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The lore of the *leið*

Tracking Viking Age voyages through traditional seafaring

GREER JARRETT
DEPARTMENT OF ARCHAEOLOGY AND ANCIENT HISTORY | LUND UNIVERSITY

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LUND UNIVERSITY

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Abstract: Ships, seafarers, and the sea were central to the events and transformations of the Viking Age, but major knowledge gaps remain regarding the maritime dimensions of the Viking world. The overarching aim of this thesis is to close the gap between scholar and seafarer by empirically reconstructing the routes, practices, and perspectives of Viking Age seafaring. Specifically, this research tackles four research questions: What were the technological and logistical affordances of Viking Age seafaring? To what extent can experimental voyages using traditional clinker boats serve as a window on the Viking Age? What factors influenced the selection of Viking Age havens, and where were they located? How did maritime practices and worldviews shape patterns of interaction over time in Scandinavia and the North Atlantic?

To address these questions, a programme of experimental sailing trials and trial voyages was designed and executed onboard vernacular Norwegian boats. These experiments investigated sailing and rowing performance, surveyed potential havens, and identified the factors influencing route choice.These approaches generated a comprehensive, first-hand understanding of the practicalities, risks, and potentials of long-range voyages through key seascapes of the Viking world. This approach pioneered a new interdisciplinary methodology which helps characterise Viking Age maritime networks.

The empirical core of this thesis is made up of four articles. These studies make an integrated set of original contributions to knowledge and understanding in the relevant field: they revise estimates of the windward and offshore performance of Viking Age ships and boats through extensive sailing trials onboard analogous vessels; characterise the distinct nature of Viking Age seafaring networks through the identification of probable routes, anchorages, and landing sites; establish Åfjord sailing practices as strong analogies for Viking Age seafaring through the evaluation of change and continuity in the broader Nordic clinker tradition; and expand Viking Age seafaring ranges through the reconstruction of maritime encounters and interactions in the high arctic, encouraging a revision of areas and degrees of cross-cultural contact across the boundaries of the Viking world. These findings confirm that many vital aspects of the Viking Age can only be understood from the sea. This demands direct engagements with seafaring practices, vessels, and seascapes to fully understand the enduring effects upon world history of this period's extraordinary voyages.

Key words: Viking Age seafaring, Norse seafaring, navigation, experimental archaeology, ethnoarchaeology, maritime archaeology, digital archaeology, seascape, maritime mobility

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Abstract

The Viking Age (c. 800 – c. 1050 AD) was a period of dramatic change and transformative encounters across Europe and the wider world. Ships, seafarers, and the sea were central to these developments but, paradoxically, the Viking Age is generally studied through evidence and approaches on land. This has consistently hindered scholarly understanding of the maritime dimensions of the Viking Age; surviving terrestrial evidence indicates the origin and destination points of trade goods, animals, and individuals, but leaves unanswered questions about the voyages between these points. Current scholarship struggles to answer these questions because of major knowledge gaps regarding the technical capabilities of Viking Age vessels; the strategies, routes, and havens chosen by Viking Age sailors; the processes shaping navigational choices; and the networks of interaction and exchange that emerged during this period.

The overarching aim of this thesis is to close the gap between scholar and seafarer by empirically reconstructing the routes, practices, and perspectives of Viking Age seafaring. Specifically, this research tackles four central research questions:

- What were the technological and logistical affordances of Viking Age seafaring?
- To what extent can experimental voyages using traditional clinker boats serve as a window on the Viking Age?
- What factors influenced the selection of Viking Age havens, and where were they located?
- How did maritime practices and worldviews shape patterns of interaction over time in Scandinavia and the North Atlantic?

To address these questions, a programme of experimental sailing trials and trial voyages was designed and executed, covering over 5,000 km onboard Åfjord boats, technological descendants of the vessels of the Viking Age. The trials involved a detailed study of sailing and rowing performance, the survey of potential anchorages and landing sites, and the identification of quantitative and qualitative factors influencing route choices. Practical and experimental research was integrated with complementary approaches, pioneering a new interdisciplinary methodology which was used to reconstruct seafaring routes, locate important maritime sites, and characterise networks of mobility and interaction. Together, these combined approaches generated a comprehensive, first-hand understanding of the practicalities, risks, and potentials of long-range voyages through key seascapes of the Viking world.

The empirical core of this thesis is made up of four interconnected case-studies, published in four articles. These studies make an integrated set of original contributions to knowledge and understanding in the relevant field:

- Improvement in estimates of the windward and offshore performance of Viking Age ships and boats through extensive sailing trials onboard analogous vessels.
- Characterisation of the distinct nature of Viking Age seafaring networks through the identification of probable routes, anchorages, and landing sites.
- Establishment of Åfjord sailing practices as strong analogies for Viking Age seafaring through the evaluation of change and continuity in the broader Nordic clinker tradition.
- Expansion of Viking Age seafaring ranges through the reconstruction of maritime encounters and interactions in the high arctic, encouraging a revision of areas and degrees of cross-cultural contact across the boundaries of the Viking world.

Together, these findings confirm that many vital aspects of the Viking Age can only be understood from the sea. This demands direct engagements with seafaring practices, vessels, and seascapes to fully understand the enduring effects upon world history of this period’s extraordinary voyages.

List of articles

Article 1

Jarrett, Greer. 2025b. '"Toward, Not to" – Seafaring Worldviews from Viking Age and High Medieval Norway'. in *The Archaeology of Seafaring in Small-Scale Societies: Negotiating Watery Worlds*, edited by A. Garcia-Piquer, M. Fauvelle, and C. Grier. Gainesville: University Press of Florida. [published 12th December 2025]

Article 2

Jarrett, Greer. in press. 'Maritime Mindscapes: Using Experimental Archaeology to Reconstruct Viking Age Seafaring Routes'. In *Travelling Viking Age. Proceedings of the 40th Interdisciplinary Viking Symposium*, edited by D. D. Pedersen and J. Hansen. Odense: University Press of Southern Denmark.

Article 3

Jarrett, Greer. 2025a. 'From the Masthead to the Map: An Experimental and Digital Approach to Viking Age Seafaring Itineraries'. *Journal of Archaeological Method and Theory* 32(42):1–44. doi:10.1007/s10816-025-09708-6.

Article 4

Ruiz-Puerta, Emily J., Greer Jarrett, Morgan L. McCarthy, Shyong En Pan, Xénia Keighley, Magie Aiken, Giulia Zampirolo, Maarten J. J. E. Loonen, Anne Birgitte Gotfredsen, Lesley R. Howse, Paul Szpak, Snæbjörn Pálsson, Scott Rufolo, Hilmar J. Malmquist, Sean P. A. Desjardins, Morten Tange Olsen, and Peter D. Jordan. 2024. 'Greenland Norse Walrus Exploitation Deep into the Arctic'. *Science Advances* 10(39):1–12. doi:10.1126/sciadv.adq4127.

Author's contributions

Articles 1, 2, and 3

Single-authored works.

Article 4

This co-authored paper was a team effort, with major inputs from Emily J. Ruiz-Puerta, Greer Jarrett, Morten Tange Olsen, and Peter Jordan. Greer Jarrett contributed all the experimental sailing data, produced several figures, wrote key sections on seafaring, climate, and archaeological evidence in the main text, and a substantial proportion of the supplementary materials. He was closely involved in editing and revising the final published text, and his research and understanding played a major role in shaping the overall interpretations and conclusions (total contribution: 30%).

Acknowledgements

Sailing an open wooden boat without an engine through weather fair and foul can be tough. You get cold, hungry, tired, seasick, irritated, and scared. Your clothes are constantly wet up to the elbows from hauling on sodden lines. You get welts and blisters from rowing. You sleep poorly. You miss proper warm meals, hot showers, and your bed.

At first, you might try to hold it all in, and go it alone. You soldier on. Stiff upper lip, and all of that healthy stuff. But at some point, you can't keep going. You're too exhausted. Too cold. Too overwhelmed by it all. You drop the line, the oar, the frozen edge of the sail. You think it's over. But then, a hand touches you on the shoulder, and picks up the line. Steadies the oar. Sits you down on a chest and hands you a mess kit steaming with stew. *"Du er avløyst"*, you hear. "You are relieved". You are indeed.

Writing this thesis has involved many moments like this. I have learnt to stop, think, and remember that I need not go it alone. Support has been there when I needed it most, at sea and on land. For this lesson, which has come from more people than I can name here, I will always be grateful.

This book and the voyages that define it are collective achievements. Among the many people who made these possible, I first wish to thank my main supervisor, Professor Nicolò Dell'Unto. His unwavering faith in my ideas and my ability to execute them have been a fair, following wind through the duration of this project. For his faith, guidance, and feedback on this and many other texts, I cannot say "*grazie*" enough.

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The potential of conducting research across boundaries, be they academic, environmental, or cultural, first became clear thanks to Dr Brendan Foley. Early in

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Kjetil Sildnes, Steven Dirven, Tora Heide, Ingvild Sunde Stokke, Olai Sørvik, Lars Glendrange, Sigismund Vestad, Ingvild Holst, Ida-Lovise Skylstad, Inga Lilja Þorsteinsdóttir, Ingrid Kastellet Berge, Silja Ravn-Jonsen, Marie Helgesen, Eva Voetmann, Kamma Hjortkjær, Jan Eirik Kolt, Ulf Damkjer, Jonathan Bücher, Julian Bücher, Elijah Jackson, Lucas Manzano, Felix Bünz Larsson, Ivar Holand, and Sigrid Elvenes. Takk for turen!

Figure 1. The crew of trial voyage 1 in front of *Skårungen*
From left to right, standing: Olai Sørvik, Sigismund Vestad, Kjetil Sildnes, Eva Voetmann, Ingvild Holst, Inga Lilja Þorsteinsdóttir, Marie Helgesen, Lars Glendrange, and the author. From left to right, kneeling: Ingrid Kastellet Berge, Ida-Lovise Skylstad, Ingvild Sunde Stokke, and Silja Ravn-Jonsen.

“Mainn dokk attåt, karra’! Lik’ mang’ på kvar si si’!

Så sett’e vi å-hå!

Båten går å-hå!

Båten går å-håååå!”

- Traditional Norwegian chant used during a boat launch

Preface

Around the year 850 AD, a boy was born in what is now western Norway, the child of Salbjörg Káradóttir and Úlfr Bjálfason. He was named Thorolf, and grew into a tall, strong man, open of hand and heart. When he turned twenty his father gave him a ship, and sent him off on his first raiding expedition. He proved to be a capable viking leader, spending the following summers at sea and returning to his parents' estate in the autumn, laden with gifts. One autumn there came news from Harald Fairhair, who hoped to unify the coastal chiefdoms into a single kingdom under his rule. He summoned Thorolf south to Rogaland, to serve him as a retainer. This Thorolf agreed to do, bringing his ship and crew with him, and fighting for Harald not long thereafter at the battle of Hafrsfjord, in which Harald's opponents were defeated and the kingdom of Norway came into being. In the battle Thorolf's friend Bard was killed, and from him Thorolf inherited the estate on the island of Torget. Soon thereafter he also inherited Sandnes, giving him the rights to trade with and take tax from the Finns, who lived in the far north. He made several journeys north into Helgeland, stopping to trade along the way, and travelled as far as Finnmark, where he also met the Kvens and befriended their king. In the winters, he employed members of his household in the herring fishing off the Lofoten islands. With the wealth he had gathered from the Arctic he travelled southwards and raided in the Baltic and along the North Sea coast, reaching the mouth of the Elbe. But his great success turned out to also be his downfall, as King Harald grew suspicious of him, and sailed north to confront him. Thorolf died in battle with Harald at Sandnes, after which his father and brother left Norway and settled in Iceland.

Thorolf's story is preserved in *Egil's Saga*, a 13th century Icelandic text composed (most likely) by his descendant Snorri Sturluson, and containing poems and details from an oral version created by Thorolf's nephew, Egill Skallagrímsson (Pálsson and Edwards 1976). Although parts of this text may be fictional (including, possibly, Thorolf himself), the descriptions of trade, piracy, cross-cultural interaction, political struggle, and diaspora were all very real elements of the Viking Age. Uniting and shaping the events and processes throughout the Viking world was an ancient and all-encompassing bond between people and the sea. This bond gave men and women like Thorolf a unique set of maritime skills, technologies, and networks which transformed the history of Europe and indeed the world. Most of these seafarers have been lost over the horizon of time, but the stories of a few remarkable individuals have come down to us: these include Aud the Deep-Minded, who sailed her own ship from Caithness to Iceland; Ingvar the Far-Travelled, who led an expedition from the Baltic to the Black Sea and beyond; Hásteinn and Björn Ironside, whose legendary Mediterranean raid reached as far as Sicily; and Gudrid Thorbjarnardóttir, who travelled from Iceland to North America, returned to Scandinavia, and even went on a pilgrimage to Rome.

The Viking Age voyages undertaken by explorers, traders, raiders, and settlers remain hard to explain. Not only did they cross some of the most dangerous seas on earth, they did so repeatedly within individual lifetimes, establishing trade routes and networks of interaction which connected people, animals, places, and things across four of the world's seven continents. But it has long remained unclear how these voyages were undertaken, which routes were chosen, and what places were visited along the way. My doctoral studies began with the hope that the seafaring networks and practices shaped by sailors like Thorolf were not entirely lost, and could perhaps be reconstructed. This book is the result of that hope.

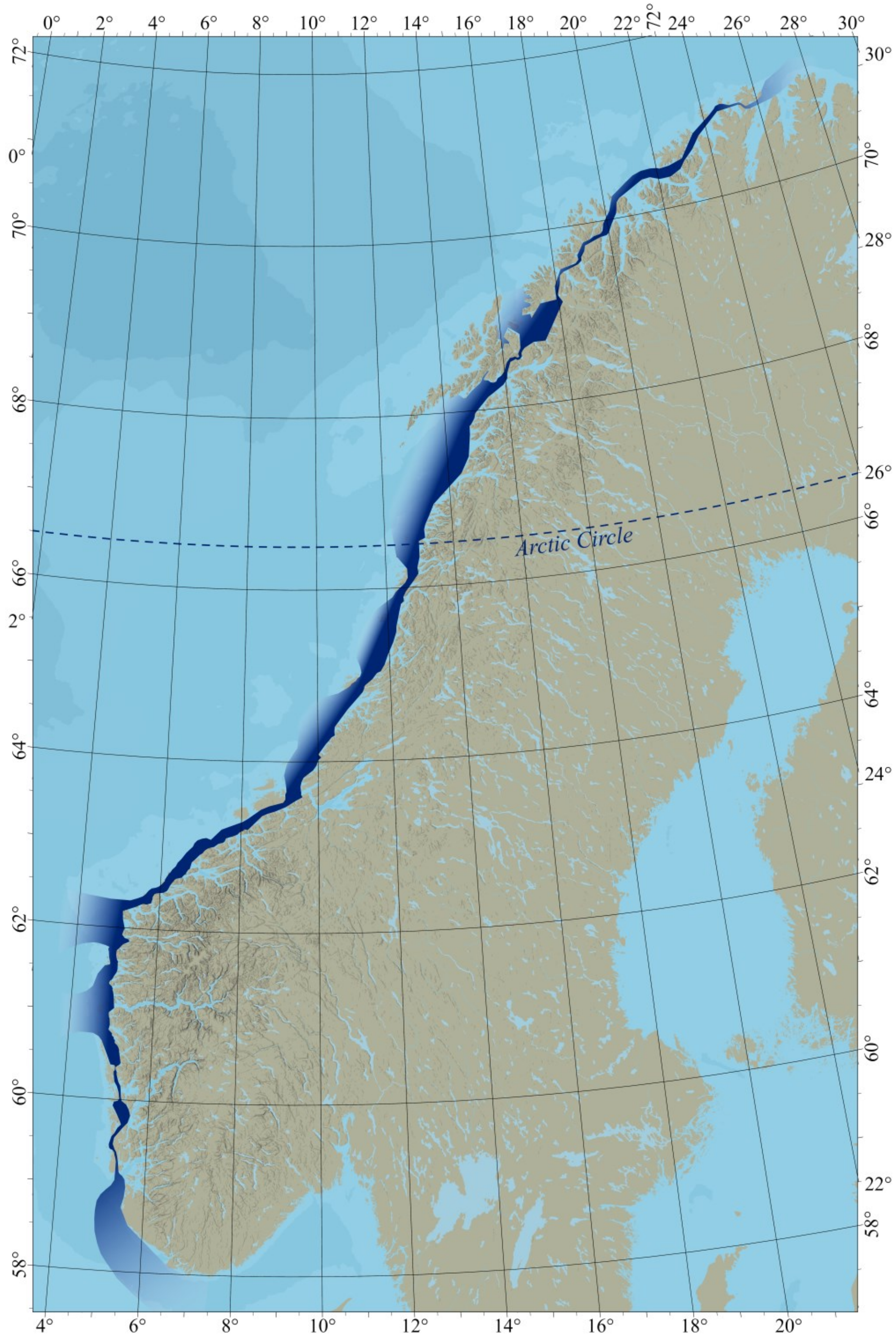
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Figure 2. The *leið*

The maritime corridor along the west coast of the Scandinavian Peninsula has been a channel of exchange and interaction since prehistory, and was a principal artery of the Viking world. It is made up of innumerable islands, islets, and skerries, creating a vast meshwork of possible seafaring routes that can only be understood by undertaking experimental voyages throughout this seascape.

1 Introduction

1.1 Research overview

The central argument in this book is that reconstructing the seafaring voyages of the Viking Age must involve a practical understanding of the knowledge and worldviews of the sailors who undertook them, and that approaching such an understanding requires undertaking comparable voyages in the present. To develop this argument, the three aims of this thesis are to present a practical, qualitative understanding of the potentials of Viking Age seafaring, obtained through first-hand engagement in analogous maritime traditions; characterise Viking Age seafaring networks by locating key sites and seascapes through seaborne survey and digital landscape reconstruction; and investigate how Viking Age worldviews shaped and were expressed in seafaring routes and practices.

To fulfil these aims, this thesis addresses the following four research questions: what were the technological and logistical affordances of Viking Age seafaring? To what extent can experimental voyages using traditional clinker boats serve as a window on the Viking Age? What factors influenced the selection of Viking Age havens, and where were they located? How did maritime practices and worldviews shape patterns of interaction over time in Scandinavia and the North Atlantic?

From a broad perspective, this study's main contribution is the assemblage of traditional seafaring lore from the long, rugged seaway along the west coast of the Scandinavian Peninsula, known in Old Norse as *leið* (Fig 2).[1] The *leið* was one of the three major arteries of interaction and exchange at the core of the Viking world, the other two being the southern Baltic and the Kattegat-Skagerrak corridors (Skre 2025:2). This lore was collected during experimental trials and trial voyages through several Scandinavian seascapes onboard vernacular Norwegian boats, cultural and technological descendants of the boats and ships of the Viking Age (Fig 4).

[1] I have chosen to use this term instead of the more common term *Nórvegr* (or variants thereof, e.g. Østmo 2020; Skre 2014, 2025) for two reasons: firstly, it is the term used by the people with whom I sailed. Secondly, it is an emic rather than an etic term: *Nórvegr* most likely means 'the way to the North' (see Østmo 2020:5–8 for a discussion and other possible origins), a name that only makes sense from the perspective of someone living south of this region, while *leið/leian*, (meaning 'the route' or 'the fairway') expresses the perspective of those who lived and travelled along it, and for whom no further description was necessary.

The four scientific articles at the core of this compilation thesis draw on the seafaring lore of the *leið* in different ways: in Article 1, the findings from the experimental voyages help define the capabilities and limitations of Viking Age vessels and crews, and illustrate the role of maritime worldviews in determining sailing routes. Article 2 compares vernacular Norwegian seafaring traditions with evidence from the Viking Age, revealing remarkable continuities throughout the Nordic clinker tradition at the microscale of everyday practice. Article 3 combines experimental and digital approaches to locate Viking Age havens throughout the *leið*, and suggests that outlying anchorages and natural harbours were essential for long-range voyages during this period. Finally, Article 4 employs data from experimental sailing voyages to reconstruct seafaring routes in western Greenland, suggesting that Norse walrus hunters travelled further into the Arctic than had previously been assumed, where they are likely to have encountered Indigenous North Americans from Late Dorset and Thule Inuit communities.

Figure 3. Viking Age beads from Slapøya, Nordland
These glass and rock crystal beads were found in a Viking Age grave on the island of Slapøya. The glass was recycled from Late Antique production sites in the northern provinces of the Roman Empire, indicating long-range maritime connections between the Arctic and mainland Europe. However, archaeological evidence like this offers little information about the seafaring networks connecting these regions. Courtesy of Dr Birgit Maixner; reproduced with permission.

1.2 Research context

The starting point for this study was the lack of current knowledge about the seafaring voyages of the Viking Age (in this thesis, this period is defined as extending from c. 800 to c. 1050 AD; see Box 1). Evidence from a wide range of disciplines connects people, places and things across maritime space during this period, but rarely provides more than their points of origin and eventual destination, deposition or burial (Fig 3). As the Viking world was primarily an oral world, very few first-hand descriptions have been preserved about the routes followed between these points, the practicalities and logistics involved in undertaking long-range voyages, and the experiences, knowledge, and worldviews of the seafarers. But perhaps a greater hindrance to understanding Viking Age seafaring is the way it is approached and represented in modern scholarship. Practical knowledge of the kind assembled in this thesis is often overlooked in academic approaches due to the temporal, environmental, and ontological gap between the land-based scholar of today and the seaborne voyagers of the past. Today, Viking Age voyages are typically represented in maps such as Figure 11.16 in Cunliffe (2017). This map is as an excellent aid for modern readers, effectively communicating the extent of Viking Age exploration, the intensity of the seaborne raids, and the complexity of maritime networks. But the brightly-coloured arrows that strike out from the Scandinavian coast across a blue, featureless expanse are far removed from the experience of Viking Age seaborne travel, and say very little about the knowledge and practices enacted during these voyages. The landforms often appear in some detail, but the sea and those who moved through it are gone.

With some notable exceptions, scholarly approaches to the Viking Age have long favoured evidence, approaches, and perspectives which are attainable from land. This is part of a general preference in modern western science for data over wisdom, stasis over dynamism, and universality over contextualism, and has resulted in profoundly maritime phenomena like the voyages of the Viking Age being represented through modern terrestrial media like the map above (Edney 1999; Ingold 2000; Kitchin and Dodge 2007). The central, underlying critique in this thesis is that such a preference hinders scholarly approaches to ancient seafaring, as it alienates the researcher from precisely the kinds of knowledge which afforded maritime movement and activity in the past, creating a perceived scarcity of available evidence.

This investigation began by considering whether practical, maritime approaches and evidence might address this presumed scarcity by revealing new knowledge about the voyages and voyagers of the Viking Age. This idea developed into the following three hypotheses, upon which this thesis is built:

1. Mobility patterns are shaped through collective engagement in particular practices and environments; reconstructing these requires first-hand experience in analogous activities and land-/seascapes.
2. Recent vernacular expressions of the Nordic clinker tradition can be employed as analogies for reconstructing Viking Age seafaring practices.
3. The combination of experimental, ethnographic, and digital methods creates a replicable, qualitative approach which can document and disseminate the maritime dimensions of the Viking Age and reconstruct the routes that were chosen during this period.

Box 1: The seafaring package of the Viking world

The Viking world is the primary umbrella term used throughout this book to denote the temporal and geographical extent within which a community was present and active whose shared practices and conceptual frameworks are usually interpreted as expressions of a common viking culture (Barrett and Gibbon 2019; Brink and Price 2008; Jesch 2015). The conceptual, chronological, and geographical borders of the Viking world were and are undeniably permeable, allowing us to include and discuss neighbouring communities, places, and times which shaped or were shaped to varying degrees by its inhabitants. The seafarers of this world seem to have shared a particular way of thinking about and enacting sailing voyages, constituting what we might call a cultural 'package' (Storli 2007:85; Valtonen 2008:449). It is the evidence for this package which defines the period, people, and geographical region under study. The seafaring package of the Viking world can be characterised by the following constituent elements:

- The construction and use of clinker boats and ships equipped with sails
- The use of a low-instrumental navigation method characterised by the absence of the magnetic compass and the nautical chart
- A subsistence pattern based primarily on small-scale agriculture and the harvesting of marine resources
- The dominance among its bearers of oral culture and polytheism
- An increase and diversification in the maritime routes taken by its bearers relative to previous periods, and an expansion of these routes beyond the coasts of the North Sea and the Baltic
- A network of mobility, trade, and power built primarily around non-urban coastal sites

This package was present along the coastlines of the Scandinavian Peninsula and the southwestern Baltic Sea from the late 8th century AD (Bill 2008, 2023). With the movement of its bearers during the following centuries beyond this area of origin, it developed new arenas of expression across the rest of the Baltic Sea, the North Sea, and the North Atlantic. Large-scale transformations during the 11th century such as the development of urban centres, the commercialisation of fishing, and the widespread adoption of Christian practices and ideas mark an end to the Viking world and the seafaring package under study. Despite these large-scale changes, elements of this package had become intricately bound up in the enactment of everyday activities, allowing them to survive in maritime communities until the widespread adoption of motorised fishing vessels in the early 20th century (see Article 2).

Figure 4. An Åfjord *fyring*
Square-rigged, clinker-built boats like this one were used throughout the *leið* from the Viking Age until the First World War. This particular vessel belongs to the Åfjord tradition of the late 19th and early 20th century, but shares features and capabilities with the ships and boats of the Viking Age. Courtesy of Tora Heide; reproduced with permission.

1.3 Research design

To test these hypotheses, this thesis focuses on the practices and perspectives of the sailors of the Viking Age: their activities, skills, knowledge, and experience, but also their view of the world and the patterns of maritime interaction that shaped and were shaped by this worldview. Focus is placed primarily on multi-day voyages conducted with non-violent goals, meaning that the results relate to Viking Age fishing, whaling, exploring, and trading more than they do to raiding and naval warfare. To create a space of shared experience with the seafarers of the Viking world, this research involved long-term, practical engagement in the analogous sailing tradition of the Norwegian district of Åfjord. *Åfjordsbåter*, as vessels from this area are known, are square-rigged clinker boats which were used between the late 18th and early 20th century for fishing, trading and transport throughout Trøndelag (Fig 4). They also took part in long-range winter voyages to the cod banks off the Lofoten islands in northern Norway (Eldjárn and Godal 1988a; Fjellsson et al. 1995). Their involvement at both regional and inter-regional scales throughout the *leið* make them ideal analogues for reconstructing Viking Age voyages.

Experiments were conducted onboard Åfjord boats between 2021 and 2024. These ranged from one-day trials concentrating on specific variables to multi-week expeditions aiming at a broader understanding of the potentials, limitations, risks, and realities of traditional seaborne travel. The focus on seafaring perspectives and worldviews encouraged the documentation of cognitive and social aspects of navigation to complement analyses of vessel performance and sailing techniques. Along with the trials at sea, data was also gathered on land in the form of interviews with traditional sailors, surveys of potential anchorages and landing places, and photogrammetric documentation of traditional boats. Although this thesis investigates voyages and environments across the Viking world, the *leið* constitutes the main study area for this project. The experimental and ethnographic data collected throughout this seascape constitutes the project's empirical foundation, and has been assembled in an Open Access data repository, accessible at:

https://doi.org/10.5281/zenodo.17340505

1.4 Thesis structure

This book is made up of seven chapters, a project evaluation (Appendix 1), and the four scientific articles constituting the empirical foundation of this research (Appendix 2). Following this introduction, Chapter 2 critically evaluates current scholarship surrounding the topic of Viking Age seafaring, identifies important knowledge gaps, and sets out the directions for this research. Chapter 3 presents three theoretical toolkits which help lead the project in the chosen directions. Chapter 4 describes how these tools were applied to fulfil the project's aims, and evaluates their strengths and weaknesses. Chapter 5 presents the project's main findings through two case studies from the experimental voyages, and connects these to the each of the four articles in this thesis. Chapter 6 discusses the contributions of this thesis to broader research, and outlines some possible pathways for future scholarship. Finally, the three central conclusions resulting from this research are presented in Chapter 7.

Figure 5. The Skálholt Map
Created by the Icelandic bishop Þórður Þorláksson in the late 17th century, it is a copy of an older, now lost map from 1570. It represents an early attempt to document the seascape of the North Atlantic as it appears in the sagas, and helped Helge Ingstad locate the site of l'Anse aux Meadows in Newfoundland. It depicts the North Atlantic as an almost-enclosed basin, reflecting the centrality of the sea in Norse conceptions of space. Courtesy of the Royal Danish Library; reproduced with permission.

2 State of the Art

Abstract

The aim of this chapter is to identify gaps in current knowledge and convert these into new research directions. It begins with an overview of the study region and historical context, before presenting the various kinds of evidence that have been drawn upon in previous research. Previous studies are divided into terrestrial and maritime approaches, according to the kinds of evidence and methods favoured, and the strengths and weaknesses of both perspectives are discussed. The knowledge gaps and methodological shortcomings identified in this overview inform this project's five research directions. These focus on the worldviews, vessels, and preferred havens of Viking Age seafarers, the degree of continuity and change in the Nordic clinker tradition, and the characterisation of maritime exchange and interaction networks. Together, these research directions shape the theoretical framework and methods discussed in the following chapters, and inform the four articles at the core of this thesis.

2.1 Research context: the *leið*

2.1.1 Geography

The *leið* consists of a relatively sheltered seaway extending for c. 2,000 km along the west coast of the Scandinavian Peninsula, from approximately 59° N to 70° N (Fig 2). It runs between the mainland and the long scatter of islands, islets, and skerries which protect it from the open sea, following the relatively flat erosion surface along the edge of the peninsula known as the Strandflat. Here, low land and shallow waters have encouraged settlement, farming, and fishing since prehistory. With waters warmed by the Gulf Stream, crops were grown along the entire length of the *leið* during the Viking Age on the small patches of arable land (Østmo

2020:11, 22; Skre 2025:7; Storli 2007:82–83). Most of the mainland was steep, rugged, and inhospitable, meaning that since the Mesolithic, journeys through the *leið* have primarily been by boat (Bjerck 2022; Østmo 2020). The centrality of the sea and the scarcity of arable land are shared features of many areas of the Viking world, making the *leið* a strong candidate for studying mobility patterns across this world. These features have led some scholars to conceive of the Viking world as a large archipelago, with "islands" of settlement linked by seascapes and waterways (Englert 2015:52; Sanmark and McLeod 2024:7). This helps emphasise the decentralised nature of settlement during this period, but still clings to the land as the primary area of study, with the sea relegated to a surrounding, silent majority. It may be worth going a step further, and conceiving of the Viking world as it appears in the 17th century Skálholt Map (Fig 5). Here, it is the land that constitutes the periphery, forcing us to conceive of seafaring as the process of going *into* the sea and *out to* land.

2.1.2 Environment

Over the last millennium, the *leið* has undergone notable environmental changes. Foremost among these is the change in relative sea-level, resulting primarily from isostatic rebound (Balascio et al. 2024; Creel et al. 2022; Romundset and Lakeman 2019). Isostatic rebound rates throughout the study region have only recently been compiled, meaning that previous studies of Viking Age seafaring routes have not incorporated these data into their reconstructions. In this project, isostatic rebound data were used to evaluate potential haven sites in Article 3 (see section 5.4.3).

Climatic changes have also occurred: the Viking Age was characterised by slightly warmer, drier summers and cooler winters (~2°C above and below modern summer and winter means, respectively; Edwards et al. 2017; Helama et al. 2012; Kirchhefer 2005; Ljungqvist et al. 2016; Moberg et al. 2005; Surge and Barrett 2012), less sea-ice coverage (Dugmore et al. 2007; Ogilvie, Barlow, and Jennings 2000), a predominance of negative winter NAO (North Atlantic Oscillation; Edwards et al. 2017; Meeker and Mayewski 2002; Raposeiro et al. 2021; Surge and Barrett 2012), and a somewhat more stable and predictable pattern of winter storms (Dugmore et al. 2007). These climatic differences, and the extreme difficulty of reconstructing determinant phenomena such as wind patterns and ocean currents, are inescapable caveats for this research. However, recent paleoenvironmental reconstructions (Kuijpers and Mikkelsen 2009; Patterson et al. 2010) seem to align well with medieval written sources (Larson 1917; Pálsson and Magnus Magnusson 1983) regarding important parameters such as the timing of the sailing season, major tidal and ocean currents, and prevailing winds.

For the purposes of this study, the most important knowledge gaps regarding the climate and environment of the Viking world relate to the exact timing of the Medieval Warm Period (Barrett 2008), as this determines the degree to which the modern-day climate can be used as an analogy for Viking Age conditions; the rate of isostatic rebound in regions with limited data such as Helgeland (Creel et al. 2022), as it will help clarify which routes and harbours would have been accessible; and the nature of summertime atmospheric circulation patterns (Edwards et al. 2017; Raposeiro et al. 2021), as these will help reconstruct seasonal wind patterns.

Figure 6. The wealth of the *leið*
During the Viking Age, a wide range of goods and materials were transported from remote northern hinterlands towards southern markets. These included soapstone vessels, furs, reindeer antler, whetstones, and iron. Courtesy of the Museum of Cultural History; reproduced with permission. Photographer: Eirik Irgens Johnsen.

2.1.3 Historical context

The *leið* has served as an artery of communication and exchange since prehistory. Marine resources and coastal sites played a central role in Mesolithic settlement

(Bjerck 1989, 2022), and by the Early Nordic Bronze Age (1500-1100 BC) the communities throughout this seascape were conducting long-range trade and developing a shared boatbuilding tradition (Kastholm 2008; Ling, Earle, and Kristiansen 2018). Maritime connections between the southern and northern reaches of the *leið* increased markedly in the 3rd and 4th centuries AD, due to the burgeoning export of Arctic commodities (Pilø et al. 2018; Skre 2025). This was followed by a period of political centralisation and decreased maritime exchange during the 5th and early 6th centuries (Carver 1990; Hedeager 2011; Iversen 2020; Østmo 2020; Ringstad 1992; Skre 2025). The 8th century saw the beginning of a new period of increased maritime interaction across the North Sea, with goods such as those in Figure 6 being transported over long distances to newly established seasonal market sites (Myhre 2000; Näsman 1991; Skre 2012). At these sites, seafarers from Scandinavia met Frisians, Anglo-Saxons, Balts, and Slavs, and undoubtedly gathered and shared knowledge and experience about their seas and seafaring traditions. Throughout the *leið*, archaeological evidence proves that long-distance maritime routes were well established by the 8th century (Ashby, Coutu, and Sindbæk 2015; Baug et al. 2019; Bill 2010; Storli 2007).

By the beginning of the Viking Age at the turn of the 9th century, trade across the southern North Sea was booming, centred around places like Hedeby, Ribe, Kaupang, and Birka (Fig 6). The *leið*, however, was an exception within this broader network, as no central market sites (*emporia*) seem to have existed here, suggesting that trade continued to be organised by the elite (Skre 2018). During the Viking Age, the *leið* was divided into two latitudinal zones: the southern half (up to and including what is now Trøndelag) was dominated by a consumption-based economy reliant on small-scale agriculture and the exploitation of marine resources. In the northern half of the *leið* crops were also grown, but wealth was to be made through the export of materials gathered from the forest, the sea, and the mountains (Bertelsen 1997; Keller 2010:16; Pilø et al. 2018; Skre 2025:357). This division mirrored other areas of the Viking world, such as Greenland, and encouraged the development and diffusion of seafaring skills across the Viking world. Several scholars have argued that rather than ethnicity, it was this practice of long-range seafaring, and the role of middlemen between circumpolar communities and those of mainland Europe, which constituted the basis for a shared identity among the sailors of the Viking Age (Sjövold 1974:349; Storli 2007:95).

Figure 7. A late Viking Age trading ship
This reconstruction of the Skuldelev 1 wreck represents the kind of ship that transported people, animals, and goods across the Viking world. It is the product of major innovations in shipbuilding during the 10th century, when specialised cargo vessels capable of transporting large volumes of goods across the North Atlantic first began to be built. Courtesy of the Viking Ship Museum; reproduced with permission.

The western reaches of the *leið* seem to have been the home of the earliest Viking raiders, who at the end of the 8th century began targeting isolated places outside of the southern North Sea trading zone, such as Lindisfarne and Iona (Ashby et al. 2015; Baug et al. 2019; Myhre 2000). Major changes followed the early raids, beginning in the 830s. From this point until the mid-10th century, opportunistic piracy was replaced by a more organised and more extensive period of maritime exploration and expansion, which Judith Jesch has termed “the Viking diaspora” (Jesch 2015; Price 2014). Seafarers from the *leið* roamed ever further over the horizon, venturing east into the White Sea and west to the Northern Isles, the Faroe Islands, and Iceland (Englert 2007; Griffiths 2019; Marcus 1980). In the late 10th century, Greenland was explored and then settled, and a generation later, explorers from Greenland reached Newfoundland (Halldórsson 1978; Kuitems et al. 2021; Seaver 2000). Genetic analyses indicate that the exploration of the northern and western Atlantic was conducted by seafarers originating or descended from communities throughout the *leið* (Speidel et al. 2025).

The effects of the Viking diaspora were felt across Europe, the North Atlantic, and the Mediterranean. The raids threatened the very existence of many Christian kingdoms, and transformed the geopolitical map of western Europe forever (Ashby 2015; Lewis 2021; Price 2014; Raffield et al. 2016). A simultaneous increase in the extent and range of maritime trade, caused in part by important developments in shipbuilding (Fig 7), transformed economic networks and integrated remote northern hinterlands into an early form of globalised exchange (Ashby et al. 2015; Keller 2010; Ruiz-Puerta et al. 2024; Sindbæk 2016). Goods and people from the *leið* travelled as far as Greenland and Constantinople (and as demonstrated by this research, probably even further), causing an influx of new wealth and new ideas throughout this seascape (Fig 8).

During the 10th century, raiding developed into more conventional forms of state-sponsored naval warfare, and a new period of commercial expansion began across the North Atlantic (Keller 2010). Increased trade was accompanied by political centralisation, as the maritime polities along the coasts of the Scandinavian Peninsula developed along the lines of the Christian kingdoms to the south and west (Iversen 2020). The end of the Viking Age came to the *leið* during the 11th century, as these polities gradually adopted Christian ideas and traditions (at least among the nobility), developed literate administration systems, founded churches (such as Nidaros in 1025), and sponsored the development of merchant towns (such as Bergen and Borgund) (Hansen 2005; Hudson 2012; Meulengracht Sørensen 1995).

Figure 8. The wealth from afar

11th century hoard from Foldøy, Rogaland, made up of 776 silver coins and several pieces of hacksilver. The coins bear the mark of Norwegian, Danish, Anglo-Saxon, Irish, Ottonian, Bohemian, Hungarian, and Arabic rulers. Hoards like this one are clear evidence of the flow of wealth into the *leið* during the Viking Age, and of the range of exchanges and interactions across its boundaries. Courtesy of the Museum of Cultural History; reproduced with permission.

2.1.4 Evidence for Viking Age seafaring through the *leið*

This brief historical outline illustrates the long relationship between people and the sea throughout the *leið*. The evidence shaping current scholarship comes in various forms. Only one first-hand account of a Viking Age voyage through the *leið* has survived: this is the description given by Ottar (or Ohthere, as he is known in Old English) to King Alfred of Wessex in the late 9th century, and preserved in the Old English *Orosius* (Bately and Englert 2007). Ottar's account is an invaluable source, but provides only schematic geographical information regarding his various voyages from his home in Hålogoland to the White Sea, southwards through the *leið* and the Danish islands to Hedeby, and across the North Sea to the British Isles. All other accounts and descriptions of seafaring through the *leið* are preserved only in later texts, the earliest of which were scribed during the 13th and 14th centuries by Christian monks and clergymen (e.g. Pálsson and Edwards 1972; Sturlason 1990; Pálsson and Edwards 1981; Cook 2001; Larson 1917). It is often assumed that despite a temporal gap of several centuries, the routes and practices described in these sources can be applied to the Viking Age (e.g. Morcken 1978; Thirslund 1997), but the safety of such an assumption has recently been questioned by Heide and Planke (2019).

Maritime placenames and nautical terminology attest to the spread of the Viking Age seafaring package. These include a swath of names across the Baltic, the North Sea, and the North Atlantic with Old Norse origins and clear indications that their names were coined from the perspective of the sailor at sea. Examples from the *leið* include zoomorphic landforms such as Stemshesten and Hådyret; the various versions of Old Norse Fólgsn, meaning 'hiding place' and referring to the harbour; and the inclusion of the prefix Smør-, meaning 'butter', probably as a positive appraisal of a potential harbour and an indication of trading activities (Kruse 2020; Østmo 2020; Sanmark and McLeod 2024; Solvang 2024; Westerdahl 2005a). Along with the names of these places, many modern European languages have inherited nautical terminology from Old Norse, illustrating the widespread impact not only of seafaring groups, but also of the practices and technologies they brought with them (Parsons 2013).

In oral societies, especially cartographically poor, sparsely populated ones such as the Viking Age communities of the *leið*, placenames play a central role as "geographical memory pegs" (Brink 2019:565). Names provide information, warnings, or reminders, and their association with mythological figures or stories serve to anchor them in people's memories and relate them to other features in the environment. As an example, the folktale of Vågakallen and the Seven Sisters involves a number of major landmarks across Helgeland and northern Trøndelag (Mathisen and Sæther 2018:164–65). Christer Westerdahl has identified a system of forbidden names and safe pseudonyms used throughout Scandinavian seascapes until recent times, similar to the system of *tabu* and *noa* names from the South Pacific. The fundamental distinction within the Scandinavian system is between sea and land, with the true names of dangerous or conspicuous places on land being forbidden when viewed or approached from the sea, and given replacement *noa* names (Westerdahl 2005a). For Viking Age seafarers, there seems to have been a degree of overlap between real and supernatural places, with remoter areas blending into quasi-mythological realms (Frog 2020; Meulengracht Sørensen 1995). These entanglements of navigational knowledge within a wider body of enacted mythology and ritual stands in stark contrast to the strict modern distinction between the real and the supernatural, and highlights the need to approach Viking Age navigation from a non-representational perspective.

Archaeological evidence offers a diverse assemblage of clues about maritime mobility. From the rich deposits of Viking Age trading centres such as Ribe and Kaupang come an array of materials and artefacts that can only have arrived there by sea. These can be divided into exports from the Viking world such as reindeer antler, whetstones, iron (of different kinds and with different properties), ivory, eider down, fur, hide rope, fish, oil, tar, and in all likelihood, slaves (Fig 6); and imports from the Continent, including glass vessels, precious metals, textiles, riding gear, weapons, grain, honey, cast bronze objects, beads, and once again, slaves (Ashby et al. 2015; Baug et al. 2019; Maixner 2021; Roesdahl, Munch, and Johansen 2003; Storli 2007). In addition, genetic and isotope analyses of human remains suggest a high degree of mobility within the Viking world, as well as the establishment of a strong ancestral link between southern Scandinavia and the Continent shortly before the Viking Age, consistent with the pattern of North Sea exchange described above; and a high degree of human mobility between the Scandinavian Peninsula and the north Atlantic islands (including the British Isles) (Margaryan et al. 2020; Price et al. 2011; Speidel et al. 2025).

Iconographic sources such as ship graffiti and engravings and the Gotland picture stones illustrate the diversity of Viking Age vessel types, and the centrality of ships and seafaring in Scandinavian cosmology before and during the Viking Age (Bill 2007:15; Heide and Planke 2019; Lindqvist et al. 1941; Westerdahl 2005a). Although these sources are hard to date, they include what is likely to be the earliest direct evidence for the use of the sail in Scandinavia (Bill 2023) and indicate various distinct crew roles onboard (Ellmers 1995).

Figure 9. The Gokstad ship
This late 9th century vessel may be similar to the one used by the merchant-explorer Ottar during his various voyages. Its proportions reflect a common measurement system shared with late examples of the Nordic clinker tradition, such as the Åfjord boats used in this project.

But it is the remains of ships and boats[2] that, for this project, constitute the most important archaeological evidence. Compared to other regions and time periods, an exceptionally large number of Viking Age vessels have survived, giving the misleading impression of a geographically and chronologically-isolated phenomenon. But as we have seen, the vessels of the Viking world were descendants of a long-standing tradition which was already shared across the North Sea by the 6th century (Bill 2010; Kastholm 2008; Morrison 1978; Parsons 2013). This is generally known today as the Nordic clinker tradition. From the 2nd century onwards, clinker boats were rowed rather than paddled, and the planks were increasingly fastened using roves and rivets rather than cleats and bindings (Østmo 2020; Rieck 2013). The boats and ships of the Viking Age should therefore be seen as expressions of a widespread, long-standing, and evolving tradition, with different boats built for different voyages, activities, and environments (Eldjárn 1995).

The general scholarly consensus is that long-range traders and explorers such as Ottar sailed onboard a vessel like the Gokstad ship (Fig 9), with a capacity for cargo

[2] In the academic literature, the term 'ship' generally refers to any vessel with an overall length surpassing 12 metres (e.g. Bill 2010; Paasche 2024). I have generally used the term 'boat' in reference to the vessels used during this project, as none of these exceeded the diagnostic 'boat length' by more than 1 metre, and all the Scandinavian language-speakers with whom I interacted referred to their craft using versions of the word *båt*.

and a large crew (Bill 2008; Christensen 2007; Eldjárn 1995:28–29). Of the surviving ship and boat remains of the Viking Age, only those found within Scandinavia survive in anything approximating their entirety. However, clinker ship fragments from the British Isles and the European mainland, along with depictions of clinker ships in medieval European art, illustrate the spread of the Nordic clinker tradition before and during the Viking Age, and its survival in traditional practices across the North Atlantic (Morrison 1978; Parsons 2013). The most famous Viking Age ships are those from Oseberg and Gokstad in southern Norway, but ships from the *leið* are also known, such as the Kvalsund 2 ship (although whether it was a rowing or a sailing vessel is uncertain), and the more fragmentary remains from the Storhaug and Grønhaug mounds at Avaldsnes (Bill 2010; Bonde and Stylegar 2016; Daly, Kimball, and Bill 2025; Nordeide, Bonde, and Thun 2020; Shetelig and Johannessen 1929). It is worth noting that timbers from the Oseberg ship and (in all likelihood) the Kvalsund ship were felled in what is now western Norway, suggesting that these ships were built in this area before voyaging to their respective deposition sites (Bonde and Stylegar 2016). None of these vessels survive with a wholly intact mast, rig, and sail; only one of the small boats from the Gokstad ship burial preserves what is probably a near-complete mast (find number C10394/c), and nothing more than small fragments of sailcloth and rigging have ever been recovered from excavations (Christensen 1979; Kastholm 2011). However, the physical characteristics of the Oseberg ship indicate that sailing vessels were probably in use for several generations before this ship's construction in the 820s (Bill 2023).

Viking Age ship and boat remains illustrate the development of shipbuilding practices throughout this period. Before the 10th century, the ships all have relatively similar proportions (with a length-breadth ratio of between 4:1 and 6:1), with low cargo capacity and propulsion based on rowing and sailing. During the 10th century, coinciding with the development of navies and the spread of elite control over maritime trade, two very distinct ship types emerged, built either as troop transports – long and sleek, with many oars – or as cargo vessels – broader, with vastly increased tonnage, and built primarily as sailing vessels (Bill 2008, 2010; Eldjárn 1995; Ravn 2016b). An example of this latter kind is shown in Figure 7. These developments are important for this project because they represent a marked change in the affordances of long-range voyages: although the ships of the early Viking Age were seaworthy vessels (see Bischoff 2020 for an in-depth evaluation), attempting the open sea passages that make up several sections of the *leið* in such vessels would involve a considerable degree of risk, while the larger cargo vessels of the late Viking Age could attempt such passages under a broader range of conditions.

Regarding the techniques of Viking Age navigation, it is easiest to begin by listing what the sailors of this period certainly did not use. This includes the magnetic compass, the astrolabe, the nautical chart, lighthouses, and written sailing descriptions, all of which appeared throughout the *leið* between the 12th and 17th centuries (Bøe 2009:64; Frake 1985:257; Hutchins 1995:93–97). A great deal more controversy surrounds the techniques that were employed in place of these absences. The most widely accepted navigational elements are land- and seamarks, including natural and man-made features such as burial mounds and *varder* (stone cairns) (Sanmark and McLeod 2024). Moving, living things may also have been used as marks or leads. In the Viking world, this could have involved migrating animals with known, regular itineraries, such as seabirds, harp seals or right whales (Bill 2008:178; McGovern 1985). Marks were also paired to create transit bearings, the so-called *méd* of traditional Norwegian fishing communities (see Uksnøy 1959 for a compilation from Møre and Romsdal). It is also widely accepted that Viking Age navigators divided the horizon into at least eight quarters or arcs surrounding their ship, as described in *The King's Mirror* (Larson 1917:86–92; see also Indruszewski and Godal 2006). These were given cardinal names equivalent to those used for directional bearings today, but it is important to emphasise that "east", for example, referred to the arc between 67.5° and 112.5° rather than a single axial direction.[3] Providing time could be kept relatively accurately while at sea, latitude sailing would have been possible by measuring the height of the sun over the horizon at solar noon (see Börjesson 2009; Engvig 2001a for experiments confirming this). Beyond these techniques, Viking Age sailors may have used a range of adventitious aids such as the colour, taste, and temperature of the sea as indications of non-tidal currents, or the shape of the swell to determine bathymetric changes (Haine 2012:106–15; Marcus 1980:109–12). These would not have served to ascertain one's exact position, but would have been enough to guide sailors towards a general direction.

Over the last century, repeated suggestions have been made regarding possible navigational instruments and techniques from the Viking Age (Binns 1972; Haasum 1974; Kemp and D'Olier 2016; Lund 1983; Marcus 1953; Ramskou 1982; Roslund and Beckman 1994; Schnall 1975; Taylor 1956). A few short arguments will have to suffice to address this ongoing discussion. Firstly, the existence of these instruments remains highly uncertain: there is no archaeological evidence for the so-called "sunstone" crystals (Ramskou 1969; Száz et al. 2017) as navigational aids.[4] The dating of the possible wind-vane from Menzlin is unclear, and may have belonged to an entirely different community; and the find contexts of the wooden discs from Uunartoq and Wolin are equally ambiguous (Filipowiak 2020; Indruszewski and Godal 2006). These 'sun-compasses' require the navigator to

3 This is also reflected in Old Norse names for different wind directions: *utsør* and *utnord* were the names given to winds coming from southwest and northwest arcs (Meteorologisk Institut 2022b), while *landsør* and *landnord* were the names of winds from the southeast and northeast arcs (Meteorologisk Institut 2022a).

4 They appear only once in the medieval Norse sources (in the anonymous, 12th-13th century story known as *Rauðúlfs þáttr*), and here the *sólarsteinn* is described as a wonder, not a well-known instrument.

maintain a course along a single line of latitude, which would have been challenging during westward voyages from Scandinavia, as vessels would be travelling against the prevailing wind. Secondly, the seafarers of the early Viking Age inherited navigational knowledge and practices from sailors who had rarely aimed to be out of sight of land for more than two days (the southern North Sea being probably the widest body of open water that was intentionally crossed). The North Atlantic voyages of the later Viking Age were therefore likely to have involved the export of a well-established tradition of coastal navigation that did not require instruments.

The *leið* was a highly militarised zone during the Viking Age, meaning sailors would have had to choose whether to recognise or avoid the various fleets and strongholds throughout this seascape. Several scholars have suggested that sailors like Ottar obtained trading privileges or rights of passage from local rulers (Baug et al. 2019; Fell 1982), a practice which seems likely especially after the political consolidation of the mid-10th century. But evidence regarding these logistical and organisational concerns is heavily reliant on analogies and descriptions from later sources. During the early Viking Age, seafaring ventures (martial, commercial, or both) seem to have been relatively independent of centralised management and authority (Meulengracht Sørensen 1995:49). This has led Neil Price to explore the idea of hydrarchy as a reflection of the fluctuating, opportunistic, and unquenchable nature of Viking Age piracy (Price 2014). Although there is little space to discuss this idea in depth, it stands alongside Barrett's "leap-frog hypothesis" (2008:675) regarding Viking Age settlement overseas as valid counterpoints to the centre-periphery and 'wave of advance' models that have long been dominant in the academic literature.

Due to the climatic continuities mentioned above, long-distance sailing probably followed the same seasonal pattern set out in medieval sources. In *The King's Mirror*, the sailing season is said to begin in early April and end in mid-October, although short winter sailing voyages are also mentioned (Larson 1917:158). Sailing in the spring and autumn may have been preferred, due to longer periods of high pressure and the possibility of astronomical navigation (Englert 2007:121; Marcus 1980:112). During these voyages, written sources and iconographic evidence suggests that the crews were divided into two watches, and were led by either two steersmen (as described in in Gunnars Saga Þiðrandabana; Jónsson 1947:324), or a steersman and a *stafnbúi* (derived from stafn, 'stem', and relating to their position in the bow; Ellmers 1995:237).

2.2 Critical Evaluation of Current Research

The evidence presented above exemplifies the diversity of source material for studying Viking Age seafaring, but also illustrates the general problem presented in

Chapter 1: namely, that most of these sources offer information about the points of origin and destination of Viking Age voyages, but say very little about what occurred between these points. The general absence of contemporary written accounts and the uncertainties regarding the applicability of medieval sources mean that it remains unclear which routes were followed in the Viking Age, how far seafarers ranged during this period, and how representative Ottar's voyages are of contemporary seafaring networks. The lack of archaeological evidence for Viking Age sails and rigging has meant that sailing performance has been hard to analyse. Ongoing debates about navigation and logistics make it hard to calculate which destinations could have been reached by Viking Age sailors, under what conditions, and how supplies, crewing, costs, communication, and maintenance were organised. The apparent lack of emporia along the *leið* makes this an especially challenging seascape for reconstructing trade networks, encouraging scholars to rely on elite sites as the assumed nodes in these networks (Lund and Sindbæk 2021:195). Finally, there is little information regarding how large-scale transformations such as the Viking raids, the emergence of kingship, or the adoption of Christianity affected seafaring routes and practices, making it hard to evaluate the extent to which later maritime networks are comparable to those of the Viking world.

Box 2: Summary of current knowledge gaps

- **Maritime worldviews**
    - Conceptions of space and movement employed in Viking Age navigation
    - Routes and practices afforded by seafaring worldviews
- **Technical affordances of Viking Age vessels**
    - Performance of Viking Age boats and ships in exposed seascapes and inshore waters
    - Windward performance of Viking Age sailing vessels
- **Selection of havens**
    - Factors influencing the selection of temporary stopping points during long-range voyages
    - Location of these havens through key seascapes of the Viking world
- **Historical transformation**
    - Factors influencing the survival or transformation of seafaring practices within the Nordic clinker tradition
    - Extent to which recent expressions of this tradition reflect Viking Age practices and perspectives
- **Networks and culture contacts**
    - Seafaring routes through under-researched areas such as the west coasts of Norway and Greenland
    - Furthest potential extent of Viking Age seafaring
    - Likelihood, frequency, and nature of contact between Viking Age seafarers and other circumpolar maritime groups

2.3 Previous approaches to reconstructing seafaring routes

The movement of a motorless vessel through the sea leaves no lasting trace, making it an archaeologically invisible act (unless it ends in shipwreck). Reconstructions of ancient seafaring routes must, therefore, mostly rely on indirect or analogous evidence. Previous approaches can be divided according to the kinds of evidence they have favoured: terrestrial approaches rely on sites, artefacts, and methods accessible from land, while maritime approaches have focused on evidence, activities, and perspectives from the sea.

Figure 10. A previous reconstruction of seafaring routes through the *leið*
The routes and dangers suggested by this map contrast markedly with the results from this project (see sections 5.2.2 and 6.3). Reproduction of Østmo (2020), Figure 1.3. Based on Engedal (2010 map 19) and Kvalø (2007:62ff). Illustration: Ingvild T. Bøckman. Courtesy of Professor Dagfinn Skre; reproduced with permission.

2.3.1 Limitations: terrestrial perspectives

These approaches tend to base their route reconstructions on textual sources, artefact provenance, and the location of diagnostic sites on land. In her excellent study of Iron Age Helgeland, Berglund outlines the usual workflow (1996:89–97). More recently, Engedal (2010) has used the modern Norwegian pilot book *Den Norske Los* (2018) to identify potential passages and areas of risk for Bronze Age seafaring through the *leið*. This research was used by Einar Østmo to reconstruct probable sailing routes through the southern half of this seascape (2020:1.3). This reconstruction is reproduced in Figure 10, and contrasts with the results of this study, as illustrated in Figure 22. Iversen (2008), Maixner (2021), and Skre (2018) have all focused on Iron Age power centres as proxies for probable maritime nodes. Network analysis has served to model the flow of (primarily) goods through Viking Age trade routes and exchange sites, highlighting distribution sites as well as origin and destination points (Sindbæk 2007a, 2007b, 2013). But inherent in all these approaches are two major problems.

The first of these is a general lack of practical knowledge and experience about boatbuilding and sailing, evident in the uncritical reliance on medieval sources and modern pilot books, and in the conservative or overly optimistic estimates of Viking Age rowing and sailing performance (e.g. Carver 1990; Palmer 2009; c.f. the results of this study, see section 5.3.1). This has led to marked contrasts in the routes and ranges of Viking Age seafaring suggested by different scholars, and to an uninformed acceptance of hypothetical route reconstructions without evaluating them through practical experiments. Examples of this include the differing interpretations of the sequence of Viking Age settlement throughout the British Isles (Barrett 2008; c.f. Griffiths 2019); the general uncertainties about the extent of Norse exploration across the north Atlantic (Ljungqvist 2005; McGovern 1985; Raposeiro et al. 2021; Schledermann 2000); the recycling of Crumlin-Pedersen's reconstruction of Ottar's route from Kaupang to Hedeby (Englert 2007; Lund 1984); and the application of the medieval itinerary of King Valdemar to Viking Age seafaring routes through the Baltic (Westerdahl 1990; c.f. Ilves 2012).

The second problem might be best described as a kind of mainland myopia: a perspective which both geographically and cognitively views the sea from the land, giving preference to places and evidence that can be accessed and viewed from land, and scaling down the relevance and centrality of seemingly remote elements of the seascape such as islands, headlands, and outlying passages. A recent example of this perspective can be found in Skre's otherwise outstanding study of emergent Iron

Age kingship across Scandinavia (2025). In his description of seafaring through the *leið*, he states: “Since alternative courses were few or none, a ship that sailed the route was likely to meet most ships that travelled in the opposite direction during the same period. The restrictedness of the route made concealed sailing difficult.” (Skre 2025:300). This perspective is understandable when examining the *leið* on a modern map, and comparing its relatively narrow breadth and apparent single axis of movement to other seascapes such as the Baltic or the Skagerrak. But in fact, like other island fringes along the Atlantic façade, the *leið* was made up of both inner and outer routes, running either *innaskjærs* (within the skerries) or *utaskjærs* (beyond the skerries), and thus allowing for a plethora of bifurcating and intersecting pathways (Bøe 2009:80–81; Macniven 2020:160; Mathisen and Sæther 2018:52). The range of possible routes, and the potential for “concealed sailing” by taking advantage of these (as well as the frequent low visibility due to inclement weather and concealing landforms) can only be appreciated when approaching seafaring itineraries from the sea (Fig 11).

Figure 11. A vast seascape
Skårungen sailing through the *Trondheimsleia*, October 2021. The breadth of the *leið*, and the many possible routes through it, can only be appreciated from the sea. Photographer: Benjamin Vilella; reproduced with permission.

2.3.2 Limitations: maritime perspectives

The centrality of the sailor’s perspective is the common theme in maritime approaches, which can be further divided into experimental archaeology and maritime ethnography.[5] Although scholarship in both these fields goes back more than a century (e.g. Aaland 1909; Andersen 1895), the theoretical and methodological development of maritime approaches was undertaken during the 1970s and 1980s (pioneering works include Crumlin-Pedersen 1978; McGrail 1974; Westerdahl 1980, 1989). Perhaps the central contribution of these approaches has been to provide a toolkit for approximating the perspective of ancient seafarers. From this perspective, it becomes possible to practically evaluate scholarly hypotheses about maritime movement and activity through ethnographic and experimental analogies (Heide and Planke 2019; Ilves 2004; Morrison 1978).

Experimental archaeology investigates how the archaeological record might have been generated, by testing how specific activities could have been conducted using the materials and methods available at the time (Coles 1979:1; Outram 2008:2). Within Viking Age studies, experimental archaeology has primarily focused on the reconstruction of ship and boat remains, such as the reconstruction of the Skuldelev 1 wreck shown in Figure 7. Over the last 40 years, these reconstructions have been analysed to better understand the process of construction (Andersen 1997; Bischoff 2023; Bischoff et al. 2014; Crumlin-Pedersen and Olsen 2002) and the resources and logistics needed to build and maintain them (Ravn 2016b). A number of ship and boat reconstructions have undertaken experimental voyages through various seascapes of the Viking world (Binns 1980; Carter 2001; Englert and Trakadas 2009; Koch Madsen, Ravn, and Sand 2019; Thorseth 1986). These voyages have resulted in the development of a relatively well-tested experimental methodology for studying various aspects of Viking Age seafaring (described in Bischoff et al. 2014), which is followed in this project (see section 4.3).

