HISTORICAL ECOLOGY OF NORSE GREENLAND: ZOOARCHAEOLOGY AND CLIMATE CHANGE RESPONSES

by

KONRAD SMIAROWSKI

A dissertation submitted to the Graduate Faculty in Anthropology in partial fulfillment of the requirements for the degree of Doctor of Philosophy, The City University of New York.

2022

Historical Ecology of Norse Greenland: Zooarchaeology and Climate Change Responses

by

Konrad Smiarowski

This manuscript has been read and accepted for the Graduate Faculty in Anthropology in satisfaction of the dissertation requirement for the degree of Doctor of Philosophy.

Date

Thomas McGovern

Chair of Examining Committee

Date

Jeff Maskovsky

Executive Officer

Supervisory Committee:

Ian A. Simpson

Andrew J. Dugmore

Jette Arneborg

THE CITY UNIVERSITY OF NEWYORK

ABSTRACT

Historical Ecology of Norse Greenland: Zooarchaeology and Climate Change Responses

by

Konrad Smiarowski

Advisor: Thomas H. McGovern

This thesis invokes Historical Ecology approach to better understand human impacts on marine and terrestrial ecosystems, and the creation of cultural landscapes and seascapes in Norse Greenland. It also investigates climate impacts on human economic strategies, as they vary substantially by island and region in the North Atlantic but were especially important in arctic Greenland.

The analysis centers on the animal bone data and uses both existing and newly generated zooarchaeological collections to contribute to the study of Norse Greenland and its place in human ecodynamics research. The newly analyzed archaeofauna shows that the culturally Nordic European settlers used to the life based around domestic livestock and associated foddering rapidly transformed their subsistence strategies to the limits and opportunities of the new environment. Marine fishing was immediately supplanted by intensive communal seal hunting, caribou hunting was rapidly organized by the elite managers, and the herding strategies were adapted to the less productive pastures. At the same time the data shows early prolonged commitment to the Norðursetur walrus hunt, despite the high risks, and does not show evidence for a reduction of the hunting effort after the 1300 CE climate impacts.

Climate change played significant role in the Greenlandic adaptations, and intensification of seal hunting and modification of the herding economy after 1300 CE, were successful strategies until a conjunction of environmental and economic events caused the disappearance of the settlements.

Different trajectories for large and small farms through time, and elite takeovers of smaller holdings after ca. 1250 CE support the picture of medieval Greenland as fully hierarchical society, which was sustainable for a prolonged period of time.

Through fieldwork that generated the new archaeofauna the research community was made aware of current climate change caused degradation of organic preservation at archaeological sites in SW Greenland, and enabled researchers to study these processes, and to organize excavations aimed at saving the remaining fragile sites from complete decomposition in the immediate future.

Suggestions for future research to make best use of available sites and materials is also provided.

This research was made possible by generous grants from the National Geographic Society, RANNIS, Social Sciences and Humanities Research Council of Canada, the Leverhulme Trust, the Wenner-Gren Foundation for Anthropological Research, the Liefur Eirkisson Fellowship Program, the American Scandinavian Foundation, and the US National Science Foundation (grants 0732327, 1140106, 1119354, 1203823, 1203268, 1202692, & 1821284).

ACKNOWLEDGMENTS

First, I would like to convey incredibly special gratitude to my advisor Tom McGovern for the opportunity to do research in Greenland, his patience, invaluable advise and help while working on this thesis; and for constantly proving that archaeology is amazing.

I would like to thank my committee, Jette Arneborg, Ian Simpson and Andy Dugmore for the support and advise throughout the years, and for all the comments on this work.

Special thanks to colleagues and trusted friends: Christian Madsen for all those years of boats, tents, digs, and hikes exploring the wilderness of Greenland and Copenhagen. Michael Nielsen for showing me what Greenland really is, and how to see that. Ramona Harrison for support when it was needed most. Morten Ramstad for welcoming me to Bergen, Norwegian archaeology, and always making sure I have a place to write.

I want to say thank you to all who collaborated with me in Greenland, from whom I learned and with whom I grew as an archaeologist: Mari Kleist, Poul Heide, Norie Manigault, Anthony Mustchin, Jade De La Paz, Howell Roberts, Aaron Kendall, Seth Brewington, Gudrun Alda, Caroline Mortensen, Frank Feeley, Fuuja Larsen, Megan Hicks and many more.

Warmest thanks to friends and hosts from Vatnahverfi: Arnaq Bjerge Petersen, Andala Lund and Karo, Magnus Hansen and Justine, Aka Simonsen, Sofianguak Kristiansen, Kathrine and Christian Isbosethsen.

Finally, I would like to thank Sophia Perdikaris for introducing me to North Atlantic archaeology and the PhD program at CUNY.

CONTENTS

TABLES

FIGURES

CHAPTER 1: Introduction

Greenland has been a focus for international scientific research for two centuries, hosting some of the earliest professional archaeological projects in the circumpolar north (Bruun 1895 et seq.; Holm 1883; Nørlund 1929, 1936; Roussell 1934, 1936, 1941; Degerbøl 1929 et seq.; Krogh 1967, 1974, 1982; Vebæk 1943 et seq.). Greenland has proven a remarkably productive research area for the investigation of human colonization of the "last settled places", for the study of different cultural impacts upon land and sea, for the impact of fluctuating climate on cultures past and present, for the study of medieval to modern world system impacts upon northern societies, and for the development of genuinely transdisciplinary sustained collaboration across disciplines (Adderley and Simpson 2006; Adderley et al. 2008; Albrethsen and Keller 1986, Albrethsen 1991; Appelt and Gulløv 2009; Arneborg 2003 et seq., Arneborg et al. 2009, 2012; Buckland et al. 1983 et seq.; Commisso and Nelson 2007; Dugmore et al. 2004 et seq.; Dussault et al. 2014; Edwards et al 2008 et seq.; Edvardsson 2013; Enghoff 2003; Fredskild 1973, 1988; Forbes et al. 2013, 2014; Frei et al. 2015; Golding et al. 2011,2015; Gulløv 1995 et seq.; Hartman et al. 2017; Hayeur-Smith 2014, 2020;; et al. 2018, 2022; Hoegsberg 2007; Keller 2010; Keighley et al. 2019, 2021; Ledger et al. 2013 et seq; Lynnerup 1998, 2004, 2014; Madsen 2009 et seq.; Mainland 2006; Mainland and Halsted 2005; Margaryan et al.2020; McGovern et al. 1985 et seq.; Mikkelsen et al. 2008; Ogilvie et al. 2009; Outram 1999, 2003; Panagiotakopulu et al. 2012, 2015; Perdikaris and McGovern 2008; Roesdahl 2005; Schmid et al. 2021; Schofield et al. 2007 et seq.; Simpson et al. 2001 et seq.; Smiarowski et al. 2007 et seq.; Star et al. 2018; Vésteinsson 2010, 2013, 2019).

