



(Sea)ways of Perception: an Integrated Maritime-Terrestrial Approach to Modelling Prehistoric Seafaring

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Abstract

The seaways have played a significant role in the movement of people, goods and ideologies since prehistory; yet, the ephemerality of movement combined with the paucity of direct evidence for prehistoric seafaring has challenged more refined understandings of the role of early seafaring in anthropogeny. Advances in digital methodologies within archaeology, such as least-cost approaches, allow more nuanced models of movement to be generated but suffer from dichotomous approaches to land and sea. These disentangled land-sea perspectives have long been criticised as ineffectual for understanding past maritime cultures, and previous discussions of prehistoric seafaring more specifically have advocated the consideration of the unique character of maritime space in order to more closely actuate a seafarer's perspective. Drawing on these ideas, this paper argues that more nuanced approaches to past seafaring are not only necessary but also achievable through holistic perspectives, heuristic methods and scaled-down resolutions, which allow for a more contextualised understanding of the spatiality and temporality—*i.e.* the human-scale—of maritime movement. This will be demonstrated through an integrated land-sea least-cost method to model Neolithic seafaring around the Outer Hebrides of Scotland. It is not the intention of this paper to advocate solely for the methodology outlined here but rather to demonstrate the need to consider and understand the unique character of maritime space and its many influences on the practices being studied. Only through such contextualised cognition can the perspectives and ideologies of past seafarers and the role of seafaring in anthropogeny truly be understood.

Keywords Prehistoric seafaring · Neolithic · Outer Hebrides · GIS · Least-cost analysis · Environment

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Introduction

The importance of seafaring to human history needs little by way of introduction; from the earliest indirect evidence for the use of watercraft to reach Sahul (Pleistocene Australia-New Guinea) more than 50,000 years ago (Clarkson et al., 2017; O’Connell et al., 2018) to the colossal cargo ships that carry the bulk of modern international trade, the seas have played an integral role in the expansion of humanity around the globe and the movement of people, goods and ideologies since. Although the seas have been afforded their rightful place within anthropogeny, more nuanced understandings of the temporality and spatiality of seafaring—*i.e.* the human-scale of maritime movement—become progressively hindered the further back in time researchers venture to look. This is not due to a lack of interest in the topic, as the large and growing body of research on early seafaring can attest to (*e.g.* Crawford, 1936; Bass, 1972; Bowen, 1972; Johnston, 1988; Broodbank, 1993; McGrail, 2001; Cunliffe, 2001; Montenegro et al., 2006; Knappett et al., 2008; Garrow & Sturt, 2011; Kaiser & Forenbaher, 2016; Gustas & Supernant, 2017; Kealy et al., 2018), but rather to the paucity of direct evidence for prehistoric seafaring, namely watercraft themselves. In a discipline bound to material culture, this lack of evidence requires researchers to adopt more holistic perspectives on the evidence that does exist, be it material or environmental, and develop innovative approaches that can incorporate these new perspectives. Following on from discussions by Garrow and Sturt (2011) and Leidwanger (2013) to name a few, it is argued here that more nuanced understandings of past seafaring can only be achieved through consideration of the unique character of the corresponding marine environment along with its influence on the maritime practices being employed. However, this paper will go one step further to argue that this influencing environment includes the land as well as the sea, and thus it is a more integrated approach that is necessary to achieving more contextualised discussions of past seafaring.

One of the greatest challenges in studying human movement, whether terrestrial or maritime, is that inherently ‘mobility lacks a presence’ (Leary, 2014, p. 6), and it is the fluidity of movement that requires equally dynamic methodologies to capture its true nature (Kador, 2007). Advances in digital methodologies within archaeology, specifically the use of computational modelling, make such approaches achievable, provided the heuristic nature of the analysis is acknowledged in the interpretation of the results. Currently, one of the most relied upon digital methodologies for modelling past movement is least-cost analysis (LCA) (Mlekuž, 2012; Verhagen et al., 2019). This method is highly suitable for analysing past mobility as it allows researchers to focus on the more tangible aspects of movement, primarily environmental influences on human physiology, in order to form a cost surface on which potential pathways of past movement can be modelled (*e.g.* Surface-Evans & White, 2012; Herzog, 2014; Groenhuijzen, 2019). As the origin and destination points for the modelled pathways can be based on the extant archaeological record, least-cost approaches thus allow for the incorporation of both the existing evidence for movement and the influencing environment

in which this movement was taking place. Hence, LCAs are pushing the methodological boundaries of how archaeologists conceptualise prehistoric movement and contextualise it through research. However, the benefits of this approach have been realised primarily within the terrestrial sphere with least-cost approaches to maritime movement remaining largely in absentia.

The reason for this is easily discernible; water is fluid and does not represent the same fixed, tangible and obviously ‘textured’ space that the landscape does, meaning it cannot be approached or modelled in the same way. In addition, the dynamic and intricate nature of maritime space engenders a range of maritime practices, or methods of movement, that must also be understood in order to consider the physiological influence of this dynamic environment on movement through it. Hence, the strong environmental distinctions between land and sea and the varying forms of movement each facilitates have justly encouraged environmentally dichotomised least-cost approaches yet have inadvertently hindered more refined understandings of past seafaring practices. Critiques of such disentangled land-sea perspectives and the methodological biases they promote have led to a call for more holistic approaches to archaeological contexts that are encompassed within both terrestrial and maritime milieux (e.g. Westerdahl, 1992; Broodbank, 2000; Boomert & Bright, 2007; Rainbird, 2007), especially given the evidentiary incongruities that exist between the two environments (Parker, 2001). With a general lack of evidence for prehistoric watercraft, much of the extant evidence for prehistoric seafaring comes from within the landscape (Westerdahl, 1992); however, a focus on this terrestrial evidence alone simply highlights points that may have been connected through maritime movement, providing little understanding of the nature of that movement itself (see Leary, 2014 for discussion of mobile objects). Conversely, focussing on the character of the seas alone to the exclusion of the landscape will omit the very milieu in which all maritime activity begins and ends, in turn divorcing discussions of seafaring from the primary archaeological evidence that supports them (Broodbank, 2000, p. 363). Accordingly, rather than allowing the interface between land and sea to act as a barrier to movement, and thus movement-based methodologies, this liminal space should be viewed as a crucial continuum along maritime routes, linking not only terrestrial and maritime activities in the past but also their study in the present. Thus, although the mutability of water may confound attempts to trace routes through the seaways like pathways through the landscape, these difficulties should not be seen as a deterrent but rather as an opportunity to explore the many facets of this dynamic space and heuristically employ equally dynamic computational approaches in order to do so.

Given the many complexities of the topic and medium under study, there may be no single suitable approach. Hence, it is not the intention of this paper to advocate solely for the least-cost approach outlined here but to demonstrate instead the need and ability to adopt more holistic approaches to land and sea if more contextualised discussions of the temporality and spatiality of seafaring are sought. This will be done through a case study of Neolithic seafaring around the Outer Hebrides, a Scottish archipelago that has long been drawn into narratives of prehistoric maritime connectivity along the western seaways between Britain and Ireland (Bowen, 1972; Burl, 2000; Cunliffe, 2001; Garrow & Sturt, 2011; Garrow et al., 2017; Henderson,

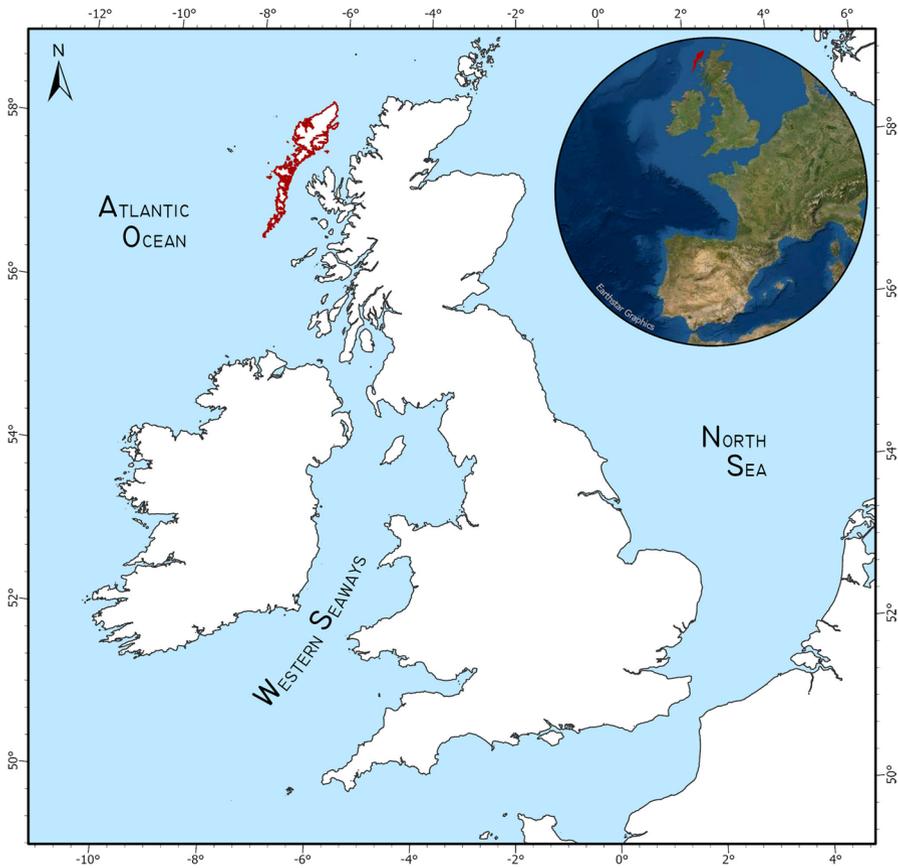


Fig. 1 The location of the Outer Hebrides (in red) at the terminus of the western seaways between Britain and Ireland

2007; Sheridan, 2004) (Fig. 1). Foreign lithics provenanced to distant islands and regions along the western seaways provide the best evidence for long-distance maritime movement to the Outer Hebrides, and regional maritime movement is also evidenced through the use of shared pottery and megalithic building traditions by Neolithic communities living on disparate islands throughout the archipelago. Although the more exotic narratives of long-distance connectivity may be the most captivating, as emphasised by Kador (2007, p. 42), a focus on broad spatial scales will ‘inevitably fail to recognise and appreciate the very subtle, fine-grained and highly varied nature of people’s movements’. This is especially pertinent when dealing with maritime movement, where the many intricacies of maritime space are enveloped within a complex array of environmental cycles or temporalities (Sturt, 2006). As stated by Mlekuž (2014, p. 14), in studies of movement, ‘issues of temporality, spatiality and practices are dialectically woven together and inseparable’. Therefore, if discussions of prehistoric seafaring are to be refined, it is the complexities of maritime space and

the temporalities that govern it that must be understood. This can only be achieved through scaled-down approaches that incorporate both marine and terrestrial environments, which in turn allow researchers to contextualise this space and build more nuanced narratives of prehistoric seafaring through these new ways of perception.

Way Makers: Theoretical Underpinnings and Methodological Advancements

The Importance of Dual Land-Sea Perspectives

The need for integrated land-sea approaches to past seafaring is predicated upon decades of discussion by maritime researchers, who have highlighted the numerous limitations of maritime and terrestrial dichotomies in archaeological research (e.g. Westerdahl, 1992, 1994, 2015; Broodbank, 2000; Parker, 2001; Ilves, 2004; Cooney, 2004; Boomert & Bright, 2007; Rainbird, 2007). Westerdahl's (1992) exposition on the need for a scientific term that could encompass and unify material culture existing on land and underwater led to the archaeological conception of the maritime cultural landscape—a term that has since had profound implications for maritime, island and coastal research. The need to assimilate conceptually the material and immaterial evidence occurring within both milieux acutely emphasises that the significance and use of the coast and the broader maritime landscape of which it is a part can only be understood through dual land-sea perspectives (Cooney, 2004; Ilves, 2004; Parker, 2001; Westerdahl, 1994, 2015). However, an emphasis on dual perspectives does not mean simply incorporating the sea into terrestrial approaches in order to consider how past communities may have perceived the surrounding seas from within the landscape. It also means incorporating the landscape into maritime perspectives to consider how being at sea would have shaped perceptions and use of the land (Robinson, 2013; Sturt, 2005). Thus, while much of the current debate has emphasised the need for terrestrial researchers studying coastal or island communities to consider the impact of and engagement with the surrounding seas, the need for dual land-sea perspectives likewise emphasises that no study of seafaring is complete without considering the influence and use of the abutting maritime landscape (Broodbank, 2000, p. 363). Ilves (2004), for example, has emphasised the different perspective that a focus on the maritime landscape promotes within archaeology—that of seeing the land from the sea. In adopting a seafarer's perspective, the characteristics of the maritime cultural landscape assume new meaning.