However, the necessarily hypothetical nature of Viking Age ship and boat reconstructions (especially regarding their rigging and sails) has resulted in differing views about their original construction and performance. Relatively few of the experimental voyages have been published in detail (a notable exception being Englert and Trakadas 2009), and several important regions have not been explored: this includes the northern reaches of the *leið* beyond the coast of Trøndelag, and the west coast of Greenland beyond the area of the Western Settlement. Furthermore, the focus on technical aspects of vessel construction has been accompanied by the widespread assumption that things at sea were done in the past as they have always been done. This has made the cognitive and experiential aspects of seafaring seem like unchanging and therefore uninteresting subjects of study (Campbell 2023; Flatman 2011:325).

[5] In Scandinavian scholarship, the study of traditional boatbuilding and sailing practices is often referred to as maritime ethnology (e.g. Hasslöf, Henningsen, and Christensen 1972). As this research focuses on a single maritime tradition in its various expressions across time, here I have employed the term ethnography, which is more commonly used to denote such an approach in English-language scholarship.

The gaps in the archaeological evidence for Viking Age seafaring have encouraged the use of ethnographic analogy. As described in section 3.4, this involves the comparison between living traditions and particular aspects of the archaeological record to better understand past phenomena. In Viking Age studies, ethnographic analogies have primarily drawn on later expressions of the Nordic clinker tradition. This tradition was documented throughout Scandinavia during the second half of the 20th century (Godal 1986; Hasslöf, Henningsen, and Christensen 1972; Nielsen 1973; Slyngstad 1951; Uksnøy 1959; Westerdahl 1989). Comparisons between this relatively recent record and evidence from the Viking Age have revealed high levels of continuity in boatbuilding and seafaring practices (Crumlin-Pedersen et al. 1980; Godal 1986; Parsons 2013). As outlined in Chapter 1, this project focused on a particular expression of the Nordic clinker tradition as a promising analogy for Viking Age seafaring, namely that of Åfjord. The building and use of Åfjord boats has been comprehensively documented by Gunnar Eldjárn and Jon Godal (1988a, 1988b, 1990), while the long-range fishing voyages to the Lofoten archipelago, in which sailors and boats from Åfjord regularly participated, have been researched by various other scholars (Fjellsson et al. 1995:125–44; Mathisen and Sæther 2018). Eldjárn and Godal's work revealed that Åfjord boats were built following a measurement system based on bodily proportions, which they also identified in the proportions of the ship and boats from the Gokstad burial (Fig 9). This system extended beyond physical measurement to encompass a unique way of talking and thinking, what the authors call a *veremåte*, a 'way of being' (Eldjárn and Godal 1988b:40–50, 1990:57, 77–80).

The continuities in Scandinavian clinker boatbuilding between the Iron Age and the ethnographic record of the late 19th and early 20th centuries have long been apparent (discussed first by Engelhardt 1866). However, ethnographic research about the Nordic clinker tradition has mostly been published in Scandinavian languages, limiting scholarship outside of the Nordic countries. Due in part to this lack of dissemination, previous research has not examined which elements of the Nordic clinker tradition were inherited from the Viking Age, and why these elements survived. In addition, Eldjárn and Godal's research suggests that a relationship existed between boatbuilding practice and the practitioners' worldview, expressed in both the recent and more distant past, but the nature of this relationship and its potential effect on seafaring routes has not been investigated.

2.4 New Research Directions

To address the shortcomings of terrestrial approaches and the gaps in experimental and ethnographic scholarship, this project establishes five interconnected directions for new research. These inform the project's research questions, and resulted in the four articles included in Appendix 2.

2.4.1 Maritime worldviews

As stated at the beginning of this book, reconstructing Viking Age voyages should begin with the sailors who undertook them, focusing on their knowledge, practices, and worldviews as primary influences on their mobility patterns. Despite a growing interest in ideology and ontology within Viking Age studies (Hedeager 2011; Price 2002; Westerdahl 2014), the relationship between Viking Age conceptions of maritime space and patterns of seaborne mobility has rarely been investigated. To address this, the first research direction relates to the worldview of Viking Age seafarers. Through an understanding of this worldview, it may be possible to suggest which routes they perceived, and which of these routes they might have favoured.

Previous scholarship suggests that Viking Age navigation was grounded in three cognitive practices: drawing on accumulated knowledge to select potential actions in the face of uncertainty, a practice which I refer to in this thesis as wisdom; conceiving of maritime space from a navocentric perspective (with the ship or boat at the centre of the orientation system); and the structuring of geographical knowledge based on expected voyage duration rather than absolute distance (Bately 2007:47–48; Indruszewski and Godal 2006:19; Kemp and D'Olier 2016:690).

Wisdom, navocentrism, and time-based geography are likely to have created a profoundly different ontology to that of modern western science. This worldview must have afforded equally distinct sailing routes to those followed by a modern sailor using digital instruments or nautical charts. But understanding how this worldview was enacted in practice, and which routes it might have encouraged, would require experimental and ethnographic research in analogous seafaring traditions. This focus on seafaring worldviews was central to designing the project's methodology (as described in Chapter 4), and was the subject of a stand-alone study presented in Article 1.

2.4.2 Technical and logistical affordances of Viking Age vessels

Seafaring routes were determined not only by sailors, but also by their boats and ships. A comprehensive study of the performance and capabilities of square-rigged clinker vessels was therefore a necessary precondition for route reconstruction. As mentioned above, experiments regarding the sailing capabilities of such vessels offer contrasting results, particularly in regards to windward sailing. Some widely-cited estimates are based on experiments that were conducted over very short periods of time, in boats that were unfamiliar to the crew and researcher (Palmer 2009; c.f. Bischoff 2023:243; Englert 2006). Disagreements are also apparent in the literature regarding the performance of Viking Age vessels along exposed coastlines or in the open sea (Binns 1980:192; Christensen 2007:114; c.f. Carver 1990:122; Marcus 1980:104–5; Schnall 1975:181); and about the meaning of some key terms from the written sources such as *dœgra sigling* and *ambyrne wind*, which further hinder estimates of sailing speed and performance (Englert 2007; Korhammer 1985; Marcus 1980:109; Morcken 1978; Schnall 1975; Vinner 1995).

To address this, long-term practical experience onboard analogous vessels was essential. This could be achieved by adapting the methodology outlined by Englert (2006) to fit the objectives of this project. Transparent, replicable experiments in a wide range of weather and sea conditions, involving crews with varying degrees of experience, would provide a first-hand, qualitative understanding of the technical and logistical affordances of these vessels. Such experiments were conducted throughout this research project, informing the results of all four articles, and are described in detail in Chapters 4 and 5.

2.4.3 Selection of havens

The 9th century account given by Ottar suggests that sailing voyages at this time were rarely conducted non-stop (Bately 2007:47). Rather, sailors relied on temporary harbours and anchorages in which to await favourable weather conditions, exchange information and news, take on pilots, or pay their respects to local magnates. Such stops are likely to have occurred at places offering the right balance between shelter, accessibility, and proximity to relevant people and resources. These places are generally referred to in the literature as havens. However, previous studies do not agree on what constituted a good haven from the perspective of Viking Age seafarers (Ilves 2009; Kruse 2020:177; Macniven 2020:157; Sanmark and McLeod 2024). There are, however, indications that many havens along the *leið* and in other seascapes of the Viking world were located on small, outlying islands and headlands (Englert 2015:54; Skre 2014:37–38; Wickler 2016).[6] Such places remained central to seafaring networks until the adoption of motorised fishing vessels in the 20th century, but have rarely been investigated for traces of Viking Age activity.

This project's third chosen research direction was therefore to evaluate and identify potential Viking Age havens, and use these as nodal points from which to trace probable seafaring routes (following a similar approach to Ulriksen's (2004) study of Viking Age harbours in the southern Baltic). It required both the findings of the previous two research directions, and due to the varying rates of isostatic rebound mentioned above, a bespoke digital reconstruction of Viking Age sea-levels at each of the potential haven sites. Locating these havens would help assess the reliability of the medieval saga literature, as the havens identified through this approach could be compared to the ones mentioned in later texts. This was the approach followed in Article 3, which focused exclusively on the *leið*, as the absence of trading emporia

[6] According to Snorre Sturlason, Harald Fairhair set out from his manors on the west Norwegian coast to fight the Vikings "who lurked in the innumerable islands and bays along the route", pursuing them out westwards all the way to the Irish Sea (Sturlason 1990:58).

throughout this seascape made the identification of potential havens a particular priority. Locating probable havens throughout the *leið* would also help reconstruct routes in other areas of the Viking world with similar climates and geographies, such as western Greenland and the west coast of Scotland.

2.4.4 Historical transformations

Due to the dearth of direct evidence for Viking Age seafaring routes, studies of worldviews, vessel performance, and potential havens must all draw on analogous evidence from other places and times. For the purposes of this study, the most promising analogies were to be found in later expressions of the Nordic clinker tradition, especially in the well-documented record of Åfjord boatbuilding and sailing practices. Apparent continuities in vernacular practices had been noted by previous scholars not only in the clinker construction of hulls, but also in rigging and nautical terminology (Bischoff 2020:148; Parsons 2013:29–33). Enduring names of Old Norse origin for land- and seamarks suggested a continuity in seafaring routes (Kruse 2020; Østmo 2020:22–23), while the documented belief in the pagan, watery spirit *draugen* was thought to be a reflection of prehistoric cosmology (Mathisen and Sæther 2018:31, 90–91; Westerdahl 2005a:29). The aforementioned measurement system used in the construction of Åfjord and Nordland boats also hinted at the possible survival of pre-Christian forms of thought and practice within vernacular traditions. To evaluate the strength of these analogies, the fourth research direction was to examine which elements of the Åfjord tradition might have had parallels in Viking Age practice, and to investigate the causes for continuity and change. This critical combination of different kinds of analogy was an approach maintained throughout this project, and is discussed in depth in Chapter 3 and Article 2.

2.4.5 Networks and cross-cultural contacts

Seafaring routes and practices were also shaped by the communities that Viking Age sailors encountered across the boundaries of their world. In areas inhabited by other oral societies, such as the circumpolar north, scholars have struggled to characterise the cross-cultural encounters hinted at by the sparse archaeological record (Gulløv 2008; Mathisen and Sæther 2018; McGhee 1984; Storli 2007; Sutherland 2009). The roles played by Sámi and Inuit communities in shaping seafaring networks were for a long time downplayed in scholarship, due to the association of the Viking Age with ethnically and linguistically Scandinavian communities. However, advances in the natural sciences offer new potential proxies for reconstructing ancient mobility networks, and for qualifying the nature and extent of these encounters. Genetic and stable isotope analyses of human and animal remains provide new evidence for Viking Age mobility (Price et al. 2011; Ruiz-

Puerta et al. 2023; Speidel et al. 2025), but require qualitative evidence to transform points of origin and destination into seafaring routes and interaction networks. The final research direction chosen for this project was to combine qualitative evidence from this project's experimental and ethnographic research with new quantitative data from the natural sciences. This resulted in a multidisciplinary collaboration investigating the networks of Viking Age and medieval walrus ivory along the west coast of Greenland, which is presented in Article 4.

Summary

From this critical review of current scholarship, it is clear that maritime networks were central to the events and transformations of the Viking Age, but remain poorly understood. This is due in part to the nature of the evidence, but this chapter has argued that the prevalence of terrestrial approaches further hinders our understanding of the maritime dimensions of the Viking Age by spreading a kind of mainland myopia. Although maritime approaches are a promising alternative, they have largely focused on technical aspects of vessel construction. This results in five major knowledge gaps: the nature and effects of maritime worldviews; the performance of Viking Age vessels; the location of Viking Age havens; the utility of vernacular seafaring traditions as analogies for Viking Age practices; and the nature and extent of Viking Age maritime networks.

Five research directions are chosen to address these knowledge gaps:

- Focus on the cognitive and ontological aspects of seafaring to reconstruct the worldview of Viking Age seafarers and suggest which routes this worldview might have afforded.
- Quantifying the performance of Viking Age vessels through experimental trials, helping to establish which routes would have been feasible, and under what conditions these might have been followed.
- Identification of Viking Age havens through the *leið* through experimental voyages and digital reconstructions of historical sea-levels.
- Critical evaluation of later elements of the Nordic clinker tradition as potential analogues for studying Viking Age seafaring routes and practices, and the investigation of the causes for continuity and change.
- Establishment of the range of Viking Age seafarers into circumpolar regions, and characterisation of cross-cultural encounters in these areas.

3 Theory

Abstract

The aim of this chapter is to present and evaluate the three theoretical 'toolkits' which guide the project in the selected directions of research. First, theories of perception help explain how human beings choose particular routes through their environment; both indirect and direct theories of perception are discussed, with the latter seeming to fit better with recent advances in cognitive science and neuroscience, and giving a fuller voice to Viking Age epistemologies. Second, maritime mobility occurs within a particular environment, the sea, defined by specific properties. This environment plays a fundamental role in shaping seaborne movement, meaning that a clear appreciation of its unique characteristics is essential. Third, deploying an understanding of perception and the seascape onto the past requires bridging the temporal-cultural gap between modernity and the Viking Age. This can be achieved through the critical selection of analogies and the use of strong bridging arguments. Together, these three toolkits help create an archaeology of potentials: rather than attempting to reveal past realities, they provide a qualitative understanding of what might have been.

3.1 Introduction

The research directions outlined at the end of the last chapter suggest that the reconstruction of Viking Age seafaring routes requires a qualitative and critical understanding of the worldviews, practices, and seascapes of Viking Age seafaring. The aim of this chapter is to present the three theoretical toolkits required to attain at least a partial understanding of these phenomena.

These toolkits are:

1. **Perception and wayfinding:** people's movement patterns are related to their perception of the world, but there are contrasting views regarding how

perception and cognition result in the choice of particular routes. This chapter outlines the two main theories relating to this question, and evaluates their respective strengths and weaknesses. From this evaluation, it becomes apparent that what people perceive is primarily shaped by the practices and environments in which they engage, rather than by top-down factors like culture or gender. Maritime mobility patterns are therefore the result of a particular set of relations between the perceiving seafarer, their abilities, and the sea. These relations are known as affordances. The affordances perceived by Viking Age sailors can be reconstructed through experimental voyages through analogous environments and using analogous technologies, giving a heuristic sense of which routes they were likely to have followed.

2. **The seascape:** mobility does not occur in a vacuum, but rather within particular environments. Maritime space features a distinct suite of affordances from those of terrestrial environments, and exerts its agency upon human wayfinding in equally unique ways. This theoretical toolkit helps place wayfinding within the maritime cultural landscape; to do this, it identifies the underlying characteristics of seaborne movement that must be preserved in the transference of insights from the sea and onto the page, helping to give a full and fair voice to the sailors of the past.
3. **Analogic Reasoning:** the third theoretical toolkit extends this research across the temporal and cultural gap between wayfinding and seascapes in the modern day and those of the Viking Age. This is achieved through the critical deployment of analogies and their constitution into strong bridging arguments. This section evaluates the strengths and weaknesses of different types of analogy in relation to both experimental and ethnographic methods, and identified various ways in which these can be fruitfully selected and deployed.

3.2 Theories of perception

The first step in reconstructing seafaring routes is to understand how human beings choose particular paths through the environment. Throughout scholarship, it is generally agreed that conscious, wilful movement involves perception and cognition. But beyond this basic premise, there are widely differing views regarding how action, perception, and cognition relate to each other, in what order or hierarchy they occur, and at what stage meaning is generated or encountered. These views can be roughly categorised into two overarching theories, referred to here as the theories of indirect and direct perception. These theories are evaluated below, and a summary of their respective strengths and weaknesses is presented in Table 1.

DEFINITIONS

Cognition: general term referring to a spectrum of activities and processes for gathering, processing, and creating information (such as learning, remembering, or imagining), whether this be in a conscious or unconscious manner (Andrews and Monsó 2021; Bayne et al. 2019).

Perception: the process or result (this distinction is discussed below) of an individual becoming aware of their surroundings and experiences by means of the senses (APA Dictionary of Psychology n.d.; Dror and Schreiner 1998).

Navigation: goal-oriented selection of action through space (Lisman et al. 2017:1437).

Affordances: potential actions contingent on features perceived in the environment and the abilities of the perceiver (Chemero 2003).

Wayfinding: the skill of adaptively choosing paths through the environment based on the perception of particular affordances (Ingold 2000:220).

3.2.1 The theory of indirect perception

Also known as inferential perception (Ben-Zeev 1987; Chemero 2003) or disembodied cognition (Hutchins 1995), the theory of indirect perception is part of the long-established canon of western scientific thought. According to this canon, objective reality exists separately and independently of the mind, while meaning is created in the mind to make sense of the world 'out there' (Foglia and Wilson 2013:319).

This dualistic ontology has had a long-standing influence on psychological approaches to perception; throughout most of the 20th century, the generally accepted consensus asserted that human and animal bodies acquire information from the surrounding environment through the senses. Incoming impulses provide imperfect, partial information about what is being sensed, and therefore require the creation of internal schema, representations, or processors which filter and interpret information into meaning, and which exist independently of the act of perceiving (Hutchins 1995:131; Tolman 1948). According to the theory of indirect perception, a Viking Age sailor might receive a sensory impulse in the form of "small, dark, unmoving blob directly above large, blueish, moving mass". This would then be placed in the pre-existing mental category "island" by a process of fitting sensory input within a pre-established framework of cultural knowledge.

By virtue of being mental rather than physical, such frameworks cannot be biological, but must instead be acquired or developed by individuals during their lifetimes (Kaplan 1973). These frameworks are a form of cultural knowledge, with different cultures creating different ways of categorising sensory information based on what they consider important (Lynch 1973:307). From this perspective, the study of cultural forms (such as seafaring or navigational practices) consists in analysing and comparing different ways of organising sensory information. Knowledge, according to this epistemology, is not to be found in the world, but rather in the categories and representation of the world in the mind (Ingold 2000:213).

The theory's widespread and enduring predominance within western science led to the curious assumption that it was not only correct, but that the categories and concepts employed by its proponents were, in fact, universally applicable. As a result, typologies and representations produced by western scientists, such as maps, were presented as objective, accurate reflections of reality (Ingold 2000:15). This form of epistemic imperialism (Machado de Oliveira 2021:15–26) negatively affects archaeological practice by encouraging one of two dangerous assumptions: either that the people under study perceived the world in the same way as the modern researcher; or that the researcher has succeeded in transcending their own cultural biases and can record and analyse the archaeological record from a position of objective neutrality (McNiven 2016:685).

3.2.1.1 Problems

The theory of indirect perception suffers from a major logical weakness. This concerns the nature of the cognitive frameworks which (it argues) turn perceptual input into knowledge and action. There is still no consensus about how these frameworks can be present in the mind prior to and independently of sensory input and action, and yet at the same time be learnt, shared, and developed among the members of a culture (Gould 1973:216; Hutchins 1995:130–31). These contradictions have hindered the efforts of anthropologists and cognitive scientists to understand (seemingly) simple and social tasks such as hand-eye coordination and wayfinding, as they tend to resist the kind of codification that is presupposed by the perception-processing-action model.

In addition to this logical problem, the application of indirect theories of perception in anthropology and archaeology ignores the descriptions of cognition and wayfinding from the ethnographic record, and the critique of these theories from indigenous philosophies (Atleo (Umeek) 2004; Hallowell 1964; Levinson 2008; Nelson 1983). Instead of coming to know the world by sorting and representing it in the mind, these sources argue that knowledge is to be found by interacting with and attending to one's surroundings. Meaning, therefore, is in the world 'out there', and can only be gathered through moving, sensing, and engaging physically with the world; in other words, by using the body as a part of cognition (Tilley 1994:54–66). Similar, non-representational perspectives seem to be expressed in the archaeological record, as Hedeager has highlighted for the Scandinavian Iron Age: "the basic structural categories of the modern Western world […] do not correspond to the fundamental categories of the ancient past when *a body could exist beyond the boundary of the skin*" (2011:12, emphasis added).

3.2.2 Contributions from cognitive science and neuroscience

A fundamental shift in theories of perception occurred during the 1990s. Critiques of the established view and a growing openness to epistemological diversity led cognitive scientists to re-evaluate the role of cognition and perception in wayfinding and navigation. Key to these early efforts was Edwin Hutchins' *Cognition in the Wild* (1995). Hutchins argued against the existence of a grand, categorising overview of the world in the mind of the individual, and in favour of a collective form of perception-cognition involving both other humans and inanimate objects such as navigational instruments. This "cognitive ecology" was in itself a cultural form, which shaped human action based on qualitative value judgements rather than objective, individual calculations. Hutchins therefore opposed the long-established metaphor of the mind as a computer, and speculated that any internal mental structures (note that he did not deny these outright) were there to coordinate cognition, rather than to represent the world and generate meaning.

Many of the suggestions made by Hutchins' research have appeared more recently in the field of neuroscience. Navigation, both with and without the support of instruments, has been shown to be a much more complex process than what traditional pathfinding experiments suggested. Sailing is specifically mentioned as an example of the capacity (common to ants, birds, rodents, and monkeys, as well as humans) to move beyond sensory input and employ sophisticated correlational thinking in the task of choosing a path through a dynamic environment (Frake 1985:268; Lisman et al. 2017:1438; c.f. Tolman 1948). This capacity is known as path integration, and is performed in the hippocampus and the dorsocaudal medial entorhinal cortex (dMEC) by a variety of neuronal cells. Pioneering research into these cells identified 'place cells' and 'head-direction cells' in the hippocampus, which responded, respectively, to the subject's position and orientation (O'Keefe and Dostrovsky 1971; Taube, Muller, and Ranck 1990); while the firing fields of 'grid cells' in the dMEC was found to exhibit a regularly-spaced, tessellating pattern which correlated to the subject's spatial environment (Hafting et al. 2005).

The firing patterns of these cells were taken as proof of a topographically organized representation of the environment existing in the mind, independent of context; in other words, of a cognitive map. However, this has been questioned recently on several grounds: firstly, the similarity of laboratory experiments seems to have played a role in the conclusion that the structure of this map was universal. Instead, grid cell firing patterns seem to be strongly influenced by cues in the environment (Lisman et al. 2017). Additionally, the network of grid cells has been shown to be activated in many other cognitive processes beyond spatial orientation, such as in understanding temporal relations, value, and social hierarchies (Neupane, Fiete, and Jazayeri 2024). While the mechanisms behind path integration are yet to be fully understood, contemporary neuroscience suggests that human conceptions of their environment are in fact context-dependent, and that uniform neuronal networks provide a more general, non-representational consistency to cognitive processes, more akin to a rhythm than a map.

Figure 12. “What things *do*”
The frames of this Åfjord *fyring* are made out of curving timbers from between the trunk and roots of a spruce tree. The combination of perception in the environment (tree, curve) with particular human abilities (woodworking, sailing) create specific affordances: in this case, a specific kind of boat, whose own capabilities afford particular routes through the seascape.

3.2.3 The theory of direct perception

The importance of environmental and bodily cues, and the absence of direct representations of the world in the mind, form the central pillars of the theory of direct perception. This theory has been strongly influenced by Bourdieu’s discussions of practice (1977, 1990), and has been a part of the recent shift within the humanities away from idealism and towards realism. The Norwegian archaeologist Hein Bjerck sums up this shift: “what matters is what things *do* in their co-working wholes – not the static description of the separate machine parts – what things *are* – that all too often are given priority in archaeology” (Bjerck 2022:156, original emphasis). For Bjerck, “things” includes human beings, as well as the cultural forms that they create such as tools, boats, or beliefs.

Contrary to Cartesian dualism, this theory argues that sensory and motor functions play an inextricable role in cognition (Dawson 2019; Foglia and Wilson 2013; Shapiro and Spaulding 2025). Examples of the body enabling and constraining cognitive processes include the use of the hands in arithmetical calculations (Foglia and Wilson 2013:321) and as we saw in Chapter 2, the role of bodily proportions in shaping the abstract and physical conception of vernacular boats. From this perspective, cultural forms are not a product of abstract internal schemas, but rather fruit of different actions in the world, including the act of perceiving. Knowledge is generated by the engagement of the mind in the world through the body and the senses, meaning that ways of acting and perceiving are in and of themselves also ways of knowing (Ingold 2000:9).

Without a comprehensive representation of the world in the mind, action must be enabled and constrained by how and what humans and animals perceive. This is the basic premise of James Gibson's theory of affordances (2014:119–35). The present research follows the interpretation of Gibson's affordances given first by Chemero (2003), and introduced to archaeology by Gillings (2009, 2012). According to this reading, affordances are not resources in the environment, nor properties of it, but rather the relations between the perceiver's abilities and certain features of the environment (Chemero 2003:186). For example, a person's abilities to use woodworking tools and to row, combined with their perception of a long, straight branch, could offer up the affordance "oar, rowing". But this affordance is not a thing in the world, and depends on both the perceiver's abilities and the features in the environment. A bird, possessing the abilities of flight and balance, might encounter a different affordance, such as "perch, landing".

Throughout their lives, people learn and are taught to attend to their surrounding environment according to their individual and collective suite of abilities. In attending to the world, they are perceiving not so much the features in it as the potential actions that seem possible with it, and in learning new abilities, they also come to perceive the world in new ways (Gillings 2012:606; Ingold 2000:153). This makes abilities and environments absolutely central to a diachronic study of seafaring routes such as this one, as it is these factors that offer up a particular range of affordances. Such affordances include choosing particular routes, havens, or weather conditions in which to travel (Fig 12). According to the theory of direct perception, the acquisition by the scholar of a similar range of abilities and the engagement in similar environments to those familiar to the community under study will allow them to perceive a similar range of affordances. Not possessing these abilities or not exploring these environments, on the other hand, will lead to entirely misguided conclusions, as the scholar will be quite literally blind to the ways of life they are studying.

3.2.3.1 Challenges

The theory of direct perception has yet to find widespread application in archaeological research. This is partly due to it being a young and heterogeneous body of thought, but also because of the challenge it poses to the western scientific canon outlined above: the idea of the mind being in the world, and of meaning and knowledge existing beyond the mind will require a fundamental ontological shift before they can be comfortably fitted into scientific practice.

In addition, scholars who adhere to this theory still tend to fall back on the comfortable idea of a gap somewhere within cognitive processes. While the theory of indirect perception saw a gap between reality and cognition, Gibson's theory of affordances seems to argue for a gap between perception of the environment and our imagination of possible actions in it. This is where the work of Tim Ingold, already influential on the discussion above, becomes particularly crucial, as he manages to present an explanation of this process that does not require abstract, computational filters or frameworks. For Ingold, neither the real environment nor the imagined action have yet come to be. Instead, the perceiver inhabits an immanent world, one in which actions are the result of a judgement about how best to adapt to a not wholly known set of circumstances (2022:38).

Other problems remain, however; much of the literature on direct perception (including Ingold's work) remains strongly focused on the individual at the expense of collective or social aspects of human activity. Although perception may indeed be direct, observations of this process indicate that potential actions are also enabled and constrained by collective abilities, shared experience, social rules, hierarchies, and structures of power and obligation (Bishop, Oliver, and Aporta 2022; Gillings 2012; Hutchins 1995).

Finally, the theory of direct perception poses an additional challenge for archaeological research. The argument that structuring principles of the modern western worldview such as logic, causality, perceptual salience, and optimisation are not universal means that the actions of past individuals apparent in the archaeological record cannot be explained by such principles. Instead, they require an understanding of the individuals' bodily engagements with the world. Developing this understanding requires strong bridging arguments based on a critical choice of analogies; these are discussed further in section 3.4.3, as part of the third theoretical toolkit in this chapter.

Table 1. Strengths and weaknesses of the theories of direct and indirect perception.

	Indirect perception	**Direct perception**
Strengths	-Relatively complete and unified theory -Widespread and enduring predominance within western science, in alignment with its structuring principles (logic, causality, perceptual salience, optimisation)	-Aligns better with how perception actually works (as suggested by neuroscientific research, non-western thinkers, and ethnographic evidence)
Weaknesses	-Epistemic imperialism: negates the widely-documented (although often ignored) statements from many non-western cultures that there is no division between mind and world; or if there is, that knowledge does not come exclusively from the rationalization of sensorial experience	-Theoretical heterogeneity: varying approaches and unanswered questions -Requires a new ontology: clashes with some of the epistemological foundations of western science -The inescapable cognitive gap: tends to fall back on abstract computation somewhere between perception and action

	-Logical weaknesses: no consensus about how structuring frameworks can be present in the mind prior to and independently of sensory input and action, and also be cultural forms that are learnt, shared, and developed among a community	-As actions cannot be explained through universal principles, cross-cultural studies require the use of analogy -Individualistic: much of the literature disregards social and collective cognition

3.2.4 Deploying the theory of direct perception

The theory of direct perception offers some distinct advantages over the awkward dualisms of conventional Western thought. First and foremost, it aligns better with how perception seems to actually work. The recent advances in neuroscience discussed above align with philosophical discussions of experience by phenomenologists such as Heidegger (1988), Husserl (1973), and Merleau-Ponty (2002) in suggesting that engagement in the world plays a key role in cognition. This is a position which is also held by many indigenous thinkers: the Nuu-chah-nulth chief Umeek has argued that faith, emotion, intuition, will, experience, and the relations between these elements play a much greater role in shaping perception and action than that ascribed to them by categorical western rationalism (Atleo (Umeek) 2004). Similarly, members of the Labrador Inuit community of Nunatsiavut have argued that seasonal cycles and the relations between different elements of the environment are the primary factors shaping their perception and action in the world (Bishop et al. 2022). Finally, the medieval Norse sources mentioned in the previous chapter describe seafaring as a process of adaptive judgement based on accumulated experience, echoing Ingold's understanding of affordances and wayfinding (Gertz 1922; Larson 1917). This is discussed at length in Article 1.

The support for this theory from such a wide range of voices makes it at least worthy of testing. It fits particularly well with the research questions of this study, as it explains how different understandings of the world can be shared across cultural and temporal boundaries: in other words, how a modern archaeologist can attempt to enact themselves into the world of Viking Age seafaring. Achieving this, however, requires a second toolkit, focusing on the environment in which seafaring occurred.

3.3 Theorising the sea

The conception of space shared among Viking Age sailors seems to have been profoundly different to the predominant worldview of the modern west. As we saw in the previous chapter, it was rooted in perception and practices enacted from the sea, which promoted judgement over computation, navocentrism over universality, and time over distance. The maritime environment was thus a central factor in Viking Age seafaring knowledge, and must be fully accounted for when approaching seafaring routes from the perspective of the sailor. To do so requires tools which can highlight and preserve aspects of the maritime environment that are absent or less evident on land.

3.3.1 The maritime cultural landscape

Coinciding with the shift towards embodied cognition discussed above, the turn of the 21st century saw an emerging interest in the intangible aspects of culture, a focus on landscapes rather than isolated sites, and the employment of reflexive approaches to archaeological interpretation (Aston 1985; Hodder 2000; Tilley 1994). These ideas were first assembled and adapted for maritime archaeology by Christer Westerdahl in his article 'The maritime cultural landscape' (Westerdahl 1992), which alerted scholars to the rather limited view of the maritime past that had been dominant until this point. The concept of the maritime cultural landscape has been widely debated, interpreted, and applied, making its original impact harder to appreciate (e.g. Flatman 2011; Ilves 2004; Sanmark and McLeod 2024). For the purposes of the present discussion, it is worth outlining what ideas were contained in this text, and why they had such a widespread impact.

The main contributions of Westerdahl's article have been threefold: first is the proof that the maritime past can be studied as more than isolated shipwreck sites; there is, in fact, "a gigantic maricultural exploitation area" (Westerdahl 1992:5), containing a wide range of tangible and intangible cultural features on land and underwater, such as placenames, harbours, sailing routes, and seamarks. It is this wide range of human engagement in maritime space that makes up the maritime cultural landscape (Westerdahl 2011:337). Related to this is the second idea that maritime space was to be approached and understood "by way of the cognitive perspective of local tradition" (Westerdahl 1992:5); in other words, that a distinct relationship with (and conception of) the maritime environment existed among the communities who lived on and by the sea. Finally, the text contains the somewhat more implicit argument that the maritime cultural landscape has long been misunderstood, ignored, or even silenced by terrestrial, literate, and elite cultures. Attendance to "genuine tradition, verbal, mental, or manual" through multi-disciplinary approaches (Westerdahl 1992:5) is therefore a necessary step in attaining a fairer and more holistic view of past maritime practices and perspectives.

Figure 13. The hypersea
It may be static and bounded in this image, but the sea is a dynamic, all-encompassing entity with its own agency. Movement through this environment is defined by contingency, creating profoundly different mobility networks to those on land. Stadhav, June 2022.

3.3.2 The sea - a hyperobject?

Westerdahl's original concept and his later works (Westerdahl 1995, 2005b, 2005a, 2010b, 2010a, 2011) have been perhaps the most influential body of theory for maritime archaeology of the last three decades. But theoretical discussions have of course continued, and the ongoing shift towards materialism has encouraged a critical review of the maritime cultural landscape. For the present research, the most relevant critique is that put forward by Peter Campbell. Campbell draws on object-oriented ontologies (introduced to archaeology in Olsen 2010; and explored in maritime contexts by Normark 2014; Steinberg and Peters 2015; Peters and Steinberg 2019) to explore the sea as "a real entity, an actor with agency, which simultaneously operates on multiple scales" (Campbell 2020:208). According to Campbell, the sea is as an example of Morton's (2013) concept of the hyperobject: an entity existing beyond human scales of space and time in apparently non-contiguous and non-continuous form, and yet also ever-present and inherent in other entities (Fig 13). Humans can only perceive the local, sensual properties of hyperobjects through their relations with other objects, including themselves (Campbell 2020:211; Normark 2014:196–97).

Campbell argues that the maritime cultural landscape is only the human reflection of the marine hyperobject, and is therefore an expression of modern western anthropocentrism, different to the more holistic view of the sea as an animate, agency-laden entity that prevailed in the past. Such a view has been identified among the Maya (Normark 2014), in the Classical Mediterranean (Gillis 2012:54–55), and seems also to be expressed in the personified description of the seasons in Old Norse texts (Larson 1917:87–92). These perspectives reflect a conception of seafaring as a negotiation between dynamic forces and agents, something which Campbell argues is lacking in Westerdahl's approach (2020:219).

Campbell's critique is thought-provoking, and a timely exploration of contemporary theory in a subfield that remains dominated by technological studies. But it is largely unfair to the core tenets of Westerdahl's original idea. Very nearly explicit in the 1992 article is the idea of the sea as an active agent, shaping the "tradition of usage" through "the influence of local winds and currents" (1992:8). Furthermore, many of the properties of hyperobjects are also explicit qualities of the maritime cultural landscape, such as its vast geographical and temporal extent, its 'viscosity' (i.e. its extension beyond the physical limit of the shore), and its non-locality. Substituting the maritime cultural landscape for the 'Hypersea' does not, therefore, immediately open up new perspectives on the maritime past. What is valuable in Campbell's article is his subsequent discussion of how the sea, possessing these properties, might have been experienced by maritime societies in the past. As an active agent, the sea can determine the outcome of a voyage, making maritime travel a profoundly contingent undertaking, and emphasising the role of uncertain judgement over absolute computation in decision-making and route choice.

Seeing the sea not as a passive backdrop for human action but as an active agent in human experience ties in with the theory of direct perception, as it is a clear case of context playing a central role in people's conception of their surroundings. As a multi-faceted assemblage, perceivable only through its relations to other objects, the sea also qualifies as an affordance, according to Chemero's interpretation. Conceiving of the sea as a relational assemblage, defined by flows and continual recomposition (what Ingold calls 'whirls', 2022:42), means that maritime places can only be understood in the context of movement (Steinberg and Peters 2015:248). This inherent dynamism and tendency to resist representation prevent it from being codified or ever fully known; understanding, albeit partial, of past maritime practices and networks can only come through direct attendance and experience in comparable maritime contexts, making analogical reasoning a central tool for a study such as this one. This is the subject of the following section.

3.4 Ethnoarchaeology and experimental archaeology

The paucity of direct evidence for Viking Age seafaring routes means that these need to be reconstructed through bridging arguments: diachronic reasoning drawing on empirical research in the present and deployed into the past through the critical combination of different types of analogy (David and Kramer 2001; Wylie 1985, 2002). Potential analogues for Viking Age vessels, practices, and routes can be found in later expressions of the Nordic clinker tradition, and employed as windows on the past through experimental archaeology. However, such an approach requires an evaluation of the risks and opportunities involved in using analogies, and an understanding of how to critically select and deploy them.

3.4.1 Risks

The use of analogy has long been a part of archaeological practice (David and Kramer 2001; Marciniak and Yalman 2013), but its ubiquity should not blind us to the risks involved. It is, after all, a technique which compares observed human behaviour from the present or recent past with the interpreted, fragmentary evidence for much earlier practices. The involvement of human interlocutors adds an additional layer of subjectivity between the archaeologist and the ancient community under study. Due to the small number of living human beings relative to the accumulated population of our species, only a handful of the practices and perspectives that have existed throughout time are evident among people today (Seetah 2008:144). This dearth can cause logical errors in archaeological research, such as the fallacy of affirming the consequent; in other words, the assumption that only the causal relationship observed in the present can explain a comparable effect in the past (Gould and Watson 1982:372). Furthermore, diachronic studies such as this one must engage with communities that are at least to some degree influenced by contemporary cultures, technologies, and environments. This influence is likely to add a degree of anachronism to any diachronic analogy (Eldjárn and Godal 1988a:22). Finally, no standard methods exist for the experimental archaeology of ships and boats (Bischoff et al. 2014:243), meaning that this research project needed to test, evaluate, and select appropriate analogues and data-gathering techniques; these are presented in the following chapter.

3.4.2 Opportunities

At the same time, ethno- and experimental archaeology encourage long-term, practical engagement with living people and traditions across cultural boundaries. Regular, local interactions with human interlocutors over long timespans, along with the development of mastery in skills from other cultures and times, help challenge the assumed universality of modern western concepts and avoid mistaking easily-identifiable correlations for the underlying causes of archaeological phenomena. The great strength of ethno- and experimental approaches, therefore, lies in their capacity to guide archaeologists towards other ways of doing, thinking, and being across an epistemologically-level playing field (McNiven 2016:685; Sahlins et al. 1996:425).

Following, the theory of direct perception, this guiding can be understood and documented as a process of learning to perceive a new set of affordances, fruit of the development of new abilities and new ways of attending to the environment. If the analogies are well-chosen, then the movements, practices, and environments in which the scholar engages will create a shared space of experience with the community under study. This experiential bridge can lead to the perception of similar affordances, allowing the archaeologist to suggest what courses of action might have been taken in the past. In the case of this study, this means acquiring abilities from analogous seafaring traditions, enacting them through the seascapes of the Viking world, and documenting which routes such practices and environments afford.

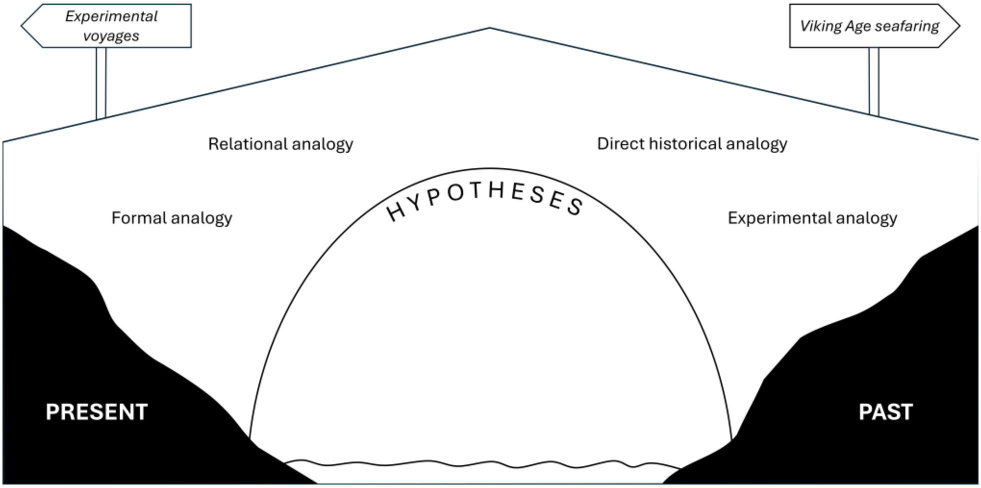


Figure 14. Bridging arguments
Analogies allow for the dynamics of the past to be understood in the present. In this project, they are critically combined into bridging arguments based on testable hypotheses.

3.4.3 Deploying analogies as bridging arguments

Analogies allow for the dynamics behind the (now largely) static archaeological record to be investigated. Archaeological analogies involve a subject and a source: the subject is the phenomenon apparent in the archaeological record that is the focus of a research question. The source is the analogue, the contemporary phenomenon observed or enacted in the hopes that it will be relevant to the enquiry (Stahl 1993). In this project, several types of analogy are combined to construct a bridging argument between modern and Viking Age voyages through the *leið* (Fig 14). The physical similarities between vernacular clinker boats and the vessels of the Viking

Age allow for the use of formal analogies (although changes in certain materials and construction techniques must be kept in mind; see Appendix 1); the involvement of sailors from the Åfjord tradition in regional and inter-regional seafaring networks, geographically and environmentally overlapping with those of the Viking Age, provide relational analogies; the cultural continuities between the sailors of the Viking Age and those of the Åfjord tradition offer a direct historical analogy; while the undocumented routes and practices of Viking Age seafarers are investigated through experimental analogy.

A strong bridging argument is one that addresses the research question in full and offers wide-ranging proof of the comparative potential between subject and source. This requires a critical and informed choice of source, as described in the next chapter. The use of direct historical analogies comes with the risk of applying the behaviours of contemporary subjects onto prehistory (Gould and Watson 1982:359). Such direct, uncritical application will inevitably result in the bridging argument revealing an unrealistic degree of continuity between subject and source (Eppich 2020:31). Instead, analogies should be used as heuristics, highlighting change as well as continuity, and helping archaeologists to identify exactly which practices are comparable and which are not (Lyons and Casey 2016:516). This approach to analogy constitutes the foundation for the fourth research direction presented in the previous chapter, and for Article 2.

Despite its interpretive aspects, the deployment of bridging arguments built on analogies is a kind of scientific experiment. It follows the conventional process of hypothesis and deduction, whereby a formulated hypothesis is first tested to see if it can be disproven, and becomes a valid explanation only if it resists such testing. The hypothesis may then be used for the time being, but must never be taken or presented as absolute truth (Outram 2008:1). These basic principles are important because they help emphasise that regardless of scientific advancement or theoretical sophistication, analogies and bridging arguments cannot reveal past realities. At best, they provide a nuanced understanding of what activities are likely to have created the archaeological record, and how these activities might have been undertaken by people in the past (Ravn 2016a:137).

3.5 An archaeology of potentials

These three toolkits allow for the maritime dimensions of the Viking Age to be approached in fruitful new ways. The deep dive into theories of perception allows for a study of wayfinding at sea to be incorporated into the project's trial voyages (see section 5.3.2), thereby extending experimental archaeology beyond purely technical aspects of vessel construction and performance. The integration of object-oriented ontologies and the idea of the sea as a hyperobject helps counter mainland myopia, and encourages a focus on the inherently dynamic and contingent nature of maritime mobility. Finally, the critical and transparent use of analogies allows for the incorporation of new ethnographic evidence from the broader Nordic clinker tradition as a potential window on Viking Age seafaring.

The value of these theories lies not only in their synergy, but also in their ability to guide the scholar towards approaches and perspectives that might otherwise be ignored or underrated (Terrell 2003:74). This study involved approximately 1,000 hours spent at sea, but this makes up less than 2% of the five years of total research. I remain a profoundly terrestrial, western, and modern individual, prone to rational and categorical thinking, and lacking mastery in most of the abilities possessed by Viking Age seafarers. A strong and explicit bridging argument helps identify and limit some of the biases that I bring with me, and encourages alternatives to the conventional terrestrial perspectives discussed in Chapter 2. The integration of multiple theories from different disciplines further increases these benefits, as each theory can reveal different kinds of knowledge: a qualitative approach to cognition and experience allows for the intangible aspects of maritime traditions to be documented, while hypothetico-deductive reasoning deployed through analogy allows for replicable experiments providing quantifiable results.

The overarching goal in selecting and deploying these theories has been to develop what Marcos Llobera called an “archaeology of potentials”; namely, a practically-informed and communicable understanding of “how particular processes or concepts may play out within the specifics of a certain context” (Llobera 2012:504–6). In the case of this project, this meant reconstructing the routes and places that might have been favoured by Viking Age sailors through experimental, ethnoarchaeological, and digital approaches. The methods employed to fulfil this goal are presented in the next chapter.

Summary

This chapter has presented the project’s theoretical foundations in the form of three toolkits. These set the project along the new directions of research identified in the previous chapter by explaining how human beings find their way through the environment; how the maritime environment shapes wayfinding in particular ways; and how modern maritime movement (in the form of experimental voyages) can be deployed across time to reconstruct the seafaring routes of the Viking Age. These theories allow for new insights into Viking Age seafaring by incorporating the role of ontology in studies of maritime networks, integrating dynamism and contingency into analyses and representations of seafaring, and allowing for the inclusion of new ethnographic evidence through critical bridging arguments.

4 Methods

Abstract

This chapter presents a methodological overview of the research, and explains how maritime and terrestrial perspectives are integrated in the collection of qualitative and quantitative data. Experimental sailing trials and trial voyages onboard vernacular Norwegian boats quantify the technical affordances of Viking Age seafaring and document the processes influencing route choice. Potential stopping points used during long-range Viking Age voyages are identified through archival research, seaborne and terrestrial surveys, and the digital reconstruction of historical topographies. The diversity of these methods, and of the evidence they produced, encouraged the design and publication of a project data repository, which complements the four articles at the core of this project. The strength of this methodology lies in its capacity to harness the strengths of quantitative and qualitative evidence, while also addressing their weaknesses.

4.1 Introduction

The previous chapter concluded that the completion of this project's objectives depended on several factors:

- A qualitative understanding of the relationship between practice, perception, and movement at sea;
- the direct, practical, and long-term engagement of the researcher in analogous practices and environments;
- the critical selection of analogous sources;
- and the transparency and replicability of selected methods.

Due to the lack of standardised experimental and ethnographic methods, the project's focus on cognitive as well as practical aspects of seafaring, and the under-researched nature of the study region, fulfilling these objectives required the design and implementation of a bespoke methodology. This chapter presents the project's methods as a general research pipeline; for specific, technical details regarding their application, the reader is directed to the corresponding sections in the four articles (Appendix 2).

Data-gathering methods and their relationship to the project's research outputs are presented in Figure 15. As described below, the project's focus on sailing routes and practices encouraged the use of traditional Åfjord boats as analogues for Viking Age seafaring. Experiments onboard Åfjord boats fell into two categories: sailing trials and trial voyages. Sailing trials tested specific variables and research questions such as windward sailing performance. Trial voyages generated a broader perspective on the affordances of long-range seafaring by following routes suggested by archaeological and documentary evidence. Together, these experiments fostered a practical, first-hand understanding of the technical and logistical affordances of Åfjord seafaring. Through the critical use of analogy, these affordances helped reconstruct Viking Age seafaring routes and locate probable havens.

Data was also gathered between trials, on land. This included historical research, interviews with crew members and local practitioners; photogrammetric modelling of the project's vessels; and digital analyses and reconstruction of potential haven sites. The data generated through seaborne and land-based methods were compiled into an open-source, online data repository, and compared with the surviving evidence for Viking Age seafaring practices. Together, these methods were employed to reconstruct traditional seafaring worldviews (Article 1), identify elements of the Åfjord tradition which represent continuities from the Viking Age (Article 2), locate potential Viking Age haven sites throughout the *leið* (Article 3), and reconstruct networks of ivory acquisition and exchange in the high Arctic (Article 4).

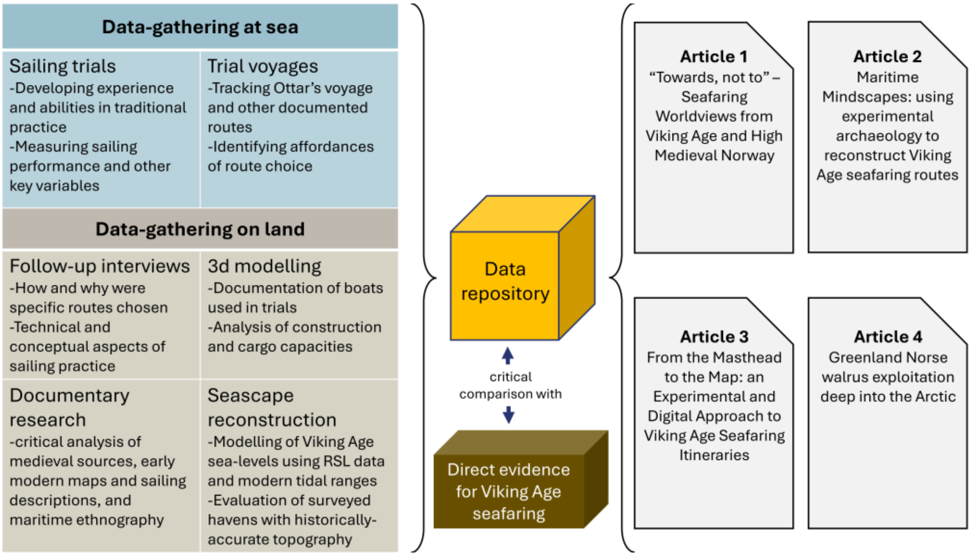


Figure 15. The project's research pipeline
Various forms of data-gathering were conducted for this project, and the evidence they produced was assembled into an Open Access online data repository. This evidence was then compared with surviving traces of Viking Age seafaring, and the resulting findings were turned into four independent research articles.

4.2 Preparation

Experimental sailing voyages in analogous vessels and environments were selected as the optimal approach for addressing persistent knowledge gaps in current scholarship regarding the affordances, worldviews, and networks of Viking Age seafaring. Undertaking these voyages and enacting the practices of analogous seafaring traditions would provide a qualitative understanding of what Viking Age vessels and their crews might have been capable of, and what routes might have been favoured. This approach was first evaluated during a pilot study in the spring of 2021 in the southern Baltic (Box 3). This study emphasised the potential of a seaborne approach, but also highlighted the importance of direct engagement in the practices under study

Box 3: Pilot study

This study was designed to test and evaluate data-gathering equipment, methods, costs, and logistics. It was conducted in April 2021, thanks to a collaboration with Dr Brendan Foley, who had chartered the diving vessel *Stora M* for an underwater survey in southern Sweden. *Stora M* was returning to her home port of Västervik after the survey, and the crew accommodated me onboard for the duration of this voyage. During the voyage I conducted informal interviews with the crew; took regular observations of the vessel's position, speed, and heading; photographed and recorded the weather and sea conditions; made note of important landmarks that were pointed out to me; and documented navigational choices as they were made, adjusted, or changed.

The pilot study influenced the development of the project's methodology in several ways.

Lessons

During the voyage I was not an active member of the crew, and was attempting to document seafaring practice and experience from outside, following the convention of the removed, objective scientist. It quickly became apparent that taking such a position would result in partial and filtered information being offered by the crew. The interviews could not appear organically during pauses between required tasks, but rather had to be initiated deliberately, without knowing if the interviewee would be willing to share more than the necessary minimum. Landmarks and features of the seascape were rarely pointed out without me asking first, and I was not privy to the process of route choice, only to the final results.

Potentials

Despite these limitations, the pilot study revealed the potential of conducting studies about the sea from the sea. The experience of maritime space from onboard a moving vessel generated completely different ideas and possibilities than what would have been conceivable by approaching the sea from the land. Features of the seascape that had seemed unimportant from land became central anchors of perception from the ship, such as the small island of Blå Jungfrun in the Kalmar Strait. These hints suggested that an extended, seaborne fieldwork campaign in which I participated actively in the handling of an analogous vessel while also gathering data could reveal a wealth of new evidence.

4.2.1 Vessel selection

Åfjord boats and the accompanying sailing practices of this tradition were selected as cautious analogies for reconstructing Viking Age seafaring practices and mobility patterns. There were several clear advantages for this project in using these boats rather than reconstructed Viking Age ships: thanks to the generosity of the staff at Fosen Folkehøgskole (located in Rissa, Norway), I had unobstructed access to their collection of Åfjord boats throughout the year and could, with permission and a crew, skipper them myself and conduct experiments wherever I chose. Furthermore, several examples of Åfjord boats survive from the last decades of their commercial use at the turn of the 20th century (such as the *fembøring* displayed at Sverresborg Folk Museum), meaning that unlike the Viking Age ship reconstructions, their construction and physical properties are fully understood. To this can be added the detailed ethnographic research regarding their construction and handling (discussed in Chapter 2), offering a potential window on much older traditions; and the greater number of working examples with which to develop a comprehensive and comparable corpus of experiments.

Åfjord boats also serve as strong analogies according to the criteria set out in the previous chapter: the maritime approaches discussed in chapter 2 have shown the comparative potential between subject (Viking Age seafaring) and source (vernacular Åfjord traditions), although exactly which practices are directly analogous requires further investigation (see section 5.4.2); experiments could be conducted over a long field campaign, involving frequent interactions with local practitioners, and a number of different vessels; the data-gathering could follow a hypothetico-deductive workflow of my own design, independent of other scientific agendas; and the source tradition was sufficiently well-preserved to reveal changes as well as continuities from the Viking Age. Ottar's 9th century voyage through the *leið* served as a promising focus for the analogy, as it involved the documented experiences of a particular individual, rather than an essentialised imagining of a generic Viking Age seafarer. If, after conducting these experiments, new knowledge was revealed about Ottar's itinerary, then the methodology could be further applied to other archaeologically-attested but undocumented voyages throughout the Viking world.

It is important to emphasise that practitioners of living traditions like Åfjord boatbuilders and sailors are by no means isolated from modern society, and their perspectives, skills, and knowledge are a reflection of the negotiation between tradition and modernity. Consequently, the results of the project's experiments should be taken as an approximate, minimum standard for what Viking Age crews could have accomplished.

4.3 Experimental sailing trials and trial voyages

The experimental research onboard traditional boats conducted for this project follows the method developed at the Viking Ship Museum (summarised in Bischoff et al. 2014). The primary distinction within this method is between sailing trials and trial voyages. Sailing trials are short experiments conducted under relatively controlled conditions, in which a particular variable or research question is tested. Trial voyages are longer expeditions carried out through historically-attested environments, with a minimum of modern aids, and under conditions known from the period under study. In this case the goal is to explore multiple variables over a longer, continuous period, and attain a broader understanding of the experience and possibilities of ancient seafaring (Bischoff et al. 2014; Englert 2006). These research methods require:

- **Active and embodied participant observation**: to accurately record and interpret seafaring practice, it is essential that the researcher develops first-hand experience in the abilities under study, and operates as an active member of the crew, fully involved in the suite of tasks onboard. This is important because the knowledge being passed on, and the way of thinking of the informant, is intimately tied to the practices and movements of the body and the boat. (Englert and Ossowski 2009; Hutchins 1995; Westerdahl 2011).
- **Flexibility**: given the practical realities of participant observation, a pragmatic approach is essential whereby researchers switch roles: according to seasoned ethnographers, the most fruitful approach involves a combination of formal and informal interactions interspersed with collective work, prioritising the establishment of mutual trust (Eldjárn and Godal 1988a; Westerdahl 2011).
- **Adaptability**: due to the unpredictability of weather and sea conditions, it is essential that trial voyages remain free of obligatory itineraries and schedules (Englert 2006).
- **Follow-up interviews**: structured interviews on land, after shared sailing experiences with the interlocutor, allow for not only hypothetical questions ("what would you do in situation X?") but also explanatory ones, thereby illuminating how and why specific routes were chosen on particular occasions.

To ensure that experimental voyages are soundly based in archaeological evidence and can contribute to scholarship, Anton Englert established a set of authenticity criteria (2006:36–37) with which to structure and plan these voyages. These are listed in Table 2.

Table 2. Englert's authenticity criteria for trial voyages (adapted from Englert 2006: 37).

Vessel and maritime environment	Use an authentically-built reconstruction of a well-documented ship/boat find **Sail through the same seascapes as the original vessel did** **Use natural anchorages and landing places rather than modern harbours**
Navigation	Employ historically-accurate navigation methods (when safe) **Do not use engines** **Do not accept external assistance (e.g. towing), except in emergencies** **Do not follow a pre-determined itinerary or timetable**
Mental aids	Maintain personal hygiene without modern comforts

	Eat and drink authentic food and beverages Wear authentic clothing
Safety	**Possess sufficient equipment and experience to ensure the relative safety of the crew**

Although these criteria are foundational to this project's experimental approach, this research also follows Englert's advice "to concentrate on some of the proposed conditions and to maintain them, [rather] than to try to keep them all at once, only to lose sight of them one by one" (2006:37). As this project's primary goal was to reconstruct Viking Age seafaring routes, the criteria that most directly relate to this goal were prioritised. These are highlighted in bold in Table 2. In choosing Åfjord boats rather than Viking Age ship reconstructions as analogous vessels, the first of Englert's criteria could not be followed; however, the greater depth of documentation regarding the construction and handling of Åfjord boats when compared to Viking Age vessels seemed to counterbalance the risk of anachronism. This question is further evaluated in Article 2.

Some elements of the Åfjord sailing tradition did not survive the transition to motorised vessels in the early 20th century. This includes traditional navigation techniques and weather prediction methods. Because of these losses, navigation during this project's experiments was conducted using paper charts, a handheld compass, dividers, and a parallel ruler. For weather forecasting, the daily written coastal forecast published by the Norwegian Meteorological Institute ("Tekstvarsel for kysten") was used.

4.3.1 Data collection

The first period of experimental trials began in August 2021, and lasted until the end of June 2022. Subsequent, shorter campaigns were conducted in the late summer and autumn of 2022; the summer of 2023; and the summer of 2024. The sailing trials and trial voyages involved the data-gathering methods outlined below.

4.3.1.1 Log

A standardised set of key variables were recorded before and at regular intervals during each experiment (Table 3.2). Information was gathered immediately before each trial, and approximately every 4 hours during these experiments.

Table 3. Variables recorded before and during sailing trials and trial voyages.
This 'context sheet' was complemented by data collected in other formats.

Variables recorded before experiments	Variables recorded during experiments
1. Voyage number	1. Voyage number
2. Start and end dates	2. Date and time

3. Boat	3. Position
4. Context	4. Wind direction and speed
5. Goals	5. Sea state and current
6. Possible route	6. Weather
7. Wind forecast	7. Temperature
8. Weather forecast	8. Visibility
9. Wave forecast	9. Propulsion and setup
10. Crew	10. Speed
11. Høvedsmann and halskarr	11. Heading
12. Watch system	12. Crew roles
13. Crew experience levels	13. Changes in plan
14. Ballast and baggage	14. Mental and physical state
15. Other info	15. Other info

These variables were recorded on waterproof notebooks with timestamps defining each entry. Also recorded in the log were the timing and execution of manoeuvres, discussions about route choice, notable land- and seamarks, accounts of previous voyages, and autoethnographic entries regarding my own perception, physical, and emotional state. The log was digitised after each experiment, and combined into the log spreadsheet that is included in the project's data repository.

4.3.1.2 Wind measurement

During the first experimental trials, wind speed and direction were measured using an OpenWind™ device attached to the masthead. Due to technical difficulties with this device, a handheld anemometer and compass were used during later trials. The variables measured with these instruments were integrated into the log spreadsheet.

4.3.1.3 GPS track

The track of each trial was recorded using a Garmin GPSMAP® 66 s device. This was attached to the vessel near the stern. The device logged one point every 10 seconds, with a maximum error of 3 metres. A backup Garmin eTrex® 10 device was also kept onboard. After each experiment, the GPS tracks were downloaded and imported into ArcGIS Pro, where they were converted into shapefiles and additional variables were calculated. These included speed over ground (SOG), course over ground (COG), distance from previous point, duration from previous point, latitude and longitude (DMS and DD). The attribute table from each shapefile was then exported and included in the project's data repository.

4.3.1.4 Photography

Photographs and video footage were taken using a SONY Alpha 6600 camera. Photography served to complement the log by providing visual descriptions of weather and sea conditions, important land- and seamarks, and activities onboard. It was also an integral part of the survey of potential havens (see section 4.4). A selection of photography from the experiments is included in the project data repository.

Figure 16. Photogrammetric model of an Åfjord *fembøring*
Models like this one were made to create an accurate, shareable record of the boats used during this project's trial voyages.

4.3.1.5 3D modelling

Photogrammetry was employed to record the physical dimensions of the boats used during the trial voyages, and compare them to the evidence for Viking Age vessels. Photographic acquisitions were undertaken during the winter months, when the boats were on land. The photographs were taken using a SONY Alpha 6600 camera equipped with a SIGMA 16mm F1.4 lens. Agisoft Metashape Professional software was used for processing the photographs and building the meshes and textures. Due to the general difficulties that photogrammetric software has with modelling thin or narrow objects, the mast, sail, and rigging were removed from the boats before acquisition.