Norse Greenland has also become famous as a controversial case of collapse of the medieval Social-Environmental System (SES) in the mid-15th century. Norse Greenland has been described as a society that "chose to fail" (Diamond 2005, but also see Dugmore et al. 2007 et seq.; Berglund 2010; Jackson et al. 2018; McGovern et al. 2015). The end of Norse Greenland has become iconic in the growing literature of the archaeology of sustainability (Constanza et al. 2007, Crumley 1994, Butzer and Enfield 2012; Hambrecht 2020; Hegmon et al. 2014; Nelson et al. 2016; Redman et al. 2004, Rick and Erlandson 2008, McIntosh et al. 2000; Van der Leeuw and Redman 2002; Van der Leeuw et al. 2011) and in environmental history (Haldon et al. 2018; Hoffman 2014; Jackson et al. 2022) and in new syntheses of Viking-Medieval studies (Lund and Sindbaek 2021, Jesch 2015; Price 2018, 2020) Norse Greenland has recently featured in popular articles as a warning on the human cost of global change in *Science Magazine, National Geographic*, Smithsonian Magazine and the *New Yorker* (Kolbert 2016, Kintisch 2016, Folger 2017). Norse Greenland now represents a classic case of human island ecodynamics with significance for both circumpolar historical ecology and for current efforts to promote future resilience and sustainability (Fitzhugh et al. 2019). Norse Greenland as a study area also presents both a rich tradition of multi-disciplinary scholarship and exciting set of ongoing research challenges and unanswered questions, many of which are directly relevant to the author's specialties in zooarchaeology and paleoeconomy.

The author has participated in nine Greenlandic field research seasons since 2006 and has had responsibility for midden and structural excavation and zooarchaeological analyses that have generated large new data sets and produced multiple publications (Smiarowski et al. 2006 et seq.). This thesis is an element in major ongoing multi-investigator investigations aimed at improving our understanding of long-term human ecodynamics in Greenland and the North Atlantic that has attracted sustained international funding support for multiple interlocking projects in the current century. While centered on Norse Greenland, this study takes a regional perspective that connects to other North Atlantic Island settlements and to the larger societies of Viking Age and medieval

Europe. This thesis owes a great deal to the international, interdisciplinary *North Atlantic Biocultural Organization* research cooperative (NABO) and represents one element in a coordinated multi-investigator international effort to better understand the complex interactions of culture, climate, history, and arctic environment that produced and then ended a unique society in the circumpolar north.

This thesis will thus draw upon the work of many collaborators and upon a research tradition that extends over multiple generations. While it will make use of different lines of evidence from stable isotopes to landscape survey and will provide summary overviews of diverse relevant data sets, the core contribution of this work will be in using the tools and data of zooarchaeology and drawing upon the theoretical framework of Historical Ecology (Armstrong et al. 2017, Balée 1998, 2006, Balée et al. 2006; Crumley 1994, 2007, 2012, 2018a, 2018b; Sinclair et al. 2018). It will focus upon issues of human-animal interaction in Norse Greenland and upon the economic organization of a system that combined subsistence production based on both hunting and farming with a remarkable long-range hunt for arctic trade goods. The thesis will make full use of new chronological frameworks for the settlement, expansion, and contraction of Norse Greenland developed in the past decade through stratigraphic excavations and multiple AMS radiocarbon dates which for the first time allow for effective chronological control of multiple archaeofauna (animal bone collections). It will also make use of large newly excavated collections previously unavailable for the Norse Eastern Settlement, allowing effective comparisons with older collections from the Western Settlement and other parts of the North Atlantic. It is now possible to document changing balance of marine hunting and terrestrial farming and caribou hunting through time, and to compare economic strategies on farms of different size and status. This thesis will thus present new data sets that will expand our understanding of economic responses to climate change and inter-regional trade, and which allow systematic comparisons with directly comparable archaeofauna elsewhere.

This thesis will use these new data to focus upon issues of adaptation to climate change and changing effects of transatlantic contacts, and it will make use of comparative zooarchaeological data sets from Iceland and the Faroes to better document the diverging pathways taken by these related North Atlantic Island societies. It will seek to engage with some of the "grand challenges for archaeology": A. Emergence, communities, and complexity, B. Resilience, persistence, transformation, and collapse; C. Movement, mobility, and migration; D. Cognition, behavior, and identity; E. Human–environment interactions (Kintigh et al. 2015), by providing fresh zooarchaeological perspectives on the environmental and economic forces that supported Norse Greenland for nearly five hundred years while failing the ultimate test of sustainability in a rare case of full-scale SES collapse and complete societal extinction.

This thesis will also draw upon exceptionally productive collaborations between the NABO teams and scholars working in other regions, especially the *Long -Term Vulnerabilities and Transformations* project (LTVTP) in the Desert Southwest (Dugmore et al. 2013; Hegmon et al 2014, 2018, Nelson et al. 2016, 2017, Smiarowski et al. 2017). It will make use of concepts of robustness, vulnerability, inter-scale economic interactions, limits to traditional knowledge, conflicts between short term and long -term adaptation, causes and results of social pathway dependence, and the adaptive consequences of tradeoffs between resilience and hierarchy and between isolation and long- distance contacts.

As a contribution to knowledge and in support of ongoing research, this thesis will provide a review of all existing analyzed zooarchaeological data for Norse Greenland and provide full documentation of new excavations of archaeofauna conducted by the author up to 2016. It will provide evidence for rapid loss of organic preservation in SW Greenland and provide rationale and suggestions for new investigations in the region and future research directions.

It will **not** seek to duplicate already published work, particularly the doctoral project of Christian Madsen (2014). Madsen's thesis reviews the history of archaeology in Greenland from the 18th century to the present, describing survey methods and results, in summarizing environmental and climatic data for SW Greenland, in creating a major new classification framework for Norse buildings and structures, and making the lasting contribution of a comprehensive *Ruin Group Database*. This thesis will in many ways represent a compliment to Madsen's monograph, with focus upon animal bones rather than farm layout and settlement pattern and generating a new comprehensive *Norse Greenland Archaeofauna* database. It will engage with many of the same research questions and problems as Madsen's thesis, but from a different perspective and with different data resources.

This thesis will present a discussion of the theoretical grounding for this research effort (Chapter 2), before moving to a presentation of background and prior research of Historical Ecology and Zooarchaeology in Norse Greenland (Chapter 3). It will provide a discussion of methods used in excavation, analysis and recording of the new archaeofauna (Chapter 4), and an assessment of the special potentials and limitations of these data sets. In Chapter 5 it will present a focused set of discussions of major applications of the current zooarchaeological record. Chapter 6 will present interpretations of changes in Norse Greenland paleoeconomy through periods of climate change and draw on prior publications to present a case study of farm to shielding transition and contrasting pathways in later medieval Iceland and Greenland. Chapter 7 will draw together major findings of this study, make suggestions for future research in Greenlandic zooarchaeology, and sum up contributions to knowledge.