From a terrestrial perspective, the maritime landscape is a liminal space that lies 'betwixt and between', but from a seafarer's perspective, the maritime landscape presents fixed markers for navigation and safe places for crossing this natural divide (Westerdahl, 1992, 2003). Thus, as stated by Ford (2011, p. 764), 'the coast was as much a bridge between terrestrial and maritime lives as a perceptual, physical, or cultural border'. It is within this space that seafaring routes converge with terrestrial movement, resulting in places identified by Westerdahl (1992, pp. 6–7) as transit points. These places would have been significant points along maritime routes, requiring a change in transportation methods and serving as a liminal space for the

exchange of goods and ideologies. Bradley et al. (2016) have elaborated on these transitional places, distinguishing between two types: maritime havens and landing places. The former refers to sheltered bays where boats would have moored, sites that could have been in use for extended periods of time, and the latter refers to more ephemeral places that may have changed in relation to the type of watercraft being used as well as existing seafaring routes (*ibid*, p. 126). Hence, these transitional places provide a crucial link between maritime and terrestrial activities in the past as well as their study in the present.

Although an analysis of the maritime landscape may aid in the identification of suitable transitional places, the detection of them is challenged by the dynamic nature of the littoral environment in which they would have existed. Within the intertidal zone, ‘the mark of the social is repeatedly washed away’ (Jones, 2010, p. 200), yet the rhythms and patterns that govern this indefatigable space persist. Thus, despite its inherent liminality, the maritime landscape, at present, provides the most tangible space through which to analyse prehistoric seafaring (Westerdahl, 1992), both spatially and temporally. As stated by Sturt (2006, p. 120), ‘maritime archaeology’s point of engagement with the environment forces a more sensitised approach to space, temporality and change than occurs in terrestrial archaeology’. This nuanced approach can only be achieved by striving to understand this unique maritime space, both land and sea, and its influence on the nature of seafaring practices. In addition, the development and use of these transitional places for maritime practices would not have been due to conducive geographies alone but also existing maritime technologies and traditions along with various other cultural influences (Westerdahl, 1992). These factors would in turn influence seafaring routes, further demonstrating why studies of seafaring cannot be divorced from the maritime communities that engage in these practices (Westerdahl, 2007) nor the broader contexts that encompass them. If more refined discussions of past seafaring are sought, it is the physicality of the maritime landscape and the perceptibility and pervasiveness of the rhythms played out within this space that may thus offer a more tangible lens through which to adopt a seafarer’s perspective. Only through this holistic and contextualised perspective of maritime space can a greater understanding of inherently ephemeral maritime movement be generated.

Least-Cost Approaches to Prehistoric Seafaring

In striving towards a more refined understanding of prehistoric movement through computational approaches, least-cost analysis has been a well-used and informative methodology. Verhagen et al. (2019, p. 240) recently presented an overview of least-cost approaches in archaeology, demonstrating ‘its considerable potential for understanding ancient movement’. Underlying this method is the assumption that movement will be optimised whenever possible, and by quantifying this movement and representing it as a cost surface, least-cost pathways can be modelled. The concept of a least-cost approach to movement is grounded in the notion of affordances, derived from the work of psychologist James Gibson. According to Gibson (1979, p. 121), an affordance ‘is equally a fact of the environment and a fact of behaviour.

It is both physical and psychical, yet neither. An affordance points both ways, to the environment and to the observer'. Thus, as regards movement, affordances refer to an individual's ability to act or move in their environment based on the potentialities offered by it; in other words, affordances can only be explored by considering both the environment and the movement capabilities of individuals (Verhagen et al., 2019, pp. 218–219). General assumptions regarding the nature of past movement—*i.e.* the method of movement and speed of travel—must be made and subsequently converted into cost estimations; however, a focus on the environment highlights physiological affordances and constraints that would have influenced movement, thereby providing a more tangible surface on which movement assumptions can be based. There are many critiques of the least-cost approach, primarily revolving around the reduction of the complexity of human mobility down to a static surface of projected cost values (see Conolly & Lake, 2006 for a review), but for the present study, this method was nonetheless deemed most suitable. This is due to its emphasis on the environmental influences on movement and its adaptability to the unique environment of the given study area—factors deemed crucial for analysing maritime movement as previously discussed. Further, the inherently quantitative nature of the vector-based results allows for a greater understanding of the spatiality and temporality of movement, the subsequent exploration of which can imbue the results of the analysis with greater corporeal meaning.

Although LCAs have a long history of development and adaptation, resulting in many methodological derivations (*e.g.* see papers in White & Surface-Evans, 2012; Polla & Verhagen, 2014), its application has been almost exclusively focussed on addressing movement through the landscape, a more concrete and knowable entity than the seas. For terrestrial movement, slope degree has the longest history of use in LCAs, believed to be a good predictor of the physiological cost of human movement through the landscape (Kantner, 2012, p. 226). By contrast, waterborne movement requires the ability to reconstruct a dynamic and multifaceted environment—affected by a combination of factors such as winds, waves, currents and tides—and estimate the influence and cost of these factors on the variable aspects involved in this form of movement—*i.e.* the type of watercraft, method of propulsion and form of navigation. Given these complexities, little research has been conducted on movement through marine environments (Gustas & Supernant, 2017, p. 40) and even less involving the quantification of prehistoric movement through water (Verhagen et al., 2019, p. 221).

The few examples of the application of least-cost methods to address questions related to prehistoric seafaring come from the Pacific. Gustas and Supernant's (2017) analysis of Late Pleistocene and Early Holocene migration along the Northwest Pacific coast focussed on three categories of cost: physiological (travel distance), cultural (visibility and proximity to coast) and environmental (beach slope and aspect as well as proximity to freshwater). Their results provided insight into the relative significance of these various categories for prehistoric seafaring, demonstrating the greater significance of cultural factors on the efficacy of least-cost models. Kealy et al.'s (2018) models of human dispersal from Sunda to Sahul at 70 kya and 65 kya considered visibility from the sea and intervisibility between sea and land along with additional landscape factors (*e.g.* land slope and proximity to rivers).

Their results suggested the strong influence of coastal visibility on seafaring routes and highlighted suitable landing and launching points for these routes. Although both analyses incorporated palaeogeographic reconstructions into the cost surfaces, allowing for a greater understanding of the influence of the landscape on past seafaring routes, the conditions of the seas themselves were conspicuously absent. Essentially, despite addressing research questions bound to the nature of maritime movement and employing methodologies aimed at modelling specific routes of this movement, these approaches failed to incorporate the very environment in which this movement was taking place. The incorporation of cultural and perceptual factors is indeed significant to understanding human mobility, as has been stated previously and will be demonstrated subsequently through the case study of the Outer Hebrides; yet, the assimilation of these cultural factors is inherently flawed if a more comprehensive view of the environment is not taken. Such approaches inadvertently represent this dynamic environment, crucial to the heart of the research question, as a blank space devoid of complexity and meaning, and it is this complexity of maritime space that makes its incorporation into seafaring models both pivotal and problematic.

This is well illustrated by Indruszewski and Barton's (2008) least-cost models of Viking Age seafaring in the Baltic Sea using modern wind data. The ability to compare their results to historical accounts of a voyage in the late ninth century as well as real-time sailing data from an experimental reconstruction of that same voyage allowed for the validity of the models to be assessed, but the inherent difficulties of modelling the environmental cost of seafaring through an LCA were also exposed. Although sea conditions are affected by multiple elements, in practice it is highly challenging to model all factors affecting maritime movement (Verhagen et al., 2019, p. 228). This is firstly due to the need to combine these factors into a single multi-criteria cost surface (see, e.g., Howey, 2007; Nolan & Cook, 2012), requiring the use of relative rather than actual cost values, and secondly, and more significantly, to the two variables that make up a single cost factor—*i.e.* the intensity *and* direction of each element (Indruszewski & Barton, 2008, p. 62). For instance, the physiological influence of slope on terrestrial movement can be measured along a fixed parabolic scale, allowing a roughly uniform cost value to be assigned to slope degree regardless of the direction of movement. In contrast, the cost value assigned to each maritime element is not dependent solely upon intensity but the direction of this intensity in conjunction with the desired direction of movement. In other words, a steep slope becomes a steep hill based on the direction of travel, but both will generate roughly the same cost to move across; however, strong winds moving in the same direction as desired travel will assist movement, thereby incurring a lower cost, but if moving in the opposite direction of desired travel will hinder movement, thereby incurring a higher cost. Hence, the direction of travel is far more influential, and problematic, when modelling maritime movement.

Despite these methodological challenges, previous approaches to maritime LCAs demonstrate the adaptable nature of this method and the ability to tailor it to the individual research question, incorporating localised factors deemed most applicable to the study area, including, perhaps most importantly, both marine and terrestrial environments. Other computational approaches to modelling past seafaring

have contributed greatly to the discourse, but they also demonstrate why more holistic environmental approaches are necessary. For instance, Callaghan and Scarre's (2009) computational modelling of Neolithic seafaring between Brittany and various locations around Britain and Ireland incorporated a range of factors related to past sea conditions and the nature of Neolithic seafaring including winds, tides, seasonality, directionality, type of boat and method of propulsion. The authors thus were able to demonstrate varying environmental constraints on seafaring as well as the feasibility of various generic routes and their potential durations. However, by demonstrating the strong influence of the environment on maritime movement, their models also reveal why a more environmentally holistic approach is crucial to achieving more nuanced discussions of prehistoric seafaring. As demonstrated by other computational and network-based approaches to maritime connectivity, the use of fixed point-to-point routes to model maritime movement bears little resemblance to the actual experience of seafaring (Knappett et al., 2008; Leidwanger, 2013). This shortcoming was likewise acknowledged by Callaghan and Scarre (2009, p. 367), who stated that given the profusion of proximal potential landfalls along the west coast of Britain, 'it is perhaps plausible to envisage frequent stopovers, especially in the case of paddled boats where crews may have needed to rest and reprovision'.

Consequently, in omitting considerations for the landscape within seafaring models, the full nature of seafaring practices—in this case the use of coastal pilotage and hopping—cannot be considered. This not only limits any refined spatial understanding of the routes themselves, including where they begin and end within the maritime landscape, but also any temporal understanding of the entirety of the journey. Accordingly, it is only through a more holistic approach to the environment that a more informed understanding of its influence on the method and manner of maritime movement can be formed. With this understanding established, more temporally and spatially detailed seafaring models can be generated and more contextualised discussions of past seafaring produced. Thus, drawing on the entreaties for integrated land-sea approaches and building off previous least-cost approaches to modelling prehistoric seafaring, the following methodology demonstrates a way in which this may be achieved.

A Way Forward: a Case Study of the Outer Hebrides

The Neolithic Archaeological Record

Situated on the far north-west edge of Europe, the Outer Hebrides are composed of 15 inhabited and more than 50 uninhabited islands that stretch through the tempestuous North Atlantic off the west coast of mainland Scotland. The island chain is separated from the Scottish mainland by a deep and dynamic inner seaway known as the Minch. Given its depth, and with distances from the archipelago to the mainland varying between 23 and 72 km, the Minch would have separated the Outer Hebrides from mainland Scotland since at least the beginning of the Holocene (Brooks et al., 2011; Sturt et al., 2013). This indicates that the earliest evidence of activity on the archipelago, c. late-8th millennium BC (Bishop et al., 2013), as well as the

later arrival of the Neolithic, c. 3800 BC (Garrow et al., 2017, p. 115), would have been borne through the seaways. Furthermore, the arrival of foreign materials and the adoption of distinctively inter-regional pottery styles and megalithic building traditions in the Outer Hebrides demonstrate recurrent long-distance connections along the Atlantic façade throughout the Neolithic (Ritchie, 1968; Sheridan, 1992, pp. 198–201; Cummings et al., 2005; Henley, 2005; Garrow et al., 2017).

