange. These sites include Flinty Bay, where the resource was collected, and Plum Piece, which has been theorized as a connection point by other researchers (Hofman and Hoogland 2003). Evaluation of route layout between several sites in the region indicates that St. Kitts could also have played a large role in Archaic Age lithic mobility and exchange networks in the northern Lesser Antilles. As of this moment, I am unaware of archaeological evidence or analysis that suggests this island's linchpin status. While routes may not directly influence the placement and connection of sites, the number of indirect routes that pass by known sites leads me to believe that pathway location can link to site location. The placement of modeled routes suggests that pathways were a part of social considerations in the Archaic Age, including site settlement and community interaction.

The routes calculated in this chapter demonstrate places where pathways may suggest stopover connections. If canoers were following similar routes to these least-cost travel corridors, they may have 'broken -up' their voyages instead of only following direct connections between sites. The extent to which these islands engaged with these practices is not known. It is difficult to gauge the number of materials, like Long Island flint, within an assemblage that were traded directly versus indirect trade that may have taken advantage of stopover options to visit other sites. In the past few years, researchers have been considering the issues of lithic sourcing and exchange in the Lesser

Antilles using network models (*e.g.,* Amati *et al.* 2014; Hofman *et al.* 2014, forthcoming; Knippenberg 2007). These models are, as yet, not fine-grained enough to make a clear statement about when seafarers were stopping at several locations and when they were not. As such, sea-based least-cost route modeling is currently one of the only ways to track how and where this movement could have occurred. Hypothetical pathways can at least indicate possible options for stopover connections in various seasons. The indirect routes discussed above are good starting points to evaluate the process of moving materials in the Archaic Age Caribbean.

Stopover points proved to be a fundamental aspect of route layouts. Several sites evaluated as potential links within the northern Lesser Antilles lithic exchange are positioned along routes headed elsewhere. The occurrence of these sites along the modeled least-cost pathways suggests that the location of stopovers and sites involved in the exchange of Long Island flint were connected. These data show that what had been thought of in the past as island-to-island relationships in some cases needs to be re-evaluated as potential island-through-island relationships. Routes between two sites often link three islands allowing for Amerindian peoples to expand their social networks without accruing additional time cost. Amerindian communities may also have sought to take ownership over these routes, allowing for Amerindians living at these sites to exert more influence over these social networks.

Investigations and discussions about potential stopovers points should include seasonality. This region does not display large variations in returned route costs, as reflected in the points evaluated or runs made using either the current tool and the route tool. However, the layouts of the pathways associated with these time costs show that season does influence route trajectory. Throughout the year these northern Lesser Antillean stopover points have a continually shifting status from connected to unconnected, which can be linked to seasonal variations. Canoers could have opted to travel at a specific time of year to take advantage of social or economic opportunities.

When looking at the direct movement between the second and third legs of certain voyages, routes often follow a similar trajectory to those observed in indirect routes. This confirms the prominent influence of current direction on these modeled canoe pathways. Current's effect likely shaped which legs of long distance voyage were undertaken in which seasons. For example, route 1-0-2011-07-12T15 that travels between Jolly Beach, Monserrat, St. Kitts, and by Barbuda may represent only the first two legs in a three- or four-leg voyage. If there were crews that followed the same trajectories as the least-cost routes modeled here it could be after stopping at St. Kitts they would have chosen to head back towards Jolly Beach when currents were more favorable. Perhaps the hypothetical canoers had to wait to head to Barbuda until there was a seasonal current that pushed them closer to the island.

The separate legs of a prolonged multi-island voyage can be checked against seasonally-available resources, such the Audubon's Shearwater that roost on Saba from February to July (Hofman and Hoogland 2003). As discussed above, Audubon's Shearwater and other birds represented food and a way to navigate towards islands and fishing grounds. The routes traveling towards Saba in this season have relatively similar returns to other routes. However, there is a slight ease in movement between Anguilla and Saba in the same period as when birds would be available. Other resources, like the Saba Bank, would have been easy to reach from the site of Plum Piece. Positioned behind the west coast of Saba, the Saba Bank is passed by some routes in this case study. That there may have been canoers traveling through this area is a sign that the Saba Bank was connected to Amerindian seafarers making rounds in the northern Lesser Antilles. Routes also move through the Anguilla Bank in some cases, indicating that this area was also a part of a broader inter-island exchange network. Connections between Saba and Anguilla made by Amerindian seafarers may have incorporated these areas as part of their seasonal movement. Further analysis of species collected from these environments and materials from other islands can shed light on whether routes to Saba and Anguilla were also centered on making use of these resources.

Route trajectories could have also impacted connections between islands in later periods. Archaic Age routes sometimes moved past areas possessing sites from later periods, as evidenced by the connections between Long Island and Guadeloupe. Identifying routes that transcend the Archaic Age can be difficult. In part, this is because several of the sites used during this time continue to function as either lithic source or seasonal encampments in later periods (Hofman *et al.* 2007; Knippenberg 2007). However, the fact that these connections can be seen in modeled routes indicates that the sharing and passing down of wayfinding maps often led to the construction of sites.

From the myriad of possible routes modelled, it is clear that no least-cost route should be taken as the 'one true' path. Instead, canoe routes modeled for this work can be overlaid and compared to suggest a corridor through which canoers likely paddled in the Archaic Age, thus placing weight on the human element. The general layout of these pathways hints at the constancy of these corridors through different periods. This fact likely enhanced the confidence in and accuracy of navigation patterns used by Amerindians. It enabled these seafarers to maintain the connections used as the template for this case study. What is important about this case study to the broader conversation of seafaring in the Caribbean is the focus on route cost between islands. These generated isochrone travel costs can be used to discuss repeated social interaction between peoples and materials from different islands.

6

Modeling Canoeing Across the Mona Passage and the Anegada Passage

Connecting the Greater and the Lesser Antilles

For this second case study, I modeled routes between islands in the Greater and the Lesser Antilles in the Late Ceramic Age (AD 1200 – 1500). Inter-island interaction during this period is attested by archaeological evidence (*e.g.,* Hofman 1993, 1995; 2013; Hofman and Hoogland 2011; Hoogland 1996; Hoogland and Hofman 1999). Ceramic and lithic materials with shared stylistic elements of the Chicoid series show the spread of Greater Antillean social concepts (Allaire 1990; Hofman and Hoogland 2011; Keegan and Hofman 2017). These objects and elements typically relate to the so-called Taíno, the term used to describe culturally and materially linked polities in the Late Ceramic Age Greater Antilles (Rouse 1992), and ritual and associated political ideas that are found in the Lesser Antillean arc (see Curet 2009; Hofman *et al.* 2008a; Hofman and Hoogland 2011; Mol 2013, 2014; Rodríguez Ramos 2010; Rodríguez Ramos and Pagán Jiménez 2006). The ceramic typologies establish both the temporal (the Late Ceramic Age) and geographic (Hispaniola to the northern Lesser Antilles) limits of the sites connected. However, there is limited data available concerning the specific provenance of stylistic elements from the Greater Antilles for any of the materials found in the smaller islands (Hofman and Hoogland 2007; Hofman *et al.* 2008a) and archaeologists have found little to no evidence of Lesser Antillean materials on the larger islands to the east (Knippenberg 2007), nor of reciprocated exchange. Routes modeled between sites across the Greater Antillean/Lesser Antillean divide were used to evaluate what areas or sites facilitated the spread of materials and ideas between the island chains and to propose possible reciprocal links between them.

The possible routes modelled between islands in the northern Lesser Antilles in the previous chapter were also likely known by Greater Antillean voyagers and these voyagers likely included them in an individual's or community's wayfinding map (*sensu* McNiven 2008; Terrell and Welsch 1998). Though not discussed in the previous case study, the networks and routes of exchange established between the islands of the northern Lesser Antilles in the Archaic Age were already connected to sites in the west (Righter *et al.* 2004). Island peoples continued to exchange Long Island flint in the Ceramic Age while adapting their strategies to include new materials and ideas. These components came from beyond the Virgin Islands and Puerto Rico, the initial point of contact with the Greater Antilles from the Lesser Antilles. Whether these inter-island interactions were based on direct contact between Hispaniola and the Lesser Antilles, or mainly occurred through several steps or stops around Puerto Rico and the Virgin Islands, will be evaluated.

For this chapter, I selected route starting points from a series of connected sites drawn from the work of other researchers (*e.g.,* Allaire 1990; Curet 2009; Hofman and Hoogland 2011; Hofman *et al.* 2008a; Keegan and Hofman 2017; Mol 2013, 2014; Rodríguez Ramos 2010; Rodríguez Ramos and Pagán Jiménez 2006), with a shared time frame and similarities in materials that connect the so-called Taíno culture. I placed starting points within the broader context of regional exchange during the Late Ceramic Age to ensure that the resulting models reflected human reality (Curet 2005; Ingold 2000). This broader context safeguards that all routes modeled for this work are linked to known avenues of pre-Columbian Amerindian mobility.

Modeling between sites in 'separate' island chains is a way to evaluate the feasibility of long-lasting linkages across large channels. While these sites may not have been occupied at the same time, they are suggested to have all been involved in the same network of cultural and material exchange (*e.g.*, Hofman and Hoogland 2011; Hofman, *et al.* 2014; Keegan and Hofman 2017). Though these sites span over 300 years of history, their placement along canoe travel corridors suggests the continual use of transportation routes across the Anegada Passage and the existence of a cross-passage mental wayfinding map. The archaeological evidence that links these sites to connected communities provides justification for the creation of least-cost pathways over a longer time span. The long history of these connections (see Hofman 1993,

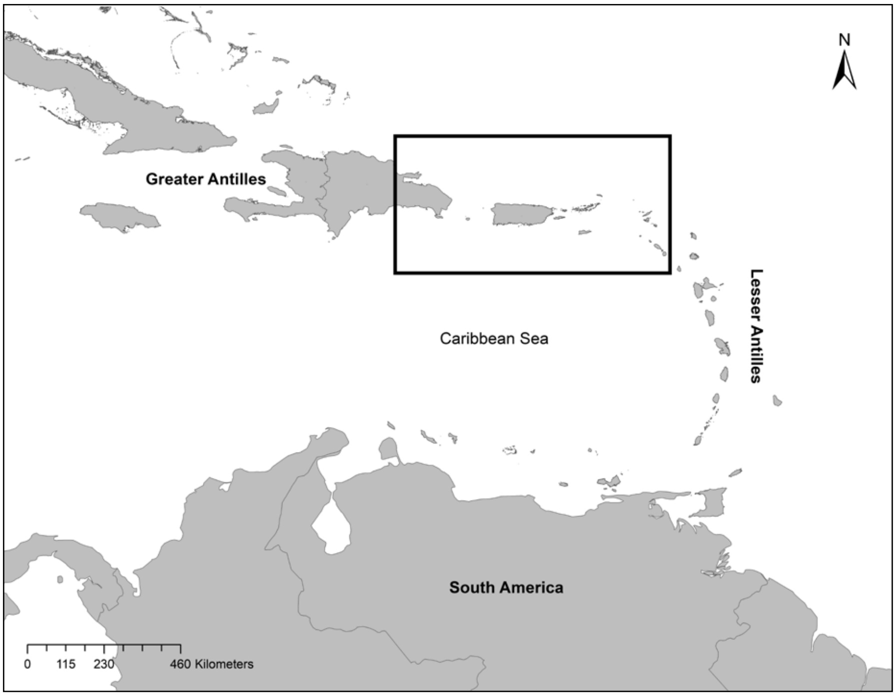


Figure 52: Map of the Caribbean region with the case study region outlined.

2013; Hofman and Hoogland 2011; Hofman *et al.* 2008a, 2008b, 2014; Keegan and Hofman 2017; Oliver 2009; Righter *et al.* 2004) supports the argument that seafarers would have engaged semi-regularly in cross-channel trade.

Sites used as the origin and termination points of these routes were selected for their evidence of interconnection through a review of a range of archeological assemblages and associated analysis of regional networks (Hofman *et al.* 2007; Keegan and Hofman 2017; Mol *et al.* 2015; Righter *et al.* 2004). Due to the lack of evidence for reciprocal exchange and limited presence of these Taíno-inspired objects in Lesser Antillean assemblages, the area of direct and indirect exchange for Greater Antillean materials, objects, and stylistic elements is not well-defined (Hofman *et al.* 2008a; Samson 2010). There is currently no material evidence of cultural influence to show a reciprocal link, or materials from the Lesser Antilles arriving in Hispaniola, between these two spheres. Therefore, archaeologists cannot be certain of the underlying motivations for the structure of social patterns forming these connections (Fitzpatrick 2015; Hofman *et al.* 2008a; Mol *et al.* 2015). While the degree and frequency of these interactions is unknown, a distinction can be made between those routes that connected the Greater Antilles with islands in the north and the islands of the Lesser Antilles in the south. This is likely due to the added difficulty in canoeing over larger distances. This case study, built upon material evidence, includes a basic structure of the Taíno culture from Hispaniola and Puerto Rico to support the mobility of peoples, materials, and ideas. The current research also expands on the background for some sites that were included as points in the case study. The hypothesis of reciprocal links between sites in the northern Lesser Antilles and sites in the Greater Antilles can be furthered, as there are no confirmed points of direct contact between them. The aim of this case study is to evaluate whether digital modeling can uncover possible travel corridors for moving of peoples, materials, and ideas in and out of the Greater Antilles.

6.1 Connecting the Greater Antilles and Lesser Antilles

Many archaeological studies have looked for ways to identify interaction between Amerindians of the Greater Antilles and the Lesser Antilles (see Allaire 1990; Crock and Petersen 2004; Hofman *et al.* 2008a; Whitehead 1995). By analyzing hypothetical reciprocal canoe routes that would have carried materials between islands, I suggest that materials and ideas were being moved across the Anegada Passage as a part either of one-to-one relationships or through multi-stage routes. I am evaluating what modeling reciprocal one-to-one relationships can reveal about direct and possible indirect exchange patterns.

In this case study, I analyzed the time cost and trajectory of reciprocal voyages to identify possible routes for the movement of archaeological materials. The physical structure of the islandscape changes by including islands across the Anegada Passage (*sensu* Broodbank 2000). The longer shape of the archipelago becomes apparent as the islands now appear to be spread out in a chain. While the northern Lesser Antilles are connected through a continuous visual progression, the Anegada Passage divides the northern Lesser Antilles and the Virgin Islands, breaking up a canoer's viewshed.

At a little over 100 kilometers, the Anegada Passage is one of the few visual breaks between Caribbean islands (Friedman *et al.* 2009). This passage would represent the most challenging point for voyaging. At its center, canoers would lose land-connected

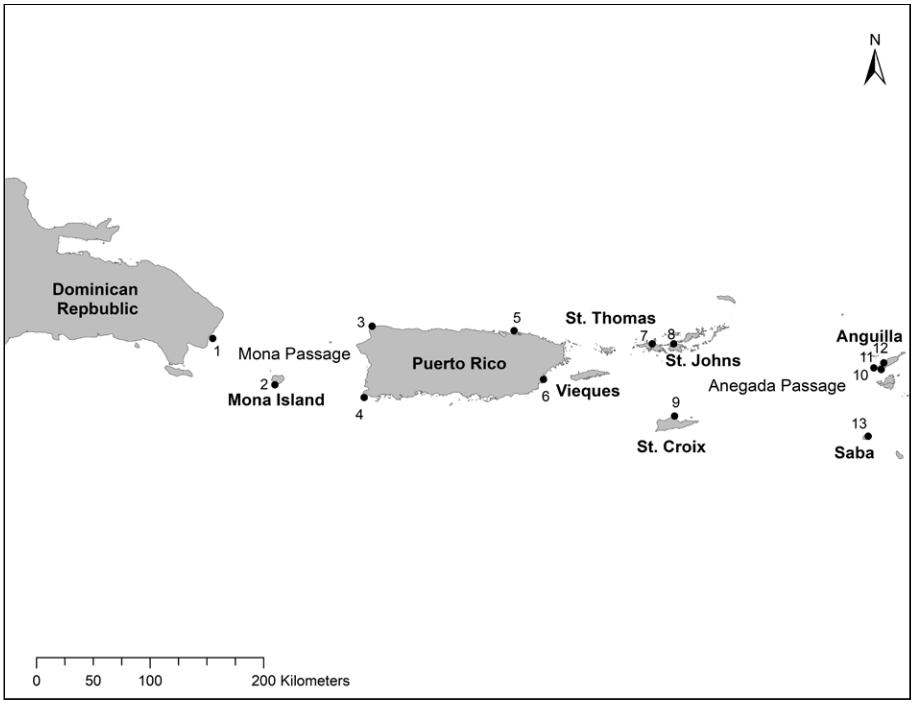


Figure 53: Map of the case study region. Points are as follows, 1: El Cabo, 2: Mona Island egress point, 3: Aguadilla Pueblo, 4 near Bajo Casabe in Cabo Rojo, 5: Punta Las Marias, 6: Punta Candelero, 7: Tuto, 8: Cinnamon Bay, 9: Salt River Site, 10: Barnes Bay, 11: Rendezvous Bay, 12: Sandy Ground, 13: Kelbey's Ridge Site.

cues and would have had to rely on other techniques and knowledge to navigate. These tactics would have included celestial navigation and watching for changes in current patterns, storms, or birds on the horizon (Agouridis 1997: 16-18; Bérard 2012; Bilić 2009; Billard *et al.* 2009; Fitzpatrick 2013; Lamarche 1993; Lewis 1994; Torres and Rodríguez Ramos 2008). These wayfinding techniques can only be observed indirectly using the model, due to the tool's focus on environmental factors. Canoe routes generated for this work can help to uncover what style of pathways were used and whether canoers passed by in-between islands. By modeling directed canoe routes I hope to show the layout of these possible canoe travel corridors.

These modeled canoe routes show that the possible pathways through the Anegada Passage often passed close to Puerto Rico, St. Croix, and the Virgin Islands This movement is consistent with archaeological evidence from both sides of the passage. (Hofman 2013; Keegan and Hofman 2017; Rodríguez Ramos 2010; Righter *et al.* 2004). Similarities in materials from the Leeward and the Virgin Islands, including Lesser Antillean-sourced lithic materials, suggest these connections began in the Archaic Age (2000 – 800 BC) (Hofman *et al.* 2014; Knippenberg 2007; Pagán Jiménez 2011; Righter *et al.* 2004). Puerto Rican influences can also be seen in assemblages from the Lesser Antilles (Hofman *et al.* 2014; Knippenberg 2007). These lines of evidence suggest reciprocal relationships between communities in the Greater Antilles and the Lesser Antilles were in existence for hundreds of years before the start of the Ceramic Age.

6.1.1 Taíno across the Antillean Divide

Many archaeologists and contemporary communities refer to the groups of Caribbean Amerindians who lived on the islands of Hispaniola and Puerto Rico during the Late Ceramic Age as Taíno (*e.g.,* Rouse 1992). However, there is a strong debate over the use of the term and whether it can be used to cover all Ceramic Age polities or communities in the Greater, or even the Lesser, Antilles (*e.g.,* Curet 2009; Keegan and Hofman 2017; Rodríguez Ramos 2010; Rodríguez Ramos and Pagán Jiménez 2006). In recent discussions, regions within the Greater Antillean political sphere of influence have been given subset qualifiers (Curet 2009: 8-10). These regions can further be separated into regional and micro-regional communities, each adhering to the cultural norms of its area while still maintaining some tie to the Central Taíno community in Hispaniola. Though these terms and classifications are contested and, in many cases, may not adequately define the cultural associations of a past Antillean group, I have loosely used them here to form the base on which routes between distant communities can be modeled and inter-regional connection evaluated.

The Late Ceramic Age brought a widespread trend of stylistic and cultural elements connected with the spread and consolidation of Taíno culture to the Greater Antilles (Oliver 2009). Sites that lie on the outer edges of the so-called Central Taíno area have been referred to as the Western Taíno for those from Cuba and Jamaica, while the Eastern Taíno refers to those found in the Lesser Antilles, St. Croix, and the Virgin Islands (Curet 2009: 8-10; Crock 2005; Keegan 2013; Keegan and Hofman 2017). These regional splits are potentially still too general as individual communities in these areas observed Taíno practices and stylistic elements to different extents (Curet 2014). The current study uses the categorical split of Classic Taíno groups from Hispaniola and Eastern Taíno (Rouse 1992) from the Virgin Islands and northern Lesser Antilles (Crock and Petersen 2004) to showcase where crews launched their canoes when heading between the Greater and the Lesser Antilles.

Due to regional differences, the Taíno should be thought of as more of a "cultural mosaic" (Curet 2014; Wilson 2001). This cultural mosaic was made up of separate communities whose assemblages adhered to the stylistic and cultural patterns to varying extents (Curet 2014). So-called Taíno sites are largely identified by their villages' layouts, burial practices, and ceramic manufacturing styles (Hofman *et al.* 2008a, 2008b; Rouse 1948, 1992; Samson 2010). Taíno culture is found on many archaeological sites within Cuba, Hispaniola, Puerto Rico, and the Lesser Antilles in a variety of ways and degrees, with a higher concentration in the central Greater Antilles (Rouse 1992). In many sites materials – ceramic, shell, bone, and stone – were stylized in a in a similar vein, following zoomorphic, anthropomorphic, or political themes common to that central area (Rouse 1992). Though numerous examples were produced locally (Crock 2000; Crock and Petersen 2004; Knippenberg 2004), the stylistic trends seen in these objects suggest a cross-channel link between communities. These elements are thought to have originated in the Greater Antilles (Hofman *et al.* 2008a; Oliver 2009; Rouse 1992).

These elements are intertwined with the strengthening of a political power and community organization under the direction of local chiefs, also known as caciques (Oliver 2009; Rouse 1992; Wilson 1990). In Hispaniola, these chiefdoms were hierarchical (Keegan and Hofman 2017; Wilson 1990). In Puerto Rico, the caciques' power was malleable and adapted to fit local interpretations (Curet 2002; Keegan and Hofman 2017; Oliver 2009; Torres 2012). When progressing outside the center of Classic Taíno culture, defined by Rouse (1992) as Hispaniola and western Puerto Rico, the sociopolitical structure in the eastern chiefdoms varied (Curet 2014). In part, the "variation in leadership capabilities" resulted in fluid relationships between caciques and power (Righter *et al.* 2004: 104).

Structures, spaces, and materials can help to define the spheres of engagement within the core area of Taíno habitation (Curet 2014; Righter *et al.* 2004; Rouse 1992). The number, size, and style of ball courts and other physical structures and the objects associated with them indicate the level of interaction between Central Taíno habitation areas and periphery sites. These structures also separate cultural centers from outposts, and direct connections from possible indirect routes of exchange. Connections between movable objects and permanent structures to central areas and outposts follow forms of exchange and navigation techniques globally (Broodbank 2000, 2002; Fitzpatrick 2013; Terrell 1977). to participate in regional activities and be considered Taíno peoples (Curet 2005, 2009; Hoogland and Hofman 1999; Siegel 2004; Torres 2010). There were differences between outposts, which received objects and enforced cultural norms of a faraway polity, and gateway sites, which actively promoted Taíno wares and ideas. Siegel (1999: 214) defines outposts as camps or settlements that function as a branch or outlying position of a group. The presence of Taíno objects alongside plazas and ball courts in a site outside the Taíno core area suggests that the site likely acted as an outpost, such as the sites of Salt River on St. Croix (Faber-Morse 2004) and Belmont on Tortola (Drewett 2004). The relationship between outposts may have changed over time due to the shift in influence of Taíno polities over outlying communities. Routes between these communities may also have responded to changing alliances or sympathies.

Siegel (1999) also argues for a separation between "locally emerging polities" and the so-called "spheres of influence" that extended into the northern Lesser Antilles. Outpost communities were introduced to Taíno material through core-periphery relationships (Allaire 1990; Hofman and Hoogland 2011). These periphery sites adopted several aspects of Greater Antillean cultural identifiers without assuming the same polity structure observed in either Hispaniola or Puerto Rico (Curet 2009; Hoogland and Hofman 1999). The connections between periphery sites and those in the liminal space between core site and outpost can be evaluated to assess the flow of information and materials through the region.

Sites sometimes acted as both outposts and gateways, though to function as a gateway site the community must have put effort towards the dispersal of goods between different groups perpetuating core-periphery entanglements. It is difficult to establish how the transfer of materials and knowledge was organized, whether it was a concentrated effort to push a cultural narrative or the result of many different points of contact. These patterns of exchange could have resulted from multiple factors (Hofman *et al.* 2008a). Several of these factors are displayed in the production and deposition of Lesser Antillean artifacts. The evolving series of inter-island connections through gateway sites makes them ideal nodes for this case study.

6.1.2 Ceramic Styles

Ceramic typological evidence has been used to define cultural groups in the Caribbean for many years (*e.g.,* Hofman 1979; McKusick 1960; Rouse 1948, 1952, 1992). Correlations in ceramic stylistic elements between the Greater and the Lesser Antilles are a strong indicator of connection and interaction during the Ceramic Age. Pottery styles from the region have been discussed in depth by past researchers (see Faber-Morse 2004; Hofman and Jacobs 2000; Hofman *et al.* 2008a, 2008b; McKusick 1960; Roe 1989). As the focus of this study was to develop and utilize a method to evaluate least-cost pathway analysis over water environments, ceramic styles will be used to ground the placement of origin and termination points for route modeling. The ceramic evidence referenced here indicates possible political and cultural ties between the peoples of the Greater and the Lesser Antilles.

The provenance data of these artifacts is still fragmentary, although it has shown that many of the ceramics analyzed were produced locally. Hofman (1993) attributed the spread of these stylistic elements and/or similarities in local ceramics to the movement of Amerindian peoples from the Greater Antilles to the Lesser Antilles. These ceramic types in the northern Lesser Antilles would reflect the fusion and fission of interacting worldviews (Hoogland and Hofman 1999). These styles include Chican Ostionoid ceramics (Allaire 1990; Crock 2000; Crock and Petersen 2004; Curet and Stringer 2010; Hofman 1993; Hofman *et al.* 2008a; Tables 7 and 8). The Chican Ostionoid style is a distinct identifier of Taíno culture or influence and archaeologists have used this ceramic series to suggest contact across the Anegada Passage (Hofman *et al.* 2008a). The Chicoid ceramic style was popular from AD 1200 to 1500 (Rouse 1992; Siegel 1996), which coincides with this case study. Chican Ostionoid ceramics have been found in several assemblages across the northern Lesser Antilles (see Crock 2000; Henocq and Petit 1995; Hofman and Hoogland 2011; Hoogland and Hofman 1999). First identified in sites in the southern Dominican Republic (Hofman 2013; Keegan and Hofman 2017), the Boca Chica style of the Chican Ostionoid ceramic complex is found throughout Puerto Rico (Crock 2000; Hofman *et al.* 2008a) and some of the Leeward Islands (Hofman *et al.* 2008a; Hoogland and Hofman 1999). Boca Chica ceramics are strongly linked with the western side of Puerto Rico (Carlson and Torres 2011) and follow the narrative of shared ceramic culture in the Central Taíno sphere. Other examples of Chican ceramic styles that moved east include Esperanza, from Puerto Rico, and Capa, from Puerto Rico and the Virgin Islands (Rouse 1958; Siegel 1996; Torres 2012). These styles link to the transitional or outlying areas of Taíno polities, bridging the divide between Hispaniola and the Lesser Antilles. Thus, Chicoid ceramics can be used to justify modeling connections from Hispaniola past Puerto Rico and into the Lesser Antilles.

Boca Chica Chicoid ceramics have been found on several sites in the Lesser Antilles, including the Kelbey's Ridge site on Saba (Hoogland and Hofman 1999, 2011, 2013). Other Leeward Islands with Chicoid ceramic stylistic influences include Anguilla and St. Martin. Isolated stylistic features from the Greater Antilles have been found on St. Martin, St. Eustatius, Antigua, Guadeloupe, Marie-Galante, Martinique, St. Lucia, St. Vincent and the Grenadines (see Allaire 1990; Bonnissent 2013; Crock 2000; de Waal 2006; Douglas 1991; Henocq and Petit 1995; Hofman 1993, 1995; Hoogland 1996; Knippenberg 2007, 2013; Rouse 1992). These islands provide possible locations for

<table>
<tr><th colspan="2" rowspan="2">Periods</th><th colspan="3">Cuba</th><th colspan="2">Hispaniola</th><th colspan="2">Puerto Rico</th><th rowspan="2">Virgin Islands</th></tr>
<tr><th>Western</th><th>Central</th><th>Eastern</th><th>Haiti</th><th>Dominican Republic</th><th>Western</th><th>Eastern</th></tr>
<tr><td colspan="2">IV</td><td rowspan="2"></td><td></td><td>Pueblo Viejo</td><td>Carrier</td><td rowspan="2">Boca Chica</td><td>Capa</td><td colspan="2">Esperanza</td></tr>
<tr><td rowspan="2">III</td><td>b</td><td colspan="2">Bani</td><td>Meillac</td><td></td><td>Santa Elena</td><td>Santa Elena</td></tr>
<tr><td>a</td><td colspan="3" rowspan="4">Guayabo Blanco and Cayo Redondo</td><td>(Macady)</td><td>(Corales)</td><td colspan="2">Ostiones</td><td>(Ostiones Like)</td></tr>
<tr><td rowspan="2">II</td><td>b</td><td rowspan="3">Cabaret and Couri</td><td rowspan="3">(Railroad Cave)</td><td colspan="3" rowspan="2">Cuevas</td></tr>
<tr><td>a</td></tr>
<tr><td colspan="2">I</td><td colspan="2">(Coroso)</td><td>(Krum Bay)</td></tr>
</table>

Table 7: "Chronological Profiles for the Eastern Caribbean Area" (Rouse 1958: 191, Figure 2). This chart roughly corresponds to the relationship between different ceramic styles in the Greater Antilles, though it has been updated by more recent scholars (see table 8 and Figure 54).

Time Period	Dates	Social organization	Community organization	Ideological organization	Disposal of the dead	Cultural complex
PII	500 BC - AD 600	Tribe/complex tribe	Village-oriented, central plaza ringed, by communal houses	Ancestor worship; egalitarian ethic	Community based; central plaza area	Hacienda Grande, Cuevas
PIII	AD 600 – AD 1200	Complex tribe/simple chiefdom	Small village-large village-ball court	Ancestor worship; incipient ascriptive social inequality	Community based; ball courts	Monserrate, Santa Elena
PIV	AD 1200 – AD 1500	Simple chiefdom/complex chiefdom	Polity-based, village hierarchy	Ancestor worship with ideology of domination	Clan-based; mounds; socially partitioned spatially and by grave goods	Esperanza, Capa, Boca Chica

Table 8: Social organization and cultural complex through time (Siegel 1996: Table 2; Torres 2013: 24.1).

origin nodes. However, not every island mentioned above will be used as a location for launch and landing points. Instead, a sample of islands will be selected as targets for the export and import of stylistic elements to assess the possible location of travel corridors and connectedness in these pre-Columbian communities.

6.1.3 Three Pointers and Shell Masks

Taíno cultural objects such as three pointers (*zemis*), shell masks (*guaízas*), and paraphernalia associated with the consumption of hallucinogens have been identified in assemblages from the Lesser Antilles (Allaire 1990; Crock 2000; Crock and Petersen 2004; Curet 1992; Hofman *et al.* 2008; Mol 2014; Oliver 2009; Wilson 2007). These objects often follow the

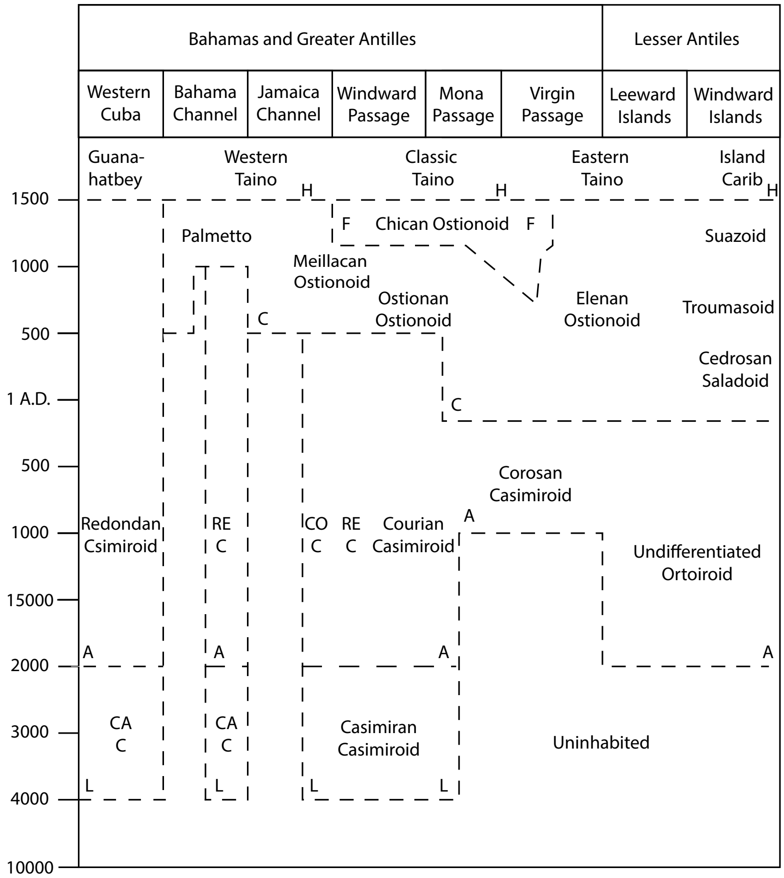


Figure 54: Modified from Rouse 1992 Figure 8, "Chronology of the series and sub-series of the West Indies" (Rouse 1992: 32,). This figure roughly shows the relationship between different ceramic styles in the Greater Antilles and Lesser Antilles. Here, the archaeological periods, or ages, are represented as A: Archaic, C: Ceramic, F: Formative, H: Historic, L: Lithic.

iconographic characteristics common in the Chican Ostionoid style and suggest the spread of Greater Antilles Late Ceramic Age Amerindian culture through the Caribbean region.

Of these objects, perhaps the clearest link to the political practices of the Greater Antilles are the three pointers. Three pointer figurines are made from various types of stone, shell, or wood. These items represent divine-like beings associated with Taíno ancestors and are often carved with anthropomorphic representations highlighting this connection (Oliver 2009). Three pointers can be shaped into statuettes, but often appear in a three-pointed isosceles shape (Breukel 2013; Oliver 2009; Rouse 1992). These objects were imbued with certain spiritual forces and their power could be transferred to anyone who physically possessed them (Oliver 2009). Three pointers have been linked with a Taíno cacique's political authority. As documented in ethnohistoric sources, the presence of three pointers connects to the competitive nature of different Taíno communities. The procurement of a rival's three pointers to gain their spiritual power was the objective of raids (Oliver 1995). The fact that these objects are found in the Lesser Antilles could indicate the spread of the "chieftain ideology of domination"

(Moscoso 1981; Siegel 2010). Three pointers are also a material link to the political objectives of those competing for dominance on islands like Puerto Rico. It is possible that caciques expanded their area of influence by exchanging or capturing three pointers (Oliver 2009). Three pointers were present in the Lesser Antilles from Saladoid times on, indicating that by the Late Ceramic Age they would have formed established links to Taíno political influence in the region.

Large stone three pointers have been found on Anguilla, Guadeloupe, and Dominica (Crock 2000; Hofman *et al.* 2007; Honeychurch 1997a; Knippenberg 2007; Oliver 2009). Small three pointers have been found throughout the Lesser Antilles, even as far south as Grenada (Crock 2000; Hofman *et al.* 2007; Honeychurch 1997; Knippenberg 2007; Oliver 2009). Three pointers have also been found on multiple islands of the Lesser Antilles, above and below the 'direct influence' split found around Guadeloupe (Hofman *et al.* 2008a). Three pointers found in these islands depict anthropomorphic, zoomorphic, or anthropozoomorphic features associated with Taíno ancestors and could have been used to solidify a cacique's power in outpost communities (Curet 1992; Hofman *et al.* 2008a). They have been found on islands not directly addressed here, such as Guadeloupe and Dominica (Crock 2000; Hofman *et al.* 2008a; Honeychurch 1997a). The presence of these objects suggests that communities in the Greater Antilles were influencing the culture and production of three pointers in the Lesser Antilles (Crock 2000; Hofman and Hoogland 2011; Hoogland and Hofman 1999). That these objects were made locally would suggest that communities in the Lesser Antilles had some level of Taíno social and/or political affiliations.

Shell masks alongside three pointers and ceramic traits, also fall into the category of Taíno anthropomorphic stylistic elements. Anthropomorphic features associated with shell masks can range from representations of human faces to what could be considered masks (Hofman *et al.* 2008a). Several of these shell masks have been found in the Lesser Antilles, including on the islands of Anguilla, Antigua, Marie-Galante and La Désirade off Guadeloupe, St. Lucia, and Il de Ronde in the Grenadines (Hofman 1995; Hofman *et al.* 2004; Mol 2007, 2014). Ceramics that showed evidence of a Chicoid influence were also found on these islands. The presence of three pointers, shell masks, and ceramic stylistic traits indicate islands and sites to use as nodes to model canoe routes through the Greater and the Lesser Antilles.

6.2 Islands and Points

The macro-regional movement of cultural items shows the spread of Taíno cultural influence eastward from Hispaniola through Puerto Rico, ending in the Lesser Antilles. Movement of ceramics and other objects into the Lesser Antilles aligns with the existence of a "west to east corridor of influence" (Rodríguez Ramos 2001; Rodríguez Ramos and Pagán Jiménez 2006: 121). As evidence for cross-passage links is found throughout the Lesser Antilles, it is unclear which island communities were in direct contact with Taíno emissaries and which indirectly received materials from others within their own micro-regional sphere. Hofman *et al.* (2008a) argued that there is a distinct separation for the sphere of direct interaction around the island of Guadeloupe. Though Taíno materials are spread further to the south, items are more diffused there than in the northern islands. This supports one-to-one relationships across the Anegada Passage terminating north of Guadeloupe.

The routes modeled for this case study help to illuminate which groups might have been in contact, and what sites would have acted as cultural mediators. For this research, I will focus on a comparison of movement between gateway sites, which acted as distribution and introduction points for Taíno influences in the Lesser Antilles, from the Dominican Republic through Puerto Rico, the Virgin Islands and St. Croix, to the islands of Saba and Anguilla in the northern Lesser Antilles.

6.2.1 Southeastern Hispaniola

As there is no confirmation, at least through the presence of reciprocated exchange, that any specific site in the Greater Antilles acted as an exportation center, the origin and termination points for the route model will be located on the southeastern portion of the island of Hispaniola, which was divided into several paramount chiefdoms (Curet *et al.* 2008). I restricted site selection in the Greater Antilles to this island as little remains of this region's Later Ceramic Age settlements (Samson 2010). There is a high density of Late Ceramic Age sites on this portion of the island, especially around the Punta Cana region (Keegan 2006). As there has also been a large amount of site destruction along the coastlines, only one site, El Cabo, will act as a distribution center and represent the origin of Taíno influence that spread from Hispaniola (Hofman and Hoogland 2016). This site will stand in for all other sites that could have engaged in the cross-island inter-regional trade evaluated.

El Cabo is an example of a Classic Taíno site (Keegan and Hofman 2017) that dates to the Late Ceramic Age (Samson 2010). The site overlooks the Mona Passage (Hofman *et al.* 2014), indicating it was a coastal connection point for canoers moving west from Mona Island and Puerto Rico. The structure of El Cabo, which could be classified as a Central Taíno site, is in line with intra-site settlement patterning from Puerto Rico. The site has roughly 50 structures, of which more than half were houses, reflecting four different configurations of house trajectories over a 250-year period (Samson 2010: 239-242). Excavations of the latest phase at El Cabo have produced Chican Ostionoid pottery, in line with other assemblages dating to this period (Hofman *et al.* 2007; Samson 2010; Samson and Hoogland 2007).

El Cabo was still occupied in the early period of European interaction (Samson 2010). Though it was one of the final areas to be placed under Spanish control, Spanish materials appear in the site's assemblage (Ernst and Hofman 2015; Hofman *et al.* 2014; Valcárcel *et al.* 2013). It is unlikely that these materials came into the site through direct contact due to the geographical distance between this site and initial Spanish settlements. The presence of these materials indicates that a series of well-defined exchange systems were used to transfer objects and ideas outside direct spheres of influence (Hofman *et al.* 2014). This feeds into the narrative of El Cabo existing as a point of transfer for materials both in and out of the Hispaniola (Hofman *et al.* 2014; Samson 2010), making the site a strong candidate for inclusion in this study.

6.2.2 Mona Island

Mona Island lies almost directly in the center of the 120-km long Mona Passage separating Hispaniola from Puerto Rico (Samson and Cooper 2015). Occupation of the island likely began around 2800 to 1000 BC, based in part on radiocarbon dates from Cueva de los Caracoles (Dávila Dávila 1998, 2003; Samson *et al.* 2014: 3). Peoples continued to come to Mona Island through the Ceramic Age and into the early colonial period (Crusoe and Deutschle 1974; Dávila Dávila 2003; Rouse 1952; Samson *et al.* 2014). Mona Island was a "magnet for indigenous communities" as late as the sixteenth century (Samson *et al.* 2014: 4), well after the period discussed in this chapter. In fact, Europeans entering the region recorded the importance of Mona Island to the indigenous peoples of the Antilles (Arana-Soto 1969; Samson *et al.* 2014). Mona Island likely played a key role in the initial expansion of peoples into the Antilles (Dávila Dávila 2003; Rouse 1992; Samson and Cooper 2015; Samson *et al.* 2014: 5), which may have established it as a point of contact or a rest area for navigators.

Despite its small size (50 km^2) (Samson and Cooper 2015) large sites have been found on the island, including the site of Sardinera with the combined length of its middens running over two km^2 (Rouse 1952:366; Samson *et al.* 2014: 4). Mona Island also holds several cave sites (Dávila Dávila 1989, 2003; Rouse 1952; Samson *et al.* 2014; Vieten *et al.* 2016). Caves on Mona Island were widely used, by both Amerindians and Europeans, perhaps due to their status as a unique resource (Samson and Cooper 2015: 41; Samson *et al.* 2014). This use is documented through alterations to the cave walls and ceilings, either by incisions into the rock or by the addition of pigment (Samson *et al.* 2014: 7). In part, these caves were important to passing travelers because they are the only source of water on the island (Samson *et al.* 2014: 11). Additionally, the position of some of these cave sites along the north coast of the island may signal a connection between Mona Island and movement between Puerto Rico and Hispaniola. Communities engaging in and with these caves maintained connections across "generations, between people, ancestors, and non-human entities" that could have been understood by peoples across the Mona Passage and beyond (Samson and Cooper 2015: 52). The continuation of these connections may have linked Mona Island to an individual's, or community's, mental seafaring map and promote the use of the island as a node within this case study.

6.2.3 Puerto Rico

Curet *et al.* (2004) suggest that Puerto Rico was split into several smaller competitive polities, unlike Hispaniola that likely had larger chiefdoms. From AD 600 to 1200 the Puerto Rico population increased, leading to a dramatic surge in the number of sites on the island (Curet 1987; Curet *et al.* 2004). This trend coincided with a change in the social and physical patterns of sites, particularly in site layouts (Curet *et al.* 2004; Torres 2010). At least on the eastern end of the island, communities moved towards centralized habitation (Curet 1992; Siegel 2010; Torres 2010). This shift aligned with the consolidation of power under the burgeoning chiefdom system.

The geographic dispersal of these sites changed how peoples related to coastal areas. During this period, nucleated communities in the interior developed an arrangement of linear settlements near the coast (Crock 2000; Rodríguez Lopez 1992; Siegel 2010). Early connections with the coast likely cemented the position of interior communities within broader inter-island networks. Canoe voyages were essential in maintaining micro- and macro-regional exchange networks that supported the exportation and expansion of Taíno culture. A continued presence on the coast ensured that these peoples remained in contact with their neighbors, both on their own island and beyond it.

In this modeling, some generalizations in the use of sites on Puerto Rico and its outward affiliations were made to justify connections between sites. I assumed connections could occur between all nodes and that connected areas were representative launch points for travel throughout the region. As with El Cabo, there are no confirmed specific site-to-site reciprocated connections. Areas close to the coast were chosen to be a part of this study to represent high contact areas. Nodes connected using the route tool were placed in areas with evidence of coastal habitation during some phase of the Ceramic Age. The resulting five areas with active settlements sometime between ca. AD 500 to 1500 – Punta Candelero, Punta Las Marias near Bajo, Casabe in Cabo Rojo, Aguadilla Pueblo, and Mona Island (see Keegan and Hofman 2017) – were selected as representatives for all possible connection points on these islands. In future research, evaluating more sites from around the coast will allow for a greater representation of pre-Columbian Puerto Rican communities within the network.

6.2.4 St. Thomas and St. John

Between the Greater Antilles and the Leeward Islands sit the Virgin Islands. Amerindians living in the Virgin Islands in the Ceramic Age were connected to the Taíno sphere of influence (Righter *et al.* 2004). The position of these islands makes it likely that they acted as stopover points for crews traveling across the Anegada Passage.

As on sites in the Lesser Antilles, Boca Chica style pottery has been found on two sites on St. Thomas (Righter *et al.* 2004). These ceramic materials evidencing zoomorphic stylistic elements include two petaloid celts, stone collar fragments, a vomiting stick (de Booy 1919), an anthropomorphic representation on a stone pestle (Kay 1976), and a shell carved into a bird effigy (Hatt 1924). Similar materials, including a sculpted stone head, stone bead and celt with sculpted anthropomorphic face, and Taíno-styled shell adornments have been found on St. John (Righter *et al.* 2004). Multiple shell inlays, which may have adorned several three pointer statues or figurines, were also recovered (Alegria 1981). These items have been associated with Greater Antillean elites or ceremonial activities (Righter *et al.* 2004) and support some form of involvement with Taíno religious and social hierarchy (Wild 2001). Righter *et al.* (2004) determined that these materials were a result of direct contact with eastern Puerto Rican Taíno communities during the Late Ceramic Age.

The sites of Tutu on St. Thomas (Lundberg 2002; Righter 2002; Righter *et al.* 2004) and Cinnamon Bay on St. John (Righter *et al.* 2004; Wild 2001) will be considered as additional nodes for modeling because they also possess material evidence of Taíno influence.

6.2.5 St. Croix

Another possible stopover point in the study area is the island of St. Croix, which lies at the southern edge of the Anegada Passage. Many sites on St. Croix dating to the Late Ceramic Age are found on the coast and within easy reach of approaching canoes (Hardy 2008). Some of these sites have been linked through archaeological evidence to those on the Virgin Islands (Righter *et al.* 2004), Puerto Rico, and the Leeward Islands (Hardy 2008). As in the Virgin Islands, communities on St. Croix also adopted Ostionoid style pottery (Faber-Morse 1995, 2004; Lundberg and Righter 1999). Boca Chica stylistic elements found on pottery from the island reflect Later Ceramic Age connections between the island and others in the region (Hardy 2009). Ceramic sherds, which have been sourced to Puerto Rico, also appear in some assemblages (Ferguson and Glascock 2006; Hardy 2008). The Salt River site (Faber-Morse 2004) reflects ties to Eastern Taíno communities. Much like its counterparts on Puerto Rico, the Salt River site contained a ball court and Chican Ostionoid pottery (Faber-Morse 1995, 2004).

St. Croix has been considered as a key eastern outpost of the Classic Taíno sphere of influence (Rouse 1992; Keegan and Hofman 2017). The materials found within the island indicate peoples from the island participated in so-called Taíno culture through the production of Greater Antillean-styled ceramics and political objects, such as three pointers (Rouse 1992). The presence of larger structures, such as ball courts and civic ceremonial sites (Faber-Morse 2004; Rodríguez Ramos and Pagán Jiménez 2006), at places like Salt River suggest that peoples living on this island had a closer relationship with Greater Antillean social structures than those inhabiting islands to the east. As Curet (2003, 2005, 2009: 8-10, 26) suggests, it is likely that communities in the Eastern Taíno zone were in fact autonomous communities, or "peer polities", that engaged in a shared regional culture without being wholly governed by it. However, due to its position between Puerto Rico and the Leeward Islands, it is possible that communities on the island facilitated the expansion of Greater Antillean objects and stylistic elements.

6.2.6 Anguilla

Crock and Peterson (2004) suggest that Anguilla was an active part of the Greater Antillean sphere of influence (see also Hofman *et al.* 2008a; Siegel 2010). An argument has been made for a lesser Taíno chiefdom operating on the island (Crock and Peterson 2004). A Taíno-related ceremonial site, Fountain Cave, with carved petroglyphs and a large stalagmite anthropomorphic statue, has been found on the island (Crock 2000; Waters 1991). These carvings are like those found on Hispaniola and Puerto Rico (Kerchache 1994; Stevens-Arroyo 1988). It is possible that, like in the Greater Antilles, multi-island chiefdoms developed around Anguilla and the islands in the Anguilla Bank (Crock and Peterson 2004: 144).

Anguillan assemblages show examples of decorated ceramics that resemble those found on Hispaniola and Puerto Rico, particularly the Boca Chica and Esperanza styles (Crock 2000; Crock and Peterson 2004), including the presence of zoomorphic and raised node adornos (Crock 2000). These styles stand out amongst the other pottery examples from the island as they are not heavily decorated (Crock and Peterson 2004). Amerindian villages on Anguilla were active members of Late Ceramic Age inter-island networks, though access to these ceramics was possibly restricted and subject to a good relationship between canoe owners and traders (Crock 2000). Crock (2000: 233) even suggests that a village's yearly supply of ceramics may have arrived in one large canoe. Annual shipments of materials may relate to seasonal accessibility of routes across the Anegada Passage.

Three pointers, shell masks, snuffing tubes, and vomiting spatulae found on the island also suggest the presence of a local polity (Crock 2000; Knippenberg 2004). Lesser Antilles three pointers were predominantly made on Anguilla (Crock 2000), as indicated by archaeological evidence that shows that calci-rudite three pointers were produced on the island (Crock 2000; Knippenberg 2004). The presence of locally manufactured three pointers at the sites of Rendezvous Bay, Barnes Bay, and Sandy Ground (Crock 2000; Crock and Peterson 1999) nominates these three points for inclusion in the network of sites modeled below. Movement to and from Barnes Bay will be modeled to evaluate possible one-to-one relationships between the Greater Antilles and the Lesser Antilles.

6.2.7 Saba

The site of Kelbey's Ridge (AD 1200 – 1350) has been suggested as a link in the Greater Antillean Taíno extended sphere during the Late Ceramic Age (see Hofman and Hoogland 2011; Hofman *et al.* 2008a, 2014; Hoogland and Hofman 1999; Mol *et al.* 2015). Saba complements Anguilla as a likely point of contact for those making the journey east due to the island's position close to the Anegada Passage, and thus to the Greater Antilles. Saba is currently the only Leeward Island with a large Boca Chica-style assemblage within the bounds of a Taíno-affiliated settlement (Hofman *et al.* 2008a). It is possible that Kelbey's Ridge may have been an outpost (Hofman *et al.* 2014), or perhaps a gateway site, for those in the Greater Antillean sphere.

Access to the Saba Bank may have also encouraged peoples to settle on Saba, tying access to marine resources to the success of the site. Kelbey's Ridge possibly began life as a resource procurement center (Hoogland and Hofman 1999, 2011; Keegan and Hofman 2017), evolving into a site that could exert influence over materials imported to the Lesser Antilles from the Greater Antilles (Keegan and Hofman 2017). The layout of Kelbey's Ridge suggests that it may have fallen within the sphere of Eastern Taíno influence (Keegan and Hofman 2017). As evidenced by the five 6 x 8 m diameter round or oval houses uncovered within its premises, Kelbey's Ridge was a habitation site (Hoogland and Hofman 1999). The house trajectory of these structures, with burials under the house floors (Hofman and Hoogland 2011; Hoogland and Hofman 1999, 2013), is similar to those found in the Greater Antilles and the Virgin Islands from the same period (Curet *et al.* 2005; Keegan 2007) and to that of El Cabo (Hofman and Hoogland 2013; Samson 2013), suggesting cultural affiliations between the peoples living at this site to those from the eastern part of Hispaniola.

It is possible that Kelbey's Ridge acted as a gateway site for Taíno ideas, as Chican Ostionoid style ceramics were manufactured on the island (Hofman 1993; Hofman and Hoogland 2011; Hoogland and Hofman 1999). Hoogland (1996) stresses the importance of these materials, suggesting they indicate that groups already present on Saba either were incorporated into the larger political sphere extending out from Hispaniola or were Taíno colonists on Saba. Ceramic links include decorated ceremonial vessels adorned with depictions of Taíno mythological figures. Non-local ceramic material has also been found on Saba in small numbers, which XRF testing suggests holds possible origins in neighboring islands and the Greater Antilles (Hofman *et al.* 2008c). These pieces also support the argument that there was some form of connection between peoples living in Hispaniola or Puerto Rico and Saba. Despite the 'foreign' stylistic elements, most of the pottery was manufactured locally (Hofman 1993; Hofman *et al.* 2008a, 2008c), suggesting that although these ceramics were not made from the same materials as those in the Greater Antilles, Lesser Antillean pottery was made in a similar tradition.