CHAPTER 2: Historical Ecology, Grand Challenges, and Norse Greenland Research Questions and Broader Significance

2.1 Historical Ecology as a Common Theoretical Framework for Human Ecodynamics Research

The *School of American Research Advanced Seminar* in Santa Fe held in 1990 that produced the initial edited volume *Historical Ecology: Cultural Knowledge and Changing Landscapes* (Crumley 1994) included a chapter on Norse Greenland (McGovern 1994), and northern case studies have been part of the developing agenda of Historical Ecology (HE) from the outset. Historical Ecology is now a mature and flourishing research program involving environmental humanities, local and traditional knowledge, archaeology, history, paleoecology, and modern resource managers. It forms a key element of the IGBP/*Future Earth* core program IHOPE (*Integrated History and Future of People on Earth*, http://ihopenet.org/) based in Uppsala Sweden and led by Carole Crumley. A recent blog post by Crumley provides a useful and authoritative summary of the Historical Ecology program:

> *"Historical ecology is a practical framework of concepts and methods for studying the past and future of the relationship between people and their environment. While historical ecology may be applied to spatial and temporal frames at any resolution, it finds particularly rich sources of data at the "landscape" scale, where human activity and cognition interact with biophysical systems, and where archaeological, historical, ethnographic, environmental, and other records are plentiful.*
>
> *The term historical ecology draws attention to a definition of ecology that includes humans as a component of all ecosystems and to a definition of history that goes beyond the written record to encompass both the history of the Earth system and the social and physical past of our species. Historical ecology provides tools to construct an evidence-validated, open-ended narrative of the evolution and transformation of specific landscapes, based on records of human activity and changing environments. Historical ecology offers insights,*

> *models, and ideas for the sustainable future of contemporary landscapes based upon a comprehensive understanding of their past.*
>
> *Several independent developments in the 1990s were products of an effort to increase collaborative research across certain disciplines. Archaeologists, anthropologists, geographers, and ecologists drew on common themes and concerns.*
>
> *Historical ecology in archaeology and anthropology derives, for the most part, from archaeological best practice, which routinely amalgamates information about the past from disparate sources. In a local and regional context, applied archaeology aids heritage management, historic and environmental conservation, ecological restoration, and landscape archaeology.*
>
> *Paleoecology, an old friend of archaeology, offers knowledge of vanished landscapes: vegetation dynamics, dendrochronology, disturbance history, paleoclimatology, wetlands history, seed banks, and plant communities. Historical ecology has helped reconstruct a remarkable span of history, from the ancient landscapes of early hominids to historic agrarian landscapes and gardens….*
>
> *Thus, the emergent, collaborative, transdisciplinary research environment of historical ecology draws on a broad spectrum of concepts, methods, theories, and evidence taken from the biological and physical sciences, the social sciences, and the humanities. It is not a new discipline so much as a cluster of mutually compatible questions, concepts, methods, and values that are germane to diverse challenges. It is a rich environment within which to find common cause with other initiatives. Such communities are taking shape and broadening their inclusivity."*
>
> *(Carole Crumley 24 July 2014, Blog post http://www.hercules-landscapes.eu/blog.php?what_is_historical_ecology&id=10)*

Historical Ecology is thus a conceptual tool kit for successful interdisciplinary research more than an ideologically driven theoretical paradigm (Meyer and Crumley 2011; Crumley 2012). In practice, HE archaeology integrates both core processual and post-processual perspectives and bridges the science/humanities divide by connecting human intentionality, stores of traditional knowledge, politics, and bounded rationality with environmental science in place-based research with the fundamental realization that landscapes are product of the biosphere, humans, climate, geology, and time. Historical Ecology has provided support for diverse archaeological attempts to more effectively engage with modern issues of sustainability, adaptation and resilience, and HE participants include restoration ecologists and resource managers with a practitioners' interest in using the past to more effectively manage current resources and landscapes for the future, as well as cultural heritage managers working towards creating potential economic resource for local communities (Balée and Eriksson 2006, Costanza et al. 2012, Hartman et al. 2017, Hicks et al. 2016, Jackson et al. 2018). HE has served to effectively connect the perspectives of the French Historical *Annales* school (*Longue durée*, conjunctures, cross-scale interactions, human landscape creation, (Harsgor 1978) with the influential formulations of the *Resilience Alliance* (panarchy, fast and slow variables, cross-scale and cross-temporal interactions, resilience, vulnerability, robustness, trade-offs, pathway dependence; https://www.resalliance.org/).

These perspectives of the *Annales* School and the Resilience Alliance can also be connected to an influential early article in *Antiquity* (McGlade 1995) which introduced the term "human ecodynamics" to capture the sense of intense interaction between natural and human systems and the potential for unexpected emergent properties from either to produce sudden change (see also updated discussion in Fitzhugh et al. 2019). IHOPE human ecodynamics research approaches thus explicitly reject simplistic determinism ("it got cold, and they died"; McGovern 1991) and seem particularly appropriate for the complex and controversial case of Norse Greenland.

On the operational level, Crumley's call for a "longitudinal research strategy" in HE that focuses upon a landscape changing through the *longue durée* rather than artificial periodization (e.g., Viking Age, Medieval, Early Modern) has had several important consequences for NABO-led North Atlantic research. One has been the creation of common long -term, landscape- focused research areas where multi-disciplinary teams can return for multiple seasons, sharing logistics and saving funds. Bringing paleoecology pollen coring and archaeological excavation teams into the same camp where mutual learning takes place over shared meals and logistics chores also creates trust and understanding of different disciplinary needs and capacities. These sustained contacts and shared interest in different aspects of the same landscape provide a powerful tool for getting interdisciplinary collaboration done on a practical level, especially when graduate students can share labor on each other's projects and form personal bonds across disciplines. Returning to the same research area for multiple years likewise allows more comprehensive site survey and follow up excavation, a deeper understanding of place and natural variability as well as closer collaboration with local residents and scholars and produces positive research benefits as well as rationalized logistics and improved health and safety. This longitudinal approach also encourages a mindset in which nothing is "pre- or post-interesting", and the early modern record can be used to better understand the medieval and Viking Age patterns in the same landscape just as later residents inherit the landscape modifications of the past. This approach is evident in Madsen's doctoral thesis (Madsen 2014) in which the well-recorded experiences of 19th-20th century Inuit Greenlandic farming in the former Norse Eastern Settlement proved exceptionally useful in modeling the challenges faced by Norse farmers 500 years before. The sustained focus on the same region also has great benefits for zooarchaeology, where archaeofauna from neighboring sites (potentially once members of a working community) can be compared and the potential effects of local site catchment, site status, and large-scale environmental change can be better assessed than in a scattershot pattern of widely separated sites in completely different districts (McGovern et al. 2007).

In Iceland, this commitment to landscape- scaled longitudinal strategies has resulted in highly productive long- term research areas in Svalbardshreppur (Gísladóttir et al. 2013; Dupont-Hebert 2013, 2017, 2020), Mývatn region (Hicks et al. 2016, Lucas 2009; McGovern et al. 2007), Eyjafjord, (Harrison et al. 2005 et seq., Roberts et al. 2002 et seq.) and Skagafjord (Bolender et al. 2008, 2011, 2013; Cesario 2021). The decision to focus international research teams on the Vatnahverfi area in SW Greenland for multiple field seasons thus can be seen as part of the HE-influenced Longitudinal research strategy as well as a measure to improve direct comparability between the Icelandic and Greenlandic portions of the IPY and CIE projects.

2.2 Grand Challenges for Archaeology and Broader Significance

Beginning in 2011, a diverse and distinguished group of archaeologists held a series of workshops and conducted a broad crowd-sourcing polling exercise aimed at identifying "problems of broad scientific and social interest that could drive cutting edge research in archaeology for the next decade and beyond" (Kintigh et al. 2014). This thesis, and the NABO cooperative effort overall has direct relevance to many of the "grand challenges" identified by this collaborative visioning process:

A. Emergence, communities, and complexity, B. Resilience, persistence, transformation, and collapse; C. Movement, mobility, and migration; D. Cognition, behavior, and identity; E. Human–environment interactions.