These models served several functions: firstly, they provided a shareable and reuseable record of the vessels under study, included in the project's open-source data repository. Secondly, they helped establish approximate cargo capacities. Thirdly, they functioned as an excellent dissemination tool which, by virtue of being three-dimensional, could clearly communicate the similarities and differences in hull shape and construction techniques with the vessels of the Viking Age.

4.3.2 Sailing trials

Seven different boats were used during the sailing trials, of four different types: two *fembøringer* (LOA: 13 m), two *to-lestringer* (LOA: 10 m), and two *fyringer* (LOA: 9 m), all built in the Åfjord tradition; as well as a *geitbåt* (LOA: 6.7 m), a traditional clinker boat from Nordmøre with an asymmetrical quadrilateral sail. The questions addressed by the sailing trials are listed in Table 4. Sailing trials were conducted in relatively safe and enclosed waters, such as the Trondheim Fjord, and did not involve overnight sailing. In addition to measuring the listed variables, they served to provide regular training and experience in a range of conditions and environments, improving the authenticity of the subsequent trial voyages.

Table 4. The questions investigated in the project's sailing trials and their associated parameters.

Question	Parameters
Vessel types	fyring, to-lestring, åttring, fembøring, geitbåt
Manoeuvres and sail handling	raising and lowering the sail, raising and lowering the mast, reefing, jury-rigging, wearing, tacking, man overboard, kedging, mooring, anchoring, landing, loading and unloading
Night sailing	visibility, communication between vessels, navigation techniques
Seasonal sailing	prevalent wind and sea conditions, weather windows, comfort and survivability
Windward performance	best effective windward angle, ballast placement and trim, manoeuvre duration
Capsizes	survivability, potential of righting the vessel, emergency protocols
Risks	To vessel, to crew, real, perceived, risk margins, effect of experience on risk assessment

4.3.2.1 Windward performance

Of these variables, the analysis of windward performance was of particular importance for establishing the technical affordances of Viking Age voyages. Sailing vessels can undertake two different manoeuvres for making progress towards the direction of the wind: for square-rigged vessels, these are known as tacking and wearing, and are illustrated in Figures 17 and 18.

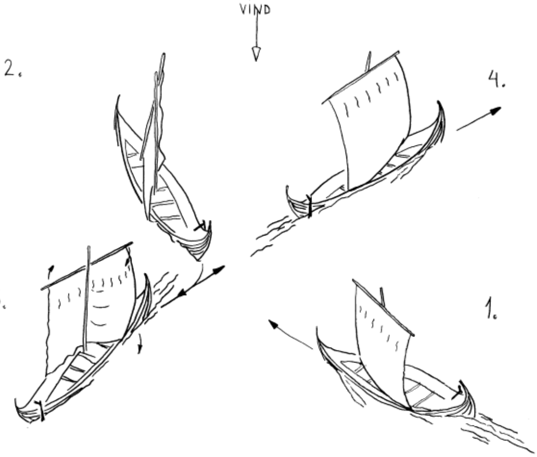


Figure 17. Tacking in a square-rigged boat
Courtesy of the Viking Ship Museum; reproduced with permission. Drawing by Søren Nielsen.

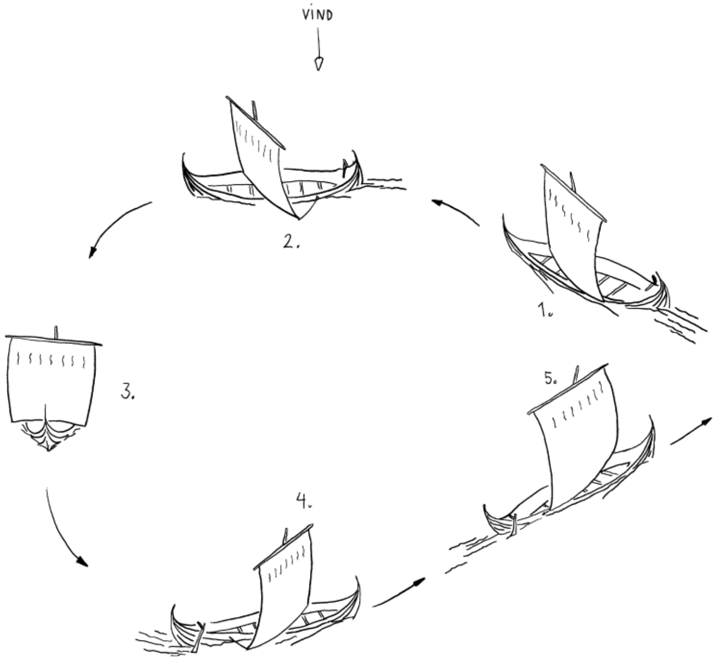


Figure 18. Wearing in a square-rigged boat
Courtesy of the Viking Ship Museum; reproduced with permission. Drawing by Søren Nielsen.

The extent to which square-rigged clinker vessels (like those used in this project and in the Viking Age) could make progress against the wind is a question that has long divided scholarship. Recent opinions still range from *de facto* impossibility (Gal, Saaroni, and Cvikel 2023b; Palmer 2009) to total feasibility (Gillmer 1979; Whitewright 2011). A small degree of difference in a vessel's windward sailing angle has a large impact on the distance the vessel covers 'over ground' (the actual track of the vessel) to accomplish the same distance 'made good' (the distance covered in the intended direction of travel). In Figure 19, vessel A is sailing against the wind with a windward sailing angle of 80°; it has to tack or wear 7 more times to cover the same distance in the intended direction of travel as vessel B, which has a windward sailing angle of 60°. As a result, vessel A ends up covering a much greater distance, wearing out the ship and the crew, and making such a journey much less feasible than is the case for vessel B.

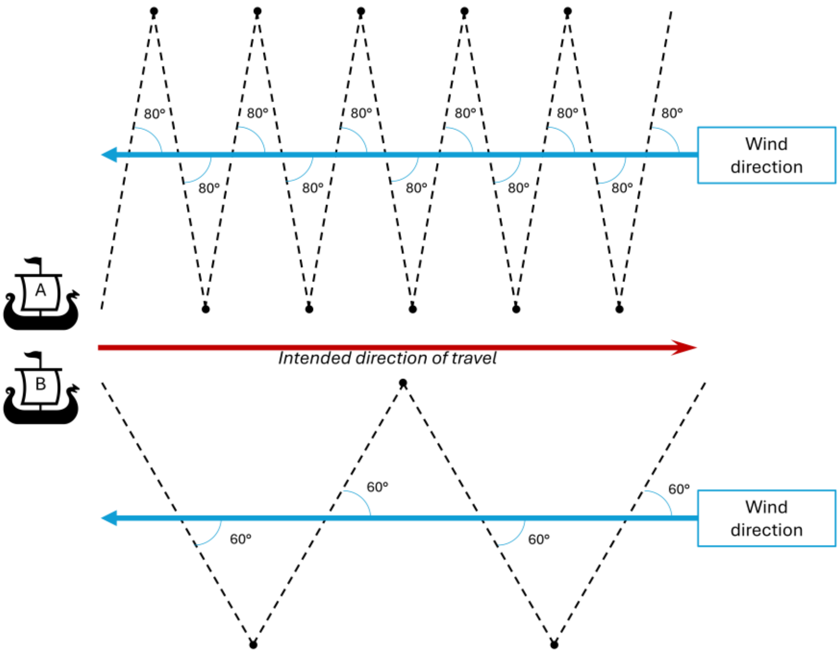


Figure 19. Windward sailing performance
A diagrammatic explanation of the effect of windward sailing angle on the distance a vessel must cover to make progress against the wind.

Although some of the estimates proposed in previous studies have been the result of extensive sailing trials (Bischoff 2023; e.g. Nielsen 2009), others are based on very short experiments with a vessel that was unfamiliar to the researcher (e.g.

Palmer 2009, where the experiment lasted less than a day). In most cases, estimates are given without being backed up by the data that informed them, such as the GPS track files from the experiment.

Establishing a well-informed estimate of windward performance was therefore a central objective for this project's sailing trials, as this would contribute to understanding which wind and sea conditions would be needed to follow certain routes or access and depart from certain havens. Windward performance trials were conducted in a range of different vessels and conditions, and with crews with different levels of experience. The results of the windward performance analysis are presented in detail in the following chapter (see section 5.3.1).

4.3.3 Trial voyages

Trial voyages were designed around departure and destination points known from historical and archaeological evidence. The routes between these points were investigated by tracing them through experimental voyages onboard Åfjord boats, generating data and insights regarding vessel performance, voyage duration, areas of risk and opportunity, and possible stopping points used along the way. Trial voyages 1, 2, and 4 focused on different sections of Ottar's southbound 9th -century voyage from Hålogoland to Hedeby (Bately and Englert 2007). Trial voyage 3 focused on seafaring routes through the Baltic, drawing on the medieval document known as 'King Valdemar's Itinerary' (Flink 1995).

The physical dimensions and properties of the vessels used during these voyages are presented in Table 5. As displayed in this table, the fyring used for two of the trial voyages is significantly smaller than the other vessels. This vessel was chosen as a comparison to experiences and data gathered onboard the *fembøringer*, and as a way to study the seafaring routes available to the humbler echelons of Viking Age society. The itineraries, vessels, duration, and distances of the project's four trial voyages are presented in the next chapter in Table 8 and Figure 22.

Table 5. The vessels used during the trial voyages
LOA: length over all; LWL: length at waterline. Note that tonnage is measured in barrels, as per the traditional Norwegian *lester* system. 1 lest = 12 barrels; 1 barrel = 115 litres.

Name	***Skårungen***	***Båra***	***Braute***
Type	fembøring	fyring	fembøring
LOA (m)	12.95	9.06	12.7
LWL (m)	12.36	8.5	11.9
Beam (m)	3.25	2.04	3.12
Draft (m)	0.72	0.55	0.71
Tonnage (*lester*)	40	8	34
sail area (m^2)	39.44 + 7.51	18	38+7

max rowers[7]	8	8	8
min crew	4	2	4
max crew	15	7	12
top speed sail (kts)[8]	8.4	7.9	7.5
top speed row (kts)	3.5	4	3.5
avg speed sail (kts)	3.7	2.7	3.3
avg speed row (kts)	2	2	2
best recorded windward angle	59	69	71

The data-gathering methods used during the trial voyages followed those outlined for the sailing trials, and resulted in a digitised record consisting of the log, meteorological data, the GPS tracks, and a selection of photography and video footage. In addition to these methods, the trial voyages focused on documenting the affordances of route choice. To this end, special attention was paid to the factors that influenced route choice in the Åfjord sailing tradition. Two processes were documented: the decisions and discussions before and during the trial voyages that resulted in a particular itinerary being chosen; and the changes in how these decisions were made as the crews developed mastery in traditional practice. The potential affordances of these decisions are listed in the table below.

Table 6 The potential affordances of route choice
These variables, and their relative influence on route choice, were recorded before and during trial voyages.

Type of affordance	Specific variables
Environment	Weather conditions (wind speed and direction, visibility, precipitation, temperature) Sea conditions (wave height and period) Land and seamarks (both within and beyond current horizon)
Vessel	Sailing and rowing performance Condition
People and social networks	Knowledge and familiarity with the local seascape Aims and context of the voyage Seafaring experience and risk margins of the crew Physical and mental state of the crew Social dynamics within and beyond the boat (conflicts, contacts, mutual trust) Conceptions of maritime space and navigation techniques employed in route choices

[7] All three of the vessels used during the trial voyages were equipped with 4 pairs of oars. Historically, Åfjord boats of these kinds only had three pairs.

[8] These values refer to the maximum recorded speed during this project's trials. In the case of both *Skårungen* and *Braute*, higher speeds have been recorded during other voyages, up to a maximum recorded half-planing speed of 17 knots (Ivar Holand personal communication 2022).

The reconstructed vernacular seafaring ontology was then compared with evidence for Viking Age maritime practices and traditions, to evaluate whether routes might have been chosen based on a similar set of affordances in the Viking Age. This ontological comparison is the central topic of Articles 1 and 2.

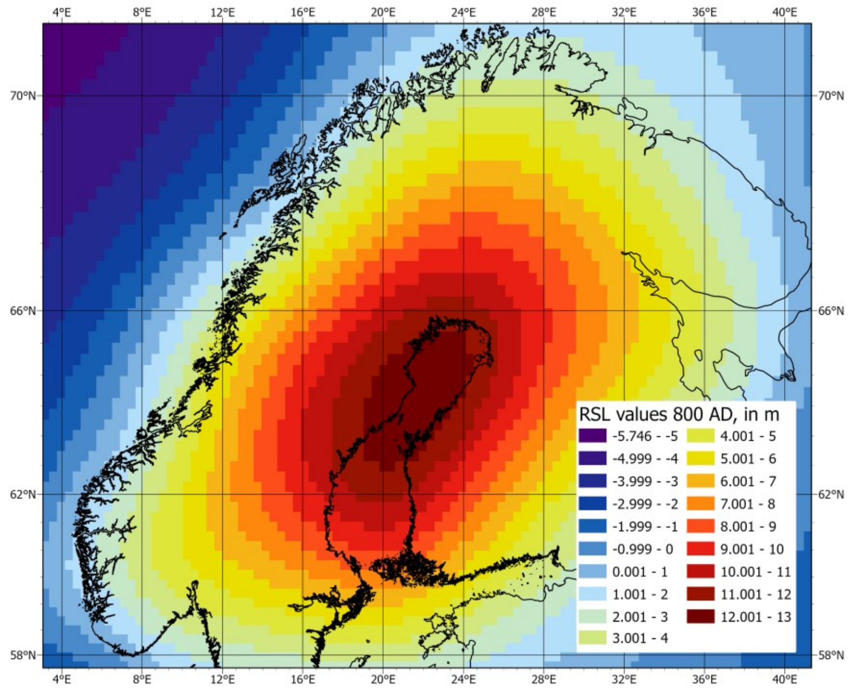


Figure 20. Isostatic rebound since the 9th century AD
This map displays the difference, in metres, between current and 9th-century elevation values across the Scandinavian Peninsula. These changes are not heterogenous, meaning that macro-scale modelling of Viking Age topography has long been a challenge. This project is the first to apply these data to Viking Age research. Created using the Open Access dataset published by Creel (2022).

4.4 Havens

The data gathered from sailing trials and trial voyages helped identify potential havens used during long-range Viking Age voyages through the *leið*. Natural harbours and anchorages encountered during trial voyages were surveyed from onboard Åfjord boats, noting the facility of locating them from afar, potential approach and departure routes, the ease or difficulty in following these routes, and the possible areas for landing or mooring. Along with the estimates of sailing performance generated by the sailing trials, this helped establish a set of practical criteria with which to evaluate potential haven sites from the perspective of the Viking Age sailor.

Potential havens visited during the trial voyages were also surveyed from land. This involved documenting the level of shelter available from prevailing winds, the availability of important resources (especially fresh water), and the view of the surrounding seascape from a nearby vantage point. After the trial voyages, sites displaying promising characteristics were further investigated through documentary research using historical sailing descriptions, maps, and nautical charts; and the digital reconstruction of historically-accurate sea levels using RSL data (Fig 20). This illustrated possible routes of approach and departure, and potential landing or mooring places, as they would have appeared in the Viking Age. This part of the research is described in detail in the Methods section of Article 3. Together, seaborne and land-based research served to develop a series of practical criteria with which to evaluate potential Viking Age havens. These criteria and the havens that fulfil them represent the core finding of Article 3.

4.5 Data management

Various kinds of interpretation were involved in the development of this project. Meteorological data, recorded interviews, GPS tracks, and 3D models are all partial reflections of the original evidence, and therefore involve an inevitable degree of data loss. Many of the qualitative data could not be directly represented as text or two-dimensional images (still the only universally-accepted formats of scientific knowledge dissemination), and therefore could not be included in the academic articles that form the primary scientific output of this project.

Following the example of Gal et al. (2023a), the entire dataset collected during this project was published in an online data repository on Zenodo.org. This repository can store data in a much wider range of formats than can be disseminated through printed articles. The repository has been designed according to CARE and FAIR principles (CARE Principles n.d.; Wilkinson et al. 2016), and is publicly accessible under the Creative Commons Attribution Share Alike 4.0 International license. Like the working list of potential Viking Age routes and havens, this repository enhances the transparency of the experimental process, and will hopefully support future research on related topics.

4.6 Conclusions

The contingent relationship between seaborne movement, attendance, and skill discussed in the previous chapter meant that for a project such as this one, it was essential to approach Viking Age seafaring with experience and practical knowledge in an analogous tradition. The methodology described in this chapter has been designed with this goal in mind. At the same time, the subjective angle is balanced out through the creation of a transparent data repository, allowing future scholars to evaluate and replicate the experiments conducted for this project. This methodology can therefore be seen as an attempt to combine the strengths of qualitative and quantitative approaches while simultaneously avoiding their weaknesses. This is perhaps most evident in the approach taken to Viking Age havens: by using both experimental and digital methods, and terrestrial and maritime perspectives, these sites could be evaluated through practical, enacted experience and through abstract, quantitative analyses.

Finally, the project's 'slow science' approach provides a fuller and fairer picture of how practices and voyages were enacted in the Åfjord tradition, rather than how these things should, rationally, be done from a modern perspective. By giving voice to traditional maritime knowledge, future scholars will be able to build models and representations based not on simple correlations or enduring stereotypes, but instead on activities and phenomena that would have been meaningful to the sailors of the past.

Summary

This chapter has introduced and explained the project's methodology. The selected methods are founded upon three central arguments:

1. Åfjord boats can be deployed as strong technological analogues for studying Viking Age seafaring.
2. Undertaking experimental sailing trials and trial voyages onboard Åfjord boats through key seascapes of the Viking world allows for the identification of primary seafaring affordances, and thereby helps suggest which routes would have been favoured by Viking Age sailors.
3. Enacted experience of traditional sailing, along with the quantitative and qualitative seafaring affordances that emerge through these journeys, produces a diverse suite of novel insights that can be used to critically reassess many of the current assumptions about Viking Age maritime networks and practices.

The diversity of approaches and evidence involved in this methodology create a fuller and fairer understanding of maritime practices and perspectives.

5 Results

Abstract

This chapter presents the results of this project at different scales. First it provides an overview of the sailing trials and trial voyages. The kinds of evidence collected during these campaigns, and the way these data were used to reconstruct possible seafaring routes, is then illustrated by way of two case studies. The first case study establishes the windward performance of square-rigged clinker boats. The second one identifies the main affordances of long-range voyages onboard smaller boats, and locates a potential Viking Age haven at a key junction along the *leið*. After these examples, the four scientific articles at the core of this project are presented in turn. Together, these studies establish three central findings: they extend and modify the seafaring networks suggested by previous research; they establish collective risk judgement as the central affordance of route choice; and they highlight the role of outlying havens in shaping the distinct maritime networks of the Viking Age.

5.1 Introduction

This chapter offers an overview of the main results generated over the course of this research project. The kinds of data and results produced by the two main experimental methods are illustrated in representative case studies. The first of these presents the analysis of windward performance of square-rigged clinker boats, a key issue in characterising the degree of maritime interaction during the Viking Age. The second describes the risks and potentials of long-range voyages onboard small boats, and illustrates how these affordances informed the reconstruction of Viking Age routes and havens.

The combination of these methods is then examined in relation to the project's four central research outputs, which are published as stand-alone articles. The first of these establishes the central affordances of route choice in the Åfjord tradition; the second identifies which of these affordances can be identified in Viking Age evidence, and evaluates reasons for their survival; the third locates probable stopping points used by Viking Age sailors along the *leið*; and the fourth investigates the extent of Norse seafaring into the high Arctic, and reconstructs the potential routes, strategies, and effects of these voyages. These four studies come together into three, large-scale results regarding Viking Age seafaring routes and practices, which are presented at the end of this chapter.

5.2 Illustrative results from research at sea

As described in the previous chapter, the data generation conducted for this project involved two distinct methods of seaborne fieldwork. Both methods involved experimental sailing onboard Åfjord boats, but had distinct objectives:

1. **Sailing trials:** short, targeted studies to establish the sailing capabilities of square-rigged clinker boats (see case study 1 below).
2. **Trial voyages:** longer expeditions providing a broader perspective on the affordances of long-range seafaring; focus on the factors which determine route choice before and during voyage (see case study 2 below).

Together, the sailing trials and trial voyages covered 2,790 nautical miles throughout a range of Scandinavian seascapes. The sailing trials are presented in Figure 21, and the trial voyages in Figure 22. These experiments were conducted almost entirely without the use of engines or external help.[9] The entire dataset collected during this project (log, GPS tracks, pre- and post-voyage documentation, photography, 3D models, and RSL maps) has been published as an Open Access data repository on Zenodo.org, accessible via this link:

https://doi.org/10.5281/zenodo.17340505

[9] Of the c. 900 hours spent onboard, only 15 hours were spent under engine or being towed by another vessel.

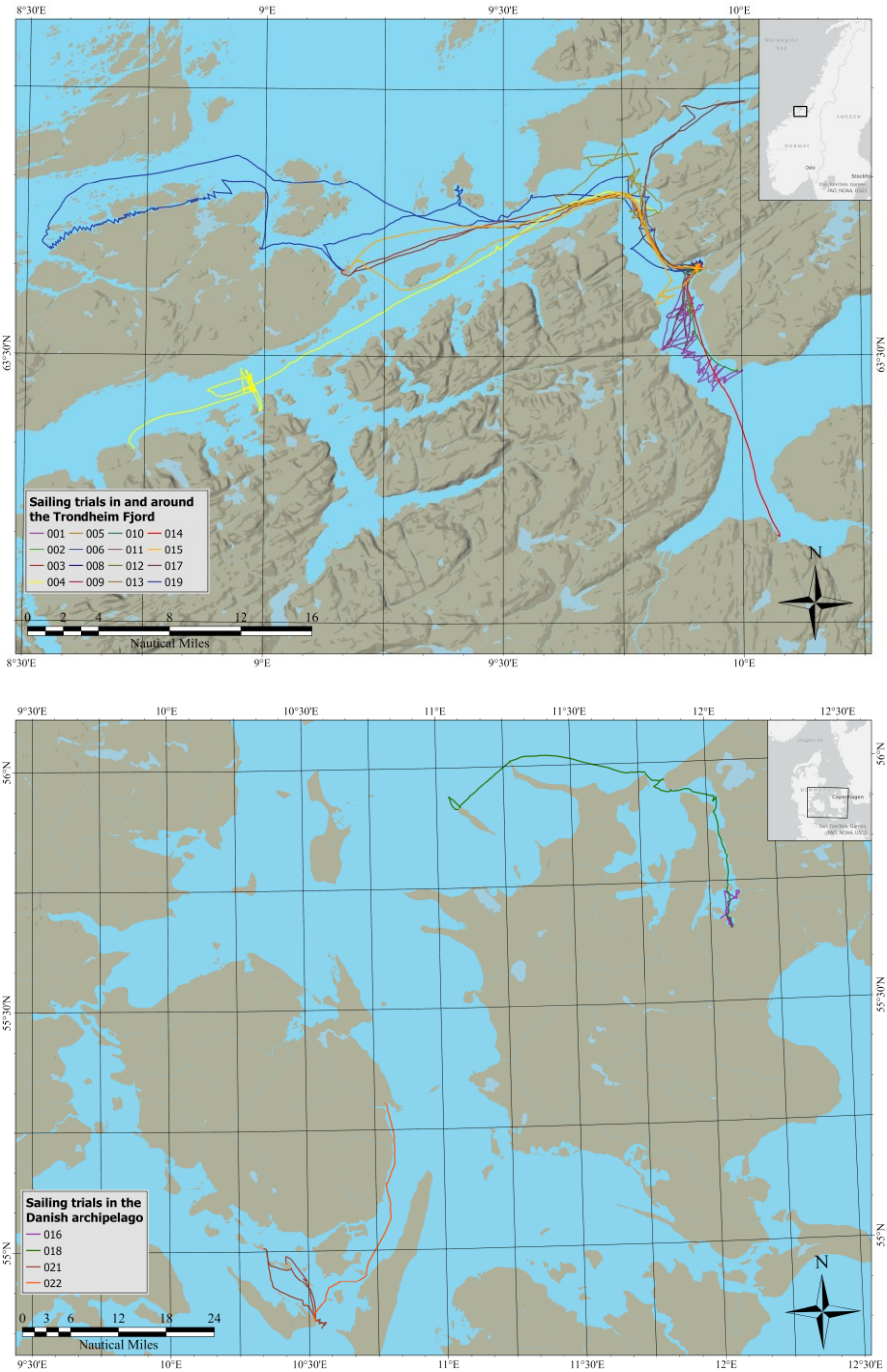


Figure 21. The sailing trials
Sailing trials were conducted in and around the Trondheim Fjord (above) and in Danish waters (below).

Figure 22. The trial voyages
Four trial voyages were conducted for this project in key seascapes of the Viking world. They tracked Ottar's 9th voyages and the 13th-century itinerary known as *Kung Valdemars segelled*.

5.2.1 Method 1: Sailing trials

21 sailing trials were designed and conducted between August 2021 and May 2024, corresponding to the following sail IDs in the log: 001-006, 008-019, 021, and 022.[10] The trials were conducted in and around the Trondheim Fjord and in Danish waters (Fig 21). Case study 1 (see below) illustrates the implementation of the project's methodology during one of these experiments.

5.2.2 Method 2: Experimental voyages

Table 7 The trial voyages
Details of the project's four trial voyages. The field "sail_id" corresponds to the shapefile in the project data repository. Nm = nautical miles.

Voyage number	Sail_ID	Vessel name	Vessel type	Itinerary	Duration	Distance (nm)
1	Lofotturen	*Skårungen*	fembøring	Rissa-Lofoten-Rissa	29 April – 18 May 2022	794.7
2	fyringtrip	*Båra*	fyring	Rissa-Bergen	8 June – 1 July 2022	374.1
3	020	*Braute*	fembøring	Stensund-Hanko	22 June – 14 July 2023	356.6
4	023, 024	*Båra*	fyring	Fredrikshavn-Bassholmen-Rørvig	2 – 22 July 2024	308.6

The four trial voyages aimed to identify likely routes and havens used by Viking Age sailors during long-range voyages through several key seascapes of the Viking world. This was done by establishing the technical and logistical affordances that determined route choices during these experiments. The details of the four trial voyages are presented in Figure 22 and Table 8. The first two trial voyages are the main focus of articles 1, 2, and 3, and are therefore presented only briefly below. The results of the third and fourth trials voyages have not yet been published, and are described in more detail. Case study 2 illustrates how these voyages informed the results of this project.

5.2.2.1 Voyage 1

Conducted between April 29th– May 18th 2022 onboard the fembøring *Skårungen*, this voyage tracked Ottar's 9th century sailing route from his home in arctic Norway southwards along the coasts of Helgeland and Trøndelag.

[10] Sail007 was not included in the project log due to data loss.

5.2.2.2 Voyage 2

This voyage began on June 8th 2022, and was conducted onboard the fyring *Båra*. It represented a continuation of trial voyage 1 in that it also focused on Ottar's southbound voyage, with the preliminary goal of reaching Kaupang, as he did. Due to adverse weather and conflicting schedules, Kaupang was not reached, and the experiment ended upon arrival in Bergen on July 1st 2022. Nonetheless, the voyage identified several potential havens in areas where Viking Age maritime networks are poorly understood. Case Study 2 (see below) presents an example of the project's methodology during a day of this trial voyage.

5.2.2.3 Voyage 3

The third trail voyage focused on seafaring routes between middle Sweden and the eastern Baltic. The primary source of evidence for this region is the document known as 'King Valdemar's sailing route' (*Kung Valdemars segelled*), a 13th-century written description of a route from Blekinge to Tallinn which followed the east coast of Sweden and then crossed the Baltic via the Åland archipelago (Flink 1995). There has been some debate about the extent to which this written itinerary represents an established sailing route from the Viking Age (Ilves 2012:98), and so it seemed fitting to test its navigability through a trial voyage. This was conducted between June 22nd – July 14th 2023, onboard the fembøring *Braute*, beginning in Stensund, Sweden, and ending in Hanko, Finland. A full study of this voyage lies beyond the scope of this thesis and will be the focus of future research. Preliminary analyses suggest that *Kung Valdemars segelled* represents a likely itinerary for Viking Age sailors, but that the environmental and technological affordances of Baltic seafaring are profoundly different to those of the *leið*. The log and accompanying documentation are included in the project's data repository to illustrate the marked differences in these affordances and networks.

5.2.2.4 Voyage 4

The fourth trial voyage focused once again on Ottar's account, this time on his journey from Kaupang southwards towards Hedeby. Previous researchers had suggested that Ottar set out south-eastwards from Kaupang, hugging what is now the west coast of Sweden down to the Kullen Peninsula, and then turning westwards along the north coast of Zeeland (Crumlin-Pedersen 1984; Englert 2007). Although this route had been attempted by volunteer crews from the Viking Ship Museum in Roskilde, the results had only been published in very summarised formats (Englert 2015:2), so this trial voyage aimed to evaluate the proposed route in a more transparent manner. This trial voyage was conducted onboard *Båra*, which departed from Rørvig, Denmark on June 26th, 2024, and sailed up through the Kattegat to Frederikshavn. Here we decided to abort the crossing to Norway due to strong westerly winds and large waves, and instead sailed northeast towards Sweden, reaching Bassholmen on July 9th. After a few days of rest the return voyage began on July 15th, crossing to Jutland, sailing down the centre of the Kattegat, and reaching Zeeland once more on July 22nd. The risks involved in the Skagerrak crossing illustrated the limits of small boats like *Båra*. Although this vessel was capable of long-range coastal sailing, as proven during the second trial voyage, it would have been unwise to cross long stretches of open water in anything other than ideal conditions, limiting the effective range of small boats to either side of the Skagerrak. The results of this experiment indicate that regular contact between western Sweden and the Oslo Fjord (evident in Falck 2024) had to contend with the northward current along the coasts of the Kattegat, suggesting that an indirect route via the islands of Læsø and Anholt might have been preferred (Fig 23). For the voyage log and the accompanying documentation, see the project data repository.

5.2.2.5 Summary of results from trial voyages

The trial voyages illustrate the importance of approaching seascapes and seafaring affordances through long-term maritime practice. This allows for the diversity of seascapes and seafaring affordances to be appreciated, and for major influences on seaborne travel which are not apparent from land to be experienced and investigated. Examples of this include the opposing currents encountered during trial voyage 4, and the importance of low-lying seamarks for navigating inshore passages, where large, seemingly obvious landmarks are often obscured by the weather. The voyages also highlight the role of social networks in shaping navigational practice and route choice, as judgements and decisions onboard were often made in consultation between various members of the crew, and accounted for people and places on land. Finally, the voyages suggest that Viking Age seafaring networks were distinct from those suggested in previous scholarship: as illustrated in Case Study 2 (see below), exposed passages were traversed safely even in smaller boats like the fyring, indicating that frequent, long-range interaction was likely even at non-elite levels of Viking Age society. The ideal areas for finding shelter during long-range voyages were located between outer and inner passages, in what I have called ‘transition zones’; an example of such a zone is shown in Figure 29. It is in these transition zones that hitherto unidentified Viking Age sites are likely to be located.

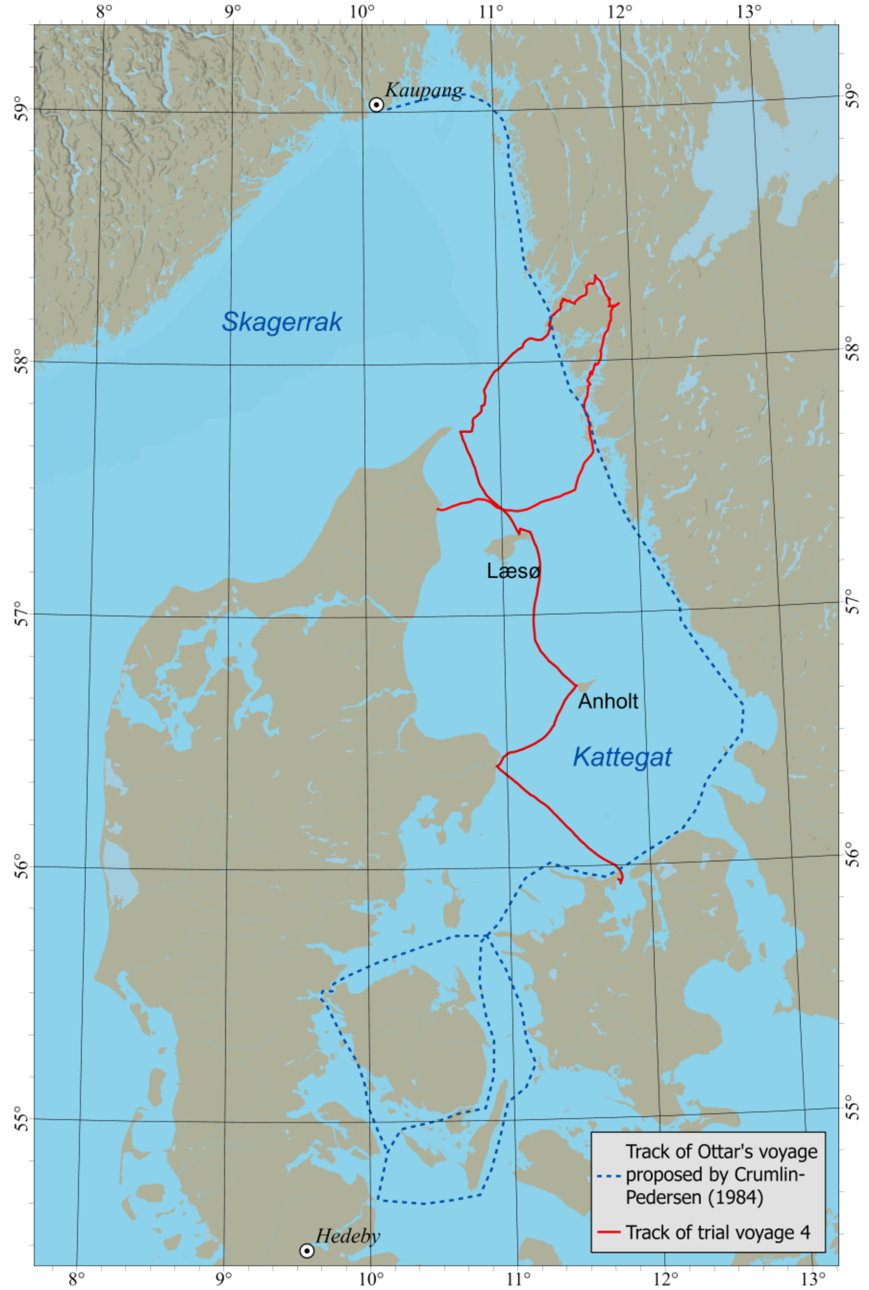


Figure 23. Trial voyage 4
This experiment focused on the central part of Ottar's voyage between Kaupang and Hedeby. It resulted in a very different itinerary to that proposed by Crumlin-Pedersen (1984). This was primarily due to the constant outflowing current encountered on both sides of the Kattegat, encouraging a route down the centre of this strait via the islands of Læsø and Anholt.

5.3 Empirical Case Studies

5.3.1 Case Study 1: What is the windward performance of square-rigged clinker boats?

Figure 24. Analysis of windward performance
The windward performance of square-rigged clinker boats was measured during this sailing trial through the Dolmsund. 60 tacks were performed in succession, resulting in an average windward angle of 59°. The results of this experiment indicate that previous scholarship has underestimated the sailing capabilities of these vessels.

As described in the previous chapter, sailing against the wind involves tacking or wearing manoeuvres. The extent to which square-rigged vessels were able to make effective progress against the wind has long been a matter of scholarly debate (Bischoff 2023; Gal et al. 2023a; Gillmer 1979; McGrail 1997; Palmer 2009; Vinner 1995). This is a major issue for Viking Age studies because the prevailing winds along the west coast of Scandinavia blow from the southwest; if Viking Age vessels could not sail against the wind, this would drastically reduce the opportunities for outward voyages towards mainland Europe and the North Atlantic islands, as voyages would be limited to the short, intervening spells of easterly winds. The frequency and feasibility of long-range maritime interaction during the Viking Age is therefore directly affected by this technical affordance.

A targeted sailing trial focusing on windward performance was conducted as part of this project in the summer of 2023. This was undertaken onboard the Åfjord fembøring *Skårungen*, which had been used for five previous sailing trials, and for the trial voyage to the Lofoten islands in 2022. Windward performance data was collected during the 14th and 15th of June, while sailing eastwards through the Dolmsund, a sound between the island of Hitra and the smaller islands along its northern shore. The weather and sea conditions were ideal for this experiment, with light to moderate breezes (Beaufort 2-4) from the ENE, clear visibility, temperatures between 11°- 13° C, and waves below 0.2 metres.

Due to the optimal conditions encountered during this experiment, only tacks were performed. This manoeuvre is equivalent to a three-point turn in a car, as illustrated in Figure 17 and Figure 24. The vessel is sailed on a diagonal course relative to the wind direction (Fig 24a), and is turned into the wind until the sail no longer draws and begins to fill from the windward edge (Fig 24b), pushing the vessel around and slightly backwards, through the eye of the wind (Fig 24c). Once through, the sail is shifted around so that the opposite edge is pointing forwards, and attached with a belaying pin to the hull (Fig 24d). The sail now fills from the back side once more, and the sheet is hauled in (Fig 24e); the vessel begins moving forward, but in a near-opposite direction to before (Fig 24f). This is a complex manoeuvre requiring excellent judgement and coordination among the crew, as executing any part of the manoeuvre too early or too late will result in the vessel not coming through the eye of the wind, which can be a major risk if there is no room to attempt the tack again. Tacking with an Åfjord fembøring requires at least 4 crew members, if it is to be performed efficiently. For this experiment, 5 crew members were involved in each tack.

The Dolmsund runs in an almost straight line from WSW-ENE, offering an excellent pathway along which to measure velocity made good (VMG) during windward sailing. The main part of the experiment began at 15:57 on the 14th of June, and the first tack was performed at 16:21. A total of 60 tacks were performed over the course of the next four hours, with the track of the trial recorded on a GPS device attached at the stern. During each tack I recorded heading, apparent wind direction, and apparent wind speed, as well as timing each manoeuvre on a stopwatch. These data were analysed after the experiment, resulting in an average windward angle of 59° to the true wind and a VMG of 1.2 knots (Fig 25).

The results highlight the importance of long-term engagement and practical skill, as they are more positive than those achieved during this project's earlier sailing trials, and those obtained during the rather brief experiments conducted by Palmer (2009). The windward performance results from this trial are similar to those published by Nielsen (2009:268) and Bischoff (2023:243) from trials onboard the reconstruction of the Skuldelev 2 wreck and the Oseberg ship (60° and 65°, respectively). This similarity underlines the strength of the Åfjord tradition as an analogy for Viking Age seafaring. Furthermore, the small difference between the results obtained during this project and those from trials onboard reconstructed Viking Age ships suggests that improving windward performance was not a central concern for innovators within the Nordic clinker tradition after the Viking Age. Instead, improvement efforts may have focused on other capabilities, such as the vessel's capacity to handle large ocean swell. This sailing trial directly informed the haven criteria developed in Article 3 by indicating the amount of sailing room required to access and depart from a potential haven site, and the necessary wind conditions for navigating through narrow, straight passages such as the Trondheimsleia.

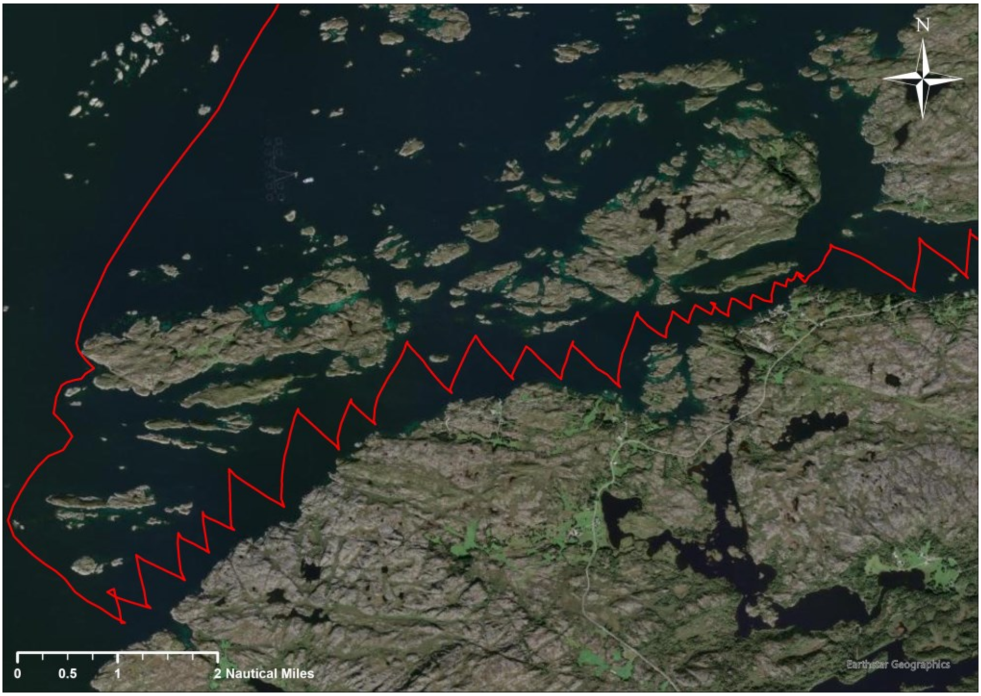


Figure 25. Windward performance analysis results
Tacks were undertaken from west to east against a light-to-moderate breeze from the ENE.

5.3.2 Case Study 2: long-range sailing and haven preference in small boats

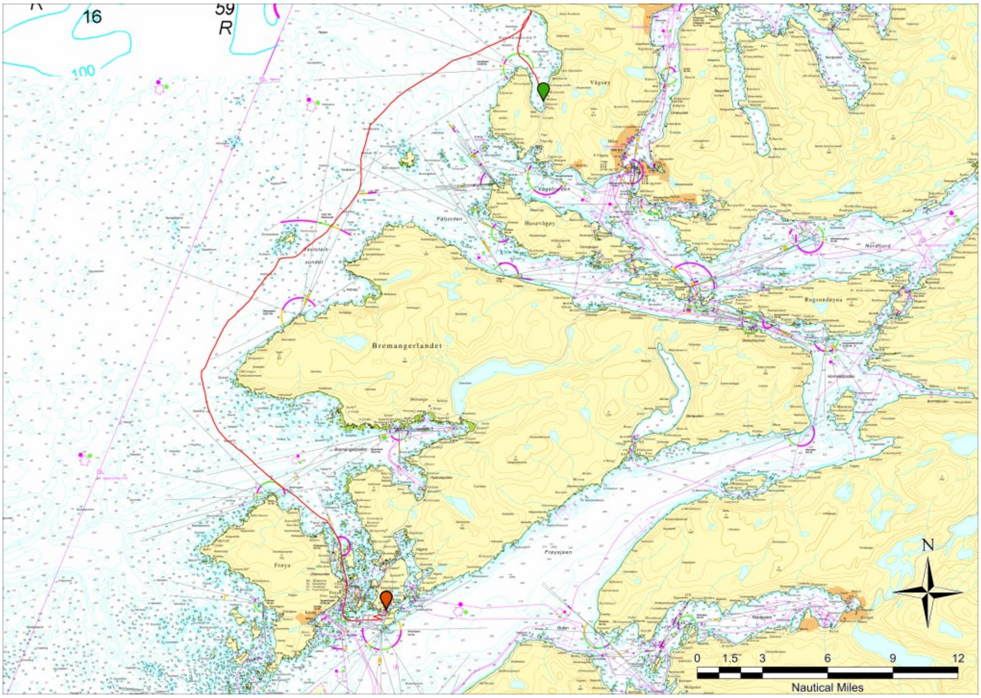


Figure 26. A day during trial voyage 2
This map displays the route chosen during Case Study 2, undertaken onboard the fyring *Båra* in June 2022. This experiment demonstrated the potential of following exposed routes even in small boats, and the importance of outlying havens between different zones of risk.

Trial voyage #2 aimed to reconstruct the route taken by Ottar between Trøndelag and Kaupang. This voyage was conducted onboard the Åfjord fyring *Båra* (Table 5). *Båra* departed from Rissa on the 8th of June 2022, and made steady progress southwards through the *leið*, with several stops along the way to weather south-westerly gales. For most of this voyage, the crew consisted of myself as acting skipper and four others. Two research questions were investigated during this voyage: how feasible were long-range voyages through the *leið* onboard smaller boats? And which locations might have been used as havens during such voyages?

On the 21st of June *Båra* sailed along the Vestland coast from Vågsøy to Smørhamn (Fig 26). We departed under oars at 10:30 from the bay known as Torskangerpollen, with the plan of potentially sailing as far as the island of Reksta. When we arrived on the outer coast of Vågsøy the wind was still very light and blowing from the southwest, so we waited here for several hours until a moderate breeze (Beaufort 4) began blowing from the NNW. We departed from Vågsøy at 15:40, and set a course south-westwards around the steep, exposed coastline of Bremangerlandet. The weather was heavily overcast, and the waves were between 1-1.5 metres high. This was the third outer passage we had attempted with *Båra* during this trial voyage, the other two being Hustadvika and the Stadhav. On all three occasions, the fyring performed admirably, riding over the swell and remaining very stable as long as she was steered actively (Fig 27).[11] At around 18:00 we began turning southeast into the bay between Bremangerlandet and the island of Frøya. This brought us under the lee of Brattefjellet, a 400 m ridge which disrupted the northerly breeze and caused irregular katabatic gusts (known in Norwegian as *fallvind*) to descend onto the sea around us. We proceeded carefully into the Oldersund, a narrow channel with many reefs and skerries which would have required detailed local knowledge before the introduction of nautical charts. At the far end of the Oldersund, where it met the Frøysjø fjord, lay the historical trading post of Smørhamn (Figure 28). We had been invited to make a stop here by an acquaintance from Fosen Folkehøgskole, and as the day was drawing to a close, we decided to abort the plan to continue to Reksta and stop here for the night.

Figure 27. Exposed passages in small boats
Bremangerlandet, June 2022. Compared to the katabatic gusts and choppy seas encountered directly under the land, the conditions along this exposed passage were fairly calm.

The experiences from this trial voyage laid the foundation for the traditional seafaring ontology presented in Article 1. The primary experiential aspect of the

[11] Steering actively means guiding the boat over individual waves by steering against the force of the swell, and thereby preventing the boat from broaching.

voyage was that of total dynamism, evident in the sea, the wind, the sail, the view from the deck, the position of the perceiver, the level of danger, and even the destination. This created a need for unfaltering attentiveness. Due to the lack of a chart plotter, navigational decisions were made based on attending to these dynamic phenomena, something which was often done collectively. This meant that routes were chosen based on collective judgements of potential outcomes, rather than computations of objectively-known variables.

This trial voyage also demonstrated that under certain conditions, the exposed sections of the *leið* were significantly less dangerous than passages under steep coastlines or through narrow sounds. Using *Båra* proved that long-range voyages through the *leið* did not require large ships, and could have been conducted by the non-elite, as argued also by Engvig (2001a, 2001b). The encounters with katabatic winds during this experiment suggest that the square rig may have survived throughout this area due to it being much quicker to lower than a fore-and-aft sail in the event of such unexpected gusts.

The choice to stop at Smørhamn illustrated the major influence of social relations on route choice, something which undoubtedly also affected the decisions of Viking Age sailors. Arriving at Smørhamn, we were informed by a local resident about the history of the trading post and of the many *jekter* (large, square-rigged cargo ships used in the stockfish trade) that used to congregate here, waiting for a fair wind before proceeding southwards toward Bergen.

Together, the evidence and experience from this voyage highlighted the nodal role of small, outlying harbours in preindustrial seafaring networks, and led to the evaluation of such places as potential Viking Age havens in Article 3. Marked changes in sea-level were evident at many of the harbours and anchorages visited during these trials. This encouraged the digital reconstruction of Viking Age sea-levels as part of the evaluation of potential havens in Article 3.

Figure 28. Smørhamn
This historical trading post was used in the stockfish trade throughout the Early Modern Period. The results of this study indicate that it may also have been used in the Viking Age.

5.4 Summary of major research outputs

5.4.1 Article 1. "Towards, not to" – Seafaring Worldviews from Viking Age and High Medieval Norway

5.4.1.1 Goals

This article investigates whether untapped sources of evidence such as practical traditions and cognitive approaches can expand our understanding of Viking Age seafaring. Drawing on the recent alignment between psychology, anthropology, and neuroscience regarding the relationship between perception and movement (see section 3.2.3), it argues that the Åfjord sailing tradition involved a particular set of practices and decision processes which determined route choice. These were documented during this project's trial voyages and in structured interviews with skilled practitioners on land. They are used to suggest which routes might have been perceived and favoured by Åfjord boat sailors and by analogy, the sailors of the Viking Age and High Middle Ages.

5.4.1.2 *Results*

The article identifies 8 central affordances of route choice from the Åfjord sailing tradition, which differ markedly from those apparent during modern voyages on modern vessels. Viking Age and high medieval evidence is then examined to search for reflections of these affordances in archaeological and historical sources. It is argued that many of the affordances of the Åfjord sailing tradition can be identified in this evidence, allowing them to be used to characterise an ontology of Viking Age and high medieval seafaring.

5.4.1.3 *Contributions*

This article revealed the wealth of living knowledge within traditional seafaring communities, much of which has never been disseminated in academic circles, or only exists in Scandinavian languages. The reconstructed ontology suggests that Åfjord boat sailors conceived of maritime space as "a conditional, sequential, and relational seascape" (Jarrett 2025:236). These aspects complement the theoretical framework of Westerdahl's maritime cultural landscape (1992), aligning it with the recent developments in maritime theory discussed in Chapter 3.

5.4.1.4 *Significance*

This article serves as a theoretical foundation for the subsequent papers in this thesis. It also highlights the difficulties in recording and communicating practical knowledge and enacted wisdom through conventional scientific practice, meaning that alternative methods are needed to give full voice to seafaring perspectives from beyond the modern western world.

5.4.2 Article 2. Maritime Mindscapes: using experimental archaeology to reconstruct Viking Age seafaring routes

5.4.2.1 *Goals*

This conference paper acts as a proof of concept regarding the use of the Åfjord sailing tradition as an analogy for Viking Age seafaring. Building on the traditional seafaring affordances identified in the first article, it examines a wide range of linguistic, documentary, archaeological, and iconographic evidence for Viking Age maritime practices, and focuses on identifying which elements of the Åfjord tradition are reflected in this material.

5.4.2.2 *Results*

This article reveals a number of remarkable continuities at the micro-scale of everyday activity, such as the use of Old Norse place names and naming traditions, similarities in vessel handling and performance, and the enduring role of risk judgement in navigation. It also highlights the major transformations evident at wider temporal and geographical scales, such as the variations in relative sea-level, geopolitical changes, and the effects of Christianity and literacy. The elements that survived these transformations seem to be related to the maritime context of use; in other words, micro-scale practices and forms of thought, which seemingly contradicted overarching technological developments and worldviews, survived because the large-scale transformations did not offer practical alternatives to everyday needs and problems. Focusing on these enduring practical elements, this article tentatively suggests a number of potential Viking Age havens.

5.4.2.3 Contributions

The study concluded that practice was the key determinant of unity among contemporary Viking Age sailors, and a major cause of continuity in seafaring traditions across time. The ontology presented in the first article could therefore be used as a "window" on the Viking Age, but only through the development of common ground between scholar and sailor based on shared skills and experience.

5.4.2.4 Significance

The explorative nature of this paper allowed for the strength of the Åfjord analogy to be tested from a wide range of angles, and for changes in seafaring practice, as well as continuities, to be considered. In this way, the paper addresses the risk of direct historical analogy discussed in Chapter 3. It also includes several sources of evidence which seldom appear in Viking Age studies.

5.4.3 Article 3. From the Masthead to the Map: an Experimental and Digital Approach to Viking Age Seafaring Itineraries

5.4.3.1 Goals

This article establishes a set of criteria with which to evaluate potential Viking Age havens throughout the *leið*. These criteria are developed from a combined experimental and digital approach, focusing on how havens might have been chosen from the perspective of the sailor.

5.4.3.2 Results

The established criteria are applied to 39 sites throughout the *leið*, including confirmed centres of Viking Age maritime activity, possible harbours and anchorages suggested in previous research, and locations that were visited during this project's trial voyages. The criteria fitted well with many of the confirmed sites, dismissed some previous suggestions (including two of my own from Article 2), and identified four possible new havens.

5.4.3.3 Contributions

This study made two significant contributions. Firstly, it showed that Viking Age power centres are not always located at favourable stopping points on long-range seafaring routes, and that many of the previously-proposed havens in fact display little sign of elite activity. This suggests that in some areas of the *leið*, seafaring networks were less centred around power centres than has previously been assumed. Secondly, the integration of RSL data illustrated the changes in the seascape from the Viking Age to the Middle Ages. This showed that several of the harbours that appear in the written sources were underwater during the Viking Age, indicating that the authors were describing known itineraries from their own time rather than those of the period they were chronicling.

5.4.3.4 Significance

The article presents a replicable workflow for identifying maritime sites which can be applied to other seascapes of the Viking world, and represents the first use of large-scale RSL data in Viking Age studies. The four suggested havens serve as potential focal areas for future archaeological surveys and excavations.

5.4.4 Article 4. Greenland Norse walrus exploitation deep into the Arctic

5.4.4.1 Goals

This co-authored paper investigates the acquisition of walrus ivory in Viking Age and medieval Greenland. It tests three possible acquisition strategies: direct harvesting by Norse hunters; acquisition via trade with Late Dorset and Thule Inuit groups; and evolving strategies progressing from direct, local acquisition to increased interaction as more distant stocks were increasingly targeted. To test these scenarios, data from this project's sailing trials and trial voyages was used. These data allowed for the assessment of Norse voyages into remote hunting grounds; the identification of havens, routes, probable cargo capacities, and hunting strategies; and the evaluation of the extent and nature of contact with Late Dorse and Thule Inuit communities.

5.4.4.2 Results

The genetic analysis resulted in two major findings: firstly, there was a clear shift in Norse ivory harvesting strategies from the 12th century onwards, moving from stocks in Iceland, eastern, and western Greenland, to stocks further north and west. Secondly, these later hunting grounds were much further into the High Arctic than had previously been assumed, and centred around the Northwater Polynya. The archaeological research and experimental evidence reconstructed a possible itinerary from the Norse settlements to these remote hunting grounds, concluding that direct acquisition of ivory by the Norse was possible, but was reliant on larger ocean-going ships. Occasional Norse presence in areas like the Northwater Polynya made cross-cultural contact highly likely, but the lack of technological transfers between Norse and North American hunters suggests that it remained sporadic.

5.4.4.3 Contributions

This study expanded the ivory trade network of the Viking Age and Middle Ages to include people and places in far more distant regions than had previously been assumed. It established the interconnected nature of human and animal lives in an early example of a globalised trade network, and represents a fruitful combination of quantitative sourcing methods with qualitative evidence from experimental research.

5.4.4.4 Significance

The reconstructed itinerary used by Norse hunters lays the foundation for future archaeological surveys along the west coast of Greenland. These findings highlight the need for further research to characterise the nature and extent of interaction between Norse and Indigenous North American communities, and for experimental research conducted from the perspective of Late Dorset and Thule Inuit seafarers.

Figure 29. The mouth of the Trondheim Fjord
This area is a perfect example of a transition zone, as discussed in Article 3. It connects the exposed seascape of Folda with the inner waterways of the Trondheim Fjord,and is likely to feature hitherto unidentified traces of Viking Age maritime activity. One of the havens discussed in this article, Storfosna, is circled.

5.5 The three central results of this project

The case studies and research outputs presented above contribute to the three central results of this project.

1. The analysis of windward sailing in Case Study 1, along with the feasibility of exposed passages and the various inshore hazards illustrated in Case Study 2, indicate that long-range voyages were possible in smaller boats and in a wider range of conditions than has previously been assumed, and that sailors may have favoured offshore passages to a greater extent than has been suggested before.
2. The focus on the cognitive and social aspects of route choice in Articles 1 and 2 highlights the central role of collective judgements of perceived risk in shaping route choice during the Viking Age; this distinct navigational practice has been partially preserved in later expressions of the Nordic clinker tradition through its enactment in everyday seafaring practice.
3. The evaluation and reconstruction of routes and havens in Articles 3 and 4 indicates that Viking Age sailors favoured small, outlying islands and headlands as stopping points during long-range voyages. The networks that these routes and havens created were distinct from those of later periods, suggesting that medieval textual sources are poor analogies for studying the maritime mobility patterns of the Viking Age.

From a broad perspective, these results illustrate the convergence of the project's research questions, theories, methods, and data upon one central theme: the role of practice in shaping, maintaining, and transforming the seafaring routes of the Viking Age. The project's theoretical framework encouraged an understanding of perception as cultural practice; reconstructing routes therefore involved developing the skills needed to perceive in similar ways to the sailors under study. Methodologically, this meant long-term engagement in analogous practices, and the design of data-gathering methods that could record and communicate how and why things were done in certain ways at sea. The data assembled through such methods illustrates the distinct nature of route choice afforded by Åfjord sailing practices, and the ramifying, contingent networks that such practices afforded. The focus on what Viking Age seafarers *did*, rather than who or what they might have been, alleviates scholarly reliance on medieval texts and terrestrial proxies, allowing for the incorporation of a broader range of evidence from analogous maritime contexts. The full implications of these findings are discussed in the following chapter.

Summary

This chapter has presented the main results of this project from various perspectives. The two case studies give 'on the sea' examples of how the chosen theories and methods were applied during experimental trials, and illustrate the kinds of evidence that informed the reconstruction of Viking Age seafaring routes and affordances. The four articles suggest that Viking Age sailors travelled further and along different routes than has previously been assumed; that these routes were chosen based on an enduring tradition of collective risk judgement; and that a network of outlying havens created distinct mobility patterns from those of the Middle Ages.

6 Discussion

Abstract

The aim of this chapter is to outline the project's contributions to scholarly understanding of Viking Age seafaring, and to discuss future applications of this new knowledge. The project makes four specific contributions to ongoing debates: it defines the primary affordances of Viking Age seafaring, including the technical capabilities of Viking Age vessels and the processes of route choice enacted by the sailors; it establishes practice as the main agent of continuity in maritime activities and mobility patterns after the Viking Age; it provides a set of criteria for evaluating and locating havens in several underexplored seascapes of the Viking world; and it indicates a broader geographical range for Viking Age voyages than previously assumed. On a wider scale, it characterises Viking Age seafaring as occurring within contingent networks rather than along pre-established vectors of interaction. The impact of these contributions is illustrated through a new reconstruction of probable seafaring routes through the study region. Future applications of the project's methods and results are then discussed within this seascape, across the broader Viking world, and in other comparable cultural contexts. Alternative representation methods which can account for maritime practices and perspectives are highlighted as a priority for future research, after which a more exploratory application relating to sustainable shipping technologies is presented.

6.1 Introduction

The results presented in the previous chapter contribute to broader research within and beyond Viking Age studies. This chapter discusses these contributions in a nested format. It begins with the project's research questions, evaluating their effect on specific debates within the field. These contributions are then brought together to present an updated reconstruction of Viking Age seafaring routes through the study region. After this, the future application of the project's research pipeline is discussed in relation to new research questions and broader cross-cultural studies.

6.2 Contributions of the research questions to specific debates

This thesis began by identifying major knowledge gaps regarding Viking Age seafaring routes within current scholarship. The lack of descriptive evidence and an over-reliance on terrestrial approaches have created enduring uncertainties about the maritime dimensions of the Viking Age. These include the performance of boats and ships, the affordances of route choice, the location of key passages and havens, and the possible survival of these elements in later expressions of the Nordic clinker tradition. This thesis has aimed to address these uncertainties by reconstructing the practices, networks, and worldviews of Viking Age seafaring in four interconnected studies. Each of these studies makes specific contributions to scholarly understanding of maritime mobility in the Viking world, and lays the foundation for further advancements within the field. These contributions are outlined briefly below.

Figure 30. Collective judgement of perceived risk
During this sailing trial in February 2022, uncertain, changing conditions highlighted the role of collective judgement in adapting to unexpected events and shaping the outcome of sailing voyages.

6.2.1 RQ1: What were the technological and logistical affordances of Viking Age seafaring?

The first goal of this project was to move beyond untested assumptions about ancient mobility and investigate the practicalities of route choice onboard vessels akin to those used in the Viking Age. The sailing trials and trial voyages conducted to fulfil this goal revealed several important insights.

Firstly, these experiments demonstrated that Åfjord boats performed remarkably well in large swell and severe weather conditions. Their light, flexible clinker hulls allowed them to twist over the waves, while the square rig allowed for the sail to be adjusted or lowered at a moment's notice. These technical advantages reduced the risk of offshore passages and of katabatic gusts. Secondly, the analysis of windward performance presented in the previous chapter provided more positive results than previous studies. Together, these results suggest that Viking Age sailors could have travelled along more exposed routes than those presented in previous studies (e.g. Fig 10), and dealt effectively with dangerous gusts and contrary winds. The frequency and range of long-range Viking Age voyages may therefore have been greater than has been assumed until now.

