Seascape corridors : modeling routes to connect communities across the Caribbean Sea

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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 ide-

as, 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

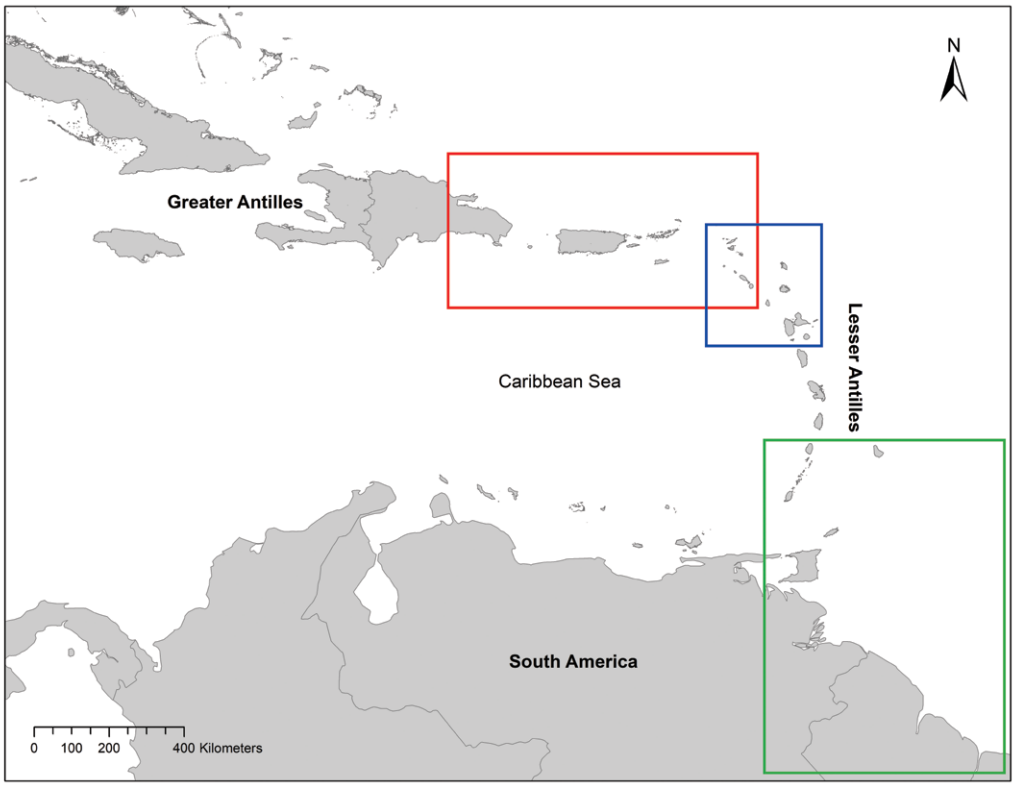

Figure 1: Map outlining the three case study regions. From left to right: the eastern Greater Antilles and the northern Lesser Antilles (Chapter 6), the northern Lesser Antilles (Chapter 5), mainland South America and the southern Lesser Antilles (Chapter 7).

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.