Hofman and Hoogland (1999: 178) have hypothesized that, in addition to sharing ceramic stylistic elements with the Greater Antilles, Kelbey's Ridge also acted as a periphery site representative of the so-called Central Taíno (*e.g.*, Curet 2009: 8-10, Rouse 1992) interaction sphere. It is possible that the site grew from its beginnings as a resource procurement camp to take advantage of passing exchange from the Greater Antilles to the Lesser Antilles. This may have included materials coming from as far away as mainland South America (Keegan and Hofman 2017), highlighting its possible role of intermediary of prestige goods (Hofman and Hoogland 2011; Hoogland and Hofman 1999). Saba's position may have placed it in a prime position to take advantage of travel corridors moving out from St. Croix. In this case, movement from Saba towards St. Croix and Puerto Rico should be tested to determine the ease of connection between the Greater and the Lesser Antilles.

6.3 Modeling Routes between the Greater Antilles and the Lesser Antilles

The canoe routes discussed here differ from the previous case study in part because of the geographic relationship between the islands. In the last chapter, the islands were clustered around the open space through which the canoe moved. Islands and sites studied in this chapter are laid out in an arc rather than a cluster. In many cases there is no island available to provide a break between the current's push and the open sea. Crews crossing between the Greater Antilles and Leeward Islands had to brave the large divide of the Anegada Passage instead.

The following runs will determine the least-cost connections between Hispaniola and the northern Lesser Antilles. Crews moving through this arc had to contend with both the resulting time cost and the associated trajectory of these voyages. Modeling these factors can indicate the more likely avenues of canoe movement across the broader region. Evaluating the cost and trajectory of routes can highlight stopover points along coastlines that are passed in the middle of a journey. The layout of these routes can suggest possible centers for connection over different periods of the year.

6.3.1 Underlying Environmental Factors

Route time costs are based upon the environmental data, namely currents. These currents are different at different times of year, thus influencing the seasonal variations inherent in these routes. The current tool (see Chapter 4) was used to evaluate the reliability of underlying currents and the existence of seafaring seasons. This tool samples the underlying current direction and force values (see Chapter 4), which can then be used to determine the months that can be assessed as optimal canoeing seasons. In keeping with the methods used in the previous chapter, several points were selected across the region to evaluate for regularities in the current. I could determine the currents' force and direction when they were least influenced by the presence of islands by checking current values in channels. Points were centered in the channels between the

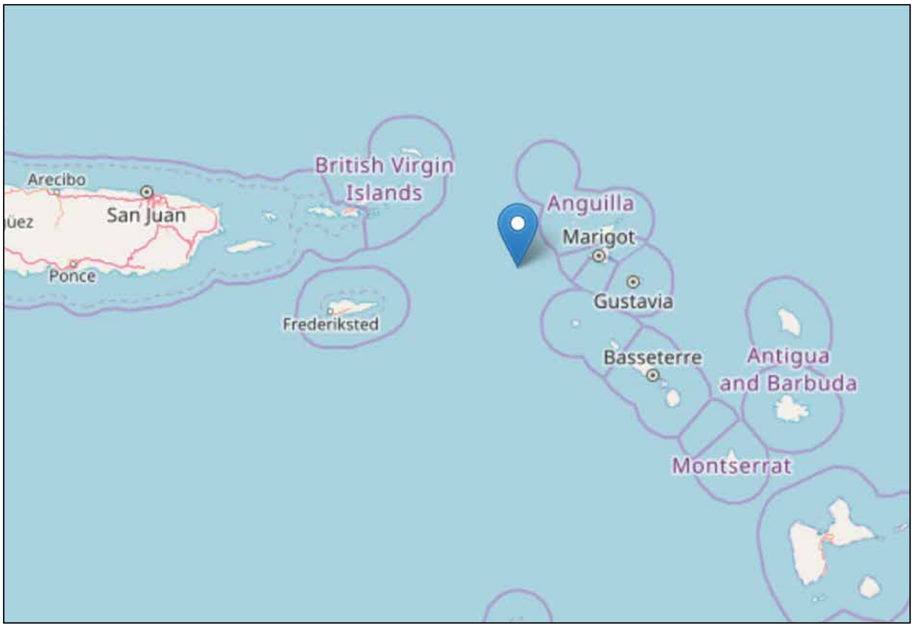


Figure 55: Map showing the first point (17.978733, -63.632813) tested with the current tool.

major islands of interest. These include the Mona Passage and the Anegada Passage. Two points were placed in the expanse between the Greater Antilles and the Leeward Islands to ensure that the currents at either end of the channel were evaluated.

Point 1 (17.978, -63.632) is located north of the Saba Bank at the eastern edge of the Anegada Passage. Here, current strength remains stable throughout the year (see Figure 55). Trends observed across all years show that current force remains below, or just above, 0.5 knots. Currents never exceed 0.75 knots. There is more variation in the direction of current. Currents typically head to the northwest or west, yet can also trend towards the east or south, most commonly from January to June 2014 to 2016 and July to December of 2013 (see Figure 56).

Three clear seasons emerge when looking at the 15- and 30-day averages for all years (see Figure 57). The first season centers on December to April (see Figure 57). During this time, currents head in a west to southwest direction. This could indicate that current values towards the northwest, west, southwest, and south averaged to move to the southwest. During the spring and summer, from May to September, current-forces push towards the northwest (see Figure 57). This is consistent with current movement through the northern Lesser Antilles during this period. From September to November current force pushed to the south and then the east, before returning to a westward movement (see Figure 57). Radical shifts in current direction over these months likely made this 'travel season' more difficult for crews.

Point 2 (18.135, -64.379) is located near the east Virgin Islands. It also lies north of the eastern edge of St. Croix (see Figure 58). Point 2 captures current movement at the western end of the Anegada Passage. Current strength values for this point sometimes resemble those observed in the northern Lesser Antilles, in that they do not commonly exceed one knot (see Chapter 5). At the second point, average current flow

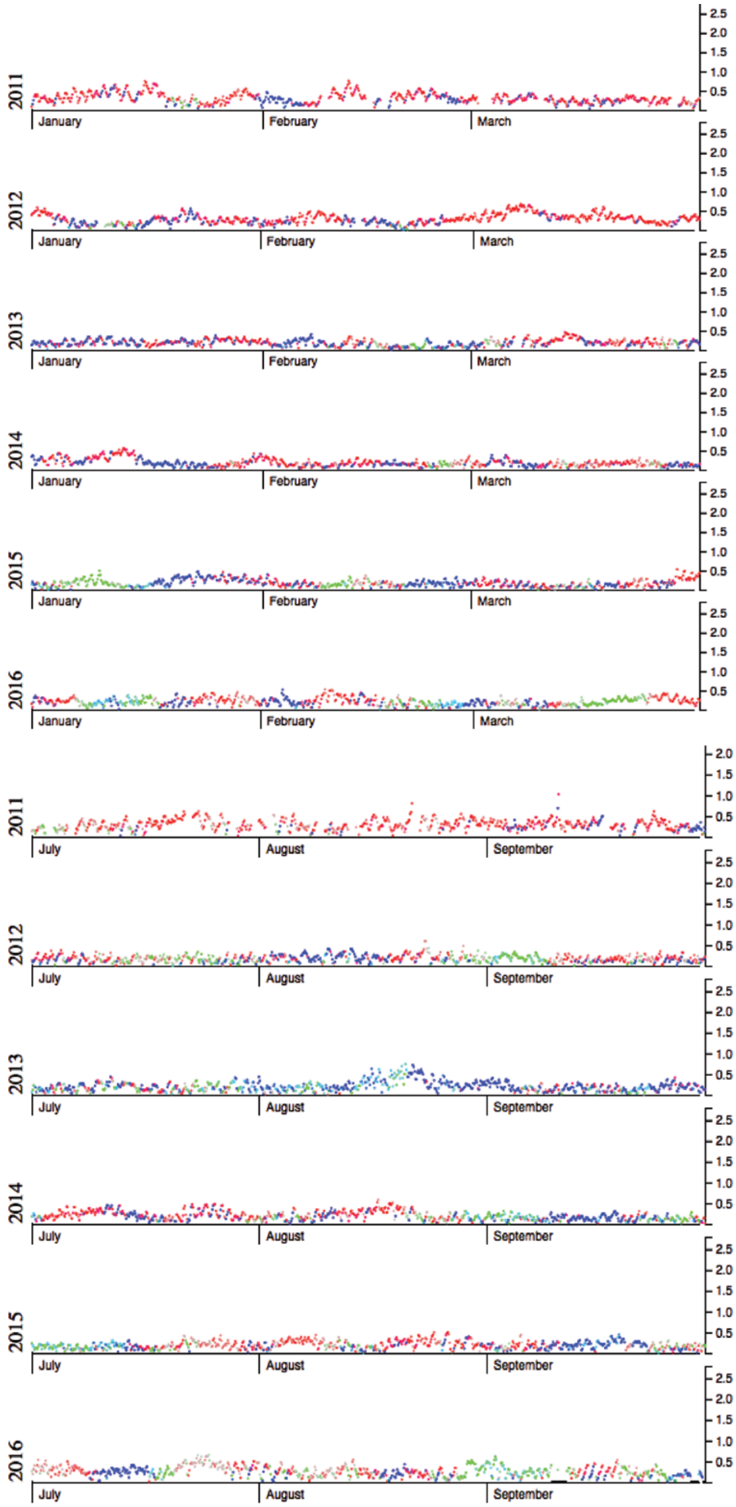
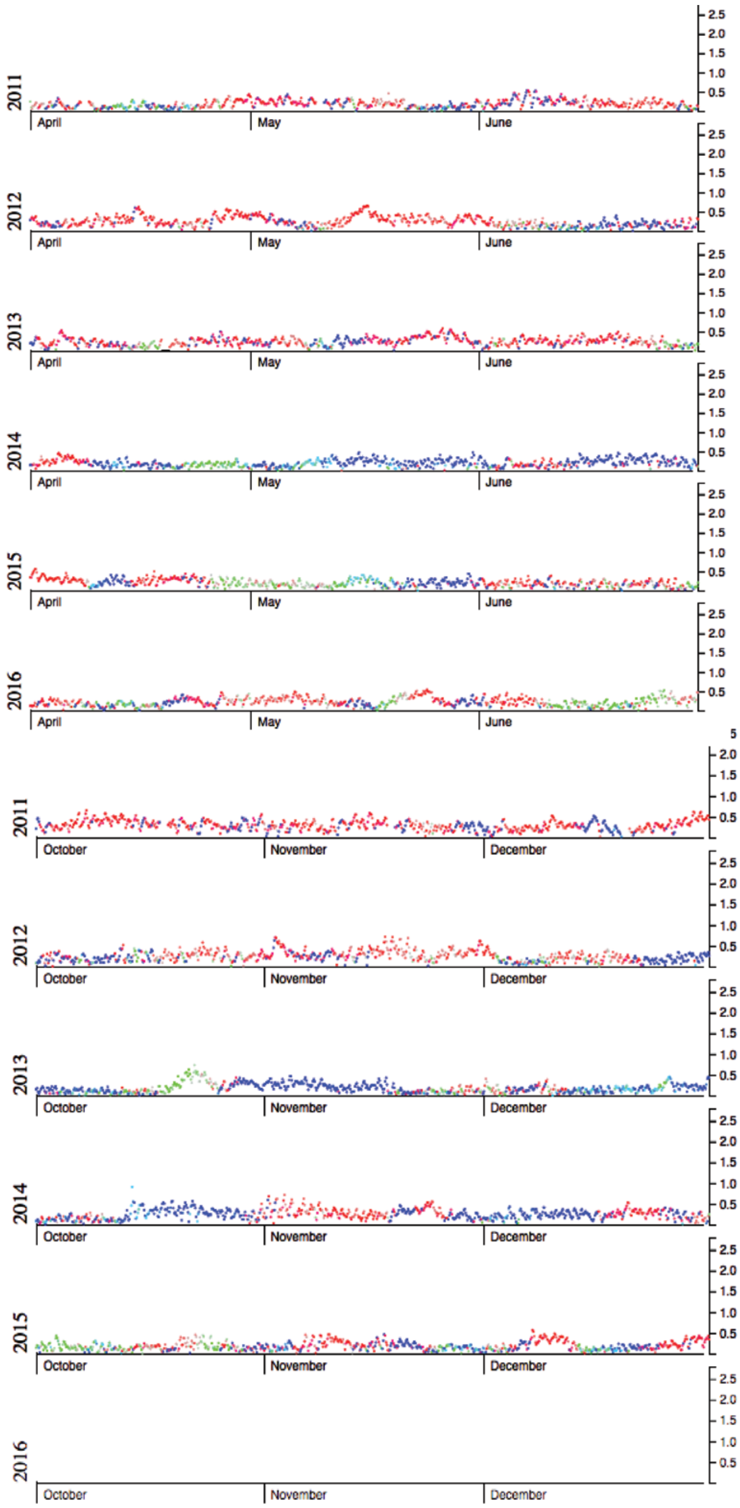


Figure 56 (continued on opposite page): Charts showing the direction and force of current at Point 1 (17.978733, -63.632813) from January to December 2011 to 2016.


2011
2012
2013
2014
2015
2016
April
May
June
October
November
December
2.5
2.0
1.5
1.0
0.5

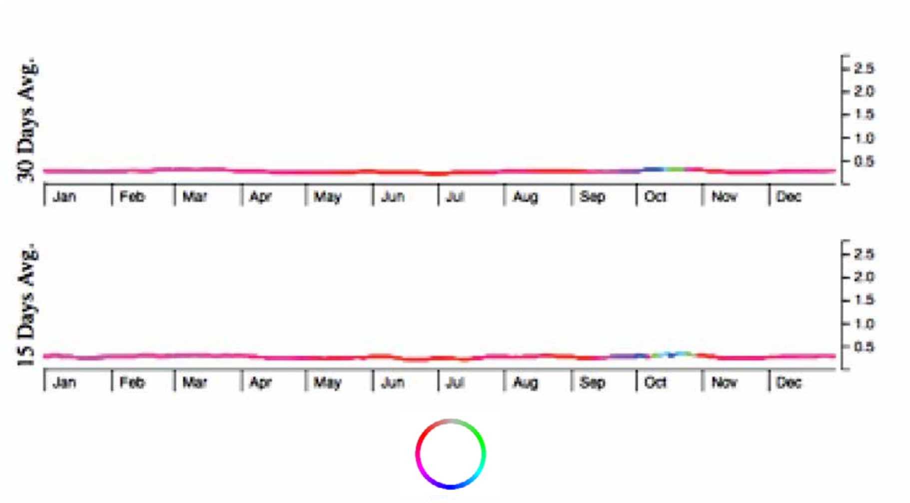


Figure 57: Charts showing the 15- and 30-day averages of direction and force of current at the Point 1 (17.978733, -63.632813) from 2011 to 2016. North moving currents are represented on the color wheel by grey, south by blue, west by red, and east by green (see Chapter 4).

Figure 58: Map showing point 2 (18.135412, -64.379883) tested with the current tool (see Chapter 4).

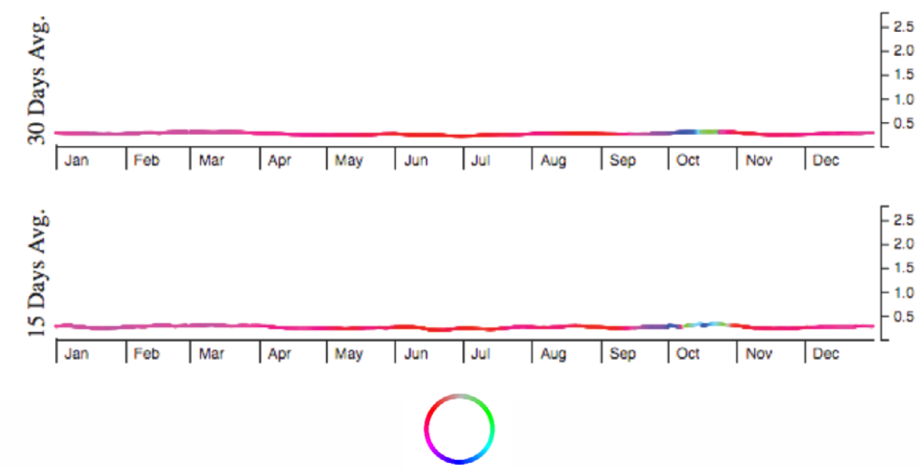


Figure 59: Charts showing the 15- and 30-day averages of direction and force of current at Point 2 (18.135412, -64.379883) from 2011 to 2016. North moving currents are represented on the color wheel by grey, south by blue, west by red, and east by green (see Chapter 4).

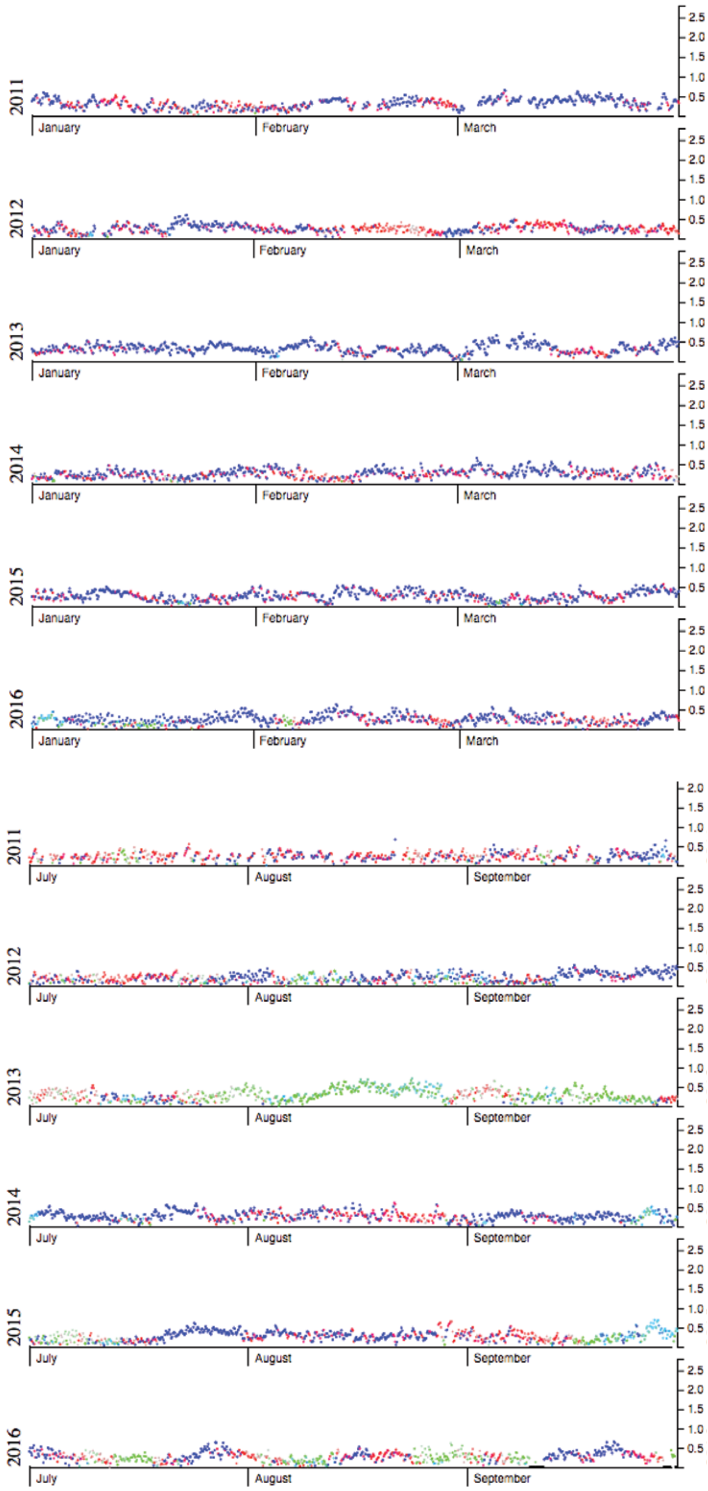


Figure 60 (continued on next page): Charts showing the direction and force of current at Point 2 (18.135412, -64.379883) from January to December 2011 to 2016.

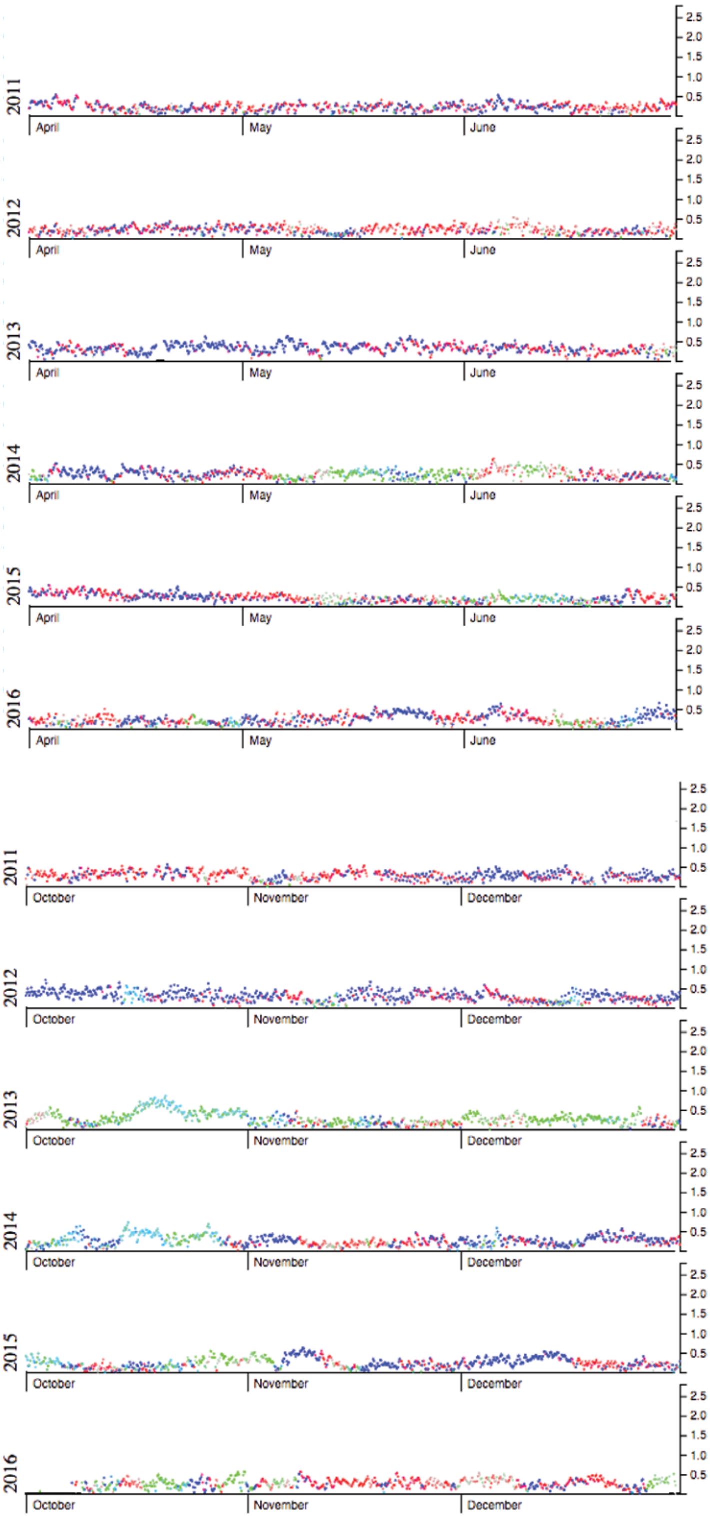


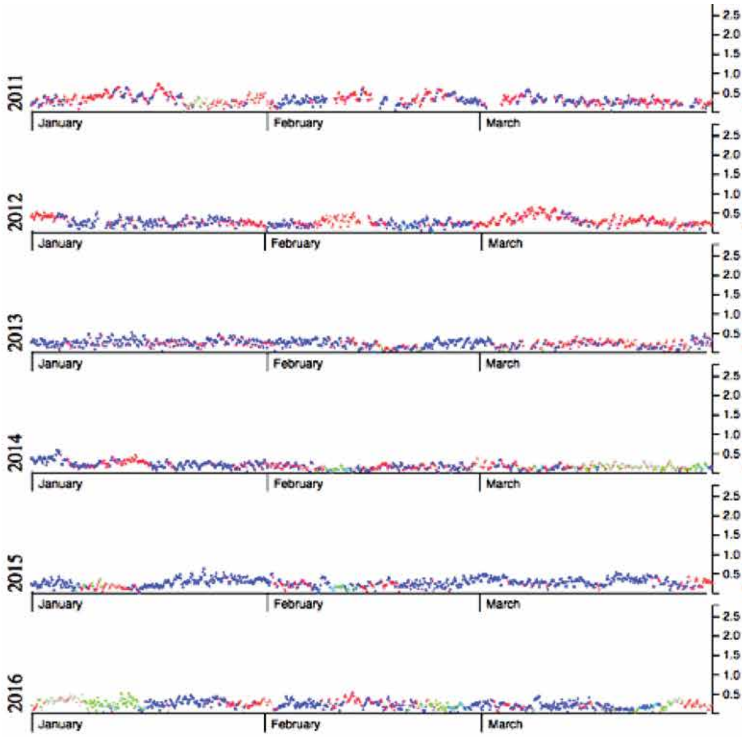
Figure 60 (continued).

Figure 61: Map showing point 3 (18.051867, -63.874512) tested with the current tool (see Chapter 4).

moves towards the south from January to March (see Figure 59). Between April and June, currents continue to head to the south. However, currents also move towards the northwest and northeast during this summer period. This shift could indicate that currents were less reliable in the 'spring' months. This mix of directions is repeated for the summer months of July to September. Between October and December routes more commonly trend south and east.

The averaged current direction values captured for Point 2 trend to the west and south between December and March across all years (see Figure 59). Current headings in fall, or between September and November, were highly variable (see Figure 59). In this season, currents begin by pushing to the southwest before heading to the south, then east, and finally to the north. The changes during this period, both in the 15- and 30-day averages suggests this period was not optimal for travelling through the western edge of the Anegada Passage. It is plausible that canoers waited for a period with a more consistent current force direction. However, this assumption needs to be evaluated further before it can be confirmed. Conversely, it could be that small trips were made during the fall period between neighboring islands.

To evaluate the consistency of these values across the entire channel, Point 3, (18.051, -63.973) in the center of the Anegada Passage was selected (see Figure 61). Currents associated with this point are similar to those in the first case study (see Chapter 5) in that they have a relatively low speed of below 0.5 knots, and a similar direction, from the west to southwest. Unlike the examples from the points on either side of the passage, movement at this point is relatively stable all year round. Only two periods of possible travel corridor seasonality exist. One, from October to February, shows movement trending slightly southwest. Another, from March to September, has



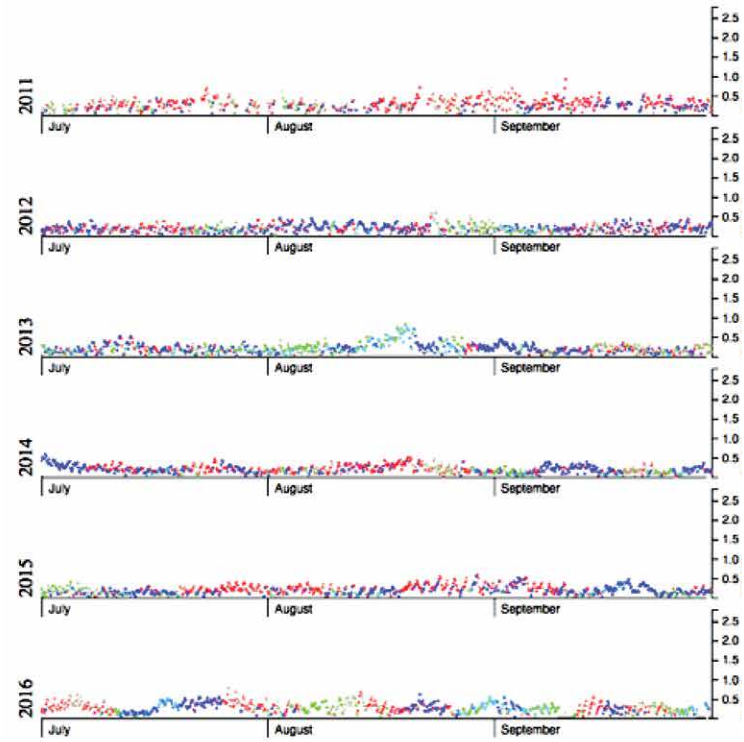
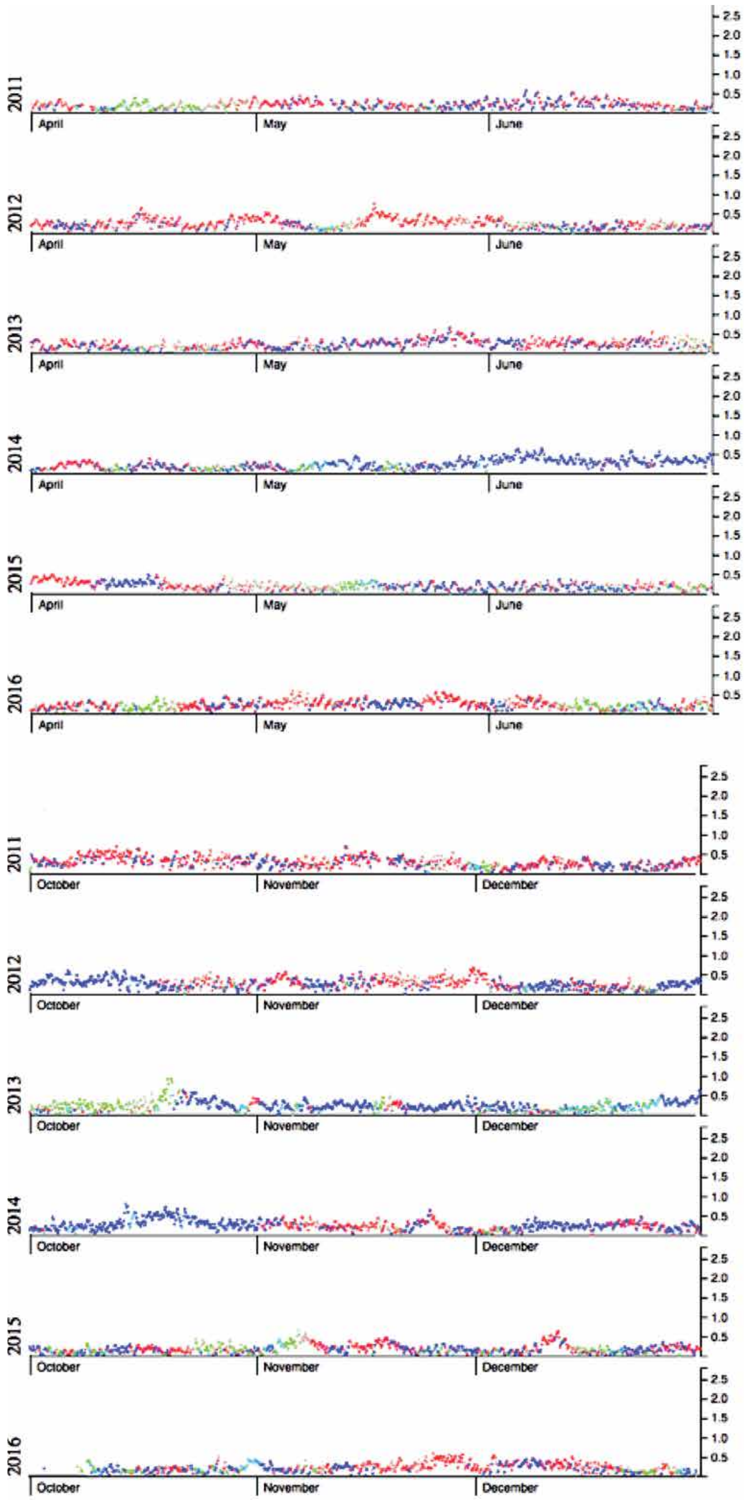


Figure 62 (continued on next page): Charts showing the direction and force of current at Point 3 (18.051867, -63.874512) from January to December 2011 to 2016.


2011
2012
2013
2014
2015
2016
April
May
June
October
November
December
2.5
2.0
1.5
1.0
0.5

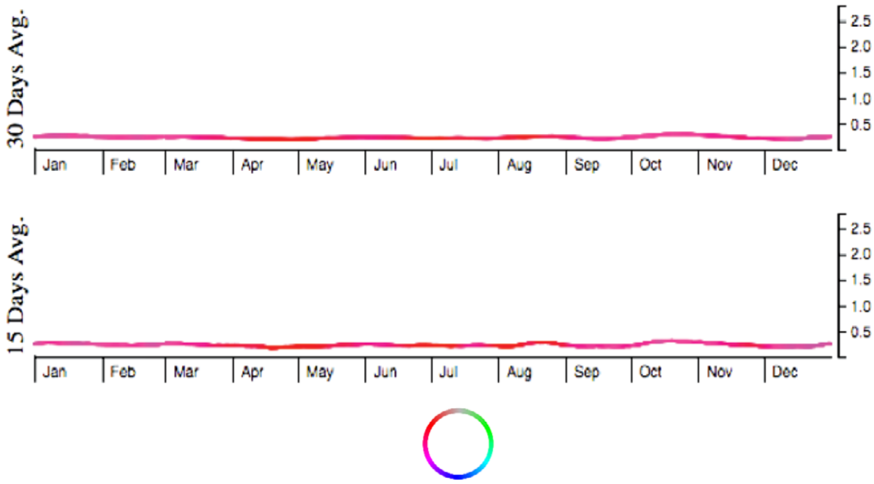


Figure 63: Charts showing the 15- and 30-day averages of direction and force of current at Point 3 (18.051867, -63.874512) from 2011 to 2016.

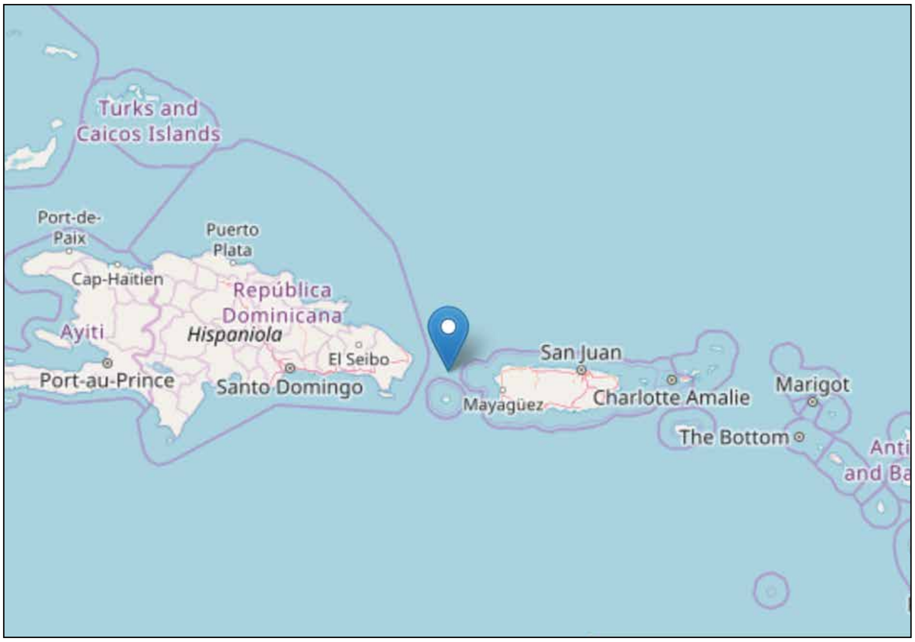
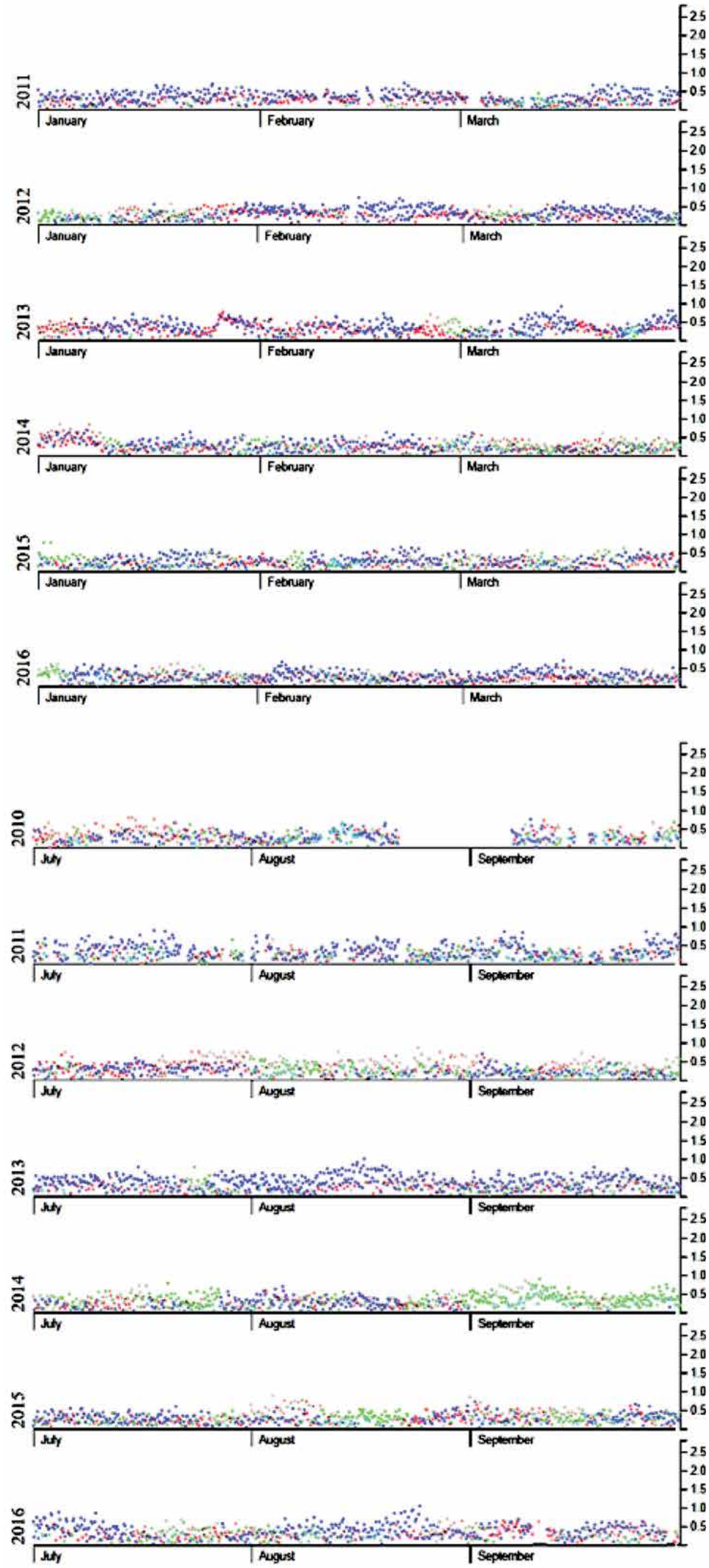


Figure 64: Map showing point 4 (18.417079, -67.884521) tested with the current tool (see Chapter 4).

Figure 65 (opposite page; continued on next page): Charts showing the direction and force of current at Point 4 (18.417079, -67.884521) from January to December 2010 to 2016.


2011
2012
2013
2014
2015
2016
January
February
March
2.5
2.0
1.5
1.0
0.5
2010
2011
2012
2013
2014
2015
2016
July
August
September
2.5
2.0
1.5
1.0
0.5

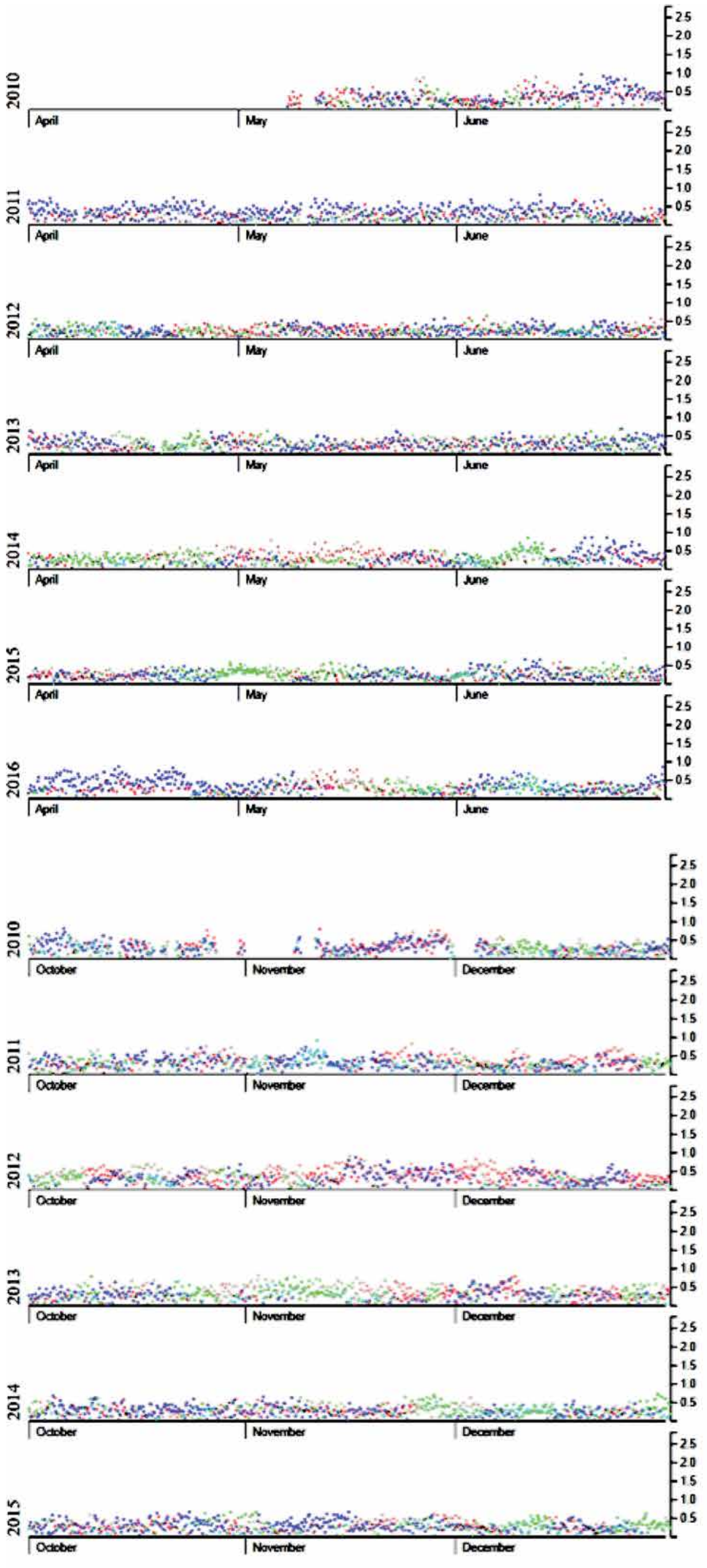


Figure 65 (continued).

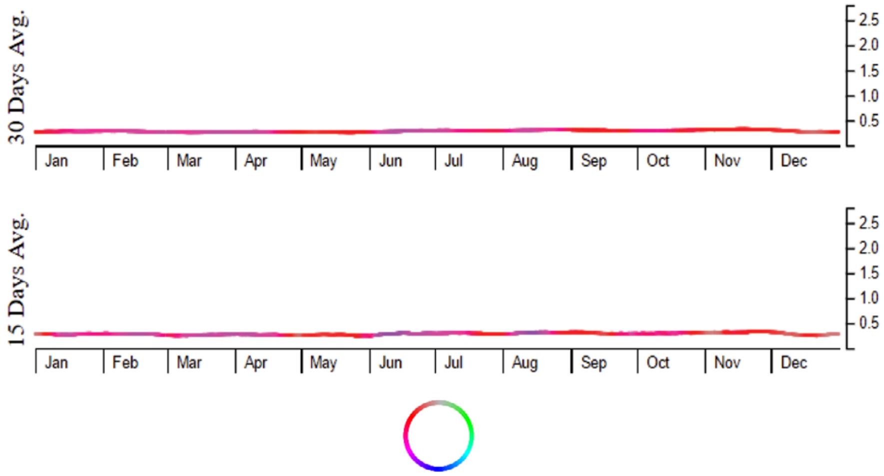


Figure 66: Charts showing the 15- and 30-day averages of direction and force of current at Point 4 (18.417079, -67.884521) from 2011 to 2016.

currents heading due west on average (see Figure 62). Although these directions are applicable for further modeling, it must be borne in mind that some of the consistency in these directions may be a result of averaging.

Point 4 (18.417079, -67.884521) is located between Hispaniola and Puerto Rico in the Mona Passage (see Figure 64). Though the channel is small, a point between these two islands was necessary as travel through this corridor was an essential part of movement east (Samson and Cooper 2015a, 2015b). The importance of canoe routes across this channel has been highlighted by archaeological finds in caves on Mona Island (Samson and Cooper 2015a, 2015b; Samson *et al.* 2013). Based on these finds, the point is placed directly north of Mona Island.

Current forces in the Mona Passage show a limited range of direction values. Though there is a slight trend in current movement to the southwest in February and April, the rest of the year shows a concerted westward movement. Following the trends observed at the first, second, and third points, there is a seasonal period between September and October with shifts in directions. In this case study, current strength is similar to that seen in the northern Lesser Antilles. All current force values stay below one knot, often close to 0.5 knots. This indicates that while current direction may have partially determined seasonal travel directions, crews wanting to go against the current could overcome its force.

Current force and direction values returned at these four points indicate there are three seasonal periods in this case study. To compare these travel periods with those in Chapter 5, I will be evaluating routes from January, April, July, and October. January, April, and July all represent key separations in average current direction at all points. Adding the additional non-conforming month of October to these runs allowed me to determine if radical shifts in underlying current affected route times within one period. These seasonal patterns will act as a guide for when to model routes between the Greater Antilles and the Leeward Islands.

6.3.2 Failed Routes and Navigation Challenges

In some cases, routes could not be completed between Greater Antillean and Lesser Antillean points. This is due to an insurmountable current that runs through the region, which did not allow the modeled routes to overcome pathway loops, leading to failed or incomplete routes. In these cases, direct pathways with loops were discounted and instead route segments were judged to increase the accuracy of the model's analysis. As most generated routes connect the northern Lesser Antilles directly to Hispaniola in both directions of the reciprocal routes, it is probable that Amerindian canoers did not use these impractically long routes. It is more likely that crews looked for opportunities to stop on the coastlines of in-between islands. These stopover points, or areas where routes run close to or into coastlines, could be possible areas to consider in future modeling. As this case study considers least-cost routes, or the optimal scenario, as the most likely past reality, we can discount routes that do not fit into that ideal.

Some routes modeled for this case study are not physically possible. This includes routes that run through islands (*e.g.*, route 0-1_2011-04-29T03). However, these points of contact with an island can be strong indicators of stopover potential. For example, movement through the Rojo Cabo area sometimes disrupts routes. In these cases, where the island has not been properly excluded from the underlying environmental data, it is impossible to say whether the trajectory or cost of the route is representative of a possible canoe pathway. Routes which run through islands were typically excluded from consideration in this case study.

Other unusable routes included loops. Although loops in these models were smaller than those detailed in the previous chapter, they still indicate routes that are not truly representative of a least-cost route. For example, route 2-10_2011-04-05T18 runs past the north coast of Mona Island only to loop back and come south along the eastern coast. This route can be discounted because it adds segments. A more extreme example of loops on a route is shown in route 2-10_2011-04-10T15, which loops at several points. These hypothetical routes, although based on environment constraints, may indicate that Amerindian canoers could have waited for better currents rather than running the risk of taking these routes.

There are also routes with superfluous segments. For example, route 1-9_2011-01-16T06 pushes north from Anguilla, loops around in the north, before returning to Anguilla to head west. This route can be discounted because of the additional time the loop added to the voyage. This pattern is observed in other routes, such as route 1-9_2011-01-17T03, route 1-9_2011-01-17T06, route 1-9_2011-01-18T06, and route 1-9_2011-01-22T21, 23T12. Amerindian canoers traveling along similar corridors to these least-cost routes perhaps chose to wait for optimal currents or push against the currents seen here to circumvent these additional route segments.

6.3.3 Route Cost

This research evaluates generated optimal routes and the time costs of canoe pathways between islands. To determine if a route's time cost was an effective method for analyzing canoe movement, I compared time costs for routes across the various channels in the region. Without first evaluating the limits and advantages of routes through the Mona Passage and the Anegada Passage it would be impossible to know whether seasonality or current variation played a role in cementing the location of canoe corridors throughout the year.

I attempted to model canoe routes from El Cabo on the Dominican Republic to all nodes within the case study area to determine how seasonality affected route time costs when crossing from the west to the east. I hoped to determine if direct voyages from El Cabo across the Anegada Passage were possible. However, the route model was not able to model pathways past Puerto Rico. This indicates that in-between points Mona Island and Puerto Rico need to be assessed to determine where crews may have started their journey across the Anegada Passage. Reciprocal links from the Leeward Islands would also need to be evaluated to determine the difficulty encountered on the return trip. Though routes originating in the Leeward Islands were not able to reach Hispaniola directly, they provided the opportunity to evaluate the indirect interaction sphere of peoples in the Lesser Antilles.

Because of these preliminary findings, I also modelled between Mona Island, the four points on Puerto Rico, the Kelbey's Ridge site on Saba, and the Barnes Bay site on Anguilla, towards all other points in the case study. These key points within the interaction sphere represent both the outer limit (*i.e.* the Leeward Islands), and the center (*i.e.* Puerto Rico), of the study area. While all canoe pathways are directed from an origin point to a termination point, sometimes routes moved past nodes on in-between islands. This practice could indicate where direct routes may have been disrupted in favor of rest points. Routes modeled from these points are the best to judge the direct and indirect movement of peoples, materials and ideas between the Greater Antilles and the Lesser Antilles. Patterns appeared when modeling canoe routes heading east and west. For example, moving from east to west is less costly than heading in the other direction. The change in difficulty depending on the canoe's heading may have played a role in a crew's decision to take stopover breaks along the coast of Puerto Rico. Patterns, like this one, helped to set the rhythms of travel and rest across the case study region.

Time costs of several routes between the same areas can demonstrate if and where canoe travel corridors existed in the region. It is possible that due to the similarity in underlying current strength the seasonal influences on routes were limited. However, small variations in route costs may exist based on the location of nodes within the case study region. Origin and termination points are located at or near areas where the archeological evidence shows peoples interacted, which ties the generated optimal pathways to reality. As many of the islands within this case study are located near one another, or between other islands, I only modeled reciprocal routes between half of the sites due to the similarity in time cost between different points and due to the large time investment of the digital modeling component. This time component relates to the run times between origin and termination points, but also to the number of returned routes that would need to be analyzed. As discussed in Chapter 5, for every month models were run, each reciprocal canoe corridor has at least 480 individually modeled routes associated with it. If I successfully modeled routes from one origin point to all termination points discussed above for every month and year possible I would have generated over 125,000 routes. By limiting the number of sites and seasons evaluated, I could effectively and thoroughly compare the feasibility of canoeing across the Anegada Passage in different seasons.

6.3.3.1 Movement across the Mona Passage

Comparing movement between Mona Island and Puerto Rico underscores the importance of islands as shelters against stronger currents. The Mona Passage presented a challenge to Amerindian canoes as it was the first channel crews needed to cross when heading east from the Dominican Republic. It was the initial space where voyages could be blown off course. The Mona Passage also holds a stopover area,

From	To	Month	Min	Max	Average
Dominican Republic	Mona Island	January	11.08	15.133	12.669
Dominican Republic	Mona Island	April	10.7	14.485	12.682
Dominican Republic	Mona Island	July	10.083	14.436	12.379
Dominican Republic	Mona Island	October	9.74	15.715	12.606
Dominican Republic	Puerto Rico(SE)	January	47.956	52.149	50.507
Dominican Republic	Puerto Rico(SE)	April	22.937	52.055	49.741
Dominican Republic	Puerto Rico(SE)	July	48.202	52.171	51.21
Dominican Republic	Puerto Rico(SE)	October	49.758	52.064	51.268
Dominican Republic	Puerto Rico(SW)	January	18.037	43.437	24.7033
Dominican Republic	Puerto Rico(SW)	April	22.937	46.0115	18.6793
Dominican Republic	Puerto Rico(SW)	July	17.805	51.119	24.292
Dominican Republic	Puerto Rico(SW)	October	24.786	46.765	30.537
Dominican Republic	Puerto Rico(NW)	January	18.108	46.147	24.23
Dominican Republic	Puerto Rico(NW)	April	18.436	50.656	23.094
Dominican Republic	Puerto Rico(NW)	July	16.474	38.876	21.151
Dominican Republic	Puerto Rico(NW)	October	21.931	40.8371	27.542
Dominican Republic	Puerto Rico(NE)	January	38.81	52.183	47.053
Dominican Republic	Puerto Rico(NE)	April	41.683	52.105	47.04
Dominican Republic	Puerto Rico(NE)	July	36.392	51.788	45.461
Dominican Republic	Puerto Rico(NE)	October	33.022	51.955	33.022

Table 9: Route cost times (in hours) from the point off the coast of the Dominican Republic near El Cabo towards Mona Island and Puerto Rico in all months.