Although the recovery of foreign lithics provides the greatest evidence for broader maritime movement, direct exchange between the provenance of these lithics and their locations of recovery cannot be assumed nor can the frequency of this occurrence beyond a single event. In other words, focussing solely on an object's provenance or find spot gives little sense of the 'flows' of movement that the object may have experienced (Leary, 2014, p. 11). Beyond foreign lithics, however, long-distance connectivity has been indirectly evidenced through the use of distinctively inter-regional pottery styles: Unstan Ware in the Early Neolithic, c. 3600–3000 BC (Copper, 2015; Copper & Armit, 2018), and Grooved Ware in the Late Neolithic, c. 2700 BC (Garrow & Sturt, 2017, pp. 171–172; Squair & Ballin Smith, 2018). Further indirect evidence for long-distance connectivity comes from the profusion of megaliths that are scattered throughout the archipelago. Chambered tombs—ancestral monuments distinct to the Atlantic Neolithic (Cunliffe, 2001, p. 159)—reveal forms resembling the Clyde cairn tradition of south-west Scotland (Henshall, 1972, pp. 15–16), and later standing stones and stone circles demonstrate the adoption of a tradition in practice throughout Britain and Ireland during the Late Neolithic (Henley, 2005). Altogether, this evidence suggests cultural affinities between Neolithic communities living along the Atlantic façade of Britain and Ireland; however, the frequency and extent of this connectivity throughout the Neolithic remains unclear (Fig. 2).

In addition to these insinuations of broader maritime connectivity, the archaeological record demonstrates several distinctively Outer Hebridean traditions that were in use amongst communities living on disparate islands. A local pottery style, known aptly as Hebridean Ware, has been found in profusion at many Neolithic sites throughout the archipelago (Copper, 2015; Squair, 1998), and a local adaptation of the chambered tomb tradition, referred to as Hebridean-type passage tombs, also occurs throughout the region (Henley, 2003, 2004; Henshall, 1972). Given the geographically fragmented and topographically complex nature of the island chain, the transmission and maintenance of these various cultural affinities would have required some form of established maritime movement along the coasts of the archipelago. Indeed, as highlighted by Serjeantson (1990, p. 16), during the early inhabitation of the Outer Hebrides, 'all except the most local journeys must have been made in boats'.

Thus, the evidence as a whole suggests the presence of strong maritime traditions during the Outer Hebridean Neolithic. This had led Gannon (2016) to propose that Neolithic Hebrideans—like many communities residing on island chains—were engaged in three overlapping layers of mobility: local, regional and exotic. Although exotic narratives of long-distance connectivity and exchange may be the most captivating, a refined understanding of this broader maritime movement is presently hindered by limited material evidence and absolute dates (Blankshein, 2019), meaning

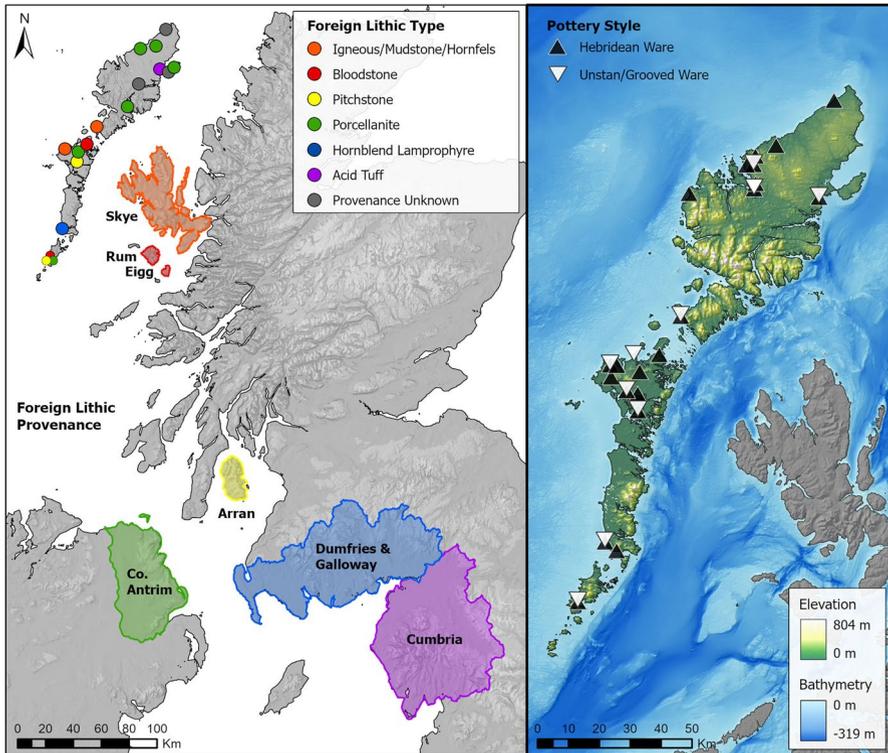


Fig. 2 The types and locations of foreign lithics found in the Outer Hebrides along with their provenance (map outlines), demonstrating long-distance maritime connectivity (left image). Regional (Hebridean Ware) and inter-regional (Unstan and Grooved Ware) pottery styles recovered from Neolithic sites, demonstrating both regional and inter-regional maritime connectivity (right image). (See [Supplementary Materials](#) for archaeological and environmental datasets)

any modelled connections between these places would be spatially and temporally generic and thus antithetical to a more refined approach. In contrast, regional movement throughout the archipelago offers the opportunity to explore the local and regional maritime practices that underpin broader narratives. As it is the local knowledge gained through diurnal and seasonal maritime movement that would have aided seafarers on longer-distance journeys, it stands to reason that it is with local and regional seafaring practices that any refined understanding of Neolithic seafaring along the western seaways must begin.

The Dynamic Maritime Landscape

The Outer Hebrides are a geographically and topographically complex archipelago filled with diverse islandscapes delimited by a fragmented and fluctuating coastline—the result of 1500 million years of tectonic and metamorphic activity and the successive carving of these major land formations by recurrent episodes of glacial

expansion and retreat (Fettes et al., 1992; Hall, 1996, p. 5). Although generalisations are only broadly applicable, the archipelago can be roughly divided into northern and southern island chains. The northern landmass of the Isles of Harris and Lewis (which are in fact one island) exhibits strong north–south geological delineations formed around a large massif landscape that stretches across the archipelago’s widest point. In contrast, the series of islands to the south, known collectively as Uist, exhibit strong east–west delineations that follow a major thrust zone running along the eastern maritime landscape of the islands (Fig. 3). Around the archipelago, the coastline is repeatedly interrupted by secondary fault lines and glacial valleys that have formed long and narrow inlets, known as sea lochs, that penetrate deep inland, resulting in an intricate coastline that stretches to approximately 1800 km. Where the rocky and elevated terrain of Harris and Lewis meets the sea, steep cliffs overlook prominent sea stacks, and elsewhere the more rugged landscapes of the eastern seaboard form shingle beaches backed by small rocky islands or skerries. In contrast, much of the lower-lying coasts, especially the western and northern coasts of Uist, are formed of a unique calcareous white-shell sand known as machair. Along Uist, these deposits form sweeping sandy beaches backed by shallow turquoise waters, and elsewhere they exist as small, sandy bays that offer reprieve from an otherwise rugged coastline. With such an extensive and pervasive coast, no point in the archipelago is more than 11 km from the sea, and in actuality, most of the archipelago could be considered to reside within a maritime context; the glacially carved interior forms the characteristic Outer Hebridean landscape consisting of undulating hills, rocky outcrops and a multitude of loch-filled scours, many exhibiting shorelines as intricate as the coastlines that encompass them.

Given the great diversity brought about by a dynamic geomorphology, it is apparent that the Outer Hebridean environment does not exist in stasis, and indeed, it is only through an understanding of the palaeoenvironment that any understanding of the archipelago’s prehistory can be formed (Harding, 2000). The Holocene landscape has been transformed through blanket peat expansion and woodland decline, and the coastline has been significantly altered due to sea level rise, machair formation and migration, and continual coastal accretion and erosion. Thus, any more nuanced analysis of Neolithic maritime practices around the archipelago is predicated upon an understanding of the palaeogeography at that time. This understanding has been more concisely formed and conveyed through a palaeogeographic reconstruction of the Outer Hebrides, which was generated using glacial-isostatic adjustment (GIA) values from Sturt et al. (2013) (Fig. 4).

The palaeogeographic reconstruction estimates total inundated land in the Outer Hebrides since 4000 BC to be upwards of 500 km², in some places leaving the coastline as much as 1 km outward from its present location. What is more revealing, however, is the variation in inundation around the archipelago, with a clear concentration towards the west coast due to its greater distance from mainland Scotland, which has experienced isostatic rebound since the last glacial maximum (Dawson et al., 2002) (see isobases in Fig. 4). Greater subsidence combined with a low-lying coast has compounded inundation on the western seaboard, especially in the southern half of the archipelago. Around Uist, which is currently formed of three main islands separated by sandy tidal channels, lower sea levels would have left these

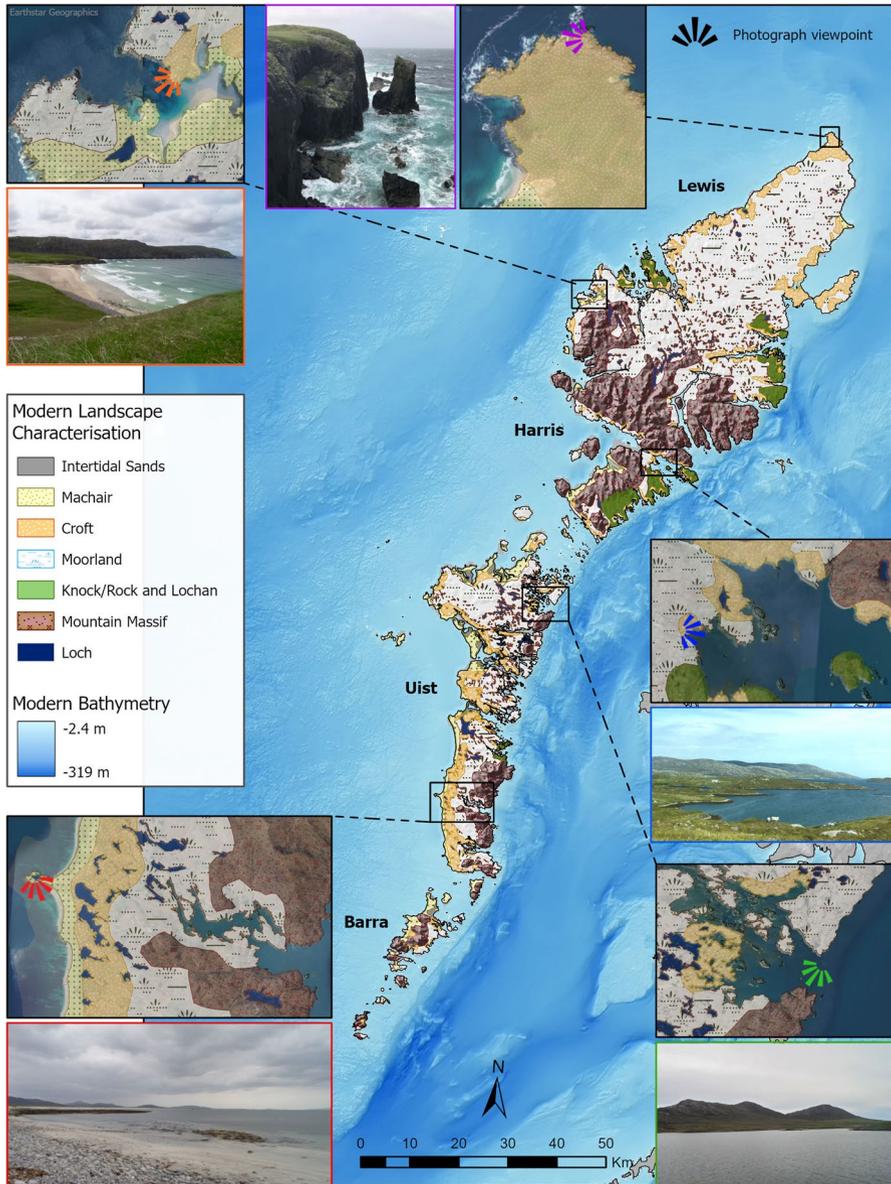


Fig. 3 Modern landscape characterisation of the northern and southern island chains, demonstrating the strong north–south (Harris and Lewis) and east–west (Uist) geological delineations formed by mountain massif landscapes. The diversity of maritime landscapes resulting from a dynamic geomorphology is revealed in the insets along with photographs taken by author of these landscapes. (See [Supplementary Materials](#) for environmental datasets)