A similar multi-staged crowdsourced review process begun in 2014 led by early career researchers active in HE flags up 50 questions for new and ongoing Historical Ecology research (Armstrong et al. 2017). The following sub-set of the 50 research questions drawn from this study have direct relevance to this thesis, and reflect the broader disciplinary significance of this research:

"Climate and environmental change and variability

1. What roles have humans played in extinction events and what can we learn about these large and small-scale changes?

2. When did human activities begin to have significant impacts/effects on their environments?

3. What factors allow human populations to become more decoupled from immediate environmental constraints?

4. What are the archaeological proxies of past climatic stability or instability?

8. How did past societies respond to sudden environmental shocks (e.g., extreme weather) and what can we learn from this?

9. What factors have made some communities more adaptable to environmental change than others?

Multi-scalar, multidisciplinary

10. How do historical ecologists address different temporal and spatial scales, how do we define/communicate them, and how do we study their interactions?

13. How do we constitute humans as integral parts of ecosystems and how do we conceptualize humans as one of many species in an ecosystem? At the same time, how can environmental history, in which humans are always regarded to be the protagonists of ecosystem change, effectively cooperate with historical ecology, which regards humans as one of the many species in an ecosystem?

14. How do we engage with the concept of sustainability in historical ecology, especially given constantly changing environmental dynamics, with or without humans?

15. What data standards should we develop to aggregate relevant information in a consolidated open-source database?

Biodiversity and community ecology

16. How does the removal or introduction of species affect landscape and seascape ecology?

Resource and environmental management and governance

29. How are past relationships between centers and peripheries (e.g., urban centers and hinterlands) characterized in terms of resource management and governance?

30. Why do different cultural groups in the same bioregions utilize resources in dissimilar ways?

32. How do traditional resource management practices of migrant human populations shape newly encountered land- and seascapes?

33. What is the role of geopolitical power in the development, maintenance, and dissolution of cultural ecosystems?

34. How has the construction of borders, boundaries, and frontiers (and distance) affected land-use practices?

35. How have people altered and managed their land- and seascapes to enhance desirable resources in coastal regions?

Methods and applications

41. How can we see and understand gendered relationships to foodways, past and present?

(e.g., food and food systems operating in dynamic socio-cultural environments connected to issues of health and nutrition, livelihood security, labor and power divisions, and cultural and biocultural renewal).

42. What unique contributions might historical ecology make to emergent cross-disciplinary conversations about the Anthropocene?

45. How can we differentiate between natural and human-mediated range expansions for plants, animals, and other organisms?

46. How can historical ecology engage with Indigenous and local oral traditions that may incorporate diverse spatial and temporal scales?

Communication and policy

47. How can we develop evidence-based frameworks that highlight and overcome the problem of shifting baselines by incorporating long-term archaeological and historical data into contemporary policies and governance?" (Armstrong et al. 2017).

2.3 Research Questions for Norse Greenland

The NABO cooperative invokes the HE agenda and the value of the long-term human ecodynamics approach in its three- point common research program to better understand the interactions of:

- **Human impacts** on marine and terrestrial ecosystems and the creation of cultural landscapes and seascapes. Intentional and unintended introductions of domesticates, crops, weeds, parasites and commensals and the creation at Landnám of an influential landscape heritage. Drawdown of *Natural Capital* (bird colonies, walrus, woodland, soils) is part of the Norse North Atlantic story, but so is sustainable Natural Capital management on the millennial scale. Fixed investments in immobile *Landesque Capital* (churches, farm buildings, herding structures, landings and routeways) potentially have both beneficial and negative implications for long term resilience and sustainability in Greenland, as last settled places become islands with human history and a part of the paleo-Anthropocene.
- **Climate impacts** on cultural landscapes and seascapes and human economic strategies vary by island and region but were especially important in Greenland. As Norse settlers moved south and west to Greenland, they crossed multiple climate gradients with implications for crop production, animal husbandry, hunting, and technology. Greenland is certainly the most arctic of the medieval North Atlantic settlements, and climate fluctuations have played a major role in theories of isolation and extinction. High resolution multi-proxy climate data now increasingly allow climate impact assessment at the "human scale" of years and seasons. Simplistic climate determinism is giving way to a better understanding of the limits of resilience of Norse adaptive strategies in the face of ongoing climate variability.

- **Human impacts upon other humans** include initial culture-contact situations, evolving core-periphery relationships between large European population centers and the distant Greenland community, and changing governance structures within the island communities. The Norse colonists in the Viking age introduced a hierarchical manorial social system that arguably evolved towards increasing inequality through time. Both the interactions of Norse Greenlanders with Dorset and Thule hunters and with European traders and administrators and the consequences of internal social hierarchies have formed key areas for research in Norse Greenland. Researchers increasingly recognize that the *Social Capital* represented by accumulated LTK, community solidarity, tight control of communal labor, and shared piety may represent the key resource that both sustained resilience and robustness and may have contributed to ultimately fatal pathway dependence and social inequality.

These three NABO themes connect closely with the broader community research goals laid out in both the *Grand Challenges* and *50 Questions* surveys, and they also provide some general and specific research questions to be addressed by this thesis. This thesis centers on the animal bone data, and its aim is to use both existing and newly generated zooarchaeological data to contribute to the study of Norse Greenland and its place in human ecodynamics research. These are important but often difficult questions to answer and verify outcomes . Zooarchaeology gives a vital and robust approach to them.

CHAPTER 3: Overview and Prior Research

3.1 Overview of Icelandic and Greenlandic Long-Term Human Ecodynamics

When Icelandic settlers crossed Denmark Strait in the late 10th century to found two communities on the west coast (Eastern Settlement in modern *Kujalleq* district, Western Settlement in *Nuuk* district further north) they crossed significant climatic and biological frontiers, though these may not have all been immediately apparent (Dugmore et al. 2013). In Greenland they encountered caribou, polar bear, and huge populations of walrus as well as both familiar North Atlantic and unfamiliar Arctic seals and whales. Greenland was probably always beyond the reach of significant cereal agriculture though flax and cereal pollen has been recovered and use of Lyme grass has been hypothesized while finds of grindstones and baking plates at E47 Garðar, E2 Tingimiut, and GUS 'Gården under Sandet' suggest some consumption of grain by the bishop's household and a few other places (Vésteinsson et al. 2014, J. Arneborg personal communication, June 2nd, 2022, see discussion below chapter 5).