From	To	Month	Min	Max	Average
Dominican Republic	Mona Island	April	10.7	14.485	12.682
Mona Island	Puerto Rico (NW)	April	16.279	52.105	21.216
		Total	26.979	66.59	33.898
Dominican Republic	Puerto Rico(NW)	April	22.937	46.0115	18.6793

Dominican Republic	Mona Island	April	10.7	14.485	12.682
Mona Island	Puerto Rico (SW)	April	12.806	50.992	18.859
		Total	23.506	65.477	31.541
Dominican Republic	Puerto Rico(SW)	April	18.436	50.656	23.094

Table 10: Two tables showing the cost differences between traveling directly from the Dominican Republic to Puerto Rico and traveling through Mona Island in April.

Mona Island. For these modeled routes, Amerindian peoples leaving El Cabo could canoe towards three landing points, one on Mona Island, a second at the southwest corner of Puerto Rico, and a third near the northwest corner of Puerto Rico. The node on Mona Island is located near the only entrance point onto the island. The Puerto Rican points are located near Amerindian population centers on the island. It is possible that canoers could have stopped elsewhere along the coastlines of Mona Island or Puerto Rico at sites that have not yet been archaeologically uncovered. These points provide a base for modeling voyaging times towards the western coast of Mona Island and Puerto Rico.

Modeled canoe routes from El Cabo crossing the Mona Passage illustrate the ease of movement between the Dominican Republic and Puerto Rico (see Table 9; Appendix C). Though Mona Island may have provided a possible rest area for canoers traveling along routes like those modeled here, it may not have been necessary for crews to stop over on the island. This was because time costs returned by direct routes between the two islands were roughly only 10 hours more than those would for pathways stopping at Mona Island (see Table 8; Appendix C). At the lowest end of the range of time costs, the differences could be as low as five hours (see Table 8). However, crews crossing the Mona Passage may have chosen to stop anyway to break up the voyage, conserve their ene.g., or to visit sites on the island. There were social motivations to stop at the island, as it was significant to local Amerindians and sites in the caves on the north side of the island may have been key wayfinding points for pre-Columbian navigators (Samson and Copper 2015; Samson *et al.* 2015; Vieten *et al.* 2015).

Movement from El Cabo towards either the northwest or the southwest corner of Puerto Rico resulted in relatively similar route costs to voyages that included a leg to Mona Island and a second leg from Mona Island to Puerto Rico. For example, in April moving between Mona Island and the northwest corner of Puerto Rico takes roughly 21 hours, while traveling to the southwest corner takes around 18 hours (see Table 8; Appendix C). These values are similar to time costs returned for direct voyages from Puerto Rico. The difference between the average route costs for these direct voyages and those that stopped on Mona Island was less than five hours across all months evaluated (see Appendix C). The consistency in route time costs indicates that route time did not necessarily play a large role in Amerindian crews' determining where on Puerto Rico they would make landfall, if crews followed the same trajectories as the least-cost pathways modeled here.

6.3.3.2 Movement across the Anegada Passage

While the Mona Passage provided the first test to canoers carrying Taíno materials from El Cabo, the Anegada Passage represented a greater obstacle. Movement across the Anegada Passage began in the Archaic Age (Hofman *et al.* 2008a; Righter *et al.* 2004), which may indicate that an established navigational mental map was in use at the onset of the Ceramic Age. Terrell and Welsch (1998) and Terrell *et al.* (1997: 168) suggest that peoples maintained knowledge of friendly, or inherited friendships, places over generations in order to facilitate. It is possible that such systems also existed across the Caribbean archipelago from the Greater Antilles and into the Lesser Antilles, as suggested by Samson and Cooper (2015).

The longest leg of any voyage from Hispaniola to the Leeward Islands did not offer crews opportunities to rest until reaching the Virgin Islands or St. Croix. Demonstrated by sites in the Virgin Islands, in-between communities likely acted as go-between or friendly ports for canoers making the hop across the Anegada Passage (Righter *et al.* 2004). The placement of these sites strengthened ties across the Antillean divide, and many seafaring communities likely knew their positions. Canoers crossing this passage may have adhered more to seasonal schedules than was observed in movement through the Leeward Islands (see Chapter 5). These islands can be tied to different micro-regions with a southern and northern division between routes that pass by St. Croix or the Virgin Islands.

The three micro-regions within this case study had different optimal seasons for crossing, or beginning the trip across, the Anegada Passage. Based solely on a comparison of route completion over the four months evaluated, movement across the passage was unhindered throughout the year. The inability of the model to generate routes between the Dominican Republic and the Lesser Antilles, exemplified by the failed route between El Cabo and Saba, suggests that direct routes between these areas likely did not exist. To analyze these three regions, I modeled direct travel between Puerto Rico and the northern Lesser Antilles, Puerto Rico and the Virgin Islands, and Puerto Rico and St. Croix (see Figure 67). This allowed for an evaluation of route time costs for direct travel and routes with stopovers in the north or south.

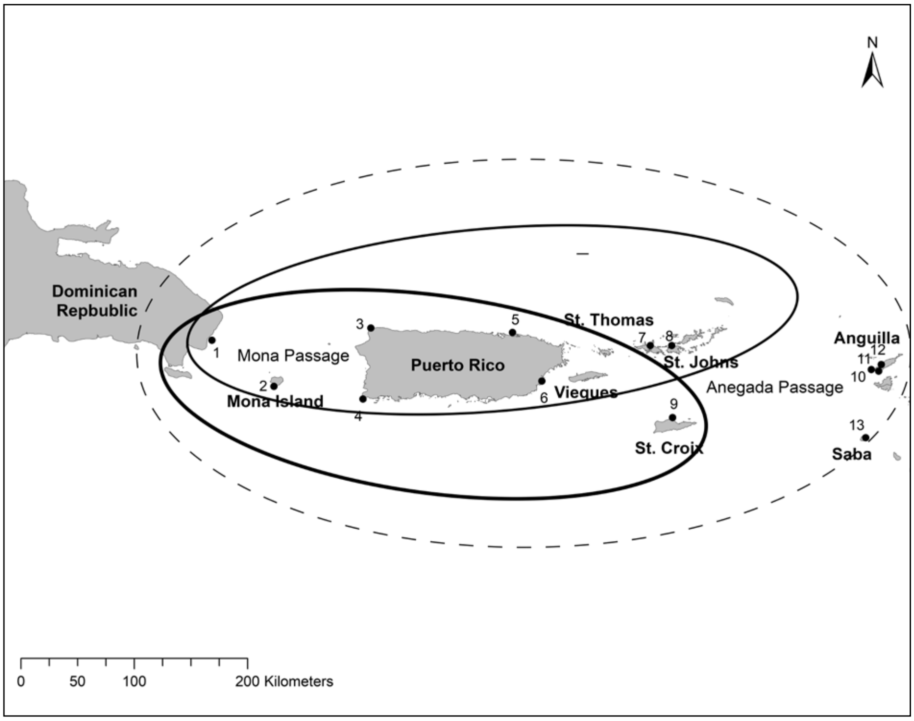


Figure 67: Map showing three micro-regions within this case study encircled. From top to bottom: Puerto Rico and the Northern Lesser Antilles, Puerto Rico and the Virgin Islands, and Puerto Rico and St. Croix.

Puerto Rico and the northern Lesser Antilles

Testing movement across the Anegada Passage proved to be the only way to measure possible travel corridors, as routes from Hispaniola to the Lesser Antilles could not be calculated under the model's parameters and the underlying current data. There were no direct travel corridors between the so-called Central Taíno sphere and the periphery Taíno sites. Instead, past seafarers likely stopped at either Puerto Rico, the Virgin Island, or St. Croix. Route modeling allows for new ways to evaluate the theories of connections between zones of interaction between sites in the Greater Antilles and Saba proposed by Hofman and Hoogland (1999) (see also Allaire 1990; Hofman and Hoogland 2011; Hofman *et al.* 2007; Keegan and Hofman 2017). As such, routes were modeled between Puerto Rico and Saba as well as Puerto Rico and Anguilla.

There is no clear distinction between route costs for voyages between Anguilla or Saba and Puerto Rico (see Tables 9 and 10; Appendix C). Heading from Saba or Anguilla to the southeast point on Puerto Rico takes roughly 45 hours during all months assessed (see Tables 9 and 10; Appendix C). Reciprocated movement from the Greater Antilles shows similar results, where routes to Saba or Anguilla often come within five hours of one another (see Appendix C). The lack of extreme differences in average time costs when launching from the two islands towards the northeast of Puerto Rico suggests that Amerindian communities on Saba and Anguilla had equal physical access to the Greater Antilles and vice versa. Both sites could have acted as gateways for Taíno materials into the Lesser Antilles.

Based solely on route cost there is no clear best choice of origin, termination, or connection point for routes moving between Puerto Rico and the Lesser Antilles. This is supported by the similarity of Greater Antillean materials or stylistic elements in archaeological assemblages in these areas. Archaeological evidence from Saba and Anguilla does not indicate one site was preferred over the other in interactions with Puerto Rico (Hofman and Hoogland 2011, 2013; Hoogland and Hofman 1999). As a result, direct travel preferences were probably the result of route layouts or social factors rather than the time of canoe voyages.

Canoers following similar routes moving from Saba or Anguilla to Puerto Rico may have preferred to travel to the southeast corner of the island, as the modeled least-cost routes took less time than those to the northern coast. This preference may be limited as the cost difference for moving from the Leeward Islands to either coastal area is quite small (see Tables 9 and 10; Appendix C). The difference between traveling to the northeast and southeast corner of the island is typically between one and three hours (see Table 9; Appendix C). These similar results indicate that the route time cost was not the dominant factor behind choosing which area of Puerto Rico to land on; however, the location of the northeast Puerto Rican point, further to the west than the southeastern point, means this hypothesis could benefit from further evaluation (see Figure 53).

From	To	Month	Min	Max	Average
Anguilla	Puerto Rico(NE)	January	43.705	51.902	47.607
Anguilla	Puerto Rico(NE)	April	47.043	52.181	50.213
Anguilla	Puerto Rico(SE)	January	40.924	50.503	46.122
Anguilla	Puerto Rico(SE)	April	41.329	50.976	46.038

Table 11: Time costs for routes from Anguilla to Puerto Rico on January and April.

From	To	Month	Min	Max	Average
Saba	Puerto Rico(SE)	January	41.48	49.341	45.504
Saba	Puerto Rico(SE)	April	41.369	48.658	44.739
Saba	Puerto Rico(SE)	July	41.682	51.98	47.852
Saba	St. Croix	January	26.551	32.964	29.826
Saba	St. Croix	April	25.678	29.116	27.356
Saba	St. Croix	July	25.477	32.359	28.856
Saba	St. Thomas	January	29.831	39.5277	33.244
Saba	St. Thomas	April	31.368	35.147	32.95
Saba	St. Thomas	July	29.825	37.747	34.0553

Table 12: Time costs for routes from Saba to Puerto Rico, St. Croix, and St. Thomas in January, April, and July.

Puerto Rico and the Virgin Islands

Movement to the north of the channel allowed for contact between Puerto Rico, the Virgin Islands, and the Lesser Antilles. The small differences in time cost, however, would not create a distinct preference for travel from either island to the west. The similarity between cost values for routes heading either directly towards the Greater Antilles or through the Virgin Islands suggests that an additional time cost was not a disincentive to traveling indirectly across the Anegada Passage.

For example, time costs when traveling from Anguilla are slightly less than travel from Saba when moving towards St. John and St. Thomas (see Appendix C). These lower time costs could be a result of Anguilla's higher placement in the Lesser Antillean island chain. However, as with direct travel to Puerto Rico, the difference in voyage costs between these two islands and the Virgin Islands typically falls within a five-hour range (see Table 11; Appendix C). This can also be said for traveling towards St. Thomas and St. John from Puerto Rico. Travel to either of these two islands returns a similar cost when traveling from both the Greater Antilles and the Lesser Antilles. These results are due to the close placement of St. Thomas and St. John. Cost values when moving from Saba to the sites on St. Thomas and St. John are relatively equal across the year (see Table 12; Appendix C). For example, values range from 29 to 35 hours for travel between Saba and the Virgin Island sites (see Table 12; Appendix C). The time costs returned for the canoe routes between Saba and St. John or St. Thomas rarely go above 40 hours (see Table 12; Appendix C). This similarity in route costs indicates that time cost was not a reason to prefer travel either from Saba to St. John or St. Thomas. A trip from Saba to St. Thomas has a time cost of around 30 to 35 hours (see Table 12; Appendix C). If this time is added to the 21-hour voyage from St. Thomas to the northeastern node on Puerto Rican it returns almost the same time cost as the direct route, 49 hours (see Appendix C). It is possible real-world canoers traveling along pathways with similar trajectories to these least-cost routes lacked a preference for travel periods, suggesting that canoers would choose where to navigate their vessels based on other factors.

However, there are exceptions to this rule depending on the point towards which the modeled routes are heading. Pathways running from Saba towards the southeast corner of Puerto Rico are costlier than those towards the Virgin Islands. Here, direct

From	To	Month	Min	Max	Average
Puerto Rico (NE)	St. Thomas	January	17.768	29.633	25.802
Puerto Rico (NE)	St. Thomas	April	19.47	27.595	24.147
Puerto Rico (NE)	St. Thomas	July	21.609	37.337	26.895
Puerto Rico (NE)	St. Thomas	October	21.07	31.415	25.747

Table 13: Time costs for routes from the Puerto Rico northeastern node to St. Thomas.

From	To	Month	Min	Max	Average
Saba	St. Thomas	January	29.831	39.5277	33.244
Saba	St. Thomas	April	31.368	35.147	32.95
Saba	St. Thomas	July	29.825	37.747	34.0553
Saba	St. Johns	January	26.551	32.964	29.826
Saba	St. Johns	April	27.555	32.109	29.513
Saba	St. Johns	July	27.538	34.847	31.2577

Table 14: Time costs for routes from Saba to St. Thomas and St. Johns.

routes to the southeast coast of the larger island ranges from a maximum of 52 hours to a minimum of 40 hours (see Table 10; Appendix C). However, this route is less costly those moving directly towards the northwest coast of Puerto Rico. Based on these hypothetical pathways, it is possible that canoers favored direct movement to Puerto Rico's southeast corner or chose to head to the north if they wanted to break their journey's time cost by resting on the Virgin Islands. It is also conceivable that real-world crews headed further south to stop over on St. Croix when traveling towards Puerto Rico's southern edge. This would have a similar effect of providing a rest point as moving towards the Virgin Islands.

Puerto Rico and St. Croix

Routes through the south of the channel sometimes connected with St. Croix, which is consistent with the archaeology that has been found on the island (see Faber-Morse 1995, 2004; Hardy 2008; Lundberg and Righter 1999). The cost values returned for routes to and from St. Croix indicate it would be an ideal stopover point when moving through the Anegada Passage. For example, it typically took 30 hours in January to canoe from Saba to St. Croix (see Table 13; Appendix C). Canoe voyages from St. Croix to Puerto Rico lasted roughly 18 hours (see Table 13; Appendix C). As mentioned above, a direct voyage between Saba and the southeast of Puerto Rico typically takes 45 hours (see Table 13; Appendix C). The combined total cost of moving from Saba through St. Croix towards Puerto Rico carries almost same time cost as a direct crossing (see Table 13; Appendix C). The slight difference between a direct and indirect crossing from the Leeward Islands to Puerto Rico suggests routes that stopped at St. Croix may have had a greater chance of success, because if crews used these pathways they could rest and recuperate on the island. The Salt River site on St. Croix (see Figure 53) was likely a popular stopover location as resting at the site would not have added an extra time cost to the voyage. This is supported by archaeological evidence from the island (Faber-Morse 2004; Homan *et al.* 2007).

From	To	Month	Min	Max	Average
Saba	St. Croix	April	25.678	29.116	27.356
St. Croix	Puerto Rico (SE)	April	15.353	19.793	17.453
		Total	41.031	48.909	44.809

Table 15: Example of route time costs from Saba to Puerto Rico through St. Croix in April.

Beyond archaeological evidence, the ease of movement between Saba and St. Croix and St. Croix and Puerto Rico indicates St. Croix was probably a link in exchange networks connecting Puerto Rico and the island of Saba. The time costs for voyages heading from St. Croix to the south of Puerto Rico were lower than for routes heading to the north. Modeled routes between St. Croix and the southwest coast of Puerto Rico returned time costs of roughly 17 hours in April (see Appendix C). This is less than half the time cost of voyages connecting St. Croix and the northwest point of Puerto Rico in the same month (see Appendix C). The reciprocal voyage from the northwest point of Puerto Rico towards St. Croix is shorter, around 35 hours (see Appendix C). From this point, if real-world canoes were following similar pathways to the ones modeled here they might have to paddle an additional 10 hours to make the return trip possible. Therefore, the time costs of the hypothetical routes suggest that on the return voyage to the Leeward Islands crews traveling along these movement corridors may have found stopping at St. Croix undesirable due to the added time cost.

However, the ease of movement from Saba towards St. Croix and Puerto Rico may support the conclusion that St. Croix not only represented a prominent link within exchange networks but also was the main tie between Kelby's Ridge on Saba and the so-called Taíno culture of the Greater Antilles. This stop may have supplanted any direct connections between Puerto Rico, or even Hispaniola, and Saba. More research between materials in assemblages on St. Croix, Saba, Puerto Rico and the island of Hispaniola could be compared to check the parameters of this possible mobility network.

Most of the route costs generated for trips across the Anegada Passage do not indicate one season is more cost-effective than another. At best, the time cost for routes across this expanse could indicate whether it is easier to travel east or west. As the cost difference between seasons can be as little as one hour, these pathway time costs are suggestive rather than definitive examples of an optimal travel period. The lack of a clear optimal travel period is mirrored in those routes that offered stopping points. Routes heading through the south of the channel were less likely to come into a position allowing a stopover than those in the north, possibly due to the similar cost of traveling direct versus through the Virgin Islands. Given the low difference in time cost across modeled routes, it is possible canoers traveling along similar trajectories to the least-cost routes choose to stopover based on social preferences.

6.3.4 Route Trajectory

During my analysis, it became clear that route trajectories would be a key factor in determining the importance of specific canoe pathways. The similarity between route costs for voyages modeled in this case study suggest that Amerindian canoers following like travel corridors may have had more freedom to select routes that would benefit them socially or economically. These trajectories can be grouped into corridors of movement that split off in many directions depending on the origin point, the canoe's heading, and in some cases an extended time cost. Discussing a crew's deviation from the typical route layout is valuable as these pathways often pass by in between islands. Instead of weighing the pros and cons of attempting a route of a specific length, canoe navigators may have focused on where canoe travel corridors were located. This could have involved reliance on mental maps, constructed over a lifetime of learning from older canoers who instructed individuals in the art paddling between in similar ways peoples taught others to traverse landscapes (*sensu* Ingold 1993, 2011). As such, a comparison of the trajectory of canoe runs can point to possible indirect connections more accurately than just comparing similar route cost. The following sections detail notable route layouts returned for this case study.

6.3.4.1 Movement across the Mona Passage

The first route layout analysis centers on movement across the Mona Passage. Routes through this channel are a key component in any journey between the Dominican Republic and the Lesser Antilles and can suggest possible points of departure from the Dominican Republic as well as connections between Hispaniola, Mona Island and Puerto Rico.

Reciprocated links between Puerto Rico and the Dominican Republic demonstrate the ease of movement across the channel. Many routes between the larger islands also included possible connections with Mona Island. Routes moving from the Dominican Republic and Puerto Rico often pass the northwest coast of the island. These routes coincide with the placement of cave sites on the island that overlook the sea to the north (Samson *et al.* 2013; Samson and Cooper 2015a, 2015b). However, although routes pass close to the island, there is no guarantee that direct contact with the coast of Mona Island was made due to the presence of high cliffs on the island's north coast (Samson and Cooper 2015a, 2015b). It is possible that if real-world crews choose to travel along these modeled least-cost routes, they may have chosen not to stop over at the island but to take advantage of the visual aid provided by the coastline to visually reinforce Mona Island's relationship to a communal mental navigation map (*sensu* Ingold 1993; Lewis 1994; Terrell 1997). It is possible that over time canoers altered travel corridors to come in sight of these caves, adapting navigation maps to fit with changing cultural places (*sensu* McNiven 2008). Routes that travel north of Mona Island, such as route 0-3_2012-04-12T06, would have been in prime position to view the caves set into the island's northern coastal cliffs (Samson *et al.* 2013). In some cases, these routes lie less than 10 km off the coast of the island (*e.g.*, route 0-3_2012-04-08T00; see Appendix C). If people in these caves lit fires, the smoke created could be visible to passing canoes (Brughmans *et al.* 2017).

Several routes modeled for this work demonstrate the possibility of a relationship between seafarers and peoples on Mona Island. However, these routes show that relationships with the island change depending on the origin of the canoe pathway. For example, routes from the southwest coast of Puerto Rico, or the Boquerón peninsula, are less likely to make direct contact with the island than routes coming from the north coast (*e.g.*, route 3-0_2012-04-20T15; see Appendix C). When pathways from Boquerón do make direct contact, it is because they move diagonally northwest, or directly west before heading north, mirroring routes coming from the Dominican Republic (*e.g.*, route 0-3_2012-04-08T00, route 0-3_2012-04-12T06_00, and route 3-0_2011-10-22T09;

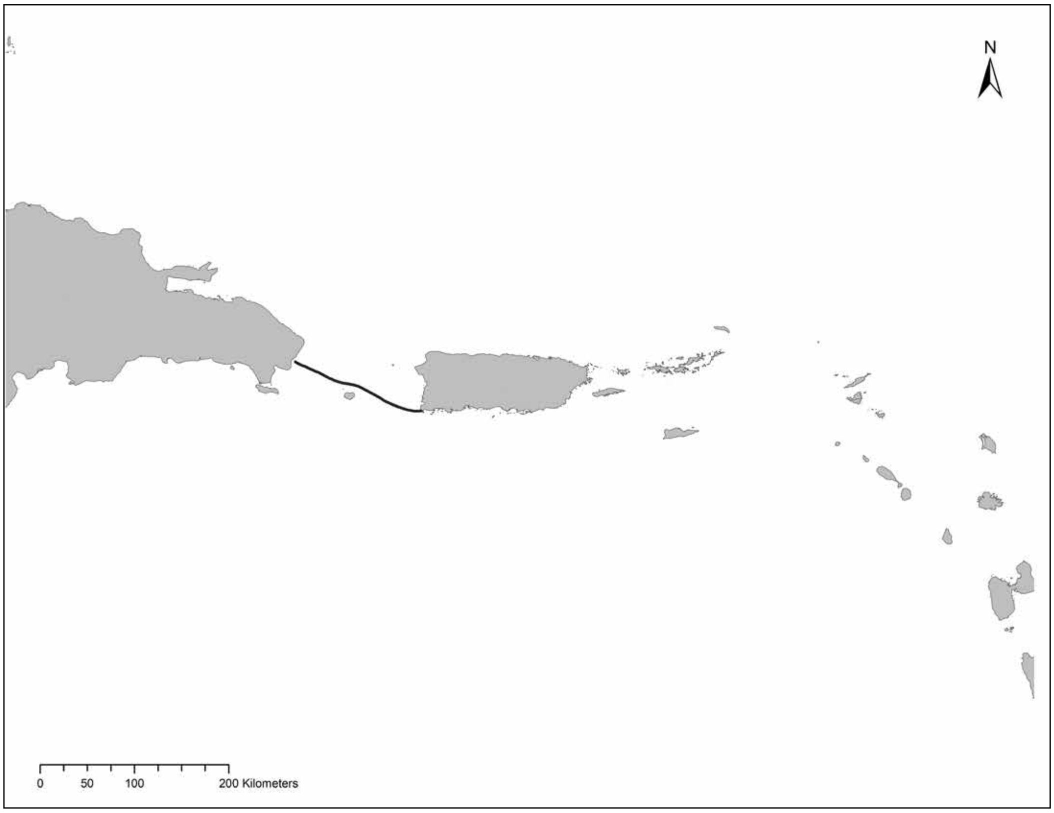


Figure 68: Route from near the site of El Cabo on the Dominican Republic to the southwest corner of Puerto Rico, or the Boquerón peninsula, in April. Route launched at 12am on the 8th of April 2012, Route: 0-3_2012-04-08T00.

Figure 68; see Appendix C). These routes follow Mona Island's eastern coastline. Canoe routes from the southeast of Puerto Rico also follow this trajectory (see Appendix C). This variation in possible relationships with Mona Island may also suggest the ability of canoe navigators to avoid or connect with peoples on the island.

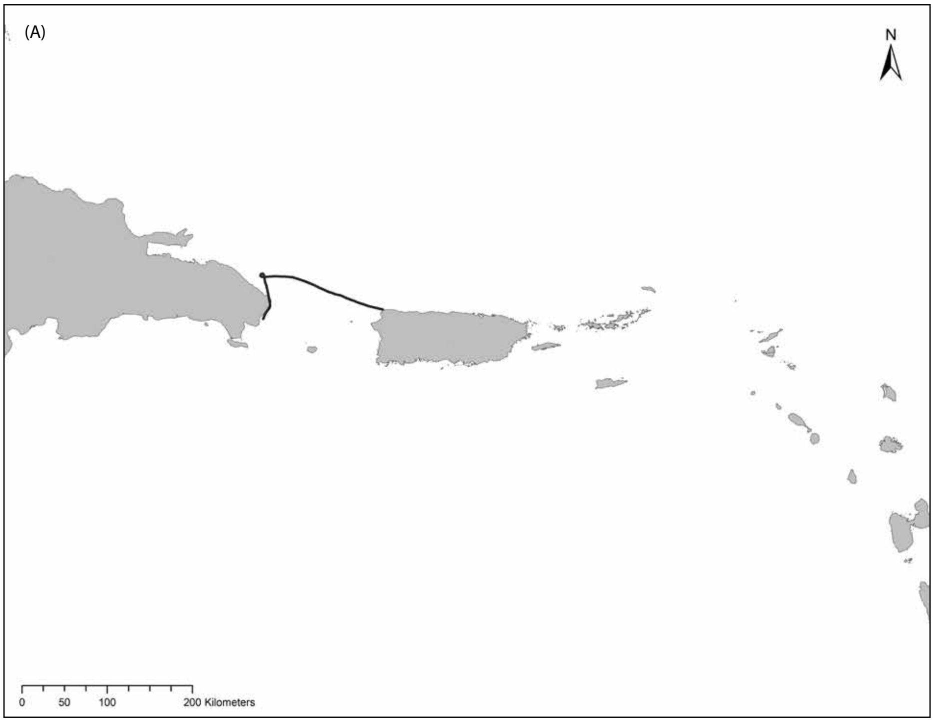
Routes completing the reciprocal voyage past Mona Island sometimes headed directly across the channel. Canoe routes heading towards Boquerón typically went due east from the Dominican Republic to connect with the western coast of Puerto Rico (*e.g.*, route 3-0_2012-04-17T00_00, route 0-3_2012-04-23T09, and route 0-3_2012-07-05T09; see Appendix C). Some routes even travel north while still protected from stronger currents by the island; these routes mimic real world seafaring choices (*sensu* Billard *et al.* 2009; Bowditch 2002). These trends may also point towards the location of possible stopover points along the coast of Puerto Rico. As these routes hug the coastline, taking advantage of protective navigation techniques, canoers that may have travelled along them could have met with other peoples who lived along the coast. Sites along these stretches of coastline passed by canoers likely acted as recipients and distributors for materials from the Dominican Republic. This area could represent the first stage of exchange towards the northern Lesser Antilles.

Routes from and to the Dominican Republic also hint at the location of additional origin sites for Taíno peoples who were exporting materials to the west coast of Puerto Rico. Some April routes from El Cabo pass the northwest coast of the Dominican Republic before turning towards the northwest coast of Puerto Rico (*e.g.,* route 0-11_2011-04-03T00, route 0-11_2011-04-09T09; see Appendix C). During all months, routes are pushed far to the north of the node on the Dominican Republic, passing parallel to the city of Uvero Alto (*e.g.*, route 0-1_2012-07-16T09, route 0-1_2012-07-10T06, route 0-1_2012-04-07T21_00, and route 0-1_2012-04-15T15_00_isochrone; Figure 69; see Appendix C) or Punta Cana (*e.g.*, route 0-10_2011-04-14T03, route 0-10_2011-01-3T09; Figure 69; see Appendix C). In a few cases, pathways launched in April movement to the north of El Cabo before heading directly east from Punta Cana (*e.g.*, route 0-11_2011-04-07T12). Other routes show canoes headed north for roughly five km before heading east (*e.g.*, route 0-3_2012-04-02T12_00). This last route is shaped to take advantage of the current that runs to the north of Puerto Rico. The routes to and from the Dominican Republic that pass by this location support the idea that the Punta Cana region was an export center of Taíno materials. The link between the higher density of known habitation sites in this area (see Keegan 2006) and these least-cost routes should be explored in future works.

These routes can point to areas where reciprocated links were established to exchange materials between Puerto Rico and the Dominican Republic. The presence of foreign materials within sites found between these areas or along the modeled routes should be re-evaluated in this context. The location of El Cabo fits within this interpretation, as it is located south of the densely populated Punta Cana region (see Keegan 2006; Figure 69). Even though selection of El Cabo as a node may have influenced this interpretation, the fact that routes never approach the site from the south indicates that the northeastern coast of Hispaniola should be considered for possible stopover connections due to its continual connection with Puerto Rico within the routes modeled. In future, routes directly to and from the Punta Cana region can be tested to evaluate ease of connection between this heavily populated area and Puerto Rico.

Canoe routes returned by the route tool often mimicked real-world sailing practices of small vessels whose navigators may have favored predictable currents. This is reflected in the stretches of times where routes followed similar pathways, or micro-travel periods. For example, routes from route 0-11_2011-04-10T06 to route 0-11_2011-04-10T15 show movement between the northwest coast of Puerto Rico and the northwest coast of the Dominican Republic. Leaving during this nine-hour stretch increased the opportunities of people from El Cabo to connect with communities on the north coast of the Dominican Republic and Puerto Rico. Stretches like these would have made travel safer for Amerindians as navigators with the right wayfinding map could navigate these predictable micro-travel period trends to reach their destinations.

How origin points and destination points were connected, or the trajectory of routes between them, likely shaped travel rhythms in the region. This is true for crews connecting with export areas on the Dominican Republic and canoers hoping to pass by Mona Island. Those who wanted to head towards Mona Island from Puerto Rico may have prioritized coming from the south coast of the island to allow currents to push them past the smaller island. Where crews launched their vessels affected in the terms of contact.



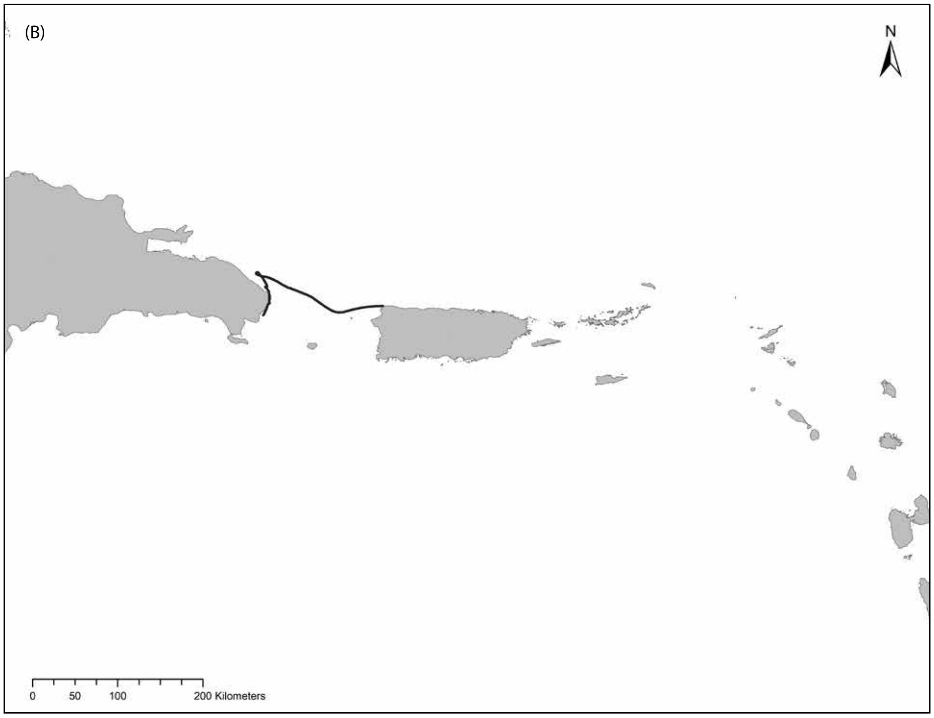


Figure 69: Route from near the site of El Cabo on the Dominican Republic to the northwest corner of Puerto Rico. (A) Route launched at 3pm on the 15th of April 2012, Route: 0-1_2012-04-15T15, (B) Route launched at 3am on the 8th of July 2012, Route: 0-1_2012-07-08T03.

As a result, possible decisions made by navigators had a great effect on how materials were moved across the Mona Passage.

6.3.4.2 Movement above and below Puerto Rico

Though routes across channels have shown to be significant aspects of route trajectories, movement along the coast of islands can also indicate important areas of connection. In many cases routes along the coast could relate to possible regional control of caciques over canoe corridors (Curet *et al.* 2004; Crock 2005; Siegel 2001). The concepts of Eastern and Western Taíno communities, and the separation of more divided polities on Puerto Rico, may be related to the movement of Lesser Antillean and Greater Antillean material through the island (Crock 2005; Curet *et al.* 2004). Where canoers moved past the coastline, they could have altered the shape of these communities and the regions they influenced. Peoples in these areas could have viewed canoers coming and going along the coast (Torres and Rodríguez Ramos 2008), increasing their connection to inter-regional mobility networks. Therefore, a discussion of pathways along Puerto Rico's coast is an important step to uncovering mobility patterns connecting Hispaniola to the Leeward Islands.

Canoe pathways often hugged the coasts of Puerto Rico. There are several archaeological sites along the south edge of the island (Crock 2005; Keegan and Hofman 2017; Pagán Jiménez 2007). It is possible that sites grew along these coastal areas and the nearby interior inhabitation zones, to take advantage of both mangroves along the

Figure 70: Route from the Dominican Republic towards northeast of Puerto Rico in January. Route launched at 12am on the 30th of January 2011, Route: 0-12_2011-01-30T00.

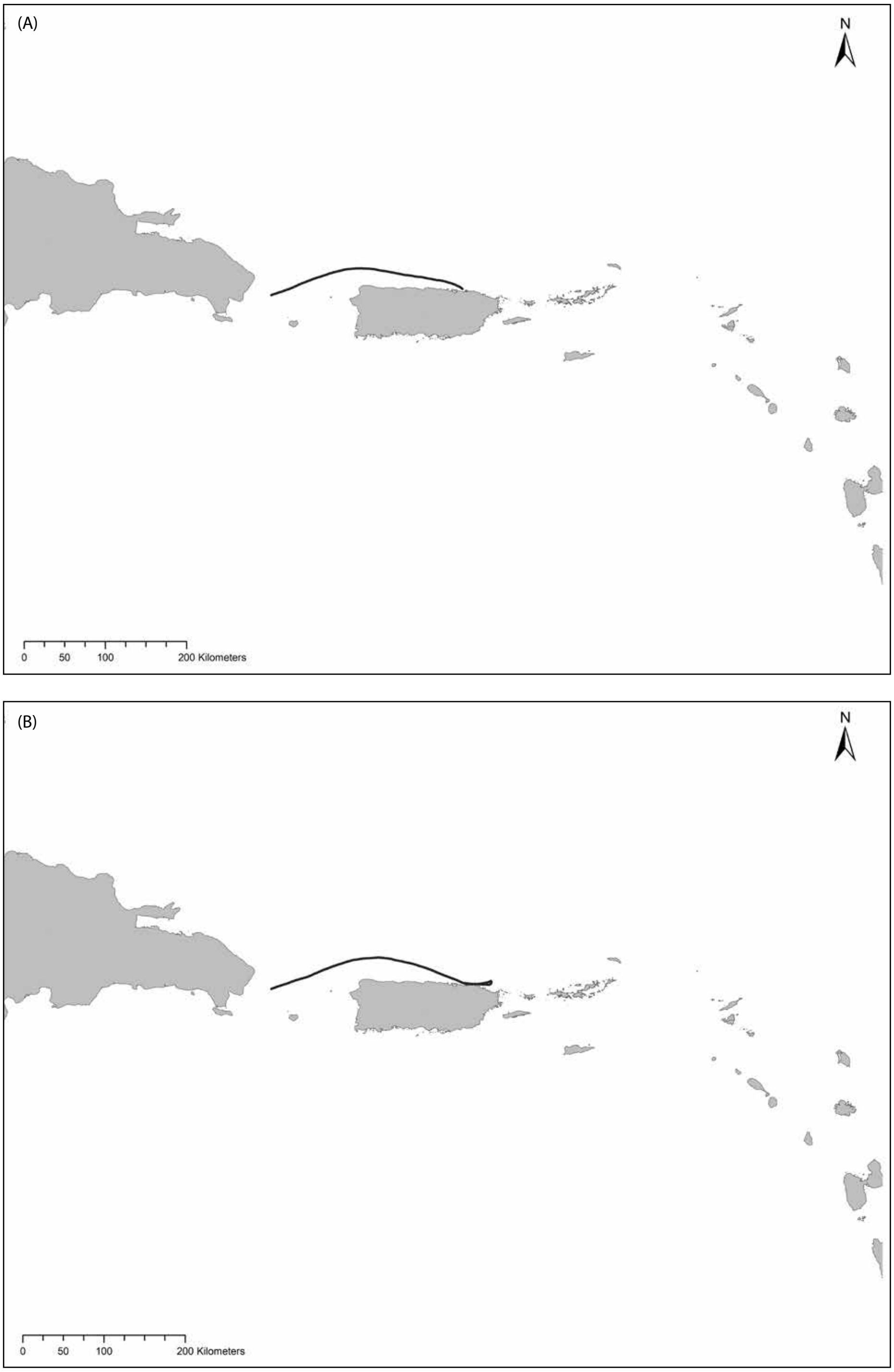


Figure 71: Route between northeast of Puerto Rico towards the Dominican Republic in January. This route has a looped section at the right end of the pathway over Puerto Rico's northeastern coast. (A) Route launched at 9pm on the 8th of January 2011, Route: 12-0_2011-01-08T21, (B) Route launched at 6pm on the 4th of January 2011, Route: 12-0_2011-01-04T18.

Figure 72: Route between northeast of Puerto Rico towards the Dominican Republic in July. Route launched at 3pm on the 3rd of July 2011, Route: 12-0_2011-07-03T15.

coast (Martinuzzi *et al.* 2009) and the canoe corridors that travelled along the southern coast. Routes also passed along the north coast. Though there are not as many mangroves or sites currently recorded in this area, crews that may have traveled along these hypnotical least-cost coastal pathways would have been presented with opportunities to rest and meet with different peoples.

Voyages from the Dominican Republic often hug the north coastline of Puerto Rico when moving east (*e.g.*, route 0-12_2011-01-30T00; Figure 70; see Appendix C). This stands in contrast to routes from the northeast of Puerto Rico towards the Dominican Republic that typically arced far north of the coast (*e.g.*, route 12-0_2011-01-08T21; Figure 71; see Appendix C). Some of these arced routes can be discounted as they begin by heading east before looping back around by the point to head west, possibly due to a strong current rising up along the coast during these periods (*e.g.*, route 12-0_2011-01-04T18; Figure 71; see Appendix C). In reality, canoers leaving from this point may have waited out adverse currents until it was easier to paddle west.

Hypothetical routes moving past Puerto Rico indicate that real-world canoers traveling in this direction had the option to go above or below the island depending on the heading of their vessel and the season of the year. Route layouts past the island suggest that in January and October it was easier to go east when moving above the island and west when moving below it (*e.g.*, see Figures 71 and 73; Appendix C). This pattern is also seen to a lesser extent in pathways modeled for the month of April (see Appendix C). Moving in either direction in July over the top of Puerto Rico shows routes relatively near the coast (*e.g.*, route 12-0_2011-07-03T15; see Figure 72;

Appendix C). As a result, traveling in July increased safety for those who may have been traveling along the same trajectory as the hypothetical least-cost routes modeled here, suggesting that this may have been the preferred season to travel north of the island when heading east. In these cases, routes that passed far off the coast of Puerto Rico may be viewed skeptically. Here, crews that may have traveled in the same direction as these routes could have chosen to hug the coastline and prioritize safety and resource access over speed. Following these respective routes increased voyage safety levels as the pathways stayed as close to the coastline as possible (see Figure 72). Similarly, these seasonal direction preferences could have made taking stops easier in certain periods.

These seasonal separations between January, October, April, and July could also have formed the base for reciprocal travel seasons. For example, an Amerindian group from El Cabo that followed similar least-cost pathways to those modeled here could decide to travel to the northeast coast of Puerto Rico in April and return in July. This ensured those would-be canoers had a greater chance of sticking to the coastline when traveling east and west. The direction of travel also influenced stopover connections for routes passing by Puerto Rico. These options are corroborated by the cost values for these routes (see Appendix C).

Sailing seasons that influenced travel to and from Puerto Rico also affected a crew's ability to pass by Mona Island, as routes to Puerto Rico do not always pass by the coast of the island. Periods during which canoe pathways pass the island vary over the year and depend largely on the direction of travel. When moving east from the Dominican Republic some routes pass north of Mona Island before hugging the underside of Puerto Rico (see Figure 73). Canoe routes in April pass closer to the southern edge of Puerto Rico (*e.g.*, route 0-1_2011-04-13T00; Figure 73; see Appendix C). January canoe routes do not hug the coastline as much, but typically pass closer to Mona Island (*e.g.*, route 0-1_2011-01-10T18, route 0-1_2011-01-13T21; Figure 73; see Appendix C). Even in cases where modeled canoe pathways reach the southwest corner of Puerto Rico, January routes do not adhere as closely to the coastline as routes in other months (*e.g.*, route 0-1_2011-01-13T06; see Appendix C). This could suggest a possible seasonal preference existed not just within the confines of the modeled routes but among real-world canoers as well, with past canoers possibly avoiding travel to the west in January.

Many hypothetical routes would have allowed for canoers following similar travel corridors to stop at Mona Island. Crews who wished to stop at the island had to land on the island's southwest coast, as the rest of the island's coastline consists of high cliffs. From landing beaches Amerindians could then walk to the caves on the island's north coast. Some of the modeled canoe routes employed interesting techniques to reach this landing area. Many routes pass over the north coast of Mona Island before coming around the western coast to reach the landing point (*e.g.*, route 2-1_2011-04-04T00, route 2-1_2011-04-08T15, route 2-10_2011-04-05T09, and route 2-1_2011-04-23T21; Figure 74; see Appendix C). In January, these routes could arc further to the north of Mona Island (*e.g.*, route 2-1_2011-01-07T03, route 2-1_2011-01-08T03; see Figure 74). Canoers who may have gone to the far side of Mona Island before attempting to make landfall would have been sheltered from the current as they approached the landing area. Additionally, these routes would have had direct visual access to the northern coast of Mona Island (Samson and Cooper 2015a, 2015b). The distance between the pathways and the caves would have been possible

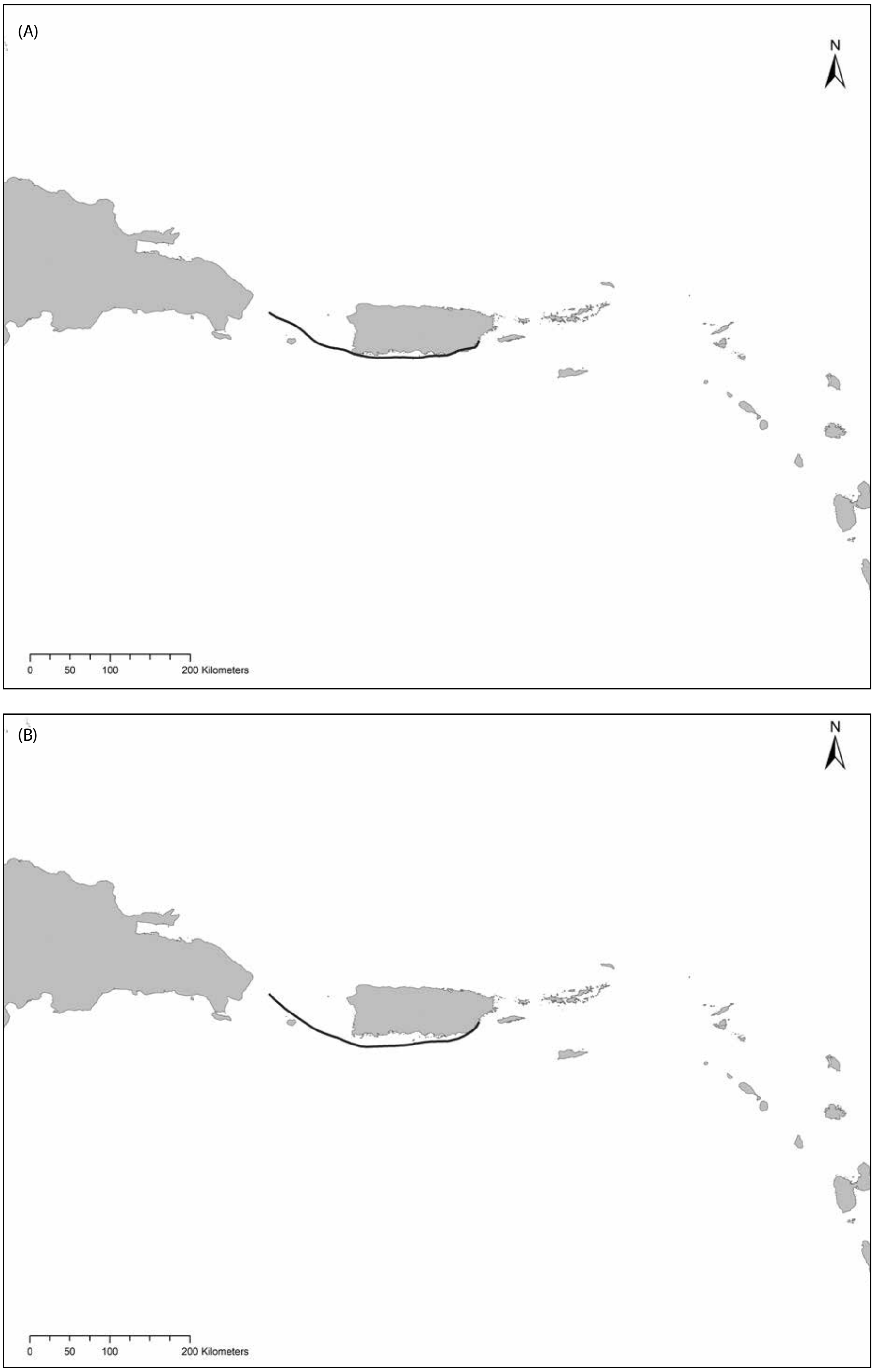


Figure 73: Route from near the site of El Cabo on the Dominican Republic to the south-east corner of Puerto Rico. (A) Route launched at 12am on the 13th of April 2011, Route: 0-1_2011-04-13T00, (B) Route launched at 9pm on the 13th of January 2011, Route: 0-1_2011-01-13T21.

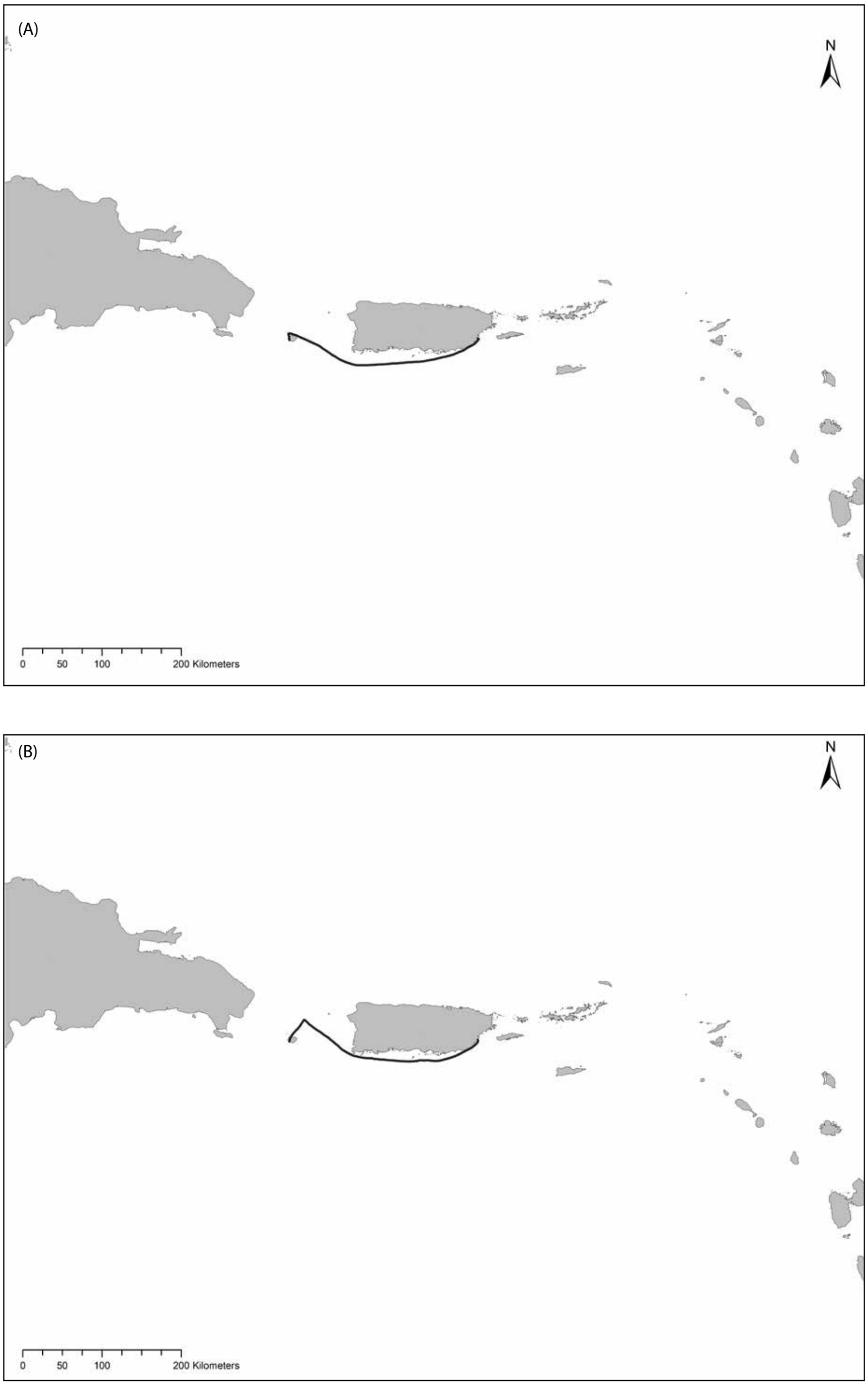


Figure 74 (continued on next page): Route from the Southwest of Puerto Rico towards Mona Island. (A) Route launched at 9pm on the 23rd of April 2011, Route: 2-1_2011-04-23T21, (B) Route launched at 3am on the 7th of January 2011, Route: 2-1_2011-01-07T03, (C) Route launched at 3am on the 8th of January 2011, Route: 2-1_2011-01-08T03.

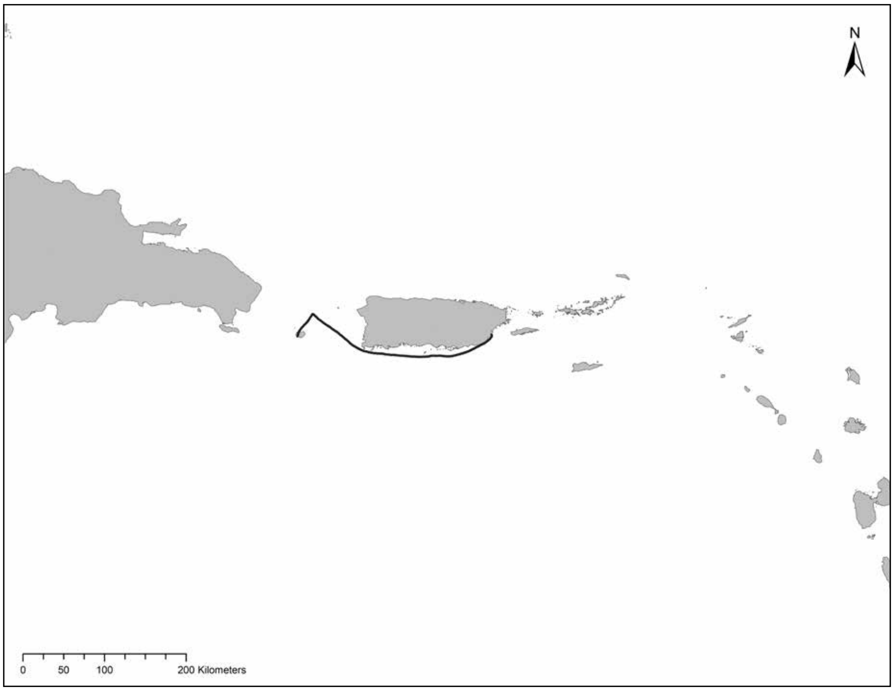


Figure 74 (continued).

to see across, cementing relationships between the peoples on Mona Island and those passing it. Given their visual prominence, these caves also represent a strong candidate for Amerindian wayfinding points.