The assessment of vessel performance established the technical affordances of Viking Age sailing. Attention was also paid to how these factors combined with cognitive processes and social dynamics to shape traditional sailing practice. By employing theories of perception and ethnographic fieldwork in addition to experimental voyages, it became clear that the collective judgement of perceived risk (to the vessel and the crew) was the primary affordance of route choice onboard Åfjord boats (Fig 30). Through a critical examination of evidence from the Viking Age and High Middle Ages, it seems highly likely that this was also a central factor in the voyages of these periods.

By framing mobility around this affordance, it becomes possible to approach seafaring as a collective practice involving dynamic and uncertain phenomena (including beings and things that today could be considered supernatural), which are judged (rather than computed) through accumulated skill and experience. This finding allows for future models and representations to be built around an affordance that was central to the sailors under study, instead of one that reflects modern concerns. Rather than optimising speed or minimising costs, Viking Age sailors seem to have focused on remaining within an acceptable margin of risk during their voyages, based on the dangers and opportunities that they perceived in their natural and social environment. Ottar's voyage is discussed below to exemplify how an understanding of such judgements can shape the reconstruction Viking Age seafaring routes.

6.2.2 RQ2: To what extent can experimental voyages using traditional clinker boats serve as a window on the Viking Age?

The central role played by analogy in this project merited a critical examination of the degree of continuity and change between the subject (the voyages of the Viking Age) and source (the Åfjord seafaring tradition). This evaluation reveals that the primary agent of continuity and change in seafaring routes and activities throughout the *leið* was the context of use: techniques, pathways, and perspectives that remained useful, and for which no practical alternative was provided by large-scale societal transformations, survived through their enactment in everyday practice. These surviving elements extended beyond boatbuilding techniques to encompass ways of thinking and moving at sea, constituting a *veremåte* or way of being.

The role of practice in shaping and preserving seafaring traditions addresses an ongoing problem within Viking Age research, namely that it is difficult to delimit the people under study through conventional classifications such as burial practices, subsistence strategies, religion, or language. Such distinctions threaten to stretch the Viking world until it encompasses everything from Newfoundland to Constantinople between the 7th and the 12th centuries (Lund and Sindbæk 2021).[12] By focusing on practice, the Viking world can be defined based on what people and things *do*. From this perspective, the geographical and chronological span within which the Viking world existed can include a great number of other worlds (such as the circumpolar world, the Christian literate world, the world of the enslaved, and the children's world), allowing for non-dualistic approaches to interaction and exchange.

6.2.3 RQ3: What factors influenced the selection of Viking Age havens, and where were they located?

By conducting experimental voyages through the *leið*, and reconstructing Viking Age coastal topographies with RSL data, this research identifies four probable Viking Age havens in this seascape. The location and characteristics of these four havens highlight the importance of islands and headlands between exposed and inshore passages, whose centrality is only apparent when approaching them from the sea. The combined experimental and digital approach employed to evaluate these havens represents a viable methodology for studying seafaring routes in other seascapes of the Viking world, such as western Greenland (see below).

These findings may serve to guide archaeological investigations in locating new Viking Age sites throughout the *leið*. The havens suggested by these studies are likely to have also served as places of small-scale or temporary exchange and

[12] This risk is evident in the use of the Salme boat burials to extend the Viking Age back to the mid-8th century (Lõugas and Luik 2023).

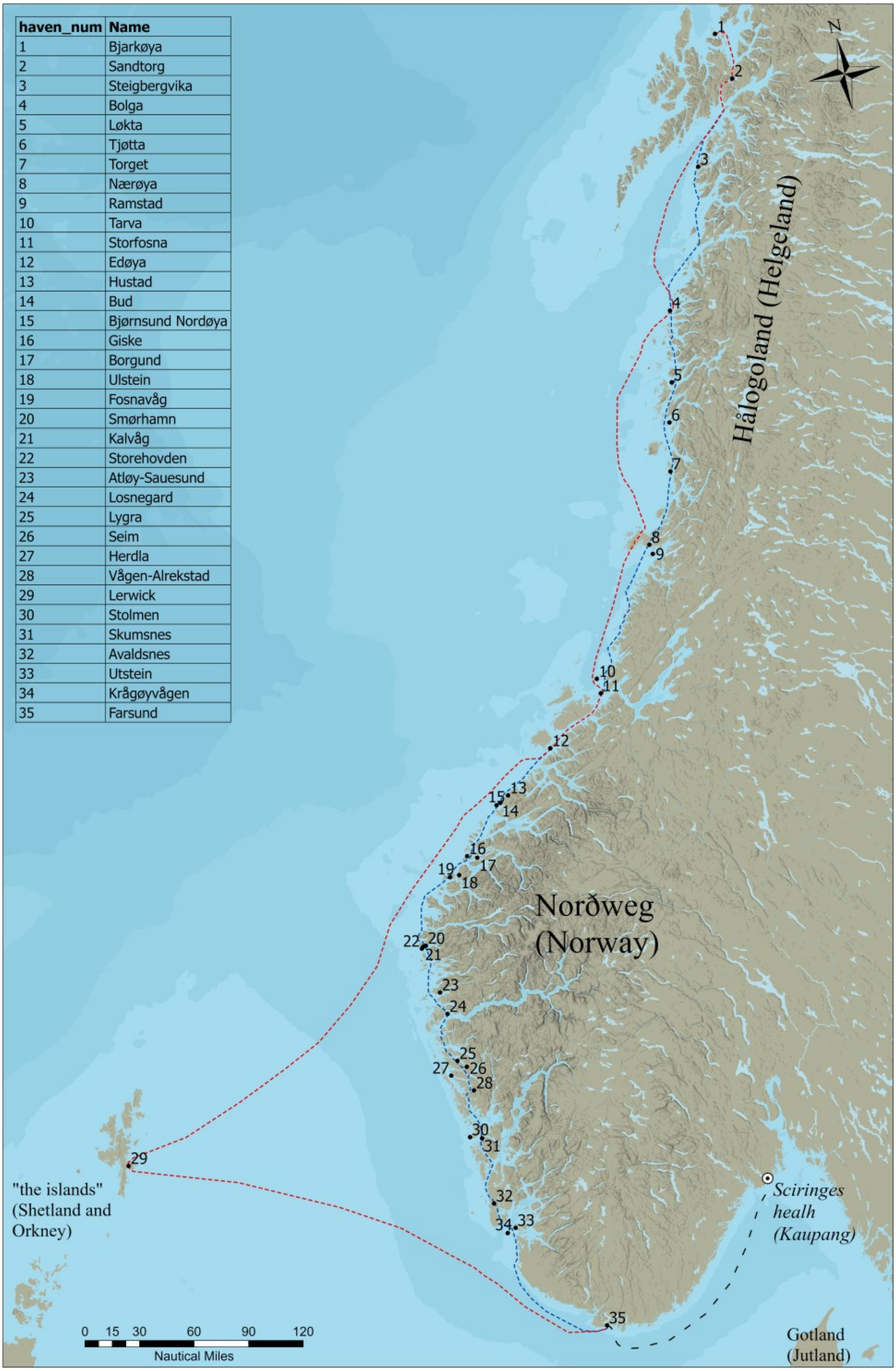
assembly, meaning that such investigations may widen the range of known sites beyond the elite settlements that have long been the focus of Viking Age research (Lund and Sindbæk 2021:198).

The integration, for the first time in Viking Age studies, of macro-scale RSL data offers a fruitful way to balance out experimental evidence and documentary sources with historically-accurate topographical reconstructions. The RSL data indicate important changes in coastal topography between the Viking Age and the time of the written sources, suggesting changes in seafaring networks between these times. These changes serve as a warning against the direct application of places and practices recorded in medieval sources backwards in time: their authors seem to have been drawing on contemporary seafaring rather than describing the routes and havens used three centuries earlier.

6.2.4 RQ4: How did maritime practices and worldviews shape patterns of interaction over time in Scandinavia and the North Atlantic?

The three previous research questions allowed for seafaring routes to be reconstructed from a position of practical understanding. This perspective was employed to investigate the Viking Age and medieval ivory networks along the west coast of Greenland, where the seafaring range of Norse hunters and the extent and nature of interaction with Indigenous North Americans had long remained uncertain. The itineraries and strategies established in this research reveal the remarkable range of Norse hunters into the high Arctic. This range is likely to be mirrored in other areas, making Viking Age voyages into the Foxe Basin, down the east coast of North America, and to Macaronesia seem increasingly possible.

Such a vast seafaring range opens up new seascapes for investigation, and suggests that encounters with other small-scale maritime societies occurred over large, overlapping territories. It is likely that important transfers of knowledge and technology occurred in these areas, even if these have not yet been identified in the archaeological record. Studying these encounters from multiple cultural perspectives, and combining indigenous knowledge with archaeological research, may help reveal their tangible and intangible consequences.



haven_num	Name
1	Bjarkøya
2	Sandtorg
3	Steigbergvika
4	Bolga
5	Løkta
6	Tjøtta
7	Torget
8	Nærøya
9	Ramstad
10	Tarva
11	Storfosna
12	Edøya
13	Hustad
14	Bud
15	Bjørnsund Nordøya
16	Giske
17	Borgund
18	Ulstein
19	Fosnavåg
20	Smørhamn
21	Kalvåg
22	Storehovden
23	Atløy-Sauesund
24	Losnegard
25	Lygra
26	Seim
27	Herdla
28	Vågen-Alrekstad
29	Lerwick
30	Stolmen
31	Skumsnes
32	Avaldsnes
33	Utstein
34	Krågøyvågen
35	Farsund

Figure 31. Southbound voyages through the *leið*

This map presents the places mentioned in Ottar's account along with two possible southbound itineraries. The two routes represent contrasting choices: the red route runs primarily offshore, thereby avoiding tidal currents, katabatic winds, and local magnates; while the blue route follows the inshore passage, sheltered from the ocean swell and the offshore wind. A Viking Age sailor might have chosen to sail inshore or offshore for different legs of their voyage. The coastal route is 861 nautical miles long, while the offshore route is 1072 nautical miles long. The reduced speed required to negotiate complex inner waterways means that the average voyage duration for both routes would likely be similar (4-6 weeks). The leg from Farsund to Kaupang is only depicted schematically, as it falls beyond the scope of this research.

6.3 Broader insights: reconstituting the *leið* through an updated view on Ottar's voyage

Together, the answers to the project's research questions establish a practical understanding of the routes and practices likely to have been favoured by Viking Age sailors. The results of this thesis suggest that seaborne interaction and exchange during the Viking Age did not occur along linear marine highways, but rather through contingent networks shaped by risk and opportunity. This highlights the danger of viewing ancient seafaring as direct arrows across a big blue void, and encourages a revision of important seafaring itineraries throughout the Viking world. This section illustrates the wider implications of this project's results by re-examining Viking Age voyages through the *leið*. Focus is placed here on the possible routes available to Ottar when departing from his home in Hålogoland. This does not represent a direct interpretation of the route he ended up taking and describing in his account, but rather the potential routes he *could* have chosen (which is, arguably, a more interesting historical question). This reconstruction is intended to complement rather than critique the evidence assembled in previous research (Bately and Englert 2007; Craigie 1917; Eldjárn 1995; Lund 1984; Meulengracht Sørensen 1995).

Two possible routes southwards from the Arctic are presented in Figure 31. Both of these routes were considered at some point during this project's trial voyages, but differ markedly from those suggested in previous scholarship (e.g. Fig 10). Choosing one route over another involved the collective judgement of perceived risk, as argued above. The inshore route (blue) grants greater protection from large waves, gales, and seasickness, and offers a greater number of landmarks for navigation and frequent havens for rest and re-supplying. For Ottar, travelling south from the Arctic, this route would have been preferable during periods of westerly winds. The offshore route (red), on the other hand, would have been safer during periods of easterly winds, as these cause dangerous katabatic gusts near the coast, but do not generate large swells out to sea, and often bring better visibility. Under these conditions, Ottar would have been safer staying off the coast, and would have used a few iconic landmarks visible from afar (Fig 32). This route covers a greater distance (1072 nautical miles as opposed to 861 inshore), but would have resulted in a higher average speed due to stronger offshore winds. Expected voyage duration, the primary form of measurement used by Viking Age sailors, would therefore have been roughly similar.

Figure 32. South towards Bolga
Outlying, recognisable landmarks like the island of Bolga (visible just off the starboard bow) are essential for navigation during offshore passages. Vestfjord, May 2022.

A central theme throughout this project's results is the nodal role of seemingly remote and isolated places in Viking Age seafaring networks. This has informed the reconstruction in Figure 31 through the incorporation of routes and havens that may not seem logical when viewed on a modern map. Shetland, for example, is far off the direct route between Helgeland and Kaupang. However, during the project's voyages it was observed that northeasterly winds (which would have been preferred for such a voyage) tend to blow down the coast of Norway until they reach Stad, where they veer off westwards across the North Sea, leaving light and unstable airs further south along the coast. By using the northeasterlies to cross to Shetland, Ottar would then have been in a strong position for the next leg, as the prevailing westerlies would allow for frequent opportunities to return eastwards, potentially allowing him to reach Kaupang without needing to stop. This helps explain the reference to seemingly distant places in Ottar's account; places like Shetland may have been considered as potential stopping points before and during his voyage.

Figure 31 represents the culmination of this project's objective to think from the sea about Viking Age seafaring, through active engagement in analogous practices. The approaches, evidence, and results of this project establish a new research pipeline for studying seafaring societies. The emphasis on practice and worldviews establishes new, multidisciplinary frameworks for investigating maritime mobility, drawing on cognitive science, indigenous philosophies, and anthropology to complement and expand experimental methods. The evidence gathered through these approaches provides an extensive, replicable record, and a holistic picture of the potentials of Viking Age seafaring. This opens up new pathways and places for investigation, and revises scholarly understanding of Viking Age maritime networks. The pipeline can be applied in parts or in its entirety to other seafaring contexts within and beyond the Viking world, and will hopefully help illuminate the key role of the maritime environment throughout human history.

By presenting two possible routes, Figure 31 emphasises the hypothetical nature of the project's results, and the inherently contingent nature of seafaring networks: it is entirely possible that Ottar, like many wise sailors after him, had multiple destinations in mind when he set out from his northern home. The future success of archaeological studies of ancient seafaring will depend on their ability to integrate these contingent networks into their approaches and models. Some possible pathways for upcoming studies are suggested in the following section.

6.4 Research outlook

The range of topics and data-types involved in this project result in many potential future pathways. These applications depend on the cultivation and dissemination of traditional maritime heritage through practical engagement, emphasising the importance of widening academic conventions to give voice to seaborne ways of thinking, doing, and knowing.

Figure 33. View of Solskjelsøya from Edøya
Solskjelsøya, the low-lying island in the middle-background, may have been paired with Edøya during the Viking Age as alternate havens at the mouth of the *Trondheimsleia*. They would have been easy to locate thanks to the iconic peaks of Tustna and Stabblandet behind them.

6.4.1 Further research within the study region

The third article in this thesis presents a number of suggested Viking Age routes and havens requiring further investigation (summarised in Table 4, Article 3). The first and most obvious step for future research, therefore, is to 'ground-truth' these suggestions through archaeological surveys and excavations. The havens presented in this article represent a non-exhaustive list, and subsequent discussions with colleagues and commentators have led to the idea that many of the havens along the *leið* existed in pairs, meaning that more sites should be added. Each pair of havens would have offered contrasting kinds of shelter and accessibility depending on weather and sea conditions: for example, havens with little protection from northeasterly winds, such as Edøya, may have been paired with other locations within the same transition zone that were more protected from this direction, such as Hamna on Solskjeløya (Arne Kruse personal communication, 2025). This potential pair of havens is visible in Figure 33.

The distinct nature of the traditional seafaring ontology (Article 1) and the importance of seemingly remote places (Articles 3 and 4) reinforce the need for caution when applying modern, terrestrial concepts and structures to the maritime past. In Article 3 this is discussed in relation to core-periphery models, which do not seem to match the evidence for Viking Age mobility networks throughout the *leið*. A further example is evident in scholarly discussions about the organisation of

Viking Age boat- and shipbuilding: a common assumption in the academic literature is that Viking Age elites financed and directed the construction of boats and ships, and therefore had total control over both the design of the vessel and the commercial or military ventures for which it was built (e.g. Ling et al. 2018:495; Maixner 2021:182; Price 2020:337). The use of modern economic concepts such as sponsorship, investment, and cost-effectiveness in an evidently non-modern context is not only anachronistic; it also contradicts the accounts given by traditional boatbuilders and fishermen. At least in recent history, the knowledge needed to build boats and ships by hand, and to navigate them through complex and dangerous seascapes like the *leið*, has been kept deliberately hidden from literate, terrestrial elites (Eldjárn and Godal 1988a:39); there is, to my knowledge, no reason to doubt that this would also have been the case in the Viking Age. In Norwegian accounts of traditional voyages, the acquisition of a vessel was a collective project funded through credit initiated by the fishermen themselves, who retained control over the vessel and its use (Bojer 1921). This applied to larger ships built for long-distance voyages such as fembøringer and jekter as well as smaller boats.

It is of course difficult to evaluate whether these accounts reflect long-standing traditions with roots in the distant past. For now, they serve as interesting thought experiments for re-thinking Viking Age seafaring:

- How was Viking Age power simultaneously enacted upon land and at sea? Were Ottar's voyages necessary for the survival and sustenance of his community, or were they the key to a particular kind of status based on seafaring experience rather than landed property?
- To what extent did seafaring skill and generational knowledge about routes and safe (or hidden?) havens shape the early expansion of the Kingdom of Norway?
- Were Viking Age and medieval seafaring skills and knowledge shared openly with contemporary literate clergymen? Or are the vagaries and inconsistencies in the written sources regarding maritime geography and navigation perhaps deliberate omissions by the informant?

Modern scientific biases encourage us to approach boatbuilding and seafaring as economic activities afforded by practical constraints such as resource availability, efficiency, and functionality. However, this research has highlighted elements of maritime practice which involve imagination, intuition, judgement, belief, and performance. In traditional boatbuilding and seafaring, specialised knowledge is applied through an organised sequence of activities, and through real-time engagements with seen and unseen agents in order to accomplish specific goals. The boundary between the real and supernatural is often blurred during such practices, and specific, sometimes non-sensical activities are required at certain places or in certain contexts. Names, stories, songs, and chants (such as this book's epigraph) play a central role in the teaching and retention of this knowledge, and so do the body, its movements, and its proportions. All of these are characteristics which are more typically associated with ritual practice than with economic activities like transport and trade. In light of this, it may prove fruitful to re-imagine Viking Age boatbuilding and sailing as expressions of a world in which ritual and subsistence practices were one and the same. Recognising the partially ritualistic nature of traditional boatbuilding and sailing means that these practices can be approached as expressions of cosmology as well as technology, and can serve to study worldviews as well as economic activities.

6.4.2 Research beyond the *leið*

Despite a strong focus on the seascapes of western Scandinavia, the project's methodology can also be applied in other areas of the Viking world. As mentioned in Chapter 2, the Nordic clinker tradition was exported across Europe and the North Atlantic as part of the Viking diaspora, resulting in strong commonalities in maritime heritage across a vast area. This means that many of the lessons from experimental voyages throughout the *leið* may be applicable in other seascapes, especially where the climate and physical geography are similar. Four areas stand out as promising candidates for future seaborne fieldwork of the kind undertaken for this project: the northern reaches of the *leið* from the Tjeldsund to the Finnmark coast (and if possible, into the White Sea), focusing on Ottar's northern voyage; the west coast of Greenland and the Davis Strait, to evaluate the suggestions made in Article 4 regarding voyages to the Northwater Polynya and access to the Foxe Basin; the northern and western coasts of the British Isles, to attempt the various routes proposed by Griffiths (2019) and contribute to the ongoing work by Sanmark and McLeod (2024); and finally, the eastern coast of North America, to follow the timber-gathering voyages from the Greenland settlements to Labrador, and the exploration routes from l'Anse aux Meadows.

The study of ivory networks conducted for Article 4 highlighted the interconnected networks that co-existed within the Viking world: along Arctic and subarctic coastlines, seafarers participated in an export-based economy and interacted with circumpolar hunting and herding societies, such as the Thule Inuit and the Sámi; while along the shores and rivers of temperate Eurasia, seafaring overlapped with sedentary agriculture, and sailors interacted with kingdoms, caliphates, khaganates, and empires (Keller 2010:16; Skre 2025:357). Future scholarship should therefore develop a better understanding of the differences between these two networks, and investigate whether different practices and mobility patterns emerged in different areas as a result of different economic activities and interactions with profoundly different groups. Some possible research questions on this topic include:

- Was Ottar's involvement in both these networks unusual for his time, or did such interconnectivity distinguish the Viking world from the more segregated economies of the Middle Ages?

- Were technological developments like the medieval Highland galley typical results of cross-cultural maritime interaction in the Viking Age, and can other similar cases be identified elsewhere (in e.g. Normandy, the eastern Baltic, or northwestern Iberia)?
- Did seafaring itineraries in newly settled or explored areas follow the routes used by local populations, or did incoming Viking Age sailors pioneer new pathways based on their own skills, knowledge, and preferences?

6.4.3 Cross-cultural comparisons

The methodology developed for this project has empirical utility in Viking Age contexts, as demonstrated throughout this thesis. But it is also portable to other world regions, and encourages cross-cultural studies which emphasise the permeable boundaries of Viking world. Future studies of interaction and exchange should aim to collaborate across these boundaries with descendants from the many cultures impacted by the Viking diaspora.

Such collaborations have several benefits. Firstly, the integration of multiple knowledge traditions will help keep the cultural biases of each scholar in check, fostering stronger bridging arguments and a more epistemologically-level playing field. Secondly, the seafarers of the Viking Age were a mobile, polytheistic, and oral community; it may prove fruitful, therefore, to approach them through the methods and perspectives of indigenous studies. Comparative research like Price's (2018) work in Hawai'i, as well as collaborative projects such as Aporta's (2009) work with the Inuit, seem to offer the most promising route forward for fostering fuller and fairer understandings of Viking Age maritime culture. This project's research pipeline may also be applicable in other small-scale seafaring societies; Article 1, published within a comparative study of such societies (Garcia-Piquer, Fauvelle, and Grier 2025), illustrates the parallels with other seafaring groups such as those of the Pacific Northwest Coast and Patagonia, and the potential for cross-cultural comparisons.

It is vital, however, that such approaches provide tangible benefits for the Indigenous communities involved, rather than simply extracting valuable data from them. Viking Age studies currently enjoy a position of privilege within academic research, being the subject of widespread popular interest and deemed worthy of support by some of the most powerful governments on Earth. The lessons, methods, and networks developed within Viking studies over the last 50 years can and should be used to preserve and disseminate maritime knowledge and craft traditions belonging to less affluent communities around the world. Only through such a holistic understanding of human relationships with the sea will it be possible for modern science to develop enduring solutions to contemporary challenges such as the climate crisis and the economic marginalisation of traditional hunting and fishing communities.

Preserving and disseminating maritime knowledge will also require alternative representation methods. This project has shown that a profoundly different conception of maritime space was shared among Viking Age seafarers to that which is common in modern western society. Conventional western cartography, reliant as it is on abstract, static, and universalising representations, is unsuited for recording, analysing, and disseminating the practices and perspectives of Viking Age seafarers (making many of the maps in this book poor reflections of the practices and experiences they attempt to illustrate). This misalignment between scientific representations and cultural geographies is a well-documented and well-discussed issue within indigenous studies (e.g. Chao 2017; Hirt 2012; Pearce 2008; Pearce and Louis 2008), but one which has received little attention in relation to the Viking Age. Figures 34-37 display different perspectives on maritime space from societies around the world. New knowledge about Viking Age seafaring may come from exploring these alternative perspectives and mapping methods, and thereby expanding the media and formats in which science can be produced and communicated. The burgeoning subfield of counter-mapping may be a good place to begin (Byrne 2016; Hunt and Stevenson 2017).

Box 4: Sustainable Futures – traditional seafaring and WAPS technologies

Today, 90% of global trade is carried out by sea (Khan et al. 2021). Modern cargo ships, propelled by the combustion of fossil fuels, are major emitters of greenhouse gases and important contributors to ocean pollution. To help reduce fossil fuel emissions (and in reaction to the rising price of crude oil), a number of projects have investigated the use of wind power as an alternative source of ship propulsion (e.g. Oceanbird n.d.; Orcelle n.d.; Seawing n.d.). These 're-innovations' are collectively known as Wind Assisted Propulsion System (WAPS) technologies, and use a range of machinery including rotor sails, wing sails, DynaRigs, and kites. Research into WAPS technologies has shown that they significantly reduce fuel consumption in a wide range of maritime environments (Chou et al. 2021; Lu and Ringsberg 2020; Reche-Vilanova, Hansen, and Bingham 2021), but their widespread adoption is hindered by a number of major challenges.

These challenges can be grouped into two general issues: firstly, the adoption of WAPS technologies involves major upfront capital expenditure. This is required to refit currently operating vessels with new sails, kites, or rotors, train crews in their operation, and develop new navigational software (Argyros 2015). Secondly, there is a high degree of uncertainty regarding several aspects of these technologies, such as the design of optimal sail plans for different maritime regions, the plotting of optimal routes, and the long-term, accurate prediction of weather conditions to avoid unwanted delays (Khan et al. 2021). In more general terms, the technology's reliance on the wind involves the re-introduction of qualitative factors, contextual adaptability, and inherent uncertainty into the rigidly scheduled and strictly regulated world of modern shipping.

In reading about WAPS technologies, I was surprised to discover that none of the current projects under development have drawn on the c. 6,000 years of historical and archaeological evidence for sailing technologies from across the globe. I would argue that maritime archaeology, and particularly projects involving experimental and digital approaches, have the potential to contribute to the timely development and adoption of WASP technologies. The knowledge and data produced by projects such as this one can be employed to this end in several ways.

Firstly, experimental sailing voyages result in the reconstruction of probable sailing routes from the past, the accumulation of vast amounts of data regarding sea and wind conditions, and the identification of favourable passages and areas of risk for vessels travelling under sail. These data can establish optimal sailing routes for wind-assisted shipping, identify specific risks and windows of opportunity along important routes, and highlight areas in which wind-assisted vessels should deviate from conventional itineraries.

Secondly, this project involved studying the development of collective sailing skills through hands-on learning in a range of sailing boats and conditions. This kind of practical training proved highly effective, with several individuals who took part in this project's trials going on to successfully skipper larger square-rigged vessels through various parts of the *leið*. As discussed in Article 1, practical mastery was accompanied by a new way of thinking about voyages and the maritime environment, giving these individuals a practice-based mental framework with which to make wise and safe choices. The crews of wind-assisted ships would greatly benefit from these skills, as they result in the kind of adaptable competence needed for successful navigation onboard any vessel powered by the wind.

Thirdly, experimental research can conduct relatively low-cost, real-world experiments with a wide range of rigs and trims. This project's sailing trials experimented with a range of these, identified in historical sources or suggested by experienced sailors. This included mobile ballasting by members of the crew during tacking manoeuvres; additional sails such as kites and studding sails; and various modifications to the running rigging. Experiments of this kind, along with subsequent performance analyses, may help complement wind-tunnel and water tank tests in the quest for optimal sail plans for wind-assisted ships.

Finally, the need for new navigation models for wind-assisted shipping overlaps with the need for new representation methods within the archaeology of seafaring. In both cases, research and innovation are hindered by the inability of current tools to model uncertainty, dynamism, and subjective judgement, inherent features of seaborne mobility. This common need could lead to fruitful interdisciplinary collaborations involving experimental archaeologists, naval historians, traditional seafaring communities, and WAPS projects. Developing practice-based digital models based on the particular affordances of sailing vessels would therefore help trace the seafaring routes of the future as well as those of the past.

6.5 Conclusion

This thesis has made a series of targeted and original contributions to scholarly knowledge and understanding. It presents the primary affordances of Viking Age seafaring, including both practical and abstract factors; it establishes the causes and extent of continuity in maritime practice between Viking Age and ethnographic contexts; it locates probable new havens in various underexplored regions of the Viking world; and it argues that Viking Age maritime interaction was based on contingent, dynamic networks rather than pre-determined pathways. These findings contribute directly to a new reconstruction of Viking Age sailing routes through the *leið*, illustrating the central role of seemingly remote routes and places. The approach taken in this project creates a new research pipeline for maritime archaeology, applicable both within and beyond Viking Age studies. It serves as a foundation for developing new practice-based models of seafaring societies, and can potentially contribute to the development of sustainable shipping technologies.

Summary

This chapter has outlined the main contributions made by this project's four research questions to scholarly understandings of Viking Age seafaring. These are applied to a new reconstruction of seafaring routes through the *leið*, which suggests that Viking Age sailors may have chosen different passages and havens to those suggested previously, and illustrates the central role of seemingly remote places in Viking Age maritime networks. The project also lays the foundation for future research in various fields: it defines promising areas for archaeological investigations throughout the Viking world; it highlights the need for alternative models and representation methods to give voice to the seafarers of the past; and it provides valuable insights for the development of sustainable shipping technologies.

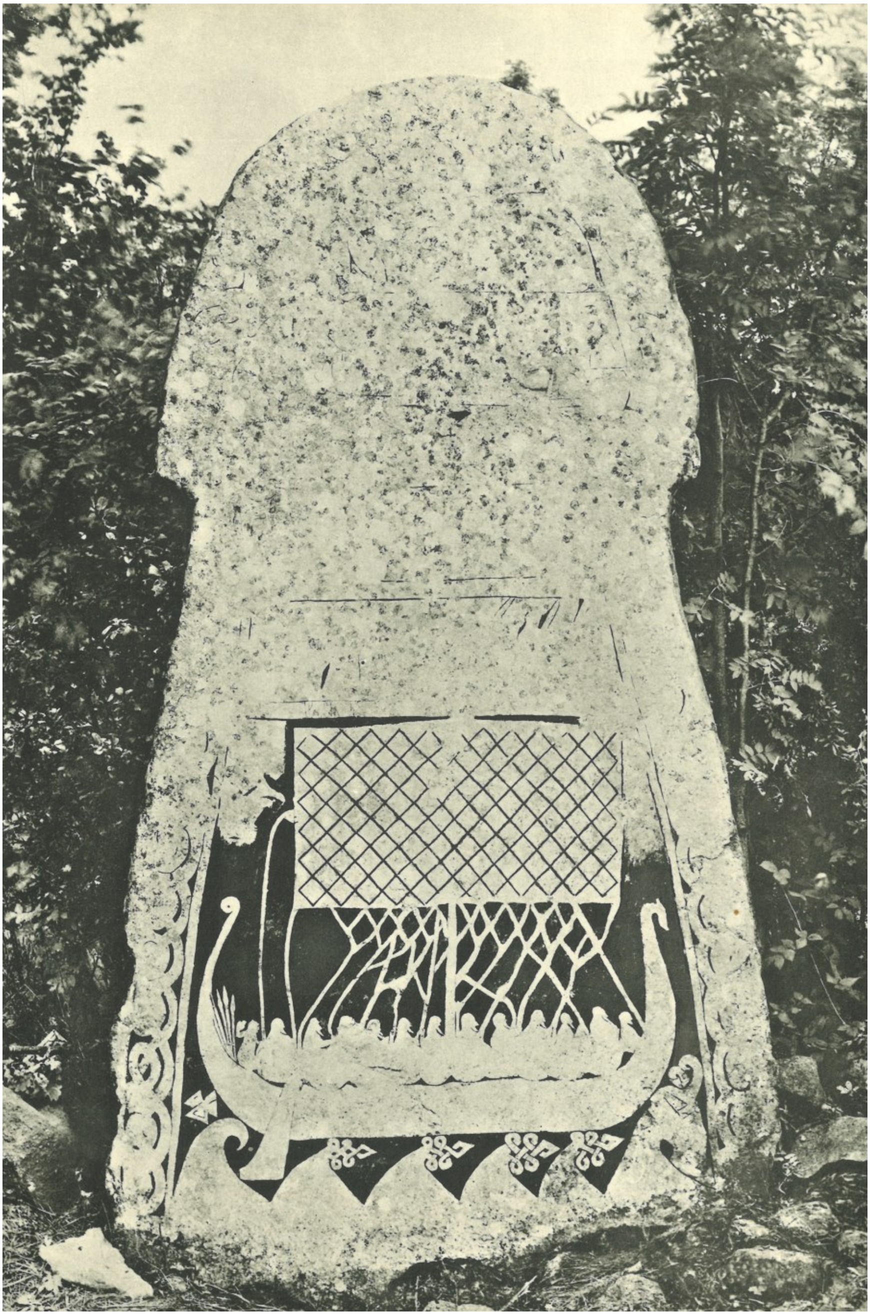


Figure 34. Gotlandic picture stone
Ships are a recurring motif in iconographic evidence from the Viking Age, illustrating the centrality of seafaring to the people of the Viking world. The Gotland picture stones may be closest we will ever come to a depiction of maritime space from the Viking Age. GP 184 Hejnum Riddare. Modified from Lindqvist et al. (1941), Figure 79.

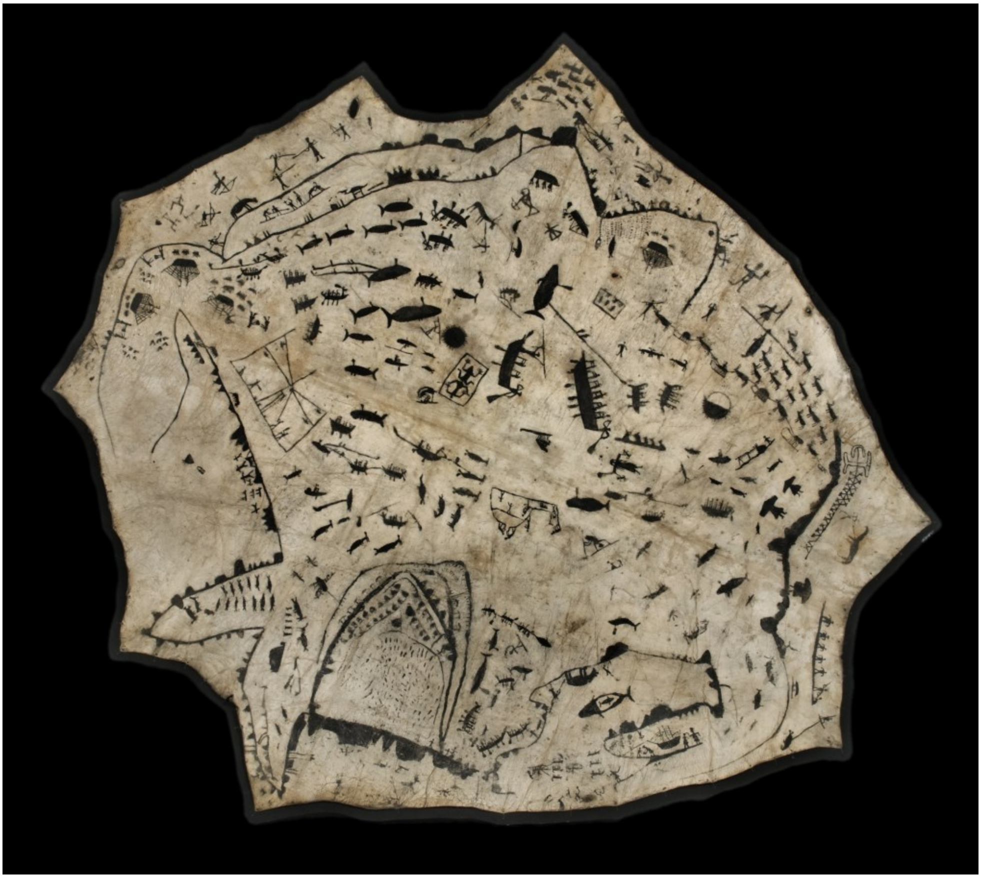


Figure 35. Chukchi sealskin map

This artefact is a geographical representation of Chukchi territory, the seascape now know as the Bering Strait. It contains images of traditional Chukchi vessels (kaiaks and umiaks), everyday activities such as fishing and hunting, as well as the passage of time (illustrated as the black circle, night, and the half circle, day). A three-masted European ship is depicted in the bottom right, illustrating the long-range maritime networks in which the Chukchi people participated. Just like the Skálholt Map, it encourages us to think from the sea. Accession number 1966.19.1. Courtesy of the Pitt Rivers Museum; reproduced with permission. © Pitt Rivers Museum, University of Oxford.

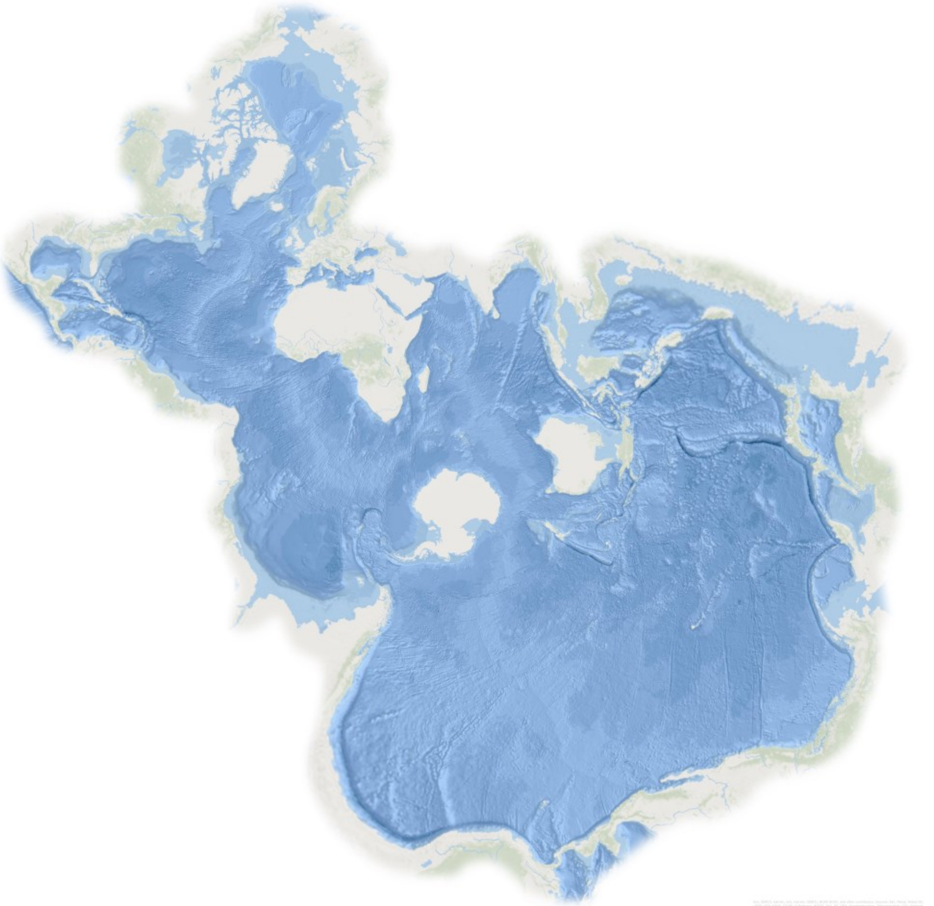


Figure 36. The Spilhaus projection
This cartographic projection emphasises the interconnected nature of the world’s oceans, echoing the Chukchi map. It demonstrates that modern mapping methods can be employed to think in new ways about maritime space, and challenge the current conventions of spatial representaiton.

Figure 37. The Ammassalik maps
These wooden, tactile maps were carved by Kunit, a member of the Tunumiit community, in 1885. They depict the fjords and islands along the east coast of Greenland, and are intended to be rotated as one proceeds along the coast. Courtesy of the Greenland National Museum and Archives; reproduced with permission.

7 Conclusions

The aim of this thesis has been to tackle the blind spots of land-based research by collecting and disseminating knowledge from the sea. Viking Age seafaring practices and networks have been systematically reconstructed by pioneering new methods and undertaking experimental sailing trials and trial voyages in underexplored seascapes. This approach generated new evidence and insights that address important knowledge gaps and uncertainties regarding the transformative seafaring voyages and technologies of the Viking world.

The combined findings of this integrated research pipeline support three overarching conclusions:

- Scholarship has underestimated the capabilities of Viking Age crews and vessels, while also ignoring some major risks present in the seascape. This indicates that Viking Age sailors travelled significantly further than had previously been assumed, and followed different routes to those proposed by land-based studies. A reconsideration of the probable locations and extent of Viking Age maritime activity in both local waters and remote seascapes is therefore advisable.
- The selection of sailing routes and safe havens was informed by a particular way of thinking, being, and operating at sea, creating what I have called a "maritime cultural mindscape" (Jarrett 2025:236). Tangible and intangible elements of this maritime ontology have survived into the present day via inherited traditions of boatbuilding and sailing. Employing these traditions as direct historical analogies offers a robust methodology for empirical research, offering a living window on the Viking Age at the microscale of everyday practice.
- The seafarers of the Viking Age travelled *within* contingent networks rather than *along* predetermined routes, and these networks were distinct from those of later periods; the unique character of these networks, along with the capabilities and ontologies of the seafarers who enacted them, encourage a thorough revision of scholarly approaches to (and understanding of) the maritime dimensions of the Viking Age.

The project's methodology establishes tested pipelines and frameworks which should be built into future research designs. The experimental and ethnographic fieldwork confirms the interpretive utility and analytical value of 'slow science from the sea', revealing that practical skills and adaptive judgement, rather than the computation of absolute data, shaped patterns of maritime interaction. The reconstruction of Viking Age seafaring routes demonstrates their integration within contingent networks of interaction, highlighting the need for critical modelling methods that can incorporate dynamism and uncertainty as essential characteristics of maritime mobility. Such models will give voice to a broader range of knowledge traditions and worldviews, enriching our understanding of past societies and providing a broader range of alternatives for the future of the marine environment.

The shore has always been a boundary between different domains of activity and interaction, but for Viking Age seafarers it was never a barrier. By venturing beyond the tideline and into the sea, what had once been no more than a bluish backdrop becomes a complex, living world, revealing new perspectives, relations, and possibilities that were not apparent from land. The research presented here has pioneered new approaches for studying the maritime past, generated a new understanding of the practices and perspectives of Viking Age sailors, and opened up new directions for future research. Many lessons from the time spent at sea have been assembled here, but much remains to be learned, or relearned. The sea beckons once more, in need as much as in promise; it is time to bring the boat back down to the water, step the mast, and set sail towards new horizons.

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Appendix 1

Project Evaluation

The experience of research

From a personal perspective, this project has been an overwhelmingly positive experience. In terms of research goals, I believe it represents a successful first step towards the reconstruction of Viking Age seafaring itineraries, and contributes to this goal in the following ways: by highlighting some of the problematic gaps and assumptions in academic approaches to the maritime past; by offering examples of the kinds of knowledge and evidence which can be gathered through engagement with traditional seafaring; by showing how this knowledge and evidence is of direct relevance to our understanding of the Viking Age; by identifying a number of probable havens and sailing routes which merit further archaeological investigation; and by discussing patterns of change and interaction throughout the maritime networks of the Viking world.

As mentioned already in chapter 1, this project is as much a work of knowledge translation as it is one of knowledge production. Beyond the scientific research goals, my aim has been to help preserve and disseminate the Nordic clinker tradition by recording the skills and experiences of individuals who are far more knowledgeable and skilled than I am. I feel very privileged to be in a position where I can contribute in this way, and hope this book illustrates the importance of preserving and promoting maritime heritage across the globe.

My ongoing emphasis on there being more evidence "out there" than what is typically employed in Viking Age studies may seem like a naïve and underwhelming conclusion, particularly for Scandinavian readers who are well-acquainted with the long-enduring craft traditions in this part of the world. However, the wealth of practical wisdom and traditional seafaring experience encountered during this project's sailing trials and voyages came as a great surprise to me, and may be equally exciting for other readers who first approached the Viking Age through Anglo-Saxon scholarship. Although some experimental seafaring projects have been published in English, they have been brief, unsuccessful, or regarded as unscientific (e.g. Palmer 2009; Carver 1995; Binns 1980, respectively). Scandinavian scholars and sailors, on the other hand, have undertaken a range of impressive experimental voyages, but due to how they have been published (if at all), they have rarely received the international attention they deserve. The publication of this project's data repository along with this book is intended to address this dearth of experimental evidence.

The absence of the Åfjord tradition within most English-language scholarship, and the lack of standard data-gathering methods for archaeologies of seafaring have meant that the approach taken here was not pre-determined, but rather the fruit of unexpected opportunities, sound advice, and ongoing trial and error. Such experiences are inherent characteristics of experimental archaeology, and I therefore do not see them as flaws in this research. However, the completion of this project definitely feels more like a beginning than an ending: I am now in possession of lessons and data with which to conduct further experiments, as well as a network of experienced sailors and boatbuilders with whom to continue collaborating.

Anachronisms and lacunae in the sources

Materials and construction techniques

The sailing trials and trial voyages were conducted onboard boats built within the last 20 years, following the Åfjord boatbuilding tradition of the late 19th century. Consequently, the materials and techniques were in some cases the product of technological developments that occurred after the Viking Age. Viking Age boats and ships were built using cleaved planks, which in central and northern Norway tended to be of pine (*pinus sylvestris*) and oak (*quercus robur*) (Daly et al. 2025; Meyer Pedersen 2002; Nordeide et al. 2020). The sails were most likely square (rather than trapezoidal) and made of wool, while lime bast and hide were used for rigging (Ravn 2016b:42–49). In contrast, the boats used in this project were built using sawn planks of spruce (*picea abies*), and rigged with linen sails and hemp rope, reflecting 19th century innovations (Godal 2016:69). In addition, Åfjord boats are built with a stern rudder rather than the side-rudder used in the Viking Age. The difference in performance between these two rudder types has been much discussed, with early experiments concluding that side-rudders were problematic and ineffective (e.g. Thorseth 1986). However, decades of experimentation have led to a better understanding of how Viking Age side-rudders should be shaped and attached, and the conclusion that they do not negatively impact vessel performance as much as was previously thought (Bischoff 2023:226–45). They therefore represent less of a problematic anachronism than might previously have been argued.

Voyages and seascapes

The nature of the trial voyages, and the seascapes through which these were undertaken, were also different to their Viking Age counterparts. Firstly, the voyages were not conducted out of necessity or entrepreneurial spirit, but rather as a context for research and education. Secondly, the clothing of the crew, the food consumed onboard, and the safety and navigational equipment were all relatively modern. Thirdly, the surrounding environment displayed significant natural and cultural differences both above and below the water. Coastal erosion and isostatic rebound have significantly altered the topography of the Norwegian coast, with relative sea levels throughout the *leið* changing through such processes by as much as 6 metres (Creel et al. 2022). Humans have further contributed to these changes through dredging and channel clearance, the construction of mole harbours, and the development of an intricate and unavoidable network of navigational markers (Bøe 2009). Along with these additions, some features of the Viking Age seascape have disappeared, such as piracy, inter-regional conflict, and the pattern of scattered coastal settlement (Wickler 2016).

Implementation: lessons learned and to be learned

Several unexpected problems and constraints were encountered throughout the course of this research. These fall broadly into two categories: issues with data gathering, and limitations to the scope of this research.

Data gathering

Perhaps the least transparent form of evidence used in this project are the interviews. These are not included in the data repository for various reasons: in some cases, the interviewees did not want to publicly share their views, opinions, and experiences; and in others, the interviews consisted of informal conversations (as recommended by Eldjárn and Godal 1988a:19), and appear only as paraphrases in the field notes.

The project also demonstrated that although there are many benefits to participating as an active member of the crew during experimental trials, this can lead to the loss of important data. Several critical moments and experiences were not recorded until later, and the need for sleep further reduced the chances for data-gathering. This could be partially addressed by having at least two people onboard willing to record and measure the relevant variables. Data was also lost due to malfunctioning equipment which was not suited for the harsh environment of the North Atlantic; in general, simple tools and instruments with long battery-lives and minimal features were far more suitable than advanced and overly-sensitive ones, although this sometimes resulted in a loss of precision. Changes in plan during the trials due to safety concerns or unexpected commitments also compromised the strength of some experiments, and encouraged a kind of ‘conservative opportunism’ in their execution, whereby initial research goals were modest, but experiments were expanded or diversified when possible. Finally, the involvement of modern humans represents a potential weakness in the project’s bridging arguments. The results of the experiments should therefore be seen as no more than a rough estimate of past possibilities, with factors such as the crew's relative inexperience, geopolitical stability, modern safety equipment, and the use of weather forecasts all influencing the analogy in not-entirely-quantifiable ways. These weaknesses can only begin to be addressed through long-term seaborne research in the widest possible range of weather and sea conditions, underlining the importance of 'slow science' and experiments in suboptimal conditions for gaining even a partial understanding of Viking Age seafaring potentials.

Scope

There are four areas in which the project fell short of my intended aims. Firstly, the performance analyses during the experimental trials were limited by the basic instrumentation available to me at the time, meaning that some variables such as heel and pitch angles could not be calculated. Performance comparisons between vessels built with different materials or techniques would also have been informative, such as the difference between linen and woollen sails, or between hulls built with sawn or cleaved planks. Secondly, the trial voyages covered the majority of the intended study region, but missed a significant portion of the Norwegian coast between Hordaland and the Oslo Fjord, due to the voyage onboard *Båra* being cut short. This will hopefully be the focus of a future experiment, as it was a nodal region for Viking Age seafaring networks. Thirdly, the fieldwork uncovered only the very tip of the ethnographic iceberg: in particular, further work regarding placenames (both on land and underwater) would help evaluate some of the routes and havens explored in this project. Finally, due to time constraints, much of the data from beyond the *leið* could only be included here for comparative purposes, and reconstructions of potential Viking Age itineraries through these seascapes will have to await future opportunities.

Implementation: successes

Along with these limitations, the approaches and experiments included some remarkable successes. Conducting experiments onboard traditional wooden boats made us the subject of great local interest when arriving at a new harbour or anchorage, to the extent that we were frequently welcomed into people's homes, given food and supplies, and regaled with stories from lifetimes bound to the sea. People's willingness to share knowledge and information (even when encountering a Danish-Swedish speaking crew in a Norwegian boat!) went far beyond my expectations, and I am sure this would not have been the same had these experiments been conducted in modern vessels. As illustrated by the windward performance experiment in Chapter 5, repeated sailing trials produced increasingly positive results, contrasting markedly with previously-stablished estimates regarding sailing capabilities and potential routes. Accumulated experience combined with growing levels of mutual trust among the crew allowed for an entirely different margin of risk in the later trials than early on in the project. Many of the routes chosen in later trials and voyages, such as the crossing of the Kattegat in the fyring *Båra*, would not have been conceivable early on, and yet turned out to be entirely possible with a sufficient level of skill and experience.

On a more general note, I feared that the qualitative nature of much of the data collected during this project would hinder collaborations with more quantitative disciplines. But the experience has been quite the contrary; natural science research stands as much to gain from integrating a qualitative angle as archaeology does from the inclusion of quantitative methods. Article 4 is a clear example of how knowledge from different worlds can be fruitfully combined, and hopefully represents an early step towards further multidisciplinary approaches including fields such as material sciences, earth sciences, hydro- and aerodynamics, procedural modelling, and genetics.

Finally, the project's findings are backed up by a comprehensive body of experimental and digital data, organised into the project data repository. This open-access archive enhances the transparency of the project's results, and allows future researchers to evaluate them through similar experiments. By disseminating research data in formats that do not fit onto the pages of this book, it directly contributes to the project's goal of integrating alternative sources of evidence into studies of Viking Age seafaring.

Errors and misprints in the articles

Article 1

- p 220
  - “… of the Viking Age (Figure **12.2**)”: should be 12.4
- p 226, footnote
  - “Two of the seven boats from this project”: should be “two of the six Åfjord boats from this project”
- p 228
  - “conditions in the present moment (Figure 12.5)”: should be 12.6
  - “May and July along the Norwegian coast (see Figure 12.5)”: should be 12.6
  - “south side of Bremangerlandet (Figure 12.6).”: should be 12.5
- p 231
  - “nature, duration, and outcome (see Figure 12.5).”: should be 12.6
- p 236
  - “and was believed to exist beyond”: should be “and what was believed to exist beyond”

Article 3

- p 18: second line from the bottom, the word should be “boats”, not, “boast”

Appendix 2 (Articles 1-4)

Article 1

12

Toward, Not To

Seafaring Worldviews from Viking Age and High Medieval Norway

Greer Jarrett

For the coastal communities of Scandinavia, seaborne movement has been a ubiquitous aspect of life for at least the last four millennia (Østmo 2020). Multidisciplinary evidence for ancient maritime activity connects people, places, objects, and ideas across this region's seascapes but rarely provides us with more than a point of origin and eventual destination, deposition, or burial (Marcus 1980: 108). Surviving information about the sea voyages between these points is extremely scarce until the development of maritime ethnology in this region in the early- and mid-twentieth century (Færøyvik and Færøyvik 1979; Hasslöf et al. 1972; Westerdahl 1989; Figure 12.1). This scarcity hinders our understanding of the practical aspects of ancient maritime mobility (navigation and sailing, routes and itineraries, voyage duration, seasonality, costs and risks) as well as the cognitive and ontological dimensions of seaborne travel. In this chapter, I address this problem by exploring how human mobility patterns are entangled in culturally specific worldviews and how reconstructing the worldviews of ancient seafaring societies may help us retrace and characterize their voyages.

Seafaring is a skilled, collective, and intrepid form of maritime activity (Broodbank 2006: 200, 208) that played a central role in Scandinavia during the Viking Age (ca. AD 800–ca. 1050) and the High Middle Ages (ca. AD 1050–1300) (Bill 2010: 20). Over this timespan, Scandinavian maritime communities gradually lost most (but not all) of the attributes that would characterize them as small-scale societies, such as low population densities, subsistence economies, decentralized social and political organization, and religious diversity (Reyes-García et al. 2017; for a discussion of this in relation to the Norwegian Iron Age, see Berthelsen 1997). This loss also incurred the shedding and ac-

Figure 12.1. Bernhard Færøyvik measuring a larger Åfjordsbåt known as a *fembøring* in 1936. The thorough documentation work conducted by Færøyvik and others during this period allowed for the survival of the Åfjord tradition and informed the construction of the boats used in this study. Photograph by Kristian Kielland, Norwegian Maritime Museum, Id: NSM.1701-161.

tive suppression of a pre-Christian and pre-urban maritime worldview, the reconstruction of which forms the focus of this chapter. The primary material for this reconstruction is made up of a series of experimental voyages on board traditional Norwegian boats, cultural and technological descendants of the boatbuilding and sailing traditions of the Viking Age (Figure 12.2). Through an analysis of these voyages, I identify the primary affordances of route choice and navigation and present the likely characteristics of the accompanying worldview. By better understanding the emergent relationship between seafaring practices and worldviews, it becomes possible to get a sense of the suite of risks and opportunities that Viking Age and high medieval sailors would have perceived during their voyages and thus suggests which routes they would have favored.

Like the other authors of this volume, during this research I have attempted to give voice to the perspective of the sailors who undertook these voyages, and to "take seafaring on its own terms" (Grier et al., Chapter 13, this volume). Such a perspective is often lacking in our profoundly terrestrial academic tradition, making this attempt of use to other scholars also seeking to "think from the ocean" (Steinberg and Peters 2015: 261, as well as most of the chapters in this volume). As some have shown, our lack of knowledge about ancient voyages (by which I mean physical and planned seaborne movement using culturally

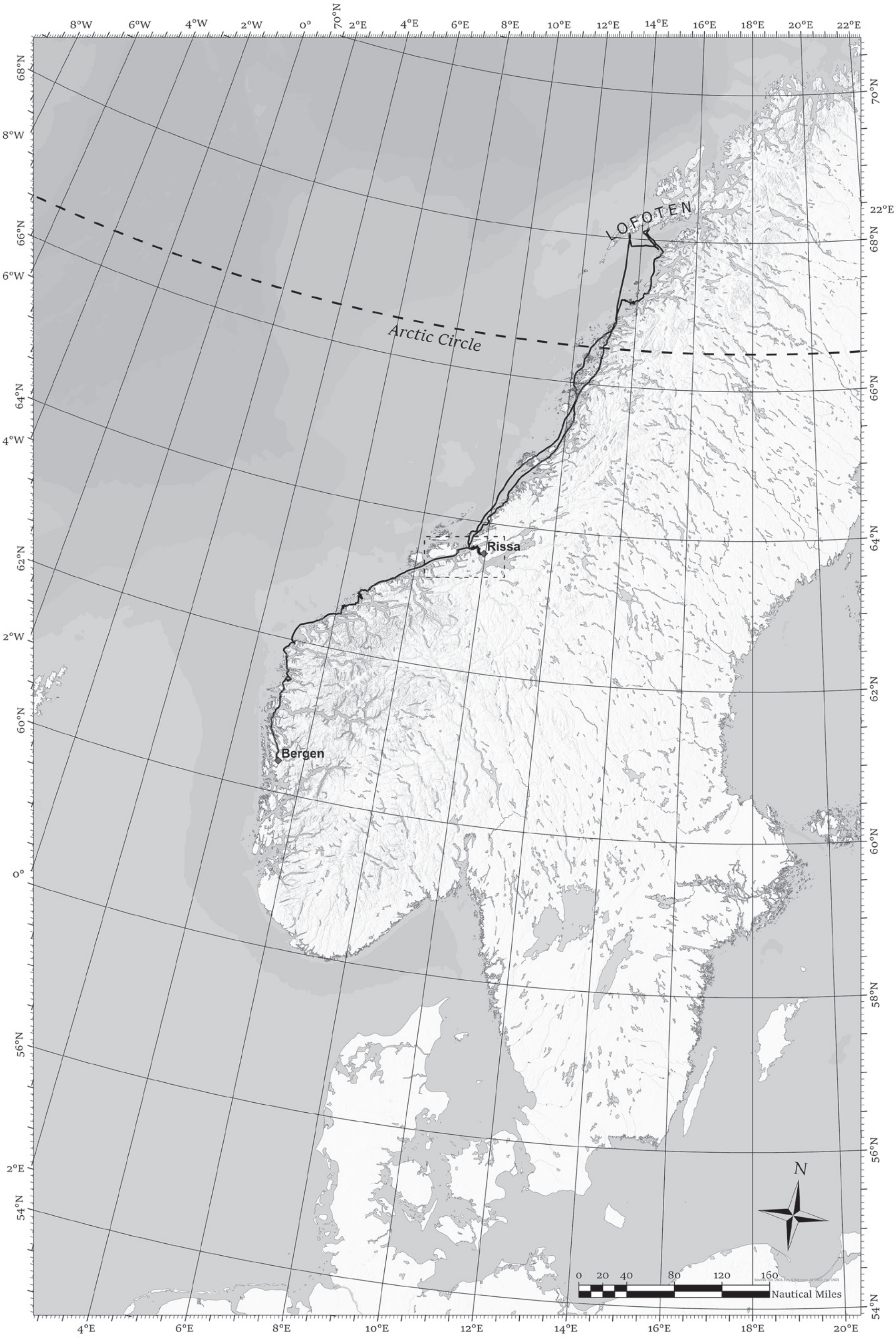

Figure 12.2. The Norðvegr, with places mentioned in the text. The lines indicate the return voyage from Rissa to Lofoten and the voyage from Rissa to Bergen, and the rectangle marks the area where the sailing trials were conducted.

specific watercraft) cannot be exclusively blamed on a lack of evidence: we are at least equally impeded by the great ontological distance separating modern scholar from ancient sailor (Frog et al. 2019: 13; Safadi and Sturt 2019: 1). This distance seems to originate in the context of use—that is, in the way culturally specific activities and environments offer up distinct understandings of space, movement, and the world (Hutchins 1995; Ingold 2000). To bridge the gap between different contexts of use, studies of maritime mobility face the challenging task of developing methods that can acknowledge, analyze, and interpret past maritime activities and environments for a modern and terrestrial audience. This means actively moving beyond the conventional analytical and representational tools of western science, which often encourage the reduction of ancient voyages to abstract values or colored arrows across empty blue expanses (Edney 1999: 167; Gillings 2012: 608; recent examples of such reductions can be found in Brink and Price 2012; Cunliffe 2017; Østmo 2020). To gain a fuller understanding of Viking Age and high medieval seafaring (which includes voyages but also the technical knowledge, skills, and experience required to undertake them), we therefore need alternative approaches and models at least as much as we need new evidence. As several of the chapters in this volume exemplify, creative and critical approaches to ancient seafaring are in a stage of healthy development in the Americas (e.g., García-Piquer, Chapter 2; Rorabaugh, Chapter 3), but a notable lag in this innovation is apparent in the context of Scandinavian archaeology.

Seafaring as Wayfaring

In exploring these alternatives, I have found a strong alignment between new breakthroughs in neuroscience and theoretical perspectives on wayfaring and affordance. Both suggest that human mobility is culturally and environmentally contingent, and that an understanding of the context of use is therefore essential for reconstructing ancient pathways. A brief outline of these will serve to preface their application to the project's experimental voyages.