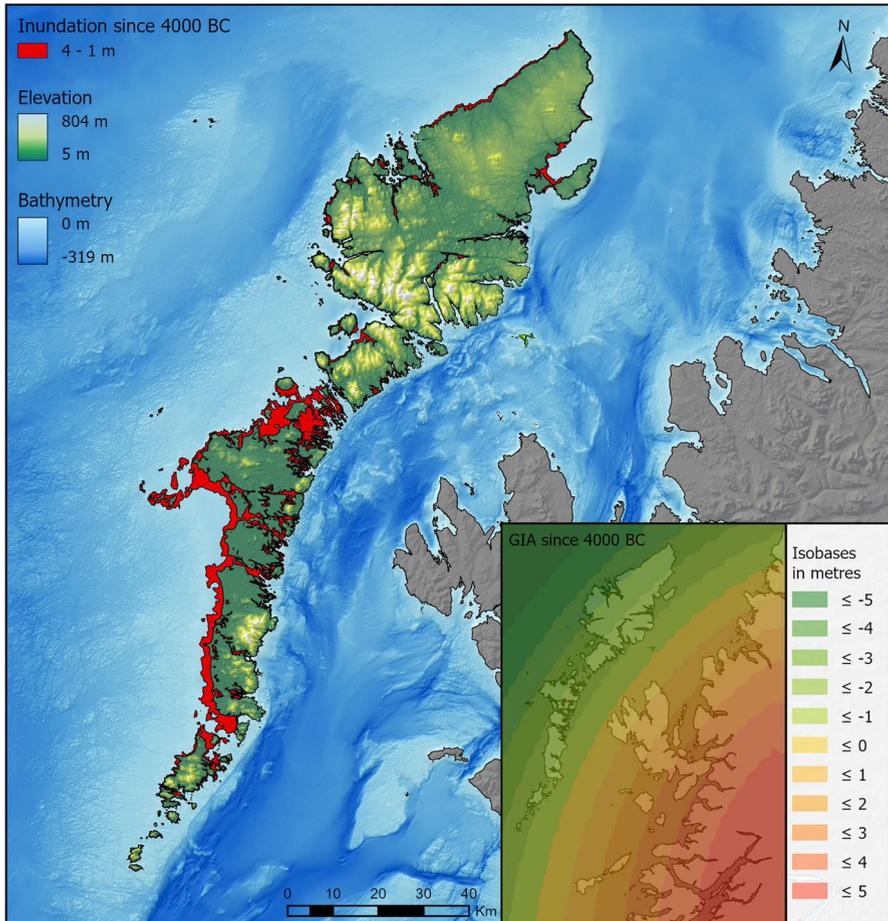


Fig. 4 Palaeogeographic reconstruction of the Outer Hebrides for the year 4000 BC based on glacial-isostatic adjustment values from Sturt et al. (2013). Elevation data for the model is derived from OS Digimap Terrain 5 DTM and EMODnet 25 m Bathymetry

islands connected, at least during the Early Neolithic. Although the models do not take into account more localised factors that would have influenced coastal geomorphology, such as sediment erosion and accretion, the connection of these islands during the Neolithic is supported by intertidal samples taken from the north channel that date the submergence of this region to 3200–2500 BC (Edwards et al., 2005; Ritchie et al., 2001). The connection of these islands would have enabled terrestrial connectivity between various communities living on these now separate islands, but it does not preclude the existence of maritime connectivity given the many hindrances to terrestrial movement that still exist within this topographically complex and loch-filled landscape. Further, the palaeogeographic reconstruction suggests that Uist would have already been separated from Barra to the south as well as the Isle

of Harris to the north during the start of the Neolithic, thus necessitating maritime movement to connect these places.

While the character and extent of the Neolithic coastline can be broadly deduced and modelled using a mix of modern and palaeoenvironmental data, understanding the nature of past sea conditions and their influence on seafaring practices presents a greater challenge. The importance, as well as the many complexities, of understanding and incorporating past sea conditions into discussions of prehistoric seafaring along the western seaways of Britain has been highlighted by Garrow and Sturt (2011). The unique character of maritime space is formed through a series of intricately related environmental factors that can be spatially and/or temporally predictable as well as unpredictable. The range of unpredictable and sometimes fleeting elements that help form the character of the seas (*e.g.* waves, winds, storminess and oceanicity) present just as much of a challenge to researchers as they do to seafarers; thus, it may be assumed (rather necessarily) that many of these elements and the challenges they present would have been avoided or at least mitigated by choosing optimum seasons, conditions and routes. For example, McGrail (2001, p. 171) has suggested that early seafaring along the Atlantic façade would have taken place between May and September as increased winds and storminess would have restricted travel in the winter months. Hence, by omitting broader and less predictable constraints, what remains to be considered are the more recurrent and discernible elements, which, in the case of the Outer Hebrides, are winds, currents and tides.

In the strong oceanic climate of the Outer Hebrides, high winds are common year-round but are particularly strong in the winter (Bennett et al., 1990, p. 283), and these predominately south-westerly winds in conjunction with the turbulent conditions of the North Atlantic create some of the most powerful wave conditions in the world (Neill et al., 2017, p. 10). The North Atlantic also has a strong influence on tidal cycles around the Outer Hebrides, being semi-diurnal and exhibiting a three- to four-metre spring tidal range. When these tides are funnelled through the Minch, with its multifaceted coastal geography and seafloor topography, they generate strong and complex tidal currents that can vary substantially in speed and direction over short distances (Ramsay & Brampton, 2000, p. 9; Neill et al., 2017, p. 6). Combined, each of these elements would have influenced seafaring practices in a variety of ways, but, as previously demonstrated, the incorporation of all maritime factors into a least-cost analysis is highly challenging. This feat is further complicated by the need to know and reconstruct the nature of these conditions in the past. In the absence of more specific data on ancient sea conditions, the use of modern environmental data has been advocated (Murray, 1987, 1995; McGrail, 2001, p. 169). While this comparability may be suitable for initial discussions of seafaring, acclimatising the researcher to the character of the seas, in striving to move away from generic discussions of prehistoric seafaring, it is ultimately through the reconstruction of past sea conditions that more nuanced approaches can be achieved (Sturt & Van de Noort, 2013, pp. 55–56). Hence, a compromise must be found between the incorporation of various relevant factors and their level of discernibility.

Palaeoenvironmental work has revealed a drastically different early Holocene environment in the Outer Hebrides (Bennett et al., 1990; Birks, 1991; Fossitt, 1996; Langdon & Barber, 2005) as well as the potential for broader climate fluctuations

throughout this time (Tipping, 2010). As wind and wave conditions around the archipelago are strongly linked to the North Atlantic climate (Neill et al., 2017), the nature of these elements during the Neolithic remains far from clear. This challenges the level of discernability of wind and wave patterns and hence the ability to reconstruct them. Likewise, Ward et al. (2016) have demonstrated the highly sensitive nature of tidal dynamics around northwest Europe in relation to relative sea levels; however, given the long history of iterative palaeogeographic modelling (e.g. Lambeck et al., 1998, 2010; Shennan et al., 2000; Shennan & Horton, 2002; Sturt et al., 2013), equally detailed palaeotidal models for northwest Europe have been able to be generated (Shennan et al., 2000; Uehara et al., 2006; Ward et al., 2016). This perceptibility of past tidal patterns along with their temporal predictability makes them advantageous for modelling past seafaring, and palaeotidal data also has the added benefit of being able to be temporally and spatially matched to the palaeogeography in order to generate a more seamless Neolithic land-sea surface with which to generate the least-cost models.

Neolithic Seafaring Practices

Given the absence of evidence for Neolithic watercraft in Britain, understanding and ultimately costing movement capabilities requires the assumption and generalisation of a number of factors related to the nature of Neolithic seafaring practices. Factors affecting movement capabilities would have included the type of boat, method of propulsion and form of navigation, all of which would have been affected by sea conditions and would have in turn influenced, along with the maritime landscape, specific routes taken as well as the location of transitional places. Prehistoric log boats have been found throughout regions along the Atlantic façade (McGrail, 2001, p. 172)—with nearly 20 dated and more than 150 total log boats having been recorded in Scotland alone (Mowat 1996). However, none of these Scottish log boats has been dated to the Neolithic, and further, as argued by Muckelroy (1978, p. 128), these vessels would have been constructed primarily for use on inland waterways and therefore may not have been deemed suitable for the turbulent North Atlantic seas. In a discussion of fishing practices in Neolithic Orkney, Sturt (2005, p. 75) has suggested the need for a ‘seaworthy craft capable of dealing with Orkney’s frequent rough seas and strong currents’. This may have been a skin or hide boat that given its light frame provides enough freeboard, even when loaded, to maintain seaworthiness while also allowing it to be easily pulled ashore (Case, 1969, pp. 178–180; McGrail, 2001, p. 183). Although there is no direct evidence for the use of skin boats during the Neolithic, their use along the western seaways has been suggested based on iconographic and ethnographic evidence. Two prehistoric artefacts have been suggested to depict prehistoric skin boats—the Bronze Age Caergwrle bowl from North Wales and the Iron Age Broughter boat from Northern Ireland (Johnston, 1988, pp. 124–128)—and traditional Welsh coracles and Irish currachs have provided historical analogies. Although this type of watercraft can be sailed (see Severin, 1996 for the reconstruction of Saint Brendan’s medieval oxhide boat), the use of a sail leaves these lightweight vessels vulnerable to winds and adverse tides (Case, 1969). Thus,

with no extant evidence for the use of sail prior to the Bronze Age—and assuming the use of paddles as an essential part of the seafaring assemblage regardless of sail—paddling, at present, is the assumed method of propulsion for prehistoric skin boats (Muckelroy, 1978, p. 128; McGrail, 2001, pp. 182–183).

In addition to the type of watercraft and method of propulsion, the form of navigation would have strongly influenced sea routes, and as previously highlighted, along the highly indented coastline and tidally governed waters of the western seaways, there is great potential for coastal hopping and pilotage (Callaghan & Scarre, 2009, p. 367; Garrow & Sturt, 2011, p. 62). This is especially true for paddled voyages which would have involved longer travel times and more energy expenditure, thus necessitating more frequent stopovers than sailing. Indeed, Callaghan and Scarre's (2009) work suggested that even when sailing, single-leg voyages were often not possible or else lasted a duration of several weeks. Thus, at present, it is more plausible to view established Neolithic seafaring routes as a series of short voyages strung together through the use of the maritime landscape, and in this context, the relevance of tidal cycles, which would have governed landing and launching along this journey, is reinforced.

Integrated Maritime-Terrestrial Least-Cost Methodology

Focussing on palaeotidal and palaeogeographic data, the establishment of a maritime-terrestrial least-cost method within ArcGIS Pro was a long and exploratory process, requiring numerous iterations to adapt the method to the selected datasets. As previously stated, it is not the intention of this paper to form a didactic discourse on the established methodology, only to demonstrate why more holistic environmental approaches are essential to *any* methodology established to address prehistoric seafaring. Further, it is not simply through the computational analysis itself that a more contextualised perspective is achieved but through the entirety of the process: from the selection of parameters for the analysis to the interpretation of the results. Thus, the following discussion of the established methodology will instead focus on what is deemed by the author to be the most significant, and challenging, part of this process: the integration of palaeogeographic and palaeotidal datasets into a single cost surface.