Some least-cost pathways leaving from the southwestern edge of Puerto Rico move partway up the west coast of the island before heading east towards Mona (*e.g.*, route 2-1_2011-01-08T03; Figure 74; see Appendix C). These routes sometimes moved northwest only to turn back south off the coast of the Dominican Republic near El Cabo (*e.g.*, route 3-2_2012-04-16T12; see Appendix C). If indeed crews travelled along these routes they may have continued on the coast towards El Cabo. These routes indicate that El Cabo was well placed to take advantage of least-cost routes from Puerto Rico, as routes head straight across would reach the site area.

Movement around Vieques

As routes modelled for this work pass along both the southern and northern coastline of the Vieques, movement past the landmass links with most of the island's sites (Pagán Jiménez 2007). Most sites on Vieques lie on the southern coast (Pagán Jiménez 2007) and pathways that run along this edge of the island are more likely to make direct contact with Vieques' coastline. This is consistent with the tendency of modelled canoe routes to pass south of the island (*e.g.*, route 1-3_2011-07-18T21; Figure 75; see Appendix C). On the other hand, routes that pass the northern coast typically directly connect with the northwest portion of the island (*e.g.*, route 1-3_2011-07-18T12; Figure 76). This pattern is related to the trend of site placement on the island, as routes often connect with the coastline near to most northern

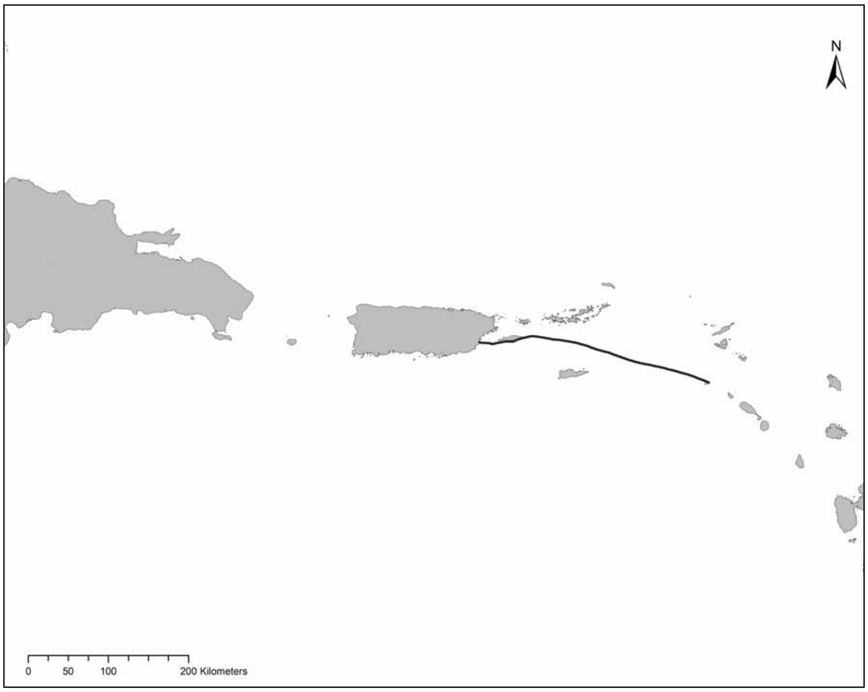


Figure 75: Route between Saba and Puerto Rico that passes below Vieques in July. Route launched at 9pm on the 18th of July 2011, Route: 1-3_2011-07-18T21.

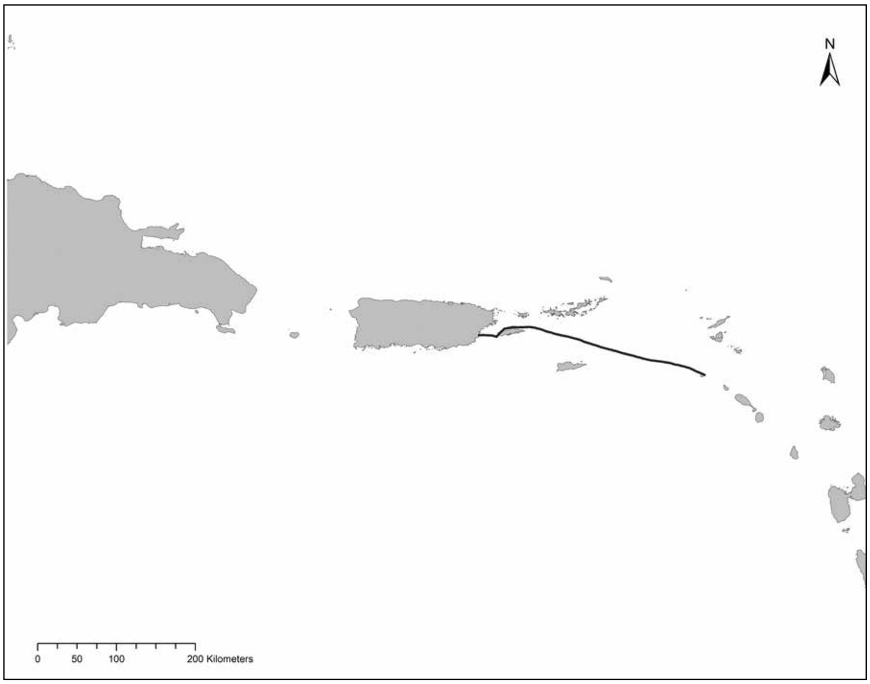
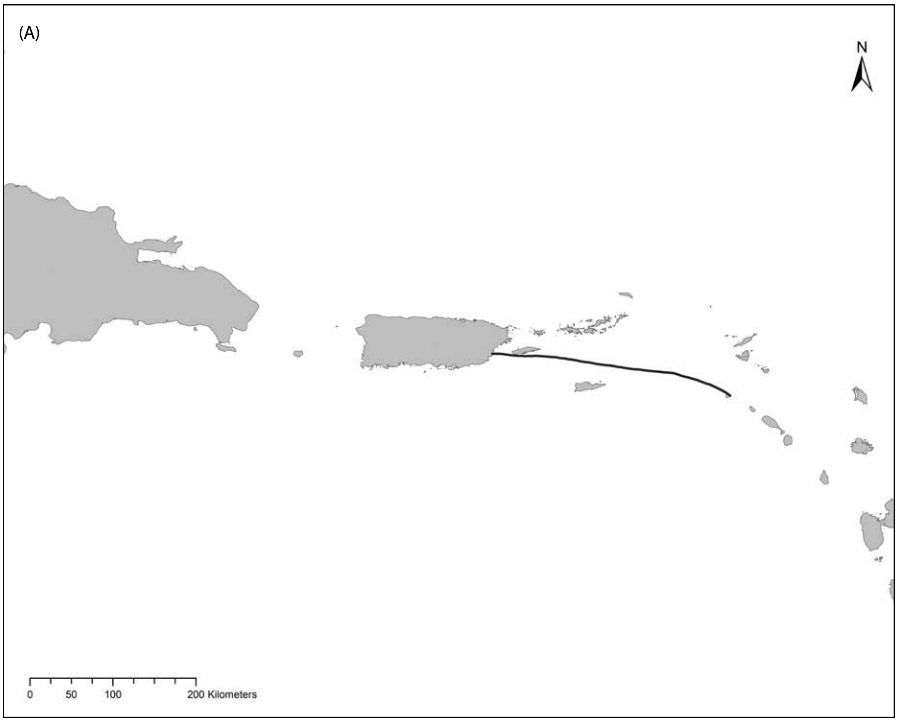


Figure 76: Route between Saba and Puerto Rico that passes over Vieques in July. Route launched at 12pm on the 18th of July 2011, Route: 1-3_2011-07-18T12.



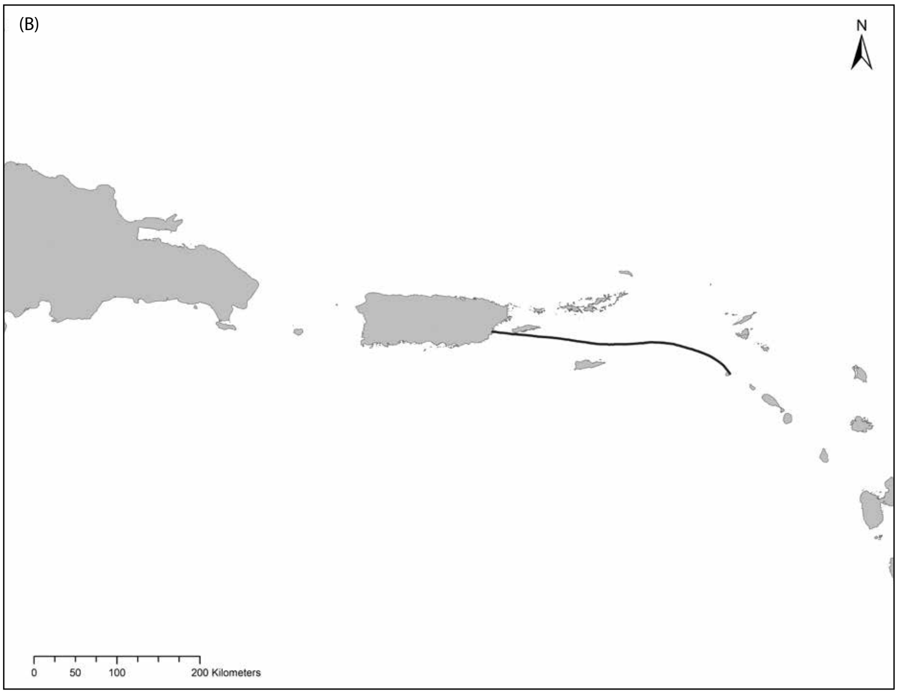


Figure 77: Routes between Saba and Puerto Rico that pass below Vieques in October.
(A) Route launched at 5:12pm on the 23[rd] of April 2012, Route: 1-3_2012-04-23T17_12 and
(B) Route launched at 12 am on the 17[th] of January 2011, Route: 1-3_2011-01-17T00.

sites (Pagán Jiménez 2007) (*e.g.*, route 1-3_2011-07-18T12; Figure 76; see Appendix C). Perhaps real-world canoers traveling near these least-cost routes found it was easier to push south when slightly sheltered by the island, making landfall in this area easier. Amerindians may have established sites where canoe pathways met the coastline. This could indicate a connection between route trajectories and site placement.

Vieques may have had a prominent role in the network of Ceramic Age sites due to its placement and the location of sites on the island. The modelled pathways show the ease of connection between Vieques and Puerto Rico, as well as prominent positions along routes travelling to the southeastern portion of Puerto Rico from the Lesser Antilles. Movement from Saba and Anguilla to Punta Candelero almost always connects with Vieques (see Appendix C). Considering the island's status as a feasting or gathering site (Crock 2005; Hofman *et al.* 2014; Pagán Jiménez 2007), this leads to interesting questions about the connection between canoe travel routes and feasting and procurement sites.

Movement past Isla De Culebra

Isla De Culebra was selected by Rouse (1992) and Oliver (1995: 493) as a representation of a transitional area for so-called Taíno cultural material and stylistic elements. It is possible that communities on this island could choose to either engage or disengage with certain stylistic ideas coming from the eastern edge of Puerto Rico (Oliver 1995: 495). This may be highlighted through comparison with materials on and modeled optimal movement around Vieques. Isla De Culebra does not have the same intensity of occupation as Vieques (Crock 2005; Pagán Jiménez 2007). This could be due to the infrequency of contact made with the island when not moving to or from the Virgin Islands, as there is a lack of direct connections with the Lesser Antilles. However, many routes pass by Isla De Culebra when moving between the northwest coast of Puerto Rico and many of the Virgin Islands (see Appendix C). This could indicate that although Isla De Culebra did not play a major role in exchange across the Anegada Passage, it may have been a key point for canoers paddling in the Virgin Islands.

For example, routes between Puerto Rico and St. Thomas often reach either the north or south coast of the island (*e.g.*, route 12-8_2011-01-04T21, route 12-8_2011-05T00; see Appendix C). Other routes form a straight line between Puerto Rico and St. Thomas by passing to the north of the island (*e.g.*, route 12-8_2011-01-12T15). While routes heading from Saba to the northwest coast of Puerto Rico had ample opportunity to contact Isla De Culebra (*e.g.*, route 1-2_2012-04-27T21; Figure 78 and 79), there were no direct connections between the two, suggesting that any connection was an indirect one.

Both St. Thomas and Isla De Culebra may have been visible to real-world crews paddling in a similar trajectory to form a possible travel corridor. This makes both islands candidates for visual navigation markers for crews. These visual links and the close relationship between route and island establish the options for some crews passing through the Virgin Islands to stop at Isla De Culebra. A deeper comparison of materials from St. Thomas, Puerto Rico, and Isla De Culebra could further uncover the island's involvement in the broader Late Ceramic Age sphere of inter-island interaction.

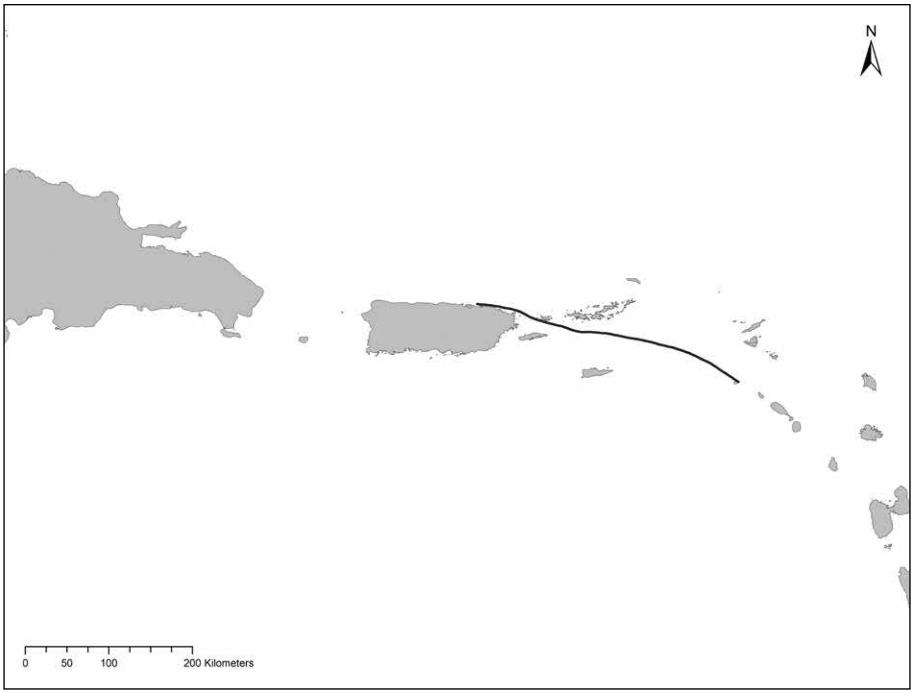


Figure 78: Route between Saba and Puerto Rico that passes below Isla De Culebra in April. Route launched at 9pm on the 27th of April 2012, Route: 1-2_2012-04-27T21.

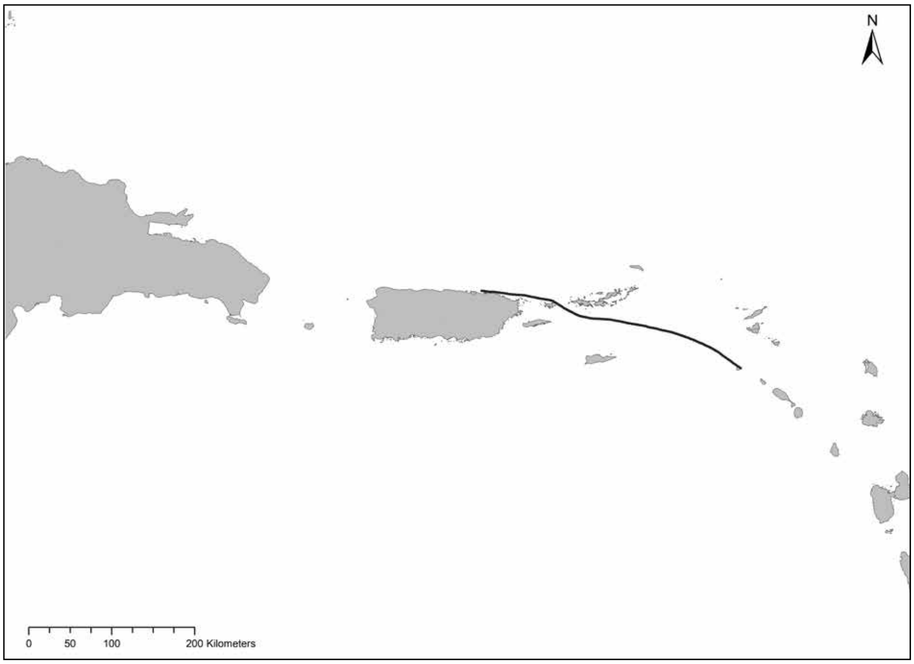


Figure 79: Route between Saba and Puerto Rico that passes below St. Thomas and to the north of Isla De Culebra in April. Route launched at 6pm on the 27th of April 2012, Route: 1-2_2012-04-27T18.

6.3.4.3 Movement across the Anegada Passage

Many of these routes represent possible corridors of connection between the so-called Central Taíno interaction sphere and the Taíno periphery sites. Movement across the channel may be able to shed light on the specifics of these connections. Analysis of modeled pathways can indicate whether the trajectory of optimal routes fit with social relationships uncovered in assemblages (*e.g.,* Crock and Peterson 2004; Curet *et al.* 2004; Faber-Morse 2004; Hoogland and Hofman 1999; Keegan and Hofman 2017; Righter *et al.* 2004; Torres 2010), tying Anguilla, Saba, St. Croix, and the Virgin Islands to the broader regional exchange network. These interactions between island communities may have varied depending on the cost and layout of routes and the geographic relationship of the islands to one another.

The biggest challenge for crews lay in crossing the Anegada Passage, due to the size of the channel and the visual disconnect at its center (Torres and Rodríguez Ramos 2008). Routes often covered large stretches of the channel out of sight of land. The modeled routes also indicate increased difficulty as currents often pushed the pathways to head away from a straight-across route. It is possible that crews used these currents to their advantage by engaging with the islands they passed when forced into an indirect route. The least-cost pathways modeled here suggest there may have been many opportunities for real-world crews traveling in this area to stop and participate in exchange or use in-between islands as visual markers.

Figure 80: Route between Saba and Puerto Rico that passes below St. Thomas in January. Route launched at 3pm on the 23rd of January 2011, Route: 1-2_2011-01-23T15.

Least-cost routes running from the Lesser Antilles to Puerto Rico suggest that canoers may have had many opportunities to engage with peoples on the Virgin Islands. Many routes modeled for this work show routes that head north to the Virgin Islands before moving towards the Greater Antilles (*e.g.*, route 1-2_2011-01-23T15; Figure 80). Routes like these highlight the connection between Saba and Virgin Islands sites like Tutu and Magens Bay that lie along pathways (see Figure 80; Appendix C). Pathways from Anguilla to Puerto Rico also show movement that passed Late Ceramic Age Virgin Island sites (see Appendix C). This is another indication that site location was linked with route trajectory.

However, not all routes originating in Saba and Anguilla follow the same travel corridors to Puerto Rico, as routes ran both north and south of the Virgin Islands (*e.g.*, route 1-2_2011-01-23T15, route 1-2_2011-01-28T00; see Figures 80 and 81). The modeled routes suggest that canoers travelling in these areas may have been able to choose which portion of the Virgin Islands they passed on their way to Puerto Rico. These choices often resulted from the position of the origin point in relationship to the Virgin Islands. Modeled canoe pathways suggest Anguilla had a better connection with peoples on the northern coasts of the Virgin Islands (see Appendix C), including northern islands that are not passed by routes leaving Saba, such as Virgin Gorda and Anegada (see Figure 80). As such, past navigators who may have followed similar trajectories and were looking to travel to the north of the Virgin Islands could have chosen to launch their vessels from Anguilla to take advantage of the currents pushing

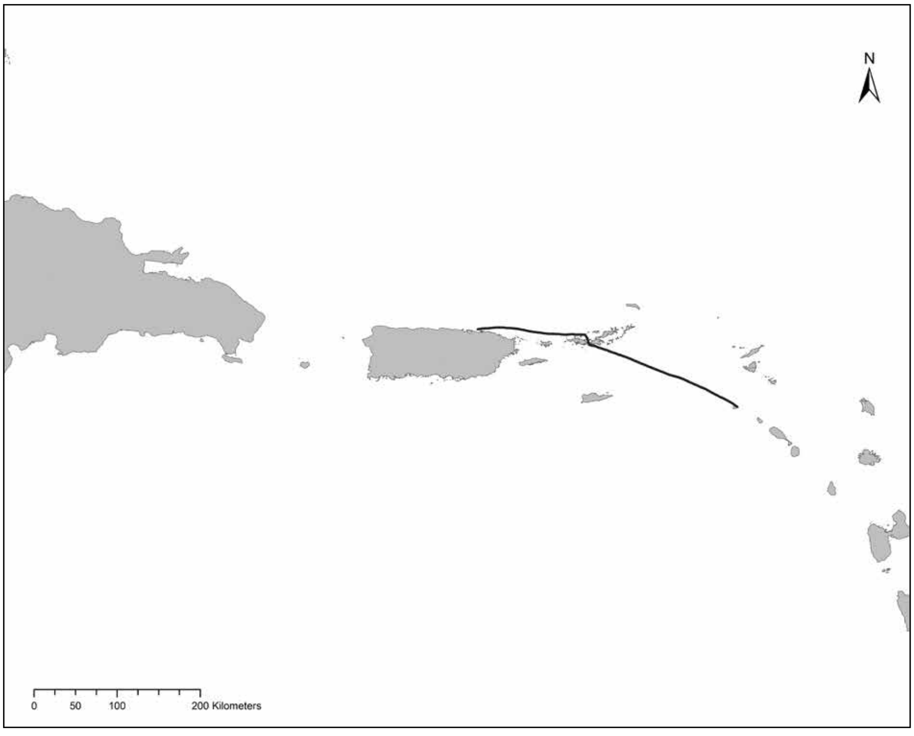


Figure 81: Route between Saba and Puerto Rico that passes St. Thomas and to the north of Isla De Culebra in January. Route launched at 12am on the 28th of January 2011, Route: 1-2_2011-01-28T00.

them northward. This may have involved first moving from Saba to Anguilla before embarking west. Conversely, if peoples adhered to least-cost routes and wanted to avoid interactions with peoples in the north of the Virgin Islands they may have chosen to launch from Saba.

Movement to St. Croix

St. Croix, which represents the other micro-region of the Anegada Passage, could have played a major role in connecting the communities in the northern Lesser Antilles to communities in the Central Taíno sphere. It stands as the southern mirror of the Virgin Islands, offering crews blown to the southeast a chance to rest or engage with communities before reaching Puerto Rico. Routes from St. Croix that pass below Puerto Rico hug the contours of the island, as is common in routes traveling to the west (*e.g.*, route 9-10_2011-01-22T06; Figure 84).

Routes from Saba to St. Croix typically head almost straight across the channel (*e.g.*, route 1-0_2011-07-17T18; Figure 82; see Appendix C) and sometimes enter the Saba Bank. These routes are dependent on the season, with routes in October less likely to connect with the area. Still, the fact that most pathways to St. Croix head through this resource area suggests pathways may have been linked to specific sea-based resources in a communal mental map. It is likely that individual knowledge of this area differed (*sensu* Ingold 2011; Tilley 1994). However, possible community relationships

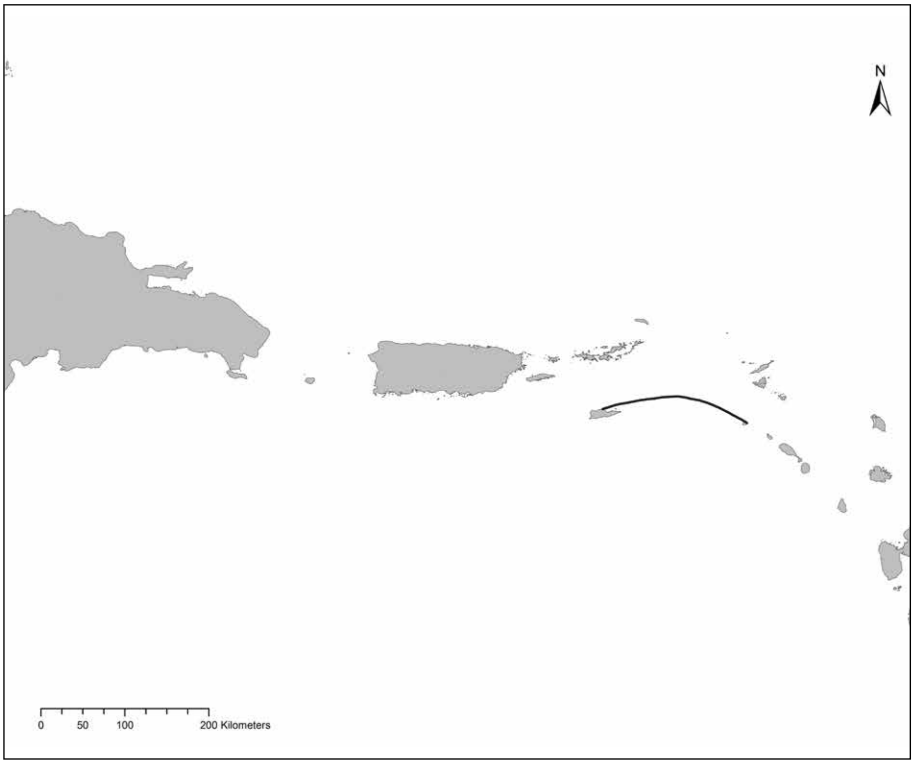


Figure 82: Route between Saba and St. Croix in October. Route launched at 9pm on the 10th of October 2011, Route: 1-0_2011-10-10T21.

with the fishing grounds at Saba Bank may have supported this connection (*sensu* Basso 1996; Hofman and Hoogland 2011; Schlanger 1992). This trajectory may have been a motivating factor for crews to leave from Saba to Puerto Rico, as they could take advantage of fishing resources when heading past St. Croix. Reciprocal routes from St. Croix to Saba had a greater probability of moving deeper into the Saba Bank than voyages heading west (*e.g.*, route 1-0_2011-10-10T21; Figure 83).

Connections between St. Croix and Puerto Rico suggest that canoers may have stopped on the island to take advantage of the higher success rates for routes from the middle of the passage. Routes from St. Croix to the east side of Puerto Rico succeed more often than voyages originating in the Lesser Antilles (see Appendix C). Passing through St. Croix can seem complicated compared with the straight across routes from Saba to Puerto Rico. However, as mentioned in the route cost section, the overall time cost for traveling in either canoe corridor is relatively similar (see Table 10). Traveling through St. Croix may have benefited canoers, as it would have given crews an opportunity to resupply and rest.

The hypothesis that St. Croix was actively in contact with communities in the northern Lesser Antilles and in the Central Taíno sphere is also supported by the close connection of routes from St. Croix to the west coast of Puerto Rico. Some westward-heading routes that pass below Puerto Rico hug the contours of the island (*e.g.*, route 9-10_2011-01-22T06; Figure 84) and these pathways suggest that canoers on similar routes could choose to push towards the underside of the island. The coast-

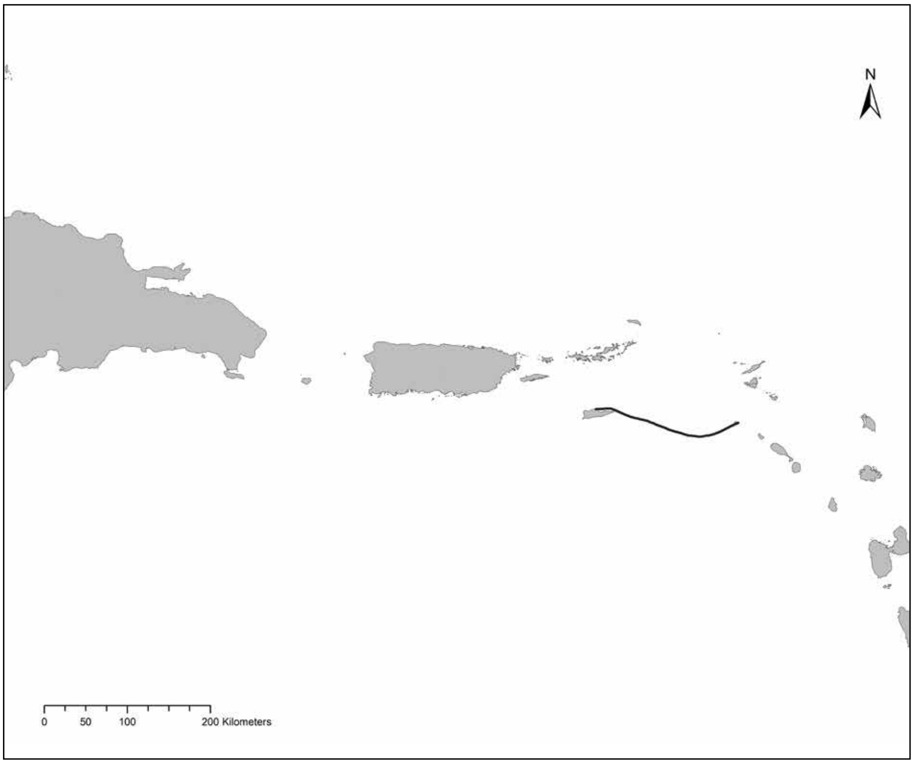


Figure 83: Route between St. Croix and Saba in July. Route launched at 9am on the 20th of July 2011, Route: 11-1_2011-07-20T09.

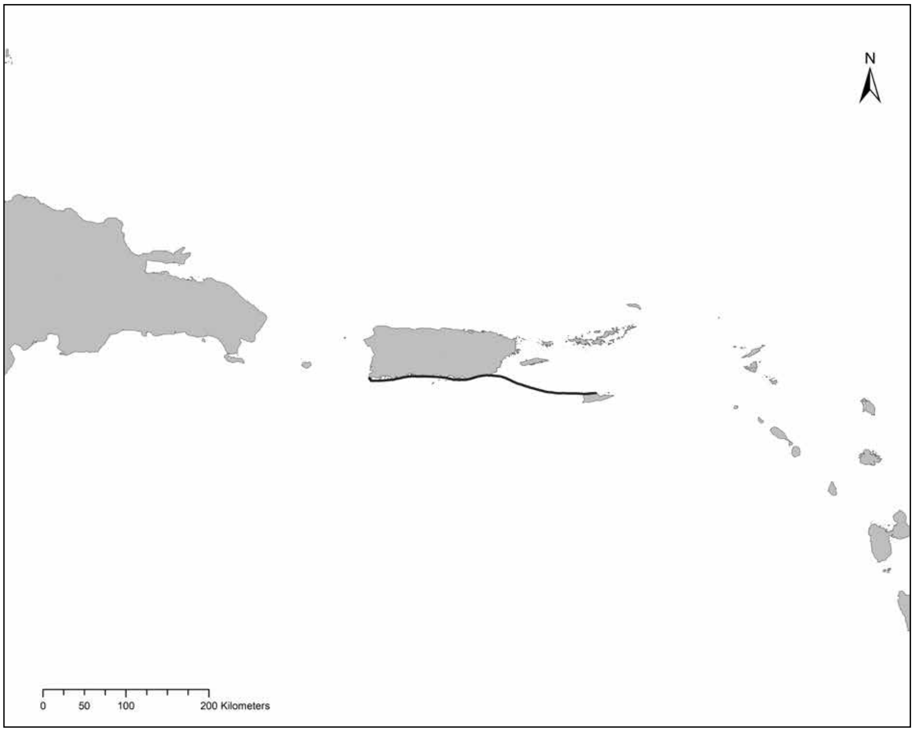


Figure 84: Route from St. Croix to the southwest corner of Puerto Rico that hugs the island's south coast. Route launched at 6am on the 22nd of January 2011, Route: 9-10_2011-01-22T06.

line is closely followed once contact is made with Puerto Rico (see Figure 85). This contrasts with voyages heading east where routes tend to separate somewhat from the coast. While east-facing voyages still stay relatively close to the coastline, they do not follow the coast as closely as routes heading west. The constant contact with the coast would have allowed groups traveling from St. Croix to take advantage of local resources and stopover points, and to contact Puerto Rican Taíno communities. To determine if there was a special connection between St. Croix and Puerto Rico, taking another look at the archaeological evidence would be beneficial.

Modeled routes suggest that canoers' may have had a preference for hugging the coast of St. Croix, as shown by the routes between Saba and the southeastern point on Puerto Rico, such as route 1-3_2011-07-16T12 and route 1-3_2011-07-25T18 (see Figures 85 and 86). These routes reaffirm the model's tendency to mimic real-world trends of following along areas of safety near coastlines (see Figures 86 and 87). For example, route 1-3_2011-07-25T18 shows a route hugging the coastline as it passes by St. Croix and passing by a series of sites on the south side of the island. Route 1-3_2011-07-16T12 along the north coast of the island passes by Salt River, one of the selected node points in this case study. It is possible that the Salt River site grew out of the need for a stopover point between Saba and Puerto Rico, possibly developed over years of peoples passing by this stretch of coastline. Canoe routes from Saba to St. Croix are more likely to run along the north coast of the island, signaling the possible significance of Salt River to Amerindian communities.

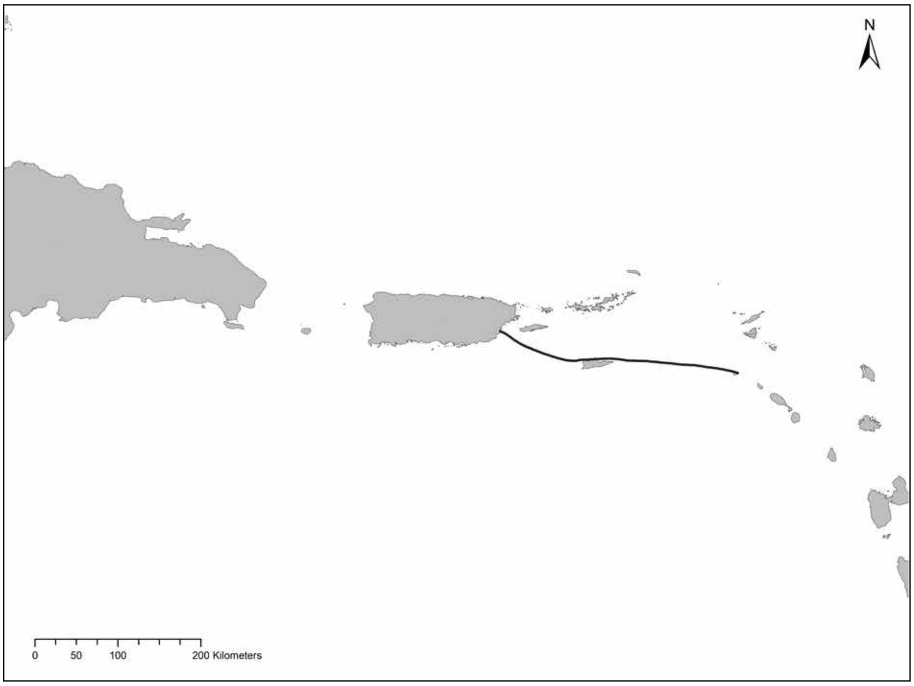


Figure 85: Route between Saba and Puerto Rico that passes above St. Croix in July. Route launched at 12pm on the 16th of July 2011, Route: 1-3_2011-07-16T12.

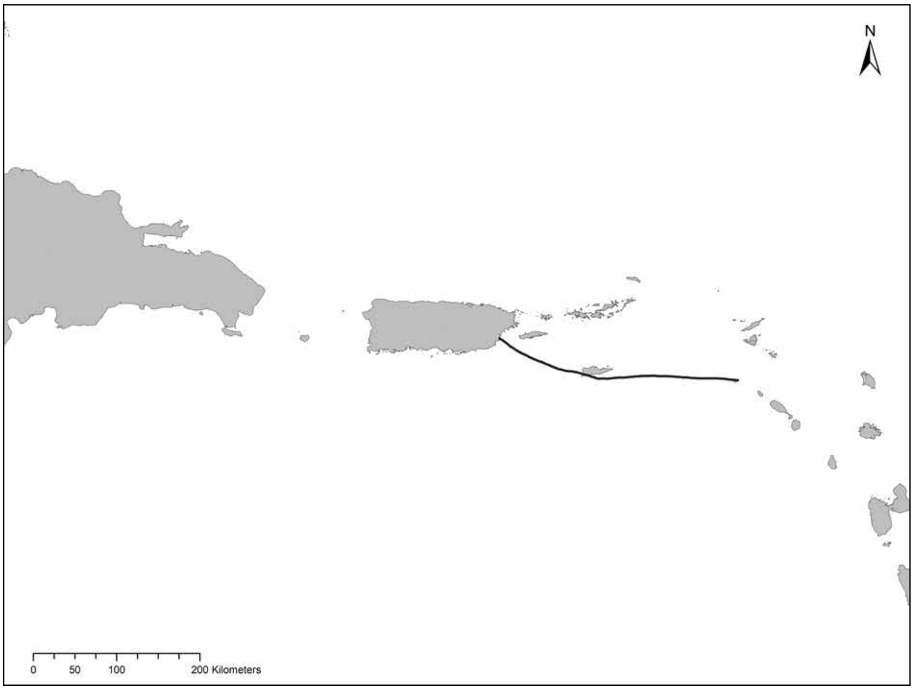


Figure 86: Route between Saba and Puerto Rico that passes below St. Croix in July. Route launched at 6pm on the 25th of July 2011, Route: 1-3_2011-07-16T06.

6.4 Conclusion

The mobility of materials and peoples across these routes demonstrates the underlying tensions of movement between islands. Tracking movement between sites on neighboring islands may not be as easy as straight lines on a map indicate. Connections between neighboring islands likely depended on an intricate interaction between social structure and the placement of canoe routes.

This case study joins the first in demonstrating the value of evaluating links between islands using least-cost pathway methods, showing its specific utility for island chains. Analyzing the time costs and trajectories of routes for possible trips between separate island groups adds support to existing theories about inter-island travel (Hofman *et al.* 2008a; Keegan and Hofman 2017). Tying together several routes to form canoeing travel corridors suggest what pathways acted as sections within longer voyages. Evaluating traveling in different directions can inform on which routes from different islands best served crews that may have paddled along the least-cost corridors. Canoe routes generated by the isochrone route tool can indicate what areas of the sea were likely used in the past and how these corridors may have linked together to form the pre-Columbian Amerindian mobility network that connected the Greater and the Lesser Antilles.

These modeled routes establish that route trajectories and the location of canoe travel corridors offer insight into connections between islands. Pathway layout provided a broad scope for comparison between seasons and between island linkages. The consistency of route placement, both in direct and in indirect routes, shows that past navigators would have been able to retrace these pathways over several years. Amerindian peoples from these islands may have been equipped with the navigation knowledge necessary to complete routes successfully. This foreknowledge of canoers may have minimized the likelihood of crews not completing a voyage. The inability of some modeled routes to complete over longer distances could suggest that these routes were not used by past canoe crews. Similarly, the preference for specific route trajectories or time costs may have influenced canoers' movement between islands.

Several routes returned by the model indicated stopover opportunities. Many routes, however, went directly towards their destination without coming close to the coastline of another island (see Appendix C). The position of islands within this region allowed for a greater number of routes to avoid connecting with in-between islands when traveling across the Anegada Passage. Still, the number of routes that pass in-between islands indicates that if Amerindian seafarers moved through these travel corridors they could choose when to connect with other islands. That the time costs associated with indirect routes that pass by in-between islands are often similar to costs for direct routes suggests that peoples could have preferred to utilize stopovers for the opportunity to resupply and connect with local communities. These decisions could have strong implications for the existence of an exchange network with many stopover possibilities, as routes passing by sites on in-between islands showcase possible connections built around canoe travel corridors.

The archaeological sites located along modeled routes may indicate two processes. First, the placement of sites along modeled canoe routes could signify that Amerindian peoples used them as safe landing sites where necessary. Second, that Amerindians wished to be a part of an inter-island mobility network and established sites that could take advantage of canoe travel corridors. At present, it is not possible to differentiate between these two processes nor are they exclusive to each other. In fact, they may be intricately linked.

More work needs to be done to evaluate connections between origin points, termination points, and the sites passed on the voyages connecting them. It is possible that evaluating movement and exchange along these corridors can reveal more information on how Taíno materials and ideas were spread throughout the region. Furthermore, route analysis considered alongside archaeological materials may help to identify what were direct one-to-one avenues of exchange and what sites were considered hubs for distributing imported materials to communities on other islands.

The resulting pathways suggest possible candidates for central points in a possible or hypothetical exchange network. If the location of modeled corridors past the Virgin Islands and St. Croix accurately reflect pre-Columbian travel in the region, they could indicate possible stopover connections in both the north and south of the Anegada Passage. The inclusion of Mona Island in this study supports the theory that stopover points in the Mona Passage were a vital part of seafaring mental maps. This connection supports the theory of navigation points, like the caves on Mona Island being viewed and remembered from the sea (Samson and Cooper 2015). The connection between community knowledge of sites and their role as landmarks for navigation has been discussed in other works (Ingold 2000; Tilley 1994). This is consistent with the association between points within a landscape and the seafarer (*sensu* Ingold 2009) as well as the association of meaning to sea-based activities (*sensu* Cooney 2003; McNiven 2008), including navigation. The caves containing archaeological evidence on the north coast of the island overlook many of the routes modeled for this case study. This work supports the theory that these sites were used as a highly visual connection point for crews paddling by the north coast of the island (Samson *et al.* 2013; Samson and Cooper 2015a). This connection suggests that navigation markers were a key part of any route, even short voyages.

Modeled movement from El Cabo towards Mona Island also resulted in the greatest number of completed routes, which shows the importance of short distance connections in a broader inter-island mobility network. Theories of the spread of Taíno materials to the west are also supported by the ease of movement from El Cabo past sites on Puerto Rico. This ease demonstrates links were possible for many months of the year and likely supported canoe travel corridors over generations. The consistency in current force throughout this region suggests that canoers could travel between points during multiple periods of the year. This is true for shorter and longer voyages. It could be that if Amerindian crews were using routes similar to these least-cost routes they may have relied on shorter voyages, allowing navigators to put several route segments together to form their entire trip. Longer trips may show a slight seasonal component for voyages crossing larger expanses, like the Anegada Passage. This could mean that peoples traveling from El Cabo through Mona Island to Puerto Rico were planning voyages in smaller stages to reach beneficial currents at a later time.

Traveling through the Anegada Passage relied on extensive planning. Mental wayfinding maps may have helped crews from either side of the channel plan a suitable route for crossing the expanse. This route could have been direct, or taken through the Virgin Islands or St. Croix. Routes modeled for this work do not indicate any specific site acted as an optimal departure point for cross-channel connections on either side of the Anegada Passage. It is difficult to determine whether Saba or Anguilla was the better candidate for a connection point for Taíno peoples and materials to move into the northern Lesser Antilles based on the currently available data. In many cases, the differences in route layout and time costs would not have prohibited Amerindian canoers from choosing to visit a friendly island or avoid a hostile one.

The makeup of assemblages in the Leeward Islands suggests contact was ubiquitous. In this sense, it is possible that there was not one connection point but rather several. These connection points could have functioned as semi-equal partners within the broader network of mobility and exchange. Peoples may have used different departure points depending on what in-between connections they wished to make on the way towards their destination.

Even when sites on the east side of the Anegada Passage are indicated as periphery connections to the Central Taíno (Rouse 1992), it is unlikely that there was direct contact with communities living in Hispaniola. For example, even though Kelbey's Ridge likely acted as a periphery site for so-called Taíno culture (Hofman 1993; Hoogland and Hofman 1999; Keegan and Hofman 2017), the optimal routes discussed above indicate that it would have been impossible to travel directly between the sites where these stylistic elements originate, such as the eastern Dominican Republic. In part, this is due to the model's inability to complete routes over this distance, containing an abundance of loops or time cost errors that prevented the pathway from being calculated. Furthermore, the frequency that modeled routes pass St. Croix could indicate that Taíno materials passed through this island. This could reaffirm St. Croix's status as a gateway site and Kelbey's Ridge as a periphery site. This is likely also the case for relationships between sites on Anguilla, the Virgin Islands, and Puerto Rico. The establishment of sites in the Leeward Islands as Taíno periphery outposts that monitored access to objects and stylistic elements may have influenced the placement of travel corridors to the south and the position of gateway sites within the Eastern Taíno sphere. Route modeling could be extended from Kelbey's Ridge to islands in the south to assess if there were any limiting factors when moving between Puerto Rico, St. Croix, and other islands. Communities on islands within the Anegada Passage, like St. Croix and St. Thomas, should be revaluated as mediators of Greater Antillean materials and their relationships with the islands to the east and west reconsidered.

Route modeling is not the only method that can expand our understanding of possible Taíno expansion into the Leeward Islands. In the future, comparison of routes with additional archaeological evidence, such as XRF (*e.g.*, Hofman *et al.* 2008c) and isotopic (*e.g.*, Laffoon 2012; Laffoon and Hoogland 2009, 2012) research, can aid in locating links between the Greater Antilles and the Lesser Antilles. As more information becomes available, a finer understanding of how the routes fit with archaeological assemblages can influence how we understand connections in this region.

7

Voyaging Over Longer Distances

Connecting the South American Mainland with the Windward Islands

Based on the ceramic evidence of vessel shapes and decorative motifs, scholars have established the existence of connections between Kaliña Koriabo communities from the mainland in Guyana, Suriname, and French Guiana and the Kalinago peoples with their Cayo ceramic complex in the islands of the southern Lesser Antilles between ca. AD 1250 – 1600 (see Allaire 1980; Boomert 1986, 2004; 2009; 2016; Bright 2011; Hofman and Hoogland 2012; Hofman *et al.* 2008b; Jacobson forthcoming; Keegan and Hofman 2017). Within the island group, there is also evidence of exchanged materials originating from the South American mainland such as pendants made from the teeth of tapir and peccary, and flutes made of deer bones (Hofman 2016; Hofman *et al.* forthcoming). The non-local provenance of these faunal tooth pendants is established by their isotopic signature and the fact that these animals did not live on the islands (Laffoon *et al.* 2016). The strong parallels in ceramic typology, alongside the presence of these exported pendants and flutes, attest to a recurrent exchange of trade objects between the mainland and the islands and suggest continued contact between the Windward Islands and the Guianas after Europeans entered the wider region. However, the specific mechanizations behind these ties are not entirely clear, as there are no solid arguments for directly linking mainland (Kaliña) settlement to island (Kalinago) settlement in the archaeological record.

By seeking to determine the cost of moving peoples and materials between these areas, least-cost pathway modeling provides an additional layer of analysis to existing information gathered through the archaeological analysis of ceramic styles (Bright 2011; Boomert 1989; Hofman and Hoogland 2012) or linguistic analysis comparing language used by South American and Windward Island peoples (Boomert 2008; Hoff 1994; Hofman 1993). The cost of movement, while not prohibitive in many cases, influenced whether and when Amerindian peoples would have moved between places (Callaghan 2001; Cooper 2010). The trajectories of these routes can indicate the location of stopover points and the outlines of the physical process of moving through the region. The models can be used to evaluate reciprocated movement and offer a valuable new way to explore the process behind human mobility patterns and the introduction of materials and ideas to island communities.

In this third case study, I applied least-cost pathways analysis onto the existing archaeological and environmental dataset and modeled canoe pathways between the Guianas and the Lesser Antilles to determine if route cost and route layout influenced the shape of mobility and exchange networks. The nodes or points of connection were selected for their shared pottery tradition. Knowledge of the full effort required for canoe voyages in the past underlines the importance of material and social links connecting Kaliña and Kalinago peoples. Generating least-cost routes across this geographic layout allows an evaluation of the model's effectiveness over larger distances. Unlike routes run in the Leeward Islands, or between that group and the Greater Antilles, there are fewer islands between the Guianas and the Windward Islands that could act as stopover points during voyages, which would have increased the level of danger and uncertainty for any crews that may have attempting these routes.

This is the first attempt to use computer modeling to study reciprocal movement from the Guianas to the Lesser Antilles. These least-cost pathways explore where interconnection between the mainland and the Windward Islands may have occurred. Determining the ability of canoers to make direct contact from the mainland to the islands without stopping at in-between islands such as Trinidad or Tobago or sections of mainland coast can influence our understanding of these networks. Hypothetical canoe travel corridors can shed light onto how people entered the islands, which is currently obscured. Plausible entrance and egress points may indicate who may have wanted to be in this network and where these pathways could have taken them when traveling back and forth from the mainland to the islands.

This lack of stopover potential and seasonal variation in routes suggest time costs may have been a greater factor in this region. The distance from Guyana to the Windward Islands (roughly 700 km) allows for a stronger variance in seasonal route times than observed in the other two case studies. The longer voyages have time costs of several days rather than hours. Because the currents moving between Tobago and Grenada fluctuate more than those in the northern half of the Caribbean Sea, route costs across this distance can better assess how seasons influence canoeing networks in the region when compared to the routes modeled for previous chapters.

In addition to these connections between the Guianas and the Lesser Antilles, there is also archaeological evidence that suggests connections between the Guianas and the coast of Venezuela, Tobago or Trinidad, and Grenada or St. Vincent (Boomert 2016; Hofman *et al.* 2008b). Modeling routes that pass Trinidad and Tobago could determine if the locations of assemblages on these islands were related to the layout of canoe pathways or social preferences. It is possible that some crews avoided parts of this region, in particular the coast of Trinidad, to avoid contact with Spanish forces or antagonistic Amerindian communities. These social factors are not present in the model, indicating the importance of including links with historic and archaeological sources. These factors present a way to evaluate the feasibility and functionality of this isochrone least-cost pathway model by allowing the hypothetical routes to be measured against possible social preferences to avoid certain areas.

This analysis relies on the understanding that seafaring communities would have built up extensive mental navigation maps over generations to allow the modeled routes to represent reality (*sensu* Terrell and Welsch 1998: 59; Terrell *et al.* 1997). The continual movement of peoples north and south in this region would have led to shared community navigation maps (Basso 1996; Schlanger 1992; Tilley 1994). The 170-year span of this case study increases the likelihood that mental maps existed for movement between sites, due to the possibility of tighter links between the generations of navigators (*sensu* McNiven 2008; Terrell *et al.* 1997). Routes linking nodes, represented here as optimal least-cost pathways, can indicate where generations of canoers learned to travel to take advantage of current movement. Voyaging across such a large distance would have required knowledge of these currents, as movable environmental features and celestial bodies were the only visible navigation markers. Thus, the water's surface must have acted as a guide for these Amerindians. This case study allows for a better understanding of how that guidance would function over longer routes where visibility of coastlines was limited.

It is difficult to say which sites or areas played a role in disseminating the Koriabo style into the Lesser Antilles through archaeological evidence alone. Route modeling can bolster these conversations. Here, I have explored how difficult it would have been to travel between Guyana and the Windward Islands. As least-cost routes can indicate where travel corridors between the mainland and the Lesser Antilles might have been located, these first attempts can indicate broader situations that might have been faced by canoers.

Figure 87: Map of the case study region, including Guyana, Suriname, and the Windward Islands.

Not all routes generated by the model were able to complete, perhaps due to the difficulty with the reach of underlying environmental data, the completeness of data for cells near the extremity of the NOAA AmSeas3D data set, and the high route costs and tendency to loop for routes traveling long distances against stronger currents than found in the previous case studies. In addition, routes that exceeded seven days were discounted post-modeling due to the extensive time cost, and associated physical cost, that would have been placed on the canoers following these optimal routes. This has led to the inability of a full seasonal comparison between all points on the Windward Islands and Guyana points.

7.1 Kaliña and Kalinago

This case study evaluates reciprocal movement between the South American mainland and the islands of Grenada and St. Vincent during the period just before and after European arrival in the region, with radiocarbon dates between AD 1430 and 1600 from the site of Argyle on St. Vincent and La Poterie on Grenada (Hofman *et al.* forthcoming). Other researchers (Boomert 1986) have suggested that the exchange of Koriabo stylistic elements may have begun as early as AD 1250, corresponding with the advent of the mainland ceramic style. Origin points for this chapter will be based on sites occupied after AD 1400 with evidence of Cayo ceramics. It is possible that pathways shown here were used in earlier periods as well, expanding the possible temporal applicability of this research.

Sites selected for analysis come from the Guyana coast, Grenada, and St. Vincent. These have enough material links to justify modeling canoe routes connecting the Kaliña and the Kalinago communities. Evidence of this movement can be tracked through multiple avenues: archaeology, linguistics, and the historic record. This case study also draws on ethnohistorical accounts to tie the spread of language to island and mainland connections, particularly in the split of Mainland and Island Carib as defined by Allaire (2013) and Boomert (1995, 2002). Finally, historic accounts also add information on how Amerindians canoed through the region and suggest the location of stopover areas.