We can begin with neuroscientific understandings of path-finding and navigation. According to the current consensus, spatial and directional information from sensory experience and path integration is gathered, computed, and represented in the hippocampus. This results in a regular pattern of firing neurons, often referred to as a cognitive or mental map, due to its role in spatial awareness and navigation (Hafting et al. 2005; Tolman 1948; Whittington et al. 2022). However, recent research on entorhinal grid cells, which play a key role in this process, suggests that we should not think of the information these cells encode as a direct mental reproduction of "what is out there." Rather than "maps," these cells create structured frameworks of cognition for organizing and communicating thoughts and experiences about wayfinding and navigation but also about family trees, social networks, or sequential practices (Whittington et al. 2022). For movement and navigation, this framework serves as a kind of metronome of abstraction, allowing the traveler to integrate spatiotemporally encoded impressions of their surroundings into a broader understanding of space in a consistent fashion, thereby revealing possible routes or itineraries toward an intended goal or destination.

It is the yielding of potential pathways through relational thinking that makes cognitive processes so crucial for studying ancient mobility. Significantly, and contrary to earlier hypotheses, grid cells seem to be strongly determined by particular environmental cues, meaning that the patterns they create do not exist independently of our experience and movement through our surroundings (Lisman et al. 2017; cf. Hafting et al. 2005). The neuroscientific shift toward context and dynamism aligns remarkably well with relational readings of Gibson's theory of affordances (Chemero 2003; Gibson 2014: 119–135) as well as archaeological applications thereof (Gillings 2012; Wernke et al. 2017). According to these, a community's shared movements, practices, and environments shape their perception, understanding, and representation of the world. This encourages and constrains certain patterns of choice and action, which in turn generate particular conceptions of space and particular ways of finding one's way through it (Ingold 2000: 161; 2011: 151). Thus, both scientific and theoretical perspectives seem to reject the static, universalizing metaphor of the mental map and encourage us to imagine ancient paths or routes as being afforded by particular worldviews, which originate, in turn, in patterns of movement and practice through particular environments.

It follows that any reconstruction of ancient maritime mobility must begin with an understanding of the affording worldview. Central to this chapter's approach is the ethnoarchaeological hypothesis that such an understanding can be reached through active, long-term engagement in the practices and environments under study, in collaboration with the local bearers of descendant traditions (David and Kramer 2001: 59; Lane 2016: 605). This engagement allows the fieldworker to inhabit a common space of experience with ancient practitioners and thereby attune themselves to a similar suite of affordances. The establishment of this experiential nexus encourages the development of similar understandings of space and movement, allowing the modern scholar to suggest which routes might have been favored in the past (Ingold 2000: 166–167, 216).

Fortunately, practical engagement in traditional Scandinavian seafaring has a long and decorated history, with over a century of research by archaeologists and ethnologists. Experimental sailing voyages on board historical and reconstructed boats and ships have revitalized expertise in ancient sailing techniques and resulted in a relatively standardized data-gathering method, which is followed in this study (Bischoff et al. 2014; Crumlin-Pedersen et al. 1980; Englert 2006, 2012). Parallel to these efforts, ethnological research among traditional seafaring communities across Scandinavia has revealed strong continuities over centuries or even millennia in the practices of boatbuilders, sailors, and fisherfolk, suggesting that fragments of a possibly pre-Christian worldview may have also endured (Eldjárn and Godal 1988: 17; Westerdahl 2010).

The insights gained from experimental archaeology and ethnology illustrate the potential of alternative approaches to ancient maritime mobility and highlight the importance of physical engagement when studying fundamentally practical traditions such as navigation, sailing, and boatbuilding. This study expands on previous research by focusing on sailing voyages along the Norðvegr (the coastal route along the western coast of the Scandinavian Peninsula; see Figure 12.2), an area that has received less scholarly attention than southern Scandinavia (e.g., Englert and Trakadas 2009; Indruszewski and Godal 2006). The reconstructed ontology draws on voyages conducted by the author as well as previous scholarship regarding seafaring practices and worldviews along this coastline (e.g., Storli 2007; Valtonen 2008). The study period (AD 800–1300) spans the time from the first indisputable evidence for the use of clinker-built sailing boats like those used in the project's fieldwork to the diffusion of the magnetic compass and the nautical chart, which afforded abstract and increasingly modern conceptions of space (Kemp and D'Olier 2016).

Experimental Methods

This project's primary data-gathering method consisted of long-term, practical engagement in traditional sailing practices along the Norwegian coast and the consequent establishment of an experiential nexus with sailors from the past, as discussed above. The main objective was to identify the affordances of maritime mobility and route choice that were revealed through these shared experiences. The affordances were then compared with historical and archaeological evidence for their presence in the timespan under study and used to reconstruct the characteristics of a Viking Age and high medieval seafaring ontology, which is presented at the end of the chapter (Figure 12.3).

The fieldwork consisted of a series of sailing trials and trial voyages on board six different Norwegian boats built in the Åfjord tradition of the late nineteenth century (Figure 12.4). For the purposes of this study, it seemed most fruitful to use vessels whose handling and constituent parts are fully evidenced and understood, rather than adding more uncertainty by reconstructing an older,

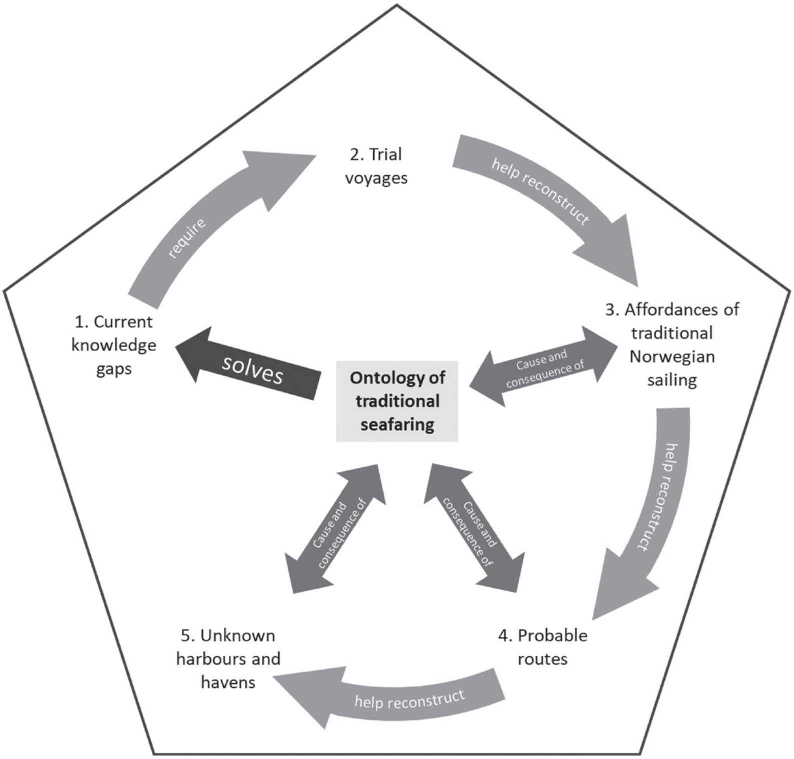

Figure 12.3. This chapter's methodology in schematic form. Note the two-way relationship between worldview and practice.

less well-preserved, and more hypothetical craft. Åfjord boats are double-ended, square-rigged vessels; clinker-built of pine, spruce, or both; and equipped with multiple pairs of oars. They were used until the early twentieth century for fishing and transport throughout Trøndelag but are most renowned for their annual voyages to and from the cod spawning grounds off the Lofoten archipelago, a round trip of some 700 nautical miles typically undertaken between January and April (Eldjárn and Godal 1990; Parsons 2013). The boats' basic characteristics are common to Norwegian boatbuilding for at least the last 1,200 years; in this sense, late examples of the tradition can serve as analogies for exploring what routes might have been followed along the Norðvegr in earlier periods (Eldjárn and Godal 1988: 13; Weski 2006: 64). The uninterrupted continuity of this heritage, coupled with the role these craft played in both local and regional mobility networks, makes them particularly promising candidates for the present research.

Figure 12.4. A traditional Norwegian boat built following the Åfjord tradition. Rissa, Trøndelag, September 2021. Just like the boats of the Viking Age, Åfjord boats are built frame-first and rigged with a square sail. Image courtesy of Tora Heide.

Fifteen sailing trials and two trial voyages were undertaken between September 2021 and June 2022. The sailing trials, lasting between one and four days, were conducted in and around the Trondheim Fjord in a wide range of weather conditions and in all interceding months. Two longer voyages of approximately three weeks each were conducted between April and June 2022: the first was a return voyage from Rissa to Lofoten, and the second a one-way voyage from Rissa to Bergen (see Figure 12.2). A total of 1,494 nautical miles were covered over ground during this campaign.[1] The sailing trials were used as a way for the volunteer crews to gain familiarity and skill in the practices of sailing as well as to allow for the study of specific aspects of the vessels' performance, such as the possibility of recovering after a capsize or the boats' windward sailing capabilities. The two voyages were conducted after the trials and focused on evaluating potential ancient routes and havens along the Norðvegr.

Data was gathered before and during these trials in the form of field notes, interviews, photographic and video footage, meteorological data and obser-

1 Two of the seven boats from this project were equipped with engines, which were used on two occasions, and there were four instances of towing; this amounted to about 15 hours, or 3.1%, of the 467 hours spent in motion.

vations, and a GPS track of each trial. This provided a comprehensive record, including the performance of the various vessels under a range of conditions, the routes taken, and the range of human and environmental affordances of mobility and route choice. Upon completion of each voyage, field notes, photographs and other data were organized and digitized, and an evaluation was made of which factors were the primary affordances of the route chosen.

Results

What follows is a presentation of the primary affordances of route choice identified during the project's sailing trials and trial voyages. These results inform the seafaring ontology outlined at the end of this chapter as well as the proposed reconstructions of Viking Age and medieval sailing routes, which are elsewhere (Jarrett 2025; Ruiz-Puerta et al. 2024).

When traveling aboard an open boat without an engine and powered only by wind and oars, the foremost contrast with modern travel is the conception of travel itself (discussed in the context of Indigenous Baja Californian seafaring by Des Lauriers and García-Des Lauriers, Chapter 5, this volume). In an interview with skipper and sailing teacher Lena Börjesson, I asked how she would think of a sailing voyage to a specified destination both before and during a voyage. She answered: "Jag vill inte segla *till* någonting . . . , jag vill segla *mot*" ("I do not want to sail *to* somewhere, I want to sail *toward* it"; personal communication 2022). This statement illustrates the inherent unpredictability of a voyage under sail: in October 2021, during a trial in the Trondheim Fjord, our intended destination changed no less than four times within one day. Even with accumulated experience, such changes remained common the following year; during an attempted crossing of the Vestfjord toward Lofoten in May 2022, major wind changes over a 24-hour period forced us first to abandon the crossing and then to entirely change our itinerary, arriving the following morning in Bodø, some 50 nautical miles southeast of our intended destination.

The opportunistic and adaptable sailing practices evident in these experiences are often presented in the academic literature as the harnessing of "favorable" weather conditions, but what this means is rarely explained (e.g., Englert 2012: 273; Marcus 1980: 101). During this study it became clear that "favorable" is rarely synonymous with "pleasant" or "optimal." On the first of May 2022 we sailed from Leka toward Sandnessjøen, covering 65 nautical miles in just under 12 hours despite constant heavy rain and fog and winds up to Beaufort 7 (near gale), requiring one and sometimes two reefs in the mainsail. In contrast, a second crossing of the Vestfjord was attempted on the eighth of May from Bodø in what first appeared to be "favorable" weather, with calmer

Figure 12.5. Bremangerlandet, June 2022. After a successful passage around Stad in large but gentle swells, we encountered strong katabatic gusts and steep waves upon approaching land. This experience highlighted the risk of approach areas even when conditions are favorable on the open sea.

winds (Beaufort 2–4), clear skies, and excellent visibility. However, conditions throughout the morning became very unstable, with snow flurries, sleet, and gale-force gusts descending from Landegode. The skipper therefore decided to abort the crossing once again, and we changed course for Steigen. As these episodes show, the stability and predictability of the weather is much more conducive to long-distance sailing than seemingly optimal conditions in the present moment (Figure 12.5).

Spells of stable, usable weather represent opportunities that cannot be missed, regardless of when they occur. This sometimes involves sailing through the night, and the trials proved that this is perfectly achievable between May and July along the Norwegian coast (see Figure 12.5), as has also been shown for the Baltic by Indruszewski and colleagues (2008). What is perhaps less clear in current scholarship is the relative danger posed by different stretches and features of the Norðvegr. Many scholars have highlighted the risks of exposed areas such as Hustadvika or Stad (e.g., Kruse 2017; Østmo 2020; Skre 2014). However, during this study the moments of greatest peril occurred along the relatively protected approaches to and from exposed areas, such as in Linesfjorden, Breisundet, or along the south side of Bremangerlandet (Figure 12.6). Narrow sounds or coastal waters featuring sharp bathymetric change can be dangerous even when the weather and wind conditions out to sea are stable and favorable. Irregular, steep wave patterns, strong tidal currents, reefs, and the

Figure 12.6. *Top:* A *fembøring* sailing at night, May 2022. *Middle:* A clear example of unstable weather, Sandnessjøen, April 2022. *Bottom:* A world within a world: the profoundly social nature of life on board. Trondheimsleia, May 2022.

infamous katabatic winds known as *fallvind* constitute major risks for open sailing boats that are often disregarded in academic literature (Eldjárn and Godal 1988: 94). In a discussion about possible routes during the trial voyage from the Trondheim Fjord to Lofoten, skipper Kjetil Sildnes described a route running from Buholmråsa to Vega via Ytter-Vikna, Hortavær, and Muddværet that he used when the wind blew from the east or southeast (personal communication 2022). This route deliberately kept away from the coast to avoid the *fallvind* and take advantage of stronger and steadier winds further out to sea. This evidence suggests that sailing crews may have needed to wait for safer conditions not only when departing for the open sea but also when approaching the mainland, indicating that ancient maritime nodes may have been located along the outer coast rather than within the inner fjords, as they are today.

The subject of navigation in Viking Age Scandinavia has generated decades of debate (for a comprehensive recent discussion, see Filipowiak 2020). Although safety concerns meant that the boats used during these trials were equipped with some modern navigational aids (paper charts, compass, and VHF radio), some remarks can still be made on this topic. The Norðvegr is primarily a coastal environment flanked by monumental landforms with unique associated names, poems, and tales (Morcken 1978; Westerdahl 2010). During the trials this allowed for a combination of pilotage using named land- and seamarks (such as Skrova, Bolga, Landegode, and Stemshesten) and careful dead reckoning during open-sea stretches or in low visibility (sometimes using a tally system, as suggested by Marcus [1980: 108]). In the absence of digital navigational instruments displaying absolute data, extreme attentiveness and effective communication had to be maintained during critical navigational episodes between the lookout, the navigator, and the person steering. Collective attentiveness was particularly important because much of the information used for making decisions about routes or destinations was available to all crew members in their surrounding environment (landmarks, wind direction, sea state, incoming weather systems). This meant that many of the skipper's decisions were made collectively, or at least in consultation with other members of the crew, rather than through the reading of specialized instruments displaying absolute data.

Navigation was by no means the only collective task, however. The trials involved crews of 4–15 people, and although rotating roles were usually assigned, a great deal of the work was undertaken collectively, such as reefing, tacking, mooring, or preparing food. To be able to sleep while under way, the off-duty watch needed to have total trust in the technical competence of the watch on duty. This collective reliance led to the development of strong social bonds during the sailing trials, allowing the skipper to delegate an increasing level of responsibility to the crew, and for the crew to develop confidence in themselves. Social networks also extended beyond the boat and included people encountered or accounted for along the way, who played an important role in providing mooring and shelter, local knowledge and information, and access to supplies or materials. It was thanks to such contacts that we heard of the unnatural calms around Hitra (Kenneth Bjørkli, personal communication 2021), the dangers of the Breisund (crew of *Storeggen,* personal communication 2022), and the hidden channel south of Askvoll known as Sauesund (Arvid Thuland, personal communication 2022).

This collective, social dimension is arguably the most dominant of the seafarer's experiences. The interactions, relationships, and dynamics between the people involved in the voyage are of primary consequence for the voyage's route, nature, duration, and outcome (see Figure 12.5). Additionally, collective tasks and the total absence of privacy meant that technical skill and experience did not always matter most; the crew's morale, their capacity for teamwork, and their levels of mutual trust were equally crucial.

Attunement to the Seascape Through Practice at Sea

The sailing trials involved repeated routes along and around the Trondheim Fjord. As the same seascapes were repeatedly traversed, previously unperceived or unknown elements of practice and of the environment became deeply familiar. This familiarity developed collectively as the crew learned to work and communicate together using shared skills, place-names, and nautical terminology. The process and extent of this experiential transformation cannot be described in its entirety here, but several of its effects are significant for the present discussion.

First, measurements of absolute distance were rapidly shed in favor of notions of voyage duration. This was apparent already in October and November 2021, probably due to the hard lessons learned in the mercurial autumn weather; questions like "how far is it?" rapidly became "how long do you reckon it will take?" Throughout the following months, the crews gradually came to trust their own rapidly expanding experience over the information provided in textual sources, such as tide tables, as these rarely accounted for complex local conditions.

Second, as notions of absolute distance faded, a network of known and named landmarks slowly developed in the collective geography on board. We began to think of particular routes not as lines on a map but as a sequence of remembered places colored by the accompanying experience of sailing in their vicinity. The places where several possible routes met, such as Agdenes, Bolga, or Landegode, became particularly important mnemonic anchors, as it was here that final choices had to be made. Thus, the crew began describing routes as a sequence of ordered place-names: typically this would be phrased as "you sail toward [place A], and then when you pass it you have [place B] to port/starboard, and then you have [place C], and after that [place D]." Few details are given about these places, other than perhaps the most serious dangers, as it is assumed the listener will know of them. During the trials, we continued to use nautical charts for navigation, but this kind of embodied remembering of a route, and of the good or bad choices made, often outshone the mental image of a plotted course to such a degree as to almost replace it.

The third and final effect to mention here is related to the development of practical skills and bonds of mutual trust. These brought about a rapid expansion in the crew's conception of what routes and conditions were deemed safe, opening up the seascape to possible voyages that would previously not have been considered. For example, initial encounters with katabatic winds, winter sailing, or rigging breakages led to changes or abandonment of attempted sailing trials. But having learned from these encounters, similar experiences during the trial voyages were no longer perceived as seriously dangerous, allowing us to continue toward our intended destination. Conducting experimental trials in suboptimal conditions was thus of huge benefit to the general results of the project as the crews developed a level of competence that would otherwise never have been reached.

Navocentrism, Attendance, and Perceived Risk

As such sequential descriptions make clear, the orientation system at work during this kind of sailing is entirely centered on the moving boat. This perspective is reinforced by the total dynamism of the surrounding land- and seascape as it seemingly rises, falls, and revolves around the observer and appears and disappears behind curtains of weather, rolling waves, or other landforms. The boat thus becomes the only fixed axis of orientation, with places and possible routes considered in relation to it and its movement along a remembered path. As the trials primarily involved coastal navigation, this orientation system took mental precedence over modern abstract geographies of regions beyond the horizon. It would be of great interest, however, to see whether traditional sailing practices afford this kind of "navocentric" orientation system even during voyages out of sight of land.

One of the primary results from the experimental trials was the establishment of a clear relationship of affordance between the dynamism of the environment and the nature of traditional Norwegian navigation and seafaring practices. The changing and unpredictable nature of the weather and the sea along the Norðvegr required constant and collective attentiveness from the crew, as any change, no matter how small, could herald a vital opportunity or the advent of disaster. Navigational choices were made according to that which was collectively perceived, known, or believed to exist in the environment. This implied a constant level of uncertainty: decisions and choices taken were rarely objective calculations based on quantitative data but rather were judgments of possible outcomes based on perception, knowledge, and experience. An example of this was our changing attitude to potentially dangerous areas: early encounters with the strong currents around Agdenes, a promontory that features frequently in the medieval sagas (Sturlason 1990: 153, 373, 559), led us to give this headland a wide berth during the initial sailing trials. But as the crew became familiar with the tidal cycle in this area, we learned to judge when it was safe to take the more direct route close to the promontory. Although uncertainty remained, our accumulated experience changed our attitudes to Agdenes from an area to be categorically avoided to a place whose potential risks could be judged through attendance to our increasingly meaningful surroundings.

To return to this chapter's main research question, the central factor that afforded route choices during the project's trials were these value judgments of possible outcomes—in other words, judgments of perceived risk. This is perhaps best expressed as the following question, rarely voiced but clearly implicit in the choices made during these trials: Judging by the current circumstances, does taking this route represent an acceptable level of risk to vessel and crew?

Seafaring Affordances Through Time

The traditional boats and sailing practices studied during the project's trials encouraged the development of an undeniably distinct conception of maritime space and movement, anchored in collective judgments of perceived risk. However, the value of this as an analogy for studying ancient seafaring depends on the identification of similar patterns of practice and movement through similar environments in the past. Here I briefly present parallels between the seafaring affordances identified during this project and those apparent in the surviving evidence for maritime mobility along the Norðvegr in the Viking Age and High Middle Ages.

The contingent nature of traditional sailing is highlighted both in modern scholarship (Campbell 2020) and in medieval written sources. In *The King's Mirror,* for example, the narrator describes fair weather as a temporary peace between dangerous forces (Larson 1917: 90). In Norwegian folklore, these dangers are personified in the figure of the *draug* (Mathisen and Sæther 2018). The use of watches to allow for night sailing during this temporary peace is attested for in the archaeological evidence for Viking Age ships (Ellmers 1995: 237; Ravn 2016: 133) and in later saga literature (e.g., Jónsson 1947: 324).

The core elements of traditional Norwegian boatbuilding and sailing practices display high levels of continuity across both space and time. In their study of boatbuilding from Åfjord and Nordland, Eldjárn, and Godal (1990: 79) were able to identify a system of proportional measurement used from the time of the Gokstad ship until the early twentieth century. Perhaps even more strikingly, Parsons (2013) has shown that many of the terms, roles, practices, and even knots recorded by these two authors in the mid-twentieth century were in use on board West Highland galleys in medieval Scotland, suggesting that these traditions accompanied the introduction of Scandinavian boatbuilding to the Celtic world during the Viking Age while remaining in continuous use in Scandinavia ever since.

With similar boats, the danger of approach areas was also a historical constant, as is expressed regularly in the sagas (e.g., Smiley and Kellogg 2001: 54; Turville-Petre and Olszewska 1942: 58). The need for outlying maritime nodes mentioned above may also explain the location of the five earliest Norwegian royal manors linked to Harald Fairhair, which are closer to the outer coast than earlier Iron Age power centers and later towns like Bergen (Skre 2014).

Navigational practices before the diffusion of the magnetic compass are harder to reconstruct from the surviving evidence. However, it seems likely that the coastal environment of the Norðvegr and the long history of movement along this coast afforded a kind of low-instrumental navigation that was widespread by the time transatlantic voyages began to be conducted in the late ninth century. This does not mean that navigation was an unstructured, subjective process; indeed, experiments showing that it is possible to accurately estimate the time of day while at sea (Börjesson 2009; Engvig 2001; Bill personal communication 2021), along with evidence for collectively held average speeds for different kinds of vessel (Indruszewski and Godal 2006: 24) and Morcken's (1978) proof of a common system of measurement existing from at least the twelfth century point to a highly developed but profoundly different tradition of navigation to our own.[2] The collective nature of navigation seems also to have been important throughout this period. In the *Saga of the Greenlanders,* Bjarni consults with his crew before setting off toward Greenland (Smiley and Kellogg 2001: 637), and cooperation between multiple crew members appears to be depicted on the Gotland picture stones and the Bayeux tapestry (Ellmers 1995).

2 Although the evidence presented by Morcken for the common use of *vikur* as distance units is convincing, his arguments for instrumental navigation in the Viking Age have been extensively criticized and, in some cases, disproven (Filipowiak 2020; Sayers 2003).

Finally, Viking Age and early medieval sailors also seem to have had a time-based and navocentric conception of their voyages and made collective judgments based on perceived risk. Adam of Bremen and the *Landnámabók* both report on sailing voyages using units of time rather than distance (Adam of Bremen 2002: 218–219; Pálsson and Edwards 2007: 16), and the *Landnámabók* author describes these voyages as a sequence of places one needs to sail past, as do the accounts of Ohthere and Wulfstan (Bately and Englert 2007; Englert and Trakadas 2009). The identification of landmarks relative to the direction of the ship's movement is apparent in both these accounts and occurs throughout Norse poetry (Jesch 2015). Geographical descriptions such as that of Greenland given to Bjarni Herjólfsson in the *Saga of the Greenlanders* are given from the perspective of the perceiver (Smiley and Kellogg 2001: 637), suggesting that Norse seafarers would not have conceived of their known world from a top-down perspective. Risk judgment is perhaps best exemplified in the *Historia de profectione Danorum in Hierosolymam,* in which survival at sea is directly attributed to the "ability to rightly judge the route and the sea" (Gertz 1922: 480; translation by Stephan Borgehammar, personal communication 2023).

This brief assemblage of evidence shows that the affordances identified during this project's trials have strong parallels with maritime movements and practices from the Viking and high medieval periods. Nevertheless, we should not take such parallels as indicators of environmental, cultural, or technological stasis among the coastal communities of the Norðvegr over the last 12 centuries (Bill 2010). Nor should we assume that similarities in movement and practice equate to similarities of experience or worldview (Meulengracht Sørensen 1995). The purposes, beliefs, and cultural backgrounds of the modern voyagers who were engaged in these trials remain undeniably distinct from those of a Viking Age or high medieval boat crew.

But as we have seen, practical engagement also resulted in changes among the modern crews regarding conceptions of maritime space and travel. This seems to have occurred through a kind of peer-pressure of practice: the commonly inhabited space of experience, the use of specific language and terminology, the particular and almost ritualistic ways of performing certain tasks, the repetition of geographically situated names and stories, and the constant evaluation of perceived risk encouraged the adoption of a wholly different way of thinking. I suggest that this ontological shift occurred because traditional attitudes and approaches were more useful than conventional modern ones for the activities and evaluations involved in traditional sailing. This is in line with Hutchins' (1995: 66) arguments that different navigational ontologies developed out of different contexts of use, and that it was their usefulness, not their accurate depiction of reality, that determined their adoption.

Characterizing an Ontology of Viking Age and High Medieval Seafaring

The establishment of an experiential nexus with ancient seafarers is apparent in the changes of perspective among the modern crews toward attitudes and practices evident in the archaeological and historical record. This connection through practice serves as a window not only on everyday activity but also on the broader maritime worldviews of the seafaring communities under study. We can therefore use the experimental and historical evidence assembled in this chapter to propose some possible characteristics of a Viking Age and high medieval seafaring ontology from the Norðvegr. Such an ontology seems to have consisted of the following: (1) an ever-changing set of named and storied places, used as mnemonic anchors across (2) a meshwork of possible routes, which together created (3) a boundless but thoroughly interconnected seascape. The shared conceptualization of this seascape was based not on universal representations of it but rather on (4) a dynamic and not wholly universal tradition of usage founded on practical experience in maritime activities. This practice-based geography led to the prevalence of (5) temporal or proportional systems of measurement founded on (6) commonly held averages rather than absolute values (average sailing and rowing speeds, average sizes of body parts used in boatbuilding), and a common understanding of the conditions under which such averages were applicable. This afforded (7) a navocentric system of orientation from which the world was taken in as a seamless integration of directly perceivable elements and was believed to exist beyond. Voyages through this watery world involved many negotiations, but the central factor affording route choice seems to have been (8) a collective judgment of perceived risk to vessel and crew.

Conclusion: A Maritime Cultural Mindscape?

Ancient mobility, and particularly ancient maritime mobility, is an essential part of the human story that has proven difficult to analyze and represent with conventional historical and archaeological methods. The aim of this chapter has been to present an alternative approach that can bridge the ontological gap between modern researcher and ancient sailor. With this approach I have been able to identify the primary affordances of traditional Norwegian seafaring, evaluate their potential as a window on Viking Age and high medieval maritime ontologies, and suggest some of the possible characteristics of these ontologies. The result is a conditional, sequential, and relational seascape, with a voyage understood as a series of possible routes, and route choices determined primarily by collective judgments of perceived risk.

Over 30 years ago Christer Westerdahl identified an assemblage of maritime heritage that he used to define the maritime cultural landscape (Westerdahl 1989, 1992). The present study has revealed a conception of space and mobility that is equally embedded in coastal and maritime life and equally distinct from terrestrial worldviews. Hoping to move beyond the ideas of mental mapping and cognitive landscapes as direct representations of space in the brain, and inspired by Westerdahl's seminal work, I suggest that the ontology presented in this chapter is best understood as a maritime cultural mindscape. This mindscape is developed by a moving and perceiving person in the world and is therefore inherently contextual and alive; it spreads out from the perceiver to relate to other human and nonhuman agents; and it is not purely computational or representational but includes experience, skill, knowledge, and judgment, all of which play a role in actions and choices.

Various scholars within the Blue Humanities have suggested that approaches to ancient maritime activity could benefit from the inclusion of dynamism, contingency, and relationality (Campbell 2020; Steinberg and Peters 2015). The focus on experience and practice taken in this chapter, along with the concept of the maritime cultural mindscape, may serve to complement Westerdahl's work in this way. But beyond conceptual concoction, it is paramount to remember that the choices made by sailors in the past were founded on skill and wisdom, not data. The greatest challenge facing future models and analyses of ancient seafaring is, therefore, to base their representations and computations not only on quantitative environmental and nautical variables but also on culturally specific judgments of perceived risk and opportunity. As we have seen, both influenced ancient seafarers, as well as the nature and outcome of their voyages, and the wider, watery world through which they traveled.

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Supplementary Data

The complete dataset collected during this project's sailing trials and trial voyages will be published as part of the author's doctoral thesis.

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Article 2

Maritime Mindscapes: using experimental archaeology to reconstruct Viking Age seafaring routes

Greer Jarrett

Fig. 1. The Norðvegr. The black rectangle indicates the area within which the sailing trials took place. The two major voyages conducted for this study are indicated by red and green lines. The names in bold indicate havens that are known to have been used during the Viking Age or High Middle Ages, whilst those in cursive are put forward as potential additions in the light of the project's trials.

Abstract

In this paper I evaluate the feasibility of reconstructing Viking Age sailing routes through experimental and ethnographic fieldwork onboard traditional Norwegian boats, focusing on aspects of Viking Age route choice, risk judgement, and the location of possible anchorages and harbours. The goal with this approach is to reconstruct the 'scapes' of Viking Age seafaring: the seafaring routes and environments, as well as the practices and worldviews of a maritime society. It is argued that through this approach, we can discover not only where people travelled, but also what these journeys were like, what understandings of the world they were entangled in, and how these afforded the practices observable in the surviving evidence. Some elements and aspects of these scapes survived in relatively unaltered form into the 20th century, allowing us to employ them as analogies for Viking Age affordances, and reconstruct possible maritime itineraries along the Norwegian coast.

Introduction

By the Viking Age, the western coast of the Scandinavian Peninsula was a profoundly interlinked region, dominated by magnates and petty rulers whose power was founded upon agricultural lands and the control of the sailing route known as the *Norðvegr* (Iversen, 2020: 290; Skre, 2014: 42–43; Storli, 2007: 86) (Figure 1). This route continued to play a determining role in European history over the next twelve centuries, transporting people, animals, ideas, and goods from reindeer antler to natural gas. The evidence for its use during the Viking Age comes from a range of disciplines (history, archaeology, place-name studies, genetics), but is usually limited to a point of origin and destination for the data in question, rarely shedding any light on the voyages and voyagers that bound the Viking world together across its vast seascapes (e.g. Heen-Pettersen, 2014; Hedenstierna-Jonson, 2016; Margaryan et al., 2020).

Here, I would like to present an approach that attempts to address these gaps in our knowledge by exploring the *Norðvegr* from the perspective of the sailor (Heide and Planke, 2019). I have recently taken part in a series of experimental voyages along the Norwegian coast in traditional Norwegian boats, descendants of the clinker tradition that underlay the maritime character of the Viking Age. The aim of this paper is to evaluate whether the perspective of the traditional sailor, gained (albeit only partially) through these voyages, can be used as a window on the travelling Viking Age. This evaluation is presented as a tentative 'proof of concept' from which further experimental and analytical research will follow. First-hand sailing experiences are compared with archaeological, historical, toponymic, and environmental evidence for Viking Age seafaring. I argue that traditional Norwegian seafaring practices can serve as analogies for similar activities from the Viking Age, allowing us to reconstruct the most frequented sailing routes from this period, and even suggest which harbours and anchorages were used.

A shared maritime worldview in the Viking Age?

The first step for this study should be to establish whether sufficient evidence exists to speak of a shared maritime culture along the *Norðvegr* in the Viking Age. Only if this is the case will it be possible to compare this with the experimental and experiential results from the recent trial voyages. Despite the large geographical area under consideration and the hindrances to travel posed by the harsh climate, the coastal communities of western Scandinavia seem to have been thoroughly interlinked since at least the Late Iron Age (Iversen, 2020, p. 295; Østmo, 2020, p. 10). By the time the merchant-explorer Ottar visited the court of King Alfred of Wessex in the late 9th century, the inhabitants of this region had a common name, *Norðmaðr*, reflecting a conception of geographical unity either in the mind of the scribe or in the account given by Ottar himself (Bately, 2007: 40–50; Storli, 2007: 85; Skre, 2014: 35). In either case, it seems likely that a "feeling of community" existed throughout this seascape, based on shared practices and movements (Storli, 2007: 85). Such connections would have been strengthened by a similar range of subsistence patterns, considerable genetic continuity since the Bronze Age, and the use of a common language (Ling et al., 2018: 509).

A shared maritime heritage is also evident in the creations of the Viking world, be they place-names, writings, or artefacts. Several scholars have pointed to the use of unique names for important landmarks both in Scandinavia and in the territories settled overseas, reflecting a common maritime cosmology throughout these areas (Stylegar and Grimm, 2003; Westerdahl, 2005; Kruse, 2020).

Fig. 2. Stad from onboard Båra, June 2022. The Åfjordsbåt used during this voyage was surprisingly comfortable in the large swell common around exposed headlands like this one, and throughout this project's fieldwork it proved safer to sail further out to sea rather than directly under the land, as this minimised the risks of katabatic gusts and strong currents.

Fig. 3. Such unpredictable winds recently resulted in the capsize of a fembøring off Kunna in Northern Norway. Photograph courtesy of HRS Nord-Norge (No. 330 Squadron RNoAF).

Norse creations such as the ship-prow engravings presented by Heen-Petersen in this volume, the common maritime motifs and *kennings* in the surviving poetic corpus (Jesch, 2015), and the mental geography of Icelandic medieval writers (Jackson, 2009), all point to a shared tradition of maritime practice, and intertwined with this, a common understanding of maritime space.

Seafaring worldviews then and now

The data-gathering exercises for this project consisted of a series of experimental sailing trials and trial voyages throughout the *Norðvegr*. These were undertaken onboard traditional clinker-built, square-rigged fishing and trading boats from Trøndelag known as *Åfjordsbåter* (Figure 4). The trials ran between September 2021 and July 2022 and ranged from one-day excursions to multi-week expeditions, covering the Norwegian coast from the Lofoten archipelago to Bergen (Figure 1). The aim of this fieldwork was to identify the primary factors that influenced navigational choice before and during sailing voyages onboard *Åfjordsbåter*, as an understanding of these would allow for the reconstruction of sailors' decision processes. If sufficient parallels between the practices of *Åfjordsbåt* sailing and those of the Viking Age could be established, then an understanding of these traditional decision processes might serve as a foundation for suggesting which routes and havens were most likely to have been frequented in the Viking Age. To fulfil the research objective, I gathered qualitative and quantitative data regarding how and why certain routes were chosen, focusing on environmental and technical factors (wind and sea conditions, visibility, boat performance) as well as cognitive and social ones (experience, morale, skill, judgement). Data-gathering followed the guidelines set out by Englert (2006) and Bischoff et al. (2014), with the assembled dataset consisting of field notes, photographs, and video footage, interviews, wind and weather readings, 3D models of the boats, and a GPS track of each voyage.

A fundamental finding from this fieldwork was the observed development both within myself and among the crew of a new way of thinking and doing at sea, tightly bound to the practices and environments of traditional Norwegian sailing. I would argue that this occurred through the gradual, collective attunement to a new way of perceiving, acting in, and thinking about the seascape, what Eldjárn and Godal refer to as a *veremåte* (1988a; 17) (Ingold, 2000: 166). This 'maritime cultural mind-scape', as I have called it elsewhere (Jarrett, 2025, forthcoming), seemed to be intimately tied to its context of use, with a strong inter-dependence between understandings of maritime space and the traditional practices of *Åfjordsbåt* sailing (Hutchins, 1995). The conception of travel, for example, was bound to the inherent uncertainty of sailing a boat without an engine, creating a conditional and tangential attitude to route-planning and navigation which anticipated changes of itinerary and destination at any moment. Mental attitudes and sailing practice were also evidently connected in the relationship between the boats' sailing capabilities and the risks posed by different areas of the Norwegian coast. *Åfjordsbåter* are built with light and flexible hulls with very shallow draft, allowing them to ride over the large swell typical along exposed coastlines, but making them very vulnerable to strong currents and katabatic winds (*fallvind*), which are most prevalent in narrow sounds and fjords (Figures 2 and 3). This points to a different assessment of danger and risk than that which might be made when travelling in a modern sailing boat.

The data gathered during this project revealed that the primary affordance of route choice before and during the voyages was a judgement of perceived risk, which was often made collectively, or at least in consultation with the most experienced crew members.

Fig. 4. A smaller Åfjordsbåt known as a *fyring*, in Rissa, Trøndelag, September 2021. The parallels with the surviving evidence for Viking Age boatbuilding are apparent in both the hull shape and the rig. Photo courtesy of Tora Heide.

When considering different routes, individuals conceived of possible itineraries as a sequence of named landmarks, with their own associated level of danger taken from previous experience or second-hand information. In this way, navigating the *Norðvegr* became a qualitative assessment of potential pathways, reliant on the collective wisdom necessary for success in the face of uncertainty. The clear relationship between this judgement-based navigation and the vessels upon which it occurs, and in turn, the similarities between these craft and the boats of the Viking Age, makes it very tempting to apply this 'mindscape' to studies of Viking Age seafarers and seafaring. However, such direct and uncritical application may be unwise; instead, I believe it will be more fruitful to take a comparative approach, considering both continuity and change in attitudes and approaches to the sea and sailing throughout the history of maritime travel along the *Norðvegr*.

The Maritime Cultural Mindscape and the evidence for Viking Age sea-faring

So far I have suggested that Viking Age communities throughout the *Norðvegr* shared an understanding of maritime space and mobility, and have briefly described some aspects of the traditional sailing perspective that emerged during the project's trials. In the following section, I examine the core elements of maritime heritage along the *Norðvegr*, comparing the data gathered during the project's voyages with our evidence from the Viking Age and Early Middle Ages. The aim here is to identify which aspects of traditional seafaring may represent continuities or at least enduring agents that would have also afforded mobility patterns in the Viking Age. These can then be used to reconstruct sailing routes and itineraries from this period.

The seascape

The sea is a constant, all-encompassing presence for those living along the west coast of Scandinavia. Since long before Ottar's time, the sailing route along this coast had provided access to the wealth of the Arctic and a connection southward into European networks, creating an axis of trade, travel, and interaction that remains in use today (Meulengracht Sørensen, 1995: 48–49; Storli, 2007). When compared to agricultural and industrial landscapes, the maritime environment displays less signs of recent transformation, and this apparent stability may have contributed to other cultural continuities along its length. The actual extent of environmental change is often hard to assess: marine temperatures and salinity levels seem to be similar today to those of the Early Middle Ages (Haine, 2012: 104–105), but notable changes in relative sea-level have occurred, primarily due to isostatic rebound (see Changes, below). In terms of prevailing wind and weather patterns throughout the year, the summer is dominated by successive low-pressure systems circulating up the coast, bringing south-westerly gales interspersed with brief periods of light and often unstable northerly and north-easterly winds (Binns, 1980: 193). Spring and autumn sailing involves rougher conditions, with frequent rain, sleet, and even snow, but also stabler winds due to more frequent high-pressure windows (Englert, 2007). In winter, the short daylight hours and frequent storms, along with the increased strength of katabatic gusts (due to the greater change in temperature between the sea and the snow-covered mountains) means that both the effort and danger involved in covering even shorter distances is greatly increased.

Wind and air pressure patterns from the Viking Age are difficult to reconstruct, but written sources such as The King's Mirror describe similar weather and seasonal windows as those experienced during this project's voyages (Larson, 1917: 87–90). The King's Mirror and the Vinland Sagas also present a remarkable understanding of currents and tides, as well as the movement of whales, fish, walrus, seals, and sea-ice (Larson, 1917: 90–102; Pálsson and Magnusson, 1965). This deep acquaintance with marine life and environmental patterns echoes the knowledge recorded among whalers and fishermen in the North Atlantic in the 19th century (Scoresby, 1820). The evidently long tradition of attendance to such rhythms was likely due to the equally enduring affordances and risks inherent when sailing in square-rigged, clinker-built boats.

The documentary sources also refer to the great danger of sailing near land, suggesting a possible preference for outlying havens in this period (Kruse, 2020, pp. 176–177; Marcus, 1980, pp. 104–105). This seems to align well with the location of the royal manors linked to Harald Fairhair in Hordaland, which display a marked preference for outlying coastal areas when compared to centres of mobility and trade from before and after the Viking Age (Skre, 2014, pp. 37–38). This preference may be tied to the aforementioned risks posed by narrow fjords and sounds when sailing in vessels of the kind used in the Viking Age. From this perspective, we may wish to imagine that the preferred location for a harbour or anchorage in the Viking Age was one that served as a safe haven between exposed and sheltered sections of the sailing route. These different kinds of seascapes posed different but equally serious challenges and may have often involved waiting for favourable conditions and the help of local pilots before proceeding with the voyage.

Boats

Norway possesses a rich and diverse heritage of traditional boatbuilding, with different regions displaying diverse but related responses to the needs of maritime life (Godal, 1986). This diversity is undoubtedly not a recent phenomenon, and it would be unwise to imagine a common *Urform* from which all recent boat-types descend (Frog, 2020, p. 571). Instead we should envision an equally wide variety of vessels existing in the Viking Age, but with certain physical features being shared across space and time (Eldjárn, 1995, p. 28). The boats used in this study are reconstructions of fishing and trading vessels from the late 19th century, but their basic structural elements already existed in the Viking Age (Figure 4). Boats from both periods were built from the keel up as a double-ended shell of overlapping planks, into which frames are inserted to provide strength and stability. The rig consists of a loose-footed square sail controlled by sheets, the *bolina* and the *priar*, and hung upon a yard which is attached to the single mast with a parrel. The mast rests upon a sturdy mastfish and can be lowered easily by loosening the shrouds or the forestay. Aside from the sail, the boat is equipped with several pairs of oars, allowing for travel against the wind and for manoeuvring in an out of harbours (Christensen, 2007; Eldjárn and Godal, 1988a, 1988b; Engvig, 2001a, 2001b).

Structural similarities are matched by remarkable continuity in performance and handling. Several scholars have identified common estimations of average rowing and sailing speed for various kinds of vessel from medieval written sources, along with a common understanding of average distances covered, just like the modern idea of "an hour's drive". These estimates are similar to the average speeds attained during the voyages conducted for this study: average rowing speeds oscillated around 2 knots, while average downwind or broad-reach sailing speeds were approximately 5 knots for the *fembøring* and 4 knots for the *fyring* (c.f. Englert, 2015, 2007; Indruszewski and Godal, 2006, p. 24; Morcken, 1978, p. 56; Sæther and Eldjárn, 2002). When these voyages lasted more than a day, a system of watches was established by dividing the crew into two halves: this too is documented in medieval sources as being a long-established custom (*sjømenns skikk*, Salvesen, 1969, p. 116), and Ravn (2016) has argued that such a system was in place onboard the *Skuldelev 2* longship in the 11th century.

The enduring nature of Norse seafaring practices is also evident in the survival of specific terminology across time and space. Many of the terms used onboard Åfjord boats have clear Old Norse roots (the classic example being *styrbord*, from ON *stjórnborði*), but even more remarkable is their survival up to this day in a wide range of European languages (Martese, 2019; Sayers, 1997). In some regions where Norse influence was particularly enduring, unchanging terminology was accompanied by equally long-lasting practices: the medieval Gaelic poem *Birlinn Chlann Raghnaill*, for example, describes similar practices onboard Highland galleys as those known from traditional Åfjord boat sailing, even mentioning the same slipknot for securing the mainsail halyard (Macaulay, 1996; Parsons, 2013, p. 31).

Places and mnemonic names

Evidence for continuity in naming traditions extends beyond the boats to include the land- and seascape as well. The ancient origin for names of prominent landmarks along the *Norðvegr* has recently been discussed by Østmo (2020). Westerdahl (2010a, 2010b, 2005) has also argued for strong toponymic continuities, and has identified a naming pattern for prominent maritime landmarks that seems to apply across Scandinavia. Placenames were used by sailors as mnemonic anchors through their incorporation into songs, poems and stories, which often presented places sequentially, providing a way to remember entire itineraries without the need for a map (Brink, 2019). This can be seen in poems collected by ethnographers in the last century (e.g. Morcken, 1978, p. 46), but such mnemonic techniques may also appear in medieval texts, such as the *Landnámabók* (Pálsson and Edwards, 1972): from the perspective of a mobile, seafaring society, the opening chapters of this book can be read as a series of stories designed to give meaning to land- and seamarks across Iceland.

Navigation

Although the importance of oral culture and unique placenames is a largely accepted part of Viking Age navigation, other elements of this tradition have been more divisive. The results of this project's voyages and the evidence for environmental and toponymic continuity point to a set of navigational methods that neither encouraged nor required the development of instruments. The primarily coastal nature of navigation along the *Norðvegr* seems instead to have promoted a tradition based on memorised sequences of landmarks, which was then exported into the North Atlantic, where islands served as similar directional aids (Schnall, 1975, p. 181). This can be seen, for example, in the famous description of the voyage from Norway to Greenland found in the *Landnámabók* (Pálsson and Edwards, 1972:16). The argument for non-instrumental navigation is reinforced by other experimental voyages in Scandinavia and the North Atlantic, which have proven that time can be estimated while at sea to within 15 minutes (Börjesson, 2009). This allows for accurate estimations of midday, allowing sailors to follow a particular line of latitude by measuring the height of the sun above the horizon at this time. In areas that lack the monumental landforms of the Norwegian coast, an equally rich toponymic tradition seems to have existed, but in this case related to underwater features such as sandbanks, as evidenced by Roger of Howden's 12th century description of the sailing route along the east coast of England (Hughes, 2012; Kemp and D'Olier, 2016). The strong magnetic variation noted in high Atlantic latitudes by William Scoresby in the early 19th century (1820) may have contributed to maintaining this non-instrumental tradition into recent times.

Risk-based judgements

We can now turn to the factor that was identified as the primary determinant of route choice during this project's sailing trials, namely the judgement of perceived risk. Although Ottar's account (Bately and Englert, 2007: 40–58) does not refer to this kind of judgement directly, several second-hand sources do highlight wise judgement and reasoned choice as important traits of skilled navigators. In the entry for the year 862, the *Annals of St Bertin* tell of the Danish fleet that had been raiding along the Seine, which upon reaching the sea, "split up into several flotillas which sailed off in different directions according to their various choices" (Nelson, 1991, p. 98). The variety of directions chosen indicates that route-choice was not environmentally determined and included an element of human choice. The word for choice used here is *visum*, which may indicate the importance of perceived phenomena in making these decisions. The narrator of *The King's Mirror* also emphasises the importance of attendance by advising his son to "mark the movements of the ocean and to discern how its turmoil ebbs and swells". In this way he will "learn thoroughly when to look for dangerous seasons and bad routes, or when times come when one may risk everything" (Larson, 1917: 83, 90).

But perhaps the most direct evidence of risk judgement in a Norwegian seafaring context comes from the anonymous *Historia de profectione Danorum in Hierosolymam*, an account of a Danish expedition in the late 12th century to take part in the Third Crusade. The author compares the ill-fated Danish crusaders, who shipwrecked off the coast of Norway after departing impatiently under unfavorable weather conditions, with their more successful Norwegian contemporaries, "whose ability to rightly judge the route and the sea was reliable thanks to their long experience and frequent sailing" (Gertz, 1922: 480, translation by Stephan Borgehammar, personal communication 2022). First-hand, practical experience seems, therefore, to have been a central and long-lasting requirement for accurately judging and managing risk throughout this challenging seascape (Figure 5).

Fig. 5. Collective judgement of perceived risk in action. The author and crew on Trondheimsleia, June 2022.

Changes

This range of remarkable continuities should not blind us to some major changes that affected seafaring both during and after the Viking Age. Following the same themes as above, we can begin with environmental change: here the most notable transformation along the *Norðvegr* is the result of post-glacial land upheaval, resulting in a coastline that is currently 3-5m below the level known from 1000 AD (Creel et al., 2022; Påsse and Daniels, 2015). The greatest changes have occurred in the inner fjords, but even along the outer coast some of the shallower channels and sounds used in the Viking Age could not be explored during this project's trials. I intend to follow up this preliminary study with a reconstruction of relative sea-levels from the Viking Age to further evaluate possible routes and havens.

Travelling along the *Norðvegr* a thousand years ago involved a range of risks, both real and imagined, that were not present during the recent trials. This region was a thoroughly militarised zone in the Viking Age, with the sea-kings and the haphazardly-emerging kingdom exercising their power through naval dominance (Iversen, 2020, p. 290; Østmo, 2020, p. 17; Skre, 2014, p. 39). Certain harbours would have been unsafe or at least unwelcoming for shipping from opposed regions, and hostile ships or fleets must have been an additional, unpredictable threat at all times (Heebøll-Holm, 2020). Other entities that today would be considered mythological were clearly also present in Viking Age mental geographies, although it is difficult to assess the extent to which experienced sailors like Ottar believed these to be tangible elements of reality (Frog, 2020, p. 680; Meulengracht Sørensen, 1995, p. 53). Despite the cosmological changes introduced by Christianity, some of these entities survived into recorded tradition, such as the figure of the *draug* (Mathisen and Sæther, 2018). However, we should not presume to understand the complex entanglement of mythological forces in the everyday practices of Viking Age sailors, but we can at least recognise the role of different cosmologies in shaping conceptions of seascape then and now.

As for the boats and their sailing, the striking continuities outlined above must be weighed against several technological developments that occurred in Norwegian boatbuilding between the Viking Age and the late 19th century. Of these, the shift in the position of the rudder is perhaps the most discussed (Nielsen, 2009: 265; Thorseth, 1986: 82), with modern authors concluding that this marks a notable improvement in performance (although it is interesting to note that Andersen, whose transatlantic voyage aboard *Viking* in 1895 employed professional sailors, considered the difference in steering capabilities between a side-rudder and a stern-rudder to be minimal (Christensen, 1986)). Other changes that have been less discussed and are harder to quantify include the differences in stem-carving (Heide and Planke, 2019), the varying levels of hull flexibility when using rivets versus cleats and lashings (Morrison, 1978), and the use of hemp line and linen sailcloth rather than the lime-bast, walrus hide, and wool which seem to have been staple materials for Viking Age rigging (Christensen, 1979). In terms of practices onboard, the most anachronistic and transformative element of this project's trials was the use of the weather forecast. The constant availability of accurate meteorological information provided a level of certainty and security when making navigational decisions that cannot have been present in the minds of Viking Age sailors. This was considered to be a necessary anachronism, as ignoring the forecast would have represented an unacceptable risk to the vessel and the crew. The largely educational or scientific purpose of these trials and the modern and literate cultural background of the crew also contrasted with the experiences of Viking Age sailors (Meulengracht Sørensen, 1995).

Applying the Maritime Cultural Mindscape to the Viking Age: risks and potentials

The comparison above is intended to pinpoint which elements of the seafaring 'mindscape' revealed in the recent trials may have had parallels in the maritime worldview shared throughout the *Norðvegr* in the Viking Age. It is this worldview that promoted and constrained culturally-specific patterns of movement, and therefore understanding it is a vital foundation for discussions about Viking Age routes and itineraries (Bekker-Nielsen, 1988: 160). In our attempt to reconstruct this Viking Age worldview and its afforded movement patterns, we may be aided by the inherently conservative nature of fishing and sailing culture. As

Westerdahl (2005: 40) argues, maritime traditions are more resistant to change than land-based ones due to the comparatively stable environment upon which they rely. It is therefore more likely for ancient cosmologies and worldviews to survive in maritime environments than in the more volatile contexts of elite, urban, or industrial culture. The communities inhabiting the *Norðvegr* experienced several major changes during the lifespan of traditional sailing and boatbuilding discussed here (ca 800-1920 CE), with some of these beginning during the Viking Age itself, such as Christianisation and the development of the stockfish trade (Solli, 1996: 90; Bagge, 2005; Storli, 2007; Perdikaris and McGovern, 2009; Wickler and Narmo, 2014). But as has been recently discussed by Frog (2020), practical and cognitive elements of Viking Age culture may have survived if they remained applicable in their context of use, with their constant application enshrining them in trans-generational knowledge despite broader changes in society and culture occurring around them. Cases of this phenomenon, which may be useful for reconstructing Viking Age maritime movement patterns occur in the evidence presented above. These can be collected into three categories:

1. The tradition of building and sailing clinker-built, square-rigged boats, and the consequent similarities in relative risk and opportunity in different kinds of seascape;
2. The surviving corpus of placenames for important land- and seamarks, and their sequential and storied incorporation into oral culture;
3. The navocentric orientation and navigation system, the conditional and tangential conception of sea voyages, and the process of route-choice based on judgements of perceived risk.

With the addition of a seemingly similar natural environment (although with a changed coastal topography), these represent the primary parallels that exist between the affordances of traditional Norwegian sailing and those of Viking Age seafaring. At this very preliminary stage, I have employed these parallels to identify a number of anchorages and natural harbours along the Norwegian coast that may have been attractive for seafarers from the Viking Age, but that have received little attention from Viking Age research. I have presented these in Figure 1, along with several known sites that display evidence for maritime activity during the Viking Age or shortly thereafter, selected for comparison. These possible havens were all visited during the project's voyages but require further analysis in relation to documentary and cartographic sources, as well as an accurate reconstruction of their physical topography during the Viking Age (Figure 6). For now, the location of these havens seems to fit well with other studies of interaction from the Viking Age, such as Sindbæk's (2013) network analysis approach, as well as displaying parallels in other seascapes of the Viking world, such as the west coast of Scotland (Macniven, 2020).

Finally, it may be worth considering how the maritime worldview of Viking Age seafarers clashed with contemporary land-based ontologies, embedded as they were in such profoundly different worlds of practice, belief, and experience. Alcuin's shock at the Lindisfarne raid, and his belief up until this event that no "such inroad from the sea [*navigium*] could be made" (Whitelock, 1955: 776), may be more than dramatic hyperbole, pointing instead to the way in which different worldviews present different possible courses of action. Adam of Bremen's confusion in recording the sailing times from Ålborg to Iceland (2002: 217) may also derive from a misalignment between different understanddings of space and travel (Morcken, 1978: 12). Such ontological clashes are evident today in the conflicting understandings of space and place that underlie struggles for indigenous land in many areas of the globe (Chao, 2017; Hirt, 2012; Pearce and Louis, 2008). It may therefore be fruitful to explore patterns of movement and action in the Viking Age as being afforded by equally diverse worldviews, shaping the record that we study today by constructing a range of understandings of possible choice and action. To do this we will need to look beyond the conventional techniques of representation and mapping that prevail in western science, and explore other ways of recording, analysing, and communicating Viking Age seafaring as a thoroughly dynamic, attentive, uncertain, storied, and peopled experience.

Fig. 6. Tarva, one of the potential havens suggested by this study. It is located at the entrance to the Trondheimsleia from the North, and offers sheltered mooring and access to fresh water, making it a possible destination for Viking Age seafarers. May 2022.

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Supplementary Data

The complete dataset from the sailing trials and trial voyages conducted for this study will be included in the author's doctoral thesis, which will be published in 2025.

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Article 3

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RESEARCH

From the Masthead to the Map: an Experimental and Digital Approach to Viking Age Seafaring Itineraries

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Abstract

The Viking Age (c. 800–c. 1050 AD) was characterised by a widespread rise in maritime mobility and interaction, as is made clear by an increasing range of evidence. However, this evidence provides limited information about the sailors and the sailing voyages that connected and transformed the Viking world. This paper presents an approach to reconstruct Viking Age maritime itineraries through the combined use of experimental and digital methods. This approach is grounded in a series of experimental voyages conducted by the author along the Norwegian coast onboard square-rigged, clinker boats built in the descendant Åfjord tradition. The experimental voyages are used to reconstruct the preferences and requirements of Viking Age sailors, helping to define practice-based criteria for evaluating which natural harbours and anchorages might have been favoured during this period. These criteria are complemented by digital reconstructions of historical topographies accounting for changes in relative sea-level since 800 AD. From this combined evaluation, a selection of four possible Viking Age havens is presented. The characteristics and locations of these havens are discussed in relation to contemporary power centres and later seafaring routes. The results suggest that Viking Age seafaring networks along the Norwegian coast may have been more decentralised than their medieval counterparts, and may have relied on relatively outlying nodes on small islands and headlands. The approach highlights the potential of critically combining experimental and digital methods and aims to promote maritime perspectives as an alternative to conventionally terrestrial academic approaches.

Keywords Experimental · Seafaring · Scandinavia · Viking Age · Mobility · Maritime

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Introduction

Ships, boats, and the people who sailed them were central to the period and geographical area known as the Viking world. The seas and oceans of this world were not uncrossable obstacles but arteries of opportunity, connecting people, places, goods, and ideas across the waves (Bill, 2010; Storli, 2007; Westerdahl, 2014). In this article, I present four possible nodes in the maritime networks of Viking Age Scandinavia, whose use during this period is suggested based on experimental sailing trials, topographical reconstructions, and the critical application of historical analogy.

The Viking Age (c. 800–c. 1050 AD) saw a marked increase in the amount, regularity, and geographical range of maritime mobility and interaction (Crumlin-Pedersen, 1991; Østmo, 2020; Ringstad, 1992). The widespread and skilled use of sea-going vessels was a key factor behind many of the major transformations of this period, such as the establishment of kingdoms, the proliferation of seaborne raids, the exploration of the North Atlantic, and the increase and diversification of trade (Bill, 2010; Iversen, 2020; Skre, 2014). However, our evidence for Viking Age seafaring is largely limited to geographical points of origin and destination. A wide range of studies have illustrated the vast distances frequently covered by people, animals, and things during this period (recent examples include Baug et al., 2019; Maixner, 2021; Margaryan et al., 2020; Star et al., 2018), but they have rarely focused on the voyages and voyagers that bound these points to each other. Attempts to reconstruct Viking Age maritime networks are also hindered by the sheer number of possible routes through the seascapes of this world; each of these routes may have been more or less attractive in the past than they are today due to changes in coastal geography and developments in shipbuilding during and after the Viking Age.

Furthermore, ancient seafaring skills and knowledge were primarily transmitted orally and practically (Kemp & D'Olier, 2016, p. 696; Sanmark & McLeod, 2024, p. 16). Scholarly approaches have often struggled to effectively record, analyse, and communicate this kind of enacted wisdom and have instead relied on terrestrial and textual proxies for ancient seafaring networks. In Scandinavian archaeology, the two most commonly employed proxies are high-status coastal sites, such as manors and burial mounds (*e.g.* Iversen, 2008, Fig. 4; Maixner, 2021, Fig. 9.9; Skre, 2018b, Fig. 29.4), and modern pilot books, such as *Den Norske Los* (2018; *e.g.* Engedal, 2010, p. 470; Kvalø, 2007; Østmo, 2020, Fig. 1.3). These are both valuable sources of evidence but come with their own difficulties. High-status coastal sites were established near major sailing routes but do not appear consistently along the coasts of the Viking world, with several major lacunae hindering the reconstruction of maritime itineraries through these areas (Iversen, 2020; Skre, 2018b). Modern pilot books are comprehensive and useful documents for maritime archaeology, but they are written with the needs, capabilities, and characteristics of modern vessels and sailors in mind, and thus have only limited diachronic value for studying Viking Age seafaring.

As a possible alternative to these approaches, Viking Age sailing itineraries are reconstructed here on the basis of experimental voyages conducted onboard Nordic clinker boats (Fig. 3). The study focuses on a core area of Viking Age seafaring: the west coast of the Scandinavian Peninsula, known in Old Norse as the *Norðvegr* (Fig. 1). The theoretical and methodological framework for this investigation follows

Fig. 1 The Norðvegr, with the coastal regions mentioned in the text, the tracks of the project's two trial voyages (black and white dashed lines), and the traditional sailing corridor along the west coast of Norway (blue shaded zone), known in Old Norse as *leið*

arguments put forward by Westerdahl (1989, 1992) and, more recently, Ilves (2004, 2012), that ancient seascapes should be explored from the sea rather than from land, and that practical seafaring knowledge should be employed in the search for ancient landing sites and harbours. The experimental sailing trials and trial voyages conducted for this investigation provide precisely this kind of maritime, practical perspective on ancient seafaring and reinforce the suggestion made by Kruse (2020) that long-range Viking Age voyages involved multiple legs between known harbours and anchorages. Retracing these voyages must therefore begin with identifying the safe havens frequented by Viking Age sailors along the way. This is attempted here by developing a set of criteria for evaluating possible centres of Viking Age maritime activity. These criteria are grounded in the results and experiences of the experimental trials, archaeological and documentary evidence of Viking Age maritime centres, and digital reconstructions of past sea levels. It should be noted that the experimental voyages were designed to emulate the long-range expeditions undertaken by traders, explorers, and settlers, rather than raiders and navies. Therefore, the evaluation presented here reflects the preferences and requirements of sailors whose main objectives did not depend on organized violence.