The creation of the land-sea cost surface began with modelling the cost of movement through the seas using Ward et al.'s (2016) palaeotidal data for the year 4000 BC. Although the creation of a tidal cost surface imposes a static temporal component on an innately fluid surface, this inherent limitation of the least-cost approach was mitigated to best effect through the creation of four cost surfaces representing half flow, flow, half ebb and ebb tides for a given month, with each tidal cycle represented by its mean maximum magnitude, or rate of flow, following the Rule of Thirds (Brown, 2006). However, each tidal surface was represented by two values, magnitude and direction, which as previously highlighted prevents the ability to assign a single cost value to each cell of the cost surface. To mitigate this challenge, it was decided to incorporate the direction of maritime movement into the tidal cost surface, thereby removing the variations in travel cost that will occur as a result of

the variable relationship between tidal direction and direction of movement and instead allowing cost values to be assigned directly to tidal magnitude based on its direction of flow compared to the direction of desired travel. This assumes the ability and tendency for Neolithic seafarers to take advantage of tidal propulsion (and avoid adverse tidal currents), but given that tides generally flow northward along the archipelago during the flood tide and southward during ebb (Ramsay & Brampton, 2000), the introduction of simplistic northward and southward directions of travel into the cost surface was deemed a suitable approach. Along with the roughly 45° geographic orientation of the archipelago, the direction of modelled movement was thus constrained to 90° windows. Thus, tidal magnitudes flowing in the direction of north to northeast were assigned the lowest cost value on the mean flow and half flow cost surfaces, and tidal magnitudes moving south to southwest were assigned the lowest cost value on the mean ebb and half ebb cost surface. From these values, tidal currents moving perpendicular and opposite to the direction of travel were then assigned increasing costs (Table 1). The reduction of tides down to essentially four directions of movement may result in more generic routes, but it also diminishes the modelling of single-cell movement within the least-cost analysis, which presents spatial constraints that are not realistic to actual seafaring (see Gonçalves, 2010 for analysis of ‘wide paths’ within least-cost modelling). Further, given the greater horizontal flexibility of maritime movement, more generic seafaring routes were deemed acceptable since the true emphasis within these models was on the juncture between land and sea.

The conversion of absolute values into relative values has been criticised by Conolly and Lake (2006, p. 255) due to the altered relationship between cells in the cost surface from a ratio to an interval scale. However, such an approach was necessary as it not only rectified the challenges created by the presence of two variables

Table 1 Relative cost values assigned to tidal magnitude based on its respective tidal direction for both northward and southward maritime movement along with the values assigned to land slope degree as derived from the palaeogeographic reconstruction. The cost value 5 serves as a tether between the palaeotidal and palaeogeographic datasets, allowing the models to cross onto land when launching or landing or when maritime movement forward is halted. The high cost assigned to the Isle of Skye was necessary to prevent movement across this landmass

Land-sea cost surface values			
Cost value	Tidal direction		Land slope
	Movement north (flow, half flow)	Movement south (ebb, half ebb)	
1	0–90°	180–270°	
3	90–180°	90–180°	
3	270–360°	270–360°	
5	180–270°	0–90°	0–8°
10			8–16°
15			16–89°
225 (Isle of Skye)			

within the tidal data (albeit through a simplification of tidal currents) but also allowed for the landscape (which has a different unit of cost) to be incorporated into the cost surface. Following experimentation with different cost values and intervals, a slightly higher value was assigned to any tidal magnitude moving opposite to the direction of travel to prevent any regressive movement. This separation between cost values was also necessary to be able to incorporate the landscape more effectively into the cost surface. By integrating the landscape at the highest cost of movement through the seas (value 5), the models were given the equivalent option of moving onto land if tidal currents prevented travel forward, but the greater separation between the cost values deterred the models from crossing the landscape too often (as they tended to do with consecutive intervals).

The cost value selected to model movement between land and sea was slope degree derived from the elevation values of the palaeogeographic reconstruction. The many physiological, cultural and environmental factors that may have been significant for early seafarers have been addressed by previous maritime LCA research (Gustas & Supernant, 2017; Kealy et al., 2018); however, given the emphasis of this study on the integration of terrestrial and maritime datasets, the focus remained on the interface between the two surfaces and the ability to merge them in a relatively seamless and effective manner. With slope being an indicator of both coastal topography and beach sediments, the use of slope to represent transitional costs ensured that the models chose crossing points conducive to launching or landing a skin boat (*i.e.* sandy and/or shallow-shelving coastlines). As most beaches with fine to medium-grained sands range in gradient between 1 and 8° (Short, 2012), this was the selected slope range for identifying potential transitional places. This slope range was thus assigned a cost value equal to that of tides moving in the opposite direction of desired travel, with increased values assigned to greater slope ranges (see land slope values in Table 1). By staggering these intervals, the models were thus induced to only move across the landscape when necessary, either for launching and landing or when encountering adverse tidal streams, and were also encouraged to

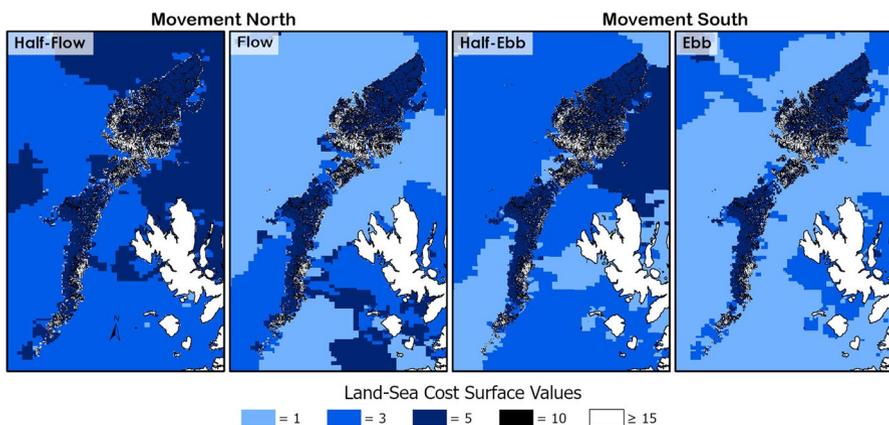


Fig. 5 Land-sea cost surfaces used for the least-cost analysis, with 1 (light blue) representing lowest cost to travel and 15 and greater (white) representing the highest cost

choose the most suitable transitional points in so doing. Applying these cost values to the associated data, four land-sea cost surfaces were created for the LCA (Fig. 5).

The analysis was conducted following the general process for the creation of least-cost pathways in ArcGIS, which includes the use of the *Cost Distance* tool to create accumulated cost and backlink rasters for each site that can then be used within the *Cost Path* tool along with the origin and destination points in order to generate vector-based least-cost pathways (LCPs). At this stage, incorporating the landscape into the cost surface had the primary advantage of allowing for the analysis to be conducted for 14 Neolithic sites of varying locations within the landscape, with pathways being generated from each site to all other sites (Fig. 6).

One Way or Another: Transitional Places, Waypoints and Waymarkers Along Seafaring Routes

Transitional Places in the Maritime Landscape

To further identify and explore the transitional places highlighted by the results, a 50-m coastal buffer was created around the palaeocoastline and all LCPs crossing through this buffer zone were extracted. The landing and launching places identified from the buffered results were then compared to modern aerial imagery as well as the Neolithic palaeogeography. This revealed, rather unsurprisingly, that the

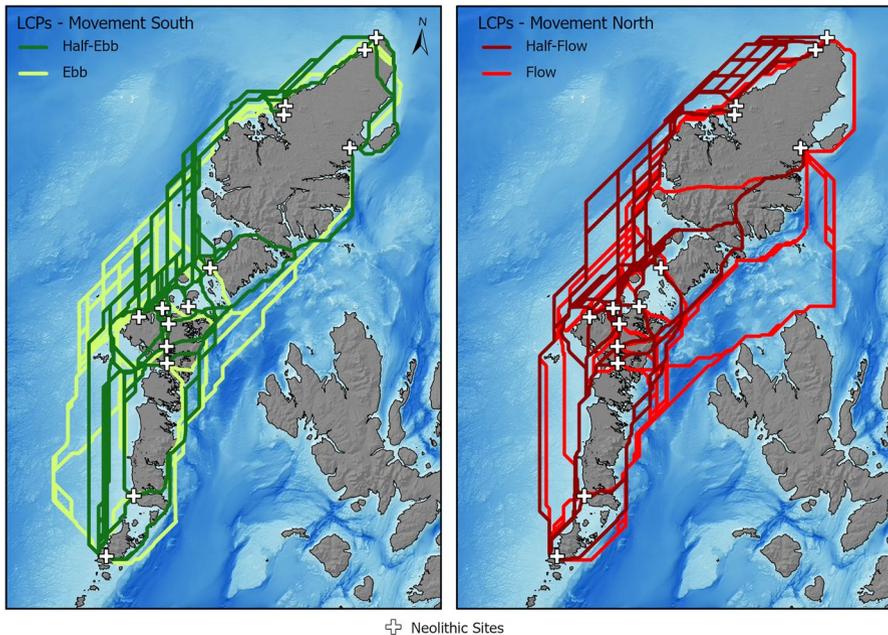


Fig. 6 Low tide, high tide and half tide least-cost pathways generated for 14 Neolithic sites. (See [Supplementary Materials](#) for further information on the sites used in analysis)

majority of transitional places identified along the lower-lying west coast are now submerged, and those that are not submerged appear to utilise suitable maritime landscapes, such as low-lying coasts or sea lochs. Also of note was the proximity of transitional places to modern maritime infrastructure, with extracted pathways crossing through or within 250 m of five major harbours (of nine in total) around the archipelago (Fig. 7). The proximity of modelled transitional places to these harbours is significant as it lends validity to the established methodology and demonstrates that, at least in these instances, the overlapping cost values and intervals that were chosen to represent the juncture between the palaeogeographic and palaeotidal models were appropriate.

As all modern harbours highlighted by the modelled pathways are located along or accessible from the Minch, a further inspection of modern maritime infrastructure around the archipelago reveals a predilection for the eastern maritime landscape. No

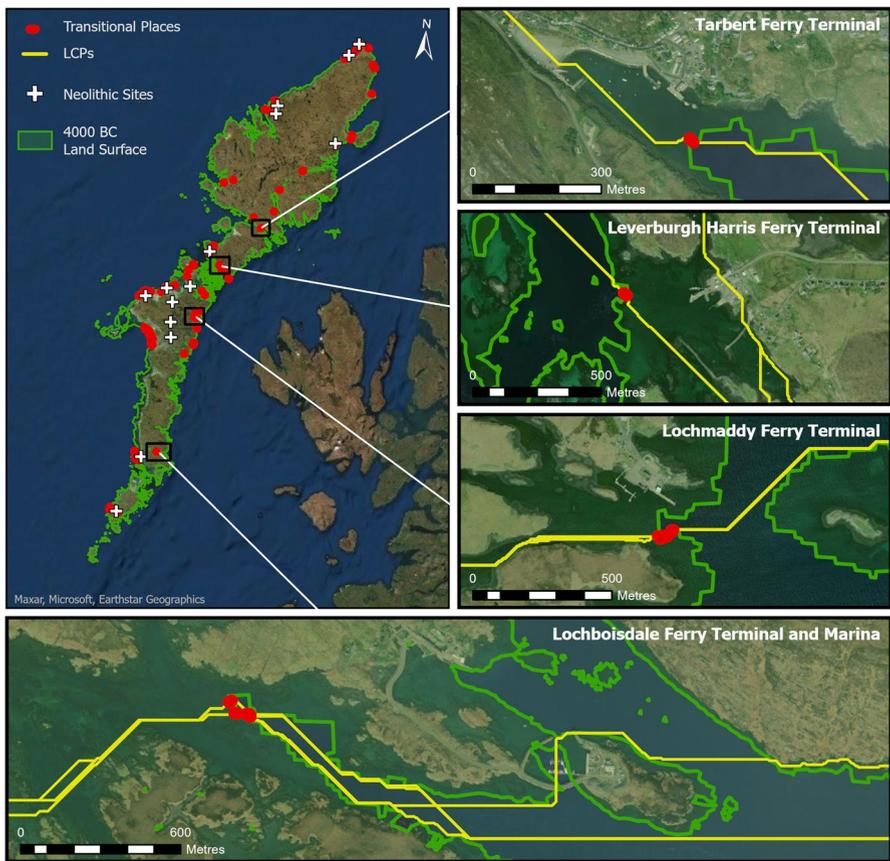


Fig. 7 Transitional places identified using a 50-m coastal buffer to extract least-cost pathways crossing the coastline, and the proximity of these identified transitional places to modern maritime infrastructure (insets)

major harbour in the archipelago is located along the Atlantic seaboard, and indeed, the buffered LCPs do not reveal a markedly greater concentration of transitional places along the west coast compared to the east coast, despite 12 of the 14 analysed sites residing on or nearer to the Atlantic. Given its geographic position, this eastward or mainland focus is comprehensible; most modern maritime movement to the archipelago, rather necessarily, arrives from the east. Yet, this eastward focus pervades not just broader maritime connectivity but also local seafaring practices. For instance, the Monach Isles, a group of islands situated in the Atlantic around 8 km from the west coast of North Uist, are the traditional fishing ground for communities living on the island of Grimsay off the southeast coast of North Uist (Norton, 2000, p. 2). This has led Rennell (2009, p. 208) to suggest a 'long established association between east coast communities and fishing practices in the history of the Outer Hebrides'. Although there may be many cultural or otherwise intangible factors leading to the establishment of this tradition, indubitably the environment would have been a major influencing factor.