7.1.1 Ceramic Styles

Archaeological assemblages from the Windward Islands show several macro-regional influences that pre- and postdate the case study period. Those on the Windward Islands likely enjoyed access to the wider circum-Caribbean regional exchange that took off during the Late Ceramic Age/early colonial period (see Allaire 1990; Boomert 2000, 2016; Hofman and Hoogland 2011; Hofman *et al.* 2007, 2011; Keegan and Hofman 2017). Sites within Grenada and St. Vincent draw from stylistic motifs from both the north and the south. Materials from the southern Lesser Antilles indicate several possible population demographics and interaction spheres on the same island or group of islands (Allaire 1990; Hofman and Hoogland 2011; Keegan and Hofman 2017). Ceramic stylistic evidence from both the Greater Antilles and the South American mainland can be seen in these assemblages (see Boomert 1995; Davis *et al.* 1990; Hofman 2013; Hofman and Hoogland 2012; Hofman *et al.* 2015). A large portion of the archaeological evidence used to evaluate these connections lies in the comparison of different Koriabo and Cayo

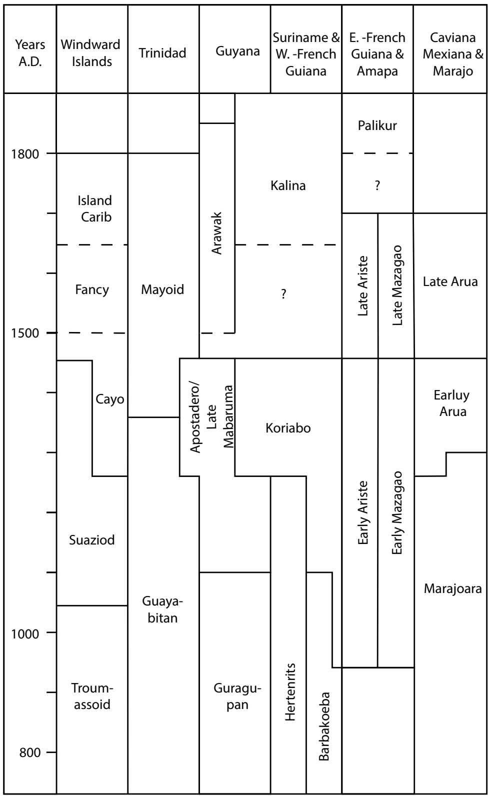


Figure 88: Chronological chart showing the cultural sequences in the Windward Islands and the Guianas (modified from Boomert 1986: Figure 15). These Cultural sequences can be linked to the ceramic styles from this region before and after the dates of this case study.

ceramic assemblages from the Windward Islands and mainland South America. Both culturally and in their stylistic motifs, the so-called Island Carib are regarded as a cultural entity separate but connected to mainland populations (Davis *et al.* 1990).

Ceramic evidence supports the existence of these relationships. Even before the period discussed here, ceramics were being moved between the islands and the mainland (Boomert 1986; Table 16). The movement of mainland influences north can be partially traced through ceramic stylistic elements. According to Bright (2011: 144), the evaluation of different ceramic series found in the southern Lesser Antilles during the Late Ceramic Age/early colonial period relies on the comparison of ten traits: "Caliviny Polychrome, lugs, legs, legged griddles, support rings, anthropomorphic adornos, loom weights, finger-indented rims, scratching and statue(tte)s". These elements help to identify one ceramic group from another (Bright 2011:144). Sites on Grenada and St. Vincent often include ceramic objects with elements from multiple groups (Boomert 1995; Bright 2011; Hofman *et al.* forthcoming).

7.1.1.1 Troumassoid Ceramics

The archaeological materials suggest that routes between these areas existed in earlier periods (Boomert 2016; Bright 2011). Materials from the Saladoid period (300 BC – AD 650/800) indicate that peoples had already developed travel corridors around the region (Boomert 2016: 16). The Troumassoid style of adornos is linked to rim decorations of the earlier Saladoid ceramic series. The anthropomorphic motifs on these adornos share stylistic affiliations with the Valencoid series from the South American coast, where the component is placed on the upper portion of the vessel (Antczak and Antczak 2006). Some examples of Suazoid (AD 1000 – 1500) ceramics found in the southern Lesser Antilles have rim incision (Bright 2011), a trend also seen in Koriabo ceramics from the mainland. Rim indentations are found in assemblages throughout Late Ceramic Age/early colonial period sites, including Guadeloupe and Tobago (Boomert 1995; Bright 2011; Petersen *et al.* 2004). Other Suazoid traits include "thick coarse and soft pottery, with scratched or scraped surfaces, inward thickened rims, legged, pedestals or annular bases, legged griddles and triangular rims" (Hofman *et al.* 2008b; Petersen *et al.* 2004:28). Many of these aspects relate to choices made by the potter, rather than technological limitations, including rim indentations that were made using the potter's finger (Bright 2011). Possibly as a result, specific techniques and implementations varied widely throughout the islands.

These characteristics and other Troumassoid stylistic elements are largely known from the Grenadines and St. Lucia, and, though present, are less common on St. Vincent (Bright 2011). The scarcity of these traits on St. Vincent is puzzling, because there is petrographic evidence that ceramics were exported from this island into Grenada (Bright 2011; Degryse personal communication 2017; Hofman *et al.* 2008b). This could indicate that route layouts between the South American mainland and individual Windward Islands differed enough for communities to possess their own travel corridors. These separate corridors could have allowed for exchange and the spread of ideas between these three locations to follow different patterns.

7.1.1.2 Cayo Complex

Allaire (1980, 1984) and Boomert (1986, 1995) have both argued that Island Carib, or Kalinago, peoples did not only produce wares assigned to the Suazoid ceramic series. Instead, they have suggested that these people were more likely to be associated with the Cayo complex of St. Vincent. Kirby (1974) was the first to classify this ceramic complex when excavating on the northeastern coast of St. Vincent at the site of New Sandy Bay. Boomert (1986) later studied the assemblage excavated by Kirby and confirmed a relationship to the Koriabo ceramics of the Guianas. He hypothesized that the genesis of the Cayo complex occurred after the beginning of the Suazoid series, around AD 1250 (Boomert 1986, 1995).

Cayo ceramic pieces are typically part of assemblages that contain multiple ceramic styles (Boomert 1986). For example, Cayo material can be found in assemblages that contain ceramics of the Suazoid series (Bright 2011; Bullen and Bullen 1972). The Cayo complex is indicative of converging stylistic influences as it bears elements from the mainland but also from the Greater Antilles (Chicoid and Meillacoid series) (Hofman and Hoogland 2012). Cayo ceramics often denote relationships to the Koriabo style from mainland South America (Boomert 1986, 2004; Bright 2011; Hofman 2013; Hofman *et al.* 2015; Keegan and Hofman 2017; Rostain 2009). This trend reflects the broad cultural milieu of peoples who were traveling through the area (Hofman 2013; Hofman and Hoogland 2012; Keegan and Hofman 2017).

Examples of Cayo ceramics are likely the result of local level production within macro-regional interaction networks (Bright 2011; Hofman 2013). Results from recent XRF studies suggest that it was the communities with potters that moved from the mainland to the islands and not only the ceramic vessels, as the clays used to make these objects all have local island provenances (Scott *et al.* in press).

Boomert (1986) has defined several decorative techniques that distinguish Cayo pottery. These decorative elements include "painted or slipped designs, incised and grooved motifs, punctuation, lobed rims and outward bossed wall sections" (Boomert 1986: 7). Examples of these decorative elements include leaving dark smudges on the exterior of the items, or Cayo ceramics being "tempered with caraipé, *i.e.* the ash of the siliceous bark of a small tree, *Licania apetala*" to color the vessel (Boomert 1995: 7). These trends have been observed on vessels found in St. Vincent. As the *Licania apetala* species only grows on the mainland, the use of this temper affirms the mainland-island Cayo connection (Boomert 1995).

The inspiration behind Cayo designs was probably the continued exchange between the Guianas and the Windward Islands that allowed for the sharing of ideas and aesthetic preferences (Davis *et al.* 1990). The Koriabo style is contemporaneous with the rise of Cayo ceramics in the Windward Islands (Evans and Meggers 1960). In fact, Cayo pottery has been considered a simplified version of the Koriabo ceramic style (Boomert 1986). The Koriabo style is commonly found in coastal areas or along large riverbanks, from the banks of the Maroni River on the border of Suriname and French Guiana, and the interior of the Guianas to Brazilian Amazonia (Groene 1976; van den Bel 2015).

Aspects of Cayo ware were likely inspired by mainland Kaliña peoples leading raids against those in the southern Lesser Antilles and exchanging marriage partners between the islands and the mainland, or simply by individuals coming to live on the islands (Boomert 1995; Davis 1990; Morsink 2013). The adaptions in style observed in some Cayo ceramics suggests that the displacement of refugees from Taíno expansion in the Greater Antilles also influenced the genesis of Cayo ware (Bright 2011; Farr 1995; Hofman 2013). Kaliña communities that may have interacted with the settlements of the relocated Taíno incorporated some stylistic trends from the Greater Antilles (Allaire 1987; Bright 2011; Hofman et. al. 2008), adding to the cross-cultural nature of the Cayo complex. These cross-cultural connections led to the blending of styles that can identify sites as Cayo.

To this date there are around 20 sites known to possess Cayo material within the Lesser Antilles, with the majority of these located on St. Vincent and Grenada (Hofman and Hoogland 2012). For this reason, sites on these two islands were used as the base for the modeled routes. Analysis of pathways to these points from the mainland will explore routes between mainland and island communities to discern any variation in and difficulty of contact between Kaliña and Kalinago groups.

7.1.2 Language

Another bridge between communities in this region is the historic and ethnographic record of the languages of the Kaliña and Kalinago peoples. The use of language among these groups has generally been categorized as a split between Mainland and Island Carib as well as between genders (Hoff 1995). Men predominately used the Island Carib language, which has an Arawakan base lexicon with Kaliña loan words (Hoff 1994; Hofman 1993; Boomert 2008). The women used a pure mainland Arawakan lexicon (Boomert 2008). It is possible that this split in male and female language use was related to the Kalinago origin myth that modern day Island Carib communities are descendants of male Kaliña warriors who immigrated into the Windward Islands from the area around the Guianas, specifically Suriname and French Guiana (Boomert 1986, 2008; Breton 1665; de Rochefort 1665).

There are enough similarities between the languages to suggest direct interaction and communication between mainland and island peoples. Taylor and Hoff (1980) have suggested that the Island Carib men's language grew out of a form of pidgin Mainland Carib dialect, specifically the Kaliña pidgin used for trade in the Guianas coastal zone (Boomert 1986; de Gomberville 1682). It is possible this subset of the language grew from a need to understand either Kaliña or Island Carib trading partners, if it did not evolve from a Kaliña invasion into the islands (Davis *et al.* 1990). Like the use of the pidgin language itself, specific words reaffirm the importance of exchange in these communities. In the Island Carib dialect, the word for 'friend' can also mean 'him with whom is being negotiated' (Boomert 2002: 89; Breton 1978: 55; Roth 1924). Mobility can even be represented in the language itself. The relationship between settlement and canoe use is indicated through the term *hueitinocou,* which means both villager and member of a canoe crew (Hofman and Hoogland 2012). The position of men as the main speakers of this language (Allaire 1980) could relate to the prestige of speaking languages during interactions with members of the other community (Taylor and Hoff 1980).

Differences in language between Kaliña and Kalinago peoples also related to the use of specific words associated with their ceramics. Some have postulated that the association of men and pottery means the production of ceramics was a male field, as in mainland communities (Allaire 1980; Boomert 1995). Boomert (2008) mentions that ceramic vessels linked with male-controlled activities or environments typically held names in the Caribbean linguistic affiliation, such as *chamacous* or "well-finished, more or less ceremonial ceramics" related to the preparation and consumption of cassava beer for communal meals or feasts (Boomert 1986, 1995, 2008; Breton 1665: 94). This contrasted with activities or environments associated with the female sphere that held names in Maipuran Arawakan or European languages (Boomert 2008). Female-related vessels were often linked with earthenware used for domestic purposes, such as griddles (Boomert 2008).

These language trends, both on a direct and added-meaning level, align with the ceramic assemblages recovered from both the mainland and the Windward Islands (see Allaire 1977, 1984; Boomert 2008; Hofman 2013; Hofman and Hoogland 2012; Keegan and Hofman 2017; Kirby 1974). Allaire (1977, 1984) suggested that similarities in names for ceramic objects could indicate that the styles of these vessels were identical. This is unlikely, as archaeological evidence suggests difference in stylistic elements between island and mainland vessels (Boomert 1986). While there are several vessel types with similar names in the Guianas and the Windward Islands, for example the cassava-beer brewing vessel called *chamacou* (Kalinago) or *samaku* (Kaliña), there are many words that exist in the Guianas that were not recorded in the Windward Islands (Boomert 1986). Additionally, ceramics may have been referred to in terms of their function and not their stylistic characteristics (Boomert 1986). Although vessel types were not the same, a similarity in language for ceramic style and use indicates that there was communication about these objects across Kaliña and Kalinago communities.

These lines of evidence confirm that a similarity between these language groups, particularly in the sixteenth and seventeenth centuries, justifies generating least-cost canoe routes based on the existence of language exchange. As the exchange of language was linked to the moving of peoples and broader interaction networks, modeling the physical layout of canoe routes can speak for how this similarity in language between Kaliña and Kalinago peoples was transmitted.

7.1.3 Ethnohistoric Accounts

The Island Carib were also documented by French ethnographers Charles de Rochefort (1665), Raymond Breton (1665-1666), and Baptiste du Tertre (1667-71) (see also Whitehead 1995; Petersen *et al.* 2004). Historic accounts also leave room for the Island Carib to describe their own social network. Raymond Breton, while on his stay in Dominica (1635), recorded that:

> *"They are descended from the people of the mainland closest to the island… The friendship they maintain with them and their commerce with them are signs of it.* [Breton and la Paix 1926: 45-46]" (Davis and Goodwin 1990: 39).

Breton later adds to this description by recounting that the South American Kaliña had branched out from their coasts to colonize the islands (Breton 1665; Davis 1990). He states that the Carib peoples were a result of this migration and the incorporation of other island-based communities (Breton 1665; Davis 1990). In contrast, de Rochefort (1658) intimates that Island Carib peoples on St. Vincent were merely associates of the Kaliña (Davis 1990). These records suggest that both groups were linked, culturally and/or genetically. Breton and Rochefort's acknowledgment of this interaction supplements the archaeological and linguistic evidence linking the two groups.

Ethnohistoric accounts also point towards the connection between Trinidad, Tobago, mainland South America, and the Windward Islands. As mentioned above, early myths of Island Carib origins mention groups from the Guianas traveling north to the Windward Islands. Ethnohistoric accounts of this myth also mention movement through Tobago (*e.g.,* Boomert 2002; Borde 1886; Menkman 1939; Rochefort 1665b: 384). Tobago would have been a primary stopping point for communities looking to engage in all forms of interaction due to its location between the mainland and the islands (see Boomert 2002; Young 1795: 5). Historical accounts mention Kalinago crews using the island to rest and resupply on their way to raid Arawak communities on the mainland (*e.g.,* Boomert 2002; Brett 1868: 485; Halliday 1837: 238; Reeves 1749: 24; Rochefort 1665a: 67).

There was likely a high level of traffic along the corridor between the Guianas and the Windward Islands. In the late 1620's, the governor of St. Kitts thought it was too dangerous to settle Tobago due to the large number of Carib vessels passing the island (Anderson 1956; Boomert 2002; Williamson 1923). The Dutch governor of Tobago also noted the frequent passage of Carib crews past the island in 1654 (Boomert 2002). He noted that many Amerindians from St. Vincent stopped on Tobago before moving to the mainland and vice versa (Boomert 2002; Mattiesen 1940). Some accounts suggest that Island Caribs would have made the journey from the Lesser Antilles to the Guianas on an annual basis (Boomert 2002; Laet 1931). Travel past Tobago could have been organized on a seasonal basis as a result. Crews leaving from the mainland during one time of year could have returned months later when the currents were more favorable for traveling in the opposite direction.

The practice of stopping at Tobago was probably adhered to for generations before contact with Europeans. This practice is demonstrated by Saladoid and Troumassoid ceramic evidence on the island that links communities to the neighboring islands and the mainland (Boomert 2016), signifying Tobago's possible inclusion in any regional mental map of navigators. Stopovers on Tobago continued well after the Spanish moved into the area (Boomert 2002; Mattiesen 1940). Some beaches on Tobago are even named for their role as landing points, for example Canoe Bay (Boomert 2002, 2010), which is first mentioned on a seventeenth century Dutch map of Tobago where it is called Kano Baeij (Anonymous 1677; Boomert 2000, 2002; Keulen 1688). The bay served as a landing point for canoes and Spanish vessels in the early historic period (Boomert 2002), and probably did so in earlier periods as well. Place names like Canoe Bay show the continued role of these beaches within inter-island canoe networks.

Connections between communities on Trinidad and in the Lesser Antilles likely became more antagonistic after the arrival of the Spanish in the region (Boomert 2008). Though Spanish influence was relegated to the west portion of the island, the Spanish arrival incentivized Amerindian peoples to settle in different areas. The Arawak peoples from the north mainland who began to exchange with the Spanish pushed Carib or Kalinago peoples living on Trinidad and Tobago into the Windward Islands to avoid meeting hostile forces (Boomert 2008). For example, some of the Amerindian groups that at first allied with the Spanish became powerful through this alliance and came to Trinidad to usurp local populations "that were natural of the place" (Boomert 2002; Raleigh 1848: 8). Spanish influence can also explain the split in connections outward from Trinidad and Tobago. Some Amerindian peoples from Trinidad allied with the Spanish in the sixteenth century (Boomert 2008). This alliance lasted for more than fifty years (Boomert 2008) and would have increased connection between communities on the mainland and the east coast of Trinidad. Conversely, to avoid members of that alliance, peoples from Tobago became more connected to communities on the Windward Islands and in the Guianas (Boomert 2002, 2009, 2010).

7.1.4 Mainland and island locations

Based on these lines of evidence, the current case study will focus on modeling routes between a small number of sites on St. Vincent, Grenada and points off the coast of Guyana. Despite being outside the geographic scope of this case study, it is possible that peoples from the northeastern coast of the mainland, or around the Guianas, were familiar with communities on these islands and mainland areas further to the west. These include Isla de Margarita, the Los Roques archipelago, and the trinity of Aruba, Bonaire, and Curaçao. Routes linking these other islands and the mainland have been evaluated in other works (Hofman *et al.* 2017; Slayton *et al.* 2015). Tested previously (Slayton 2013), modeling routes between the Windward Islands and the northern Lesser Antilles based on the archaeological record of interaction (see Bright 2011; Hofman and Hoogland 2012; Hofman 2013; Knippenberg 2007) will also need to be explored in future works.

7.1.4.1 Mainland South America

For many ceramic series found on the islands there is currently no way to determine where the styles originated. Direct one-to-one links cannot be made between settlements on the South American mainland and island settlements' ceramic series (Bright

2011). As the material styles are dispersed through many island sites, it is not clear what material, ideas, or even peoples traveled directly or by way of another community. Modeling canoe routes between potentially connected locations can begin to determine what types of links existed. Origin and termination points for the model are based on the identification of specific sites that share archaeological, linguistic, and ethnographic elements. Points selected for this region stand as through areas for canoe travel along the Guianas coastal stretch and on towards the islands (see Figure 89).

The proximity of Trinidad and Tobago to the mainland places them in the region of this case study. These islands allow for juxtaposition of route placement for voyages heading north into the Windward Islands from Galleons Passage, the channel between Trinidad and Tobago, and the Atlantic. It is possible that Tobago played a mediating role as a stopover area for rest and resupply between Trinidad, the Windward Islands, and the mainland, as evidenced by techniques observed in ceramics from Tobago and to a large extent in the southern Lesser Antilles (Boomert 2002, 2016). Trinidad and/or the nearby mainland coastline may have acted as a break area before heading toward the islands to the north. Boomert (2016) suggests that during the shift from the Saladoid to Troumassoid period island communities on Trinidad played a role in disseminating the simplification of ceramic designs found within the islands of the southern Lesser Antilles. Trinidad may also have acted as a diffusion or dissemination point for stylistic elements from the mainland. Routes passing these islands can be weighed against pathways traveling directly from the Guianas. Focusing on direct and indirect travel can allow for a reevaluation of relationships between mainland and island peoples in this region. Although it is not possible to determine if these were actual connections, it is possible to model canoe routes and suggest what role these islands played within the regional exchange network.

7.1.4.2 St. Vincent and Grenada

The Windward Islands themselves contain a microcosm of interaction. As gateway points for Koriabo materials into the Lesser Antilles, Grenada and St. Vincent are a key area for study. Previous work using a different model has shown that routes between St. Vincent and islands to the north are crucial to movement past Barbados (Slayton 2013). Focusing on direct connections between the Guianas and the Windward Islands will allow for an evaluation of the relationship between communities that traded Koriabo and Cayo ceramic styles. It is possible that connections with the South American mainland were run largely through one island. This could have led to the islands having an unequal position within the network. Routes from off the Guyana coast to both islands suggest this could be a possibility.

Grenada and St. Vincent possess sites whose assemblages suggest that each could have acted as a hub for inter-island connectivity. The presence of these sites suggests there was canoe activity through the islands during this period. St. Vincent has 12 recorded Late Ceramic Age/early colonial period sites, which is the largest quantity of Cayo ceramics on all the Windward Islands (Bright 2011: 84). Cayo sites on St. Vincent include Mount Pleasant/Rawcou, New Sandy Bay, Owia 2, Spring Friendly, Fancy, Camden Park, Lot 14, Argyle 1, Sans Souci, Grand Sable, and Brighton (Bright 2011; Hofman and Hoogland 2012). These sites are all candidates for termination points of the modeled routes. The sites of Argyle and Brighton have been selected to represent landing points within the mobility network.

Argyle lies on the southeastern coast of the island and is an Island Carib, or Kalinago, site. The site (AD 1540 – 1620) possessed artifacts with possible origins in, or at least affiliations with, the Guianas and to a lesser extent with the Greater Antilles (Hofman and Hoogland 2012, 2016; Hofman *et al.* 2014, 2015; Keegan and Hofman 2017). All of the ceramic evidence belongs to the Cayo complex. This supports the multi-ceramic aspect of these Cayo sites mentioned by Boomert (2008). Materials from Brighton on the southeastern coast of the island are very comparable to those of Argyle, and thus suggest that the site was integrated in the interaction network (Boomert *et al.* 2015; Bright 2011).

Grenada has five recorded Cayo sites, including Sauteurs Bay (Bright 2011: 140, Figure 5.44), Galby Bay (Holdren 1998), La Poterie, Artist Pointe, and Telescope Point (Hofman 2016; Hofman *et al.* forthcoming). All of these sites have been selected to represent landing points within the mobility network. These sites provide an interesting contrast with sites located in St. Vincent, as they are closer to Trinidad and Tobago.

Unlike the earlier case studies, it may be that geographical distance played less of a role in deciding which sites should be visited within this exchange sphere. The long distances between sites may have encouraged canoers to travel over shorter distances, which can be seen in the model as routes passing closely by coastlines, thus facilitating stopovers. The knowledge of stopovers or friendly sites (*sensu* Terrell and Welsch 1998; Terrell *et al.* 1997) may have aided crews in resting during a journey.

These lines of evidence all point to a sustained and systematic connection between the Amerindian peoples from the Windward Islands and those of the Guianas. Though not all sites cover the entire period, they do relate sections of coastlines with occupation and canoeports. These sites stand as nodes within the seafaring network and as possible locations of cultural activity within the generational and individual navigation associations of Amerindian canoers (*e.g.*, Terrell and Welsch 1998: 59; Terrell *et al.* 1997). While individuals at these sites reacted to the influx of materials differently, being a part of this network was a central aspect of life on these islands. These implications of interconnectedness will be explored and evaluated through modeling connections below.

7.2 Route Modeling

To add a new line of evidence to the existing archaeological, linguistic and ethnohistorical data, I applied the least-cost route isochrone tool to map both direct and indirect pathways between the Guianas and the Lesser Antilles. Modeled pathways could help to identify the possible cost of traveling north. The cost and layout of routes could then point to the interplay of inter-island networks. Possible stopover points could indicate the location of a social cost to interaction, either negative, like antagonistic relationships between local and foreign communities (Boomert 2002; Keegan and Hofman 2017), or positive, like places to rest. An evaluation of both direct and indirect routes can identify which travel corridors influenced indirect connections.

The distance that canoers would have been required to paddle to match the length of routes modeled from origin to termination points sets this case study apart. For example, canoers would have had to paddle roughly 700 km to cross to Grenada from the north coast of Guyana, the farthest point possible using the AmSeas3D data. This is 460 km more than what is required to cross between the Leeward Islands and Puerto Rico. Traveling directly from the Suriname and French Guiana border to Grenada would result in crews paddling over 1,000 km. If crews had favorable currents and paddled at a speed of three knots, it could take around 181 hours, or seven and one-half days, to make this voyage.

This does not mean that direct voyages were not possible. Direct crossings could account for the similarity in archaeological deposits from the Guianas and the southern Lesser Antilles (Bright 2011). Richard Callaghan (2001) used a different model to establish that connections between the north coast of South America and the Greater Antilles could realistically take five days. The distance between the coast of Venezuela and the Dominican Republic, or roughly 950 km, is almost equal to the distance between the Maroni River mouth and Grenada. Even though currents in these regions are different, the similarity in distance indicate that Amerindian crews could cover comparable distances successfully. However, taking longer voyages may not have been preferred due to the distance between communities, the physical strain on the body, and the capacity of a canoe to carry supplies.

This work relies on the use of modern current and wind data to interpolate surfaces on which least-cost routes are modeled. The lack of environmental data from NOAA for the area around the mouth of the Maroni River, at the border between Suriname and French Guiana, limited the process of modeling between the mainland Koriabo settlements and the Lesser Antilles. The eastern extent of AmSeas3D data falls at 57.00 degrees latitude. This posed a challenge for modeling canoe routes directly from this point, as the latitude of the mouth of the Maroni River is 53.9391477. It is possible that routes would have followed the coastline of Suriname before heading out into the open sea if crews followed the trajectory of modern real-world sailing preferences and the previous examples of route layouts. Based on that and modern sources, navigators could very likely have chosen to travel close to the coastlines in order to take advantage of subsistence resources and the safety associated in being near landing points. It is worth running the route model using the farthest extent possible to replicate the legs of a voyage between the area around Suriname and the coastline of South America, thus further reducing the limitations posed by the lack of NOAA data for this area.

As an additional complicating factor, the data from the AmSeas3D project in this area was at times incomplete, as it was not collected for all months of all years. The lack of data sometimes limited the number of possible locations to place nodes. For example, data was not available from NOAA for the months of January to March between 2014 and 2015 for Guyana Point A (see Appendix D). However, the absence of specific information at one point does not prohibit the use of the route tool, as the entirety of the pathway relies on the interpolation of data over many points to create a route.

Accounting for all the above-mentioned factors, I approached modeling routes between Guyana, Grenada, and St. Vincent from different locations. As I wanted to evaluate movement from as far south as possible, I chose to model from the geographic extent of the environmental data rather than any of several Koriabo sites that could have acted as origin points. Instead I ran routes from three separate origin points, one further away from the coastline (Guyana Point A) and two closer to the coast (Guyana Point B and Guyana Point C) (see Figure 89). Though these points are not tied to specific sites, they represent areas along the travel corridor between the Guianas and the Windward Islands. As the environmental data did not allow for direct sampling from the Maroni River mouth, these points stand in as possible points in likely travel corridors. Guyana Points A, B, and C act as if there was a continuous journey from the

Maroni River mouth. These points are therefore suggestions based on the available data of possible origin points at the furthest extent of the underlying environmental data.

Choosing origin points near and away from the coast allows the modeled routes to represent possible different options open to Amerindian mariners. Guyana Point A's position off the coastline stands in for canoe routes that were placed away from land. Points B and C are meant to represent routes for canoers who chose to stay close to the coastline. Guyana Point B is further east than Point C and is positioned below Guyana Point A, or as close to the edge of the environmental data as possible. It lies just east of the Guyana/Venezuela border. Guyana Point C is located north of the Guyana coast. These two points near the coastline allow an assessment of whether starting further west would have affected the placement of canoe routes through the Galleons Passage, or the channel between Trinidad or Tobago (see Figure 89).

Termination points on the islands were also approached in two ways. First, routes from Guyana Point A to the site of La Poterie and Argyle were modeled (see Figure 89) to evaluate the basic connection between a mid-route position from Guyana and Cayo sites on Grenada and St. Vincent. These modeled routes showed that connections were possible

Figure 89: Map of the study area with origin and termination points used for least-cost route modeling.

despite the high associated time cost. Second, Points B and C were added when generating runs from nearer the coast of Guyana to determine if there was any change in moving through Galleons Passage for sites closer to the coast of St. Vincent and Grenada. These sites include Brighton Beach and Telescope Point as well as Galby Bay. Sauteurs Bay northwest of La Poterie was added as an additional point to see if there was any difference in approach when moving towards the north of Grenada versus the south of St. Vincent. All of the island points are associated with sites where Cayo materials have been found. This will allow an evaluation of direct connections between mainland and island communities.

7.2.1 Failed Routes and Navigation Challenges

As with the canoe pathways modeled earlier, there were some routes generated that should not be considered actual optimal connections between island and mainland points. Reasons to discount these routes include the inability of routes to be completed in certain periods of the year, routes with exaggerated time costs, the presence of loops within pathways, and pathways that show extreme deviations in route trajectory from others modeled in the same period

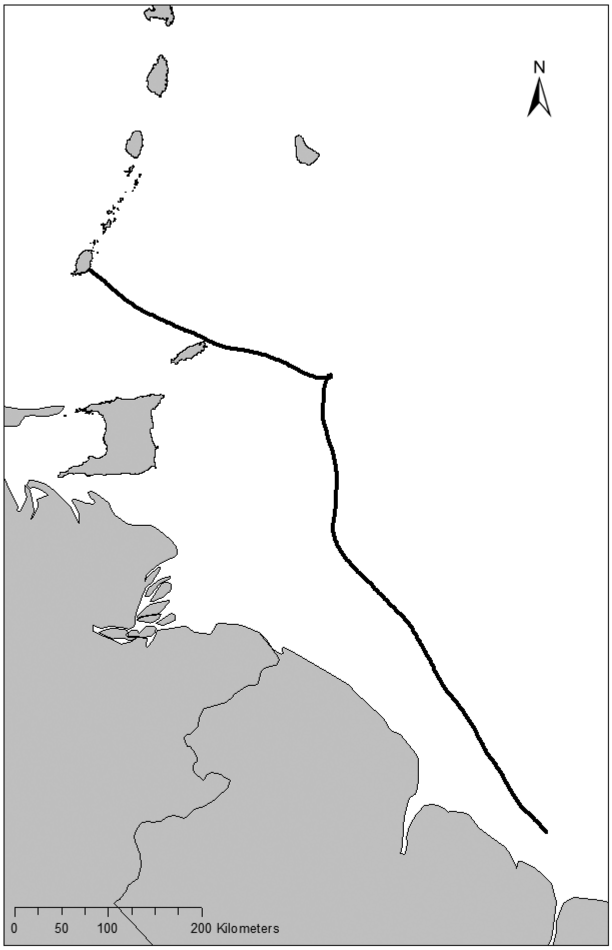


Figure 90: Modeled route from Guyana Point A to Grenada showing a loop in the Atlantic. Route launched at 3pm on the 16th of November 2013, Route: 4-1_2013-11-16T15.

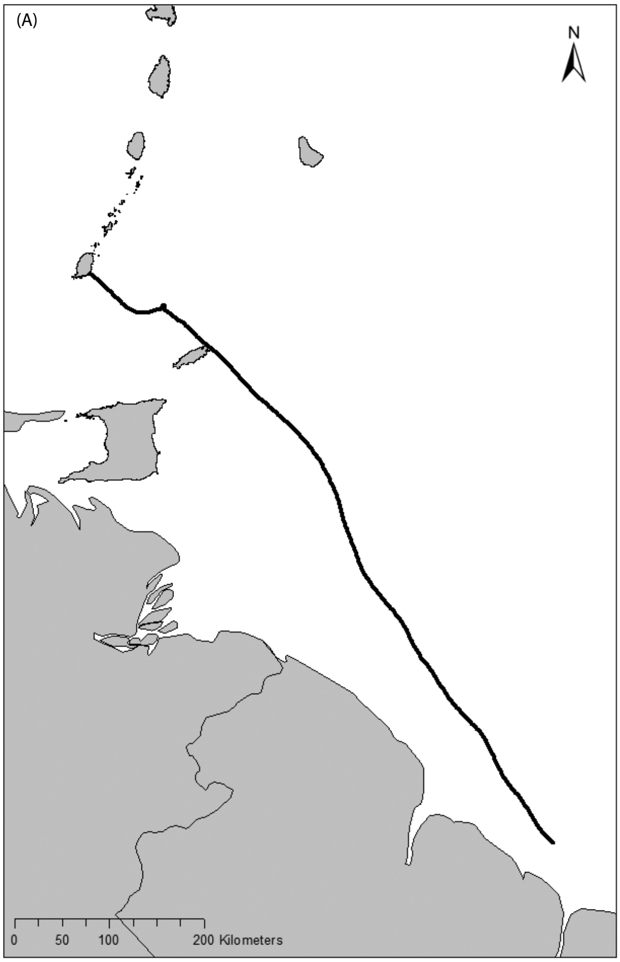


Figure 91 (continued on opposite page): Modeled routes from Guyana Point A to Grenada showing loops. (A): Route launched at 9am on the 18th of November 2013. Route: 4-1_2013-11-18T09, and (B): Route launched at 3am on the 26th of April 2014, Route: 1-3_2014-04-26T03.

Routes for this case study contained fewer loops than those created for the other studies. Loops occurred most often in routes heading south towards Guyana from Grenada. Loops like these may have been related to the need for vessels to redirect rather being caught in currents. For example, route 4-1_2013-11-16T15 shows a loop east of Tobago's longitude (see Figure 90). There is no reason for this loop to exist.

These pathways suggest routes may have continued on a straighter or curved path south rather than choosing to turn around so far from land. Route 4-1_2013-11-18T09 shows a loop in the center of the channel between Grenada and Tobago (see Figure 91 A). This loop might have been avoided by real-world crews fighting the current or picking a different time to leave. Another example of a loop route is route 1-3_2014-04-26T03 between Grenada and Guyana (see Figure 91 B). It shows a loop both to the north and south of Grenada. The disadvantages associated with loops in modeled routes may suggest that canoers perhaps planned routes over long distances based on currents at the starting point. In some cases, crews may have known that they would face adverse conditions if they did not read the currents accurately. I assumed that other modeled least-cost pathways would have been selected over these options.

Figure 91 (continued).

Navigators would have needed to have a working knowledge of the area so that they could adjust the canoe's heading if the crew became endangered. This is especially true in this case study, where there are larger changes in the currents' position and the distances covered by the routes. Some of the modeled voyages suggest that real-world canoers following close to the least-cost route trajectories would have had to paddle for more than six days. Looking at the returns from the current tool and the route tool, these voyages were subject to change. Voyages of greater lengths may have required crews to readjust route plans at multiple points to take advantage of or work around dangerous currents. Trips over these distances would have required an experienced navigator to be a part of the crew.

There are some situations where loops may have been a technique used by seafarers. For example, route 1-3_2013-11-07T09 has a loop that shows a crew making a 90° turn and redirecting their vessel from heading west to going north toward Grenada as a direct connection route (see Appendix D). However, even in these situations it is more likely that if canoers were actually paddling somewhere close to the route trajectory suggested by this modeling, they may have chosen to make landfall either on Trinidad or Venezuela if they were caught in a current pushing them father east than intended.

Navigators would also have needed to reorient routes when they were blown off course. One example of this phenomenon was observed in a route between Guyana and the Orinoco River Mouth (route 1-8_2013-04-12T18; see Appendix D). The route runs past its target and meets the northeast coast of Trinidad. On this route, a navigator could have chosen to fight the current and move closer to the coast or chosen another time to canoe towards the Orinoco River mouth. Route 1-8_2013-11-24T21 and route 1-8_2013-11-29T00 also show the crew being 'blown off' course, running as far north as Trinidad but not connecting with the island (see Appendix D). These routes also removed the crew from the goal of the Orinoco region by taking them out to open sea.

Comparing routes in this case study was difficult, as no month had a 100 percent success rate for modeling pathways at all time intervals. This indicates that not all voyages leaving from the Lesser Antilles or the Guianas would have been successful. Callaghan (2001) also commented on the return rates of failed voyages in his efforts modeling colonization voyages from the mainland to the Greater Antilles, suggesting that unsuccessful canoe trips were a semi-regular occurrence in this region for routes of this length. This also indicates the increased level of difficulty found on least-cost routes crossing from the mainland to the Windward Islands over costs for crossing the Anegada Passage. The trend has also been observed in modeled routes from Venezuela to the Windward Islands (Slayton *et al.* 2016). In the future, more work should be done to model longer voyages with multiple time-steps to see if this issue can be avoided.

7.2.2 Current tool

AI first used the current tool (see Chapter 4), to evaluate currents at several points along the coast of South America as well as between the mainland and Grenada. I was able to assess which months might be appropriate to model in these areas. These points were checked for current velocity and direction to determine periods of high and low variance in current. This case study area has the largest difference between high and low current strength throughout the year of any evaluated. This is a result of the strong current that flows through the channel between Grenada and Trinidad and Tobago. Currents between the Lesser Antilles and the mainland often reach one knot, which is about twice the average for currents observed in the Anegada Passage (see Figure 92, 104, and 106). When looking at the averages in current strength across the channel between the mainland and the Windward Islands, current average falls around 0.5 knots for the entire year (see Figure 93) This speed is equivalent to current strength through the Anegada Passage.

These changes in average current velocity are better observed in the table showing the 15-day average of current velocity at Point 1 (11.167624, 61.5344424). Here, spikes in current velocity can be seen between February and March, March and April, June and July, September and October, and in November (see Figure 93). This differs from the current averages observed in the table displaying 30-day averages, where currents spike in March, April, and June (see Figure 93). These changes provide the opportunity to evaluate movement when currents spiked, as in April, when they fell, as in July, and when they remain relatively stable, as in January. These environmental factors allow for a better assessment of changing time values over seasons than the two previous case studies, as these fluctuations in current velocity are greater.

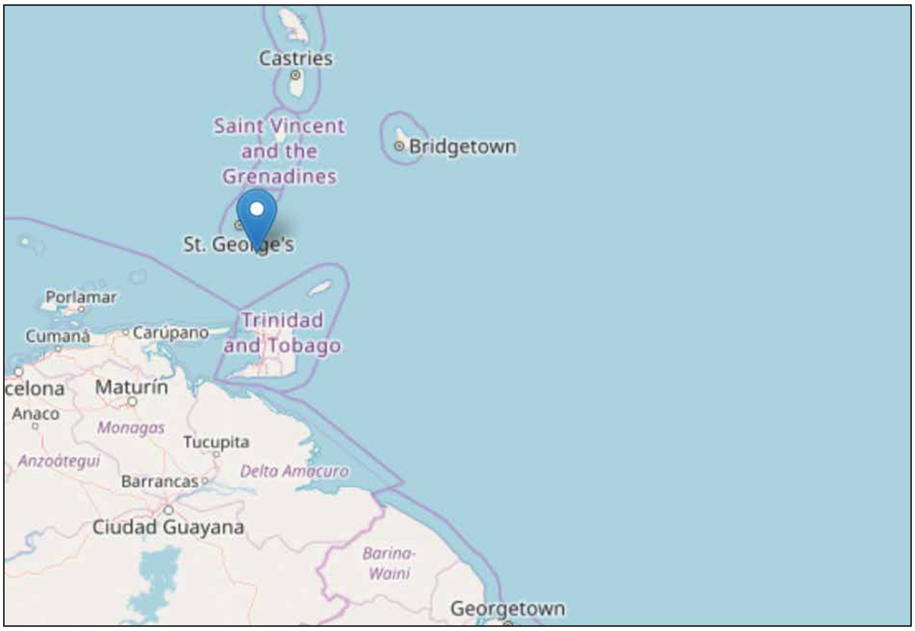


Figure 92: Map showing location of Point 1 (11.67624, -61.534424) evaluated using the current tool.

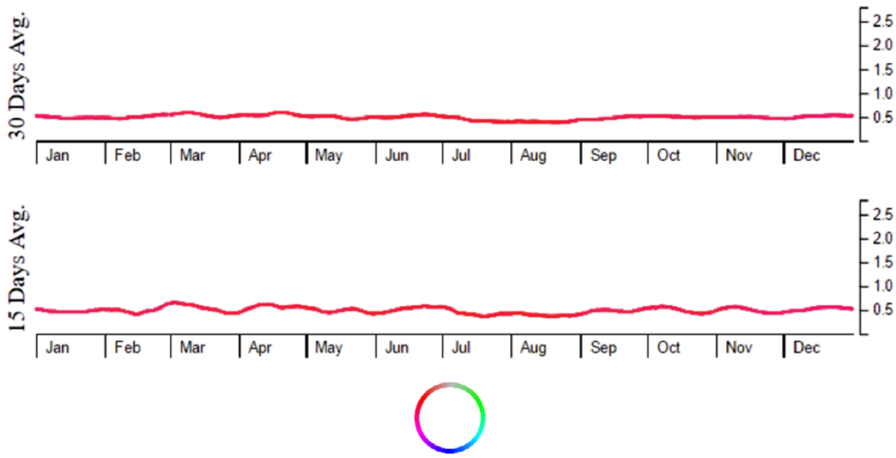


Figure 93: Graph showing the 15- and 30-day average values for direction and velocity of current at Point 1.

The fluctuations in these values also demonstrate the difference in strength and direction of current velocity over different years. While most months have similar peaks of current strength and direction, these happen at different times. For example, the current in August that generally trends to the northwest (see Figure 93; Appendix D) has also been recorded as moving to the east and the south at different times in August between 2010 and 2016.

Currents also peak at over one knot in all years tested except 2010 and 2012. However, these current peaks shift through the month. For example, in 2014 the peak sits towards the middle of the August, while in 2015 the peak is at the beginning of the month. It is possible that Amerindian canoers noticed and/or included these fluctuations in their mental maps and yearly variations in current velocity may have affected when crews travelled. The seasonal averages of current velocity peaks indicate that specific times of year could have represented optimal travel months that were used as canoeing seasons by Amerindian crews. Though the day crews set off could have varied, it is likely the period of year during which they left did not.

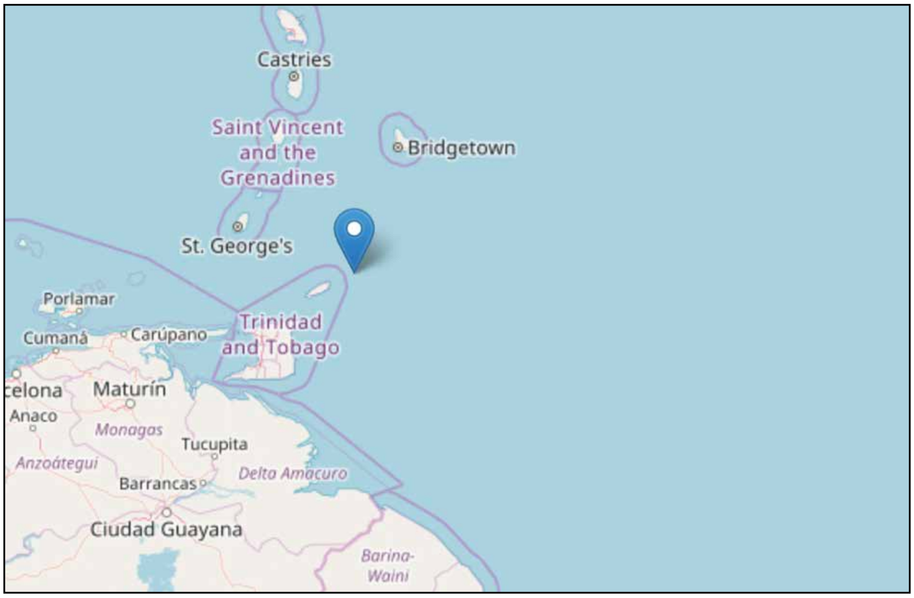


Figure 94: Map showing location of Point 2 (11.432648, -60.205078) that was evaluated using the current tool.

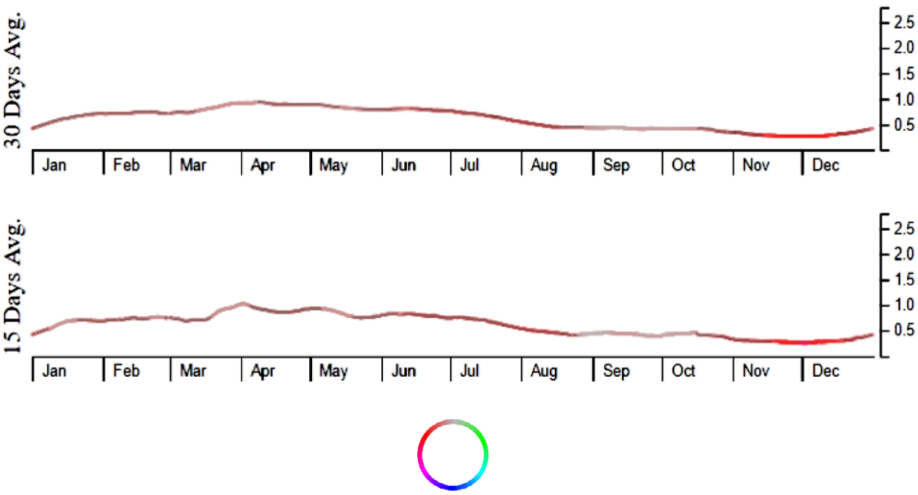


Figure 95: Graph showing the 15- and 30-day average values for direction and velocity of current at Point 2.

Point 2 (11.432648, 60.205078) shows the trend of current velocity off the northeast coast of Tobago (see Figure 94). Current direction at this point trends towards the northwest for most months over all years (see Figure 95; Appendix D). There are also shorter periods within several months where the current trends towards the northeast (see Figure 95; Appendix D). Currents from January to June fluctuate with average current strength of 0.5 knots to over 1.5 knots. This demonstrates both the strength and inconsistency of current force during these months. Current

Figure 96: Map showing location of Point 3 (7.1226996, -57.304688) that was evaluated using the current tool.

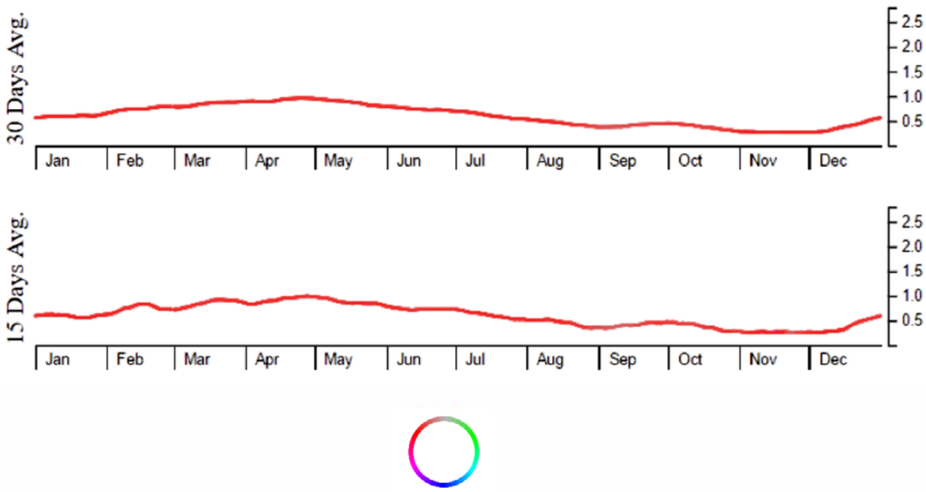


Figure 97: Graph showing the 15- and 30-day average values for direction and velocity of current at Point 3.

velocity values returned from August to September and October to December show movement toward the northeast and southeast, respectively. These periods also coincide with slower currents. The 15- and 30-day averages for current velocity and direction at Point 2 show a peak in current force towards the northwest between March and July (see Figure 95). Currents also tend to be slowest during November and December (see Figure 95). These averages suggest that the route tool should be used to check movement during these two periods to determine if either represented an optimal month for seafaring.

Current movement off the coast of South America seems to follow a more consistent pattern towards the northwest. Point 3 (9.275622, -59.32617) on the assumed direct path between Guyana and Grenada shows movement towards this direction over most months and years (see Figure 96). Both the 15- and 30-day averages of current velocity show a spike in strength between March and June (see Figure 97). The broad exception for current direction comes from some returns between August and December. Though this is a broad stretch of the year, most years do not concurrently have movement away from the northwest. In fact, most of these divergences to the south and east last only a month (see Figure 97). Movement to the south and east also coincided with the tendency for current velocity to fall below 0.5 knots. These changes were likely to be noticed by Amerindian canoers, and crews may have avoided travelling north in these periods. As currents would have pushed canoers to the south at a low velocity between August and December, crews returning from the Lesser Antilles may have chosen to travel to the mainland in this period.

Point 4 (7.1226996, -57.304688) was also sampled to test the strength and direction of current at an area near Suriname and Guyana (see Figure 98). Looking at current velocity at this point can inform on the conditions canoers would have met when travelling west from the Maroni River, at the border between Suriname and French Guiana. As mentioned above, collecting current values closer to the river mouth and the location of multiple Koriabo-connected sites, was impossible due to the extent of the underlying current data used by the tool. Measuring currents at Point 4 can be connected to possible origin points using the AmSeas3D data.

The current averages at Point 4 over 15- and 30-day periods show a reduced velocity when compared to currents from other areas within this case study. They average below 0.5 knots and trend towards the north. However, there is a spread in velocity up to one knot and direction headings to the south when looking at the individual results for data collected during all months from 2010 to 2016 (see Figure 99; Appendix D).

This trend is repeated in current values returned for Point 5 (6.55547, 57.01904). 15- and 30-day averages for this point show a low velocity trend towards the north (see Figures 100 and 101). Individual results, as with Point 5, show a movement towards the south as well. The slow current in this area could indicate that routes heading along the coast of Guyana were relatively easy compared to those least-cost routes running further out in the Atlantic.

As with the previous case studies, these points tested by the current tool help to select which months and years should be used as the base for modeled routes. I have chosen to compare movement in 2013 and 2014 for the months of January, April, August, and November for this case study to represent possible annual environmental circumstances. For example, between August and December currents would have aided movement towards the south. This suggests that this period and the one from January to July were separate canoeing seasons. Crews may have chosen to travel north during the winter and spring, while moving south during the summer and fall. This assumption was evaluated through the route tool.

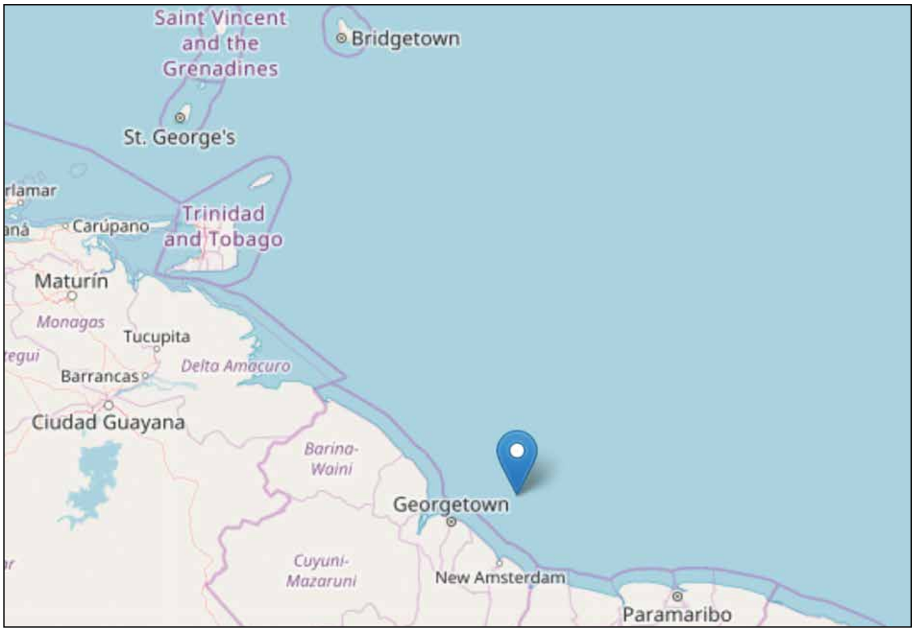


Figure 98: Map showing location of Point 4 (7.1226996, -57.304688) that was evaluated using the current tool.