This evaluation led to the identification of four possible Viking Age havens, filling in some of the gaps in probable Viking Age itineraries throughout the *Norðvegr*. Their locations and characteristics support previous suggestions regarding the importance of seemingly remote coastal areas in Viking Age maritime networks (Kruse, 2020; Skre, 2014; Wickler, 2016), while also suggesting that these networks may have been more decentralised than previously thought. Major changes in mobility patterns seem to have occurred in the Late Viking Age and Early Middle Ages, which are discussed here in relation to processes of political centralisation, commercial development, and topographical changes resulting from isostatic rebound. On a broader scale, this study's emphasis on practical seafaring knowledge and experience seeks to counter the common academic bias towards terrestrial and textual sources and worldviews. Potential applications of this methodology for studying seafaring communities beyond Viking Age Scandinavia are discussed at the end of this article.

Change and Continuity Throughout the Norðvegr

The west coast of the Scandinavian Peninsula has provided relatively safe passage from continental Europe into the Arctic since the Mesolithic, connecting people throughout a long coastline scattered with c. 150,000 islands (Østmo, 2020). Despite the central role of seafaring in human lives throughout the *Norðvegr*, direct evidence for seafaring itineraries before the Middle Ages is severely limited. The only surviving first-hand account from the Viking Age describing this sailing route was given by the merchant-explorer Ohthere (ON Ottar) to King Alfred of Wessex in the late ninth century and is frustratingly vague about his itinerary along the Norwegian coast (Bately, 2007). Archaeological clues are also scarce: unlike other areas of the Viking world, no *emporia* have been securely identified here which can serve as indicators of likely stopping places on merchant itineraries (Kruse, 2020, p. 171). In addition, we still lack a comprehensive understanding of Viking Age sails and rigging (Bischoff, 2017; Christensen, 1979), and the question of navigation and navigational instruments continues to divide the scholarly community (Filipowiak, 2020; for a thorough review of the various stances, see Indruszewski & Godal, 2006). But as has been suggested before, later elements of Norwegian maritime heritage may serve as analogies for Viking Age seafaring practices (Godal, 1986; Parsons, 2013). Such analogies are defensible due to the strong degree of continuity identified in maritime activities along the west coast of Norway between the ninth and early twentieth centuries (Jarrett, 2025a; Kruse, 2020, p. 173; Storli, 2007, p. 79). Nowhere is this more apparent than in the unbroken tradition of building and sailing square-rigged clinker boats, descendants of the vessels built in the Viking Age. Boats of this kind were used for fishing, trade, and transport in several coastal regions of Norway until the early twentieth century (Eldjárn & Godal, 1988a). For this study, experimental sailing trials and trial voyages were conducted onboard square-rigged clinker boats built in the Åfjord tradition from Trøndelag (Figs. 2 and 3, see 'Methods'). Åfjord boats serve as excellent practical guides for experimental research into Viking Age sailing. This is partly due to the similarities in their structural properties and handling relative to Viking Age vessels, but also thanks to the corpus of practical knowledge and technical data about these vessels collected by boatbuilders and researchers over the last century (Eldjárn & Godal, 1988a, 1988b, 1990a, 1990b; Færøyvik & Færøyvik, 1979; Indruszewski et al., 2009).

Reconstructing Viking Age seafaring routes throughout the *Norðvegr* is challenging not only because of the scarcity of evidence and geographical scale of the seascape under study but also due to the variations in relative sea-level (RSL) that have occurred since the collapse of the Eurasian ice sheet complex c. 9,700 years ago. Recent studies compiling RSL data (Balascio et al., 2024; R. C. Creel et al., 2022; Romundset & Lakeman, 2019) have shown that isostatic rebound rates vary across the study region, but have generally resulted in a lower RSL today than in the Viking Age, sometimes by as much as 6 m (Fig. 5). In this study, experimental and experiential data is complemented by reconstructions of historical RSLs at five century marks between the ninth and thirteenth century. These are used to examine potential routes and anchorages throughout the *Norðvegr* as they may have appeared to Viking Age and medieval sailors, and to illustrate the changes in coastal geography during this time span.

Havens: Definition and Characteristics

The natural harbours and anchorages that form the central focus of this study are referred to here as havens; these were sheltered stopping points on or near the long-established maritime corridor along the west coast of Norway known in Old Norse as *leið* (modern Norwegian 'leia'; Kruse, 2020, p. 170). They were frequented by sailors travelling towards different destinations, and were maintained over time by the people and paths of movement that came together there and that, in turn, bound them to other places throughout the known world. Sailing vessels may have called at these havens for a range of reasons: to wait out spells of bad weather in relative safety; to rest and perform repairs; to take on water and supplies; to meet other sailors and gather information about upcoming passages; or in some cases, because of the known presence or absence of local magnates or authorities, who might need to be evaded or acknowledged depending on the crew's allegiances and pursuits (Baug et al., 2019;

Fig. 2 Some of the seascapes explored during this study. The number of each photograph corresponds to a location indicated in Fig. 1. 1, Vestvågøya, Lofoten; 2, Nordskot, Steigen; 3, night-sailing in the Stigford, Helgeland; 4, Leka; 5, Tarva; 6, Trondheimsleia; 7, Stemshesten from Hustadvika; 8, Godøya; 9, Bremangerlandet; 10, Lygra

Fig. 3 Continuities in boatbuilding traditions from the Viking Age are evident in the shape and rig of this *fyring*, a smaller type of Åfjord boat similar to the vessels associated with non-elite Viking Age farmsteads. Image courtesy of Tora Heide

McGrail, 1997, pp. 265–288; Ravn, 2016; Sanmark & McLeod, 2024; Skre, 2018b, p. 794). Despite their temporary and seasonal use, havens are likely to produce a range of archaeological evidence related to their diverse functions. In the Baltic, Ilves (2012) has successfully demonstrated that although clinker boats *can* be drawn up onshore, ancient sailors preferred to avoid this time-consuming and tide-dependent process by building jetties and quays. The havens presented here should, therefore, contain diagnostic features identifiable through archaeological survey and excavation.

Unlike the wide range of reasons to call at these places, the characteristics that made a potential haven worthy of frequent use (and thus worthy of investigation) were likely to have been relatively specific, as they were based on the common capabilities and requirements of the boats and ships used in the Viking Age, and the shared needs of the people who sailed them (Kruse, 2020). To identify these affordances, and thus reconstruct the criteria with which havens were chosen by Viking Age sailors, this project began with a series of experimental sailing trials and trial voyages throughout the study region. These trials, along with the subsequent process of evaluating potential Viking Age havens from the perspective of those who used them, are outlined in the following section.

Experimental and Digital Approaches to Viking Age Seafaring

The process of locating potential Viking Age havens consisted of three stages: in the first stage, a series of sailing trials and trial voyages were conducted throughout the study area, providing data and first-hand experience from seaborne travel throughout the

Norðvegr. In the second stage, relative sea levels (RSLs) were digitally reconstructed to explore potential routes and haven sites with historically accurate topographies. In the third and final stage, data from the experimental trials, the RSL reconstructions, and surviving documentary and archaeological evidence were brought together to create a set of criteria with which to evaluate potential haven sites. This section describes the methods followed in Stages 1 and 2. The criteria from Stage 3 are developed in part out of the findings from the trials and are therefore presented in the 'Results' section.

Stage 1: Trials

The first stage of this methodology draws on the long history of experimental archaeology onboard historical boats and ships (Binns, 1980; Blue et al., 2006; Carter, 2001; Crumlin-Pedersen & Vinner, 1986; Anton Englert & Ossowski, 2009; Indruszewski et al., 2009), as well as the documentation of traditional Norwegian boatbuilding and sailing practices conducted in the last century (Eldjárn & Godal, 1988a, 1988b, 1990a, 1990b; Færøyvik & Færøyvik, 1979; Indruszewski & Godal, 2006; Slyngstad, 1951; Uksnøy, 1959). Central to this part of the investigation is the theoretical premise that an understanding of what courses of action could have been perceived as possible by members of a past community (in this case, the seafarers of the Viking Age) depends on the establishment of an experiential nexus between modern researcher and ancient subject. This nexus, in turn, depends on the researcher's long-term, practical engagement in the everyday activities, movements, and environments familiar to this individual or group (Ingold, 2000, pp. 166–167).

The opportunities for possible action perceived by an individual or community are often referred to as affordances (Chemero, 2003; Gillings, 2012). In line with the theoretical premise that past affordances can be reconstructed through the establishment of an experiential nexus, Stage 1 of this investigation was designed around the following objective: to reconstruct the affordances of Viking Age seafaring through first-hand seafaring experience onboard boats built in the Åfjord tradition. Specifically, Stage 1 aimed to identify the primary factors that influenced Viking Age sailing itineraries through a series of experimental sailing trials and trial voyages onboard Åfjord boats. The aforementioned continuities between the Viking Age and Åfjord seafaring and boatbuilding traditions made this diachronic analogy defensible. Thus, the factors affording navigational choices during the trials were taken as partial reflections of the decision processes of Viking Age sailors. These factors are employed here to develop criteria for evaluating possible Viking Age havens. Differences in the experience of seaborne travel today and in the Viking Age are discussed below and in the 'Discussion'.

Between September 2021 and July 2022, I participated in 15 sailing trials and 2 trial voyages along the Norwegian coast. The trials were conducted onboard seven different boats: 2 *fembøringer* (LOA: 13 m), 2 *to-lestringer* (LOA: 10 m), and 2 *fyringer* (LOA: 9 m), all built in the Åfjord tradition; as well as a *geitbåt* (LOA: 6.7 m), a traditional clinker boat from Nordmøre with an asymmetric quadrilateral sail, which was included for comparative purposes. The trials provided the student and volunteer crews with ample training in a range of conditions and answered specific questions about the performance and physical characteristics of the boats, such as their capacity to make progress to windward. Two trial voyages of approximately three weeks each were conducted between April and June 2022: a return voyage from Rissa, Trøndelag, to Henningsvær in the Lofoten archipelago, onboard a *fembøring*; and a one-way voyage from Rissa to Bergen onboard a *fyring* (Fig. 1; Table 1). A total of 1494 nautical miles were covered during this investigation.[1, 2]

Data gathering at sea followed the methods employed at the Roskilde Viking Ship Museum, as outlined in Englert (2006). The primary form of documentation during the voyages was the sailing log, in which variables relating to current conditions and navigational choices were recorded at regular intervals; these are listed in Table 2. Photographs and video footage helped capture important land- and seamarks, manoeuvres, weather and sea conditions, as well as life onboard (Figs. 2 and 4). Wind variables were measured and logged using a solar-powered, wireless OpenWind™ device attached to the masthead. The track of the voyage was recorded using a handheld Garmin GPSMAP® 66 s device, which was permanently attached at the stern to reduce signal blockage from the sail, and not used for navigational purposes. Finally, interviews with crew members and other informants provided diverse experiential perspectives, local oral histories, and practical advice. During the trials, special attention was paid to the anchorages and natural harbours that were visited, noting their various approaches from the sea, the level of shelter provided, and the possible routes in and out of them under various wind and sea conditions. This evidence was used in combination with an analysis of known Viking Age maritime sites and digitally reconstructed RSLs to identify new Viking Age havens for the subsequent evaluation (see below).

These methods proved suitable for the activities and environment under study but involved several challenges that affected the extent and types of data that could be collected. Firstly, data gathering occurred simultaneously with active participation in the handling of the boat, which meant that some events could not be recorded in real time. As result, the sailing log contains fewer observations and less detail from off-duty watches due to the need to sleep, and from periods of continuous manoeuvres when all hands were required. Second, experimental voyages conducted today are unavoidably confronted with modern seamarks, lights, vessels, and the laws dictating marine traffic. Ignoring any of these in unfamiliar waters in the pursuit of historical authenticity cannot be justified. As a result, the routes followed during the trials were inevitably influenced by elements of the modern seascape. However, this influence was reduced by the shallow draft and absence of an engine on most of the boats used, and thanks to the deep local knowledge of several members of the crew. These factors opened up routes and stopping points which would otherwise

[1] Two of the seven boats were equipped with engines, but neither of these were used for the trial voyages. During the sailing trials, the engines were used on two occasions, and there were four instances of towing: in total this amounted to c.15 h, or 3.1%, of the 476 h spent in motion.

[2] Data from these trials is presented in this text where relevant. The project's complete dataset (sailing log, photographic and video footage, 3D models of the boats used, and maps of each of the trials) has been uploaded to Zenodo (DOI: https://doi.org/10.5281/zenodo.15129285). This dataset will be kept under embargo until the author's doctoral defence, which is scheduled for autumn 2025. After the embargo is lifted the dataset will be available Open Access under the Creative Commons Attribution 4.0 International license.

Table 1 Summaries of the project's trial voyages. The first part of the table summarises the return voyage from Rissa (Trøndelag) to Lofoten onboard the *fembøring* 'Skårungen'; the second part summarises the voyage from Rissa to Bergen onboard the *fyring* 'Båra'

	Start date	End date	Route	Leg duration (hh:mm)	Distance (nm)	Daily avg (nm)	Avg speed (kts)	Wind direction and speed (Beaufort)
Rissa–Lofoten–Rissa	29 April 2022	01 May 2022	Rissa–Sandnessjøen	48:47	214.54	105.55	4.40	W 3–7
	03 May 2022	05 May 2022	Sandnessjøen–Bodø	42:47	119.83	67.22	2.80	W 2–4, shifting 0–2, E 4–5
	08 May 2022	08 May 2022	Bodø–Norskot	09:57	35.31	85.18	3.55	W 3–4
	10 May 2022	10 May 2022	Nordskot–Henningsvær	05:26	26.90	118.84	4.95	SE 5
	12 May 2022	13 May 2022	Henningsvær–Ballstad	22:44	60.81	64.19	2.67	SW-S 1–6
	15 May 2022	17 May 2022	Ballstad–Tarva	58:26	311.43	127.91	5.33	NE 2–5
	18 May 2022	18 May 2022	Tarva–Rissa	10:40	25.87	58.20	2.43	W 1–4
Voyage total distance					**794.70**			
Voyage averages						**89.59**	**3.73**	
Rissa–Bergen	08 June 2022	08 June 2022	Rissa–Utsetøya	11:00	31.83	69.45	2.89	NE 3–6
	09 June 2022	09 June 2022	Utsetøya–Langøya	12:13	59.75	117.39	4.89	E 3–5
	10 June 2022	10 June 2022	Langøya–Bjørnsund	6:00	23.00	92.01	3.83	N 1–3
	11 June 2022	11 June 2022	Bjørnsund–Sandøya	06:19	11.72	44.49	1.85	shifting 0–2
	14 June 2022	14 June 2022	Sandøya–Midøya	8:05	27.28	80.99	3.37	SW 3–5
	15 June 2022	15 June 2022	Midøya–Lepsøyrevet	10:23	12.41	28.69	1.20	shifting 0–2
	16 June 2022	16 June 2022	Lepsøyrevet–Ålesund	6:25	15.73	58.82	2.45	W 2–4
	19 June 2022	20 June 2022	Ålesund–Vågsøy	12:16	53.61	104.89	4.37	E 3, NE 5
	21 June 2022	21 June 2022	Vågsøy–Smørhamn	05:26	21.68	95.75	3.99	N 4–5
	24 June 2022	24 June 2022	Smørhamn–Svanøya	7:55	19.85	60.19	2.51	N 1–3
	25 June 2022	25 June 2022	Svanøya–Svanøya	8:19	15.08	43.51	1.81	W 3–5
	27 June 2022	27 June 2022	Svanøya–Askvoll	08:57	14.29	38.32	1.60	calm
	28 June 2022	28 June 2022	Askvoll–Sakrisøyna	06:40	10.65	38.33	1.60	calm, SW 3–5

Table 1 (continued)

	Start date	End date	Route	Leg duration (hh:mm)	Distance (nm)	Daily avg (nm)	Avg speed (kts)	Wind direction and speed (Beaufort)
	29 June 2022	30 June 2022	Sakrisøyna–Gråvika	13:31	24.37	43.27	1.80	NW 1–3
	30 June 2022	01 July 2022	Gråvika–Salhus	12:41	25.39	48.05	2.00	W 0–2
	01 July 2022	01 July 2022	Salhus–Bergen	03:08	7.45	57.09	2.38	N 2–3
Voyage total distance					**374.09**			
Voyage averages						**63.83**	**2.66**	

Table 2 Variables recorded in the project's sailing log. This represents a minimum standard and was often complemented with additional information or filled in at more frequent intervals. The log was designed to account for the variables that could afford navigational choices before or during the trial voyages and should be applicable to experimental sailing voyages in other contexts

Pre-departure information	4-hour log
1. Voyage number	1. Voyage number
2. Start and end dates	2. Date and time
3. Boat	3. Position
4. Context	4. Wind direction and speed
5. Goals	5. Sea state and current
6. Possible route	6. Weather
7. Wind forecast	7. Temperature
8. Weather forecast	8. Visibility
9. Wave forecast	9. Propulsion and setup
10. Crew	10. Speed
11. *Høvedsmann* (skipper) and *halskarr* (~ first mate)	11. Heading
12. Watch system	12. Crew roles
13. Crew experience levels	13. Changes in plan
14. Ballast and baggage	14. Mental and physical state
15. Other information	15. Other information

Fig. 4 The *fembøring* 'Skårungen' during the trial voyage towards Lofoten in May 2022. The voyage aimed to explore the northernmost part of the route taken by the merchant-explorer Ottar/Ohthere in the late ninth century AD. The voyage was characterised by adverse weather conditions but generally favourable winds

have been missed or avoided. Finally, to mitigate unreasonable risks, decisions as to where and when to sail were taken in consultation with modern weather forecasts. This aspect of route choice was perhaps the most distinct from Viking Age decision processes; unlike the relatively well-preserved practical traditions relating to Nordic clinker boats, much of the abstract knowledge about weather patterns was lost during the transition to motorised vessels in the first decades of the twentieth century

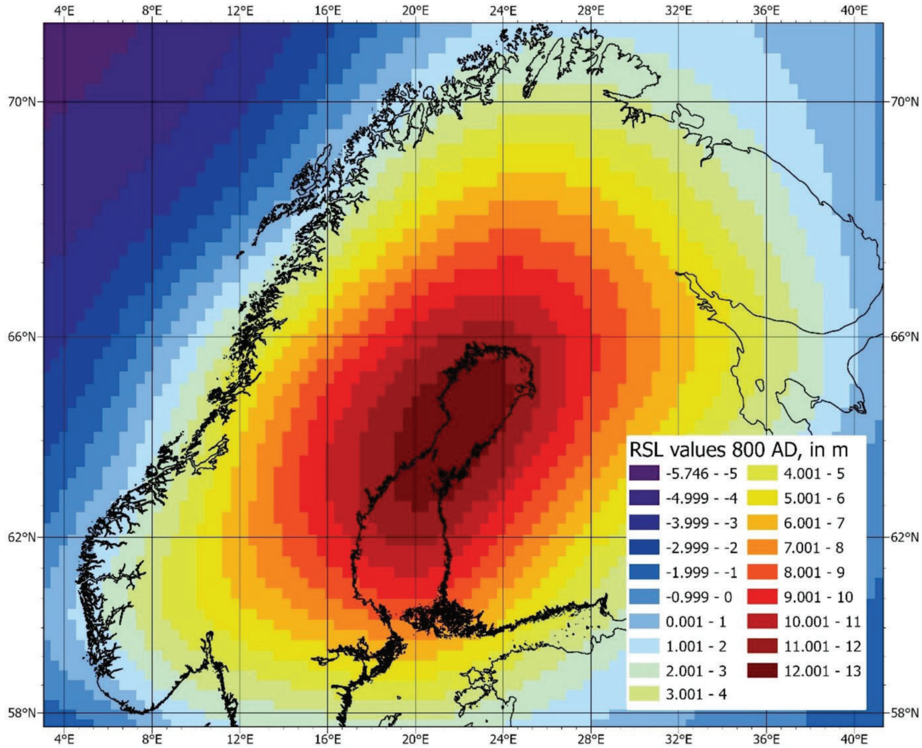


Fig. 5 Relative sea-level change in Scandinavia since 800 AD, based on the open-source dataset created by Creel (2022). Note that changes in RSL since the Viking Age are not consistent throughout the study region; developing topographical reconstructions that can account for spatial heterogeneity is therefore an important step in identifying potential Viking Age havens

(Eldjárn & Godal, 1988a, p. 83). The use of weather forecasts is therefore an unfortunate but necessary anachronism for experimental voyages across Scandinavia and the North Atlantic (*e.g.*Englert & Ossowski, 2009, p. 259).

Stage 2: RSL Reconstructions

To more accurately evaluate potential routes and havens, experiential insights and data from the trials were combined with digital reconstructions of the *Norðvegr*'s coastal topography from the Viking Age. As mentioned above, research into RSL change along this seascape has highlighted the spatial heterogeneity of isostatic rebound rates (Fig. 5). Previous reconstructions of ancient coastal topographies in this region have generally been restricted to specific sites or local landscapes due to the difficulty of modelling these changes at larger scales (*e.g.* Barnett et al., 2015; Romundset & Lakeman, 2019). Such difficulties were overcome recently by Creel et al. (2022), who created the first quality-controlled database of RSL changes covering the entire Norwegian coast. This database was instrumental for the present study, as it allowed for the Viking Age topography of the *Norðvegr* to be reconstructed in its entirety, and thus for historically accurate routes to be examined along with the havens themselves.

Establishing the RSLs of the Norwegian coast throughout the Viking Age involved three datasets: modern elevation data, modern tidal range data, and RSL data spanning the study period and region. Elevation data was acquired in the form of two Digital Terrain Models (DTMs) downloaded from the Norwegian Mapping Authority's Digital Map Catalogue ('Kartkatalogen', 2025) at two resolutions: a 10 m-resolution grid covering the entire Norwegian coast ('DTM 10 Terrengmodell (UTM33)—Kartkatalogen', 2013), and a number of local grids at 0.25 m-resolution covering areas of potential interest, used later in the process. RSL data was downloaded from the open-source database published by Creel (2022). Tidal range data was taken from the Norwegian Mapping Authority (2021), which lists tidal ranges at major ports and observation stations throughout the study region, as well as the difference between the 0 elevation datum used in the standard Norwegian vertical coordinate system (NN2000) and Lowest Astronomical Tide (LAT) at each port and observation station. This allowed historical tidal ranges to be calculated at possible haven sites, assuming such ranges were similar in the Viking Age to those observed today.

The modern 10 m DTM was imported into ArcGIS Pro and displayed as a raster mosaic. NetCDF and tabular data were downloaded from the Creel (2022) database, listing mean isostatic rebound rates for the period under study (800–1200 AD). Five rasters were extracted at the data's native resolution (cell size: 26 × 18 km), displaying mean RSL values for each cell in 800, 900, 1000, 1100, and 1200 AD. These dates were chosen to compare the coastal geography of each haven between the Viking Age and the period of the Medieval written sources, which are often employed for studying Viking Age seafaring despite a time interval of several centuries (*e.g.* Morcken, 1978; Thirslund, 1997).

To obtain the RSL values for each chosen date, the cell values of the RSL rasters were subtracted from the elevation values in the modern 10 m DTM. This produced 5 low-resolution 'paleo-DTMs' covering the entire Norwegian coast at each century mark, which were converted into contour shapefiles to more clearly illustrate RSL changes throughout the study period. These maps were used to conduct initial evaluations of potential haven sites based on the criteria developed in stage 3. Those sites which fulfilled the criteria were then further evaluated by reconstructing the local RSL at a higher resolution using 0.25-m-resolution local DTMs obtained from LiDAR acquisitions, also downloaded from Kartkatalogen. The same workflow was followed as above to obtain past elevation values, after which the tidal range at each site was delineated according to the nearest tidal gauge (Norwegian Mapping Authority, 2021). These high-resolution paleo-DTMs were then combined with data from the trials and relevant archaeological evidence. These included the GPS tracks from the trials; wind speeds and directions encountered during approach and departure from each location; the location of securely-dated Viking Age finds and features indicating maritime activity such as boat sheds and boat timbers; and, when possible, bathymetric data from historical nautical charts.[3] Taken together, these data informed a second evaluation of potential haven sites, resulting in the final selection presented in Appendix 1 (Table 4) and Appendix 2 (Table 5), and in the 'Results' section below.

Developing Criteria for Locating Viking Age Havens

The Trial Voyages

The two trial voyages undertaken for this study are plotted in Fig. 1. The dimensions and sailing properties of the boats used during these voyages are summarised in Table 3, while Table 1 presents the itineraries of each voyage, the duration and distance of each leg, the average distance and speed per 24-h period, and the wind conditions encountered during each leg. The return voyage to Lofoten was undertaken onboard the *fembøring* 'Skårungen'; the crew consisted of 11 students between the ages of 18 and 30, myself, and 2 skippers, who rotated out for different legs of the voyage. Conditions during this voyage were challenging, with almost ceaseless rain, snow, and sleet, but generally favourable in terms of wind direction (Fig. 4). The voyage followed two different routes on the northward and southward journeys and demonstrated the feasibility and possible itineraries of long-range voyages between sub-arctic and arctic areas. The voyage from Rissa to Bergen was undertaken onboard the *fyring* 'Båra', built over the previous winter at Fosen Folkehøgskole. The crew consisted of 6 people including myself as acting skipper, although this number dwindled during the voyage due to conflicting commitments. The smaller size of this vessel, the more unstable weather conditions, and the greater number of stops resulted in a lower average speed but served to demonstrate the possibility of long-range travel through the *Norðvegr* even in smaller boats, like those associated with non-elite Viking Age farmsteads (Maixner, 2020).

The Trials: Sailing Affordances

The sailing trials were all conducted in the Trondheim Fjord and *Trondheimsleia*, within a 54-nautical mile radius. This allowed the crews to become well-acquainted with the local seascape, developing a collective familiarity with the rhythms, constants, and dangers of the environment through accumulated experience. This observed process of attendance and acquaintance has led me to suggest that the navigational techniques employed by Viking Age sailors throughout the *Norðvegr* were unlikely to have relied on instruments (Jarrett, 2025b). Instead, it seems most probable that knowledgeable attendance to natural phenomena, combined with a shared

[3] Modern sea-floor DTMs were not used in this analysis. This was partly due to the irregular coverage and variable resolution of the available datasets, but also because of the dredging and clearance work that has radically altered the sea floor along the Norwegian coast over the last century. These transformations mean that the method employed here for reconstructing Viking Age RSLs would not result in accurate representations of ancient underwater topographies.

Table 3 Dimensions and sailing properties of the boats used during the project's trials. Note that tonnage is measured in barrels, as per the traditional Norwegian lester system; 1 lest = 12 barrels; 1 barrel = 115 L

Name	Type	LOA	LWL	Beam	Draft	Tonnage	Sail area	Max rowers	Min crew	Max crew	Top speed sail	Top speed row	Avg speed sail	avg speed row	best recorded windward angle
Skårungen	Fembøring	12.95	12.36	3.25	0.72	40	39.44 + 7.51	8	4	15	8.4	3.5	3.7	2	59
Båra	Fyring	9.06	8.5	2.04	0.55	8	18	8	2	7	7.9	4	2.7	2	69

corpus of named and storied marks, bearings, and itineraries, constituted the primary elements of Viking Age navigation (Börjesson, 2009; McGrail, 1997, p. 275). This system is partially preserved in the tradition of named transit bearings (*méd*) documented among Norwegian fishing communities (Godal, 1986; Uksnøy, 1959). In the absence of instruments, reaching havens in low-visibility conditions would have relied entirely on such bearings, with small seascape features, such as skerries, perhaps playing a greater role than high mountain peaks or ranges, as these were often concealed by the weather (Slyngstad, 1951). Sailing trials in heavy fog demonstrated that, without a chart and compass, havens that could be reached without crossing large expanses of open water would have been preferred, as such crossings posed major navigational challenges.

The various legs of the trial voyages often involved sailing at night. Throughout May, June, and July, sufficient natural light was available to allow for non-stop sailing, provided the wind remained favourable (as also shown by Englert, 2007, p. 117). If night sailing was expected during a voyage, the crew needed to be large enough to be split into two watches (with 2–5 sailors on each watch, depending on the size of the vessel), allowing the off-duty watch to sleep and thereby sustain energy levels over long stretches. This helps inform estimates of the size of the vessels and crews required for long-range, multi-day voyages, and, consequently, of the size of potential Viking Age havens, which needed to accommodate such vessels.

Sailing trials were also conducted in winter conditions. These demonstrated that shorter journeys could be completed during this season, but that fair-weather windows were rarely long enough to permit voyages lasting more than 2–3 days. The short days and stronger katabatic winds characteristic of winter generally allowed for much smaller margins of error compared to other times of the year. Sailing in spring and autumn often involved cold and wet conditions, but as shown in Table 1, wind conditions were observed to be more stable than in the summer months. Spring and autumn featured longer intervals of high pressure, which Englert (2007, p. 121) has suggested may have helped sailors like Ottar during long-range voyages.

Finally, the trials provide information on average speeds and windward performance under different conditions. These data informed the haven criteria by indicating the distances that could typically be covered in a day's sail between havens, as well as the amount of sailing room needed to approach or depart from these locations against the wind. With the wind aft of the beam, the *fembøring* averaged a sailing speed over ground (SSOG) of approximately 5 knots, while the *fyring*'s SSOG in favourable conditions was approximately 4 knots. When tacking to windward in a moderate breeze (Beaufort 4) and calm sea, the *fembøring*'s velocity made good (VMG) averaged 1,2 knots, whereas the *fyring*'s VMG was around 1 knot. In such conditions, the *fembøring* could achieve a course made good (CMG) of around 60° to the true wind, while the *fyring*'s best CMG was approximately 70° to the true wind (Table 1). The average SSOGs align well with the sailing speeds of historical square-rigged boats calculated by Englert (2012) and McGrail (1997, pp. 265–267), while the windward performance results are more positive than the estimates suggested by Palmer (2009). Average rowing speeds, on the other hand, were significantly below the values suggested in previous studies, with rowing speed over ground (RSOG) oscillating around 2 knots for both vessels (c.f. Carver, 1990;

Sæther & Eldjárn, 2002). This discrepancy may be due to the circumstances surrounding this study's rowing trials: averages were obtained from long stretches of 4 hours or more, in dead calms or contrary winds, using Åfjord boats ballasted for sailing, rather than empty boats built primarily for rowing. Viking Age rowing crews may well have been faster, but these estimates should serve to illustrate the more modest speeds that could be expected when rowing vessels built primarily for fishing and trading.

The Trials: Choosing Routes and Havens

Among their various functions, havens served as relatively safe shelters in which to wait out spells of unfavourable weather. Defining what constitutes adequate shelter for the kinds of vessels used in the Viking Age is therefore a necessary pre-requisite for evaluating potential haven sites. In contrast to modern sailing vessels, Nordic clinker boats are characterised by lightweight hulls, lower mast-to-hull-length ratios, and the lack of a protruding keel. This means that Viking Age vessels could shelter behind lower landforms than modern vessels, or could be beached and hauled ashore. During the trials, 9 m of elevation proved sufficient to shelter the *fyring* from south-westerly gales, but 15 m of elevation has been used in the criteria below to account for the needs of larger vessels. Hauling ashore smaller Åfjord boats such as the *fyring* could be accomplished by 4–5 people, while the *fembøring* required a team of 39, meaning that help from people (and probably animals) on land would have been required for such landing operations in the past (Vinner, 1997, pp. 100–105). Lower shelter requirements and the possibility of beaching, combined with the lower windward performance of square-rigged vessels, means that Viking Age crews would have favoured more accessible and sometimes less sheltered havens than the highly enclosed anchorages in use today.

Along with the different requirements for havens, the trials helped identify areas of potential risk along the Norwegian coast that rarely feature in scholarship on this subject. As mentioned above, previous studies have drawn heavily on *Den Norske Los* (2018), and have focused on the dangerous passages highlighted therein (primarily exposed coastlines such as Hustadvika and Stadlandet), assuming they also represented the main areas of risk for voyages in the past (*e.g.* Engedal, 2010, p. 470; Østmo, 2020, Fig. 1.3). However, results from this project's trials and from other voyages in similar boats have shown that sailing through inner passages poses a different but equally major set of challenges to open, square-rigged wooden boats. The sheer sea cliffs and narrow sailing channels of many fjords and sounds in areas such as Helgeland create unstable and unpredictable wind conditions, with katabatic gusts often being unavoidable due to the lack of sailing room (Eldjárn & Godal, 1988a, p. 94; Guttormsen & Nijjer, 2023). Furthermore, the complex coastline and archipelagos cause convoluted currents and tidal streams, and feature frequent reefs and skerries, posing additional difficulties to navigation and pilotage (Ilves, 2004, p. 167). Katabatic gusts and strong currents are major threats to the kind of boast used in this project and in the Viking Age, and have caused many of the capsizes of reconstructed vessels in recent decades (Fig. 6) (Binns, 1980; Vegard Heide, personal communication). The risks along seemingly safer inner passages suggest that Viking Age sailors may have approached inner seascapes with as much care as the more renowned exposed coastlines of the *Norðvegr*, and awaited favourable conditions not only when leaving coastal areas or sheltered waters, but also when approaching them.

Larger, square-rigged trading ships like the Viking Age *knarr* or *byrding* have limited rowing capabilities and depend on the wind for anything other than very short passages (Carter, 2001, p. 104; Christensen, 2007; Anton Englert & Ossowski, 2009, p. 264). Travelling into or out of long fjords in such vessels can therefore only be accomplished under a very limited range of wind conditions, which are often not the same as those needed for long-range travel along the north–south coastal route, as many of the fjords lie at wide angles to the coast. In contrast to the inner fjords, islands or headlands along the outer coast can be approached or departed from under a wide range of wind conditions. They also provide an uninterrupted view over the seascape, allowing sailors to observe incoming weather systems and judge the conditions out to sea. In historical times, ships called at specific outlying islands such as Halten, Valderøya or Kinn to take on pilots before entering the fjords (Löwenörn, 1975, bk. 1: 8; 2: 14; 3: 17), and such practices are also mentioned in medieval Norse sources (Þórðarson, 1887, p.

Fig. 6 Katabatic winds are caused by thermal differences between sea-level and high-altitude areas in close proximity to each other, and can be extremely dangerous when sailing near land. In the summer of 2023, a katabatic gust caused this *fembøring* to capsize off the coast of Kunna. Image courtesy of HRS Nord-Norge (No. 330 Squadron RNoAF)

342). Rather than face the difficulties and dangers of narrow fjords and sounds, this suggests that Viking Age sailors on long-range voyages may have favoured havens on easily accessible islands and headlands, located between exposed and inner areas, and featuring wide views of the surrounding seascape. Such locations would have acted as shelters between two different kinds of dangers: the outer coasts and the inner fjords. I refer to the areas between these hazards as ‘transition zones’, and employ them in the following stage of the investigation as aids in the location of possible Viking Age havens.

Results

Criteria for Evaluating Potential Viking Age Havens

The affordances and insights identified during the experimental trials can be used to establish a set of standard criteria for evaluating potential havens from the perspective of Viking Age sailors. Based on the findings above, the following preferred characteristics can be outlined.

Viking Age havens should be:

1. Reachable in low visibility using bearings from named land- or seamarks, without needing to cross featureless stretches of water wider than 2 nautical miles;
2. Large enough to accommodate multiple vessels of at least the size of a *fyring* (length: 9 m, beam: 2 m), carrying multiple crews of 4–10 people each;
3. Located within reasonable rowing distance (2 nautical miles) of multiple approach and departure routes providing $>140°$ of possible courses, allowing vessels to tack in or out against the wind;
4. Located within transition zones.

And should provide:

5. Good protection from sea swell and storm surges;
6. Good protection from prevailing winds in the form of land above 15 m elevation on at least 2 sides, OR a landing area in the form of a gently sloping (and ideally sandy) beach;
7. Wide and elevated views of the surrounding seascape, particularly towards the southwest, available within walking distance;
8. Access to fresh water.

In all 8 of these criteria, references to elevation and topography pertain to Viking Age land- and seascapes, as reconstructed through RSL-based paleo-topographies. It is important to emphasize that these reconstructions are approximate, and consequently, the haven evaluations must be regarded as preliminary. The following discussion focuses on sites that were physically visited during the trials, as first-hand experience of approach and departure by sea was considered an important form of 'ground-truthing' the digital seascape reconstructions.

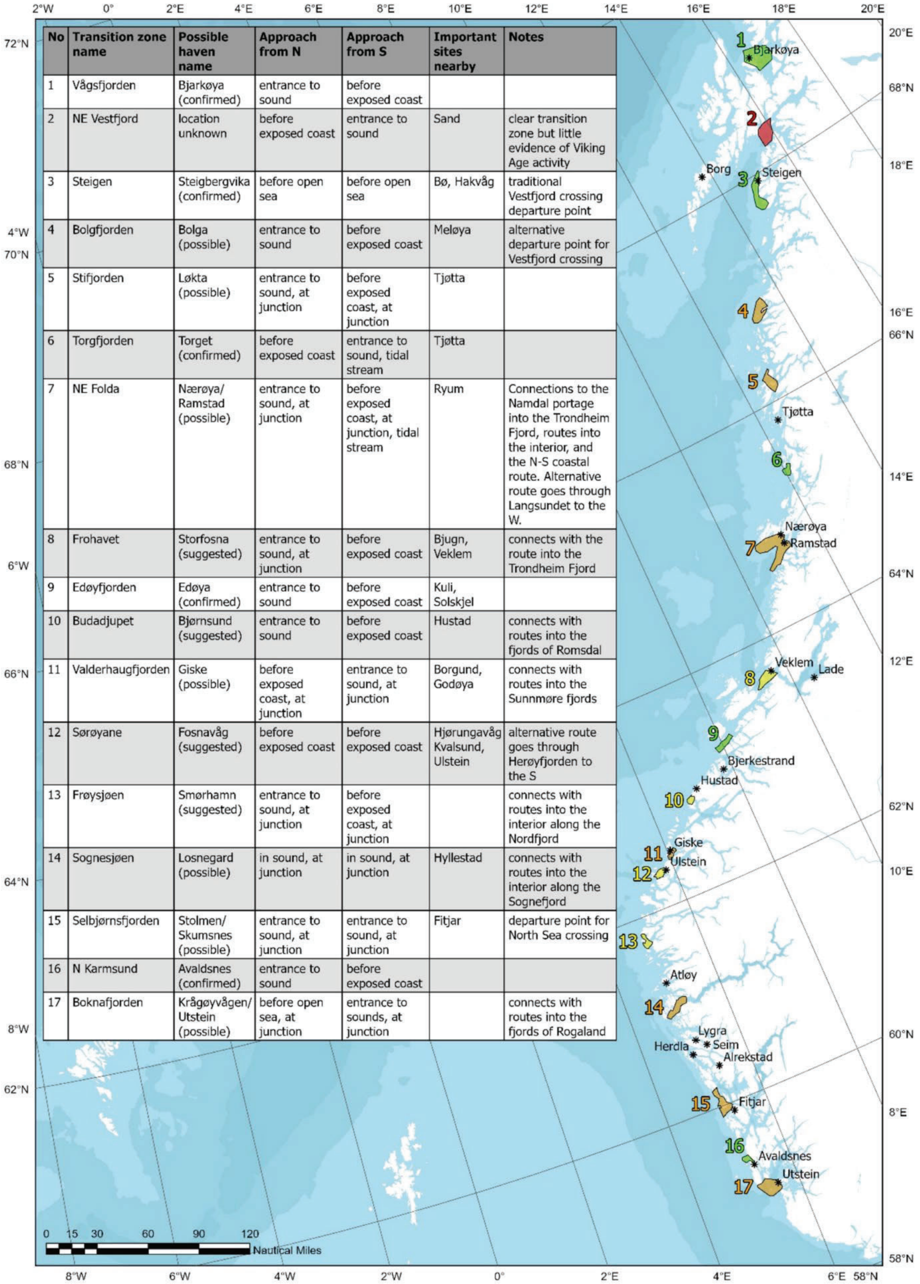
The criteria build upon previous research on this topic (Ilves, 2004; Kruse, 2020; Macniven, 2020; McGrail, 1997). Some of the requirements established in these studies aligned well with the findings from the experimental trials and have therefore been directly incorporated. Others were somewhat vague or referred to modern geographical features rather than historically accurate topographies. These have been adapted in light of the experimental trials and/or related to the RSL reconstructions.

The 'transition zones' in Criterion 4 refer to areas of the Norwegian coast where exposed outer coasts give way to fjord systems and dense archipelagos. As argued above, these areas served as ideal stopping points for square-rigged clinker boats, as they are situated between different zones of navigational risk. Transition zones feature less sea swell than the outer coast, while tidal currents and katabatic winds are weaker than in the inner fjords and sounds. A total of 17 such zones were identified as part of this project throughout the study region and are presented in Fig. 7.

The criteria are applied to potential sites according to the definition outlined above. Accordingly, this study focuses on locations that connect 2 or more sailing routes and excludes areas that are not situated along or in close proximity to the *leið*—the main long-range sailing zone along the west coast of the Scandinavian Peninsula (Fig. 1). In designing these criteria, I have aimed to be as specific as possible while acknowledging the inherently subjective nature of seafaring practices and experiences, as well as the agency of both sailors and the sea in the outcome of each voyage (Campbell, 2020; Jarrett, 2025b). These criteria should therefore be understood as the basic practical requirements by which Viking Age crews might have judged potential stopping points. However, such judgements undoubtedly involved additional factors that varied from one voyage to another, such as social relations, geopolitical circumstances, and the assumed presence of supernatural entities (Frog, 2020; Meulengracht Sørensen, 1995).

The criteria are presented in Table 4 in Appendix 1. This table relates the criteria to four potential haven sites visited during this study, as well as to 35 additional sites that have been discussed, suggested, or mentioned in previous literature. The first set of columns lists the modern names of these locations, the maritime region in which they are located, the coordinates of the proposed haven, the RSL changes since 1200 and 800 AD, and the number of the associated transition zone (where applicable), as shown in Fig. 7. This is followed by a column titled Certainty, containing values ranging from 1 to 7, after which the criteria are listed. The Certainty values represent the evaluation of each site against the established criteria and indicate the following conclusions:

- '1' indicates sites that fulfil the haven criteria and contain securely dated evidence of Viking Age maritime activity, such as boathouses.
- '2' indicates sites that fulfil the haven criteria and have been suggested by previous studies as probable centres of Viking Age maritime activity, but which lack securely dated evidence. Sites with ship burials fall into this category, as such monuments are interpreted by the author as indicating the importance of seafaring in Viking Age cosmologies, but not necessarily as indications of maritime activity among the living.



No	Transition zone name	Possible haven name	Approach from N	Approach from S	Important sites nearby	Notes
1	Vågsfjorden	Bjarkøya (confirmed)	entrance to sound	before exposed coast		
2	NE Vestfjord	location unknown	before exposed coast	entrance to sound	Sand	clear transition zone but little evidence of Viking Age activity
3	Steigen	Steigbergvika (confirmed)	before open sea	before open sea	Bø, Hakvåg	traditional Vestfjord crossing departure point
4	Bolgfjorden	Bolga (possible)	entrance to sound	before exposed coast	Meløya	alternative departure point for Vestfjord crossing
5	Stifjorden	Løkta (possible)	entrance to sound, at junction	before exposed coast, at junction	Tjøtta	
6	Torgfjorden	Torget (confirmed)	before exposed coast	entrance to sound, tidal stream	Tjøtta	
7	NE Folda	Nærøya/ Ramstad (possible)	entrance to sound, at junction	before exposed coast, at junction, tidal stream	Ryum	Connections to the Namdal portage into the Trondheim Fjord, routes into the interior, and the N-S coastal route. Alternative route goes through Langsundet to the W.
8	Frohavet	Storfosna (suggested)	entrance to sound, at junction	before exposed coast	Bjugn, Veklem	connects with the route into the Trondheim Fjord
9	Edøyfjorden	Edøya (confirmed)	entrance to sound	before exposed coast	Kuli, Solskjel	
10	Budadjupet	Bjørnsund (suggested)	entrance to sound	before exposed coast	Hustad	connects with routes into the fjords of Romsdal
11	Valderhaugfjorden	Giske (possible)	before exposed coast, at junction	entrance to sound, at junction	Borgund, Godøya	connects with routes into the Sunnmøre fjords
12	Sørøyane	Fosnavåg (suggested)	before exposed coast	before exposed coast	Hjørungavåg Kvalsund, Ulstein	alternative route goes through Herøyfjorden to the S
13	Frøysjøen	Smørhamn (suggested)	entrance to sound, at junction	before exposed coast, at junction		connects with routes into the interior along the Nordfjord
14	Sognesjøen	Losnegard (possible)	in sound, at junction	in sound, at junction	Hyllestad	connects with routes into the interior along the Sognefjord
15	Selbjørnsfjorden	Stolmen/ Skumsnes (possible)	entrance to sound, at junction	entrance to sound, at junction	Fitjar	departure point for North Sea crossing
16	N Karmsund	Avaldsnes (confirmed)	entrance to sound	before exposed coast		
17	Boknafjorden	Krågøyvågen/ Utstein (possible)	before open sea, at junction	entrance to sounds, at junction		connects with routes into the fjords of Rogaland

Fig. 7 Transition zones along the *Norðvegr* in relation to Viking Age power centres. Asterisks mark known power centres. The coloured polygons indicate transition zones where Viking Age havens are likely to be located. The polygon colours represent the current state of knowledge regarding Viking Age maritime activity in each zone: red, no known haven location; orange, possible haven location, insufficient evidence; yellow, haven location suggested in this article; green, confirmed haven location with dated evidence for Viking Age maritime activity. Note that not all power centres are within transition zones, suggesting that the relationship between high-status sites and seafaring itineraries may be less direct than previously assumed. This is a preliminary list, intended primarily as a working document to support future research, surveys, and excavations

- '3' indicates sites that have been suggested by previous studies as probable centres for Viking Age maritime activity, but that do not fulfil the haven criteria.
- '4' indicates new or rarely discussed sites that fulfil the haven criteria and are presented in the 'Suggested Havens' section below.
- '5' indicates sites that appear to fulfil the haven criteria but require further evidence before a proper evaluation can be made. These are mainly sites that were not visited during the experimental trials.
- '6' indicates alternative potential havens near the suggested sites from category 4 that fulfil the haven criteria but are deemed less likely to have seen frequent Viking Age maritime activity. These are discussed in the 'Suggested Havens' section.
- '7' indicates sites that were considered at some stage during this investigation but that do not fulfil the haven criteria.

Appendix 2 presents the relevant archaeological and documentary evidence for each potential haven, which is further discussed in relation to the four suggested havens in the 'Suggested Havens' section. The collected evidence spans from the beginning of the Iron Age (c. 500 BC) to the end of the Early Modern Period (c. 1800 AD) and was gathered from academic literature, historical maps and charts, excavation reports, historical sailing descriptions, and the online portal of the Norwegian Directorate for Cultural Heritage (Kulturminnesøk, 2024). In general, this material was used to contextualise each site within the broader archaeological seascape and to indicate current levels of knowledge about the area. In certain cases, the exact location of a place name in the written sources or historical maps was unclear. To resolve this, high-resolution paleo-DEMs covering the general area were employed to evaluate which of the possible havens was most likely to correspond to the place referred to in the documentary or cartographic sources. This was the case, for example, with the islands of Kråkvåg and Storfosna (see below), and illustrates another valuable application of digital seascape reconstruction for historical archaeology.

The Suggested Havens

From the harbours and anchorages visited during the sailing trials and trial voyages, four locations were selected that fulfil the haven criteria (Appendix 1, in bold). These potential Viking Age havens are presented below, together with digital reconstructions of their historical topographies, an examination of relevant documentary and archaeological evidence, and a discussion of their possible role within wider Viking Age seafaring networks.

Smørhamn

Evidence This small natural harbour is located at the confluence of Oldersund and the Frøysjø, linking one of the routes into the Nordfjord with the *leið*. An inn and trading post are known to have existed here since at least the late seventeenth century, and during the nineteenth century, Smørhamn was frequently used as a waiting place for the large, square-rigged cargo ships known as *jekter* on voyages towards

Bergen (Knut Arne Vedøya, personal communication; Eldjárn & Godal, 1988a, p. 55). This role is reflected in several maps and charts from the eighteenth century (Hammer, 1780; *Kartblad 123–1: Carte over det Første Bergenhuusiske Regiments District; versjon 1*, 1750; Norge 222: Kart over det sydlige Norge, 1700), and Smørhamn is described as a 'liden Stoppehavn' in Löwenörn's sailing description form 1795 (1975, bk. 3, p. 9). No securely identified Viking Age manors have been found along a 200-km stretch between Sunnmøre and Nordhordaland (Skre, 2018b, p. 788), making this section of the *leið* during the Viking Age harder to reconstruct through conventional means.

Suggested Role in Viking Age Seafaring Networks During the 2022 voyage onboard 'Båra', Smørhamn proved to be easily accessible from the outer coast with a northerly wind and offered good shelter from south-westerly gales. As shown in Fig. 8, its topography throughout the Viking Age was very similar to today, albeit with slightly clearer access from the west and a somewhat longer and broader harbour. The results from the trial voyage suggest that an outer route which rounded the headlands of Stad, Vågsøy, and Bremangerlandet is possible even in smaller, non-elite vessels (Figs. 1 and 2). This route would be quicker and less meandering than the previously suggested inner route *via* the Frøysjø, Vågsfjord, and Ulvesund (Baug et al., 2019, Fig. 2; Kruse, 2020, Fig. 1; Skre, 2018b, Fig. 29.4). Other possible havens at the confluence of Oldersund and the Frøysjø include Storehovden (at the southwesternmost tip of Frøya; Kulturminne ID: 6290) and Kalvåg (Thue, 1995). Storehovden offers little shelter and may have functioned as a small fishing station rather than an anchorage for larger vessels. Kalvåg became a major fishing port in the nineteenth century but does not feature in sailing descriptions or historical maps from before this time. The

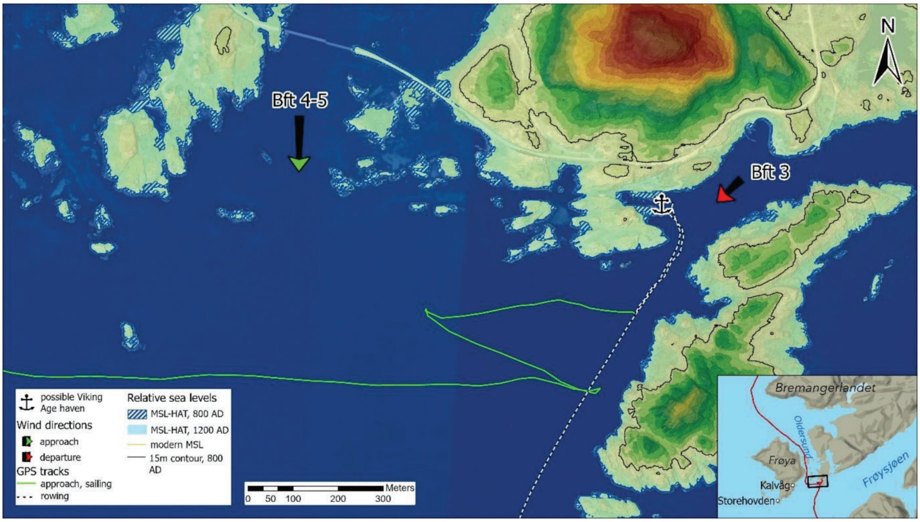


Fig. 8 Smørhamn, showing paleotopography from 800 AD and RSLs from 800 AD and 1200 AD. The track of the trial voyage and the weather conditions encountered during the approach and departure are also shown. Note that the approach to this location proved possible even against the wind

clearer approach channel into Smørhamn may have made it the more attractive stopping place until the needs of the commercial fishing industry encouraged the clearance of skerries and the development of a larger harbour at Kalvåg.

Sørøyane

Evidence The archipelago of Sørøyane lies along the *leið* between Stad and Ålesund. The Kvalsund boats, built c. 780–800 AD, were buried on the SE tip of one of these islands (Nordeide et al., 2020; Shetelig & Johannessen, 1929), and the sea battle of Hjörungavágr was fought nearby around 986 AD, outside an unidentified anchorage (Ottesen, 2010). The main sailing route in the historical period ran along the southern and eastern coasts of this archipelago *via* Flåvær and Herøya (Dellinger, 1875; Grove, 1791, p. 1). Herøya is referred to in thirteenth-century sources as a harbour used before and after sailing around Stad (*e.g.* Sturlason, 1990, pp. 144, 418), and a stone church was built there during the Middle Ages (Fig. 10) (Kulturminnesøk, 2024). Taken together, this evidence has led several scholars to suggest that a route *via* Herøya was also in use during the Viking Age (Baug et al., 2019, Fig. 2; Kruse, 2020, Fig. 1; Skre, 2018a, Fig. 29.4.

Suggested Role in Viking Age Seafaring Networks Despite the evidence from medieval sources, the more direct and visually intuitive route through the archipelago *via* the narrow approaches at Igesundsvaulen and Volsund may have been preferred in the Viking Age. Both sounds were dredged in the late nineteenth century, but there is some evidence that smaller channels were in use before this time, probably making this a navigable route for shallow-drafted vessels (Rabben, 1962, p. 361). The depth values obtained by subtracting Creel et al.'s (2022) RSL data from nineteenth-century soundings (*e.g.* Dellinger, 1875), combined with the location of the Kvalsund boats and several other prehistoric monuments, seem to strengthen this hypothesis (Knutzen, 2007, pp. 317–319; Rabben, 1962, pp. 54–55; Shetelig & Johannessen, 1929, p. 9). If this route was used in the Viking Age, the most likely location for a haven would have been the sheltered inner bay at Fosnavåg (Fig. 9). It seems plausible that isostatic rebound, coupled with the increase in the draft of medieval trading ships, may have made Fosnavåg difficult to access after the Viking Age, leading to a change in the traditional sailing route. From a broader geographical perspective, however, the Sørøyane archipelago seems to have remained of great importance throughout time as a stopping point for both north- and southbound voyages.

Bjørnsund

Evidence Bjørnsund consists of a number of small islands off the southwestern tip of Hustadvika, at the northern entrance to the fjords of Romsdal and Sunnmøre. Although its role in maritime networks was overshadowed in the early modern period by the mainland trading centre at Bud, the natural harbours among these islands are significantly more protected than the bay at Bud, which remained open to the southwest until the construction of a breakwater in the twentieth century (Bøe, 2009;

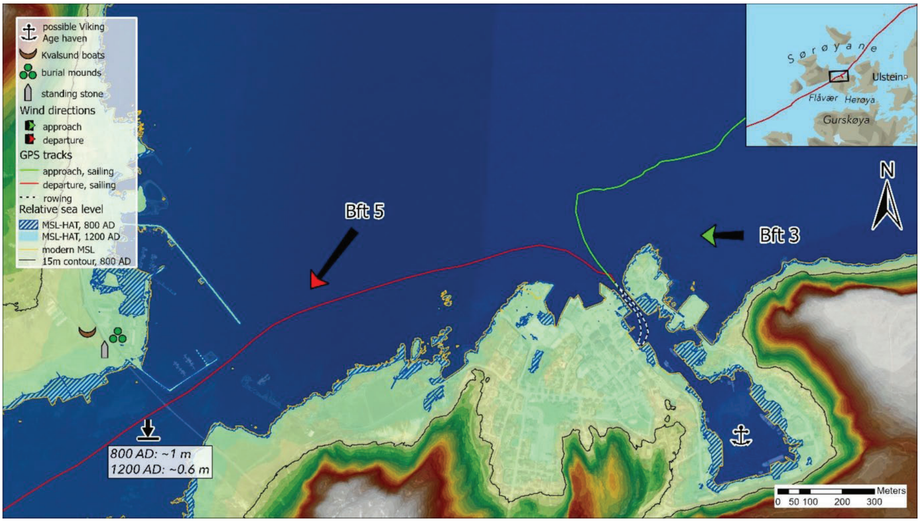


Fig. 9 Fosnavåg, with a paleotopography from 800 AD and RSLs from 800 and 1200 AD. The track of the trial voyage and the weather conditions encountered during both approach and departure are also included. Note the proximity to Early Viking Age activity at Kvalsund and the bathymetric changes in the approach channel to the west. These changes may have made Fosnavåg increasingly inaccessible after the Viking Age

Fig. 10 Herøya, with a paleotopography from 800 AD and RSLs from 800 and 1200 AD. The low elevation around this anchorage makes it less likely to have served as a haven during the Viking Age. Nevertheless, Herøya became an important stopping place during the Middle Ages, as evidenced by the construction of a church here in the twelfth century. This change in maritime itineraries may have been due in part to RSL changes, which prevented Medieval vessels from accessing the more protected anchorage at Fosnavåg

Østmoe & Fretheim, 2022; Solem, 1870). These islands are described as a 'Stoppe-Pladse' in Löwenörn's (1975, bk. 2:8) sailing description from 1792, but they do not appear in the Medieval saga literature and have produced only a single stray find from the Viking Age (Kulturminnesøk, 2024).

Suggested Role in Viking Age Seafaring Networks When compared to Bud and other nearby mainland anchorages such as Vestad, Bjørnsund is easier to approach and depart from under a wider range of wind directions and offers more ample views over the surrounding seascape. Despite the low elevation of these islands, the minor degree of isostatic rebound along the Romsdal coast over the last twelve centuries suggests that the sheltered inner bays may have already existed in the Viking Age, with Nordøya likely being the preferred haven due to its better shelter and access to fresh water (Fig. 11). Their location at the mouth of a major fjord system makes Bjørnsund an interesting comparison to other Viking Age island nodes, including Bjarkøya (Wickler, 2021, 2023), Veøya (Solli, 2008, 2014), and probably Utstein (Hillesland & Pedersen, 2024; Skre, 2018b).

From Bjørnsund, it is possible to take an inner or outer route towards the southwest; during the trial voyage onboard 'Båra', the outer route proved useable even in contrary winds, as it provided sufficient sailing room to tack down the Harøyfjord towards Ålesund. This contrasts with the route proposed in previous studies (*e.g.* Skre, 2018b, Fig. 29.4). If Bjørnsund was used during the Viking Age, it may have been in connection with the manor and assembly site at Hustad, located 8 nautical miles northeast of these islands (Bøe, 2009). Vessels bound for Hustad may have used Bjørnsund as a waiting place before navigating the notoriously perilous coastline of Hustadvika.

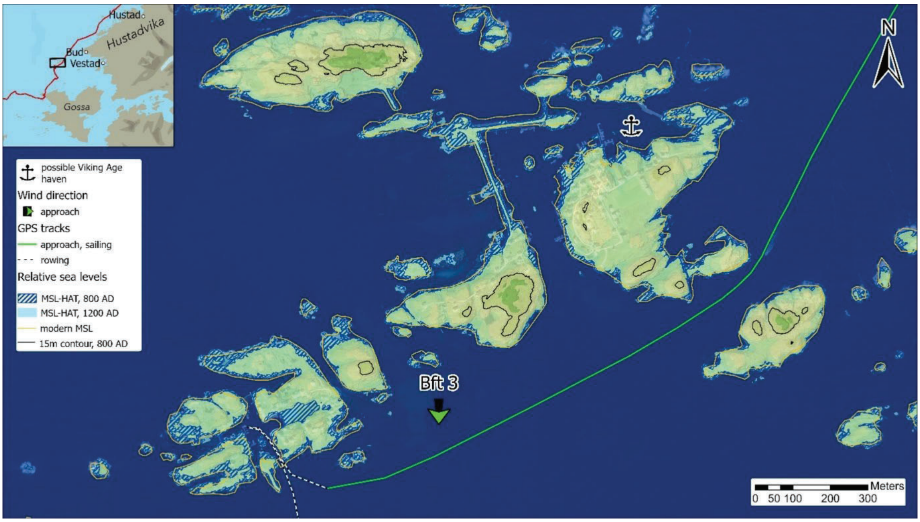


Fig. 11 Bjørnsund with a paleotopography from 800 AD and RSLs from 800 and 1200 AD. The track of the trial voyage and the weather conditions encountered during the approach are also included. Note that multiple natural harbours within this archipelago may have existed during the Viking Age, just as they do today

Storfosna

Evidence The *Trondheimsleia*, the Trondheim Fjord, and the Frohav converge off the Ørland Peninsula, connecting the Viking Age and Medieval centre at Nidaros with the *leið* (Löwenörn, 1975, bk. 1, p. 7). In *Heimskringla*, Snorri refers to a stopping place and fleet anchorage 'at the mouth of the Trondheimsfjorden' (Maixner, 2020, p. 294; Sturluson, 1870, p. 176), but does not specify an exact location. *Magnus Lagabøtes landslov*, compiled in the late thirteenth century, mentions the island of Kråkvåg as an important harbour for long-range voyages (Storm, 1880, p. 78, note 3), leading Morcken (1978) to argue that Kråkvåg also had this function in the Viking Age. This has recently been challenged by Maixner (2020), who instead suggests that the main Viking Age anchorage in this area was to be found on the neighbouring island of Storfosna. Originally known simply as 'Fosen' (from ON Fólgsn, meaning 'hiding place': Østmo, 2020, p. 19), the island already appears on charts from the sixteenth and seventeenth centuries (*e.g.* Blaeu, 1659; Waghenaer, 1588, pp. 62–63). The protected inner bay was accessible until the late nineteenth century through narrow passages from both the east and south (Øgaard, 1885). Along the shores of this bay, archaeological evidence points to high-status activity on the island during the Merovingian Period, and a continuous history of settlement into the Middle Ages (Brendalsmo & Eriksson, 2016, pp. 37–38; Maixner, 2020, p. 294).