The strong geological and topographical distinctions between east and west on the islands that comprise Uist have already been discussed, and this delineation is further accentuated through the pervasive character of the abutting seas. Gently sloping sandy beaches may sound ideal for landing a soft-hulled, lightweight boat, but a more holistic understanding of the environment and modern seafaring practices reveals a less inviting picture. The flat and homogeneous nature of much of the western seaboard would have left it exposed to the often-harsh elements of the North Atlantic, creating a dynamic maritime landscape. The machair plains that fringe the Atlantic coast provide the most fertile land in the Outer Hebrides, leading to a long history of anthropogenic use (Edwards et al., 2005; Whittington & Edwards, 1997) and thereby a greater density of Neolithic sites along the west coast (Armit, 1996). Yet, machair landscapes are also fragile and transient. The continual accretion and erosion of machair sands would have been localised based on a variety of factors, including coastal topography and orientation, sea conditions and storminess (Dawson et al., 2004; Whittington & Edwards, 1997), factors that would have likewise influenced maritime practices. As previously mentioned, the nature of storminess and oceanicity during the Neolithic is unclear, but a powerful example of the potential force of the Atlantic and its effect on the maritime landscape occurred during a severe storm in 1756 that turned regions of the west coast of North Uist into tidal islands and buried houses up to their roofs in sand (Gilbertson et al., 1999, p. 443). This exposed and dynamic maritime landscape would not have precluded seafaring practices necessarily, but it would have imbued the use of the western maritime landscape with a similar transience, both temporally and spatially.

This is evident in the transitional places highlighted around North Uist, which demonstrate a tendency for sites to be more broadly distributed around the western and northern coasts than around the east coast; in other words, landing and launching points along the western seaboard were not constrained to specific places and instead demonstrated the affordability or equal likelihood of crossing the shallow-shelving coastline at a range of places (Fig. 8). While this suggests fewer hindrances to transitioning across the west coast, the omission of winds and waves from the maritime cost surface, which today present the greatest challenges to seafaring along

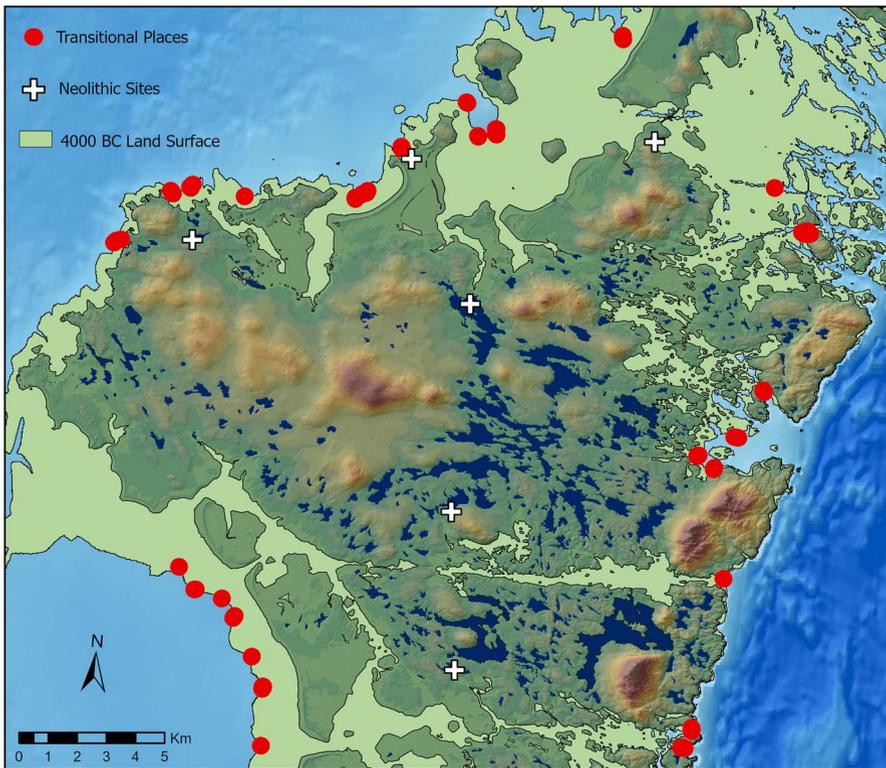


Fig. 8 Transitional places identified around North Uist showing the greater spatial variability of landing and launching places on the west and northwest coasts compared to the more restricted use of the eastern maritime landscape. (See [Supplementary Materials](#) for archaeological and environmental datasets)

the Atlantic coast of the Outer Hebrides (Ramsay & Brampton, 2000, pp. 33–34; Mason, 2017), must be noted. These elements can be both seasonally predictable and diurnally unpredictable, and their strong connection to the temperaments of the North Atlantic further illustrates an overall unpredictability of the suitability of the west coast as well as the need for any maritime practices taking place along it to continually adapt to the whims of the ocean.

Conversely, transitional places along the east coast fall within the same specific locations. This is primarily due to the fragmented geography, rugged geology and complex topography of the eastern seaboard, and while these features more strictly delineate movement across the coast, they are also the primary factors contributing to its overall suitability for seafaring practices. The east coast has also undergone less inundation since the Neolithic due to an overall more elevated and rugged coastline along with minimal isostatic subsidence compared to the west coast. This relative constancy demonstrates the more durable and stable nature of the eastern maritime landscape, which would have enabled a longer continuity of use of these spatially resolute transitional places—in addition to allowing for LCPs modelled

on the Neolithic palaeogeography to broadly coincide with modern maritime infrastructure. Yet, it is not simply the durability of this landscape but also its complexity that would have enabled maritime practices. As highlighted by Rennell (2009, pp. 288–289), the Atlantic seaboard would have been more suitable for shore-based subsistence practices, such as collecting shellfish and gathering seaweed, while the eastern seaboard would have provided the sheltered waters necessary for the maintenance of seafaring practices. Along the latter, punctuating sea lochs provide access deep inland, and numerous inlets, bays and coves provide harbours and shelters for watercraft. Although the more localised nature of inundation within the many sea lochs of the Outer Hebrides remains unclear, wherever this interface occurred, these features, chiselled into a rugged coastline, doubtless would have been conducive to movement.

The many intricacies of the eastern maritime landscape and its suitability for maritime practices are evident in modern small boat pilots which particularise the multitude of harbours and anchorages around the archipelago and their means of accessibility (Mason, 2017) (Fig. 9). Sturt (2006, p. 120) has introduced the inextricability of time and space within maritime archaeological research through the example of pilot guides, which serve to ‘bridge the gap between the lived experience of the sailor and the cartographer’s abstract conceptions’. In this case, local pilots not only offer a detailed view of the many intricacies that make the eastern seaboard suitable for seafaring practices but also provide a strong sense of the temporality that governs these maritime spaces. For instance, many harbours around the archipelago can only be accessed between half and high tide, and even movement through several sounds and channels presents a tense negotiation between tide and rock (Mason, 2017, p. 81). Whereas this is primarily due to tidal heights and affects larger watercraft with deeper draughts, tidal currents can also facilitate or hinder maritime movement. Heavy overfalls occur at the mouths of many sea lochs during ebb tide, and even modern vessels are advised not to travel against tidal currents within these lochs (Mason, 2017). McGrail (2001, p. 171) has suggested the use of tidal propulsion within Atlantic estuaries to provide a ‘free-ride’ upstream or downstream, and the same may be true for the sea lochs of the Outer Hebrides, with half tide to flow facilitating access to the maritime landscape and half tide to ebb marking the ideal start to a maritime journey. The predictable rhythm of the tides and its intricate dance with the maritime landscape would have thus engrained itself in maritime practices and been imparted through local knowledge, thereby promoting more temporally predictable and spatially consistent maritime practices along the eastern seaboard.

The strong differences between the eastern and western maritime landscapes evoke the distinctions between landing places and maritime havens elucidated by Bradley et al. (2016). Whereas the Atlantic coast epitomises the spatially and temporally ephemeral landing places, the east coast provides the maritime havens necessary for harbouring and sheltering—places suggested to have been in use for prolonged periods of time (*ibid*, p. 126) and perhaps imbued with the same rhythms. These distinctions permeate not only the rhythm and use of these maritime landscapes and the seafaring practices taking place along them but also the ability to know and understand these practices in the present.

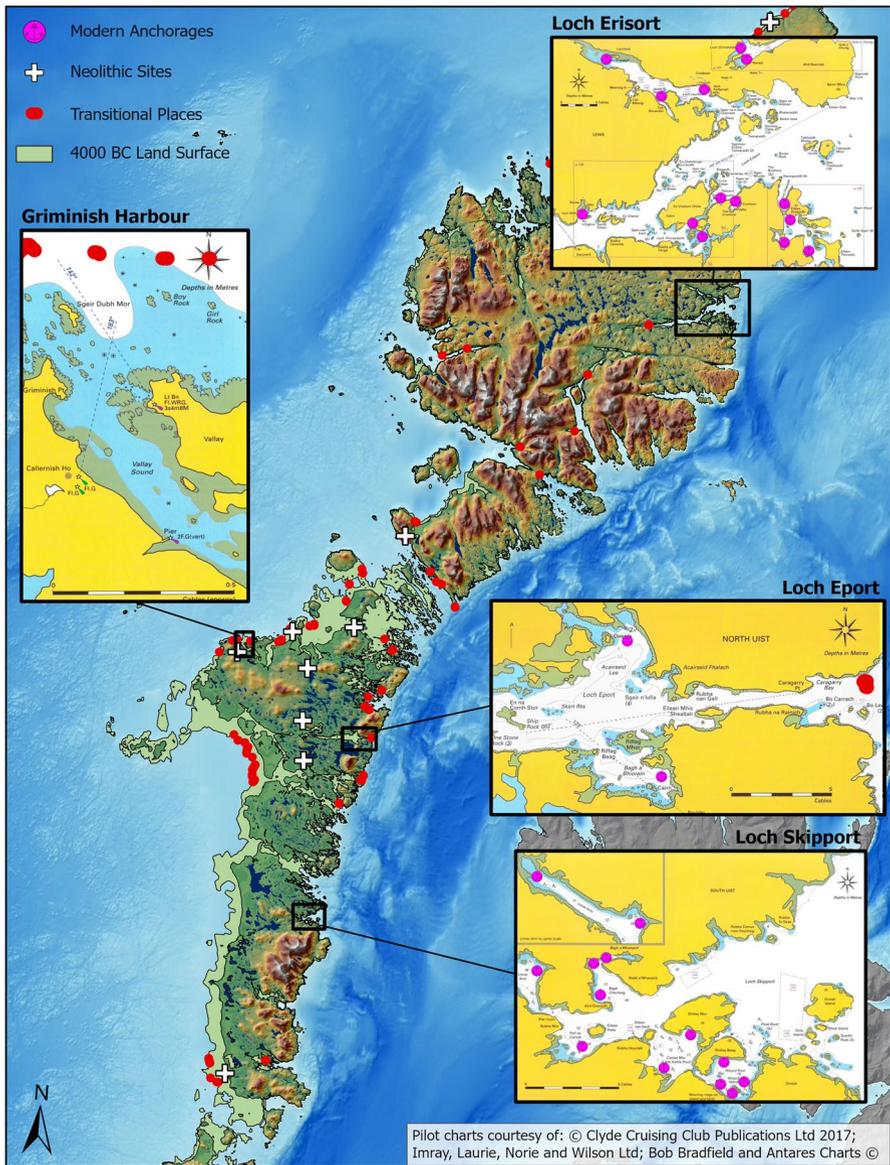


Fig. 9 Transitional places compared against modern pilot guides, demonstrating the intricacy of the eastern maritime landscape and its overall suitability for maritime practices compared to the relatively homogeneous western maritime landscape. The abundance of anchorages along the east coast further demonstrates its suitability, contrasting the single harbour on Uist that is accessible from the Atlantic (left inset). (See [Supplementary Materials](#) for archaeological and environmental datasets)