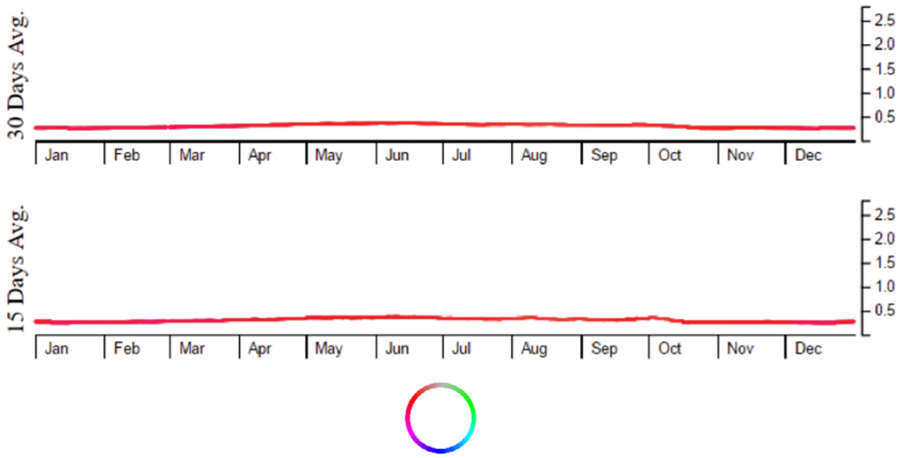


Figure 99: Graph showing the 15- and 30-day average values for direction and velocity of current at Point 4.

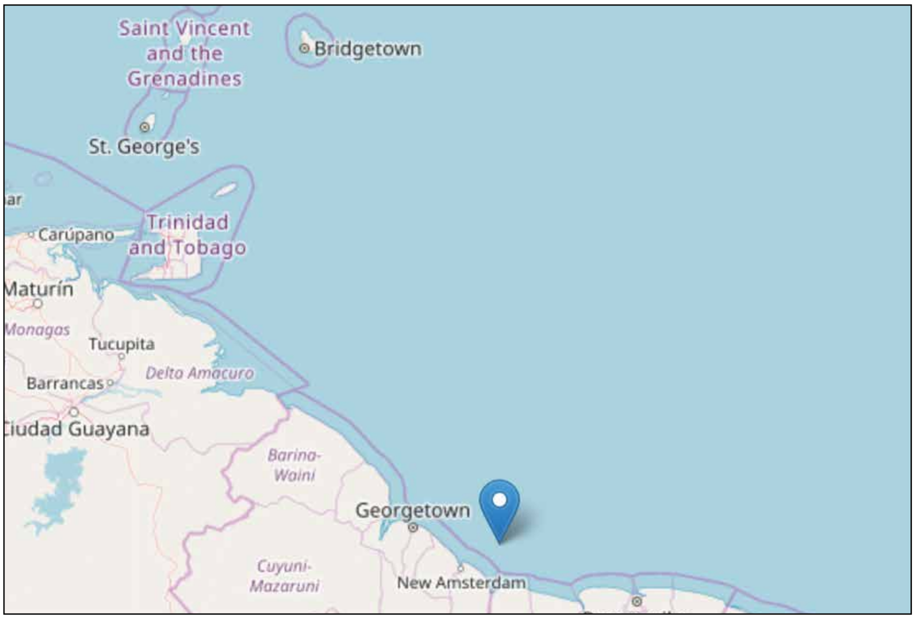


Figure 100: Map showing location of Point 5 (6.55547, -57.01904) that was evaluated using the current tool.

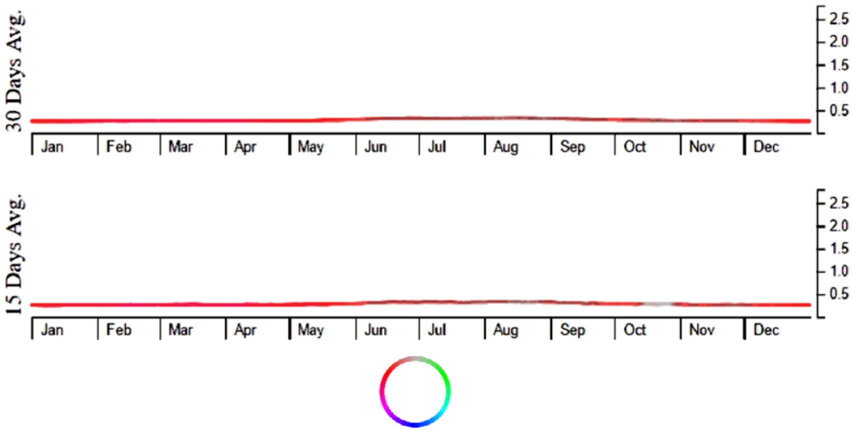


Figure 101: Graph showing the 15- and 30-day average values for direction and velocity of current at Point 5.

7.2.3 Route Cost

Another consideration in developing the routes was the physical ability of canoers to cover these distances. For voyages to cross directly from South America to Grenada, and vice versa, some routes exceeded 100 hours. This is substantially more than the regular time cost for routes to head between the Greater Antilles and the Leeward Islands, which typically took between 45 and 60 hours (see Chapter 5). As mentioned earlier, the routes modeled here fit with the time estimates made by Callaghan (2001) for direct crossing between the north coast of South America and the Greater Antilles, thus corroborating the possibility of these long voyages. Route time costs could suggest those routes that were more likely to be followed. Crews may have chosen to break a voyage at a convenient place indicated through the modeled routes' layout.

The greater distances covered by these modeled routes may also show seasonal patterns more clearly than shorter routes hypothesized between the Leeward Islands. Though perhaps relegated to determining whether travel north or south resulted in lower cost routes, these seasonal separations may present an order to the annual mobility cycle absent in the previous two case studies. The distances covered by hypothetical routes between the mainland and the Windward Islands, and vice versa, may prove to show how interconnection in different months influenced mobility patterns.

Due to the extensive distances covered by canoers I had to adapt the settings for the route tool from those used previously. As with modifying parameters for modeling least-cost routes across a landscape, I changed the iteration level, or the total number of isochrone steps evaluated, to allow for the protracted lengths of routes, to allow for the protracted lengths of routes. To evaluate the best iteration level over these large distances, four tests were run on voyages between Guyana and sites on Grenada and St. Vincent in April. The values tested were for routes between Guyana Point C off the coast of Guyana and all sites on Grenada and St. Vincent iterated at 150, 300, 450, and 600 times per run. The results of these runs were mixed. Tests for an iteration parameter set at 150 did not run at all. Iterations over 300 points along a route returned only 51 routes. Tests for iterations for 450 points along a route resulted in 53 routes. Tests for iterations parameter set at 600 resulted in 53 routes. Additionally, routes tested at less than 450 points returned high levels of 'incomplete routes'. As such, I decided that due to processing constraints the iterations parameter would be set at 450 to ensure maximum return for the run time for all other months tested. This may shift the interpretation of network connections. Modifying the parameters to accommodate these longer route trajectories can affect the results, and therefore caution is necessary when comparing this case study to the previous two studies.

This number of points necessary to model routes could also indicate a high variability in the seascape and imply that canoers possibly following least-cost travel corridors in the region had to reevaluate their headings to ensure they continued towards their goal more frequently than canoe crews in the previous two studies. Still, the number of returned routes was fewer than for previous case studies. This smaller number may be linked to the distance crews needed to cover to create a direct route between a point off the coast of Guyana and Grenada or St. Vincent. Canoe voyages covering these distances would have experienced a higher failure rate, demonstrated by the issues with the model completing certain routes.

Overall completion of the modeled routes shows that trips from Grenada had a higher chance of success than those from St. Vincent. This suggests that Grenada played a larger role in an exchange network between the Lesser Antilles and the Guianas.

As expected from the geographic position of the islands, routes from Guyana Point B towards St. Vincent took longer than those heading to Grenada. However, the difference in route cost for routes traveling from the mainland to each of these two islands can range between one hour and 30 hours (see Appendix D). Canoe crews may have been able to identify weather patterns that could help them overcome fluctuating route costs, although this may have been difficult on direct voyages to St. Vincent or

Grenada due to the time and distance associated with these trips. Canoers also had to bring enough supplies with them to avoid failure if they were caught out at sea in a disadvantageous current. These tactics were essential parts of planning and undertaking canoe voyages, as suggested by the range of voyage lengths.

The differences in these time costs can be linked to route layout, or the culmination of navigators' choices to best use current force. For example, in November, routes from Guyana Point C towards Argyle on St. Vincent that pass by Tobago and Trinidad have a higher cost than those that pass further east in the Atlantic. Canoers may have chosen to avoid direct contact with Trinidad and Tobago to dodge the additional time cost. Conversely, routes past these islands may have allowed for stopovers to break up the time cost of the whole journey. Stopping at either of these islands may also have allowed the real-world crews that may have followed these least-cost routes to alleviate some pressures.

Routes traveling from north to south during some months resulted in higher costs as well. For example, routes in November from Telescope Point to Guyana Point B typically took between 140 hours and 150 hours. This translates to six days of canoeing to make direct contact with Guyana. Routes from Argyle to Guyana Point A in January can exceed 160 hours, or roughly six and one-half days, to travel to a point so far off the coast of the mainland that it would be impossible to make port. It is possible that crews attempting a direct voyage would then have to travel for an excess of seven more days before reaching the Maroni River mouth. As a result, canoers traveling to the Maroni River mouth had to contend with a higher associated time cost than was advisable, due to the crew's need to rest and resupply. These time periods often show a similar reciprocated cost to travel to the islands. This could indicate that during some periods it was just as easy to travel north as it was to travel south.

Comparing leaving from the coastal area of Guyana to launching from further out to sea did show a small difference in time costs. At times, these routes may differ in cost by over 10 hours, although this may not have been such a great consideration for voyagers who were planning a trip of several days. This difference is compounded by the fact that some of these routes begin further into the Atlantic Ocean. Routes from Guyana Point A may have a lower returned cost but in practice a higher cost overall considering that part of the journey was not calculated. As time costs are similar regardless of a crew's starting position, the route costs can be compared against one another to assess seasonality.

Seasonal periods can affect what nodes become prominent within a network. There are examples of route cost comparison that indicate differences based on how a node's location influences travel corridors during the year. For example, movement from Guyana to La Poterie generally took less time in April than in November. In fact, in April La Poterie is consistently one of the least-cost points of contact when moving from the Guianas. However, time cost values, when averaged, show similar returns, which may indicate that the seasonal preference was minor, if it existed at all (see Table 17).

As most routes originating from the same node are comparable, I will now look at the trends in time costs over different seasons. The time costs for routes heading from Guyana Points B and C towards the Lesser Antilles stretches from 76 to 100 hours (three to four days) in April to between 90 and 130 hours three and three-fourths to five and one-half days in November (see Appendix D). Movement from Guyana Point A in April sometimes returns route-costs that are 20 hours less than the same routes costs in January and 30 less than those in August (see Appendix D). Routes to sites on St. Vincent are typically 10 hours costlier than routes to Grenada in November. In April, the cost of moving to Grenada or St. Vincent has a difference of only five hours. These time costs indicate April may have been a preferred month for travel from the mainland to Grenada or St. Vincent in comparison to other months. This trend is supported by the data returned by the current tool (see Figures 93, 95, 97, 99, and 101; Appendix D).

From	To	Month	Min	Max	Average
Guyana Point A	Argyle, St Vincent	January	100.207	121.711	109.75
Guyana Point A	Argyle, St Vincent	April	82.418	97.035	87.392
Guyana Point A	Argyle, St Vincent	August	105.683	120.822	113.414
Guyana Point A	Argyle, St Vincent	November	105.003	116.716	109.45
Guyana Point A	La Poterie, Grenada	January	87.378	110.773	100.709
Guyana Point A	La Poterie, Grenada	April	77.227	95.133	83.714
Guyana Point A	La Poterie, Grenada	August	95.463	128.026	103.414
Guyana Point A	La Poterie, Grenada	November	111.065	123.405	116.804

Table 16: Time cost values for routes from Guyana point A to Argyle, St Vincent and La Poterie, Grenada.

From	To	Month	Min	Max	Average
Argyle, St Vincent	Guyana Point A	January	149.192	152.099	150.49
Argyle, St Vincent	Guyana Point A	November	143.035	151.976	148.574

Table 17: Time cost values for routes from Argyle, St. Vincent to Guyana point A.

From	To	Month	Min	Max	Average
Guyana Point B	Argyle, St Vincent	January	130.446	152.071	141.109
Guyana Point B	La Poterie, Grenada	January	120.365	152.058	136.378
Argyle, St Vincent	Guyana Point B	January	144.075	152.169	149.354
La Poterie, Grenada	Guyana Point B	January	NA	NA	NA
Telescope Point, Grenada	Guyana Point B	January	129.108	152.151	142.656

Table 18: Time-cost values for routes to and from Guyana point B and the Leeward Islands. As the reciprocal route from La Poterie was unable to complete, I have included a route from Telescope Point, 3 km south of the first site.

From	To	Month	Min	Max	Average
Guyana Point B	Argyle, St Vincent	November	107.362	141.138	121.209
Guyana Point B	La Poterie, Grenada	November	104.166	141.138	115.723
Guyana Point B	Argyle, St Vincent	April	107.362	141.138	121.209
Guyana Point B	La Poterie, Grenada	April	104.166	141.138	115.685

Table 19: Time-cost values for routes from Guyana point B to the Leeward islands, comparing results from November and April.

These seasonal variations point to the existence of optimal canoeing periods. April seemed to return the best odds for a successful voyage. Modeled travel in August and November resulted in costlier least-cost routes. This suggests that the spring may have been an optimal season for canoe travel in this region. Routes in August and November have the highest time costs of any months evaluated for travel to Grenada and St. Vincent from Points B and C. Time costs for some of these routes can reach over 115 hours (four and three-fourths days) in August and from 107 to 120 hours (four and one-half to five days) in November (see Appendix D). Routes to and from Guyana Point A also indicate that August had higher associated time-costs, where routes towards Grenada typically

From	To	Month	Min	Max	Average
Guyana Point B	Argyle, St Vincent	April	107.362	141.138	121.209
Guyana Point B	La Poterie, Grenada	April	104.166	141.138	115.685
Guyana Point B	Argyle, St Vincent	November	107.362	141.138	121.209
Guyana Point B	La Poterie, Grenada	November	104.166	141.138	115.723

Table 20: Time costs for routes from Guyana point A towards the Leeward Islands.

From	To	Month	Min	Max	Average
Guyana Point A	Argyle, St Vincent	January	100.207	121.711	109.75
Guyana Point A	Argyle, St Vincent	April	82.418	97.035	87.392
Guyana Point A	Argyle, St Vincent	August	105.683	120.822	113.414
Guyana Point A	Argyle, St Vincent	November	105.003	116.716	109.45
Guyana Point A	La Poterie, Grenada	January	87.378	110.773	100.709
Guyana Point A	La Poterie, Grenada	April	77.227	95.133	83.714
Guyana Point A	La Poterie, Grenada	August	95.463	128.026	103.414
Guyana Point A	La Poterie, Grenada	November	111.065	123.405	116.804

Table 21: Comparison of time costs for routes from Argyle, St. Vincent to Guyana point A.

From	To	Month	Min	Max	Average
Argyle, St Vincent	Guyana Point A	January	149.192	152.099	150.49
Argyle, St Vincent	Guyana Point A	November	143.035	151.976	148.574

Table 22: Examples of movement from Guyana point B towards the Leeward Islands and return costs. Due to the inability for routes to run from La Poterie, Grenada to Guyana point B, the time cost values for Telescope Point, Grenada (3 km to the south) to Guyana point B is shown.

From	To	Month	Min	Max	Average
Guyana Point B	Argyle, St Vincent	January	130.446	152.071	141.109
Guyana Point B	La Poterie, Grenada	January	120.365	152.058	136.378
Argyle, St Vincent	Guyana Point B	January	144.075	152.169	149.354
Telescope Point, Grenada	Guyana Point B	January	129.108	152.151	142.656

Table 23: Time cost comparison between the months of April and November for movement from Guyana point B to the Leeward Islands.

lasted between 100 and 105 hours (four days) while those to St. Vincent took from 108 to 116 hours (four and one-half days) (see Appendix D). Thus, neither August nor November were a prime month for voyaging from the mainland to the islands.

The separation between time costs over various months is much clearer than in the previous case studies, allowing a comparison of route layout to connect more closely with route cost. Building upon these findings, I will look at route layouts for all months evaluated, with extra attention for the possible optimal month of April and non-optimal month of November. Assessing these months will allow a comparison between routes run in an easier and harder month to travel.

7.2.4 Route Layout

Route layout proved a vital component to the analysis of relationships between the Guianas and the Lesser Antilles. Modeled canoe routes indicated places to look for connections. The longer distances found in this case study also led to interesting pathways either out into the Atlantic or along the coast of South America. To identify possible social links in these canoe routes, the trajectories of these pathways are compared below.

Were routes direct between the Windward Island and the mainland or do the hypothetical pathways suggest stopover locations that may indicate communities connected with these islands? Archaeological remains of Cayo or Koriabo ware are found in coastal mainland and Windward Islands deposits but are limited on Trinidad and Tobago. This contact, while not currently supported by material evidence, is suggested by ethnographic accounts (Boomert 2002). Analysis of these possible canoe travel corridors is focused more on showing what types of connections were possible. Computer-modeled routes may be one of the only ways to determine if these avoidances were due to environmental influence or social factors.

7.2.4.1 Grenada and St. Vincent

The first route layouts analyzed for this work are from Guyana Point A to the sites of La Poterie and Argyle. Generating routes to and from these points was an important step in determining the basic layout of routes from the Guianas. These routes indicate that canoers from the Guianas had several options in approaching the Windward Islands. When traveling from Guyana Point A, which is set to represent travel from the Maroni River mouth, navigators could steer towards the Galleons Passage, the east coast of Tobago, or further east into the Atlantic. Return voyages could also follow these three trajectories. In fact, it is more common to travel out into the Atlantic from Guyana Point A than it is from other points. Most routes from Guyana Point A do not head west to connect with the mainland at all. Thus, leaving from Guyana Point A may have been ideal for crews, possibly following pathways similar to these least-cost routes, to avoid connections with adversarial groups along the mainland coast or on the western side of Trinidad.

As suggested by the routes' associated time-costs, a seasonal component for travel to and from these islands. Least-cost canoe routes from Guyana Point A in April were more likely to approach Grenada's windward coast, having arced their route over the east side of Tobago (*e.g.*, route 1-0_2014-04-01T00, and route 1-0_2014-04-29T15; see Appendix D). Approaching the island from the east would have allowed the current to push the route into the island. This could have made the final part of the journey easier for any real-world paddlers who may have chosen to move near the travel corridor suggested by the pathways modeled here. This technique of routes following optimal currents behind an island's coastline may be associated with the lower route costs in April. Grenada was much more likely to be approached from the east in all months but August, when pathways approached the island from the south (see Appendix D). August is the only month where routes from Guyana Point A pass over the north coast of Trinidad before heading to the site of La Poterie (*e.g.*, routes 1-0_2014-08-19T12, route 1-0_2014-08-20T00, and route 1-0-2014_08-20T03). This limited number of routes could suggest that any real-world canoers from the Guianas following the trends seen in the least-cost pathway models steered away from traveling past the north coast of Trinidad. In these cases, there may have been seasonal as well as social reasons, such as a desire to avoid antagonistic communities, behind route construction.

Trinidad, Tobago, and islands in the Grenadines may have acted as stopover locations for routes to St. Vincent. In April, movement from Guyana Point A towards Argyle approached the island from the south and passed closer to Tobago (*e.g.*, route 1-2_2014-02T06, route 1-2_2014-07T06, and route 1-2_2014-04-21T15) and was also more likely to pass by the island of Les Jolies Eaux (*e.g.*, route 1-2_2014-04-21T15,

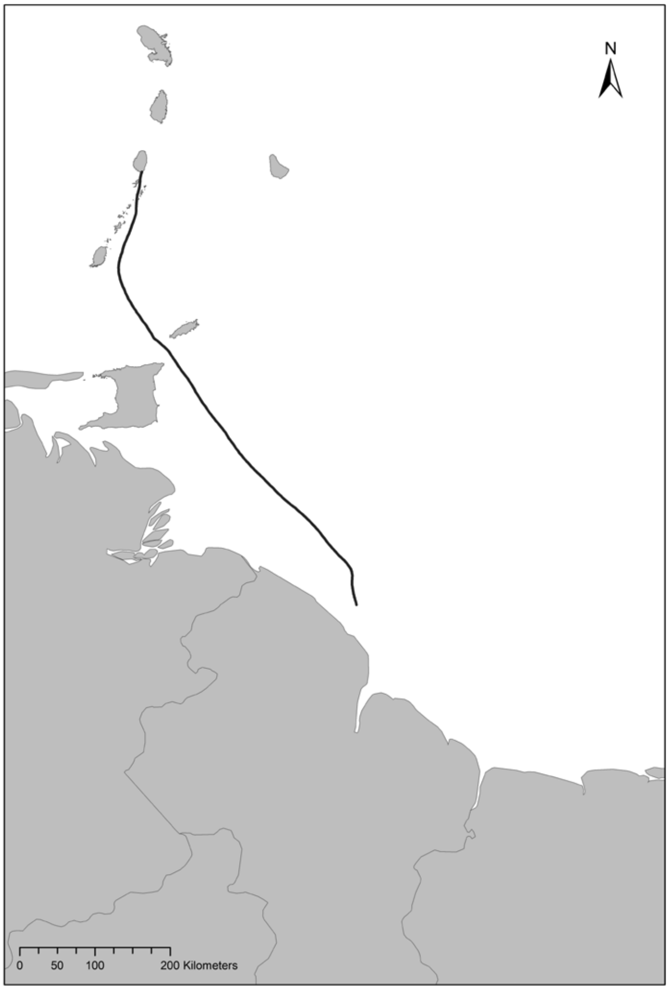


Figure 102: Route between northern Guyana point C and Brighton, St. Vincent in August. Route launched at 3pm on the 21st of August 2014, Route: 1-5_2014-08-21T03_00 (Iteration 450).

and route 1-2_2014-04-22T00; see Figure 102). In April and August, routes from Guyana Point B towards St. Vincent sometimes pass by the Grenadines (*e.g.*, route 1-5_2014-08-20T15, route 1-5_2014-08-21T03, and route 1-2_2014-08-18T03). This indicates that in some cases the Grenadines played a role as stopover points for routes to and from the Guianas. Cayo material from the Grenadines, for example on Il de Ronde (Bright 2011; Roget 2002), may have been a result of these routes. It is possible that sites on the smaller islands may have seasonal components that align with the travel periods that routed past the island. Comparisons of archaeological examples from Les Jolies Eaux, St. Vincent, and the Guianas are necessary to examine the extent of interaction between these three areas.

Though these routes may not make physical contact with the islands, they pass close enough to allow for visual links. In some cases, least-cost canoe pathways to Brighton on the southern coast of St. Vincent pass within five km of the Grenadines (*e.g.*, route 1-3_2013-04-26T21; see Figure 90). Routes towards Argyle come within one km of the Grenadines coastline (*e.g.*, route 1-4_2013-04-26T00; see Appendix D). It is likely that these routes would have had visible connections with the island as they ran par-

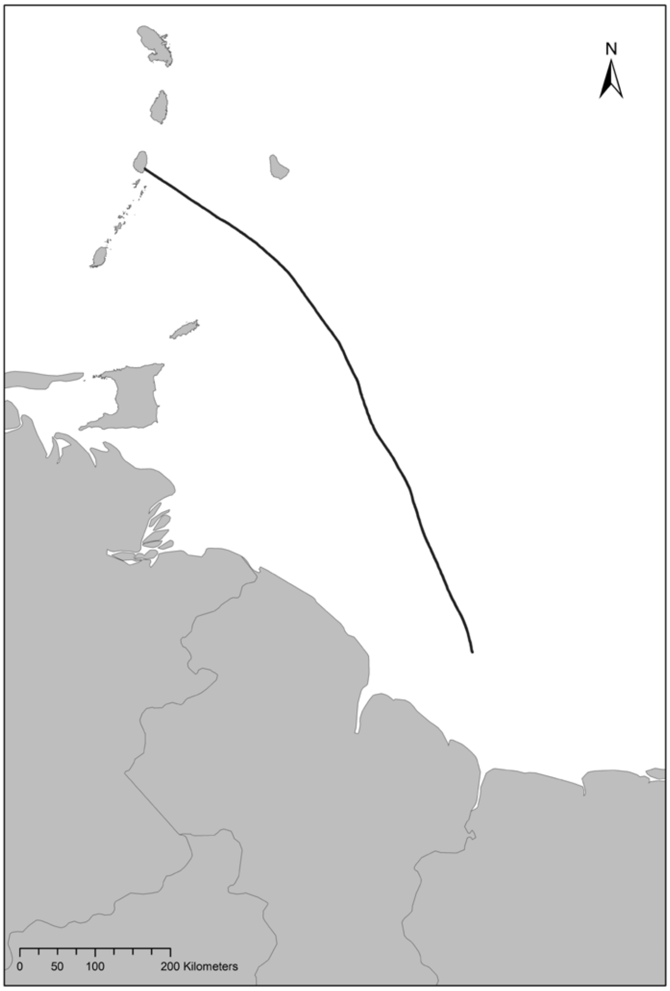


Figure 103: Movement from Guyana point A to Argyle, St. Vincent in August. Route launched at 3am on the 25th of August 2014 Route: 1-2_2014-08-25T03 (Iteration 450).

allel to it (*e.g.*, route 1-3_2013-04-05T21; see Appendix D). Visual cues from these islands may have helped orient canoers along their path and could have theoretically been represented as a part of a navigator's mental wayfinding map (*sensu* Crouch 2008; Llobera 2000; Tilley 1994).

Routes traveling both north and south may have sought to make contact with or avoid Tobago depending on the crew's relationship with peoples on that island. Hypothetical canoe routes from St. Vincent towards Guyana Point A sometimes pass further out into the Atlantic Ocean in August and July than in the other months (*e.g.*, route 1-2_2014-08_25T03, and route 2_1_2014-01_30T12; see Figure 103). Movement this far away from the in-between islands could indicate that even though August had higher time costs, canoers looking to avoid interaction with antagonistic communities on Tobago may have chosen to head south during this month. Modeled canoe routes from Guyana Points B and C towards St. Vincent infrequently reached Tobago, as the routes were typically placed more than 25 km away from the island. Routes travelling along these paths to St. Vincent were more likely to have travelled directly to the island, as there were fewer opportunities for stopovers. This trend could

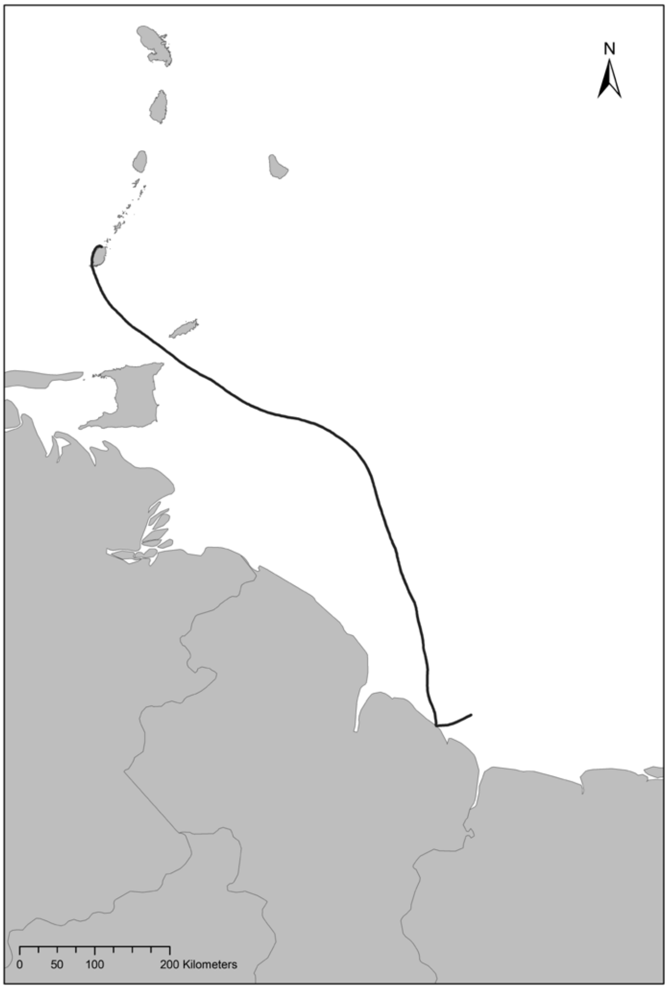


Figure 104: Route between the southern Guyana point B and Sauteurs Bay, Grenada in November. Route launched at 6pm on the 4th of November 2013, Route: 1-3_2013-11-04T18 (Iteration 450).

explain why the north of St. Vincent possesses a lower concentration of sites containing Cayo ceramics. Cayo stylistic elements may have come up to St. Vincent through contact with Grenada in the south.

The routes modeled in this case study suggest that travelers towards the islands from the mainland coast may have favored approaches to the east side of the islands, which is perhaps why sites are located on this side of the island. Most sites included in this research are on the east coast. Hofman and Hoogland (2012) state that Island Carib peoples settled on the windward side of the islands to make use of the steep cliffs and rough seas of the eastern coasts. Amerindian peoples could also have settled there to take advantage of landing spots suggested by these least-cost canoe routes. There are, however, some routes that pass by the west coast of the island in November and January (*e.g.*, route 1-3_2013-11-04T18, route 1-3_2013-11-10T03, and route 1-3_2014-01-15T03; see Figure 104) when heading from South America towards Sauteurs Bay. This pathway hugs the coast so closely that canoers who may have following this route would have had the opportunity to stop at many points before reaching Sauteurs Bay. Routes passing on the west side of Grenada benefited from the shelter provided by the island as the pathways run up the coast.

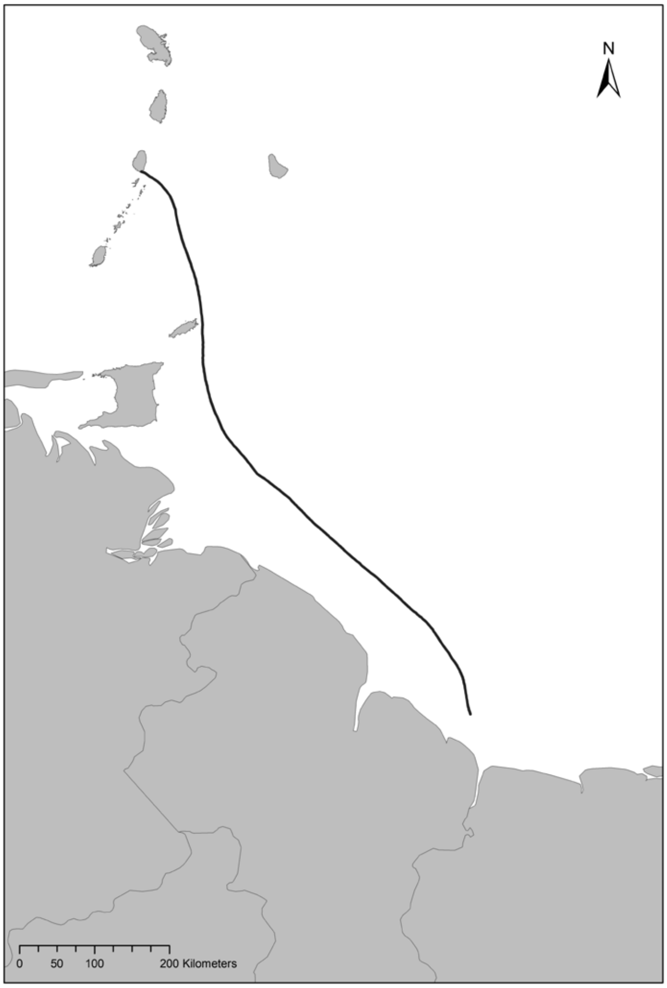


Figure 105: Route between the southern Guyana point B and Brighton, St. Vincent in April. Route launched at 9pm on the 26th of April 2013, Route: 1-3_2013-04-26T21 (Iteration 450).

7.2.4.2 Tobago

Ethnographic records show that the people on the island of Tobago at the time of contact identified as 'Kal'ina' (Boomert 2016). This connected them with Amerindian peoples from the Guianas who identified as Kalinago as well. There are few Cayo elements that would support connections between Tobago, the Guianas, and the Lesser Antilles. As suggested by Troumassoid assemblages, sites from this period could have acted as possible stopover areas for crews heading to the islands (Boomert 2016). However, sites yielding a concentration of Cayo ceramics have not been found on the island (Boomert 2016), indicating either that these peoples were not recipients of materials from the Guianas or that sites with concentrations of Cayo ware have yet to be found. Though some ceramic sherds hint at a possible connection with the Island Carib, interconnection cannot as yet be proven archaeologically. More survey work could be done around the island before a stronger statement can be made.

It is notable that the southwestern corner of Tobago was heavily occupied during the Ceramic Age/early colonial period (Boomert 2016). The placement of these sites

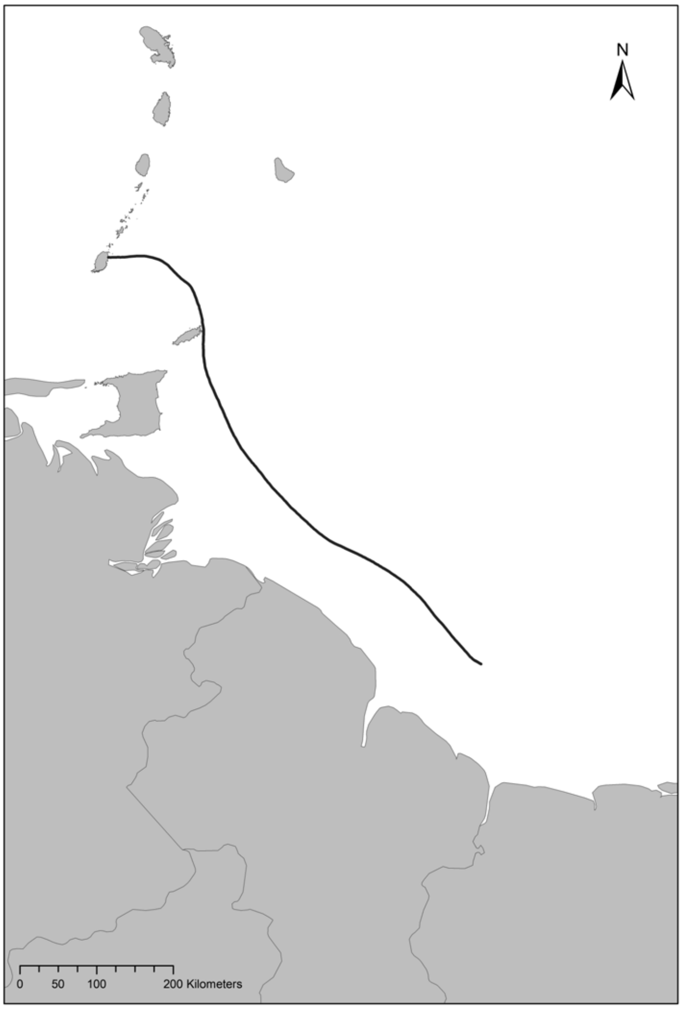


Figure 106: Movement from Guyana Point A to La Poterie, Grenada in August. Route launched at 3am on the 5th of August 2014, Route: 1-0_2014-08-05T03 (Iteration 450).

coincides with several routes modeled between Guyana and Grenada (see Appendix D). For example, routes modeled between these locations in November ran into the southwestern side of the island. The fact that there are also Archaic Age sites along this coast suggests that the placement of the Ceramic Age/early colonial period sites was related to the canoe routes that passed through this channel. These archaeological places stand in contrast to the unexplored west side of the island.

There are many historic accounts of canoes running through Tobago in the sixteenth and seventeenth centuries (Boomert 2002, 2008). These include accounts of people stopping at the island to rest when traveling from the Guianas to the Windward Islands. Historic and ethnographic records also mention the force of the current around the island. Many chroniclers referred to the current around Tobago as so strong that sailing-ships could be pushed from the east coast of the island towards Grenada (Boomert 2010; Young 1812: 89-90). Connections between Tobago and Trinidad play a large role in these accounts as well. Historic records indicate that voyages from Trinidad and Tobago across the Galleons Passage typically took one day and night (Boomert 2002,

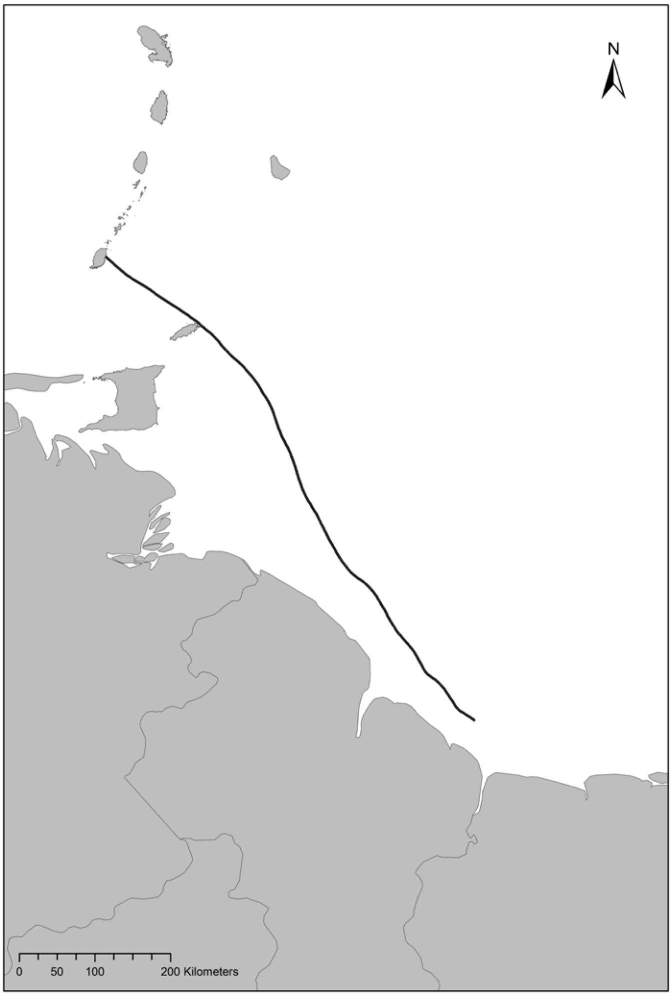


Figure 107: Route between Telescope Point, Grenada and the southern Guyana Point C in November. Route launched at 3pm on the 12th of November 2013, Route: 0-1_2013-11-12T15 (Iteration 450).

2010; Dauxion-Lavaysse 1820: 364-365). These mentions of navigation patterns and Amerindian canoe crews validate and support the routes modeled for this work.

Many of the modeled routes link up with the historic and ethnographic accounts, particularly those that run near Tobago. Pathways running to and from Guyana Point A often head past the island. Routes from this point were more likely to avoid the Galleons Passage and travel past the east end of Tobago instead (*e.g.*, route 1-0_2014-04-01T00, route 1-0_2014_08-05T03; Figure 106). In April and November, routes heading south from Grenada to Guyana passed by both sides of Tobago (*e.g.*, route 0-1_2013-11-12T00, route 0-1_2013-11-12T15; Figure 107). Looking at movement in the opposite direction, routes from the northern point off Guyana's coast in January were also likely to pass by both sides of Tobago on their way to Grenada (*e.g.*, route 1-2_2014-01-03T06).

Many routes to Guyana Point B from Grenada passed near or connected with Tobago. Several routes passed off Tobago's northwest coast (*e.g.*, route 0-1_2012-11-10T15), which can relate to the Ceramic Age/early colonial period presence on the island discussed by Boomert (2016). Most of these routes pass more than three km off the coast, which brings into question whether sites on this island would have been visible from routes in these travel corridors (see Brughmans *et al.* 2016; de Ruiter 2012, forthcoming). Most canoe pathways past the southwest coast of the island make a short connection with the coastline. Route 4-1_2013-11-16T03 is distinguished from other pathways by having the route from Barnes Bay run east below Tobago before turning south to Guyana. These routes indicate that canoers who possibly were traveling along pathways similar to these least-cost routes to and from Grenada could connect with different parts of the island and it is possible that peoples choose certain routes to ensure they could connect with specific areas or communities on Tobago.

How routes reach Grenada may have also influenced the ability of canoers on least-cost routes to successfully complete voyages. Routes north from Guyana to Grenada were more consistent in April, often passing through Galleons Passage (*e.g.*, route 1-0_2013-04-28T21, route 1-2_2013-04-29T21). However, routes moving from Guyana to St. Vincent in April typically avoided direct contact with Trinidad or Tobago (*e.g.*, route 1-4_2013-04-03T15; see Appendix D). These voyages can pass 10 km off the coast of Tobago. It is possible that if real-world canoers had knowledge of these least-cost routes, or were able to chart trajectories similar to their layout, they may have made trips during this period of the year to avoid direct contact with Tobago. This shift in route trajectory could indicate social preference for specific canoeing periods.

Depending on the preferences of crews, canoers could have stopped over on Tobago or avoided it. Routes moving to and from St. Vincent made regular contact with Tobago in November, (*e.g.*, route 2-1_2014-11-01T21, route 5-1_2013-11-14T06; see Figure 107) and in April, at points passing within three km of the northeastern edge. Routes leaving from Brighton Beach on the south side of St. Vincent were more likely to pass close to Tobago than routes leaving from Argyle. This could indicate that a closer connection should be evaluated for routes from the east side of Tobago, the south side of St. Vincent, and the whole of Grenada. These routes would have been visible to Amerindian peoples on the east side of Tobago, showing a possible connection between inhabitants of the island and those passing it in canoes. Several routes from both site nodes on the island pass close to Tobago (*e.g.*, route 5-1_2013-11-15T21). Some routes leaving Argyle even hug the coast of Tobago as they run past the island (*e.g.*, route 6-1_2013-11-14T06). This may fit with the premise that traveling south in November was easier than traveling south in January.

However, there are as yet no known prominent Ceramic Age/early colonial period sites on this side of the island (Boomert 2016) to judge as landing points for vessels or visual contact with canoe routes. This could be because crews may have avoided this area, which is possibly reflected in modeled routes leaving at different times of year. Hypothetical routes from St. Vincent to Guyana Point A in January are more likely to head out into the Atlantic (*e.g.*, route 2-1_2014-01-30T12). Only one canoe route from Guyana to St. Vincent passes by Tobago in November. Route 1-5_2013-11-18T18 runs past the northwest coast of the island (see Figure 108). This route suggests lower probability for stopover potential than observed in canoe pathways that hug the coastline as it does not make direct contact with Tobago. This is in direct contrast to movement from St. Vincent to Guyana.

Modeled routes can also indicate possible preferences for navigation through Galleons Passage. Routes from Guyana to Grenada were more likely to pass through the channel between Tobago and Trinidad in November and August. This could be

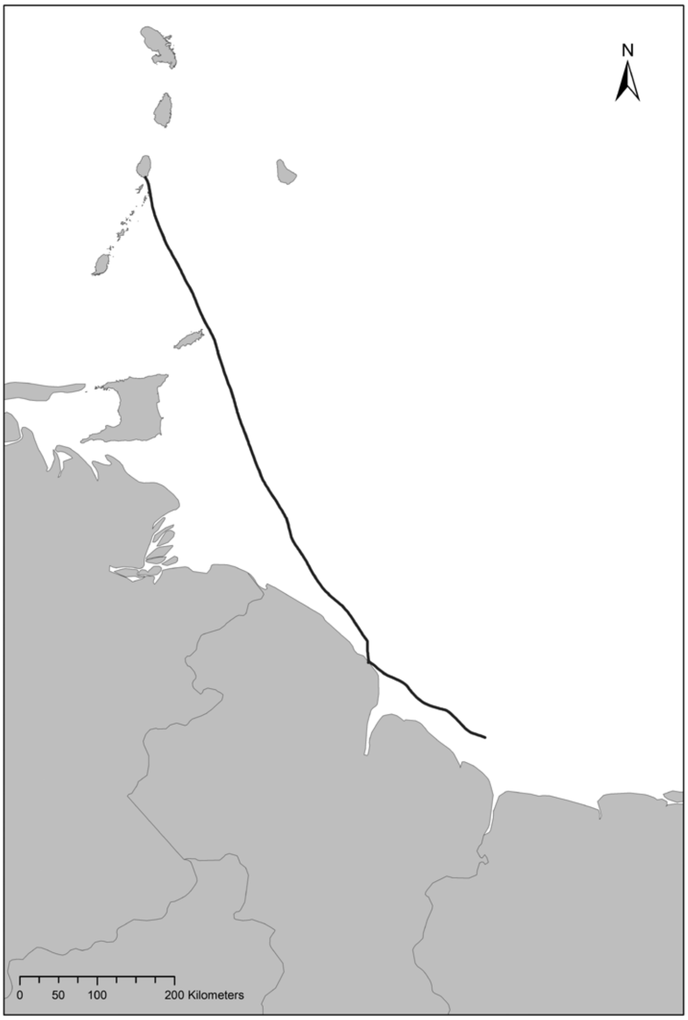


Figure 108: Route between the southern Guyana Point C and Brighton, St. Vincent in November. Route launched at 6pm on the 18th of November 2013, Route: 1-5_2013-11-18T18 (Iteration 450).

related to the stronger northward current passing on the east side of Tobago in April. Crews may have wanted to seek shelter behind the islands during this season. In April routes towards Grenada also avoid direct contact with Trinidad and Tobago (*e.g.*, route 1-4_2013-04-27T06). In the model for the 2013 environmental data, least-cost pathways stayed largely in the center of the channel, perhaps avoiding being in view of communities on these two islands. In the 2014 routes often go past the east coast of Tobago, though there are some exceptions (see Appendix D).

Whether direct contact was made, peoples moving from the south would have known how or when to maneuver to Tobago. The discrepancy in ease of movement based on the vessel's heading and the season of travel would have theoretically offered knowledgeable canoe navigators the choice of either avoiding or making connections with peoples on the island.

7.2.4.3 Trinidad

It was common for least-cost routes coming from the mainland to pass by Trinidad. Modeled canoe routes that moved closer to Trinidad than Tobago frequently travelled parallel to the larger island's east coast (*e.g.*, route 1-0_2013-11-10T09, route 1-2_2013-11-10T09; see Appendix D) and in some cases a route even hugged the

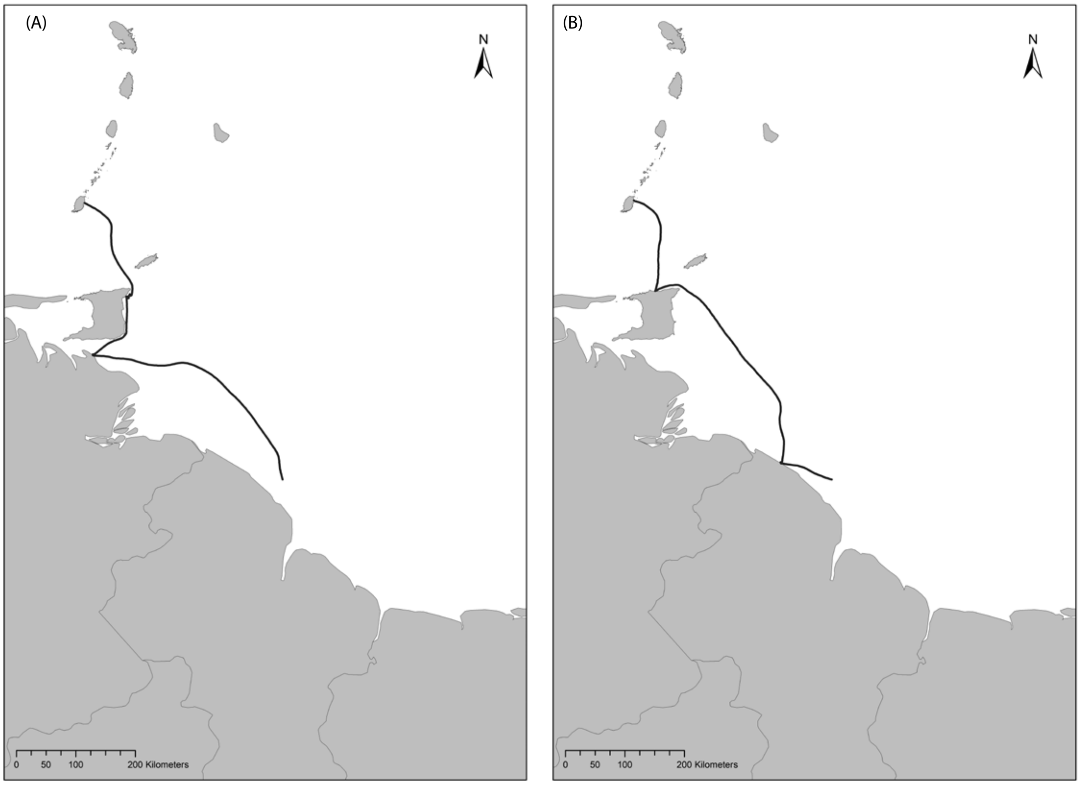


Figure 109: Routes between northern Guyana Point B and La Poterie, Grenada in April. (A): Route launched at 3am on the 26th of April 2014, Route: 1-0_2014-04-26T03 (Iteration 450), and (B) Route launched 3am on the 26th of April 2014, Route: 1-2_2014-04-01T06 (Iteration 450).

island's east coast (*e.g.*, route 1-0_2014-04-26T03, route 1-2_2014-04-01T06; see Figures 109 A and B). Routes from Grenada to Guyana also move closer to the east coast of Trinidad. These canoe pathways would have made direct contact with at least five Ceramic Age/early colonial sites on the coast of Trinidad including Manzanilla, St. Bernard, Lagon Doux, St. Catherines, and Guayaguayare (Boomert 2016).

It is likely that least-cost canoe routes traveling towards South America also passed by Trinidad's northeast coast despite the limited archaeological evidence of connection between the island and the southern Lesser Antilles. Routes from Guyana Point A are less likely to pass the island. Only routes in November and August come close to making direct contact with Trinidad's coastline (see Appendix D). Modeled routes would sometime head past the east coast of the island (*e.g.*, route 1-0_2014-08_24T15; Figure 110).

It is possible that Trinidad operated as a stopover point on a voyage from the mainland to the Lesser Antilles. For example, route 1-2_2013-11-14T06 also shows a pathway leaving from Guyana Point B making direct contact with the northeast tip of Trinidad, near Toco. This route also connects with the southwest corner of Tobago before heading north to the Grenadian site of La Poterie. These stopover points turn what

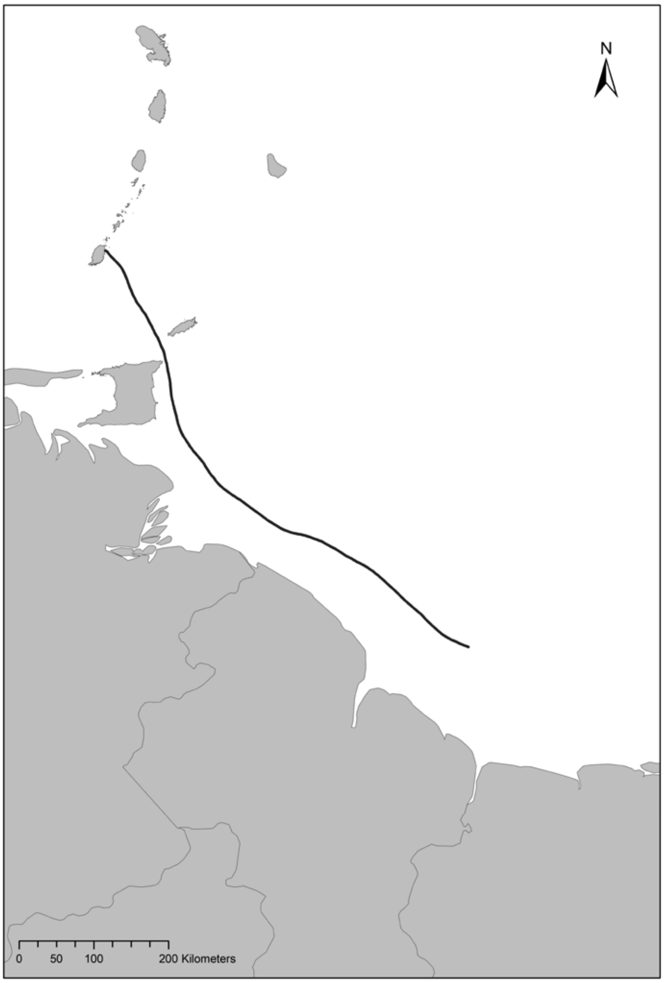


Figure 110: Movement from Guyana point A to La Poterie, Grenada in August. Route launched at 3pm on the 24th of August 2014, Route: 1-0_2014-08-24T15 (Iteration 450).

would be, by estimation, a roughly 700 km trip from Guyana to the Lesser Antilles into a 543-km voyage to Toco, with a second leg of 160 km to Grenada. This would have been advantageous to travelers, as it would lessen concerns over subsistence supplies and allow crews to travel with more materials for exchange rather than filling their canoe with food and water. Even if not used as a stopover point, some routes pass by the northeast coast of the island. Route 1-0_2014-08_28T03 also runs north of Trinidad, moving parallel to the island's north coast (see Figure 111). This route had a view of the island (routes 1-0_2014-08-19T12, route 1-0_2014-08-20T00, and route 1-0-2014_08-20T03). Any canoers who happened to follow a similar trajectory to the least-cost routes modeled in this work may have been able to reposition themselves at this point in their journey from these visual ques. This practice could have allowed for easier, or more direct, voyages to the Lesser Antilles.