Suggested Role in Viking Age Seafaring Networks The sailing trials and topographic reconstruction lend support to Maixner's (2020) suggestion (Fig. 12). Although both Storfosna and Kråkvåg meet the haven criteria and may therefore both have served as Viking Age havens, the RSL reconstructions indicate that Kråkvåg was broken up into several small islets until the thirteenth century, offering little shelter and no safe landing places (Fig. 13). In contrast, higher RSLs benefited Storfosna, as the eastern approach channel would have been navigable even at low tide, and most of the skerries observable today off the island's eastern coast would have been submerged. Storfosna lies within rowing distance of the power centre at Veklem (Berglund & Solem, 2017; Ystgaard, 2019) and may have served as the primary anchorage for this centre, offering greater shelter and accessibility than the exposed coast of the Ørland Peninsula where Veklem was situated. After the Viking Age, seafaring networks in this area were transformed by King Eystein Magnusson's decision to construct a mole harbour at Agdenes (known as Kong Øysteins havn), which drew vessels away from outlying island havens and regulated marine traffic in and out of the Trondheim Fjord (Brendalsmo & Eriksson, 2016, p. 49). Some evidence for Iron Age activity has been identified at Kong Øysteins havn (Berglund & Solem, 2017, p. 212), but it appears to have been a sub-optimal anchorage until the construction of the mole in the Medieval period (Appendix 1).

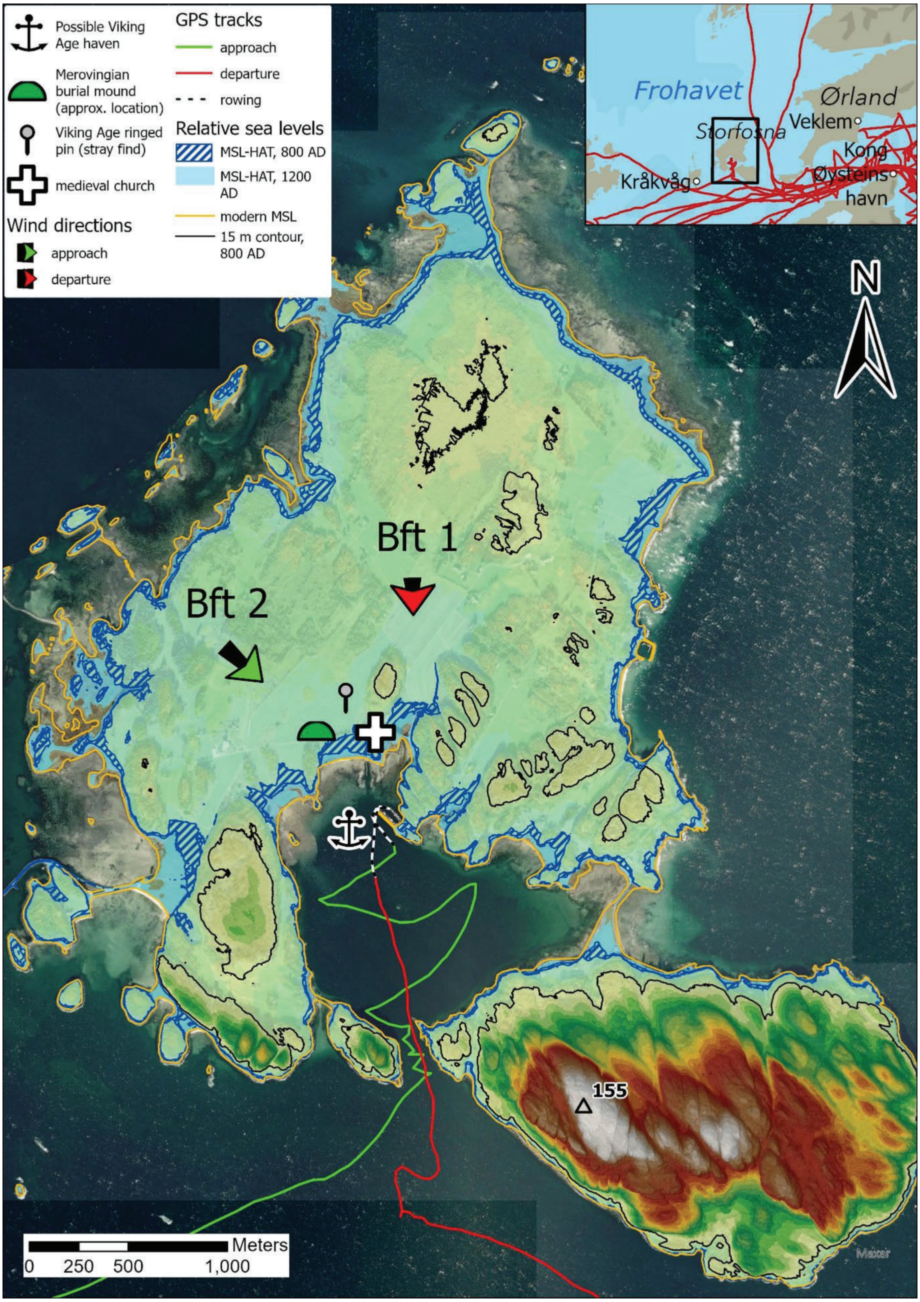


Fig. 12 Storfosna with a paleotopography from 800 AD and RSLs from 800 and 1200 AD. The track of the trial voyage and the weather conditions encountered during approach and departure are also included, along with relevant archaeological evidence near the suggested haven. Note that isostatic rebound has rendered the eastern approach channel inaccessible. The meandering departure track was caused by heavy, low-lying fog; however, the heights to the east of the entrance remained visible, allowing for approach even in such conditions

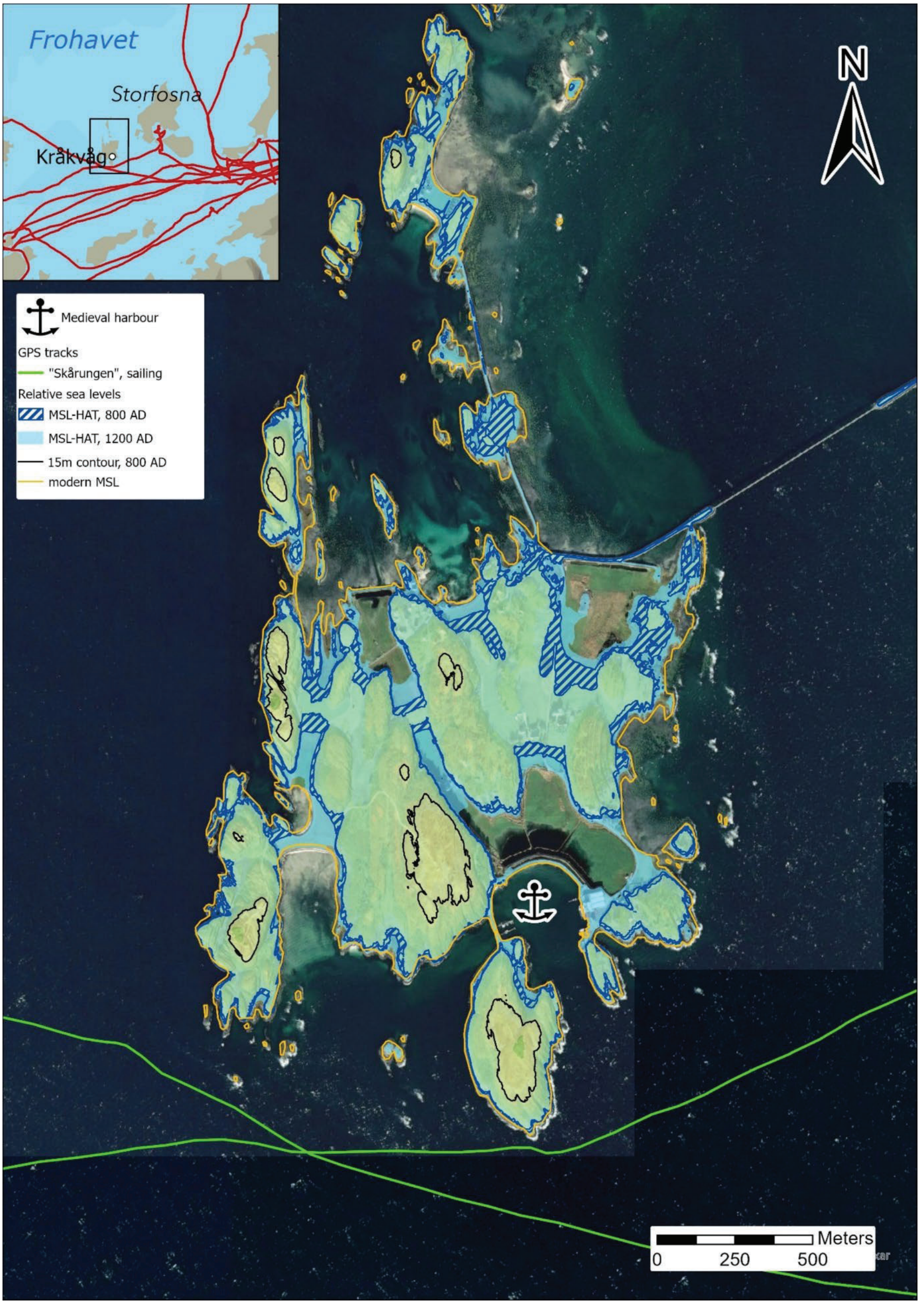


Fig. 13 Kråkvåg with a paleotopography from 800 AD and RSLs from 800 and 1200 AD. The ninth-century RSL suggests that this island would have comprised a number of scattered rocks and islets during the Viking Age, making it a less likely haven compared to the neighbouring island of Storfosna

Discussion

The experimental sailing trials and trial voyages at the core of this study illustrate that, at least from the perspective of the sailor, accessibility was as important as shelter when choosing temporary harbours or anchorages during the Viking Age. The ideal compromise between these two priorities was to be found in areas between exposed coastlines and narrow inner waterways, referred to here as transition zones. These findings have been employed here to evaluate potential havens visited during the trials, leading to the identification of four locations that may have served as favoured stopping points on long-range Viking Age sailing itineraries.

The haven criteria outlined in Appendix 1 can also be applied more exploratively to investigate other transition zones throughout the *Norðvegr*. Potential Viking Age havens within each of these zones are listed in Appendix 1 under Certainty Level 5, as they were not visited during the trials. These should therefore be taken as no more than conjectural applications of the method, although several display promising evidence.

Beginning in the north, the island of Bolga serves as an important landmark on the Helgeland coast for southbound voyages and features burial mounds containing Viking Age oval brooches and glass beads (Fig. 14; Kulturminnesøk, 2024; Østmo, 2020). At the junction between the Ranfjord and the Alstenfjord, the low-lying island of Løkta served as an assembly site throughout the Iron Age (Berglund, 1996) and offers several protected bays and landing places, safely distant from the high mountains (and consequently strong winds) to the north, east, and south. In northern Trøndelag, the Vikna archipelago links two areas of exposed coastline with the overland route into the Trondheim Fjord *via* the Namdal portage. Various potential

Fig. 14 The island of Bolga, just visible off the starboard bow during the trial voyage onboard 'Skårungen' in May 2022, is an important traditional landmark that may have featured in Viking Age seafaring itineraries from the Arctic towards southern Scandinavia and mainland Europe

havens exist in this area, with Nærøya probably being the most favourable, as evidenced by its appearance in the written sources and continued use into the Early Modern Period (Airola et al., 1990, p. 9; Solem et al., 2023; Sturlason, 1990, p. 23). In Sunnmøre, the island of Giske was suggested by Kruse (2020) as a likely Viking Age haven; it is ideally placed at the transition between the inner fjords and outer coast, but it is very exposed to wind and swell, indicating that further investigations are required. At the mouth of the Sognefjord, the Solund Islands have been mentioned by various authors as a likely waiting place for vessels bound for the British Isles (Kruse, 2020; Wamers, 1998). Maritime traffic through these islands may also have been linked to the Hyllestad quern stone quarries nearby (Grenne et al., 2008, p. 50). The gently sloping and sandy bay at the southeast end of Losna, known as Losnegard or Bussevika, is one of the few locations in the Solund Islands where boats can be beached and goods unloaded with relative ease, while still giving easy access to the outer coast and the route into the Sognefjord. To date, this location has only revealed evidence for maritime activity from the Medieval period (Kulturminnesøk, 2024), but it may already have served as a haven in the Viking Age. In southern Hordaland, recent excavations point to a possible haven at Skumsnes on Fitjar (Søren Diinhoff, personal communication; forthcoming report by Howell Roberts), while the anonymous *Historia de profectione Danorum in Hierosolymam* (Gertz, 1922) mentions a fleet anchorage and gathering place on the island of Stolmen for vessels bound for mainland Europe. Finally, the Karmsund strait was controlled at its northern end by the manor at Avaldsnes (Skre, 2018b). The southern entrance may also have featured Viking Age havens on the islands of Kvitsøy and Utstein. Recent archaeological surveys concluded that Viking Age maritime activity was likely on both islands, but no securely dated evidence has yet been identified (Hillesland & Pedersen, 2024; Wróblewski, 2017).

This list is undeniably speculative and is included primarily to illustrate the potential of evaluating possible ancient seafaring routes and havens using practice-based criteria. It should be noted that several coastal sites with evidence of Viking Age activity, such as Sandtorg and Hustad, are not included in the list above. This omission does not represent a denial of the evidence but rather reflects the conclusion that, as these sites do not fulfil the haven criteria, they are less likely to have been used as stopping places during long-range voyages. They may, however, have served as nodes in local maritime networks.

The evaluation of potential Viking Age sailing itineraries with practical and experiential criteria contrasts markedly with previous approaches. As mentioned above, earlier studies have relied heavily on evidence for high-status terrestrial sites, assuming (often implicitly) that such power centres functioned as hubs of maritime activity as well as elite residences, while remaining silent about areas where no such centres have been identified (Iversen, 2020; Skre, 2014, Fig. 2). However, it is important to remember that it was the sailing routes and havens that enabled the establishment of power centres in the Viking Age, not *vice versa*. Furthermore, the factors influencing the location of havens were not the same as those underlying the establishment of power centres. As we have seen, the former seem to have been afforded primarily by accessibility and shelter, while the latter, although they could benefit from these, were mainly chosen based on the availability of arable land (Maixner, 2021, p. 181).

This divergence can be appreciated in Fig. 7. In some cases, Viking Age power centres are located within transition zones, indicating that the equation of Viking Age power centres with the nodes of contemporary maritime networks is by no means unfounded. However, other power centres are not found within these zones and, therefore, may not have served this double function. Several of these, such as Lygra and Hustad, have so far produced no evidence of maritime activity during the Viking Age, while others, like Lade and Borg, are located at great distances from the *leið*.

Taken together, this suggests that in some areas of the *Norðvegr*, there was a degree of separation between the epicentres of elite activity and the primary nodes of long-range seafaring networks. Although the boundaries between long-range traders, raiders, and royal warriors were undeniably permeable during the Viking Age, seafarers in these various roles may have favoured different harbours and anchorages depending on the context and purpose of their voyage. Sea-kings and their navies are likely to have prioritised control over good arable land, relying on large rowing crews to access sheltered inner anchorages, while delegating the task of controlling and taxing maritime traffic to trusted subordinates (Baug et al., 2019, p. 65; Hillesland & Pedersen, 2024, p. 18). Raiders may have deliberately avoided established power centres and sought out alternative havens beyond elite control, favouring the kind of outlying havens presented here, and those suggested by Ulriksen (2004, p. 13) for southern Scandinavia. Traders may have combined both approaches, aiming for or deliberately avoiding power centres depending on their relationships with local magnates. By this argument, havens like Storfosna and Smørhamn might have originated as the hideouts or refuges of those opposed to (or independent of) powerful sea kings such as Harald Fairhair. This suggests a more decentralised system of maritime power and logistics during the Viking Age than that presented in Medieval sources such as *Heimskringla* or *Magnus Lagabøtes landslov*. Such decentralisation may help explain why Viking Age power centres along the Norwegian coast lack the thick cultural layers found at contemporary central places in southern Scandinavia, such as Ribe or Uppåkra, where craft production, cultic practices, trade, and elite activity all occurred within a contiguous area (Ellingsen & Sauvage, 2019; Hårdh, 2010; Sindbæk, 2023; Skre, 2018a).

Despite this suggested decentralisation, it is clear that a chain of havens existed along the Norwegian coast from at least the early eighth century (Maixner, 2021; Storli, 2007), allowing sailors like Ottar to break up long-range voyages into manageable legs during favourable weather windows, and thus travel safely and repeatedly between the Arctic and mainland Europe. The havens presented here may represent some of the missing links in this chain, but in many cases, they seem to have declined in importance at the end of the Viking Age. The establishment of new harbours and urban centres sponsored by political and religious authorities in the twelfth century (such as Bergen, Kong Øysteins havn, and Alstahaug), along with the development of larger, deeper-drafted, and less manoeuvrable ships built for transporting bulk goods (Bill, 2008), resulted in profound changes in seafaring networks after the Viking Age. Places such as Løkta, Avaldsnes, and Utstein seem to have played an increasingly marginal role (Berglund, 1996; Iversen, 2008; Skre, 2014). The inclusion of RSL data in this study allows us to explore bathymetric and topographical changes as additional causes behind these shifting mobility patterns. Thus, otherwise favourable havens such as Fosnavåg may have declined due to increasingly shallow approach channels, which made them inaccessible to the larger trading ships of the Late Viking Age and Middle Ages.

The large-scale transformations in political, economic, and religious life that underlay the changes in seafaring networks must be weighed against the remarkable degree of continuity in the Nordic clinker tradition. This continuity is perhaps best understood within the theoretical framework of interfacing and suspension, discussed recently by Frog (2020) in relation to the survival of pre-Christian cosmological elements in nineteenth-century kalevalaic poetry. According to these concepts, elements of ancient worldviews that are activated in everyday practice—such as the use of ancient names—and upon which everyday practices—such as navigation—depend, often survive despite broader social, economic, or ideological changes occurring around them. The concepts of interfacing and suspension hold great potential for future research into the Nordic clinker tradition, as they can be applied to ethnographic and ethnological evidence to seek out names, activities, and forms of thought that are at odds with the ideological and socioeconomic background of said evidence, and to identify practices that may have been inherited from a more distant past. Likely examples of interfacing and suspension within the Nordic clinker tradition include the system of proportional measurement employed in Åfjord and Nordland boatbuilding (Eldjárn & Godal, 1990b), and the execution of navigational choices based on collective perceptions of perceived risk (Jarrett, 2025b).

Conclusion

The scarcity of contemporary evidence for Viking Age seafaring has long hindered our understanding of maritime itineraries from this period. I have argued here that we are further impeded by a kind of 'mainland myopia', prevalent in both popular narratives and academic approaches. This has resulted in elements and phenomena of the seascape that were primarily approached and experienced through practice at sea (land- and seamarks, sailing routes, boats and ships) being studied through textual and terrestrial proxies, which are often chronologically, geographically, and ontologically removed from the maritime phenomena under study.

Here, I have followed an alternative approach, placing mobility, seafaring experience, and the preferences and perspectives of Viking Age sailors at the core of the investigation. Drawing upon long-term practical engagement with the descendant tradition of Åfjord boatbuilding and sailing, I have attempted to offer a qualitative understanding of Viking Age seafaring affordances, supported by digital reconstructions of Viking Age seascapes and a critical examination of relevant historical and archaeological evidence. Together, these data underlie a set of practice-based criteria for evaluating possible sailing routes and havens throughout the study region.

Due to the nature of the evidence, the methodology presented here can uncover potentials, but not realities. The list of possible Viking Age havens presented in Fig. 7 is intended as a working document, which can shape and be shaped by future archaeological surveys and excavations. The havens suggested here were likely intermediary stopping points on longer voyages, but as demonstrated successfully by Ilves (2012), their temporary use should not make them archaeologically invisible. Evidence for Viking Age maritime activity at these locations may include the remains of jetties and mooring posts, piles of ballast stones, boatbuilding materials, cooking pits and temporary shelters onshore, and artefacts relating to small-scale local exchange.

The combined use of experimental archaeology, maritime ethnology, and digital seascape reconstruction offers new perspectives on Viking Age maritime itineraries. The results of this approach suggest that, during the Viking Age, the primary axis of mobility and connectivity between the Arctic and the European mainland ran along the outer west coast of the Scandinavian Peninsula. This latitudinal axis connected the open sea routes across the North Sea and North Atlantic to the fjord routes leading into the Scandinavian interior. Along this thoroughfare, sailors gathered at sheltered and easily accessible locations between zones of risk, creating a chain of named havens in their shared maritime geography. At the end of the Viking Age, natural processes (isostatic rebound, silting), techno-economic change (developments in shipbuilding, a shift to bulk trade), and political decisions (the establishment of new harbours and towns under royal patronage) combined to create a more centralised network of trade and mobility, bound to a smaller number of nodes located farther from the outer coast.

It is hoped that the methods presented here may be applicable to other areas of the Viking world where research into seafaring itineraries is also ongoing, such as the Scottish Northern Isles (Sanmark & McLeod, 2024) and the west coast of Greenland (Ruiz-Puerta et al., 2024). Trial voyages through these seascapes may help trace likely Viking Age sailing routes and locate unidentified centres of maritime activity. On a broader scale, the attempt made here to give voice to maritime knowledge, skills, and experiences echoes other efforts within the humanities seeking to 'think from the ocean' (Steinberg & Peters, 2015, p. 261; see also Campbell, 2020). Creating space within academic research for practical, dynamic, and environmentally contingent knowledge and practices—such as traditional boatbuilding and sailing—will require critically adapting the conventional formats and frameworks of scientific knowledge production, but has the potential to provide a fuller and fairer understanding of our world's oceans and their inhabitants.

Appendix 1

Table 4 The 39 evaluated sites, along with corresponding geographical data and the criteria used to evaluate their potential use as Viking Age havens

haven name	maritime region	lat	long	RSL change since 1200 AD	RSL change since 800 AD	transition zone no (see Fig 7)	certainty	1. reachable in low vis from both N and S using bearings from named land/sea marks AND no open water > 2nm	2. Can fit >2 fyringer	3. multiple approach and departure routes within 2 nm give >140° courses	4. in transition zone	5. protection from SW swell	6. protection from SW wind OR landing place	7. view of the surrounding sea (especially to the SW) available within walking distance	8. access to fresh water
Avaldsnes	Karmsundet	59° 21' 16.65" N	005° 17' 43.23" E	-0.35	-0.98	16	1	x	x	x	x	x	x	x	x
Bjarkøya	Vågsfjorden	68° 59' 58.20" N	016° 32' 11.93" E	-0.54	-1.09	1	1	x	x	x	x	x	x	x	x
Steigbergvika (Engeløya)	Valsvær	67° 56' 14.71" N	014° 57' 47.23" E	-0.71	-1.47	3	1	x	x	x	x	x	x	x	x
Torget	Torgfjorden	65° 24' 46.47" N	012° 06' 11.92" E	-2.86	-4.58	6	1	x	x	x	x	x	x	x	x
Edøya	Trondheim sleia	63° 17' 15.24" N	008° 08' 08.86" E	-1.18	-2.28	9	2	x	x	x	x	x	x	x	x
Skumsnes-Fitjar	Fitjarvika	59° 57' 26.42" N	005° 17' 58.41" E	-0.72	-1.56	15	2	x	x	x	x	x	x	x	x
Kong Øysteins havn	Trondheim sfjord	63° 38' 45.48" N	009° 44' 16.9" E	-3.76	-2.12	8	3	x	x	x	x	0	0	0	x
Herdla	Herdlefjord	60° 34' 05.95" N	004° 57' 20.38" E	-0.75	-1.61	<Null>	3	x	x	x	0	x	x	x	0
Lygra	Lurefjorden	60° 41' 20.58" N	005° 07' 00.39" E	-0.69	-1.52	<Null>	3	x	x	x	0	x	0	x	x
Seim	Lurefjorden	60° 37' 11.24" N	005° 16' 02.58" E	-0.75	-1.61	<Null>	3	x	x	0	x	x	x	0	x
Tjøtta	Tjøttfjorden	65° 50' 15.41" N	012° 24' 24.10" E	-2.56	-4.12	<Null>	3	x	x	x	0	x	x	x	x
Ulstein	Ulsteinfjorden	62° 20' 37.23" N	005° 49' 25.19" E	-0.34	-0.96	12	3	x	x	0	x	x	x	x	x
Vågen-Alrekstad	Byfjorden	60° 23' 54.43" N	005° 18' 57.13" E	-0.75	-1.61	<Null>	3	x	x	0	0	x	x	x	x
Bjørnsund Nordøya	**Budadjupet**	**62° 53' 39.08" N**	**006° 49' 44.85" E**	**-0.49**	**-1.2**	**10**	**4**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**
Fosnavåg	**Holmefjorden**	**62° 20' 23.46" N**	**005° 38' 26.94" E**	**-0.13**	**-0.63**	**12**	**4**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**
Smørhamn	**Frøysjøen**	**61° 46' 11.40" N**	**004° 55' 58.16" E**	**-0.11**	**-0.62**	**13**	**4**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**
Storfosna	**Kråkvågfjord**	**63° 39' 32.43" N**	**009° 24' 03.91" E**	**-1.85**	**-3.33**	**8**	**4**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**
Bolga	Meløyvær	66° 47' 48.26" N	013° 12' 24.06" E	-1.62	-2.79	4	5	x	x	x	x	0	x	x	x
Giske	Valderhaug fjorden	62° 29' 49.84" N	006° 03' 06.18" E	-0.34	-0.96	11	5	x	x	x	x	0	x	x	x

Table 4 (continued)

Krågøyvågen (Kvitsøy)	Kvitsøyfjorden	59° 04' 01.59" N	005° 26' 10.01" E	-0.34	-0.95	17	5	0	x	x	x	x	x	x	?
Løkta	Stifjorden	66° 10' 35.67" N	012° 43' 44.67" E	-2.23	-3.64	5	5	x	x	x	x	x	x	x	x
Losnegard	Losnosen	61° 07' 29.68" N	005° 05' 50.82" E	-0.52	-1.27	14	5	x	x	x	x	x	x	x	x
Nærøya	Nærøysund	64° 50' 04.47" N	011° 12' 41.10" E	-2.82	-4.62	7	5	0	x	x	x	0	x	x	x
Ramstad	Arnøyfjorden	64° 44' 45.45" N	011° 13' 27.26" E	-0.72	-2.52	7	5	0	x	x	x	x	x	x	x
Stolmen	Stolmasundet	59° 59' 14.59" N	005° 05' 16.50" E	-0.72	-1.56	15	5	x	x	x	x	x	x	x	x
Utstein	Kvitsøyfjorden	59° 06' 04.99" N	005° 35' 26.14" E	-0.34	-0.95	17	5	0	x	x	x	x	x	x	x
Bjørnsund Sørøya	Budadjupet	62° 53' 11.83" N	006° 48' 36.83" E	-0.49	-1.2	10	6	x	x	x	x	x	x	x	?
Herøya	Røyresund	62° 18' 54.00" N	005° 40' 59.97" E	-0.13	-0.63	12	6	x	x	x	x	x	x	x	x
Kalvåg	Frøysjøen	61° 45' 53.54" N	004° 52' 29.11" E	-0.11	-0.62	13	6	x	x	x	x	x	x	x	x
Kråkvåg	Kråkvågfjord	63° 38' 20.03" N	009° 19' 57.39" E	-1.85	-3.33	8	6	x	x	x	x	x	x	x	?
Veklem	Trondheimsfjord	63° 41' 38.79" N	009° 39' 54.65" E	-2.22	-3.86	<Null>	6	x	x	x	x	x	x	x	x
Vestad	Harøyfjorden	62° 53' 24.69" N	006° 57' 56.04" E	-0.72	-1.56	10	6	x	x	x	x	x	x	x	x
Atløy-Sauesund	Granesund	61° 19' 44.49" N	005° 01' 56.23" E	-0.52	-1.27	<Null>	7	x	x	x	0	x	x	x	x
Borgund	Borgundfjorden	62° 27' 55.05" N	006° 14' 25.29" E	-0.55	-1.29	<Null>	7	x	x	x	0	x	x	0	x
Bud	Budadjupet	62° 54' 23.12" N	006° 54' 41.75" E	-0.72	-1.56	10	7	x	x	x	x	0	x	x	x
Hustad	Hustadvika	62° 57' 29.11" N	007° 05' 38.43" E	-0.72	-1.56	<Null>	7	x	x	x	0	x	x	x	x
Sandtorg	Sandtorgstraumen	68° 34' 02.54" N	016° 30' 54.56" E	-1.05	-1.93	<Null>	7	x	x	x	0	x	x	0	x
Storehovden	Frøysjøen	61° 45' 01.38" N	004° 50' 40.62" E	-0.11	-0.62	13	7	x	0	x	x	x	0	x	0
Tarva	Tarvafjord	63° 47' 39.41" N	009° 23' 46.81" E	-1.72	-3.13	<Null>	7	0	x	x	0	x	x	x	x

Appendix 2

Table 5 The 39 evaluated sites, along with the archaeological and historical evidence related to each site, and the main sources of evidence used

haven name	archaeological evidence for pre-VA IA activity	archaeological evidence for VA activity	archaeological evidence for VA maritime activity	late VA/ high medieval church	docu/arch evidence for VA/ medieval political centre	medieval/ early modern trading place	used as an anchorage according to MA sources	along or within 3 nm of *leið*	indicated/mentioned as anchorage on maps/charts/ descriptions from before 1850	sources
Atløy-Sauesund	0	0	0	0	x	possible	x	x	0	Hagen 2019; Iversen 2008; Sturlason 1990; Kulturminnesøk
Avaldsnes	x	x	x	x	x	x	x	x	x	Bauer & Østmo 2013; Iversen 2008, 2020; Skre 2014, 2018; Sturlason 1990
Bjarkøya	x	x	x	0	x	0	x	x	0	Storli 2001; Sturlason 1990; Wickler 2021, 2023
Bjørnsund Nordøya	**0**	**x (stray find)**	**0**	**0**	**0**	**0**	**0**	**x**	**x**	**Löwenorn 1975**
Bjørnsund Sørøya	0	0	0	0	0	0	0	x	x	Löwenorn 1975
Bolga	x	x	0	0	0	0	0	x	0	Kulturminnesøk; Østmo 2020
Borgund	x	x	x	x	x	x	0	x	x	Hansen 2017; Larsen 2005
Bud	possible	x	0	0	0	x	0	x	0	Bøe 2009; Østmoe & Fretheim 2022
Edøya	x	x	x	x	possible	0	x	x	x	Dahle 2021; Gabler et al 2020; Kruse 2020
Fosnavåg	**x**	**0**	**0**	**0**	**0**	**0**	**0**	**x**	**0**	**Knutzen 2007; Ottesen 2010; Rabben 1962; Shetelig & Johannessen 1929**
Giske	x	x	0	x	x	0	0	x	x	Hatling 2012; Kruse 2020
Herdla	x	0	0	0	x	0	0	x	x	Iversen 2008, 2020; Skre 2014, 2018
Herøya	x	0	0	x	x	0	x	x	x	Sturlason 1990
Hustad	x	x	0	x	x	0	x	x	0	Brendalsmo 2003; Bøe 2009; Skre 2018; Sturlason 1990
Kalvåg	0	0	0	0	0	0	0	x	0	Kulturminnesøk; Thue 1995
Kong Øysteins havn	0	x	x	x	0	0	x	x	x	Berglund & Solem 2017; Brendalsmo & Eriksson 2016; Christophersen 1991
Krågøyvågen (Kvitsøy)	0	possible	possible	x	0	0	x	x	x	Löwenörn 1975; Wróblewski 2017
Kråkvåg	0	0	0	0	0	0	x	x	0	Maixner 2020; Morcken 1978; Storm 1880; Sturlason 1990
Løkta	x	x (stray find)	0	0	0	x	0	x	x	Berglund 1996; Ytreberg 1941
Losnegard	0	0	0	0	0	x	0	x	0	Kruse 2020; Kulturminnesøk; Wamers 1998
Lygra	x	x	0	x	x	0	0	x	0	Iversen 2020; Kulturminnesøk
Nærøya	x	0	0	x	x	x	0	x	x	Brendalsmo 2003; Solem et al 2023; Sturlason 1990
Ramstad	x	x	0	0	x	0	x	x	0	Sturlason 1990; Maixner 2021; Kulturminnesøk
Sandtorg	x	x	x	0	x	x	0	x	x	Krokmyrdal 2020
Seim	x	x	0	0	x	0	0	x	0	Iversen 2008, 2020; Skre 2014, 2018; Sturlason 1990
Skumsnes-Fitjar	possible	x	possible	x	x	x	x	x	0	Iversen 2008, 2020; Skre 2014, 2018; Sturlason 1990; Kulturminnesøk; Diinhoff pers comm 2025
Smørhamn	**0**	**0**	**0**	**0**	**0**	**x**	**0**	**x**	**x**	**Löwenörn 1975**
Steigbergvika (Engeløya)	x	x	x	x	x	x	x	x	x	Sjövold 1974; Sturlason 1990; Stylegar & Grimm 2005
Stolmen	0	x	0	0	0	x	x	x	0	Gertz 1922; Kulturminnesøk
Storehovden	possible	possible	0	0	0	0	0	x	0	Kulturminnesøk
Storfosna	**x**	**x (stray find)**	**0**	**x**	**x**	**0**	**x**	**x**	**x**	**Brendalsmo & Eriksson 2016; Maixner 2020; Østmo 2020**
Tarva	possible	possible	0	0	0	0	0	x	0	Nilsen 2011; Kulturminnesøk
Tjøtta	x	x	x	0	x	0	x	x	0	Berglund 1996; Storli 2001; Sturlason 1990
Torget	x	x	x	0	x	0	0	x	x	Berglund 1996
Ulstein	x	x	0	x	x	x	x (or Hjørunga våg)	x	0	Ringstad 1992; Knutzen 2007; Ottesen 2010; Kulturminnesøk
Utstein	x	x	possible	0	x	possible	0	x	x	Hillesland & Pedersen 2024; Sturlason 1990; Iversen 2008, 2020; Skre 2018
Vågen-Alrekstad	x	x	0		x	x	x	x	x	Hansen 2005; Iversen 2008, 2020; Skre 2014, 2018; Sturlason 1990
Veklem	x	x	0	x	x	0	0	x	x	Berglund & Solem 2017; Ystgaard 2019
Vestad	0	0	0	0	0	0	0	x	x	Kulturminnesøk

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Declarations

Conflict of Interest The author declares no conflict of interest.

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Article 4

ANTHROPOLOGY

Greenland Norse walrus exploitation deep into the Arctic

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Walrus ivory was a prized commodity in medieval Europe and was supplied by Norse intermediaries who expanded across the North Atlantic, establishing settlements in Iceland and Greenland. However, the precise sources of the traded ivory have long remained unclear, raising important questions about the sustainability of commercial walrus harvesting, the extent to which Greenland Norse were able to continue mounting their own long-range hunting expeditions, and the degree to which they relied on trading ivory with the various Arctic Indigenous peoples that they were starting to encounter. We use high-resolution genomic sourcing methods to track walrus artifacts back to specific hunting grounds, demonstrating that Greenland Norse obtained ivory from High Arctic waters, especially the North Water Polynya, and possibly from the interior Canadian Arctic. These results substantially expand the assumed range of Greenland Norse ivory harvesting activities and support intriguing archaeological evidence for substantive interactions with Thule Inuit, plus possible encounters with Tuniit (Late Dorset Pre-Inuit).

INTRODUCTION

The Arctic experienced the dispersal and contraction of several major cultural groups during the Medieval Warm Period (ca. 950 to 1250 CE). The maritime-adapted Thule Inuit expanded eastward from Alaska across Arctic Canada (Inuit Nunangat) and into Greenland (Kalaallit Nunaat) as early as the 13th century CE, resulting in encounters, displacement, and eventual replacement of the Tuniit (Late Dorset Pre-Inuit) culture (*1*–*5*). Over the same period, groups with primary cultural and genealogical ties to Iceland and Scandinavia (collectively defined here as the Greenland Norse) settled in southwestern Greenland, explored surrounding regions, and established an export-led economy that supplied walrus ivory back to trade centers in Europe (*3*–*6*). Key historical questions about the Greenland Norse (ca. 985 to 1450 CE) revolve around (i) the nature and extent of Norse encounters with the Tuniit and Thule Inuit, (ii) whether organized trade in walrus ivory emerged between groups, and (iii) if so, where, when, and why such interactions occurred. These issues are important to resolve, not least because meetings between the European Norse and Indigenous North Americans represent the first "full circle" reconnection of the two major branches of Pleistocene human dispersals out of Africa (*1*, *7*–*9*). To address these questions, we genetically sourced 31 cultural artifacts made from Atlantic walrus (*Odobenus rosmarus rosmarus*) back to specific Arctic hunting grounds. These objects were central to the Norse ivory trade and were recovered from Greenland Norse settlements and several major European trade hubs (see table S1). The results were contextualized with experimental insights into Greenland Norse seafaring capabilities (*10*–*16*). Our goal was to evaluate the extent to which the Greenland Norse obtained ivory via direct hunting versus exchange with Tuniit or Thule Inuit groups and the likely locations and timings of the walrus hunts and possible intercultural encounters.

From the late 9th to the mid-14th century CE, walrus ivory was exchanged into European trade and production centers via Norse intermediaries who operated across the North Atlantic. The opening phases of commercial Norse walrus hunting were probably unsustainable, starting in Fennoscandia, then spreading to Iceland in the early ninth century, where the local walrus population was eventually extirpated; the Norse then expanded into Greenland and established permanent settlements (*17*–*19*). Here, the Greenland Norse communities (ca. 985 to 1450 CE) gained a virtual monopoly on ivory supplies into Europe from the early 12th to the mid-14th century, with exports into Europe peaking around 1250 CE (*17*, *20*). However, it is unclear whether all the ivory passing through the Greenland Norse settlements was directly hunted by Norse, or partly, or even entirely, exchanged with Arctic Indigenous groups, as both Tuniit (*21*) and the expanding Thule Inuit (*22*) were also present in adjacent areas of Arctic Canada and northwest Greenland over the same broad historical interval. The small Greenland Norse communities may have struggled to mount long-range hunting expeditions, making trade with other Arctic hunting groups an attractive alternative. Conversely, the high commercial value of ivory potentially

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encouraged the Greenland Norse to prioritize walrus hunting over other branches of their economy, including farming (*23*). The Greenland Norse were certainly aware of Thule Inuit and Tuniit groups and may have used initial encounters to explore opportunities for more formalized ivory exchange, though what the Norse could offer in return remains unclear (*24*, *25*). Some Greenland Norse contact with the Tuniit does seem likely despite the scarcity and ambiguity of archaeological evidence, especially considering the 300 years of temporal overlap in the Baffin Bay and Davis Strait area (see Supplementary Text). Indications of possible Norse-Tuniit encounters were also discovered in the Smith Sound region, located between Ellesmere Island and Northwest Greenland, including a fragment of a brass pot recovered from a reliably dated Tuniit context (*26*). There is more substantive archaeological evidence for considerable spatiotemporal overlap between Thule Inuit and Greenland Norse, including indications that the expanding Thule Inuit may eventually have hunted marine mammals in Disko Bay (*26*) and occupied seasonal sites as far south as Sandhavn, located quite close to the Eastern Settlement of the Greenland Norse (*27*).

To better understand the Arctic dimensions of the Greenland Norse ivory harvesting and trade networks, including the location and timing of intercultural encounters, we defined three contrasting Norse exploitation scenarios. These were evaluated empirically with high-resolution genomic sourcing methods to understand changing patterns of Norse walrus exploitation: scenario 1: Direct Norse Exploitation—written sources mention annual summer walrus hunting expeditions to the *Norðrsetur*, an ill-defined coastal area located north of the Western Settlement (*5*, *28*–*31*). While there is no direct archaeological evidence that the Greenland Norse possessed specialized walrus hunting equipment, they certainly had directly relevant hunting experience from Iceland and Fennoscandia, and probably used lances to target walrus at historically documented haul-out sites (*25*, *32*–*34*); scenario 2: Norse-Indigenous Trade—historical records confirm that the Greenland Norse swiftly acquired knowledge of the wider regional geography, including the presence of other cultural groups. While initial encounters with Tuniit or Thule Inuit may have involved avoidance and occasional skirmishes, formalized ivory trading could have emerged thereafter (*11*, *13*); scenario 3: Evolving Strategies—the Norse may have hunted local walrus upon arriving in Greenland, but were then forced to visit ever more distant hunting grounds as local stocks were depleted. Such voyages would have increased the likelihood of encounters, especially if other Arctic Indigenous groups were hunting similar resources in the same areas, perhaps encouraging a shift from direct Norse acquisition to some form of exchange relations. If more formalized trading relations did somehow emerge, they would represent some of the earliest steps toward circumpolar "globalization," a process that would eventually define later historical periods, including expansive culture contacts, intensive trade networks, and the market-driven exploitation of the Arctic's natural resources by distant polities and urban consumption centers.

RESULTS

Ancient DNA analyses support sourcing of walrus artifacts back to specific hunting grounds

We used ancient DNA analyses to reconstruct how the Greenland Norse harvested walrus ivory from different Arctic hunting grounds. Previous isotopic and mitogenomic sourcing efforts have identified a chronological shift in Norse walrus exploitation across the North Atlantic. The process starts with a focus on eastern stocks located closer to Fennoscandian waters, and then shifts over to western walrus populations, although the role of more specific hunting grounds remains uncertain (*17*–*19*). To resolve this gap in knowledge, we used Bayesian phylogeographic analyses of mitogenomes from 100 biological walrus samples and 31 dated cultural artifacts, allowing us to assign each traded walrus artifact back to a specific walrus stock (Fig. 1; see also Materials and Methods). The biological walrus samples were obtained from different Arctic locations and relevant chronological intervals, representing the genetic diversity and walrus stock locations at the time of the Greenland Norse settlements (ca. 985 to 1450 CE) (see table S1). The targeting of both ancient and historical samples to build the phylogeny significantly improves the resolution of previous studies and also resolves concerns that walrus stocks may have shifted or merged due to later habitat disruptions and industrial-scale harvesting (*17*). The 31 walrus artifacts were all recovered from Norse sites in Europe [see table S2; data published previously, (*17*)]. In general, the Greenland Norse shipped walrus ivory out to European markets in the form of tusks left attached to the front portions of the walrus skull, i.e., the rostrum. We assume that these "packages" were broken open relatively soon after arriving into European workshops to extract the precious ivory and produce the valuable objects required for elite consumption and display. In this way, we assume that the distinctive bone production waste serves as a direct proxy for wider ivory trade networks. This approach enabled us to genetically track the Greenland Norse ivory trade networks from European centers all the way back to specific Arctic hunting grounds and also to examine the extent to which spatial patterns of Norse walrus exploitation had shifted over time (Fig. 2).

Early Norse ivory exploitation targeted local stocks

To understand the chronology of walrus exploitation, we divide the history of Norse Greenland (ca 985 to 1450 CE) into an "Early Period" before 1120 CE and a "Late Period" after this date, following Star *et al.* (*17*) (Fig. 2; see Materials and Methods). We sourced 11 artifacts assigned chronologically to the Early Period. Our results indicate that the Norse initially exploited stocks closest to their settlement areas: first in Iceland and East Greenland (or Greenland Strait, north of Iceland), and then in the Disko Bay region after the Norse settlements in Greenland had been established (Fig. 2). Three objects recovered from Sigtuna, Sweden, originated in the now extinct Icelandic stock (clade II, WLR063) and the East Greenland stock (clade III, WLR064 and WLR065), while one walrus artifact from Dublin, Ireland, can be traced to the West Greenland stock (clade IV, WLR029). Similarly, two artifacts from Garðar (Igaliku) in the Eastern Settlement of Norse Greenland also appear to originate from the local West Greenland walrus stock (clade IV, WLR69 and WLR70). Two artifacts (from Dublin, Ireland, and Garðar, Greenland) are both assigned to the Early Period but appear to be made from ivory originating in the distant North Water Polynya, which is located between Northwest Greenland and Northeast Canada (clade V, WLR030 and WLR072). Last, and with slightly lower phylogenetic support, two further Early Period objects recovered from Trondheim, Norway, and Garðar, Greenland, can be sourced to either the Foxe Basin or to the West Greenland stock (clade I, WLR038 and clade VI, WLR071). Overall, our results from the Early Period confirm that walrus exploitation, including

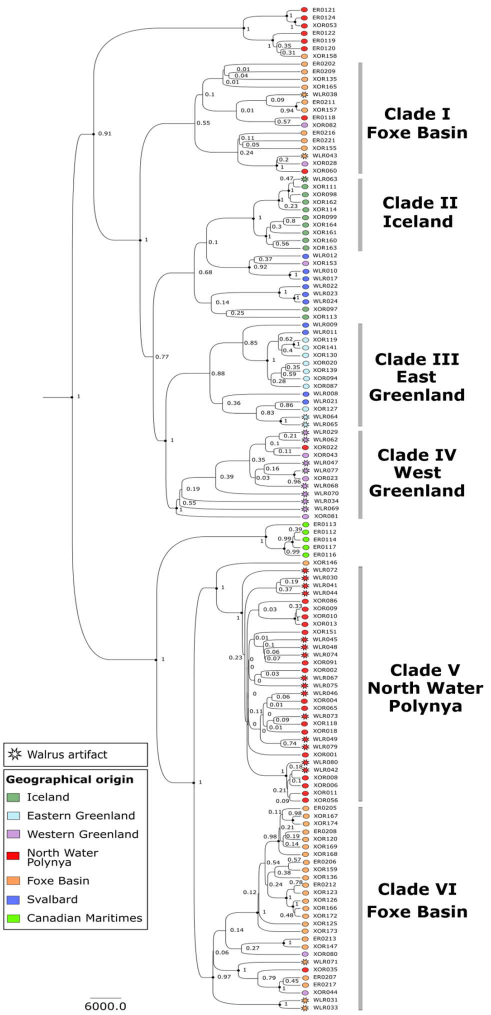

Fig. 1. Genetic sourcing of traded artifacts back to specific walrus stocks. The Bayesian phylogeny includes walrus mitogenomes from 100 biological samples and 31 cultural artifacts. These biological samples were obtained from a wide range of geographic locations and chronological periods to reconstruct genetic diversity and stock locations at the time of the Norse Greenland settlements. Our results confirm that distinct walrus stocks were located in specific locations (Fig. 2 and table S1). This combined approach enabled the walrus artifacts recovered from trade and production centers in Europe and the main Greenland Norse settlements to be genetically sourced back to specific walrus stocks and particular Arctic hunting grounds (Fig. 2 and table S2). The phylogeny is rooted against the Pacific walrus (not shown). Black circles denote nodes with >90% posterior support. Figure: E.J.R.-P. and coauthors.

the export of ivory back to distant European consumers, supported the economy of the Greenland Norse communities from their establishment. Last, these initial Greenland Norse harvesting patterns appear to have formed a logical stepwise geographic expansion of walrus exploitation into new areas, probably using similar hunting strategies. Before this, Norse harvesting efforts had focused on Fennoscandia, and then shifted out to Icelandic waters until local stocks were overexploited (*11*, *19*, *23*, *25*, *35*, *36*).

Greenland Norse obtained walrus ivory from High Arctic hunting grounds

We sourced 20 walrus artifacts assigned chronologically to the Late Period (Fig. 2). Most of these date to the mid-12th to late 13th century, an interval that corresponds to both major socio-political transformations within Scandinavia plus the peaking of demand for walrus ivory across European trade networks (*20*, *36*, *37*). Our results indicate a major geographic shift in walrus exploitation patterns: As the Greenland Norse sought to maintain their supply of ivory to European markets, they appear to have relied increasingly on harvesting ivory from more distant hunting grounds located much deeper into the High Arctic. We sourced 14 artifacts—close to half of those in our study—back to the North Water Polynya walrus stock (clade V), which centers around the marine-ecological "hot spot" of the Pikialasorsuaq (*38*). In addition, we more tentatively sourced three further artifacts back to the Foxe Basin stock (allocated to clades I and VI: WLR031 and WLR033; London, WLR043; Bergen). To exploit these much more distant stocks, the Greenland Norse must either have been mounting their own long-range hunting expeditions from their main base settlements, voyaging deep into High Arctic waters, or were meeting and trading with Arctic Indigenous groups who did the primary hunting of these more distant walrus stocks. However, it also appears that even in the Late Period, the Greenland Norse were still able to harvest at least some ivory quite close to their main settlements, with two artifacts from Schleswig (WLR068) and Kyiv (WLR077) originating in the West Greenland walrus stock (clade IV). Last, four further artifacts assumed to date to the general interval of the Greenland Norse settlements (ca. 985 to 1450 CE), albeit with some chronological uncertainties (see table S2), were also sourced: Two originated in the West Greenland stock (clade IV, WLR047 and WLR068), and two originated in the North Water Polynya stock (clade V, WLR046 and WLR048).

Greenland Norse seafaring capacities potentially supported High Arctic expeditions

The substantial geographic expansion of walrus ivory harvesting efforts in the Late Period raises a central question: Did the Greenland Norse communities have the seafaring capabilities and motivations required to access the more distant High Arctic walrus stocks located at the North Water Polynya (clade V) and Foxe Basin (clades I and VI)? Greenland Norse had limited seasonal windows available for summer hunting expeditions, probably no more than 10 weeks (see Supplementary Text). Our research suggests that two distinct vessel types were available at the main Norse settlements in southwest Greenland: (i) smaller six-oared boats with a crew of 6 or 7 (Fig. 3 and fig. S1) and (ii) larger "expeditionary" ships carrying crews of 15 to 40 (Fig. 4 and fig. S2). The latter vessels had been used on exploration voyages to Greenland and North America and were owned by wealthier farmers or sponsored by social elites (*25*, *29*, *31*). We estimated sailing times and handling capabilities of

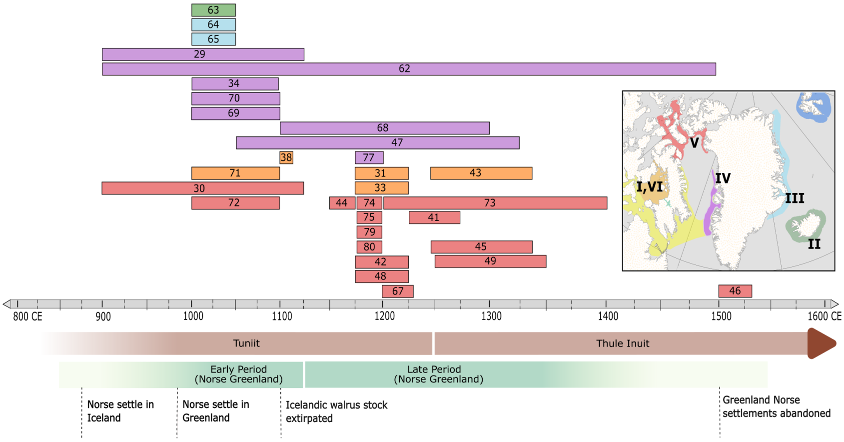

Fig. 2. Patterns of Greenland Norse walrus exploitation shifted over time. Dated walrus artifacts sourced to different Arctic hunting grounds ($n = 31$). Artifacts were allocated chronologically to either the Early Period or Late Period of Norse Greenland (before/after 1120 CE), plus allocated more specific date ranges if available (see table S2). Numbered bands are individual artifacts (for full provenance information, see table S2, using WLR0 + sample number); the colors match specific walrus stocks in the inset map (right). The main trends in exploitation indicate the following: (i) initial Norse harvesting focused on stocks near Iceland (II and III); (ii) Early Period Greenland Norse mainly harvested the local stock (IV) located near to their main settlements; and (iii) the increasing importance of High Arctic walrus stocks in the Late Period, especially the North Water Polynya (V), and also Foxe Basin (I and VI). Last, the following should also be noted (iv) even in the Early Period, Greenland Norse were also acquiring some ivory from distant walrus stocks (I, VI, and V); and (v) Late Period harvesting continued at the local stock (IV). The expanding geographic range of Greenland Norse walrus harvesting likely led to initial Tuniit encounters in several different areas; more definitive interactions with expanding Thule Inuit populations probably focused on the North Water Polynya (V). No artifacts were sourced to the Canadian Maritimes or to Svalbard (see table S2 and the main text). Figure: E.J.R.-P. and coauthors.

Fig. 3. Experimental insights into Greenland Norse seafaring capabilities: example of a "smaller" vessel (with oars and sail). This is a Norwegian fyring during sea trials. Note the very limited space for cargo (Roskilde Fjord, Denmark, June 2023). Photo: G.J.

Fig. 4. Experimental insights into Greenland Norse seafaring capabilities: example of a larger expeditionary sailing vessel. This is a Norwegian fembøring, a direct descendant of the Norse clinker tradition used in Greenland (Vestfjord, northern Norway, May 2022). Only these larger sailing ships, owned and sponsored by richer farmers and elites, would have been capable of reaching the North Water Polynya during single-summer expeditions. One major risk was becoming trapped in the expanding late-summer pack ice, forcing the crew to overwinter en route, as evidenced by the Kingittorsuaq runestone (Fig. 5) carved during the Spring, and dating to ca. 1250 to 1300 CE (see Supplementary Text). Photo: G.J.

these two different classes of vessel using documentary sources and experimental sea trials (see Supplementary Text). We also reconstructed likely sailing routes to different walrus stocks and identified possible stopping points and overwintering stations (Fig. 5 and table S3). The combined results indicate that the smaller six-oared boats could have been rowed from the Western Settlement as far as the Qeqertarsuup Tunua (Disko Bay). However, it was also clear that longer-range expeditions to the Pikialasorsuaq (North Water Polynya) could only have been possible with the larger expeditionary sailing ships capable of making the 2- to 3-day crossing from Kitsissorsuit (Edderfugleøer) to Innaanganeq (Cape York). Deploying the larger ships, the Qeqertarsuup Tunua (Disko Bay) region could probably have been reached within 6 to 10 days. However, sailing on as far as the Pikialasorsuaq (North Water Polynya) hunting grounds (clade V) would have taken approximately 30 days in total. We estimate that the return journey would have been shorter due to more favorable weather conditions later in the summer, taking approximately 15 days (table S3). Assuming Norse expeditions departed the Western Settlement in early to mid-June, they would have reached the Pikialasorsuaq (North Water Polynya) in mid-July, giving the crews 2 to 4 weeks to acquire ivory, before departing back to the Norse settlements, and arriving home in late August as the autumn storms closed in. As the Norse lacked Thule Inuit toggling-harpoon technology to hunt walrus in the open sea, it is likely that the animals were targeted at haul-out sites and then killed with lances, with several hundred animals possibly harvested and processed during each expedition (*6*, *25*, *39*–*41*) (see Supplementary Text). Depending on the precise size of Norse crews and their vessels, the harvesting process might have been completed within one sustained session at a single haul-out site. More likely, the crews undertook multiple short-range harvesting trips from a more central base camp out to surrounding walrus haul-out sites. Some archaeological features, including the "Bear Trap" (fig. S3), hint at complex mobility strategies involving the construction of central storage facilities (*25*, *32*). The hide and tusks of a large adult walrus weigh approximately 50 kg (*25*). Depending on whether crews prioritized ivory, or a combination of tusks and hides, a six-oared boat with a cargo capacity of 1 ton could only transport approximately 20 sets of hides and tusks, while one of the larger vessels could transport between 85 and 400 sets, assuming a cargo capacity range of 4.5 to 21 tons (*29*, *42*, *43*) (see Supplementary Text).

DISCUSSION

Application of higher-resolution genetic sourcing methods enabled us to track the Greenland Norse ivory trade back to much more specific Arctic hunting grounds, advancing previous studies (*17*, *19*, *44*). Our results confirm that walrus exploitation was central to the Norse expansion into the Northwest Atlantic, likely encouraging initial exploration and then more permanent settlement of Iceland and Greenland (*20*). Walrus exploitation therefore expanded stepwise into new areas, starting in Fennoscandia, then moving to Iceland, East Greenland, West Greenland, and lastly penetrating the High Arctic. This pattern potentially signals an ecological "domino model" in which the European demand drove relentless overexploitation of more accessible walrus stocks, pushing Norse hunters into ever more remote areas in their search for valuable ivory. While our overall findings confirm this general pattern, we found no evidence of Norse walrus exploitation reaching as far as the waters around Svalbard (Figs. 2 and 6; see Materials and Methods); the primary vector of Norse expansion was into the Northwest Atlantic. In the Early Period, the Greenland Norse mainly targeted local stocks, but by the Late Period, primary harvesting appears to have shifted up to the High Arctic, with efforts focusing on the Pikialasorsuaq (North Water Polynya), and possibly expanding into the waters of the Foxe Basin (Fig. 6).

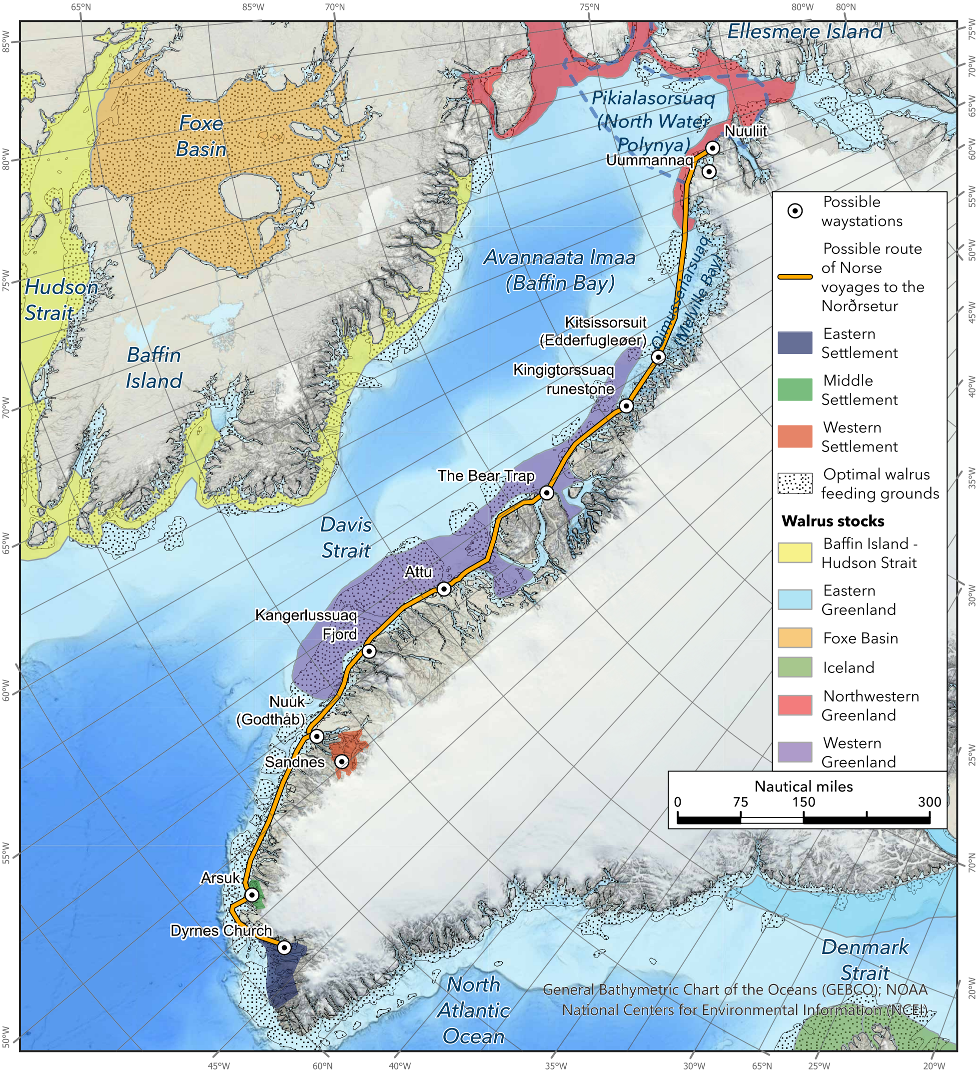

Fig. 5. Postulated south-north maritime corridor linking the permanent Greenland Norse settlements into Northwest Greenland and High Arctic Canada. This schematic map depicts the location of the main Norse settlements, primary navigation routes, and likely stopping points in relation to major walrus hunting grounds (for further details, see Supplementary Text). Map: G.J.