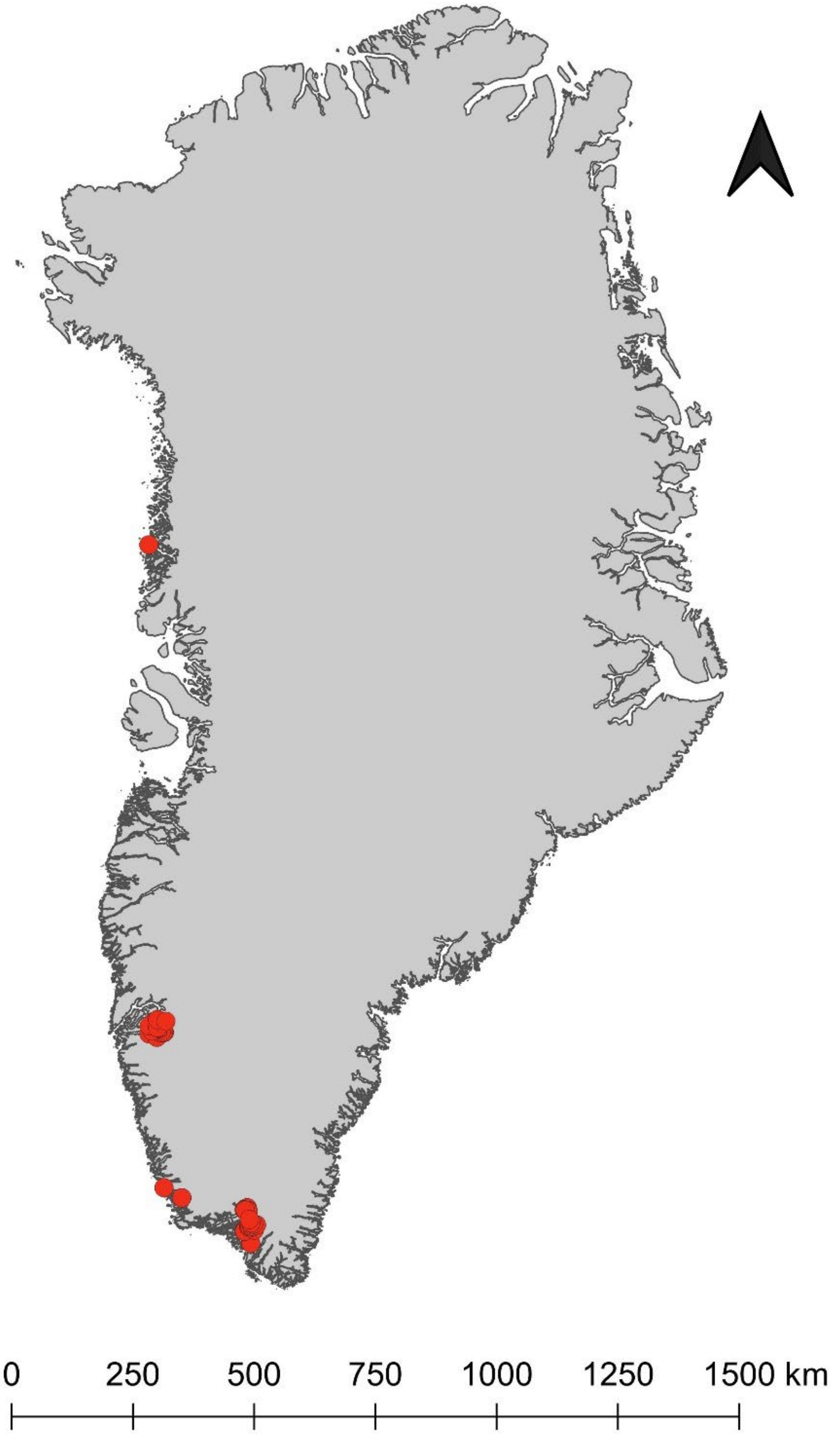


Figure 1 Map of Greenland with all sites discussed in this thesis indicated. Map by Howell Roberts and the author (source: nunniffiit.natmus.gl and QGreenland (v2).

Initially, the full Icelandic range of cattle, sheep, goats, dogs, horses, and pigs appear in early Greenlandic collections (Smiarowski 2013a, 2014, Smiarowski et al. 2017). Along with these deliberately transported animals, a suite of accidentally imported insects, plants, and house mice also made the voyage from Iceland and established themselves (at least indoors) in Greenland (Buckland et al. 1983, 1994, 1996; Dussault et al. 2014; Forbes et al. 2013, 2014). Icelandic-style pastoral farming proved successful in the richer patches of the Eastern and Western Settlement areas (Ledger et al. 2014) but there was considerable variability in pasture size and productivity (and vulnerability to climate change such as increased or more persistent snowfall). The two zones of potential farmland in the inner fjords of the southwest were isolated by thousands of kilometers of barren coast, the interior ice sheet, and within these settlement areas rough terrain, heavily indented fjord coastline and often dispersed pockets of pasture produced a settlement pattern of often widely dispersed farmsteads and shielings. As pointed out by Madsen (2014) and Vésteinsson et al. (2014) farms in Greenland are far more widely spaced (normally 3-7 km) than in Iceland (normally 0.5 -2 km, exceptionally 3-5 km). While most farms are spaced along valley bottoms, some are isolated against steep coastal mountains that would appear to restrict movement to boats or travel on winter ice. As Vésteinsson has noted, this distance between households and significant travel costs would have had both social and economic impacts on Norse society in Greenland. While Madsen's survey and site documentation work combined with the geo-archaeological and palynological research (Adderley and Simpson 2006, Adderley et al. 2008, Buckland et al. 2008, 2009; Edwards et al. 2008, 2011; Panagiotakopulu et al. 2012, 2015; Schofield 2008; Ledger et al. 2013,2014a; Golding et al., 2015) makes clear that the Norse farmers were highly skilled in getting the most out of their scattered and vulnerable patches of pasture, it seems clear that North Atlantic pastoralism was near its limits in Greenland. Coordinating labor for seasonal tasks (including seal hunting and the Norðursetur voyages), and the social and religious need for periodic face-to-face meetings also had to contend with settlement dispersal and travel costs, and it the degree of community coordination achieved by the Norse Greenlandic society is in itself an impressive achievement. The combination of a successful (if possibly fragile) farming system with long term caribou management and a strong commitment to maritime hunting while also maintaining a costly long distance commercial Norðursetur hunt for nearly five centuries despite these inherent limitations is not the sign of a society that "chose to fail".

3.2 Prior Zooarchaeological Research 1895-2005

Zooarchaeology came early to Iceland and Greenland. The Danish Captain Daniel Bruun regularly collected unmodified animal bone remains from his very professionally conducted excavations in both islands just over a century ago (Bruun 1895,1896, 1899, 1903a, 1903b, 1917, 1918; Bruun and Jónsson 1911), with pioneering zooarchaeological reports produced by Herluf Winge of the University of Copenhagen Zoological Museum (Winge in Bruun 1896, 1918). Magnus Degerbøl and Ulrik Møhl continued the Zoological Museum tradition with a series of now-classic reports based on major Danish projects in Greenland and Iceland (Degerbøl 1929, 1934, 1936, 1939). These studies not only established the key role of seals in the paleoeconomy of Norse Greenland but also led to the development by Ulrik Møhl of seal bone identification keys still used throughout the North Atlantic. Post-WW2 zooarchaeology in Greenland added radiocarbon-dated, stratified collections and sieved recovery (Buckland et al. 1996, McGovern 1985, McGovern et al. 1996, Enghoff 2003). Much of this new work centered on the Norse Western Settlement, and the majority of the Western Settlement archaeofauna come from what was probably a single community (parish or *hreppur)* centered on the chiefly church farm of Sandnes W51.