There are as yet no large archaeological sites known in the area around Toco, although the area was likely used by Amerindian peoples during the period discussed here (Boomert 2016). Route 1-2_2014-04-01T06 (iteration 600), route 1-2_2014-04-01T06, and route 1-3_2014-04-01T06 also run by the northeast

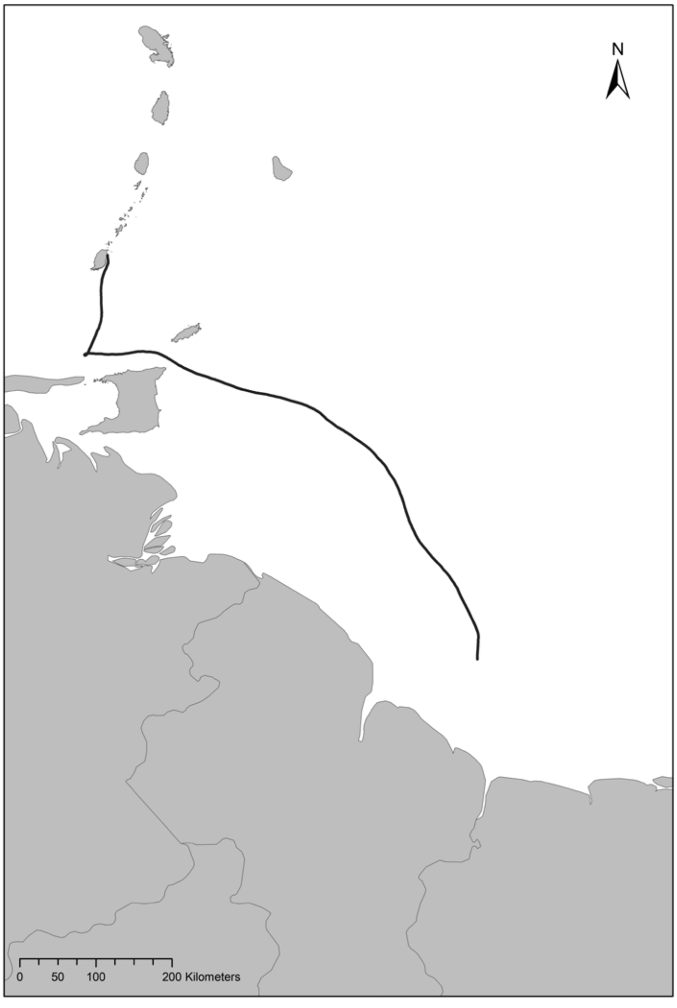


Figure 111: Movement from Guyana point A to La Poterie, Grenada passing over Trinidad in August. Route launched at 3am on 28th of January 2014, Route: 1-0_2014-08-28T03 (Iteration 450).

coast of the island before heading north, suggesting that this might be an area for further study. It is also possible that canoers decided to push on to Blanchisseuse on the north coast before heading north to Grenada rather than stopping here. This area could also be further surveyed for identifying possible locations of archaeological sites.

On a few occasions, routes ran along the north coast of Trinidad when travelling between Guyana and the site of La Poterie on Grenada (*e.g.*, November: route 1-2_2013-11-17T15, April: route 1-2_2014-04-01T06 (iteration 300/iteration 450)) and might have passed by the Ceramic Age site of Blanchisseuse. The November route turns to the north roughly 10 km west of the site (see Figure 112) and the April pathway runs into the coast almost directly where Blanchisseuse is located. It is possible that this site could have acted as an origin point into the southern Lesser Antilles from Trinidad. Communities near Blanchisseuse may have been in contact with peoples living close to La Poterie, as it is only movement towards this site that results in this trajectory. Archaeological materials from this site and the Guianas should be re-evaluated to gauge Blanchisseuse as a stopover point.

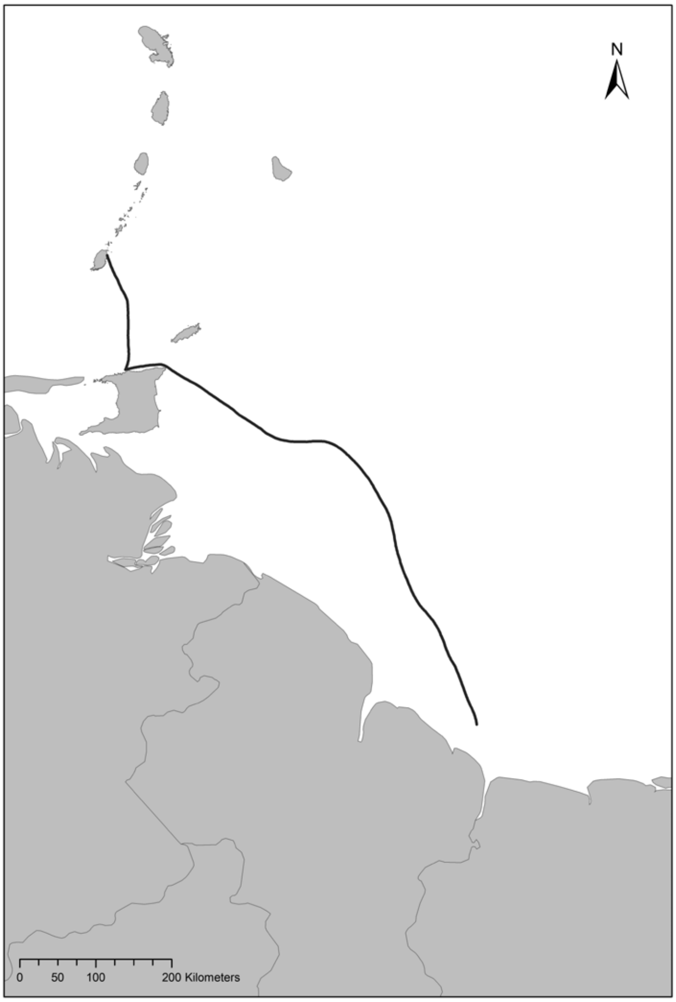


Figure 112: Route between the southern Guyana point C and La Poterie, Grenada in November. Route launched at 3pm on the 17th of November 2013, Route: 1-2_2013-11-17T15 (Iteration 450).

Routes that connect Guyana with Sauteurs Bay on Grenada follow this trend as well (route 1-3_2013-11-07T09, route 1-3_2013-11-09T00; and Figure 113), passing the entire north coast of Trinidad before turning north near Venezuela east of the Dragon's Mouth. The pathway arcs over 10 km above Trinidad before heading south towards the Dragon's Mouth. Pathways that run away from the coastline of the island may have limited the opportunities for the canoers following least-cost routes to reach Trinidad, and the site of Blanchisseuse.

The absence of other major sites on the north coast of Trinidad raises the question of how closely Blanchisseuse was related to outward exchange routes rather than intra-island connections. Routes past this site could have been added to the knowledge collected in mental wayfinding maps of individual navigators in previous generations (*sensu* Ingold 2009; Terrell and Welsch 1998; Terrell *et al.* 1997), making it a place of known safety for communities to turn towards the Lesser Antilles when canoeing over the north coast of Trinidad. Even if the site proves not to be connected to exchange routes between the Guianas and the Lesser Antilles, the modeled canoe pathways that

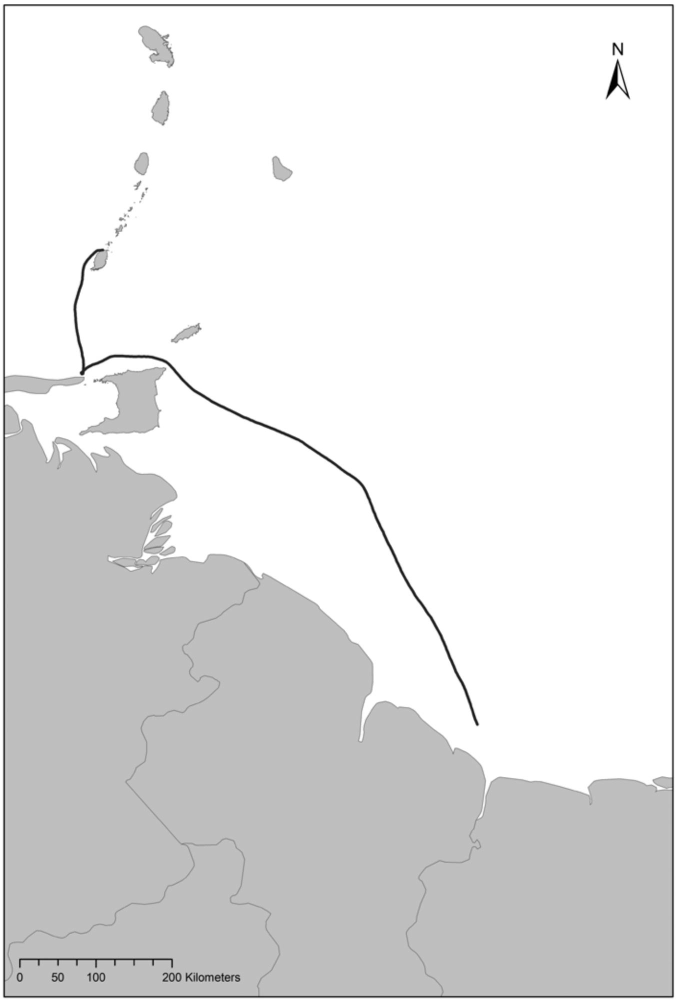


Figure 113: Route between the southern Guyana Point B and Sauters Bay, Grenada in November. Route launched at 12am on the 9th of November 2013, Route: 1-3_2013-11-09T00 (Iteration 450).

move past or to this site suggest the placement of Blanchisseuse was related to the location of sea routes. Though Blanchisseuse is associated with the Saladoid series (300 BC – AD 600), it is one of three Ceramic Age/early colonial period sites on Trinidad that yielded pieces stylistically linked to a specific production site (Mount Irvine) on Tobago (Boomert 2010, 2016). Pathways running past this site may indicate why Blanchisseuse was located at this point on the north coast, as the area was sparsely settled due to the limited number of accessible beaches and moun*taino*us terrain off the coast (Boomert 2009, 2010). This raises the question of connection between the peoples of Trinidad and communities heading north to the Lesser Antilles. More research is necessary to explore whether there are sites along the north coast of Trinidad that align with the placement of canoe routes modeled for this work.

Connections between the mainland and Grenada can also be evaluated to determine the level of contact with Trinidad. Routes heading towards Galby Bay from Guyana were more likely to pass through the channel between Trinidad and Tobago than those terminating at other sites on Grenada. Routes modeled towards this site tend to pass closer to the coast of Trinidad than pathways connecting Guyana and La Poterie because Galby Bay's location on Granada allowed routes to approach the island from the south more readily. Movement from Guyana towards points in the Lesser Antilles in August primarily runs close to Trinidad and Tobago. These routes often head to either the northeast coast of Trinidad, the west coast of Tobago, or the east coast of Tobago, but usually not more than 25 km (*e.g.*, route 1-5_2013-08-23T06, route 1-6_2013-08-06T03). Route 4-1_2013-11-15T00 passes both the east coast of Trinidad and the southwestern tip of Tobago, suggesting links between communities Trinidad and on Tobago. Canoers seeking to avoid contact with these islands probably would probably not have travelled north during this month.

7.2.4.4 Mainland South America

Modeled routes also revealed possible links between coastal mainland areas. This is consistent with the concentration of Koriabo sites along the coastal stretch between French Guiana and Venezuela (Boomert 1986). Several routes leaving from mainland Guyana Point B first move away from the coast before returning to make landfall below the Orinoco River mouth (*e.g.*, route 1-3_2014-04-26T03, route 1-0_2014-04-26T03, and route 1-2_2014-04-01T06). The area below the Orinoco was considered Kaliña territory and there are many Koriabo-associated sites along this stretch of coastline and in the interior (Boomert 1986: Figure 11). Koriabo settlements in this area were likely connected to canoe routes from Guyana.

Routes originating more south in the Guianas also would have been pushed towards the mainland, highlighting the possible connections between southern coastal areas of Venezuela, Suriname, and French Guiana. The locations of Koriabo-associated sites in this region suggest that the trajectory of canoe routes influenced the placement of sites. This is consistent with findings from the previous case studies, for example the connection between canoe routes modeled from Flinty Bay, Long Island to Jolly Beach, Antigua that pass by the site of Anse á La Gourde on Guadeloupe. Routes originating further off the coast from Guyana Point A do not show least-cost canoe routes coming back into contact with the South American coast. However, it is possible that canoers who chose to follow pathways similar to these least-cost routes near the mainland coastline to take advantage of stopover points or navigation markers. Kaliña raiding parties may have chosen to allow the current to push them towards land when interacting with Arawakan communities in and around coastal Venezuela.

7.2.4.5 Realistic Seafaring

Modeled route trajectories often mimic existing seafaring techniques. This includes routes curving towards islands or taking shelter behind coastlines. As mentioned above, routes coming from South America often passed off the east coast of Trinidad. Canoers who may have traveled these routes could take shelter from the current by passing on the west side of Tobago. This was true for canoe routes modeled past Tobago and for those moving between the Greater Antilles and the Leeward Islands that ran past St. Croix. Even over long distances, modeled routes tend to either pass behind the shelter or close to the coastline of an island. This would have proved beneficial to any real-world canoers traveling along similar corridors, as paddlers may have had the chance to rest on an island or face calmer seas while sheltered by its coastline

In some cases, least-cost pathways pushed north with the current until they could move directly west into Grenada (*e.g.*, route 1-0_2013-11-21T06; see Appendix D). This tactic may have allowed canoers following these least-cost travel corridors to be pushed into the islands of the Lesser Antilles without having to fight westward against the current. Similar to other realistic navigation practices, some routes that passed by Tobago also exhibit the curve or banana feature seen in Chapters 5 and 6. Here the curve towards the Windward Islands or arc of the voyage comes east of Tobago (*e.g.*, route 1-0_2013-11-22T21; see Appendix D). If crews followed similar routes, the current would have pushed tired paddlers either into Tobago or the southern islands. This would have facilitated the creation of a stopover on Tobago, allowing crews to rest before heading into the Windward Islands. Pathways heading south often took a different approach. Routes from the Lesser Antilles towards the Guianas did not head as far east into the Atlantic, possibly because currents often push east into the South American coastline. Both examples show that navigators may have focused on working with the current when possible, as the ability to move with the current into land increased the safety level of these voyages.

Canoe routes from this case study also indicated the differing reliability of canoeing periods. Beginning a certain route to take advantage of specific currents is a common sailing technique still in use today (Bowditch 2002). Several routes between Guyana and the Lesser Antilles showed evidence of reliable canoeing periods. These were separated into optimal and least optimal months. For example, April was a better month for canoeing north than November. These travel periods indicate possible preferences for a particular sea corridor for movement by canoe between two locations. In these cases, movement south was optimal in November, suggesting that peoples in the past may have traveled north in one season and south in another. These corridors can be measured against one another to determine what routes could have existed as part of a seasonal mobility pattern between sites on the mainland and in the islands. In future studies, researchers can evaluate if there are any seasonal components to Cayo assemblages that could confirm the use of seasonal corridors.

7.3 Conclusion

Archaeological, linguistic, and ethnohistorical evidence suggests that peoples frequently traveled between the South American mainland and the Lesser Antilles during the Late Ceramic Age and early colonial period. The archeological evidence of stylistic links between Cayo and Koriabo ceramics establishes that intensive connections existed between Grenada, St. Vincent, and the Guianas (Boomert 2008, 2010; Hofman and Hoogland 2012). The foundation of these ceramic styles fits with linguistic commonalities in these regions. Allaire (1977, 2013) attests to the exchange and similarity of language between the Kaliña and the Kalinago communities. Taylor and Hoff (1980) suggests a shared trading language evolved over the need to communicate across the mainland-island. Ethnohistoric accounts also attest the regularity of these interactions, some accounts suggesting they happened on an annual basis (de Laet 1931).

Though some routes modeled for this work passed far to the east of any islands, many canoe pathways included the potential for stopovers on Trinidad and Tobago. As there are still some gaps in the archaeological hypotheses concerning the connection between Trinidad, Tobago, the Guianas, and the Lesser Antilles (Boomert 2008, 2016), the possibility of stopping over at these islands can point to new areas for archaeological survey that can help fill these gaps. Additional surveys might be of importance for the northeast corner of Tobago and Trinidad, which is frequently passed or touched by modeled routes. Linguistic and ethnohistoric lines of evidence also point to connections between Tobago, the Lesser Antilles, and the Guianas. Archaeological evidence has yet to match these accounts (Allaire 1970; Boomert 2002). However, modeled routes between the Guianas and the Windward Islands suggest that canoers may also have connected with other islands, primarily Trinidad, Tobago, and the Grenadines.

If crews indeed followed these modeled least-cost travel corridors, they possibly traveled north from the mainland during January and returned south in November. November has more routes outside of the channel between Tobago and Trinidad and is also associated with a lower current velocity. It is possible that the consistency in the modeled least-cost pathways suggests that crews attempting to follow a least-cost corridor had more freedom to paddle where they wanted. Freedom of movement in this month may have allowed crews to raid communities in the south more easily. The raiding culture discussed by Boomert (2016) might be a reason for the lack of connection between Trinidad and the Windward Islands. Though there are shared linguistic characteristics between these areas and historic accounts exist of peoples moving through the islands (Boomert 2008), there is little archaeological evidence to support this to date.

Looking at route layout without considering the archaeological background of the islands suggests that Tobago and Trinidad were active partners in exchange routes between the Guianas and the Lesser Antilles. However, there is limited material evidence to support movement through or stopover on Trinidad and Tobago. Additional archaeological evidence may also be able to tie in with social factors that linked islands in the southern Lesser Antilles. It might be that the absence of material support for movement through these islands, raiding or otherwise, is because these regions on Tobago and Trinidad have not been surveyed. In the future, more research is necessary to develop our knowledge of coastal areas, both in these islands and in the islands of the Grenadines. Route trajectories that show connection with islands in the Grenadines may also point to other areas to survey for Cayo sites.

It is possible that social factors and not least-cost routes dictated connections between the South American mainland and the Lesser Antilles. Antagonistic relationships between communities on the Windward Islands and Trinidad or Tobago could have motivated canoers to leave during periods of the year that would have ensured less contact with the latter islands. Ethnographic evidence might support the opposite response, where crews would seek to leave during times of higher probability for stopovers. Least-cost pathways can only provide suggestions of where people moved and not information on issues of avoidance. At this point, it is difficult to say which side of the avoidance/connection dichotomy influenced Amerindian mobility in this region.

These modeled routes point towards the existence of seasonal canoe travel corridors. While not exhaustive, the results of this analysis show that canoers likely had a comprehensive knowledge of their environment. Canoe navigators would have been able to travel from mainland South America to the Windward Islands with varying degrees of success. Crews approaching islands would have been able to use these views and cues to navigate their vessels to sites within possible mental wayfinding maps. These voyages allowed for the intermingling of mainland and island peoples and their cultural traditions leading to the genesis of the Cayo complex. Routes modeled here represent these trips and offer several possible avenues of success for canoers voyaging north to the Windward Islands. This case study showed the benefits of applying least-cost pathways to island-mainland interconnection research, and that canoe routes were linked as much to social factors (*i.e.* avoidance or connection) as environment. These hypothetical canoe routes also provide possible locations for future survey and excavation, allowing for future exploration of inter-island interaction through the Lesser Antilles.

8

Discussion

Island to island movement was an essential part of life for Amerindian peoples in the Caribbean. To explore inter-island mobility, this research brought together archaeology, ethnohistory, experimental and experiential archaeology, as well as computer modeling to show how people may have moved themselves and their materials between islands in the past. It has shown that least-cost pathway modeling can provide new insights into pre-Columbian inter-island connection in the Lesser Antilles. As a part of the Netherlands Organization for Scientific Research (NWO) Island Networks Project (project number 360-62-060), I have tried to demonstrate how least-cost pathway, or optimal route, analysis can benefit the study of island networks from the Archaic Age to the early colonial period in the Caribbean (2000 BC – AD 1600). In conjunction with the project's other research (Breukel forthcoming; Hofman *et al.* forthcoming; Laffoon *et al.* 2016; Mol *et al.* 2014; Scott *et al.* in press), this work provides a range of evidence that demonstrates relationships between materials on different islands extend beyond the physical movement of objects. These pathways broaden analysis of island networks and allow for more detailed discussions of how canoers may have moved between places in the past.

To analyze inter-island travel in the Lesser Antilles I evaluated how environmental constraints, such as wind and current, and social factors likely influenced connections between Archaic Age, Ceramic Age, or early colonial peoples. Route modeling is an additional layer of analysis that can supplement existing lines of data. By tying modeled routes as closely as possible to archaeological sites used in the pre-Columbian and early colonial Lesser Antilles, I was able to determine direct and indirect connections, seasonal shifts, and possible links between site placement and route trajectories. By comparing routes between sites on various islands I also indicated new ways to look at known connections.

Replicating canoe pathways can suggest how seafarers chose their routes and can provide insight into the function and use of the social connections between islands in the past. These routes, if indeed connected to canoer choice and social relationships, can demonstrate sections of the rich and varied possible mental navigation maps relied upon by generations of canoers to maintain inter-island interaction networks. Together, modeled routes and archaeological evidence can be used to link the exchange of materials from one island to another to the process of how peoples moved in the past.

8.1 A Brief Review

The previous seven chapters have worked towards establishing the ways in which least-cost analysis theory and methods can be applied to sea-based movement. In Chapter 2 I briefly discussed theories of movement in archaeology. While there are many studies that refer to visual connections between navigators at sea and the shore, only a few works speak to the specifics of sea-based navigation (*e.g.,* Agouridis 1996; Brughmans *et al.* 2017; Friedman *et al.* 2009; Lamarche 1993). Fewer still have discussed how past peoples would have conceptualized movement on water (Crouch 2008; Ingold 2009; McNiven 2008). The process of choosing and using known pathways is similar on land and sea, with people holding the location of a place within their minds and communicating this position and steps on how to get there to others (*sensu* Frake 1985; Samson and Cooper 2015; Terrell and Welsch 1998; Tilley 1994). How this knowledge was transmitted may have changed across generations, both in teaching the location of wayfinding points and the associated meaning of sites and navigation markers. As cultural trends changed, individuals learning from their predecessors likely incorporated their own meaning or understanding of points into their individual and shared communal mental map (*sensu* Ingold 2011). However, the fundamental subliminal transmission and/or outright communication of where travel corridors were and how to use them likely cemented connections between inter-island communities. The knowledge of these corridors and sites on various islands would have supported the existence of preferred canoeing routes. This idea supports the construction of least-cost paths within each case study.

In Chapter 3 I provided a brief history of island canoes in the Caribbean. This included a summary of the archaeological evidence of seafaring materials that has been found to date (*e.g.*, Fitzpatrick 2013; Ostapkowicz 1998; Schwabe 2001) and ethnohistoric accounts of canoe use (*e.g.,* Columbus 1493 cited in Hulme and Whitehead 1992; Davies 1595; Drake 1585; Fitzpatrick 2013). To understand how vessels have been used in the past I discussed experiential archaeological approaches to canoe use (Bérard *et al.* 2016; Horvath and Finney 1969).

Throughout this dissertation, I also explored if and how computer modeling could provide new insights into canoe travel corridors. To place the use of least-cost pathway modeling on seascapes in context, I discussed least-cost pathway methods as they have been applied to landscapes. In part, this was to demonstrate both the capability of least-cost pathway analysis and the organization of route modeling in landscape research. Land-based approaches to least-cost pathways analysis have shown that route modeling can hypothesize how people choose to move between sites, as well as the physical and social cost to travelers. I provided a similar lens to apply to modeling past seafaring practices in the Caribbean.

In the past, works have focused on analyzing the true cost of water-based movement through computer modeling (*e.g.*, Altes 2011; Arcenas 2015; Callaghan 2001, 2003; Cooper 2010; Davies and Bickler 2015; Irwin *et al.* 1990; Leidwanger 2005; Montenegro *et al.* 2016; Safadi 2016), although few researchers used the same technique (see Table 1). These researchers relied on various methods, including developing their own programs or using existing tools in GIS software packages, to analyze the difficulty of sea travel in different regions around the globe (see Chapter 3). In almost every case the tools used to calculate seafaring costs have been developed independently by each new researcher in the field (see Table 1). Researchers also focused on various types of one-way movement, from long distance colonization routes to short hops between islands or along coastlines. The method used in this study builds upon the spirit of previous works, while also developing a more rigorous technique suitable for modeling directed reciprocal voyages. I have focused on specifics of reciprocated inter-island movement that had yet to be explored in depth by sea-based least-cost pathway modelers. In part, I evaluated the structure of inter-island interaction in the region, assessing how the mobility of peoples and materials may have influenced social relationships, and vice versa.

The method used to approach generating the least-cost pathways was a modification of the isochrone method developed by Hagiwara (1989), which looks at travel between two points as if people head out from an origin point in the direction that allows the furthest length of travel in a set amount of time. To achieve this result, the model constructs bands of distance achieved in set time periods outwards from the origin node. The furthest distance from the node is selected as the first leg in a least-cost route. This process is repeated until the destination has been reached. As such, every leg of a journey is based on traveling in the optimal direction towards a termination point. Wind and current data forms the surface on which the isochrone bands are calculated. Social considerations, represented by the use of known sites, are incorporated as origin and termination points for the canoe pathways.

I worked with Jan Hildenbrand (2015) to develop a tool that could be used to generate optimal canoe routes. Hildenbrand's tool is the result of discussions of the research requirements, including directed point to point routes, reciprocal travel, the need for adaptable cost surfaces, utilization of modern wind and current data to construct past pathways, variation in the time or season in which routes were modeled, control of the sampling of the underlying environmental data, and the inclusion of canoe speed. Hildenbrand's tool creates least-cost routes that can be suggestive of navigation choices made by pre-Columbian Amerindian canoers by recalculating route direction based on changing environmental conditions at each time step, just as a navigator might re-orient his vessel to take advantage of better currents. This method can be modified to consider environmental influence at different weights as well, making it an apt tool to analyze canoe travel that was propelled by wind and current force, alongside a set canoe speed replicating a crew paddling a vessel forwards. After the isochrone tool's development, I evaluated the underlying environmental data, through the use of the current tool developed by Jan Athenstädt in conjunction with this research, and was the beta tester for the user interface and application of the tools to archaeological evidence.

Hildenbrand's tool combines current and wind data at discrete points. Interpolated over the ocean where canoers may have paddled, this can represent the surface of an ever-changing sea. This use of isochrones was also beneficial as it minimized the time it takes to construct routes by focusing on the furthest point of movement in one time period, rather than movement through every pixel between the origin and termination points. Unlike landscape modeling, which often uses one static DEM, modeling sea routes requires the use and production of several cost surfaces. In essence, each route between two points at a specific time represents a unique cost surface. The ability of the Hildenbrand isochrone tool to generate pathways in this manner eased the requirements for computational power that would plague a more traditional least-cost pathways approach to seascape modeling.

The isochrone tool sets itself apart from other implementations of isochrone-like methods used to analyze sea-based movement in the Caribbean (*e.g.*, Cooper 2010) by using accurate wind and current data that can be resampled seasonally. Cooper (2010) uses an isochrone map to determine the difficulty of moving across Cuban seascapes, but there is no explicit discussion of changes over seasonal periods. This is perhaps due to the use of anecdotal data to supply cost information for sea travel in his work (Cooper 2010; see Table 1). Even Leidwanger's (2013, 2014; Table 1) work with isochrones showing the time cost in moving between different ports in the Mediterranean does not deal with seasonality. In both examples, isochrone rings were used to measure the general time cost to movement in all directions without constructing specific least-cost pathways (Cooper 2010; Leidwanger 2013, 2014; see Chapter 3; Table 1). The resulting modeled routes allowed for a comparison between the possible pathways of material or social links between specific islands.

Though modeled routes only represent possible least-cost canoe travel corridors, they can suggest how difficult it would have been to travel between islands even under optimal conditions. This allows for the use of these pathways to analyze the hypothetical structure of inter-island relationships. Some of these connections affirmed pre-existing assumptions of exchange partners (*e.g.*, Hofman *et al.* 2014). Other canoe routes indicated regions worthy of future study to evaluate possible inter-island connections in the archaeological record, such as the routes from Long Island to Saba that pass by St. Kitts (see Chapter 5). Generating least-cost routes using the Hildenbrand isochrone tool allowed me to substantiate hypotheses regarding mechanizations behind ties between different communities. I hope that by demonstrating that this method has been used successfully, other researchers will consider applying isochrone least-cost pathway modeling to their areas of study.

To better evaluate the ability of the model to produce usable canoe routes, I chose to focus on three micro-regional case studies and limited the location and number of origin and termination points. These case studies focused on possible canoe movement within the northern Lesser Antilles in the Archaic Age, between the Greater and the Lesser Antilles in the Late Ceramic Age, and from mainland South America to the Windward Island in the Late Ceramic Age/early colonial period and showcased what inter-island travel would have been like across these various geographic layouts. Navigation preferences, such as route time costs and trajectories, were assessed over the three case studies. I looked at movement within a small cluster of neighboring islands (see Chapter 5), within a prolonged arc between islands spread out over 50 km apart with a break in the middle (see Chapter 6), and across a large expanse of sea from the mainland coast to islands 70 km away with few opportunities to meet in-between islands (see Chapter 7). These three geographic layouts allowed me to evaluate the effectiveness of the Hildenbrand tool in different settings, where the distance between islands may have provided more opportunities for seasonal differences, where there was a high concentration of sites with similar materials, and where there is a gap in the archaeological record. Together these case studies explore the maximum length of voyages across the major channels and passages in this region.

The first case study (see Chapter 5) focused on lithic exchange in the Leeward Islands of the northern Lesser Antilles, specifically mapping routes associated with the distribution of Long Island flint (Davis 2000; Knippenberg 2007) during the Archaic

Age (2000 – 400 BC). It also included sites on other islands, stretching from Antigua to Anguilla (Hofman *et al.* 2014; Knippenberg 2007). Sites known to contain Long Island flint were used to generate pathways with Hildenbrand's isochrone tool. Despite prior assertions that many of these settlements were in contact with one another, routes modeled for Chapter 5 indicate that movement between islands may not have been as direct as researchers may have imagined. Instead of traveling straight to the destination point, least-cost routes often followed indirect paths that passed the coastlines of other islands. In many cases, the layout of these routes coincided with other examined nodes or known archaeological sites that were not included as origin points within this case study. This was the first indication that the layout of modeled routes may be able to indicate indirect connections as well as the location of some sites used in later periods.

The second case study (see Chapter 6) focused on the movement of goods from the Greater Antilles (specifically the eastern end of Hispaniola and Puerto Rico) to the Leeward Islands (movement from or towards Saba and Anguilla) during the Late Ceramic Age (AD 1250 – 1400) (Allaire 1990; Bright 2011; Hofman and Hoogland 2011; Hofman *et al.* 2008b). Sites from this period were chosen based on the presence of specific stylistic elements in assemblages that acted as dispersal or recipient areas. These stylistic elements were reflections of the so-called Taíno material culture from Hispaniola and Puerto Rico. Taíno-inspired or influenced objects included three pointers, ceramic stylistic elements and morphology, drug paraphernalia like speculum, and other objects that were created in response to political and social influences in the Greater Antilles (Hofman and Hoogland 2008a). House trajectories, or the structure of habitation areas, at sites like Kelbey's Ridge reflected those found in the Greater Antilles (Hoogland and Hofman 1993). The movement of these elements across the Anegada Passage suggests that there was likely some level of connectivity between the two island chains. At this moment, there is no definitive archaeological evidence for a reciprocated exchange of materials from the Lesser Antilles back into the Greater Antilles.

The third case study (see Chapter 7) examined travel between the South American mainland, specifically Guyana, and the Windward Islands of the Lesser Antilles during the Late Ceramic Age and the early colonial period (AD 1250 – 1600). Modeled routes tracked the possible dispersal of material and language from South America into Grenada and St. Vincent. I evaluated the corridors through which mainland ceramic stylistic elements were adopted and adapted based on the cost associated with reciprocal connections between nodes off the coast of the Guianas and on the Islands. These pathways proved to be strong indicators of contact points between canoers who may have passed through these travel corridors and in-between islands. Routes that ran past Trinidad and Tobago indicate the locations of possible stopover points used by mainland Kaliña and island Kalinago peoples, which is supported by historic accounts (Boomert 2011; Goodwin 1990; Hofman *et al.* 2009; Hoogland and Hofman 2008).

These case studies demonstrated that modeled routes over varying distances showcased similar trends, either in terms of seasonal differences or annual similarities, and the connection between routes and site locations. The link between hypothetical canoe travel corridors and site locations that pre- and postdate pathways is one of the most valuable findings in this work. By evaluating how possible canoe travel corridors were routed through the pre-Columbian Caribbean and connecting them to known archaeological sites, we can further support the existence of inter-island relationships in the region.

8.2 Observations on Research Questions

This dissertation has answered the primary question posed in the introduction regarding how computer models of cost-based sea travel could enhance our understanding of connectivity amongst pre-Columbian and early colonial Amerindian island communities and has demonstrated that computer-aided optimal path modeling can help archaeologists gain a better perspective on how these communities were tied together by the sea. The case studies present possible answers to the three sub-questions that relate to the broader issue of connectivity. These sub-questions are: 1) What are the possibilities or limitations for traveling between islands and how does this reflect seasonal variation? 2) How did people move between two distant islands? Did canoers follow indirect pathways to stop at intermediate islands, or were people more likely to move between islands without using stopover points? and 3) How did sea pathways influence navigation and can these computer-generated routes reveal portions of ancient navigators' mental maps? The answer to these questions are explored in the three themes. The following sections detail observations on these three research questions and the themes connected with them through the lens of each case study.

8.2.1 Seasonality

The modeling completed in this dissertation demonstrates that examining how seasonal environmental changes affect the path location of modeled routes can augment island mobility studies. Changes in underlying current force and direction shift the outcomes of these least-cost canoeing corridors, influencing when routes head in certain directions. If canoers were using optimal routes similar to those seen here, the change in current flow and the trajectory of travel corridors likely impacted their ability to connect with certain island communities. This may be the first use of a sea-based isochrone method in archaeology that applied to both the creation of set pathway and the seasonal fluctuations of routes.

This analysis uncovers a possible method to assign seasonal rhythms that can be set to specific months or even periods within months. Analysis of the placement and timing of optimal reciprocal routes can build on existing ideas of when lithic material was sourced or ceramic materials were exchanged, and can assign a season to the exchange of specific materials. For example, movement from the Windward Islands towards mainland South America was slightly easier at different times of year and peoples may have preferred to travel south in fall (see Chapter 7). This possible preference for certain seasonal optimal routes could also indicate that return voyages from mainland South America reflected these trends as well, leading to voyages heading north in the winter, when southbound travel was more difficult. Seasonal differences in route cost and trajectory may have dictated rhythms not only of who was moving when but also how long people choose to stay on certain islands, impacting social relationships of canoers traveling between several locations.

Canoers likely chose which route to use based on seasonal and daily changes in current and wind, along with social and economic factors not modeled here. The lack of notable current variation between seasons in the Leeward Islands and the eastern Greater Antilles (see Chapters 5 and 6) suggests that canoers paddling along least-cost corridors in these regions may have had more freedom to move against weaker currents than peoples traveling against currents in the south of the archipelago. Conversely, as mentioned above, crews traveling across the channel between the mainland and the Lesser Antilles faced stronger seasonal currents (see Chapter 7). As a result, real-world canoers following these routes in the northern half of the archipelago would appear to have had more flexibility when choosing launch times and days to visit different islands for social and economic reasons. This may have enabled crews moving between islands in the north to plan seasonal mobility cycles based more on the availability of resources offered on different islands than on the currents that connected them.

The seasonal trend of routes also influenced the position of pathways. Often, changing the launch month affected the time cost and/or the trajectory of the canoe pathways between the same islands, indicating that crews could have exploited different seasonal travel corridors to reach different islands or friendly sites. Hypothetical canoe routes that moved past an in-between island in one season may not connect with the same island later in the year. Communities planning on moving between sites either to take advantage of a seasonal mobility cycle or to connect with known persons on other islands would have had to plan accordingly if they wanted to limit their time on the water. Through the years, knowledge of these seasonal changes to optimal canoe routes would have transferred between individuals and grown into a community mental map of best routes in the region. Thus, while seasonal route layouts may reveal potentially important stopover sites and islands, they do not necessarily reveal which seasons supported inter-island interactions, especially in cases where current differences are negligible.

Trends observed in the underlying cost surface, discussed at the beginning of every case study, show that movement in each cardinal direction is easier at certain times of the year. These insights suggest that if canoers choose to follow optimal paths they would have headed in different directions during different periods. For example, in Chapter 5 underlying current direction and force show movement from Saba towards Long Island was easier in June, while movement from Long Island may have been easier in August. Though these values were largely smoothed over in returns from the route tool, the canoe pathways generated for this work also suggest that real-world canoers may have had an easier time moving from Long Island to Saba than from Saba to Long Island (see Chapter 5), likely because of the current flowing to the west in this region. This could indicate that if real-world crews were following paths similar to the least-cost routes generated here they may have been able to travel west from Long Island with ease while encountering more difficult or longer routes when returning to Saba. These same canoers looking to make the return voyage may have waited on Saba until a more optimal time or path trajectory could be achieved. Due to weather concerns crews could have waited several hours, days, or months before making the second leg of their voyage.

Once I established that routes could be clustered, and thus separated for further evaluation, I wanted to test the possibility of these travel corridors being split on seasonal themes. The seasonal nature of sea-based mobility as apparent in the modeled routes contributes to the discussion of annual rhythms used by Caribbean Amerindian seafarers for the purposes of inter-island interaction. Previous research (Hofman and Hoogland 2003; Hofman *et al.* 2006) has suggested the existence of Caribbean travel periods by analyzing seasonally-available materials in site assemblages. As such, I initially focused on analyzing routes on a seasonal basis to study access to seasonal resources and the possibility of annual mobility trends. I wanted to evaluate whether routes launched in certain time periods could be banded together on the basis of their time cost or trajectory. Routes forming travel corridors at certain times of year may hint at the existence of seasonal mobility periods, which are evaluated in this work. This follows in the theme of previous sea-modeling research, which often mentions the importance of seasonal components (Callaghan 2001; Leidwanger 2013). In comparison to previous research in the Caribbean, which discussed what seasonal periods resulted in the highest rates of success for colonization efforts (Callaghan 2001; Altes 2011), I approached how seasonal ranges affected island-to-island voyaging. It is probable that the same seasons that might result in the highest rates of colonization success may not equate to the best time to carry out reciprocal voyages. This allowed me to discuss the intricacies of inter-island mobility across seasons using directed site-to-site optimal routes rather than exploration corridors.

Looking at movement from Anguilla, modeled pathways passing below the Virgin Islands, above the Virgin Islands, or through the Virgin Islands responded in a small way to shifts in seasonal currents. Again, routes running by different islands may have encouraged crews using pathways similar to the least-cost routes modeled here to set off in different months when travelling towards sites in St. Johns, St. Thomas, or even Isla De Culebra. These trends may have also encouraged seasonal interaction with communities in the Virgin Islands, as it did with St. Croix, and may also have impacted the gateway status of sites in the Virgin Islands exposing communities in the Leeward Islands to Greater Antillean materials (Crock and Petersen 2004; Crock *et al.* 2008). In these cases, the location of sites on stopover islands may indicate places that were used as seasonal habitation or as hubs within a larger network whose interaction with the outside world was dictated by annual mobility rhythms.

Routes passing in between islands can be expanded to apply to routes connecting sites on different islands. Movement between sites on either side of a passage may have taken on a seasonal component that influenced inter-island interaction. Results of the model suggest when people visited certain sites and how long they may have remained on a particular island. Seasonal costs denote what extended routes are most probable during multi-leg journeys, which in turn can suggest practices for indirect mobility. While I observed possible indirect movement in every case study, this type of connection manifested in various ways depending on the region (see section 8.2.2).

On mainland South America and the Windward Islands routes (see Chapter 7) crews may have traveled north or south depending on the season, affecting when people were more likely to be in contact with Trinidad or Tobago for possible prolonged stopovers. Tobago's position between the Guianas and the Lesser Antilles would have made it a prime point of connection in a seasonal mobility cycle through the region (see Chapter 7). Shifts in time cost through various seasons depending on the direction of travel suggest that there was a seasonal component to route planning. For example, movement of modeled routes in autumn was more likely to include Tobago in routes from the Windward Islands to Guyana, indicating that crews adhering to optimal routes might have left at this time of year to stop on the island (see Appendix D). More work needs to be done to evaluate the time cost trends in other regions around the Caribbean to see how fluctuations of seasonal time costs may have affected stopover times.

Seasonal trends also affected a crew's ability to connect with both mainland and island coastlines. In cases where Amerindian peoples wanted to avoid contact, the lack of connection with the coastline when traveling in certain seasons may have been a benefit. For example, the Kalinago peoples who wanted to avoid adversaries on the mainland coast of Venezuela may have chosen to travel during November, when routes were more likely to run away from the mainland coast. Conversely, when crews wanted to make landfall, either to connect with other peoples or rest at in-between sites, they may have chosen to travel during April, when routes passed near mainland coastlines. The scarcity of material on in-between sites may be explained by this seasonal trend of route trajectories pushing further into the Atlantic, making travel to islands or intermediate stops more difficult than moving through the ocean. This trend can be explored further in future research.

Seasonal travel periods could also affect the safety level of voyages. Routes that did not pass by coastlines would have inhibited a crew's ability to take advantage of stopover points. If actual canoers did follow near to the trajectories of these modeled least-cost routes, crews may not have come within close visual range of land for long stretches. For instance, seasonal differences around Puerto Rico moved the optimal sea paths farther away from the coast, which would limit a crew's ability to follow closely along the coastline. A route's propensity to stay in proximity to the island coastlines may have been a boon to crews who followed it, as the pathway would have enabled individuals to rest when required or visit with friendly groups to exchange ideas and materials. The inability to rest or break a voyage, especially on the longer voyages as those from the Guianas to the Windward Islands, would have increased the time-cost of the trip. The ability of crews to follow along coastlines was also dependent on the heading of the route, suggesting that seasonal travel periods also existed in the northern Lesser Antilles (see Chapter 5).

Although these seasonal trends are not always apparent in the context of each case study due to the varying strength in currents, these modeled pathways, alongside archaeological evidence, provide additional ways to evaluate when people moved as well as where. These seasonal trends were likely incorporated into a mental map of Amerindian canoers, increasing the complexity of region's wayfinding traditions. The seasonal trajectory of these routes played a role in determining the connection between seafarers, navigation patterns, and site locations, influencing the areas of interaction within the Lesser Antilles.

8.2.2 Canoe Pathways and Site Placement

It is probable that canoe travel corridors spanned generations and marked long-standing ties between peoples, materials, and places (Hofman *et al.* 2014). These cross-period links suggest that islands in the Caribbean were highly interconnected and that interaction between communities was subject to the location of canoe travel corridors. As potential travel corridors represented by the modeled least-cost canoe routes could have been used by navigators over several generations, they can be used to evaluate sea-based mobility trends through time.

A good indication that Amerindian seafarers used these routes is the link between route trajectories and the location of archaeological sites. The generated routes are of particular interest because they expose a connection between route and site placement in a way not seen in past modeling efforts. For example, research by Callaghan (2001, 2008) focused mainly on undirected colonization voyages through the Caribbean Sea, which prevented a discussion of a relationship between site placement and route trajectory. Similarly, Callaghan and Bray (2007) mentioned possible midway stopover points, but only in the context of an undirected voyage. Other works, which focus on directed voyaging to uncover colonization and population dispersal patterns in the Pacific (*e.g.,* Montenegro *et al.* 2016), do not discuss there-and-back voyages. As this is also the only work that focused on stopover or in-between sites passed by inter-island routes, the analysis of the optimal routes discussed here provides new insight into the connections between site placement in the islands and route trajectory.

In this respect, pathways constructed for this work that focus on direct connections between known archaeological sites may point more specifically to connections between optimal routes and in-between stopover or habitation areas.

Extended route costs and the lack of available rest areas support the use of possible stopover points on routes across the Anegada Passage or from Guyana to Grenada. If indeed real-world crews were paddling near where these modeled optimal routes were generated, they could take shelter behind or navigate around islands. Such patterns indicate that stopover points were an important part of a least-cost voyage. It is no surprise that many routes across these channels seek out the few in-between islands when possible, as coastlines disrupt current flow. Traveling these routes, paddling past or being pushed to move near other islands may have encouraged inter-island connections.

The location of several sites, not included as nodes in this work, near generated least-cost canoe routes suggest that some Amerindian sites were established either to take advantage of passing canoe trade or to influence it. For example, the sites of Sugar Factory Pier on St. Kitts and Hitchman's Shell Heap on Nevis may have been part of a broader inter-island exchange network due to their location along possible routes between Long Island and Saba (see Chapter 5). Canoers following trajectories similar to the modeled routes would have passed near enough to these in-between islands and sites to incorporate them into a canoeing corridor. Any archaeological evidence, or lack thereof, must be considered against social factors of the time, which in this case provide reasons for inter-connection and avoidance (*sensu* McNiven 2008; Munn 1996).

Indirect routes can suggest whether real-world canoers moving along these least-cost routes between two islands were on a true one-to-one reciprocal voyage or if crews were visiting multiple islands as stopover points on a longer journey. For example, the use of sites on St. Croix suggest that connections between Greater Antillean communities ran through intermediary gateway sites rather than making direct contact with the Lesser Antilles (*sensu* Hofman and Hoogland 2004, 2011; see Chapter 6). Movement through this island may have been structured as part of a larger interaction sphere rather than just contacting one island. Similarly, movement of Long Island flint through the northern Lesser Antilles may have been organized so that several islands were visited in the process of exchange (see Chapter 5). One specific example of this phenomenon is the passage of modeled routes from Long Island to Saba by Monserrat or St. Kitts. The indirect movement of routes past these two islands could suggest that the process of resource movement was also not direct. This argument for drawn-out connections has also been suggested for materials moving from Long Island to Saba but passing through Anguilla and St. Martin (Hofman *et al.* forthcoming). The process of movement through Anguilla and St. Martin, while incurring a slightly larger cost, is feasible. Mobility patterns that linked multiple islands or stopover points may have formed a large circle of connected nodes, as is the case for movement between the Kula ring exchange in the Pacific (Leach and Leach 1983; Liep 1991; Munn 1986). If we accept that all routes modeled would have been physically possible, a direct one-to-one or reciprocal relationship is possible based on the returned time costs.

Differences in materials could reflect which direction people moved to or from an island. For example, Saban assemblages with Long Island flint indicate travel to the east (see Knippenberg 2007), while sites on Saba with Taíno-influenced materials suggest movement from the west (see Chapters 5 and 6). In reality, communities from several sites around the region engaged in indirect travel to Saba. Canoers that followed the modeled least-cost paths could have first passed through other islands before arriving to exchange materials on Saba. Furthermore, there is not always evidence of exchange reciprocity in site assemblages. There is possible evidence of reciprocal exchange, in the form of flint exported from Long Island. Additionally, the exportation of St. Martin greenstone, although not addressed in this work, formed another bridge between islands and supported the flint mobility network. St. Martin greenstone was also worked on and exported from Saba (Knippenberg 2007: 246-250; see also Hofman *et al.* 2014), further tying this island into the broader Lesser Antillean lithic network. However, whether greenstone material was ever directly transported from Saba to Long Island is unclear. Due to the position of Long Island as the clear source of flint in the area, it is more apparent that this material was exported directly to Saba.

The number of known sites encountered by these hypothetical pathways support the relationship between route trajectory and inter-island relationships. It is likely that indirect routes can indicate the location of stopover sites if there is a canoe travel corridor that passes close enough to an island's coastline. Opportunities for crews to visit stopover points may suggest a break or pause in a route's time cost to engage in stopover activities. This is especially relevant for crews crossing from Hispaniola to the Lesser Antilles, as the route tool was unable to generate least-cost pathways between these two points. Thus, the model showed direct travel between these two areas was highly unlikely, if not impossible. There were likely many stopover points on the coasts of Puerto Rico as well as the smaller islands between the Greater Antilles and the Leeward Islands. An example of this is in the trajectory of indirect routes across the Anegada Passage, which may have determined who was in contact with the Virgin Islands to the north of the channel or with St. Croix to the south (see Chapter 6). As there are no clear time cost benefits associated with traveling to or from Saba instead of Anguilla, the routes modeled here cannot definitively state which island's sites acted as a gateway for Taíno materials in the northern Lesser Antilles (see Chapter 6). In fact, it is possible that sites on both Anguilla and Saba acted as gateways to different areas within the region. The layout of routes between the Greater Antilles and the Leeward Islands can point to which islands and sites materials likely passed through while in transit. Routes leaving from Anguilla were more likely to come through the Virgin Islands. Routes departing from Saba often traveled past St. Croix. The location of and materials found at sites within the Virgin Islands, like Cinnamon Bay on St. John and Tutu on St. Thomas, and on the north coast of St. Croix, such as the Salt River site, support the movement of Greater Antillean materials through these islands. It is possible these islands acted as the initial points of distribution for Greater Antillean goods and ideas before they were moved into the Leeward Islands (see Chapter 6).

Indirect routes can sometimes be broken into sections. Each portion of the pathway, before and after a route intersected an in-between island, can be considered as a leg of one protracted voyage. For example, as discussed above, modeled routes that ran close to St. Croix suggest that the indirect least-cost pathways may have been broken to take advantage of the convenient stopover location for rest, resupply, or interaction with island inhabitants (see Chapter 6). This may also have applied to routes passing St. Kitts or Montserrat (see Chapter 5). These segments of least-cost routes can inform on where crews might naturally stop over to break a journey or indicate areas that may have been preferred for long term habitation due to their placement along an existing travel corridor.

Opportunities for crews to visit stopover points may suggest an extension in a route's time cost while canoers rested or visited with other communities. Generally, the uninterrupted time costs returned for optimal routes modeled for these case studies represent only the direct travel cost. However, there are some routes that move directly between two nodes that have similar time costs to routes passing through a node on an in-between island. For example, the time cost of a direct voyage between St. Martin and Anguilla to Saba is similar to that of a voyage between St. Martin and Anguilla to Saba that stops at Baie Orientale (see Chapter 5; see Appendix B). These "equal" routes would have been a part of a communal or individual mental map (see section 8.2.3), providing canoers with the option of choosing to stop over rather than travel directly. This may have fostered connections between communities on these three islands. As mentioned above, crews may also have wanted to stop for reasons that had nothing to do with social connections, deciding mid-voyage to break at an island. Stopover potential may impact the time frame for voyages heading directly between two sites passing an island on the way, as is the case with routes through St. Martin (see Chapter 5), or may occur for pathways that are targeted off a direct or typical course, like those through St. Croix (see Chapter 6).

Use of extended stopover areas corresponds to the idea that people not only visited sites to gather resources but also inhabited them for short periods, perhaps seasonally, as well (Hofman and Hoogland 2003; Hofman *et al.* 2006). In some cases, routes banded together to form travel corridors may indicate which season promoted a direction of travel or collection of specific resources. Results in Chapter 5 showed that there was a higher reliability and regularity in route time costs moving east to Long Island from Saba than the reciprocal journey. As a result, it is possible that planning routes towards Saba was more important because there were fewer options for the reciprocal voyage and people may have been more seasonally aware of when to move. These trends demonstrate the possibility of seasonal canoe travel corridors also acting as canoeing direction periods.

Possible travel corridors that emerged through many different modeled routes may also suggest that those seasonally advantageous pathways past specific islands in the Anegada Passage were not used merely as short-term stopover points but as seasonal habitation sites as well (see Chapter 6). The cost to travel across the Anegada Passage, how that cost is minimized by introducing stopover points, and the seasonal response to waiting for better currents on these in-between islands suggest that there may have been annual rhythms to interaction or occupation of islands between Puerto Rico and the Leeward Islands. The possible convergence of seasonal route use and the length of voyages could have encouraged stopovers, indicating that these islands played a role as a gateway site in distributing materials or cultural elements from the Greater Antilles to communities in the Lesser Antilles (Hofman and Hoogland 2011) or that peoples who inhabited these islands were able to exert influence over passing canoes. The evidence of habitation on islands like St. Croix indicate communities on islands visually separated by the sea were active members of regional social networks (see Crock *et al.* 2008; Faber-Morse 2004; see also Chapter 6), would support this argument.

Areas with limited or, as yet, no archaeological evidence make it difficult to prove the existence of stopover points located off modeled routes. In some cases, a true absence of archaeological materials and not just lack of archaeological survey or research on the coastlines of in-between islands may indicate that indirect routes that passed close to these areas were not connected with island occupation or crew rest areas. In other cases, sites used as resupply areas are not found as their presence is recorded only as small areas of ceramic scatter or single use hearths (*sensu* Bintliff 2000). However, it is also important to note that the lack of recovered evidence does not preclude the existence of short-lived stopover sites. For example, there is limited archeological evidence of Cayo ceramic culture on Trinidad, which could indicate that Trinidad was not a stopover site on routes from South America to Grenada and St. Vincent during the end of the Late Ceramic Age/early colonial period (see Chapter 7). It is also possible to explain the absence of Cayo material on Trinidad by canoers choosing routes that actively avoided the island.