Waypoints and Portages Along Seafaring Routes

In addition to suitable transitional places, the LCPs also demonstrate how the maritime landscape and its highly indented coastline may have been used along broader maritime routes. Some of these potential waypoints are now submerged, but one notable route revealed by the models is the crossing of Tarbert, a narrow isthmus

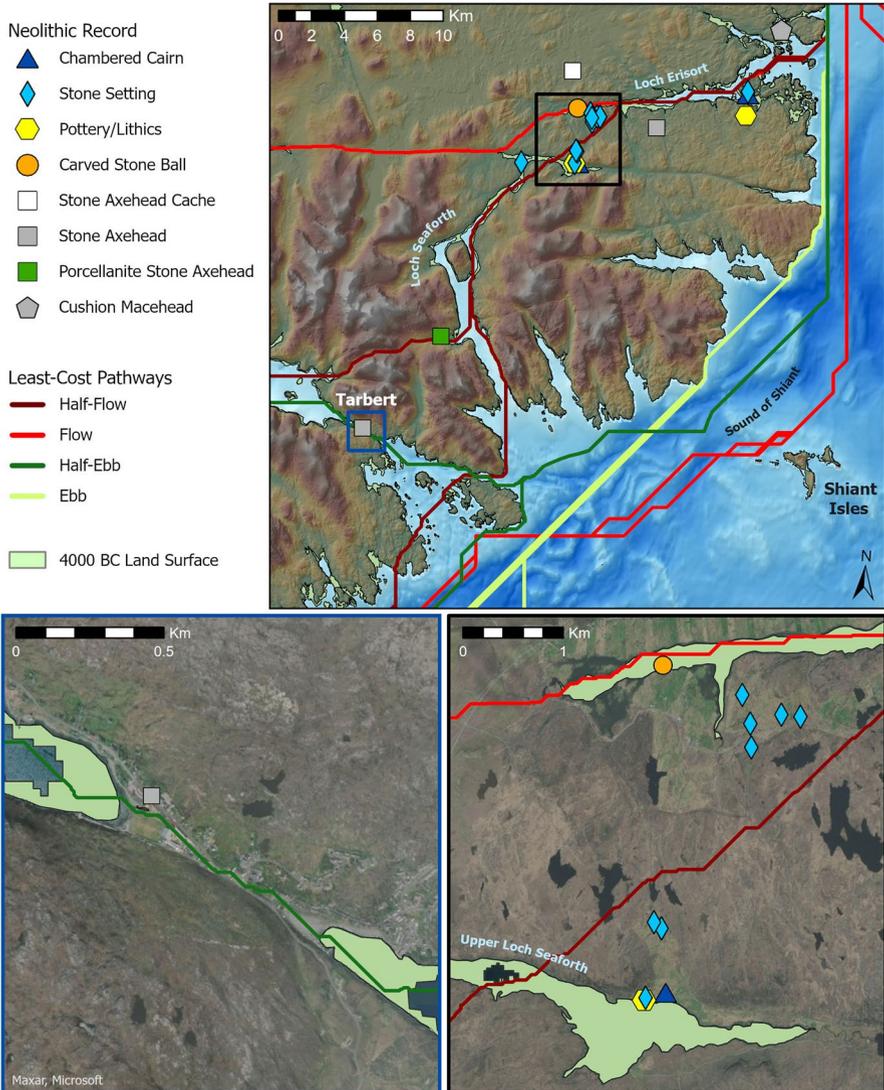


Fig. 10 Waypoints through the Isles of Harris and Lewis (top) along with location of all Neolithic archaeology in the region. The insets show the potential portage across Tarbert (left) and between Loch Seaforth and Loch Erisort (right). (See [Supplementary Materials](#) for archaeological and environmental datasets)

less than 1 km wide that connects the northern and southern landmasses of the Isle of Harris (Fig. 10). The sounds on either side of Tarbert offer ideal harbouring places, with East Loch Tarbert home to one of the major harbours highlighted by the modelled transitional places (see Fig. 7). The name Tarbert itself is derived from the Gaelic *tairbeart*, meaning ‘over-bringing’ or ‘isthmus’ (Watson, 1973, p. 505), suggesting a long history of use of this region as a portage between the Atlantic and the Minch.

To the northeast of Tarbert, the LCPs also revealed a route that involves a more extensive portage between two deeply penetrating sea lochs. Loch Seaforth is a roughly 23-km-long sea loch on the east coast of Harris that marks the traditional divide between Harris and Lewis. Entering this sea loch provides access deep inland, and upon reaching Upper Loch Seaforth, the LCPs crossed the roughly 3.5-km stretch of land between Loch Seaforth and Loch Erisort before using the latter to enter the North Minch and continue the journey northward (see Fig. 10). The region between these sea lochs may seem an unlikely candidate for discussions of seafaring, but its Neolithic usage is suggested by the archaeological record and its maritime usage may be revealed through toponymic research.

Along the northeast bank of Upper Loch Seaforth sits a stone circle, which has produced pottery and worked lithics (Curtis & Curtis, 2006), as well as a potential Neolithic chambered tomb. Around 1.5 km to the north of these sites, two monoliths sit on a knoll, and from the northernmost of these, a stone setting is visible around 2 km to the northeast (Burgess, 2004, pp. 46–47). This stone setting is one of a group of five positioned on a hillock overlooking Loch Erisort, revealing some form of intervisibility, if not connectivity, between these two regions. In addition, a carved stone ball has been recovered from the head of Loch Erisort (Marshall, 1976, p. 68) around 40 m from this potential portage, and a bit more distant but nonetheless notable, a cache of five stone axe-heads was found on the shore of a loch around 2.3 km to the north of the head of Loch Erisort, two of which have been suggested to be of foreign provenance (Cowie, 1981, p. 50). Moreover, the Gaelic name for Seaforth is *Shiphòirt*, which may need no translation but is nonetheless reminiscent of the Gaelic name for a sea loch on the east coast of South Uist, *Sgiopòirt*, derived from the Norse word for ‘ship-port’ (Raven, 2005, p. 52). Acknowledging that etymology is a complex subject, the fact that this potential Neolithic portage begins at the head of this later ‘ship-port’ is nonetheless noteworthy.

Determining whether this region formed part of a Neolithic ‘portage road’ will require more targeted fieldwork, but it is worth noting the potential evidence for portaging elsewhere in the Outer Hebrides. Toponymic research of loch names in North Uist has led to the suggestion that a portage existed between a large freshwater loch and Loch Eport—a long, narrow sea loch highlighted as a transitional place on the east coast (see Fig. 9)—which may have involved the transport of the boat itself (Angus, 2020, pp. 17–18). As stated by Angus (*ibid*, p. 22), ‘the presence of a boat-haul place-name in North Uist suggests that even dry land was not regarded as a barrier to hauling a boat’. Rennell (2009, p. 202) has similarly suggested the benefits of carrying or dragging watercraft across the Outer Hebridean landscape to move from loch to loch; having walked much of the landscape as part of her doctoral research, ‘the advantages of using a boat to help traverse this area proved clear’.

While the archaeological and toponymic records lend support to the possible presence of a portage road between Loch Seaforth and Loch Erisort, it is the nature of the surrounding seaways that may help explain its existence. The narrowed stretch of waters between the Isle of Skye and the Outer Hebrides is known as the Little Minch, and it is here that the wing-like extensions of Skye stretch towards the central islands of the archipelago, constricting the Minch at the waist and channelling tidal streams over an uneven seafloor. When peak tidal flows combine with high winds or severe weather, the Little Minch can become a dangerous stretch of waters filled with steep waves that can challenge even modern seafarers (Mason, 2017, p. 106). Within these waters, around 20 km from the northern tip of Skye and less than 7 km from the coast of Lewis, sits a small trio of islands known as the Shiant Isles. These islands were highlighted along modelled routes through the Minch, with some flood tide (or northward moving) pathways passing within 300 to 600 m of them—a noteworthy phenomenon considering the Shiant Isles were omitted from the terrestrial portion of the cost surface. Yet, this small trio of unassuming islands has played a significant role in maritime movement through the Minch, especially between Skye and Lewis. No definitive Neolithic materials have been recovered from the Shiants, but a Middle Bronze Age gold torc was discovered by fisherman during scallop dredging to the west of the islands (Nicolson, 2001, pp. 95–97), evidencing some form of maritime movement, perhaps unsuccessful, through the region during prehistory. Later, as the Kingdom of the Isles stretched across the western seaboard of Scotland, c. 1100–1336 AD, the islands became a fixture in narratives of seafaring between Lewis and Skye (Macfarlane, 2012; McDonald, 1997; McIntosh, 2016; Nicolson, 2001), and today they provide a waypoint or temporary haven for modern seafarers attempting to cross the Little Minch (Mason, 2017, p. 107).

The utility of the Shiant Isles along broader maritime routes is self-actualised, offering shelter from the challenging seas these islands help create. From the Shiants, a shallower seafloor extends towards the east coast of Lewis, further constricting the seas over a complex seafloor topography composed of ‘numerous banks, knolls and arcuate scarp and dip ridges’ (Chesher et al., 1983, pp. 3–5). This produces strong tidal currents during flood tide and dangerous overfalls at ebb (Mason, 2017, p. 108), during which waters from the surrounding sea lochs, including Loch Seaforth, rush into the Sound of Shiant at a quicker rate than the whole of the Minch can ebb into the Atlantic (Nicolson, 2001, pp. 35, 38). The dangers of this sound are thus well-noted within both navigation charts and maritime folklore. Adam Nicolson, former owner and periodic occupant of the Shiant Isles, described the effects of strong winds against a spring tide, which can result in ‘a chaos in which there are not only steep-faced seas coming at you from all directions, but terrifyingly, holes, pits in the surface of the sea, into which the boat can plunge nose-first and find it difficult to return’ (*ibid.*, p. 38). In Gaelic, the sound is known as *Sruth na Fear Gor*, or the Stream of the Blue Men, and Hebridean folklore is rife with stories recounting the lives lost to the fabled Blue Men who are said to inundate boats unless passing seafarers can hold them at bay through rhyme (Nicolson, 2001, pp. 38–39; Macfarlane, 2012, pp. 97–98, 104; McIntosh, 2016, p. 41). More judiciously, this allegory highlights the turbulent nature of this sound and the fear and awe it inspires even in modern seafarers.

The strong tidal currents through the sound thus influenced the modelled pathways to move through the sea lochs and across 3.5 km of land, despite the much higher cost of moving through the landscape as stipulated in the cost surface values. Likewise, the dynamic and at times turbulent nature of these waters may have induced Neolithic seafarers to avoid the Sound of Shiant, using the portage road through Harris and Lewis as a safer, more reliable route, at least during peak tidal currents or otherwise adverse conditions. This would have engendered a rhythm of use of this potential portage road based on the overlapping cycles of tide, season and weather, but any understanding of both its existence and its rhythms would have been obtained and transmitted through local knowledge.

Repetitive Markers for Broader Seafaring Routes

In an archipelago heavily dominated by its maritime environment, the character of the surrounding seas is pervasive. Although the North Atlantic is considered the ultimate impelling force behind human activity in the archipelago, the eastern focus highlighted by the results of the LCA demonstrates the equally strong influence of the tidally governed Minch. These opposing forces pervade the abutting maritime landscapes and envelope the archipelago and its inhabitants in a complex layering of cycles of time. The ubiquitous cycles of the season would have impacted seafaring within the Atlantic and Minch alike. For instance, Nicolson (2001, p. 91) has highlighted the dangers of crossing the Minch between the autumnal and vernal equinoxes, an act referred to as ‘crossing the equinoctial Minch’, and Rennell (2009, pp. 288–89) has noted how modern fisherman ‘only contemplate working off the west coast during summer months, and even then only in suitably calm weather conditions’.