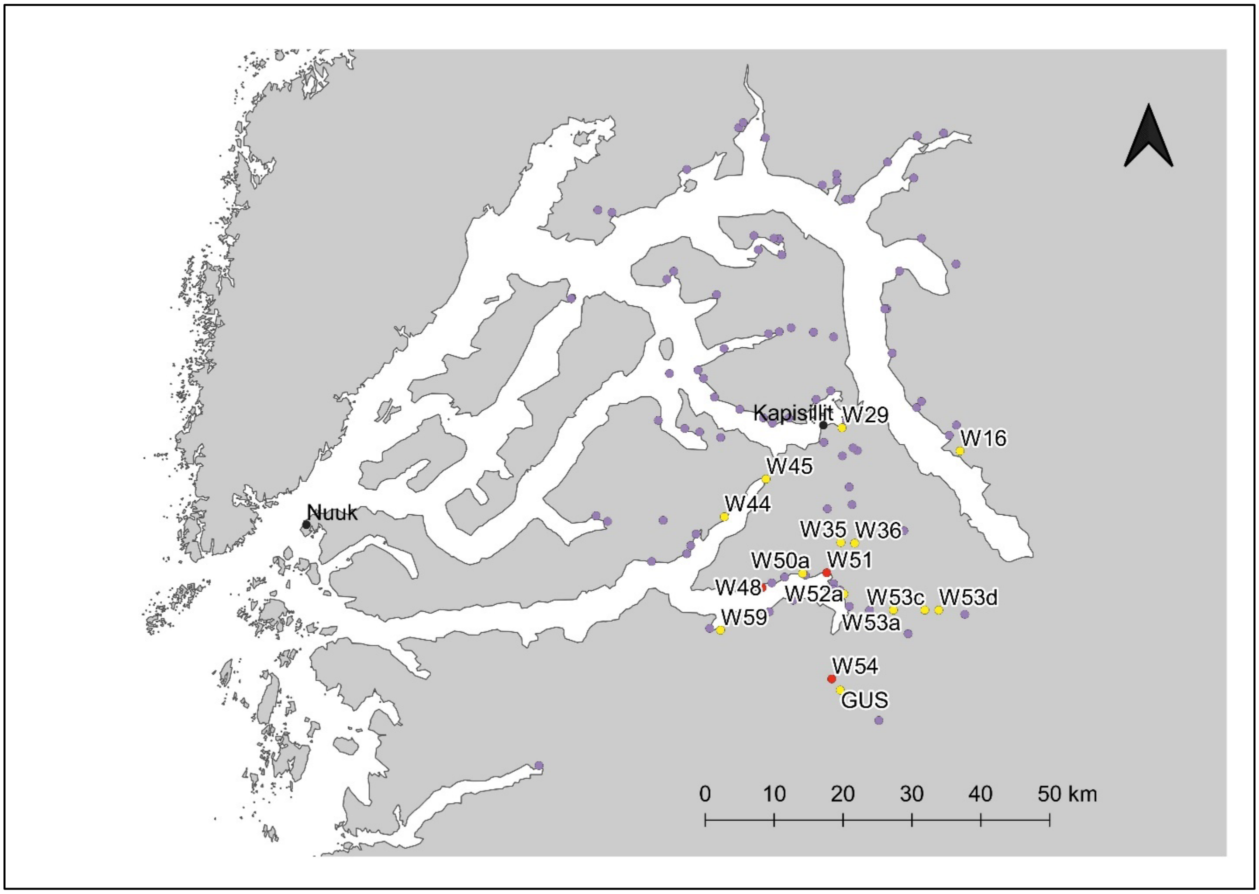


Figure 2 Map of the Western Settlement with all the sites discussed in this thesis indicated (yellow and red). All archaeofauna was analyzed prior to 2005. Red sites indicate collections re-analyzed by the author to extract seasonality signatures of domestic animals based on toothwear and eruption stages, seal teeth sectioning, and caribou teeth sectioning. Map by Howell Roberts and the author (source: nunniffiit.natmus.gl and QGreenland (v2).

During the 2007-11 *International Polar Year* and under the 2012-16 *Comparative Island Ecodynamics Project*, NABO research has focused on the diverging pathways and differing outcomes of "long-term human ecodynamics" in Iceland and Greenland. This thesis draws both upon this new work and upon a zooarchaeological research tradition extending over a century. Its main contributions to the growing zooarchaeology of Norse Greenland are in providing additional dated stratified archaeofauna and in updating and expanding the record from the larger and longer-lasting Eastern Settlement.

3.3 Greenland Fieldwork Projects 2005-2016

While drawing upon more than a century of prior research in the archaeology of Norse Greenland, this thesis is primarily the product of a series of inter-connected international, interdisciplinary 21st century fieldwork projects coordinated by the North Atlantic Biocultural Organization research cooperative (NABO). This section provides a brief overview summary of these projects' chronology and activities.