Evidence of interaction between peoples on Tobago and Cayo or Koriabo potters (Boomert 2016) suggests there may have been a few sites that acted as long-term connectors between the mainland and the Windward Islands. These possible connections through Tobago are supported by the similarity in pottery styles, such as Suazan Troumassoid rim indentations on ceramics (*e.g.,* Boomert 1995, 2016) that date to the years before the period focused on in Chapter 7. As indicated by the frequency of modeled routes passing the island, it is possible that canoers coming north from South America choose to stop over on Tobago to rest after the long voyage. This has been reported by early accounts of European chroniclers in the area (Boomert 2008). Trends in language adoption and adaption noted in ethnographic work may also point to areas of connection and avoidance among Amerindian communities.

Lack of archaeological evidence could also suggest purposeful avoidance, although this dearth of data needs to be conspicuous to draw inferences from its absence (Fowles 2008). The displacement of Carib peoples from Trinidad and Tobago into islands like St. Vincent (Boomert 2002) could have motivated mainland canoe crews to avoid traveling through the Galleons Passage between Trinidad and Tobago. It is possible that navigators chose routes that would not pass by hostile groups in the Orinoco area and Trinidad. Historic accounts report that there was an antagonistic relationship between the Windward Island Kalinago communities and the Arawak peoples from the mainland. The disruption of routes around the time of Kaliña and Kalinago exchange may be explained by this increased antagonism (Boomert 2008). This trend of avoidance may have forced canoers to choose to launch their vessel at times when routes would head east of Tobago, which fits with Amerindian canoeing practices mentioned in ethnohistoric accounts (Boomert 2008, 2016).

Environmental factors also work against the recovery of materials that would confirm the existence of these stopover points and indirect routes. Apart from the factors discussed in Chapter 3, which refer to the low levels of preservation for materials like canoes and paddles that relate directly to seafaring (Cooper 2004; Ostapkowicz 1998), there are other issues that affect access to intact assemblages or surface finds. Points of connection showing inter-island interaction have been obscured by sea-level rise, erosion, and human interference (Cooper 2010, 2012, 2013; Cooper and Peros 2010; Glassow *et al.* 1988; Hofman and Hoogland 2016). Surveys along Caribbean coastlines have not always captured the full scope of where people may have interacted, either because of lack of survey or survey bias by the archaeologists (de Ruiter forthcoming). Future surveys should focus on the coastlines of in-between islands and researchers should look for evidence of settlements or short use campsites.

The process of material mobility and transport can also be obscured within the archaeological record. Our ability to determine whether materials passed through direct exchange or through stopovers is hampered by the similarity of archaeological material evidence that links sites in the region. Though there has been work done to connect lithic and ceramic sourcing and provenance (*e.g.*, Hofman *et al.* 2008c; Knippenberg 2007), the direct flow of these materials and the trajectory routes that would have moved them are unclear. This was true for all case studies, particularly in terms of the dissemination of lithic materials and ceramic stylistic elements.

Many links between archaeological sites are determined by observing their ceramic or lithic materials, shared stylistic elements, and/or morphology (see Davis 2000; Hofman *et al.* 2006, 2014; Keegan and Hofman 2017; Knippenberg 2007). In many cases, the similarities in these materials are shared between several islands, thus obscuring the exact process of proliferation of stylistic traditions. Because the order in which peoples moved from one landmass to the next is obscure, it is almost impossible to determine whether these materials were moved directly between two islands or if their presence in an assemblage is the result of indirect exchange. Indirect exchange can refer to the movement of materials through more than one site before the materials were deposited into the archaeological record. However, the travel corridors identified here are an important new source of evidence for future analysis of material mobility in the Lesser Antilles.

For example, it is impossible to determine if Long Island flint was exchanged between communities on more than one island before being deposited into an assemblage (Davis 2000; Hofman *et al.* 2006, 2014; Knippenberg 1999, 2001, 2006; see Chapter 5). Similarly, as there are no clear one-to-one relationships between ceramic materials or Taíno objects in site assemblages across the Anegada Passage, there are also numerous possible connection points canoers could have used to move these materials. As such, reciprocal connections between the Greater and the Lesser Antilles are difficult to model (see Chapter 6). Finally, reciprocal connections between South America and the Lesser Antilles are also problematic, as the mainland stylistic elements that link Koriabo and Cayo pottery are difficult to trace (see Chapter 7). Ethnographic accounts (Petersen *et al.* 2004; Whitehead 1995) and linguistic connections (Boomert 2008; Hoff 1994; Hofman 1993) point towards a sustained multi-directional relationship between the Kalinago and Kaliña peoples, but based on the archaeological evidence alone the extent of these interactions is unclear. Modeling optimal routes based on materials that can be connected to several sites may suggest where communities were likely to canoe and where these avenues of mobility were reciprocal, sketching out a directed inter-island mobility network.

These networks can extend beyond the time period of the case study in question, linking pathways to sites dating to different periods. In all case studies, the trajectories of routes indicate where these stopover points could be located both before, during, and after the period modeled. In the case for routes in the Greater Antilles and the Lesser Antilles, many of the indirect routes returned by the model passed by sites that we know were used in later periods (see Chapters 5 and 6). For example, some routes from Long Island's Flinty Bay to Antigua's Jolly Beach pass by the Ceramic Age site of Anse á Le Gourde on Guadeloupe that postdates exchange modeled in this work. In a few cases, pathways even meet Guadeloupe's coastline near the site before turning back to reach the termination point at Jolly Beach. Similarly, many modeled routes between mainland South America and the Windward Islands pass by sites that were in use during earlier periods. This includes movement past the Saladoid site of Blanchisseuse on Trinidad. The placement of these sites along routes from other periods suggests two things: first, the location of routes is tied to site placement, and second, sites may have formed because they were along routes present in Amerindian mental maps of the region. Because canoe crews may have had reasons to pass by known sites, the links between route trajectory and site placement across time periods should be further explored.

8.2.3 Modeled Seafaring Practices, Navigation, and Mental Maps

The possible existence of travel corridors, the use of seasonal periods, and the connection between settlements and canoe routes indicate that there may have been a deeper connection between seafarers and the seascape they traveled upon. Those looking to paddle between islands likely could not rely on random choices on where to move. These seafarers had to have a deeper and sustainable knowledge of current trends and settlement or resource locations on different islands. The final set of questions asked in this work dealt with the relationship between modeled sea-based least-cost pathways and navigation techniques. Particularly, my interest was on exploring the role mental navigation maps may have played for canoers traveling routes similar to the ones generated for each case study. Did sea pathways influence navigation? If so, is there a link between the generated routes and the construction of possible mental maps? Though difficult to approach through routes alone, this work provides a preliminary assessment of how computer-generated routes might suggest past navigation techniques.

Routes that were repeated through several runs of the model suggest that pathways can be banded together to form a likely corridor of movement that could be followed by Amerindian canoers. Canoers would have made progress towards their destination by working within the geographic range of the corridor, shifting the canoe's heading in response to wind, current, wave direction, or wave height. Navigators could use these corridors to travel directly or indirectly towards their destination and use them to return when their business on the other island was concluded.

These possible navigation corridors differ from region to region. Archaic Age movement was measured through the clustered layout of the Leeward Islands (see Chapter 5). This placement allowed for a high level of inter-visibility between islands and canoers passing islands and/or Archaic Age sites. Canoes moving through areas with this concentration of visible landmarks had a safety net for their voyages and ready connections on which to affix their mental maps. The layout of the islands prevented most routes from moving too far off course. Many routes modeled for this case study followed currents along outer edges of the island cluster instead of out to sea. In contrast, the Greater and the Lesser Antilles Island sites (see Chapter 6) are in an extended arc. In many cases pathways across the large divide of the Anegada Passage did not intersect with an island that could provide a break between the current's push and the open sea. Other pathways came close to islands like St. Croix and the Virgin Islands that could be used as possible stopover points. Navigation may have been more difficult because of a lack of landmarks over the greater distances. Challenges posed to crews by lack of visible landscapes may have been removed by relying on celestial navigation.

Similarly, modeled routes from Guyana to the Windward Islands (see Chapter 7) show that real-world canoers may have faced long stretches of open sea without the option to stop or navigate using landmarks. As there may have been a preference to avoid Trinidad and Tobago for reasons discussed above, navigation over these broader was perhaps problematic. These increased distances likely resulted in the use of different navigation techniques, such as celestial navigation (Agouridis 1997; Bilić 2009; Lamarche 1993) or wave reading (Lewis 1994; Tingley 2016). Celestial skill sets, like those observed among Pacific seafaring communities (*e.g.*, Gladwin 2009; Lewis 1994; Oatley 1977), probably existed among Amerindian navigators as well (*e.g.*, Lamarche 1993). Celestial navigation may have extended the range of voyages by allowing crews to rely on the position of the sun, moon, or stars to guide their way when land was out of view and to identify their situation within the seascape and relation to landing points or areas of cultural importance (*e.g.*, Lamarche 1993; Lewis 1994). The location of islands at night underneath certain stars also enabled crews to identify the position of "their" island in the dark. These techniques made knowledge of the location and progression of celestial bodies as important as information on currents and the geographic relationship between islands.

This approach to navigation also made it possible for crews to extend voyages beyond a single day, allowing for canoes to launch before sunrise and after sunset. Night voyaging has been tested in a recent experimental voyage conducted by the Karisko project (Bérard personal communication 2014). The results of this experiment proved that crews in vessels like those used by pre-Columbian navigators could safely canoe by night, though modern atmospheric conditions and light sources from buildings on nearby Martinique may have affected this visibility. As there was no noticeable difference in time costs between day and night travel, it is possible that optimal routes could have been launched at any point within a 24-hour period. Much like seasonal similarities in time costs, this may have freed voyagers to pick routes that responded to safety concerns, such as leaving in the night using celestial navigation and landing in the day when harbors became more visible.

There are several things to learn from the layouts of these pathways. Modeled routes occurring in the same area during certain periods demonstrate that corridors of movement likely existed on the sea, mirroring those theorized by least-cost pathway modeling on landscapes (*e.g.,* Anderson 2012; Rademaker *et al.* 2012; Surface-Evans 2012; Whitley and Hicks 2003). Determining the possible location of these corridors is a step towards reconstructing Amerindian mental navigation maps. Comparing several routes trajectories and co-occurrence with intermediate sites can indicate a canoe corridor's existence within a mental navigation map (see Appendices B, C, and D). Frequency of sites along these routes may point to the likelihood of Amerindian canoers developing mental navigation maps.

It is possible that these shared information systems helped to guide seafarers through the Lesser Antilles. Certainly, these studies demonstrate that such knowledge was required to aid navigation, as mental maps probably included the use and maintenance of optimal routes. Without knowledge of currents and wind patterns that would impact these optimal routes (*sensu* Lewis 1994; Tingley 2016), peoples may have suffered from prolonged voyages that went off course or into danger. More work could be done to connect hypothetical routes to possible land or sea markers to test the theory of how wayfinding maps may have been used in this region from the Archaic Age to the early colonial period.

The consistency of later period sites along the pathways returned by the model present an argument for the existence of a wayfinding tradition in this region. It is probable that navigators benefitted from generations of seafarers sharing knowledge of the location of travel corridors, resources, or sites (*sensu* Agouridis 1997; Ingold 1993, 2011; Terrell and Welsch 1998: 59; Terrell *et al.* 1997), which were then incorporated into other mental maps. Just as Pacific seafarers needed to remember the location of far-flung islands to increase the success of colonization efforts (Irwin *et al.* 1990; Montenegro *et al.* 2016), Archaic Age and Ceramic Age voyagers also had to note which islands crews canoed by in various seasons. Over time, these mental maps enabled crews to pinpoint areas of high-probability landfall and safe harbor (*sensu* Ingold 2000, 2011; Terrell and Welsch 1998; Tilley 1994). Shared navigation points enabled canoers to build camps and settlements in areas where they could take shelter from environmental pressures.

The link between route layout and maintenance of the travel corridor was made clear in each case study, where the position of stopover points along several modeled travel corridors indicates the pathways were used over several generations. For example, although there is little evidence of Archaic Age sites on the northeast coast of St. Kitts (de Ruiter forthcoming), routes like those generated with the isochrone tool may have been pushed west by the current into St. Kitts when traveling westward from Flinty Bay, Long Island (see Chapter 5). The link between routes from Long Island to Saba and the in-between island of St. Kitts, if followed by real-world canoers, provided a tangible opportunity for crews to affix meaning to a landmark. The position of Sugar Factory Pier on St. Kitts would have taken advantage of the trajectory of many optimal routes, suggesting a possible tie to the larger networked mental map. This is some support for the notion that St. Kitts was possibly included in the mental wayfinding map of regional navigators who would come to use the island more heavily in the Ceramic Age.

Comparisons with sites present on modeled routes from later periods in the Lesser Antilles could help to determine if canoe corridor locations were used over decades or centuries. In some ways, the travel corridors may be connected with the longstanding cultural associations of monuments (sensu Schlanger 1992). For example, Schlanger (1992) suggests that persistent places can be established through corridors of movement or once occupied areas that support later visitation, thus setting up re-use that informs subsequent activity and re-visitation.

Modeled routes allow us to understand how a seafaring mental map could have stretched over several generations (*sensu* Samson and Cooper 2015; Terrell and Welsch 1997; Tilley 1994). Thus, for example, the Ceramic Age site of Anse á La Gourde (ca. AD 450 – 1350), on the coast of Guadeloupe is also located off Archaic Age modeled canoe pathways that run south from Flinty Bay, indicating that canoers developed an association with the area, and eventually chose to establish a permanent site there. The position of the site near the turning point for indirect routes from the north hints that Anse á La Gourde would have played a key role in the lithic network connecting Long Island to the west coast of Antigua (see Chapter 5).

Another example of a site that may have been connected to the trajectory of optimal least-cost routes is Blanchisseuse on Trinidad. Modeled routes from Guyana Point B to Grenada pass close to this site. In fact, routes often pivot north towards the Windward Islands directly off the coast of Blanchisseuse. Though this site predates the period of focus for canoers carrying Koriabo ware from the mainland (Late Ceramic Age/early colonial period), these modeled routes indicate that Saladoid canoers from the Guianas could have used this site as a rest area before crossing the channel to Grenada. The knowledge of how to cross from this area into the islands may have existed in the mental map of regional navigators into the Late Ceramic Age/early colonial period.

These hypothetical travel patterns may have been recorded as part of larger or macro-regional mental navigation maps. Knowledge of the location of canoe travel corridors would have been invaluable to seafarers in the region to sustain links between different communities or seasonal outposts. This process is seen in other regions around the globe, from the training of medieval navigators to use currents to their advantage year after year (sensu Frake 1985) to voyagers in the Pacific using their skills to maintain links with friendly sites (Terrell and Welsch 1998). The process of educating new navigators about these links likely happened during the process of voyaging, relaying both technical skills and cultural associations (*sensu* Crouch 2008; Ingold 2011; Lewis 1994). Experiencing the movement through seascapes for themselves would have encouraged individual navigators to add their own associations to a broader communal map, as was done by individuals moving through landscapes (*sensu* Tilley 1994). The repetitive use of these pathways probably cemented the knowledge of their position and purpose in the minds of navigators, though the exact position and feelings associated with routes may have shifted from year to year (*sensu* Ingold 2011).

Differences in travel direction also affected how crews used mental navigation maps to plan seasonal routes and when to collect materials from different islands. Canoers looking to make a specific connection in non-optimal travel periods could have used their knowledge of the environment to push against currents. Crews applying skill and technique at the right moment may have been able to overcome adverse seasonal conditions to arrive at their target. Alternatively, Amerindian canoers could have made selective choices regarding when to travel. Navigators who planned reciprocal voyages must have paid close attention to current flow and seasonal shifts as they may have affected when crews could leave on a particular trip (*sensu* Lewis 1994; Tingley 2016). It is likely that real-world crews waited out poor travel seasons on an island when heading in a certain direction. Least-cost pathways crossing the opposite way could show routes accrued lower time costs during the same period. The archaeological materials from sites used as origin and termination points suggest navigators must have known how to sail there-and-back when canoeing in this region. This would require experienced navigators to possess highly developed mental maps including knowledge of the seasonal variations of routes (*sensu* Agouridis 1997). Relying on this knowledge would have increased the likelihood of vessels successfully reaching their destination.

Stylistic elements from traditions in the Greater Antilles, the Lesser Antilles, and the South American mainland (see Allaire 1990; Bright 2011; Hofman *et al.* 2008b; Righter *et al.* 2004) suggest a common reliance on canoe technology and navigation practices. Communities from these regions would have had the opportunity to pass on knowledge of navigation markers for the surrounding islands (*sensu* Cooney 2003; Ingold 1993; McNiven 2008; Terrell *et al.* 1997). Seafarers from the Guianas likely shared navigational markers with the Windward Islands canoers (*e.g.*, Callaghan 1993, 1995, 2003, 2011). Communities in the Leeward Islands could have traded information on how to move about the region to new arrivals from the Greater Antilles. Sharing information likely made voyages a success for crews entering new areas and allowed for communities from different regions to engage in return or reciprocal voyages (*sensu* Ingold 2000; Tilley 1994). The translatable knowledge of canoe toolkits between seafaring communities on different islands and in different regions allowed canoers to make reciprocal connections.

The creation of mental wayfinding maps would have been essential to the maintenance of these connections. In turn, the maintenance of these connections would have been necessary to support the extended exchange of materials, stylistic elements, and peoples that moved through the region. In the future, it may be possible to further link the existence of a communal mental map to the location of these routes. Though these maps likely held different meanings to the individuals who used them, the shared cultural tradition of navigation corridors bonded seafaring peoples to one another. Currently, the location of travel corridors demonstrated by these hypothetical canoe routes can point to a systematic approach to seafaring that could have been observed by Amerindian canoers.

8.3 Limitations

The primary limitation of the model was the impossibility of examining corridors of movement over multiple generated routes and comparing all route connections between every node within the case studies. Modeling between origin and termination points produced hundreds of routes that moved in the same direction within a single area, creating a travel corridor. Pathways were generated for roughly 240 different seascapes per unidirectional route for one month, with each modeled seascape corresponding to a three-hour period within that time frame. For example, the first case study, which has a total of 10 sites, resulted in a possible total route return of 28,800 for just the outward connections from one site over all possible years and months to model. This is substantially different from traditional least-cost pathway studies, where routes are judged by their placement over a static landscape and one route, or sometimes even tens of routes, are produced for unidirectional least-cost paths. Though this work was able to analyze routes based on changing sea surfaces from the interpolation of wind and current data and high-resolution datasets, the computer costs required to model all possible routes across all possible cost surfaces was too great to be completed.

The canoe pathways modeled here stand as a starting point for the exploration of reciprocal voyaging in the Caribbean. Through a comparison of route trajectory and the location of known sites, the modeled pathways allow for the reinterpretation of inter-island connections. During my analysis of the modeled canoe pathways, it became apparent that indirect routes, or pathways not closely conforming to the Euclidean distance, were a vital aspect of this study. As such, this study is only the first step toward modeling routes between islands in the region. The resulting direct and indirect routes provided new insights into inter-island connections in these regions.

Connections between modeled pathways and the coastlines they pass can propose new areas for survey or indicate possible areas of past interaction. There are limiting factors, however. It is possible that real-world canoers moving between areas close to the origin and termination points used in the case studies would have stopped only for as long as it would have taken to replenish their supplies or rest. This has been reported by some ethnohistoric accounts (see Boomert 2002, 2016; Menkman 1939). Finding evidence of brief stopovers in the archaeological record would be difficult for many reasons. First, the site could be easily missed or misrepresented by surveys (de Ruiter forthcoming), as it is possible that though people returned to the same beaches they may not have camped in the same locations. Second, as mentioned previously, sites in the region may have been obscured by environmental changes, such as sea level rise, and manmade alterations, such as coastal development (Cooper 2010, 2012, 2013; Cooper and Peros 2010; Glassow *et al.* 1988; Hofman and Hoogland 2015).

The routes modeled for this study are based on modern current data and may not truly reflect the surface of the sea that existed during the periods evaluated. However, the relative stability of bathymetry from the late Archaic Age onwards in the Caribbean ensures that routes modeled between the archaeological sites used here represent plausible canoe routes for Archaic and Ceramic Age communities (Callaghan 2001). Other researchers who have modeled this region have also used modern data to reflect past currents (*e.g.,* Altes 2011; Callaghan 2001, 2003; Cooper 2010). Early attempts at modeling canoe routes in the Caribbean region represented colonization efforts that would have been in use much earlier than the pathways represented here. The canoe pathways created here stand as a first step towards understanding movement between islands for a wide range of other purposes.

Greater access to current information for areas further south than that provided by the AmSeas3D data set would have been beneficial (see Chapter 7). More work will need to be done to determine what data sets can best showcase currents of the coast of South America for use by the Hildenbrand (2015) isochrone tool. This includes a more in-depth analysis of how current is affected by tidal force closer to a larger landmass. Current data collected off the coast of South America will also need to be compatible with the AmSeas3D data set to ensure that these two sources of information can be used in tandem. An analysis on how the change in a possible additional dataset's resolution affect routes modeled here should also be considered so as to ensure the use of proper sampling rates by the model.

Moving forward, it will be important to run routes for more than six years of current data (2010 to 2015), used here to show the difference between route time costs and layouts generated. Tests on whether there are differences outside of 2010 to 2015 should be conducted to see if these years are representative of a longer time span. Climate change and sea level rise may impact underlying current data, which in turn can influence the cost surfaces on which modeled routes are based. In this sense, it may also be worthwhile to test modern current information from further in the past as Callaghan did with the United States Navy's Marine Climatic Atlas of the World (Callaghan 2001). In the coming years, researchers have the potential to recreate past current patterns that may allow for resampling of the environmental data. Incorporating new methods to calculate past currents could influence the trajectories generated by this model. The routes modeled here may need to be updated once past currents for these periods can be accurately generated at the time resolution equal to the AmSeas3D dataset (see Chapter 4).

8.4 Future Work

Predicting the location of sites is not a goal of this research. However, there seems to be a link between least-cost routes and site location. Consistent with land-based least-cost pathway analysis (*e.g.*, White and Surface-Evans 2012), these efforts can be used as a platform to judge the strength of connection between site nodes and passed sites (*e.g.*, see Borck 2012 for an example of statistically correlating en route site location with route placement to test whether the modeled route was actually an historic travel corridor). In the future, more modeling should be done to identify possible connections between modeled route trajectories and site location. This hypothesis could be tested by running the model to connect several nodes on large sections of island coastlines. If a pattern emerged between ease of movement or low time costs and site placement it could support this hypothesis. If known sites are not at the end of the optimal routes demonstrating the lowest costs, it could indicate that my assumption of ties between route layout and site location should be reevaluated. If sites are tied to lower cost routes, it could bolster the analysis provided here. Looking at coastlines passed by modeled routes can also provide options for new areas to survey for archaeological evidence of stopover points or missed sites. Another function of this work is to suggest the possible transfer of materials along direct connections. Modeling least-cost pathways across the Anegada Passage is one way to identify or hypothesize the point from which materials and ideas were exported. Research into the exchange of artifacts or stylistic traditions across the Anegada Passage is limited by the fact that there are no known production centers, origin points, or dissemination areas that can be explicitly tied to the export of materials and stylistic traditions. Though much of these materials was produced locally (Hofman and Hoogland 2008), Taíno stylistic elements are so ubiquitous throughout the Greater Antilles that the origins of objects cannot be identified from stylistic evidence alone. Modeling routes between areas known to contain these materials can help to suggest possible corridors through which Taíno cultural elements were disseminated. These routes can augment research on connections between the Lesser and Greater Antilles.

In the case of movement from Saba to St. Croix discussed in Chapter 6, researchers could continue to look at these avenues of mobility. The Taíno materials that identify connections across the Anegada Passage are often stylistically similar and made from local materials that may not reflect exportation from the Lesser Antilles, making one-to-one relationships between islands difficult to discern based on stylistic elements.

At present, it is difficult for researchers to determine if material connections passing through St. Croix originated in Saba or Anguilla (Hofman personal communication 2017). Routes modeled from these two islands can perhaps suggest that one of the islands had a closer relationship with St. Croix. Furthermore, further application of the route tool to pathways through the Anegada Passage may confirm whether certain sites within the Leeward Islands were better connected to islands in the west or if connections into the Lesser Antilles were alike in cost or social preference. These examples show that more work should be done to determine whether there is a true absence of archaeology supporting these connections or if materials that underpin or confirm the existence of these routes can be found. This could include combining route modeling with lithic analysis or network studies.

Furthermore, broadening the scope of this research to include the connections between the Leeward and Windward Islands could lead to a better understanding of macro-regional interconnections. These pathways could be used to explore links between the Greater Antilles and the Windward Islands, as indicated by the Cayo complex that shows similarities to both Koriabo and Greater Antillean stylistic elements (Bright 2011; Hofman and Hoogland 2012). Routes modeled between the Greater Antilles, the Leeward Islands, and the Windward Islands may provide some answers to the movement of Amerindian potters, who were in many ways responsible for the spread of ceramic styles. It is probable that routes already modelled across the Anegada Passage are a strong representation of canoe routes between these two island groups, as people were unlikely to travel directly from the southern Lesser Antilles to the Greater Antilles without seeking port to replenish supplies or rest.

Future work on reciprocal voyaging in this area should include an analysis of sites off the coast of Puerto Rico to expand our knowledge of how people moved across the Anegada Passage. This analysis could be tied to the hypothesized political domains of caciques across the island (*sensu* Curet and Stringer 2010; Siegel 2011; Torres 2010). Examples from Chapter 6 showed that routes modelled between the northern Lesser Antilles and a southeast point on Puerto Rico have lower cost in comparison with routes ending at other nodes on the island. This could indicate that caciques in the southwest of the island had a greater influence over goods coming in from the Lesser Antilles. Comparing these routes with pathways to the south of Puerto Rico that move through the Virgin Islands shows that there is not a clear indication that one travel corridor was favored over another. In this case, there may not have been a clear-cut distribution center on the eastern half of Puerto Rico.

An additional line of research would be to analyze potential departure points from the Greater Antilles. Calculating routes between Puerto Rico and the coast at several points over multiple seasons would reveal potential minimal time cost travel corridors that could uncover potential distribution centers for the Dominican Republic Taíno materials whose style and manufacture influenced potters, lithic producers, and objects at other sites. Additionally, adding more origin and termination points to Hispaniola's and Puerto Rico's coastline could identify stopover points in addition to the routes suggested here. For example, the points added to the Playa Grande site in the Rio San Juan region of Hispaniola are connected with the production and exportation of jadeite material to the Lesser Antilles (Knippenberg 2007; Knippenberg *et al.* 2012). New points could then be used to evaluate the locations of Taíno distribution centers. These points may also stand as areas that received materials from the Lesser Antillean reciprocal exchange, if such a link existed. Routes run from these locations could suggest areas for future archaeological survey. Though there has been no systematic approach to proposing site prediction, the trajectory of modeled routes with support from ground trothing may uncover as yet unknown sites. The nature of prominent sites or points of micro-regional material import and export can influence our understanding of how peoples moved through the larger area. It could also indicate whether site location and canoe routes were tied to the function of communities within the broader mobility and exchange network.

Adding additional sites to conduct an everywhere-to-everywhere least-cost path analysis may provide insight into the connection of site placement and routes. The presence of sites near beaches that show high concentrations of the termination of least-cost or optimal routes may indicate a tie between environment-based routes and community-based sites. Before taking this approach, more work on the viability of this kind of modeling, including the extensive computation requirements, should be conducted.

In addition to adding sites, it may also be worthwhile to broaden the scope of inquiry to include not only how pathways manifest themselves over seasons but also the result when launching at different times of day. In analyzing the three case studies I did not observe a clear indication of possible launch time preferences amongst the optimal routes. This may be because most voyages exceed 24 hours, and thus take place over the entire daily tidal range affecting canoes. As indicated by the tables showing route variance in Chapter 5, it is unlikely that leaving at different times of day precluded voyaging between certain points as many examples show a difference in travel time from less than one hour to less than six hours (see Appendix B: Tables 1 to 20). Again, this suggests that like seasonal preferences, it may be that individual canoers were less bound by the time costs of routes than by their destinations and the social conventions of voyaging. However, it may be that further analysis of route launch times reveals a preference for leaving under certain tidal influences. These tidal influences may also link back to seasonality, highlighting the importance of comparing generated optimal routes against environmental data.

In order to better understand past navigation practices and the existence of mental maps, evaluating visibility from the canoe is key. Visibility research done in the area (see Brughmans *et al.* 2017; Callaghan 2008; Friedman *et al.* 2009; Smith 2016; Torres and Rodríguez Ramos 2008), as well as ethnographic or historic accounts of how visibility can impact island sightings in the Caribbean (see Boomert 2011; Curet 2005; Torres and Rodríguez Ramos 2008), clearly suggest that more research needs to be done to consider sighting landmarks from vessels on the sea (see Appendix D). Taking an emic approach may prove beneficial for understanding the meaning or function of specific land- or seamarks. Interviewing mariners from around the Caribbean may provide key insights into traditional navigation techniques that are, or have been, used along the coastlines referred to in this work. Furthermore, contacting individuals from the Kalinago Territory in Dominica could help to place canoeing in context with traditional canoe building and seafaring practices.

Working with modern experimental voyages, such as those conducted by the Karisko project, could provide insight into the methods of wayfinding or visual relationships used by pre-contact and early colonial Amerindian navigators (see Bérard *et al.* 2016). References to drawn or mental navigation maps used by Pacific Islanders (Gladwin 2009; Lewis 1994; Tingley 2016) or known land- or seamarks used by Mediterranean seafarers (Agouridis 1997; Broodbank 2000, 2013) may prove useful in understanding how Amerindian canoers worked with environmental cues to safely travel between islands. It is probable that seafarers in the Caribbean were using similar techniques to mark out, remember, and maintain travel corridors. Researchers should also consider how to properly incorporate and analyze views from the sea, where the height of the observer restricts the possible visibility from canoes. This analysis may be connected with works evaluating navigation, including celestial navigation and wayfinding (*e.g.*, for navigation, see Agouridis 1997; Bérard *et al.* 2011; Fitzpatrick 2004, 2013; Lewis 1994; for celestial navigation, see Agouridis 1997; Bilić 2009; Lamarche 1993; Oatley 1977; for wayfinding, see Ingold 2000; see Appendices B, C, D). What is visible from vessels likely affected how canoers planned voyages and will be an important consideration when reconstructing the details of pre-Columbian navigation practices in the future.

Focusing specifically on celestial navigation, it may be possible to model what skyscapes were visible above the canoe. These connections between route trajectory and the position of celestial bodies was likely used by Amerindian navigators, and can be a way to further enhance our understanding of communal mental maps that centered around the continual use of optimal routes. Configuring these skyscapes may involve the use of computer programs such as Stellarium (*e.g.*, Brown 2015), which can project the position of stars, moon, and sun into the past, or the inclusion of ethnographic research into the identification of stars as navigation points. Stellarium in the past has been used to explore the relationship between peoples and the stars in archaeological contexts, pre-historic pyramids in Nepeña Valley, Peru (Benfer and Ocás 2017). Though these efforts have primarily focused on land-based views, there is no reason this technique could not be applied to evaluating the relationship between canoers and stars at several points along a path.

Evaluations of skyscapes could benefit the analysis of the current work, which touches on what relationships might exist between sea pathways and the islands that they pass. Celestial navigation can also be incorporated into viewsheds that include both the skyscape and landscape that are visible from the canoe, as often the position of the stars in relationship to islands is an important factor in navigation for seafarers (*e.g.*, Lewis 1994; Oatley 1977). In fact, as many voyages modeled for this work last over 24 hours, it is probable that canoers had to remember the position of islands, currents, and celestial bodies to safely follow set travel corridors between islands.

Furthermore, the Hildenbrand (2015) isochrone tool may be used in conjunction with traditional network analysis techniques to provide additional information about the inter-island ties connecting nodes when studying regional exchange. For example, the work of Broodbank (2000) and Rivers *et al.* (2011) on proximal point analysis, fixed radius network analysis, maximum entropy model, and other network models show the values of evaluation based on social factors and Euclidean distance measures. Adding the cost to movement revealed by least-cost routes can provide another layer to this approach, allowing for the consideration of the difficulty of travel often obscured when basing pathways on social relationships or Euclidian distance measures alone.

It is important to continue applying the Hildenbrand tool in other contexts to see if it is effective elsewhere. In future, this method can be applied to regions around the globe to determine the viability of this model in different water environments. This method may be of particular interest to those researching inter-island connections between communities in the Pacific. For example, reciprocal least-cost pathways may be useful in analyzing the Kula exchange ring (Leach and Leach 1983) or the practice of maintaining long distance exchange networks that has yet to be discussed by sea-based models from that region. This method could also be compared to sea-based routes generated for Roman travel in the Mediterranean, as was done for the ORBIS project (Arcenas 2015). As the resolution used in this analysis is finer-grained than other approaches to interpolating cost surfaces and the Hildenbrand (2015) tool can easily change time depth or iteration levels, this approach may provide a better understanding of route trajectory and cost than is offered by the gridded output of the ORBIS model. Use of this tool to the same resolution depends on the availably and quality of wind and current data sets from these regions.

As the Hildenbrand tool has been adapted to incorporate wind influence, it might be used to test movement of vessels using sails as well. Research evaluating the interaction between European sailing vessels and canoes from the Caribbean region could also use this method to test how technology affected route placement. This may offer opportunities to evaluate the possible divide between pre-Colombian and post-colonial seafaring practices in the Caribbean. Global case studies on smaller sail-powered vessels could also be analyzed using the Hildenbrand (2015) tool. This includes modeling vessels in the Mediterranean (*sensu* Arcenas 2015; Liedwanger 2013) or the Pacific (*sensu* Davies and Bickler 2015; Montenegro *et al.* 2016), where the research has focused on colonization efforts more than reciprocal voyages. This application may be able to provide insight into the connection between route placement and site layout in these regions as well.

Over the course of this work, I have demonstrated that modeling sea-based pathways is an advantageous additional step to other forms of traditional archaeological analysis when evaluating inter-island or island-to-mainland movement in the pre-Columbian Caribbean. The three regional examples, in which settlements and resource bases were selected to act as nodes, represent three distinct layouts and backdrops of interaction. Reflecting small centralized seasonality networks, broader regional connections across large passages, and even mainland-to-island links that would have taken several days, these geographic foci allowed me to evaluate how baseline mobility costs might have affected movement and the maintenance of social networks. Determining the cost and trajectory of routes similar to those that may have been used by past Amerindian navigators helped to determine what mechanizations of travel could have influenced interaction.

To further evaluate these mechanizations, I posed a series of questions targeted at assessing patterns apparent in routes generated for each case study. These questions, further explored in this chapter, showcase the many ways in which modeling routes do form a base for judging possible inter-island connections. In fact, many of the travel corridors modeled here suggest the location of possible interactions as well as seasons that may have been preferred, even if only minimally, by past Amerindian mariners. Modeled routes following similar corridors also showcase how canoers may have been able to rely on the consistency of wave patterns to form a mental navigation map to help them traverse the sea. Specific details of possible connections uncovered in this work, such as those between Long Island and La Désirade, can point to instances where further comparison between routes and materials may be useful. The evaluation of routes within the context of these overarching themes allowed for the questions posed at the start of this work to be answered.

Modeling sea-based interaction in the Caribbean furthers our awareness of the costs associated with maintaining social relationships across island channels. This type of modeling allows for a discussion of the movement of peoples, materials, and ideas between islands with ample opportunities to analyze possible travel corridors. The archaeological evidence that supports inter-island interaction between Amerindian communities throughout the Lesser Antilles is tied to human and material mobility as well as resource procurement of lithic, bone, shell, or ceramic resources originating in specific islands or regions. On their own, the presence of these materials cannot tell us the trajectory of the routes objects passed through before being deposited in assemblages. Stylistic elements that evolved out of inter-island links can indicate which communities were in contact but cannot define who was in contact directly or trace how the characteristics developed. The origins of some materials are better known than others, but the presence of similar materials throughout the Caribbean indicates how important canoe movement would have been to Amerindian peoples.

Though not expected, the seasonality of route trajectory was a stronger indicator of travel than mere least-cost alone. The existence of indirect routes also pointed to islands that possibly played a prominent role in inter-island travel and sites that could have been stopover points for canoe crews. For future applications of this model, route placement should be evaluated for its ability to distinguish links between canoers and coastal communities. Archaeologists can also use the canoe corridors modeled here as a suggestion of where to conduct future archaeological research. Canoe pathways created for this work contribute an additional layer to the analysis of navigation between the Caribbean islands from the Archaic Age to the Late Ceramic Age. Modeling least-cost pathways through the sea helps us to understand the possibilities of canoe travel, indicating where as well as how often optimal routes occurred. In turn, these optimal routes can expose connections between travel corridors and site locations and propose the existence of a mental framework for voyaging that helped maintain these pathways and habitation areas over generations.

Without the use of least-cost pathway modeling, these facets of Amerindian voyaging would be obscured by the surface of the sea and by archaeological evidence that points to exchange without being able to identify specifically how materials were used or moved from one island to another. The findings of this work demonstrate that least-cost pathways analysis is an appropriate method to test the fluctuating mobility corridors that supported inter-island interaction and exchange in the pre-Columbian and early colonial Caribbean. The generated pathways can suggest the who, why, and how of the physical relationships between inter-island communities and enhance our understanding of past social connectivity between the peoples of the Lesser Antilles.

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Summary

The goal of this study was to determine the feasibility of modeling past maritime connections between indigenous island communities in the Caribbean and to evaluate how computer generated routes connecting islands in the Caribbean can inform on the structure of past inter-island relationships.

The research is part of the inter-disciplinary Island Networks Project supported by the Netherlands Organization for Scientific Research (project number 360-62-060). This project examines the transformations of inter-island social relationships across the historical divide in the Lesser Antilles. Uncovering possible canoe routes between Amerindian communities can help to explain the structure, capabilities, and limitations of the physical links in social and material networks that existed prior to and just after 1492. To evaluate links between pre-Columbian island communities in the Lesser Antilles, I modeled optimal routes between indigenous archaeological sites to examine how routes in various seasons and through different regions influenced possible lines of connection. Canoe routes were generated in three different areas in the Caribbean, stretching from the island of Hispaniola to the Leeward Islands and from the Windward Islands to Guyana. This allowed for a basic test of the method's viability over different distances and environmental changes. Sea-based pathways created for this work provided new insights into the movement of peoples and material culture between islands and past Amerindians communities in this region.

Least-cost pathway analysis is a popular approach for analyzing the physical connection between sites in archaeology. Over the past three decades researchers have explored several methods to analyze least-cost pathways on landscapes (e.g., White and Surface-Evans 2012). Land-based least-cost efforts have outpaced the number of works creating optimal travel routes across the sea's surface. Perhaps as a result, no community standard for using computer- and GIS-based methods to model canoe or sailing routes exists. Though methods used in previous research often focus on determining the time-cost and success of specific routes, these measures have been calculated or judged in different ways. Colleagues from the University of Konstanz and I proposed a new tool to model past canoe routes. The tool used in this work modeled directed canoe voyages, or where the start and end points of pathways are pre-determined, a technique not yet used in the Caribbean region where work has focused on understanding undirected, or drift, voyages.

The tool used here differs from previous works as it follows an isochrone method. Based on Hagiwara's (1989) work, isochrone modeling evaluates optimal routes by having a seafaring vessel move towards a termination point over several time-intervals. By reevaluating paddling direction and underlying current at several steps, these intervals allow for the model to mimic real world canoeing techniques. The isochrone method is a convincing way to construct routes over the shifting surface of the sea.

By applying this method to three case studies spread around the Caribbean region I evaluated how crews adapted to paddling through different island layouts. This approach covers close connections, as found in the tight cluster of the Leeward Islands, and distant connections, like those between the northeastern South American coastline and the Windward Islands. I also explored how canoe pathways could be structured around a chain of islands by evaluating movement between the eastern edge of Hispaniola and the Leeward Islands. Routes generated through these three regions demonstrated the model's effectiveness for analyzing possible connections between known archaeological materials and possible canoe travel corridors.

Sites used within this study were selected based on objects within their assemblages. I focused only on a few materials or stylistic elements that were imported into the islands. Archaeological evidence to support these connections was drawn from pre-Columbian Archaic Age (2000 to 400 BC), Late Ceramic Age (1200 to 1500 AD) and early colonial period (AD 1492 to 1600) assemblages. These include both physical materials sourced for export, such as Long Island flint from the Leeward Islands, and stylistic elements, such as motifs originating in the Greater Antilles that spread into the Lesser Antilles. Where appropriate, I evaluated historic and ethnographic accounts alongside archaeological evidence. I also assessed modern experiential and experimental canoe studies to better understand what limitations should be placed on routes. When woven together, these lines of evidence provided a solid platform to realistically determine what sites were likely connected in the past. The modeled routes give shape the layout of possible connections suggested by other members of the Island Networks project (e.g., Hofman *et al.* forthcoming; Laffoon 2018).

Linking Amerindian sites shows that reconstructing canoe routes complements studies of exchange and mobility networks in the Caribbean. The generated pathways point to likely avenues of connection that cannot be seen through the presence of the archaeology alone. The material record can demonstrate the connection, computer modeling can hypothesize the travel corridors. Routes were shown to pass by other islands in the region when moving from the origin to termination points. These in-between islands may indicate places crews rested during voyages. Islands that are passed on the way to other islands could also represent points where exchange occurred. The islands suggested as in-between connectors by routes modeled in this work can point to new areas for archaeological comparison. It is possible that future works, both modeling and survey-based, will expand the capability of generated pathways to indicate the placement of past communities. The relationship between sites and the location of routes also supports the use of a mental map, or wayfinding toolkit, among Amerindian navigators.

These modeled canoe routes also allow for an evaluation of movement in different seasons. This is currently difficult to achieve through a comparison of seasonally available materials in the region. It is likely that these considerations were vital to canoe navigators as a change in environmental conditions, such as currents, affected the difficulty and trajectory of routes in different seasons. New insights into seasonal constraints on regional canoe networks can expose those communities predisposed to be in contact throughout the year and optimal (or least-cost) canoeing periods. Comparing the layouts of routes over various seasons may be one of the best ways to retrace the location of canoe travel corridors that existed in the Amerindian mental map.

Samenvatting

Het doel van deze studie was de uitvoerbaarheid te bepalen van het modelleren van maritieme connecties tussen inheemse eilandsamenlevingen in het Caraïbisch gebied en te beoordelen op welke manier verbindingsroutes tussen de Caraïbische eilanden een weergave zijn van de structuur van inter-eilandnetwerken uit het verleden.

Het onderzoek maakt deel uit van het interdisciplinaire 'Island Networks' project dat wordt ondersteund door de Nederlandse Organisatie voor Wetenschappelijk Onderzoek (project nummer 360-62-060). Het doel van dit project is het onderzoeken van transformaties in sociale relaties tussen de eilanden van de Kleine Antillen in de overgang naar de koloniale periode. De reconstructie van mogelijke kanoroutes tussen Amerindiaanse gemeenschappen kan de structuur, capaciteiten en beperkingen van de fysieke connecties in de sociale en materiële netwerken van vóór en net na 1492 helpen verklaren. Om connecties tussen pre-Columbiaanse eilandgemeenschappen in de Kleine Antillen te beoordelen, heb ik optimale routes gemodelleerd tussen inheemse vindplaatsen om te bepalen hoe routes in verschillende seizoenen en in verschillende regio's van invloed waren op mogelijke verbindingslijnen. Kanoroutes werden gegenereerd in drie verschillende gebieden in het Caraïbisch gebied, zich uitstrekkend van het eiland Hispaniola tot aan de noordelijke Kleine Antillen en van de zuidelijke Kleine Antillen tot aan Guyana. Dit maakte een basistest mogelijk van de toepasbaarheid van de methode over verschillende afstanden en voor omgevingsveranderingen. De voor dit werk ontworpen zeeroutes hebben nieuwe inzichten gegeven in de verplaatsing van mensen en materiële cultuur tussen eilanden en Amerindiaanse gemeenschappen in deze regio in het verleden.

De zogenaamde 'least-cost pathway' analyse is binnen de archeologie een populaire aanpak om de fysieke connecties tussen vindplaatsen te analyseren. In de afgelopen drie decennia hebben onderzoekers verschillende theorieën en methoden onderzocht om 'least-cost pathways' over land te analyseren (bijv. White en Surface-Evans 2012). Deze op land gerichte 'least-cost' studies hebben het aantal onderzoeken die optimale reisroutes over het zeeoppervlak creëren overschreden. Misschien is het daardoor dat er geen algemene richtlijn bestaat voor het gebruik van computer- en GIS-methoden om kano- of vaarroutes te modelleren. Hoewel de in eerder onderzoek gebruikte methoden zich vaak richten op het bepalen van de tijdskosten en het succes van specifieke routes, zijn deze metingen op andere manieren berekend of beoordeeld. Collega's van de Universiteit van Konstanz en ik hebben een nieuwe methode voorgesteld om vroegere kanoroutes te modelleren. De in dit werk gebruikte tool modelleerde gerichte kanovaarten, een techniek die nog niet in de Caraïbische regio is gebruikt.

De hier gebruikte tool verschilt van voorgaande werken aangezien het een isochrone methode volgt. Isochroon modelleren test op basis van Hagiwara's (1989) werk, de optimale routes door een vaartuig over meerdere tijdsintervallen naar een eindpunt te laten bewegen. Door het herbeoordelen van de peddelrichting en de onderliggende stroming, bij deze intervallen wordt het voor het model mogelijk om 'real world' kanotechnieken na te bootsen. De isochrone methode is een overtuigende manier om routes over het veranderende zeeoppervlak te construeren.

Door deze methode toe te passen op drie case studies verspreid over de Caraïbische regio, heb ik een inschatting gemaakt van hoe de bemanning zich aanpaste aan het peddelen in verschillende eilandgroeperingen. Deze aanpak omvat relaties over korte afstand, zoals we die vinden in de dicht bij elkaar gelegen noordelijke Kleine Antillen, en verre verbindingen, zoals die tussen de kust van noordoostelijke Zuid-Amerika en de zuidelijke Kleine Antillen. Ik heb ook onderzocht hoe kanoroutes geconstrueerd kunnen worden rondom een eilandketen door te kijken naar de beweging tussen het meest oostelijke punt van Hispaniola en de noordelijke Kleine Antillen. De routes die in deze drie regio's zijn gegenereerd, hebben de effectiviteit van het model aangetoond voor het analyseren van 'real world' kanopraktijken over verschillende afstanden.

De vindplaatsen die in deze dissertatie zijn gebruikt, zijn geselecteerd op basis van objecten uit de assemblages, waarbij de nadruk werd gelegd op materialen of stijlelementen die op de eilanden werden ingevoerd. Het archeologisch bewijs dat deze verbindingen ondersteunt is afkomstig uit assemblages daterend uit de pre-Colombiaanse Archaïsche Periode (2000 v. Chr. tot 400 n. Chr.), de Laat-Ceramische Periode en de vroeg-koloniale periode (AD 1200 tot 1600). Deze elementen omvatten zowel fysieke materialen die werden gewonnen voor de export, zoals vuursteen van Long Island in de noordelijke Kleine Antillen, en stilistische elementen, zoals motieven met oorsprong in de Grote Antillen die zich verspreidden naar de Kleine Antillen. Waar nodig heb ik historische en etnografische verslagen naast het archeologisch bewijs gelegd. Ik heb ook gekeken naar moderne ervarings- en experimentele kano-studies om beter te begrijpen aan welke beperkingen routes onderhevig zijn. Bij elkaar genomen hebben al deze bewijsvormen een solide basis opgeleverd om realistische inschattingen te maken van welke vindplaatsen in het verleden met elkaar in verbinding stonden en waar het kanoroutemodel het best kan worden toegepast. De gemodelleerde routes tonen het mogelijke netwerk van connecties dat is voorgesteld door andere leden van het Island Networks-project (bijv. Hofman *et al.*, 2018; Laffoon 2018).

Het verbinden van Amerindiaanse vindplaatsen laat zien dat het reconstrueren van kanoroutes een aanvulling is op het onderzoek van uitwisselings- en mobiliteitsnetwerken in het Caraïbisch gebied. De gegenereerde routes wijzen op waarschijnlijke verbindingswegen die enkel door de aanwezigheid van archeologische resten niet kunnen worden vastgesteld. Routes bleken langs andere eilanden in de regio te leiden bij het verplaatsen tussen start- en eindpunt. Deze tussengelegen eilanden zijn mogelijk plaatsen waar bemanningen rustten tijdens hun reizen. Eilanden die op weg naar andere eilanden worden gepasseerd zouden ook plekken kunnen zijn waar uitwisseling plaatsvond. De eilanden die door de gemodelleerde routes in dit werk als tussenverbindingen worden voorgesteld kunnen wijzen op nieuwe gebieden voor archeologische vergelijking. Het is mogelijk dat toekomstige studies, zowel op basis van modelleren als archeologische verkenning, de toepasbaarheid van de gegenereerde routes zullen uitbreiden om de locaties van vroegere gemeenschappen te kunnen aangeven. De relatie tussen vindplaatsen en de ligging van routes ondersteunt ook het gebruik van een mentale kaart, of een navigatie toolkit, door Amerindiaanse zeevaarders.

Deze gemodelleerde kanoroutes maken het eveneens mogelijk verplaatsing in verschillende seizoenen te evalueren. Het is momenteel moeilijk om dit te realiseren middels een vergelijking met seizoensgebondenheid van materialen in de regio. Het is waarschijnlijk dat deze overwegingen essentieel waren voor kanovaarders, aangezien veranderingen in omgevingsfactoren, zoals stromingen, de moeilijkheid en het traject van routes per seizoen beïnvloedden. Nieuwe inzichten in seizoensgebonden beperkingen voor regionale kanonetwerken kunnen de gemeenschappen zichtbaar maken die het gehele jaar contact onderhielden en de optimale (of 'least-cost') kanoperiodes in kaart brengen. Het vergelijken van de route lay-outs tussen de verschillende seizoenen kan een van de beste manieren zijn om de ligging van de kanovaarwegen in de Amerindiaanse mentale kaart te herleiden.

Curriculum vitae

Emma Slayton was born on October 1, 1988. After attending Sammamish High School (2003-2007), she studied anthropology, with a focus in biological anthropology, archaeology, material culture studies, and creative writing at Pitzer College (2007-2011). Her interest in seafaring and inter-island mobility was sparked when she studied the Chumash peoples of the Santa Barbara Channel Islands for her bachelor's thesis. After graduating with honors, Emma left the United States for the United Kingdom, where she studied at Oxford University. She applied least-cost pathway techniques to analyzing movement across seascapes, between islands in the Caribbean and the islands of the Cyclades in her master's research and obtained an MPhil with distinction in 2013. Over the course of her bachelor's and master's studies, Emma participated in archaeological field projects in the United States, Israel, Malta, and the United Kingdom.

Emma worked on her PhD as a part of the NWO funded Island Networks Project (project number 360-62-060). During her PhD at the Leiden University, Emma co-authored several papers, was a teaching assistant, guest lectured, presented at seven international conferences, organized three conference sessions and one conference at the SAA and EAA, and organized lectures and workshops for the Leiden Digital Archaeology Group. She participated in fieldwork in Grenada and Saba. She was also a part of several canoe training runs in Martinique organized by the Karisko project.

SEASCAPE CORRIDORS

There is little evidence of the routes connecting Amerindian communities in the Caribbean prior to and just after 1492. Uncovering possible canoe routes between these communities can help to explain the structure, capabilities, and limitations of the physical links in their social and material networks. This book evaluates how routes connecting islands indicate the structure of past inter-island networks, by using computer modeling.

Computer modeling and least-cost pathway analysis is a popular approach for analyzing the physical connection between sites in archaeology. Over the past three decades researchers have explored several theories and methods to analyze least-cost pathways on landscapes. Land-based least-cost efforts have outpaced the number of works evaluating optimal travel routes across the sea's surface. Perhaps as a result, no community standard for using computer- and GIS-based methods to model canoe or sailing routes exists. Although methods used in previous research often focus on determining the time-cost and success of specific routes, these measures have been calculated or judged in different ways. One way this book adds to the discussion of seascape modeling is by focusing on inter-island voyaging, or the process of maintained connections between island sites rather than a focus on exploration, a technique rarely explored in sea-based least-cost pathways analysis.

Relying on archeological evidence, ethnographic accounts and language analysis, and computer tools developed for this work, optimal routes between indigenous sites were modeled to determine how routes in various seasons and through different regions influenced possible lines of connection. To gain a broader understanding of the feasibility this model, canoe routes were generated in three different areas in the Caribbean, stretching from the island of Hispaniola to the Leeward Islands and from the Windward Islands to Guyana. These modeled sea-based provide new insights into the movement of peoples and material culture between islands and past Amerindians communities in this region.

Netherlands Organisation
for Scientific Research

ISLAND NETWORKS

Sidestone Press

ISBN: 978-90-8890-577-3

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