Returning to our three exploitation scenarios, our combined evidence points to scenario 1 (Direct Norse Harvesting) as the dominant pattern of exploitation in the Early Period. Most artifacts from this period source back to more accessible stocks located within easy reach of the main Icelandic and Greenland Norse settlements. Moreover, both stock locations are far removed from known areas of Tuniit and Thule Inuit settlement, making scenario 2 (Norse-Indigenous Trade) unlikely. However, sporadic encounters and some opportunistic exchange may have occurred during the initial Greenland Norse explorations mentioned above (*45*), possibly involving the Tuniit, whose communities were more widely distributed at this time. These very earliest full-circle encounters between the Norse and Tuniit potentially created an extended "frontier" of initial European-Indigenous encounters, and may predate those associated with the short-lived L'Anse aux Meadows site, which was established by expanding Norse groups in the Canadian Maritimes (Fig. 6, see Supplementary Text). Walrus populations were also located in this area, though none of our artifacts were sourced back to this particular stock (see Fig. 1 and table S2), perhaps suggesting that other factors motivated Norse explorations into this region (see table S2).

In contrast, our results confirm that the Pikialasorsuaq (North Water Polynya) had emerged by the Late Period as the primary location for Greenland Norse ivory harvesting: Tuniit communities operated here until at least 1200 CE, with Thule Inuit groups arriving slightly later. Norse (or Norse-inspired) material culture then appears in Thule Inuit sites dating to the 13th to 14th century CE, with some artifacts recovered from occupations located deep into the Canadian High Arctic (*1*, *12*, *26*, *45*–*47*). One possibility is that Tuniit or Thule Inuit were harvesting ivory at the North Water Polynya and then voyaging south to trade. However, this seems unlikely as Greenland Norse communities were short of metal and other materials that could motivate regular long-distance trading visits by Arctic Indigenous peoples (*25*). In contrast, it was the Greenland Norse who had the greatest incentive to voyage deep into the High Arctic in search of ivory; they also had the seafaring capabilities, and emergent socio-political dynamics may have led elites in Greenland and Norway to sponsor such longer-range harvesting expeditions (see Supplementary Text). Despite these motivations, the Greenland Norse visits to High Arctic hunting grounds were probably occasional rather than annual, especially after the onset of deteriorating weather and sea-ice conditions in the 13th century (*48*). Our research identified narrow seasonal windows, with the longer-range expeditions fraught with risk, generating further task-scheduling conflicts if crews failed to return by the vital hay-making season that provided winter fodder for animals back at the main

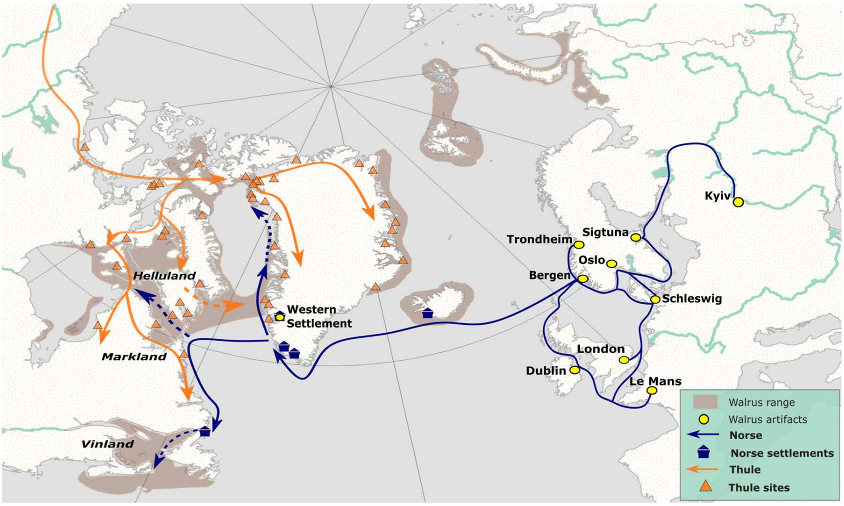

Fig. 6. Early circumpolar globalization: schematic reconstruction of the Arctic Ivory Road. Shifting walrus exploitation patterns suggest a "domino" model: the Norse systematically depleted more accessible walrus stocks to supply the booming European ivory trade; the search for fresh sources of ivory was one factor driving Norse expansion into the Northwest Atlantic, including initial colonization of Iceland, and the establishment of Norse settlements in Southwest Greenland. Exploration of coastal North America (Helluland, Markland, and Vinland) by the Norse likely resulted in initial full-circle encounters with various Indigenous North American groups across a broad "contact" frontier running from the Canadian Maritimes up to the High Arctic. However, most ivory in the Early Period (pre 1120 CE) was coming from the local stock in West Greenland (IV). By the Late Period (after 1120 CE), Greenland Norse communities were mounting regular long-range expeditions to the High Arctic to harvest ivory from the North Water Polynya (Stock V), either via direct hunting, or intercultural trade and exchange, possibly with Tuniit groups, and more probably with the Thule Inuit who were expanding across the Canadian Arctic and into this area. These routine intercultural interactions at the North Water Polynya peoples signal the onset of early circumpolar globalization, with numerous Norse artifacts recovered from Thule Inuit sites dating to this interval. The Greenland Norse may also have ventured deeper into the interior Canadian Arctic waters, or more likely hunted walrus and traded ivory with Arctic Indigenous peoples at intermediate locations (Stocks I,VI). With elite consumption trends in remote European urban centers driving these early full-circle global interactions, our preliminary reconstructions of the emerging Arctic Ivory Road bear interesting parallels with Silk Road that spanned Medieval Eurasia during the same period. Figure: E.J.R.-P. and coauthors.

Greenland Norse settlements (*49*). Despite these challenges, one successful expedition every few years, involving a handful of ships and a few weeks of intense effort, could easily generate the ivory exports of the volumes recorded in historical sources (see Supplementary Text).

We reach the conclusion that scenario 3 (Evolving Strategies) captures the main exploitation patterns in the Late Period, as the combined evidence indicates that Tuniit, Thule Inuit, and Norse groups were all operating around the Pikialasorsuaq (North Water Polynya), targeting the same resources in the same historical period, making routine encounters almost certain and some degree of formalized exchange increasingly likely. Whatever the precise character of these interactions, the Pikialasorsuaq (North Water Polynya) can now be identified as the most likely arena for the earliest phases of circumpolar globalization (Fig. 6). The extent to which the Greenland Norse voyaged to Baffin Island, up the Hudson Strait or deeper into Foxe Basin remains equivocal given adverse ocean currents and extensive sea ice during the main Norse sailing season, though hunting or trading possibly occurred at more accessible locations (see Supplementary Text). More generally, our results contribute fresh empirical insights to long-running debates about the likely location, timing, and motivations of early interaction between European Norse and Indigenous North American communities in the High Arctic. They confirm that elite consumption patterns in Europe fueled an insatiable demand for walrus ivory, and that provisioning these markets emerged as a major driving force that substantially shaped the trajectory of Greenland Norse interactions with Arctic Indigenous peoples.

Overall, our findings indicate that the major axis of walrus exploitation likely ran along a south-north "maritime corridor" linking Greenland Norse settlements to Northwest Greenland and into High Arctic Canada (Fig. 6). While all these conclusions remain tentative, they highlight the wider potential of integrating higher-resolution biomolecular sourcing methods with improved knowledge of Norse seafaring capabilities. Much larger assemblages of directly dated walrus artifacts should now be genetically sourced, and the emerging results may shift or further reinforce the preliminary interpretations presented here. Our study also highlights specific High Arctic regions requiring further archaeological fieldwork to better understand how different cultural groups operated and the extent to which they interacted. In particular, the traditional "Eurocentric" focus on Greenland Norse walrus exploitation should also be rebalanced with improved understanding of Tuniit and Thule Inuit mobility strategies, which may also have shifted over time as Greenland Norse hunting efforts and trading opportunities started to encroach (Fig. 6). Last, the methods used in this study highlight enormous potentials for a more comprehensive and truly circumpolar sourcing program to reconstruct the causes, conditions, and deeper ecological consequences of Arctic resource exploitation across different cultural and historical contexts.

MATERIALS AND METHODS

Materials: Sample provenance

See tables S1 and S2 for full details of sample provenance.

Methods: Chronological inference

This paper reconstructs strategies of Greenland Norse (ca. 985 to 1450 CE) walrus exploitation to (i) understand which Arctic hunting grounds were used to supply ivory to markets and production centers in Europe, and (ii) determine whether these patterns changed over time. Resolving these questions requires working with three different kinds of chronological inference:

First, to source traded walrus artifacts back to specific Arctic hunting grounds, we needed to genetically match each "cultural" artifact back to the unique "biological" walrus stocks that had existed in specific locations during the period of Greenland Norse exploitation (ca. 950 to 1450 CE). While modern (or recent historical) biological samples can be used to reconstruct the modern genetic diversity of North Atlantic walrus stocks, the inherent risk is that current stocks and geographic distributions are a legacy of the more recent industrial-scale walrus exploitation. These devastating impacts and ongoing disturbances are likely to have led to the displacement, merging, separation, replacement, or extirpation of local walrus stocks, creating major uncertainties about the veracity of sourcing Greenland Norse artifacts on the basis of modern genetic diversity. To resolve these problems, we needed to reconstruct the contemporary genetic diversity and stock distributions during the period of Greenland Norse walrus exploitation. This required analysis of the ancient and historical mitogenome DNA of biological walrus samples ($n = 100$) obtained from a wide range of geographic locations, and also across relevant time periods, including areas where walrus stocks are known to have been extirpated by human pressures, including Iceland and the Canadian Maritimes (see table S1). To obtain these samples, we targeted archaeological contexts, sub-fossil geological finds, and other relevant collections. Samples are allocated to general chronological (or culture-historical) time periods, with specific dates provided where available. In this way, the precise calendar age of a particular walrus sample is less important; the main requirement was to target biological samples with sufficient chronological depth and appropriate geographic coverage. On the basis of these principles, our high-resolution phylogeography of walrus stocks (Fig. 1) reconstructs the genetic diversity and stock locations assumed to have existed at the time of Greenland Norse walrus exploitation (Fig. 2).

Second, we needed to genetically track the cultural artifacts back to these specific walrus stocks to understand Greenland Norse exploitation patterns, and whether these had changed over time (i.e., different hunting grounds used at different times). To resolve these questions, three chronological issues arise: (i) we needed to identify any likely time lags between walrus harvesting (in the Arctic) and the deposition of the cultural artifacts at trade and production sites (in Europe); (ii) to understand exploitation patterns over time, we needed to allocate each walrus artifact to general time periods in the history of the Greenland Norse; and, last, (iii) where possible, we needed to generate more specific age ranges for each artifact. We dealt with each of these issues in turn: (i) Identifying time lags (between hunting, shipment, and production). The Greenland Norse shipped "packages" of ivory back to Europe, with the tusks and teeth still attached to the front part of the skull (the rostrum). These packages were broken open at processing and production centers to extract the full length of ivory tusk, generating distinctive cultural waste that serves as a direct proxy for the wider ivory trade (*17*, *19*). We assume that processing (and discard of waste) occurred relatively soon after arrival (i.e., within years or a couple of decades after the hunt) because commercial value is added by converting the raw material into precious objects. In contrast, the valuable artifacts carved from the walrus ivory (e.g., items with religious significance or used for signaling social status) may have remained in circulation for generations (many decades or even centuries) before entering the archaeological record. Specifically, the 31 walrus artifacts [original data from Star *et al.* (*17*)] are described in table S2 and mainly consist of rostra production waste ($n = 27$), tusk fragments ($n = 3$), and a tooth ($n = 1$). Overall, 27 of 31 samples were production waste (rostra) reducing likely time lags between hunting, shipment, and processing. Most samples are from European trade or production centers ($n = 27$), and a few samples are from the Greenland Norse settlements ($n = 4$). (ii) Assigning artifacts to general time periods. The paper builds directly on previous research by Star *et al.* (*17*) and we use the same approach to chronological inference: (a) first, the walrus artifacts are dated by the archaeological context from which they were recovered (see details in table S2); this generated time bands of varying widths (Fig. 2); and (b) second, these data were used to allocate the walrus artifacts to two major historical periods in the Greenland Norse settlements: an Early Period and a Late Period (Fig. 2). These two periods are divided by the key date of 1120 CE, which marks the point at which Norse Greenland communities received their first bishop [i.e., early 1120s CE (*50*)], itself a reflection of the wider socio-political and economic transformations affecting Scandinavia and the North Atlantic (see the "culture-historical timeline" below). Assigning the walrus artifacts to these two broad chronological intervals enabled us to demonstrate that general patterns of walrus exploitation had shifted substantially over time (Fig. 2). (iii) Assigning specific ages to artifacts. Generating precise calendar dates for each of the 31 walrus artifacts is more challenging and was deemed beyond the scope of the current paper. The underlying problem was also highlighted by Star *et al.* (*17*). While C14 dating methods could be used to date the individual artifacts, this could only generate a radiocarbon age for each object. This age would then need to be calibrated to assign a calendar (historical) age, taking marine reservoir effects into account. These reservoir effects vary according to geographic location and other considerations and are a particular problem for walrus given its high fidelity to localized shallow-water feeding grounds (*10*). Without calculation of a precise local ΔR value to correct for all the potentially different marine reservoir effects across our wider study area, the direct dating of the samples would add further chronological uncertainty. Now that the walrus artifacts have been sourced back to more specific geographic regions, baseline data and proof-of-concept studies to support improved radiocarbon calibration can now begin and should be a future research priority.

Third, the sourcing results need to be embedded into a wider historical context to understand the causes, conditions, and consequences of Greenland Norse walrus exploitation. Key historical processes and transformations affecting walrus exploitation and the demand for ivory include (i) initial Norse expansion into the Northwest Atlantic (pre-1120 CE) and also (ii) the fundamentally different socio-political and economic dynamics that were emerging across Scandinavia and Europe during the Late Period of Norse Greenland, including the rise of various polities (ca. 1120 to 1450 CE). These wider historical transformations can be summarized as a culture-historical timeline (all dates in CE; for further discussion of Norse-Indigenous interactions, see Supplementary Text):

• 984 to 992: Erik the Red departs from Iceland and explores the west coast of Greenland (*51*), possibly traveling beyond Disko Bay (*52*).

• c. 985: Founding of the Greenland settlements (*51*). Leif Eirikson (born c. 970, died, c.1025) credited with bringing Christianity to the Norse Greenland settlements and being the first European to visit continental North America (*50*, *53*).

• 1021: dendrochronological date for timbers from the Norse settlement at L'Anse aux Meadows (Fig. 6) in the Canadian Maritimes (*54*).

• c. early 1120s: the Norse Greenland settlements receive their first bishop (*50*).

• Early 12th century: Ari Þorgilsson writes the *Book of the Icelanders*, the earliest example of the term "Skrælinga" (*55*).

• Late 12th century: the *Historia Norvegiae* mentions *Skraelings* living north of the main Greenland Norse settlements (*56*).

• After c. 1200: Weather and sea-ice conditions begin to worsen at the Western Settlement (*48*).

• Around c. 1250: Tuniit (Late Dorset) groups withdraw from High Arctic Greenland (*26*).

• 13th century: The Bear Trap storehouse (fig. S3) constructed on the western tip of the Nuussuaq Peninsula (*25*, *26*).

• 1250s: Novgorod begins to expand as a fur-trading power, becoming a direct competitor for Greenland Norse traders (*29*).

• 1250 to 1300: Norse runes carved at Kingitorsuaq, confirming expeditions and overwintering beyond Disko Bay (*25*, *31*).

• 13th century: Thule Inuit expansion from Alaska into the Eastern Arctic (*1*).

• After c. 1250 to 1350: Norse artifacts start to appear on Thule Inuit sites, particularly in Smith Sound, but also in the Canadian High Arctic (*9*, *24*).

• 1262 to 1263: Greenland and Iceland submit to King Hákon Hákonsson of Norway; beginning of embargo on all foreign trade north and west of Bergen (*29*).

• 1266 to 1267: Two Norse expeditions into the far north, described by a Greenland priest, possibly reaching Melville Bay (*6*, *51*).

• c. 1300: Peak of the Greenland Norse population at the Western Settlement (*57*).

• 14th century: Thule Inuit expansion southward along the west Greenland coast, with establishment of winter bases in the Disko Bay area (*26*).

• 1327: Peter's Pence tax for Magnus Eiriksson's crusade against Novgorod paid by the Greenland See, primarily via a large quantity of walrus ivory: Exact amount was unclear, but worth more than the annual tax from c. 4000 Icelandic farms (*5*, *25*, *29*).

• 1341: The Norwegian priest Ívar Bárðarson is sent to Greenland on behalf of the Bishop of Bergen, and reports that no Norse taxpayers are left at the Western Settlement (*52*).

• 1347: The *Skálholt Annal*'s entry for this year records a ship, with 17 men onboard, arriving in Iceland from Greenland, which had sailed to Markland; last known reference to the Americas before Columbus (*31*).

• 1350 to 1450: period of "exceptional climate instability" in Greenland (*58*).

• c. 1360: Ívar Bárðarson writes his description of Greenland, stating that the sailing route from Iceland to Greenland is no longer possible due to encroaching sea ice (*52*).

• 1379: The *Icelandic Annals* record that "the *skræling* attacked the Greenlanders and killed eighteen men and took two boys into slavery" [transl. A. Ogilvie (*49*)].

• c. 1380: peak of the Norse population at the Eastern Settlement (*57*).

• 1408: last written reference to the Norse occupation of Greenland (*59*).

• c. 1450: Eastern Settlement abandoned, end of Norse presence in Greenland (*57*).

To summarize, these different approaches to chronological inference enabled us to (i) reconstruct genetic diversity and walrus stock locations at the time of Greenland Norse exploitation (Fig. 1); (ii) use this phylogeographic analysis to source walrus artifacts back to specific Arctic hunting grounds; (iii) allocate traded walrus artifacts into two major historical periods to understand how walrus exploitation patterns shifted over time (Fig. 2); and (iv) use these results to better understand the emergent phenomenon of the "Arctic Ivory Road"—i.e., the evolving trade, interaction, and exchange networks that started to connect the Indigenous Arctic, Norse Greenland, the North Atlantic, and European urban centers via the commercial exploitation of natural resources located in the polar regions (Fig. 6). Further research can refine and develop these emerging insights.

Methods: Using ancient DNA to reconstruct the genetic diversity and stock locations

As described above, accurate sourcing of walrus cultural artifacts required reconstruction of genetic diversity and stock locations during the period of the Norse Greenland settlements (Figs. 1 and 2). We targeted mitogenomes from biological samples ($n = 100$) to ensure sufficient geographic and chronological coverage (see table S1). All DNA work was conducted in dedicated laboratories at the Globe Institute, University of Copenhagen, following established aDNA protocols (*60*) as described in Ruiz-Puerta *et al.* (*10*). All raw DNA sequence data were mapped to a walrus reference mitogenome (NCBI accession: NC_004029.2) (*61*) using the PALEOMIX (v1.2.13.4) BAM pipeline (*62*), excluding the d-loop due to poor mapping. MapDamage (v2.0.9) (*63*) was used to assess the postmortem damage and confirm the authenticity of our ancient DNA. Adapters, ambiguous short sequences (<25), and low quality bases ($Q \leq 30$) were removed with Adapter removal (v2.3.1) (*64*). Duplicates were removed with SAMtools (v1.3.1) (*65*) and MarkDuplicates (Broad Institute). Mitogenome haplotypes were called independently with ANGSD (v0.921) (*66*) using SAMtools and BAQ computation (*67*) against the reference walrus mitochondrial genome. Bases were not called for sites where depth of coverage was <3, and reads were removed if there were multiple best hits during mapping.

Methods: Sourcing walrus artifacts to specific Arctic hunting grounds

The genomic sourcing of walrus artifacts is supported by phylogeographic analysis, in which the mitogenome "fingerprint" from a cultural walrus artifact is allocated to the biological phylogenetic clade of the walrus stock from which it was harvested (Figs. 1 and 2). This approach is made possible by the strong (maternal) population structure of walrus, with multiple discrete populations now identified in the North Atlantic (*10*, *68*), resulting in a well-resolved phylogenetic tree (i.e., there are several distinct local stocks, and each stock has a distinctive genetic identity). As discussed above, previous studies have used genetic methods to source ivory (*17*), but used a phylogeny built with short fragment mitochondrial DNA, rather than full mitogenomes, and used relatively modern Arctic reference samples that postdate industrial-scale walrus exploitation (*17*). Still, this pioneering study was able to define two large geographic walrus clades (western and eastern/mixed) and demonstrated that Norse walrus exploitation had shifted from direct hunting in Fennoscandian waters, followed by expansion of harvesting efforts into the Northwestern Atlantic in the early 12th century (*17*). However, more recent research, using mitogenome data, has indicated that the large "western" clade is, in fact, made up of several distinct walrus stocks, each located in different geographic areas, and, moreover, that a series of distinct stocks also existed during Greenland Norse walrus exploitation (*10*). This baseline work on genetic diversity establishes a much higher-resolution framework to track the cultural artifacts that passed through Norse Greenland back to more specific Arctic hunting grounds.

We built a high-resolution Bayesian phylogeny, using mitogenome data from biological samples sourced from different chronological periods and geographic locations (Fig. 1 and table S1) combined with mitogenome data from 31 walrus artifacts [data originally published by Star *et al.* (*17*)] into the Bayesian phylogenetic analysis (table S2). The Bayesian phylogenetic analysis was completed on all samples with at least 90% of breadth coverage using a relaxed clock model and 150 million iterations in BEAST 2 (v.2.5.1) (*69*), as described in Ruiz-Puerta *et al.* (*10*). The biological samples directly allowed us to define six stocks during the period of Greenland Norse walrus exploitation: an extinct stock from Iceland (II); East Greenland (III); West Greenland (IV); Northwest Greenland (North Water Polynya) (V); and Foxe Basin (I and VI). A further stock was identified in Svalbard (see pale blue shading in Fig. 1, stock not numbered in the current paper), plus an extinct stock in the Canadian Maritimes (see pale yellow shading in Fig. 1; stock not numbered in the current paper). Next, with every cultural artifact possessing a distinct genetic fingerprint, it was possible to genetically allocate each object to a specific biological walrus stock that had existed during the Norse presence in Greenland (Fig. 1). Chronologically, all sourced artifacts were allocated to either the Early Period or the Late Period of Norse Greenland [(*17*), see table S2], the results indicating that Norse harvesting strategies had likely evolved over time, with the North Water Polynya (stock V) becoming increasingly important (Fig. 2).

Methods: Reconstructing Greenland Norse sailing vessels, routes, and journey times

To contextualize the results of the genetic sourcing, and further evaluate the veracity of the three different Norse exploitation scenarios, we used archaeological, historic, and ethnographic data to reconstruct two probable Greenland Norse vessel designs: (i) smaller boats with oars and sail, and (ii) larger expeditionary sailing ships (Figs. 3 and 4 and figs. S1 and S2). We (G.J.) also conducted experimental voyages in vessels directly comparable to those available to Greenland Norse communities, generating insights into sailing and rowing capabilities, plus estimations of likely cargo capacities. This enabled us to assess their relative voyaging capabilities and reconstruct possible sailing routes and journey times (Fig. 5 and table S3), drawing on paleoenvironmental evidence to establish robust comparisons between current conditions and those likely experienced by the Greenland Norse, particularly in relation to wind direction and sea-ice coverage (*70*–*73*). These combined insights enabled us to better understand Greenland Norse seafaring capabilities, including the different operating ranges of the smaller and larger vessels, as well as likely routes, possible anchorages, stopping points, and hunting grounds (Fig. 5). We concluded that Greenland Norse needed to choose between (i) voyages northwards from the main Norse settlements located in southwest Greenland, following the western coast of Greenland, as far north as the North Water Polynya: These expeditions were risky, but still feasible within one summer sailing season, but only with the larger expeditionary sailing vessels that were owned by wealthier farmers and social elites; and (ii) westward expeditions over to Baffin Island, Labrador, and deeper into Foxe basin, which we concluded were less likely given lingering sea ice and difficult sailing conditions; voyages in this direction would also have required at least one overwintering, even with the larger sailing ships. While earlier exploration voyages may have taken these risks into consideration, more routine walrus harvesting expeditions appear to have targeted the North Water Polynya as the more viable option for the small Greenland Norse communities. For additional information on Greenland Norse seafaring capabilities, plus interactions with Arctic Indigenous peoples, see Supplementary Text.

Supplementary Materials

The PDF file includes:
Supplementary Text
Figs. S1 to S3
Table S3
Legends for tables S1 and S2
References

Other Supplementary Material for this manuscript includes the following:
Tables S1 and S2

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The PDF file includes:

Supplementary Text
Figs. S1 to S3
Table S3
Legends for tables S1 and S2
References

Other Supplementary Material for this manuscript includes the following:

Tables S1 and S2

SUPPLEMENTARY TEXT

Experimental and historic insights into Norse sailing and inter-cultural contacts

General environmental conditions

The west coast of Greenland is today characterised by prevailing northerly winds, unstable summer weather with frequent storms, rain and fog, and major inter-annual variations in the extent, location, and concentration of sea ice (*74*), This means sailing is inherently risky because weather conditions and sea ice coverage can change drastically in a matter of hours (74). The complex coastal topography between the interior Greenland ice sheets and surrounding ocean can generate strong katabatic winds with sudden, powerful gusts, particularly through the inner fjords, creating major risks for sailing vessels (*70*). Documentary and paleoenvironmental evidence from across southwestern Greenland indicates that similar meteorological and environmental conditions to those observed over the last century probably existed in the Early Period of Norse Greenland settlements, albeit with higher frequency of southerly and katabatic winds, and reduced summer fog (*70–73*). However, conditions began to worsen around the Western Settlement already in the mid-13th century, with increased storms and greater sea ice coverage. These changes began to impact the Eastern Settlement in the mid-14th century, with contemporary sources noting increased sea ice and a consequent decline in trading voyages from Scandinavia and Iceland to Greenland (*29*, *48*, *58*).

Despite high variability in the maritime climate of western Greenland, some general seasonal patterns observable today would also have impacted upon the sailing options of the Greenland Norse. The extent of the sea ice varies significantly from year by year, but ice-free conditions can generally be expected between July and October as far north as Upernavik (*74*, *75*). However, sailing beyond this point often proves impossible until July or even August, adding uncertainty and narrowing the time window for longer-range expeditions seeking to return within one summer season. Likewise, sea ice generally reaches its minimum extent in late September, but then forms rapidly again after this point, adding further constraints and uncertainty (ibid). Ocean circulation also impacts conditions with the north-flowing West Greenland Current keeping the Greenland side of the Davis Strait ice-free for longer periods, while conditions are more challenging along the coast of Baffin Island and Labrador, where access to the coast is generally blocked by dense pack-ice until August (*31*). To summarize, the most predictable sailing conditions and safest seascapes are to be expected along Greenland's west coast from the Norse settlements through to the North Water Polynya; voyages to Baffin Island, and across to Labrador and into Foxe Basin are fraught with greater risk and uncertainty, especially in relation to the sea ice (Fig. 5, Fig. 6).

Defining the length and timing of Greenland Norse sailing season

These combined climatic and environmental parameters define a sharply constrained annual sailing season for Greenland Norse walrus harvesting operations. More distant walrus stocks could have been reached, but at increased risk of getting stranded, requiring overwintering away from home. Norse sailing decisions and strategies also need to be understood in the context of the socio-economic and demographic characteristics of the main Greenland Norse settlements, which were situated at the remote outer edges of the European cultural world. Previous research has identified the Western Settlement as the main community involved in the *Norðrsetur* hunt (*6*, *29*, *51*). For this community, the early summer was taken up by the hunting of migratory harp seals, which passed the outer coast in May and early June, generating wild food supplies during the leanest and hungriest months at the end of the long winters (*49*).

Northbound walrus hunting expeditions could have departed immediately after this task. However, the crews would be needed back at the farmsteads by late August to take part in haymaking which created fodder for livestock over the winter. These two vital tasks – seal hunts and haymaking - define a narrow window of opportunity for the *Norðrsetur* hunt, which probably lasted around two and a half months, starting early June and ending late August (*6*, *25*). Unfortunately, the opening of this travel window aligns particularly poorly with the lingering sea ice along the west coast of Baffin Bay and the Davis Strait, meaning that Norse voyages to Baffin Island and Labrador were unlikely to have been undertaken from the Western Settlement on a regular annual basis, unless possible overwintering was factored into the plans: crews would then be absent for both haymaking and also the Spring seal hunt. These domestic task-scheduling conflicts would have added further risks and uncertainties to the already hazardous voyages to the west, especially if crews decided to venture deeper into Foxe Basin (Fig. 5, Fig. 6).

Reconstructing the size and diversity of Norse Greenland vessels

Our research indicates that (a) Norse voyages to the northern hunting grounds were conducted in two different kinds of vessel (compare Fig. 1 and Fig. 2, plus fig. S1 and fig. S2), and that (b), these had distinctly different operating ranges, which would have structured opportunities for walrus exploitation, and for the Greenland Norse social groups and wider networks that organised, participated and profited from the harvesting operations. No complete examples of Greenland Norse vessels have survived, but the boats and ships used for the *Norðrsetur* hunt can be reconstructed from a range of sources, including fragmentary finds, historical records, historical analogues and archaeological remains of boathouses. The direct archaeological evidence for Greenland Norse vessels is restricted to hull fragments recovered from Norse settlements and some Thule Inuit sites (possibly parts scavenged from wrecked ships) but these are too small to enable vessel sizes and cargo-capacities to be reconstructed. One small model of a four-oared boat has been recovered from Umîviarssuk in the Western Settlement. Overall, these combined insights suggest that the vessels of the Greenland Norse were probably single-masted, square-rigged rowing and sailing boats of the wider Nordic clinker tradition (*24*, *31*, *51*, *76*, *77*):

- **Smaller boats:** Written sources confirm that the most common type of vessel used by Greenland Norse was the *sexæring*, a relatively small boat of around 7 - 10 m length with six oars and a single square sail, probably owned and used by individual households (*25*, *52*). These small boats are thought to be analogous to the clinker-built fishing boats of Shetland and western Norway, which bear variants of the same name, and were in use until the early 20th century: the sixareen (Shetland) or *seksring* (Norway) (*42*, *43*, *78*) (Fig. 3, fig. S1).
- **Larger "expeditionary" sailing ships:** A larger class of Greenland Norse vessel, referred to as *skútur* or *ferja* in the sources, was probably constructed and operated under the direction of richer farmers and elites, though there is some ambiguity about their precise size and cargo-capacity (Fig. 4, fig. S2).

Vessels of this larger class were used widely by the Norse for general inshore travel, longer-range expeditions between Iceland and Norse Greenland, and exploration voyages to the Canadian Maritimes (*6*, *52*). The 14th century *Skálholt Annal* states that in 1347 (CE), there "came a ship from Greenland, smaller in size than the small vessels that trade with Iceland. […]. There were seventeen men onboard, and they had sailed to Markland" (probably coastal

Labrador, see Fig. 4) (*31*). This indicates that the ships of the Greenland Norse were smaller than the Norwegian ships that traded with Iceland, which were reaching lengths of 25-30 m by this date (*79*). To have reached Markland, this particular vessel must have been small enough to manoeuvre through the iceberg-filled waters, yet capacious enough to accommodate a crew of 17 persons. Remains of boathouses have also been identified at the Eastern Settlement and suggest vessel lengths of up to 18-20 m (*80*, *81*). Together, this evidence suggests that Greenland Norse were operating a class of larger "expeditionary" ships of 16-20 m in length, which were substantially larger than the small rowing boats described above, but perhaps somewhat more compact than the medieval Scandinavian ocean-going cargo ships. Keller (*29*) and Nedkvitne (*6*) have suggested that the 11th century *Skuldelev 3* wreck could have been similar to some of the larger class of vessels employed in the *Norðrsetur* hunts. This particular boat was built in Denmark and originally measured 14 m in length, putting it below our estimates for the larger Greenland Norse vessels; the original rig and sail plan also remain unknown, as these elements were not preserved. Alternative, and more well-documented analogues for the larger Greenland Norse boats may include the Norwegian *fembøring* or *Lofotbåt* and the *vaterbords-jekt*, which have similar dimensions of around 14 – 20 m, and were used for the stockfish trade into the late 19th century (*42*, *82*). Given the acute shortages of iron and boatbuilding timber endured by the Greenland Norse, combined with the small populations at the main settlements, we can potentially envisage *Norðrsetur* hunts involving 10-15 vessels during the peak of the Western Settlement's population (*25*, *57*), with the majority consisting of the smaller six-oared boats built, owned and crewed by local farmers, along with a handful of the larger ships likely sponsored by wealthier farmers and social elites.

Reconstructing performance characteristics of different Greenland Norse vessels

It is also important to understand the specific performance characteristics of the two different classes of vessel, given sailing conditions, the length of the summer voyaging season, and the different hunting grounds that were being targeted by the Greenland Norse in different historical periods (Fig. 2). One key issue is whether both classes of vessel were able to reach the distant walrus hunting grounds in the far north. The closest analogy to the smaller six-oared Norse boat is probably the Shetland sixareen; its length-beam ratio is closer to that of the Umîviarssuk model than that of the sleeker Norwegian *seksring*, giving it more space to carry bulky cargo. This is an important consideration given that Greenland Norse transported ivory tusks that were still attached to the rostrum, as well as bulky walrus hides (*6*). Sixareens were usually 7.5-9 m in length and crewed by 6-7 people. While these are profoundly seaworthy craft, extremely well-adapted to the large swell and gusty winds of their home regions (*42*, *43*, *78*), they are not suited for long overnight passages as they provide no shelter from the elements and cannot accommodate for both cargo and a sleeping, off-duty watch. We envisage that on summer hunting expeditions, these small boats would have been rowed in 12 hour stints, with the crews resting up on land between these stages (*6*). In contrast, the larger sailing vessels could be sailed non-stop under favourable conditions with the larger crews working and resting in different watches, saving time, and enabling substantially longer voyages within the time window (*83*).

Much of the literature on the *Norðrsetur* hunt has been founded upon an ambiguous passage in a 17th century document known as *Grœnlands annál*, particularly from the copy made by Björn Jónsson of Skarðsá (d. 1655), probably in 1643, known as *AM 115 8vo(A)*, and reproduced in Halldórsson (*52*). The text reports a series of distances between named locations along the west coast of Greenland, which are listed in terms of the number of rowing days between them. The original information is derived from an older booklet which has since been lost (*gömlu kveri*). The passage begins with a list of the fjords and churches of the Eastern Settlement, and then continues northwards along the coast:

"Þá eru Miðfirðir næst *byggðir; þá heitir *enn einn Kolluf(jörður), annar Dýraf(jörður), þá Þórvaldsfjörður, Steinsf(jörður), Bergþórsf(jörður). Þá er vj daga róður | vj mönnum til Vestribggðar sexæringi (þá telur þar upp firði). Þá er ú hinni vestri byggð til Lýsufjarðar vj daga róður; þaðan sex daga róður til Karlbúða, þá iij daga róður til Bjarneyjar, xij daga róður umhverfis – ey Eisunes; Æðanes fyrir norðan."

This translates as:

Then the Middle Settlement is the next settlement; one is called Kollufjörður, another Dýrafjörður, then Þórvaldsfjörður, Steinsfjörður, Bergþórsfjörður. Then it is six days of rowing [for] six men to the Western Settlement [in] a six-oared boat (then count up the fjords). Then from the Western Settlement to Lýsufjarðar there is six days of rowing; from there six days rowing to Karlbúða, then three days rowing to Disko Island, twelve days rowing around -- island Eisunes; Æðanes is to the north.

(translation by Sigurður Snæbjörn Stefánsson, January 2024).

Halldórsson believed this passage had been somewhat corrupted, and suggested several corrections (*52*). Other authors have offered differing interpretations of this passage (*6*, *31*). Table S3 lists the locations mentioned in this passage and their possible distances from the Western Settlement according to a literal reading of the text, as well as the various interpretations offered by recent researchers (*6*, *31*, *52*). In our analysis, we have assumed that "the Western Settlement" listed in *Grœnlands annál* refers to the entry point to the deeper fjord system in which this Norse settlement was located, and not a particular farm or hamlet within this inner chain of farmsteads (the text is explicit that rowing times within the fjord are not included). It seems likely that the larger Greenland Norse ships, which were designed for sailing but were difficult to row, would have been moored at locations near the outer coast. This means that long-range sailing distances along the coast should be calculated from the vicinity of modern-day Nuuk (*83*–*85*).

As outlined in table S3, the different interpretations of the original passage generate quite substantial differences in the rowing speeds required to cover the distances between the named locations. To evaluate these interpretations, we made use of experimental trials conducted on comparable vessels in Scandinavian waters (Fig. 2). These trials demonstrated that a *fyring*, a traditional Norwegian boat of slightly larger size than the *seksring*, could be rowed for several hours by an amateur crew of 7 (with approximately 250 kg of ballast, 6 rowers and one person steering), achieving an average speed of 1.8 knots; however, the crew could not maintain this tempo indefinitely and would need to rest at nighttime. This estimated speed aligns well with the interpretation presented in the the *Grœnlands Annal*, which states that it took 15 rowing days to reach Disko Island in a small boat from the Western Settlement. If we assume that the start and end points are Nuuk and Qeqertarsuaq, that equates to 345 nautical miles, which would mean rowing 23 nautical miles per day over 15 rowing days, requiring an average Speed over Ground of 1.9 knots, a respectable pace considering the prevailing headwind.

In contrast, Ljungqvist (*31*) has calculated that the same journey could have been sailed within only 4 days using one of the larger class of Greenland Norse sailing vessels (Fig. 3), which would 'save' 11 days on the outward journey alone. This estimate assumes non-stop sailing, and equates to 86,25 nautical miles per 24 hours, which is well below averages for Norse ocean-going vessels commonly reported in contemporary written sources (*84*, *86*). However, it aligns well with the daily averages obtained from experimental trials with a Norwegian *fembøring* (Fig. 4), and with the estimate of 80 nautical miles per 24 hours reported by Wallace (*87*), based on the crossing of the Davis Strait in 1998 by *Snorri*, a reconstruction of the 11th century *Skuldelev 1* wreck (*83*). Given the adverse and unpredictable sailing conditions along the western Greenland coast, we employ this more conservative estimate in our analysis.

We also estimated likely cargo capacities of the two kinds of Greenland Norse boats, using experimental reconstructions and ethnographic parallels: (a) the smaller six-oared boats can be compared with the Shetland sixareen, which can transport approximately 1 ton of cargo in addition to a crew of 6-7 (*31*, *43*, *78*); (b) the precise capacity of the larger Greenland Norse ships is less certain, given ambiguity over their precise dimensions: the *Skuldelev 3* vessel had a cargo capacity of only 4.5-5 tons (*29*), while the *Skuldelev 1* could ship up to 20 tons of cargo (*42*), which we take to be near the upper limit for the larger class of Norse boats involved in the *Norðrsetur* hunt.

Norse walrus hunting strategies

The *Norðrsetur* hunt would also have been influenced by the behaviour and mobility of walrus. These animals typically feed on marine bivalves at shallow depths of <100 m and then occupy haul-out sites on land or sea ice. McGovern (*25*) used bathymetric and marine sedimentary records to identify a series of likely feeding and haul-out areas along the west coast of Greenland. Zooarchaeological evidence from the Greenland Norse settlements indicates a distinctive walrus butchery pattern, with animals skinned at kill sites to remove the hide, and the skull chopped into sections to remove the valuable ivory tusks, which were left attached to the maxillae (*25*). There is no evidence that Norse hunters developed toggling harpoons nor adopted them from the Thule Inuit, so walrus were unlikely to have been hunted in the open water. Instead, they were probably harvested at haul-out sites, driven into the shallow surf from the sea, corralled on beaches by hunting dogs, and then finished off with lances. Similar strategies are reported from Svalbard and Sable Island in the 17th and 18th centuries, enabling a group of hunters to kill several hundred animals per day (*39*–*41*).

The hide and *rostrum* of a large adult walrus weigh approximately 52.5 kg (*25*). This means that one six-oared boat with a cargo capacity of 1 ton could have shipped 19 sets of hides and maxillae (even more if the bulky hides were discarded in favour of extra ivory “packages”). In contrast, a larger Greenland Norse sailing vessel could transport between 85-380 sets (assuming a cargo capacity range of 4.5-20 tons). Assuming that Greenland Norse crews were able to operate as effectively as hunters in Svalbard and Sable Island, then the 85-380 walrus kills required to fill one of the larger Norse cargo ships could easily be culled, processed and loaded onto ships within 1-2 weeks, depending on hunting conditions, the size of the crew and the capacity of their vessel. The quantity of ivory paid by Greenland Norse as a crusade tithe in 1327 has been estimated at 190-260 pairs of tusks, which would equate to only 1-3 of the larger expeditionary ships returning from the hunt fully laden with walrus products (*5*, *25*, *29*).

Norse mobility strategies during these hunts are not clear, but they may have operated from central base camps, and then journeyed out to target specific haul-out sites, returning with hides and processed skulls. Secure storage facilities to protect the contents against roaming polar bears may also have been part of this strategy. One likely example is the Bear Trap (fig. S3), a probable Norse storage facility on the northwestern tip of the Nuussuaq Peninsula (Fig. 5 (*25*, *26*)). To summarize, the culling and processing operations at remote hunting grounds could have been completed quite quickly, within a couple of weeks at most (6). This insight means that voyaging times were a more important factor in determining which class of vessel could reach the different walrus hunting grounds.

Estimating Norse journey times to different Arctic hunting grounds

We calculated journey times to the different Arctic hunting grounds, taking into consideration the performance characteristics of the two different vessel types. These estimations are based on experimental sea trials conducted with traditional Norwegian vessels in Scandinavian waters, and could be further refined by undertaking voyages along the west coast of Greenland. First, it is assumed that Norse hunters had approximately two and half months to reach and return from any of the hunting grounds. Around half of this time would probably have been spent weathering storms on land and waiting for favourable winds, leaving only 30 days of actual journey time once hunting and processing time is accounted for. Second, at 23 nautical miles per day, the six-oared boats could cover 690 nautical miles in 30 days, or 345 nautical miles in 15 days in each direction. This makes it possible to reach Disko Bay rowing from the Western Settlement, but not further. Importantly, this logistical limit on the operating range of the smaller boats would have been further enforced by the exposed and unpredictable conditions north of the Nuussuaq Peninsula (*75*). Third, we estimate that the larger Norse ships could be expected to travel c.80 nautical miles per day, covering 2,400 nautical miles in 30 days, meaning a maximum range of 1,200 nautical miles in 15 days in each direction (roughly the same distance as sailing from the head of the Oslo Fjord to the north coast of Spain). Crucially, this would place crews from the Western Settlement within potential voyaging distance of Pikialasorsuaq (North Water Polynya), and perhaps even the Kane Basin, but probably only on years with exceptionally favourable sailing conditions.

The superior operating range of the larger sailing ships is hinted at in the *Grœnlands annál*, which states that "The Greenlanders sail towards the north to the wilderness beyond the uninhabited lands, or the peninsula, both for wood and fishing" (*52*: translation by Sigurður Snæbjörn Stefánsson). The term used in Icelandic is *siglingar*, which in other contemporary sources such as *Landnámabók* is assumed to refer to open-sea voyages rather than coastal navigation. It is possible that the "uninhabited lands, or peninsula" refer to the area usually exploited by Norse hunters, i.e. the coast as far as the Nuusuaq Peninsula, while the "wilderness beyond" refers to Pikialasorsuaq (North Water Polynya), which could only be reached by crossing the open ocean west of Melville Bay. More favourable conditions on the voyage south (with prevailing northerly winds and less sea ice coverage in the late summer) would have made these return journeys somewhat faster than the outward trips.

To summarize, we conclude that the increasing reliance on the North Water Polynya in the Late Period of Norse Greenland required the use of the larger 'expeditionary' vessels, which were only owned by the wealthier farmers and members of the elite. These social factors mean that only the closer walrus hunting grounds would have been accessible to poorer households working with smaller, six-oared boats.

Locating Norse stopping points along the west coast of Greenland

To better understand the northward hunting expeditions that departed from the Western Settlement towards the North Water Polynya (Fig. 5), we examined evidence for possible anchorages and stopping points along the west coast of Greenland. Access to such locations would have improved the feasibility of journeys, offering shelter, supplies, and opportunities for emergency overwintering, and would therefore increase the probability of Norse presence at the North Water Polynya. There are indications that natural harbours were used to establish storage facilities and hunting stations. Several factors may have influenced the choice of location, including shelter from storms and northerly winds, proximity to the outer coast (providing access to the open sea, and reducing the danger of katabatic winds and becoming trapped by pack ice), as week as access to walrus haul-out sites near to shallow water feeding banks (*13*, *25*).

The Bear Trap site mentioned above fulfils all these criteria (fig. S3) (*26*, *88*). This location at the northwest tip of the Nuussuaq Peninsula remains ice free for most of the year, and offers a protected harbour during bad weather, a site function that persisted into recent times (*17*). Other hunting stations are mentioned in the written sources and ethnographic records, but their locations, infrastructure and precise role in walrus harvesting operations need to be better investigated archaeologically (*25*, *52*), though they probably shared similar affordances to the Bear Trap site (25, 91). Running from south to north, similar stopping and harvesting points may have been located at regular intervals along the western coast of Greenland, perhaps separated by two-days sailing time (ca. 160 nautical miles). Within this interval, it is possible to anticipate likely weather conditions, informing decisions about continuing with the voyage or waiting out unfavourable weather.

Karlbúða is one example of a way-station mentioned in the written sources (25,26). Using information from table S3, it is possible to estimate that it was located around 6 to 12 rowing days north of the Western Settlement, with three further days of rowing before reaching Disko Island. If boats travelled 23 nautical miles a day, this would place this stopping point around 138 to 276 nautical miles north of modern-day Nuuk, and around 69 nautical miles south of Disko Island. We suggest that according to the additional criteria established above, Karlbúða was probably located in a south-facing bay between 67° 50' N - 68° 10' N, in the vicinity of modern-day Attu (c.f. 25,26). This area offers good access to walrus feeding banks as well as shelter at the end or beginning of a long stretch of exposed coastline. Following the same criteria, another possible way-station may have been located at the mouth of the Kangerlussuaq Fjord, which sits midway between Nuuk and Attu (*25*).

Located 140 nautical miles further north than the Bear Trap is the island of Kingittorsuaq, where a Norse runestone was discovered (Fig. 5). It was carved sometime between 1250-1300 CE (*25*, *31*), which would place it in the Late Period of Norse Greenland, when more ivory was being harvested from the North Water Polynya (Fig. 2). The likely month of carving, estimated as April or May, is also significant, as sea ice would still have blocked the coast, indicating that the crew had probably overwintered in this area, perhaps after being stranded on the journey home. Further north, Seaver (*30*) presents ethnographic accounts of a Norse settlement in the Upernavik area, which we tentatively locate in the relatively protected archipelago between 72° 40’ N - 73° 20’ N. This may represent a fourth waystation on the *Norðrsetur* route (Fig. 5). From here, Norse sailors may have headed towards Kitsissorsuit (Edderfugleøerne) before attempting to cross Qimusseriarsuaq (Melville Bay). The *Greenland Pilot* (*75*) reports that whaling crews used the topographic heights of these islands to inspect the sea ice conditions in the waters further north, a practice that may also have been common in the Greenland Norse period. From Kitsissorsuit, Melville Bay could be crossed in two days.

Another day’s sailing from here would place Norse crews in optimal walrus harvesting territory, and also in close proximity to Uummannaq and Nuuliit, two of the more southern Thule Inuit settlements near the North Water Polynya (*76*, *89*; Fig. 5). Together, this chain of Norse waystations created a structured, safe and familiar sailing route that ran from the Western Settlement up to Pikialasorsuaq (North Water Polynya) and perhaps even to the Kane Basin, with sheltered anchorages and stopping points located 2-3 day’s sailing distance from each other. Operating along this familiar ‘maritime corridor’ would have made long-range harvesting expeditions more feasible. Such a chain of havens is similar to the more formalised system of inns and stopping points along the Norwegian coast established by royal decree in the 13th and 14th centuries (*84*).

To summarize, available evidence indicates that the Greenland Norse made preferential use of a familiar coastal route that led from their main settlements up to the North Water Polynya, which came to dominate walrus exploitation in the Late Period (Fig. 3).

Locating Norse stopping points: Baffin Island, Labrador, entrance to Foxe Basin

We also considered possible westward expeditions across the Davis Strait to Baffin Island, into the Hudson Strait, and to Labrador. Access to all these areas would have been severely impeded by lingering sea ice well into the summer sailing season. Voyages beyond this area, and deeper into Foxe Basin, seem even less likely due to the adverse currents in the Hudson Strait. However, documentary and archaeological evidence confirms that the Norse were visiting what is now the Canadian coastline (i.e. Helluland and Markland, see Fig. 6). For example, the *Skálholt Annal* (see above) describes the arrival of a ship in Iceland in 1347 CE that had visited

Markland, a destination that did not appear to have been exceptional; Greenland Norse may thus have undertaken occasional visits to the outer coasts of North America, probably to harvest timber for boat building and construction, which would have required larger vessels to transport the timber back to the main Greenland Norse settlements. Substantial forests only start along the Labrador coast south of latitude 58° N, in the vicinity of Napartok Bay (*31*). A direct crossing from either of the Greenland Norse settlements would be a risky endeavour, as Martin Frobisher found during his expeditions in the 1570s (*90*).

It is at least equally likely that Greenland Norse expeditions crossed the Davis Strait further north, and then followed the Labrador coast southwards, as seems to be described in the *Saga of Erik the Red* (*85*). In this case, the Greenland Norse would likely have made use of familiar waystations similar to those running along the western coast of Greenland, but further archaeological fieldwork is needed to confirm this possibility. The main open sea crossings on this route are the Cumberland Sound and the Hudson Strait; anchorages on both sides of these landforms may have been frequented by Norse sailors on their way to Markland, leading to possible encounters with Tuniit communities, and later, with the expanding Thule Inuit populations.

Interestingly, a separate walrus stock also existed in the Canadian Maritimes but has since been extirpated. Our sourcing work indicates that no ivory was being harvested by Greenland Norse from this stock (see main text, table S1, table S2), which suggests that Norse exploration voyages to this area, and the establishment of the L'Anse aux Meadows site, were motivated by other factors. These may have included information gathering, timber harvesting, and searching for suitable land for permanent settlement. In contrast, the *Norðrsetur* expeditions to northern Greenland were focused entirely on acquiring ivory and then shipping this valuable commodity back to European markets.

To summarize, Greenland Norse voyages westwards, to coastal North America, were hazardous operations, requiring at least one overwintering and possibly more, and may have had other goals, including the harvesting of timber.

Summary: Greenland Norse seafaring capabilities

We conclude that:

- Greenland Norse vessels visited Baffin Island, Labrador, and Newfoundland but were primarily involved in exploration and timber harvesting. The extreme distances and uncertainties involved in these expeditions would probably make them multi-year endeavours, with overwintering on the Labrador and Newfoundland coasts. Such expeditions would have been analogous to trading journeys to Iceland, which were also undertaken over two summers (86).
- In contrast, the 'maritime corridor' running along the west coast of Greenland, which linked their main settlements with the High Arctic, seems to have been used on a seasonal and more regular basis (Fig. 5).
- This 'maritime corridor' can be broken down into two distinct sections: (a) a more general marine thoroughfare that ran from the Eastern Settlement, via the Western Settlement, and as far north as the Nuussuaq Peninsula. This route was navigable by both the small and larger vessels and formed the initial focus of walrus harvesting in the Early Period, primarily involving direct Norse hunting; (b) the High Arctic expeditions that focused on the ecological 'hotspot' of the North Water Polynya, which were beyond the reach of the smaller boats and required larger 'expeditionary' sailing ships, which could only reach this area in years with more favourable conditions.
- The vital importance of the larger sailing ships in the Late Period of Norse Greenland is significant because these were owned by richer farmers and social elites (and not poorer households). By this point, the Greenland Norse settlements had submitted to the Norwegian crown, diverting the lucrative North Atlantic trade networks through Bergen (29). This would have created a very different socio-political context for the organisation of ivory harvesting at ever more remote Arctic hunting grounds. Possibly, these longer-range efforts may have fallen under the control of powerful individuals and elite networks. This pattern would contrast with the more opportunistic and individually fuelled acquisition strategies that likely defined the Early Period of Norse Greenland, when use of small boats by independent householders could also generate income and personal status through harvesting the accessible local stock.

Inter-cultural encounters and exchange: Greenland Norse, Tuniit, Thule Inuit

Our sourcing work confirms progressive geographic expansion in the range of Greenland Norse harvesting activities (see main text). One corollary to this conclusion is the increased likelihood of encounters and then more formalised exchange relations with the Tuniit and especially the Thule Inuit (Scenario 3). Here we explore the available evidence, bearing in mind the wider culture-historical processes underway, which saw the Tuniit widely present when the Greenland Norse settlements were established, and then the displacement of these groups by expanding Thule Inuit, especially after 1200 CE. After this, the Thule Inuit continued to expand southwards into Greenland, eventually replacing the Norse population in Greenland after their settlements were abandoned (1). Evidence for the earliest ‘great circle’ European Norse and Indigenous North American encounters takes two forms: written records (from a Norse perspective) and archaeological data. Ari Þorgilsson’s *Book of the Icelanders* (*Íslendingabók*), likely written in the early 12th century CE, is widely believed to be the first source to describe “Skrælinga”—a generic term used to denote Indigenous groups encountered in Greenland and Canada. The term appears again in the *Historia Norwegie,* probably composed in the second half of the 12th century CE, to refer to people living “north beyond the Greenlanders” (*56*).

- Norse-Tuniit (Late Dorset Pre-Inuit) Interactions: These early written references almost certainly refer to the Tuniit, as Thule Inuit did not arrive in High Arctic Greenland until after these documents were written. The archaeological evidence for direct Norse-Tuniit encounters is more equivocal, though there would have been around three centuries of temporal overlap, but with groups largely focusing on different geographic areas. Possible contacts have been inferred through objects recovered from Tunnit sites that are attributed to (or perhaps inspired by) interactions and cultural exchange with Norse visitors. Examples include spun cordage and Norse-style whetstones recovered from four Tuniit sites located in northern and southern Baffin Island, and in northern Labrador (*91*), plus traces of a copper-tin alloy within a stone vessel, which may indicate European-style smelting (*92*). However, the case for Norse-Tuniit contacts is undermined by the fact that radiocarbon dates appear to place these ‘European’ objects into earlier phases of the Tuniit (Dorset) culture, which would pre-date the widely accepted onset of the Greenland Norse presence, though this point is contested (*91*). As noted in the main text, more compelling evidence comes from the Smith Sound region, located between Northwest Greenland and Ellesmere Island, where a fragment of a smelted brass pot was recovered from a reliably-dated Tuniit context (*26*). We conclude that some initial encounters between Tuniit and Norse must have taken place, and that these related to Greenland Norse exploration of the wider region, with meetings most likely taking place in Northwest Greenland (Smith Sound) and on Baffin Island, and possibly in coastal Labrador.

- Norse-Thule Inuit Contacts: There is more substantial archaeological evidence for interactions between these groups, mostly in the form of Norse artefacts recovered from Thule Inuit sites across Western Greenland (*26*, *93*) and deep into Arctic Canada (*47*, *94*, *95*), though some items could have been scavenged from shipwrecks (76). Our insights into ivory harvesting at the North Water Polynya add an important new line of evidence to these debates. Higher levels of interaction are understandable given the presence of both groups around the North Water Polynya. Moreover, in the closing decades of the Late Period of Norse Greenland, the Thule Inuit were also expanding down the western Greenland coast, possibly due to climatic deteriorations in the High Arctic, with both groups briefly operating in and around Disko bay (26), and contemporaneous occupations reported as far south as Sandhavn (*27*). We conclude that more formalized exchange relations may have started to form around the North Water Polynya in the Late Period, possibly with Thule Inuit initially gifting ivory (and possibly Arctic furs), and perhaps later engaging in more opportunistic bartering for Norse goods and equipment. In understanding these cultural encounters, it is important to bear in mind the different social norms and expectations of the participating groups, but also how these may have evolved over time as interactions became more structured and predictable. Norse interests were clearly focused on walrus ivory, but what the Thule Inuit could receive in return has remained ambiguous. Interpretations often assume the value of iron to Thule Inuit, but the Norse Greenland settlements were also short of this vital resource. The role of Norse elites in organising the larger expeditionary vessels may be significant here, as iron could be accumulated prior to the voyages and then traded in the High Arctic. Overall, however, the volume and character of Norse goods entering Thule Inuit contexts appears to be limited and rather eclectic, and more archaeological research is needed in likely interaction areas, including the North Water Polynya. Despite this ambiguity, the growing evidence for substantial Thule Inuit interactions with the Greenland Norse are compelling, with European urban demand for walrus ivory ‘pushing’ Norse expeditions deeper into the High Arctic. We also need to calibrate our underlying expectations of the archaeological record in these polar regions; very limited volumes of European trade goods have been recovered from Greenland Inuit sites that date to the 18^{th} C CE, when extensive inter-cultural interactions and formalized exchange relations are well-documented in the historical records (95). Finally, the other enduring puzzle is why the Greenland Norse appear to have been persistently disinterested in acquiring other potentially useful technologies, equipment and practices from the Arctic-adapted Thule Inuit, including toggling harpoons, skin-boats and insulated winter clothing made from skins and hides. This enigmatic combination of High Arctic interaction and cultural separation suggests that while two very different social worlds converged via shared interests in walrus exploitation, the deeper cultural consequences of these early encounters remained quite limited, at least during the earliest phases of circumpolar globalization. By the close of the 15^{th} C CE, the Norse had departed and the Thule Inuit were expanding into southern Greenland. More intensified processes of globalized culture-contact would soon follow.

SUPPLEMENTARY FIGURES

Supplementary Figure S1. Smaller vessel employed by Greenland Norse. The Shetland sixareen (pictured) is probably the most similar surviving relative of the smaller six-oared boats used by the Greenland Norse, although such boats would have carried a square rather than a lug sail. Such boats would have been used to harvest local walrus stocks but were not suitable for the High Arctic expeditions to the North Water Polynya. Photo: Dave Donaldson (reproduced with permission).

Supplementary Figure S2. Larger 'expeditionary' vessel employed by Greenland Norse. This modern example is a compact, clinker-built, square-rigged cargo vessel based on the design of the *Skuldelev 1* wreck, which was built in western Norway c.1030 CE. Norse Greenlanders could only undertake walrus harvesting expeditions to the North Water Polynya in these larger sailing vessels, which were owned by wealthier farmers and elites, adding an important socio-political dimension to Late Period exploitation strategies. Photo: Greer Jarrett.

Supplementary Figure S3: The Bear Trap (88) and surrounding seascape. This is interpreted as a Greenland Norse storage facility, and is located on the northwestern tip of the Nussuaq Peninsula (Fig. 5). This location offered a sheltered harbour as well as proximity to the outer coast and the open sea, thereby reducing the danger of katabatic winds and becoming trapped by pack ice; the surrounding area also offers ready access to walrus haul-out sites and their shallow feeding grounds. Photo: Matthew Walsh (reproduced with permission).

SUPPLEMENTARY TABLES

Table S1: Full provenance information: Biological samples.

Table S2: Full provenance information: Cultural samples

Table S3: Estimated rowing distances based on various interpretations of *Grœnlands annál*. For further information, see Supplementary Text.

		Distances from the Western Settlement (Nuuk) in days rowing			
Places mentioned in the text (with known locations)	Nautical miles	Jónsson, literal	Jónsson as per Halldórsson (52)	Jónsson as per Nedkvitne (6)	Jónsson as per Ljungqvist (31)
Dyrnes (Eastern Settlement)	327	?	6	-	12
Arsuk (Middle Settlement)	217	6	?	-	-
Lýsufjarðar	?	6	(same as WS)	6	-
Karlbúða	?	12	6	12	12
Bjarneyjar (Godhavn)	345	15	9	15	15
Bjarneyjar (Disko Island) circumference	215	12	12	12	12

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The sailing voyages of the Viking Age were extraordinary feats of navigation which connected people, places, and things across four of the world's seven continents. They had a truly global impact on our past and remain iconic in our present, but scholars have long struggled to understand how they were accomplished. Major uncertainties regarding Viking Age seafaring technologies, practices, and worldviews have hindered the study of these remarkable journeys, and prevented archaeologists form locating important sites across the Viking world.

This thesis addresses these uncertainties by offering a practical, maritime perspective on Viking Age seafaring. This perspective has been attained through experimental voyages onboard traditional Norwegian boats, technological descendants of Viking Age vessels. The results of these experiments provide a revised understanding of the technical and logistical potentials of Viking Age ships and their crews, and extend the geographical range of this period's voyages to include new encounters, new places, and new ideas. The Viking world was defined by maritime interaction and exchange; it can therefore only be understood by thinking from the sea.

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