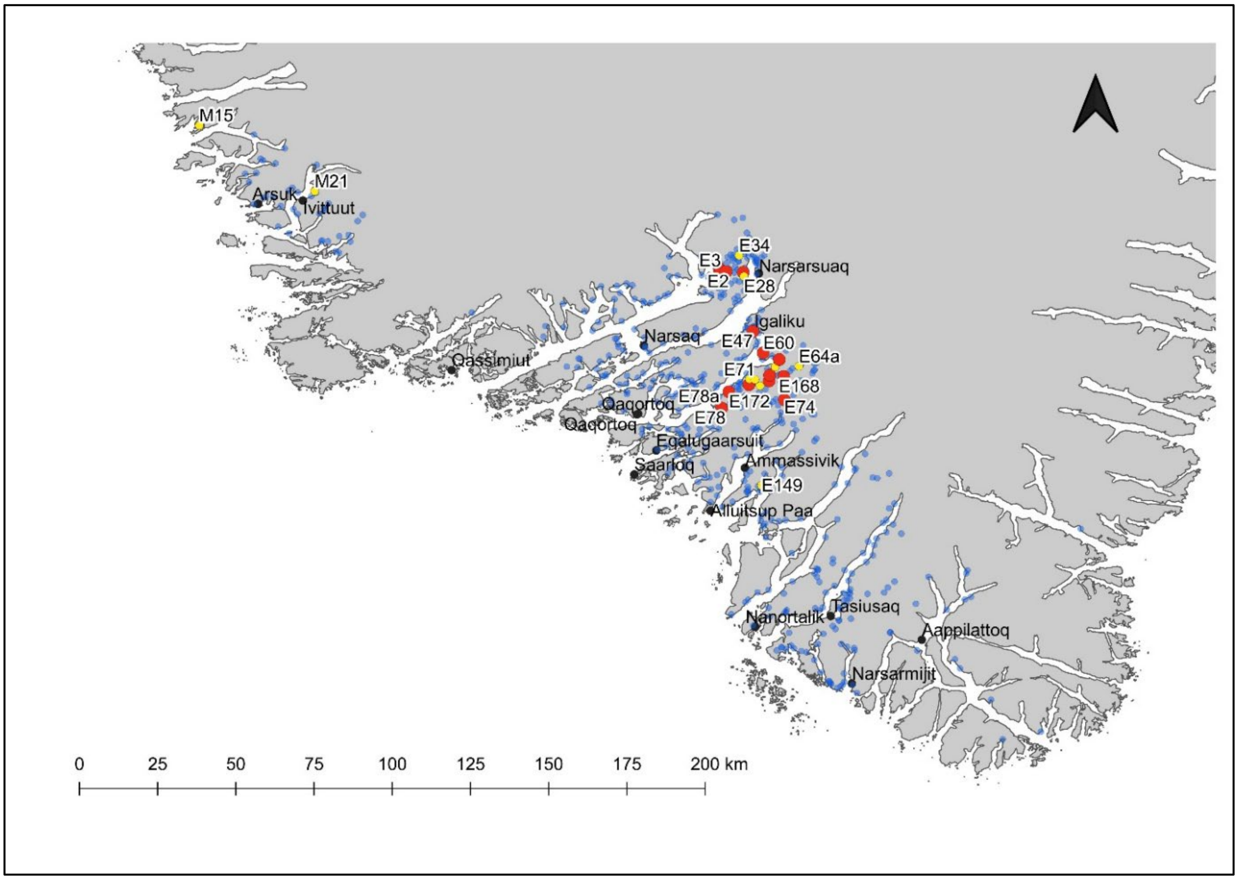


Figure 3 Map of southwest Greenland with all sites in Eastern and Middle Settlements. Map by Howell Roberts and the author (source: nunniffiit.natmus.gl and QGreenland (v2).

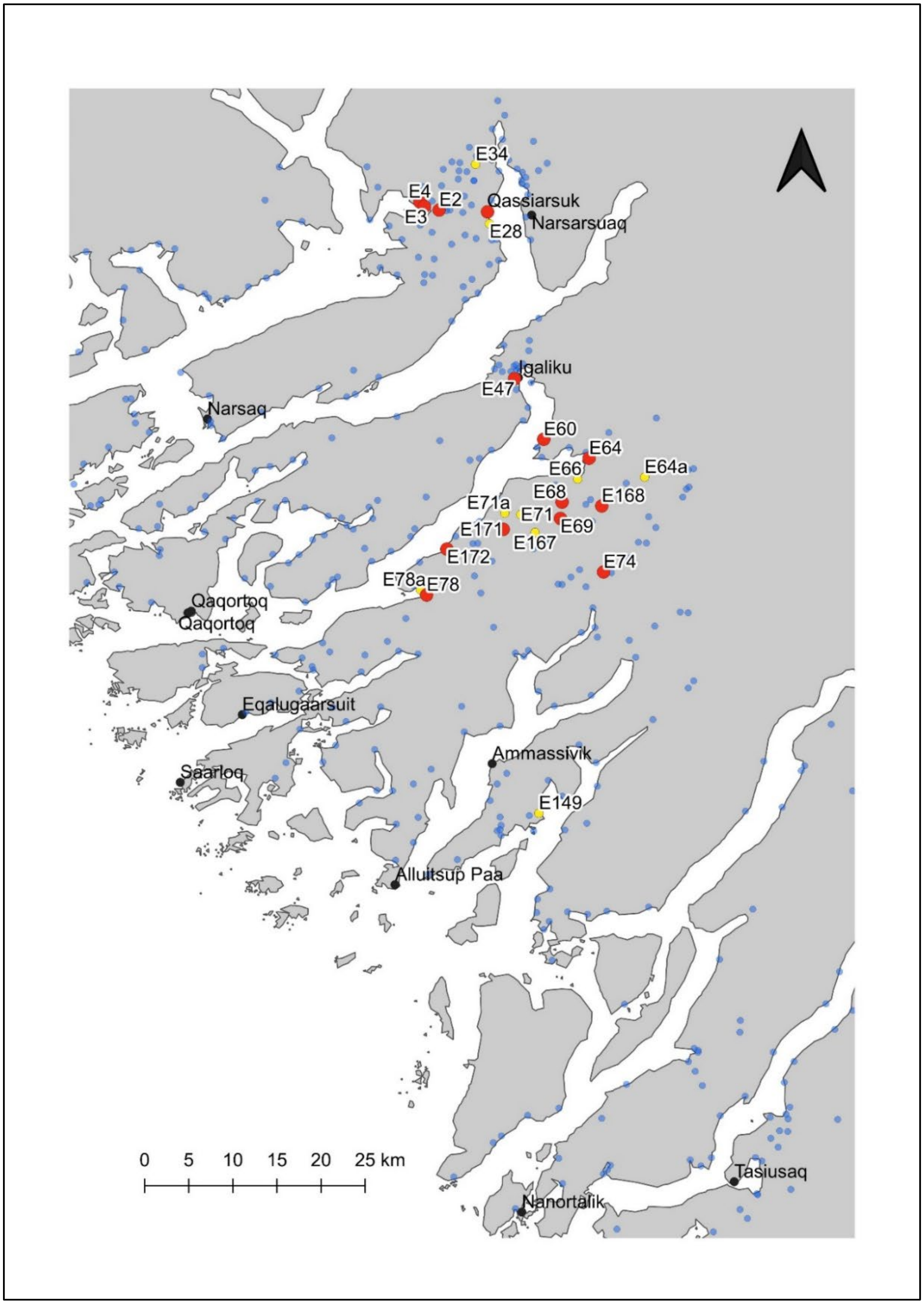


Figure 4 Map of the Eastern Settlement with all the sites discussed in this thesis indicated (yellow and red). Red dots represent sites excavated 2005-2016 and archaeofaunas analyzed by the author. Yellow sites are excavations and archaeofauna analyzed prior to 2005. Map by Howell Roberts and the author (source: nunniffiit.natmus.gl and QGreenland (v2).

The *Landscapes circa Landnám* project 2001-2006 was supported by the UK Leverhulme Trust grant to Kevin Edwards (U Aberdeen) with co-directors Andrew Dugmore (U Edinburgh), Ian Simpson (U Stirling), Paul Buckland (U Bournemouth), and Thomas McGovern (CUNY), with a supplement from NSF (1140106) to McGovern. This project combined zooarchaeology (vertebrate and invertebrate), soil science, palynology, and geomorphology to provide an environmentally focused look at the first settlement of the Faroes, Iceland, and Greenland, and supported participation by the author in fieldwork in Iceland and Greenland. The Leverhulme project was continued by an NSF-funded *International Polar Year* project: *IPY: Long Term Human Ecodynamics in the Norse North Atlantic: cases of sustainability, survival, and collapse*" (McGovern PI, NSF 0732327, $953,879.00 2007-11) which also supported excavation and survey work that connected the three island groups and supported field work by the author. In 2006-07 combined international support for a Greenland National Museum and Archives rescue project of the site E74 Qorlortorsuaq, which was endangered by hydropower construction provided the author with fieldwork opportunities, his first independent Norse midden excavation in Greenland, and a key archaeofauna. Danish funding support to the collaborative work in Greenland includes: *Ressourceudnyttelse, mobilitet og kulturel identitet i Nordatlanten – den norrøne bosætning i Nordatlanten 2007-08*. Kommissionen for Videnskabelige Undersøgelser i Grønland DKK 1,262,203 (PI Jette Arneborg), and 2005-2011 support for the *Vatnahverfi Project* (Arneborg). The Leverhulme, Vatnahverfi, and IPY project investigations through fieldwork by the author, demonstrated the rapid loss of organic preservation in the former Eastern Settlement area, and this resulted in the 2012-13 *Gardar / Igaliku Archaeological Rescue Project* (PI McGovern RAPID, 1119354 $194,900) where the author served as crew chief and head of the midden excavation team as well as carrying out the zooarchaeological analysis in post-excavation. The 2011-17

Comparative Island Ecodynamics (CIE) Project (PI Hambrecht,1202692, $1.25 million) followed the IPY investigations, with a focus on creating the basis for a better direct comparison between Iceland and Greenland from the Viking Age onwards. The author worked as site director and primary Greenland zooarchaeologist for the CIE project and continues to participate actively in this project.