While the annual cycles of the sun would have broadly delimited the optimum seafaring season, the varying phases of the moon would have imposed a range of shorter cycles performed through the rhythm of the tides. In the Outer Hebrides, ‘sufficient information to predict tides with reasonable accuracy can be gathered in as little as four weeks (a Spring-Neap tidal cycle) in most locations’ (Ramsay & Brampton, 2000, p. 8), creating predictable temporalities of seafaring affordances, especially along the tidally governed Minch. This predictability of the tides and the ability to take advantage of the cyclical affordances they provide would have been a significant feature in the lives of prehistoric maritime communities in Scotland, whether engaging in seafaring practices or coastal activities (Pollard, 1996), and the tides still maintain a powerful presence in the Outer Hebrides. As argued by Jones (2010, pp. 189–190), the great tidal fluctuations in the UK form a hybrid lunisolar temporality, driven by interwoven solar and lunar rhythms, and it is this hybrid temporality that seems to permeate throughout the archipelago. In one eighteenth century account, a visitor arriving at the Outer Hebrides was surprised to find that ‘his worldly cousins should ignore British Summer Time – then a recent innovation – in favour of solar time that governed the all-important tide’ (Macdonald, 2013, p. 7). These predictable cycles, demarcated within the maritime landscape, would have allowed for the establishment of more reliable seafaring routes and the generation

of a local knowledge base that together would have enabled more consistent routes of connectivity. As stated by Lefebvre (2004, p. 90) in his book on rhythmanalysis, ‘rhythms imply repetitions’, and repetitions imply frequency and the development of patterns. In any study of past movement, understanding patterns of movement is pertinent (Bell & Leary, 2020, p. 2), especially for movement taking place along the coast, which has its own rhythms of movement influenced by the ebb and flow of the tides (Leary & Kador, 2016, p. 8).

However, it is also important to consider what happens when these predictable cycles are superimposed by the more capricious conditions of the North Atlantic. Both seas would have been subject to unpredictable storms or the perfect storm of unfavourable conditions; yet, it is the eastern seaboard that would have offered greater protection from these elements. Today, the islands of Uist provide a breakwater for Atlantic swells and a sheltered passage for seafaring through the Minch (Raven, 2005, p. 51), which can be assumed to have been even more protected given the probable connection of the islands of Uist during the Neolithic and the profound difference in coastal and tidal dynamics that the opening of these channels has now caused (Ritchie et al., 2001, p. 121). In comparison, the relatively flat and homogeneous Atlantic coastline would have provided little shelter for seafarers; indeed there are no anchorages on the west coast of Uist and only one harbour at Griminish, which is dangerous to enter ‘in bad weather, heavy swell, poor visibility or, if entering for the first time, in anything other than benign conditions’ (Mason, 2017, pp. 134–35) (see inset in Fig. 9). This would have left little safety along a coastline subjected to the unpredictable whims of the tempestuous Atlantic, and although the greater complexity of the west coast of Harris and Lewis offers more-sheltered waters, access to these anchorages is still restricted by tides and weather.

In an environment where predictable cycles are superimposed by mercurial temperaments, the establishment of reliable maritime routes would have also been predicated upon the ability to mitigate the adverse effects of unpredictably harsh weather and sea conditions. This is well-illustrated by Neil MacEachann’s recounting of Prince Charles Stewart’s escape after the battle of Culloden that involved a harrowing journey from Skye to Lewis in the middle of a severe storm, during which:

the whole elements seemed to rebel against them, and threatened to send them every moment to eternity; the wind, which continued to blow fair the whole night, coming about to the north, quite contrary to their course... made them despair of continuing their intended voyage any further, and so [they] prepared for death, as being sure to be shattered upon the rocks of the nearest shore (Blaikie, 1916, p. 231).

They continued that way until daybreak when Rory MacDonald, who stood at the helm, piloted them safely into a harbour on Uist, which he knew to be one of the best on that coast (*ibid.*, p. 231). Thus, even with a knowledge of the character of the Minch and its tidal rhythms, access to sheltered waters and, just as importantly, the local knowledge of them becomes crucial when faced with unforeseeably inclement circumstances.

Overall, it is local knowledge of the rhythms and character of the sea and abutting maritime landscape that would have allowed for more reliable routes of maritime

movement, and it is conceivably along the eastern seaboard that this knowledge would have been imparted. This is not simply because of the more temporally and spatially stable and predictable transitional places found along it but also because, as stated at the beginning of this discussion, nearly all connectivity must necessarily arrive from the east. The rugged and durable eastern maritime landscape would have thus provided not only enduring transitional places but also the visible and distinctive features by which to safely navigate to these places. Burch (2016, p. 52), in his guide to inland and coastal navigation, demonstrates how fundamental piloting by natural ranges is to navigation, without which seafarers would have to rely on some form of dead reckoning and even then would need to use piloting to fix their position throughout the journey.

This is evident in movement between the Outer Hebrides and the west coast of Scotland. For instance, along modern routes from North Skye to Lewis, the distinctive conical form of Dun Todden provides a bearing to avoid overfalls and hazards when crossing the Little Minch (Mason, 2017, pp. 106–107), and as this large landform sits on the southern bank of the entrance to Loch Seaforth, it may have also marked the entrance to this potential pilotage road as well. Likewise, the major landforms on the eastern seaboard of Uist are used for piloting along the Minch (Mason, 2017, p. 62), and as they also mark the entrances to numerous sea lochs including Loch Eport, they may have been significant for identifying and piloting into these potential Neolithic transitional places as well. Indeed, some modelled pathways even diverted to Skye to avoid strong tidal streams in the Minch, highlighting the great potential for maritime connectivity between the two regions. Thus, these visible fixtures of the eastern maritime landscape combined with the predictable rhythms of the Minch would have enabled more reliable and thus consistent routes, which may have in turn helped establish longer-distance seafaring networks.

This stands in contrast to previous discussions of Neolithic seafaring around the archipelago, which have highlighted the denser concentration of Neolithic sites along the west coast and suggested their development in relation to seafaring routes through the Atlantic (Burl, 2000, pp. 39–40; Henley, 2005). Due to the strong tidal races that exist in the Minch, Burl (2000, pp. 93–94) has suggested that Neolithic seafarers would have avoided the Minch entirely and instead travelled along the Atlantic coast. This theory is largely influenced by the location of Callanish—a remarkable cruciform stone setting erected between 2900 and 2600 BC (Ashmore, 2016, p. 64)—near one of the few sea lochs on the Atlantic seaboard of Lewis. However, this theory does not consider the many affordances that can be achieved through local knowledge of this intricate and complex maritime space. For instance, it is plausible that the potential portage road highlighted through Harris and Lewis may have offered an alternative route to travel through the more exposed and unpredictable Atlantic as much as it offered an alternative to movement through the Little Minch. Indeed, the stone setting found on the north bank of Upper Loch Seaforth has been considered as part of the broader Callanish ceremonial complex (Curtis & Curtis, 2006), and this portage road may thus have been part of the structured journey from the outside world to Callanish as discussed by Richards (2013). Thus, while discussions of Neolithic seafaring around the Outer Hebrides have focussed on the exotic narratives of long-distance movement to the archipelago by foreigners,

the local knowledge and experience of Outer Hebridean seafarers and the many maritime affordances that could have been unlocked through this cognition have been overlooked. Yet, it is presumptively the local knowledge of these unique maritime spaces and the temporalities that encompass them that would have enabled the establishment of longer-distance seafaring routes, and thus, such broader narratives can only be built upon the local and particular narratives that underpin them.

Final Remarks

The need for more holistic and contextualised approaches to past seafaring has been borne out of a long history of maritime archaeological research, and it was through entreaties for more integrated approaches to land and sea as well as the adoption of a seafarer's perspective that such a practical application was sought. The resulting analysis has demonstrated not only the feasibility of a more comprehensive approach to the environment but also its great efficacy. As such, this study offers a tantalising glimpse of the insight that can be gained from the application of holistic perspectives and heuristic approaches to past seafaring. Although a least-cost analysis was deemed the most suitable method for this research, its effectiveness is contingent upon the ability to incorporate the factors deemed relevant to the study area. Accordingly, the exact methodology used to model prehistoric seafaring becomes subordinate to the need to consider the unique character of the maritime environment and practices being studied—factors which will vary significantly by region and period and thus suggest no uniformly appropriate methodology. Furthermore, the resulting seafaring models should not be viewed as definitive representations of past seafaring routes but rather as traces of the spaces that it may be advantageous to further explore. In this case, modern and historical seafaring practices and traditions helped bridge the gap between inherently quantitative computational models and the actual maritime spaces they highlighted through the more contextualised perspectives they enabled.

Through an informed and integrated approach, greater insight was provided into the nature of Neolithic seafaring around the Outer Hebrides, including how the combined influence of terrestrial and maritime environments would have affected the location of transitional places, the use of waypoints along seafaring routes and even the nature of routes themselves. While shallow-shelving sandy beaches were the primary focus for identifying landing and launching places, the models highlighted the greater suitability of an intricately carved maritime landscape for seafaring practices. In addition, the modelled routes highlighted the use of isthmuses and other possible portages which have heretofore not been considered in discussions of Neolithic seafaring around the archipelago. The modelling of these portage roads was the result of turbulent surrounding seas, and regardless of whether they actually existed in the Neolithic, they demonstrate the importance of a local knowledge of these multifaceted maritime spaces and the temporal cycles that govern them. This local knowledge would have enabled safer and more consistent seafaring practices, even when faced with unpredictable storms and unfavourable conditions. Hence, the transitional places, waypoints and waymarkers highlighted by this analysis provide a

clear demonstration of why disentangled perspectives of land and sea will not generate the contextualised perspectives necessary to truly understand past seafaring.

Beyond the Outer Hebrides, the movement of several routes towards the Shiant Isles demonstrates the need for reduced spatial resolutions in order to consider the role of smaller, unassuming islands along seafaring routes. Conversely, however, the movement of some routes towards the Isle of Skye demonstrates that circumscribed boundaries or modern geographical borders are often transcended when addressing past seafaring. Much like the study of island and coastal communities more broadly, in modelling past seafaring the appropriate boundary of the analysis can often become blurred, the fluidity of the seaways enabling transient trajectories of movement based on a variety of tangible and intangible factors. Although this may suggest the need to approach past seafaring from a wider perspective, it is clear that broad spatial scales do not provide the more detailed spatial and temporal resolutions that should be sought when addressing a topic as intricate and inimitable as maritime movement. As this paper has shown, more contextualised understandings of past seafaring are not only feasible and fruitful but also informative regarding potential connectivity at a broader scale. These insinuations of broader patterns of movement within more detailed models can drive future work, both subsequent iterations of past seafaring routes and archaeological research more broadly.

The move away from exotic narratives of long-distance movement and connectivity to focus instead on the human-scale of seafaring mimics criticisms of the heavy focus on broader scale migration patterns in studies of movement (Bell & Leary, 2020) as well as big data analysis as a whole (Niklasson, 2014). With regard to prehistoric maritime movement, large-scale approaches will not achieve the nuanced understandings that researchers should now be striving for; this study highlighting the argument made by Niklasson (2014, p. 62) that big data approaches do not always equate to better data outputs. By focussing firstly on local or smaller patterns of movement, the intricacies of maritime space and the temporalities that govern it can be contextualised, leading to a better understanding of the local knowledge that encapsulates and informs these practices. This knowledge would have enabled more reliable and consistent maritime movement, which in turn may have formed the basis for longer-distance maritime connections and, hence, should form the precursor to discussions of longer-distance seafaring voyages. Therefore, if discussions of prehistoric maritime movement are to be refined, it is the rhythms, complexities and particularity of this movement that must first be understood. This can only be accomplished through the incorporation of the unique character of the seafaring environment, both land and sea, and its many influences on maritime practices, both tangible and intangible. Through this holistic approach, researchers can begin to contextualise this space, enriching narratives of past seafaring through these (sea) ways of perception.

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Declarations

Conflict of Interest The author declares no competing interests.

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