The discovery of the preservation crisis during the IPY fieldwork 2007-11(Smiarowski 2008) immediately led to two seasons of large- scale excavations at E172 Tatsipataa in 2009-10 led by the author, and a RAPID project focused upon surviving organic-rich waterlogged midden deposits at the unique site of E47 Garðar (modern Igaliku) in 2012-13.

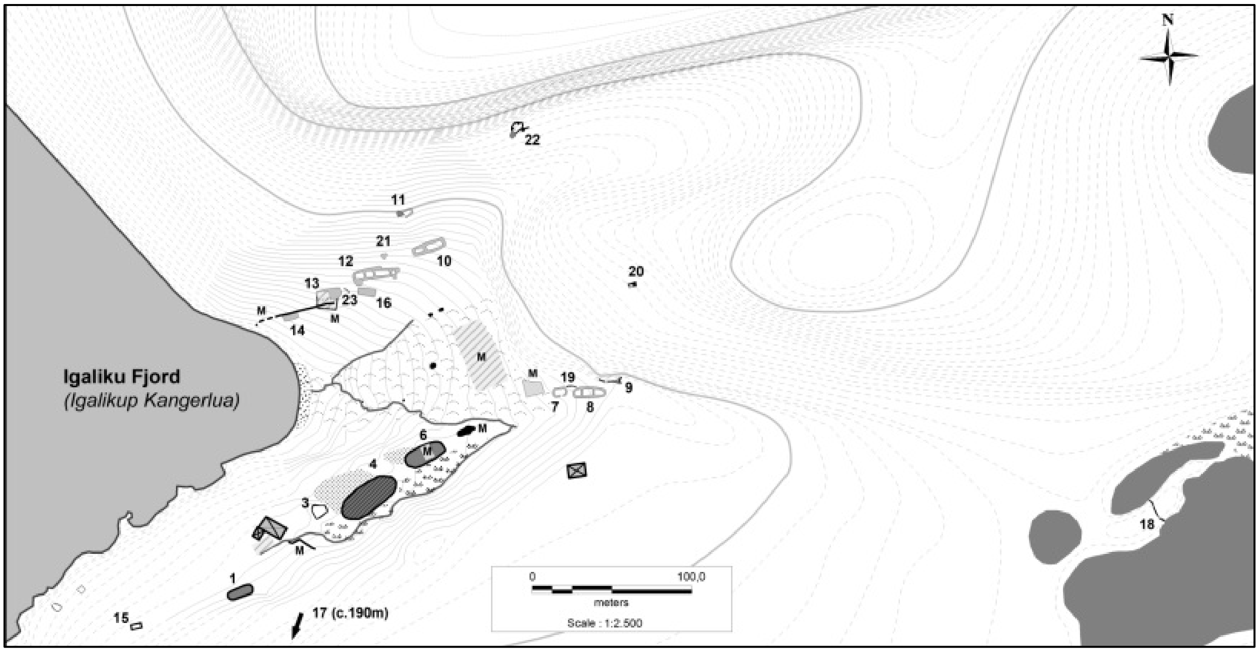


Figure 5 Site Plan of E172 Tatsipataa (Madsen 2014). The dwelling is ruin no. 4 here, and the excavated midden is the shaded area next to it.

Figure 6 Midden excavation at E172 Tatsipataa

Figure 7 Rescue excavation of the small E74 site 2006. Photo Konrad Smiarowski

Figure 8 Kite photo of midden excavations at E 47 Gardar in 2012. Photo Gardar Gudmundsson.

Both projects successfully recovered what seem to be the last surviving bone, walrus ivory, wood, wool, baleen, and leather from a middle ranking farm in Vatnahverfi, and the site of the Norse Bishops' manor (Smiarowski 2012, Vésteinsson et al. 2013).

The IPY, RAPID and Danish sources funded a rescue project at E74 and E29N involved close collaboration between US, UK, Danish, Icelandic, and Greenlandic institutions and teams, and provided valuable practical experience in effectively excavating surviving waterlogged deposits (using pump powered wet sieving) and making good use of deep experience in conservation of such finds at the Denmark National Museum. Excavations of Norse churchyard at E64 Innoquassaq led by Arneborg and conducted by the author and Christian Madsen, recovered a human skeletal sample of over 20 individuals. These included a mass burial under a fragment of a ship and a probable re-burial of an earlier pagan grave (with horse bones mixed in). The cemetery work led to the first large scale application of aDNA to the Norse Greenlanders combined with an integrated program of Sr, C, and N stable isotope analysis that allowed identification of settlers born in Iceland and further evidence for the uniquely marine – mammal focus of the Greenlandic diet that significantly expands on prior work by Arneborg's teams reported in a special issue of the Journal of the North Atlantic (2012). Rescue midden excavations led by Smiarowski at E172 Tatsipataa, E171 Tasilikulooq, E168 , E3 Tingimiut, E4 Isaroq, E68 Timerliit, E60 Isugsarfik, E78 Eqaluit, E64 Innoquassaq, were carried out during the 2008-2011 and 2016 seasons of the IPY and CIE projects, providing additional stratified radiocarbon dated archaeofauna and a substantial collection of worked and unworked wood, that formed the basis for Lisabet Guðmundsdóttir and Elie Pinta's PhD projects. The IPY and CIE projects together have more than quadrupled the zooarchaeological evidence from the Eastern Settlement, and critically; have added multiple well dated and stratigraphically separated collections that now allow a detailed understanding of the initial Norse adaptations and their response to sudden climate change in the late 13th century. A multi-year survey program led by Madsen was combined with a systematic geoarchaeology sampling program led by Simpson covering 65 sites and collecting 126 C14 samples. These new data both confirmed the extent of the "melting middens" reported by the author (Smiarowski 2008) problem and for the first time allowed for a realistic reconstruction of changes in Norse settlement pattern and assessment of the long-term results of what has proven to be a very varied and sophisticated infield soil management system. Madsen's doctoral thesis (Madsen 2014) synthesized these data sets and produced a comprehensive database of known Norse sites and structures and a three-phase model for settlement expansion and contraction.

This thesis reports the archaeofauna from all these investigations except the E 171 project, which is still ongoing with a final field season planned for summer 2022. A renewed program of survey, excavation, paleoenvironmental sampling, and community engagement funded by US NSF (OPP 1821284, $860,261, PI McGovern, co-PI Smiarowski) and the Danish Carlsberg Foundation is now underway and will extend to 2023. This thesis creates new knowledge by integrating and synthesizing the zooarchaeological data sets, providing important new understanding of Norse settlement activity in Greenland, as well as a "current state of knowledge" assessment of Norse zooarchaeology to 2016. It will be rapidly supplemented and expanded by ongoing research work in the field and laboratory.

CHAPTER 4: Norse Greenland Archaeofaunal Database

4.1 Data Characteristics and Limitations:

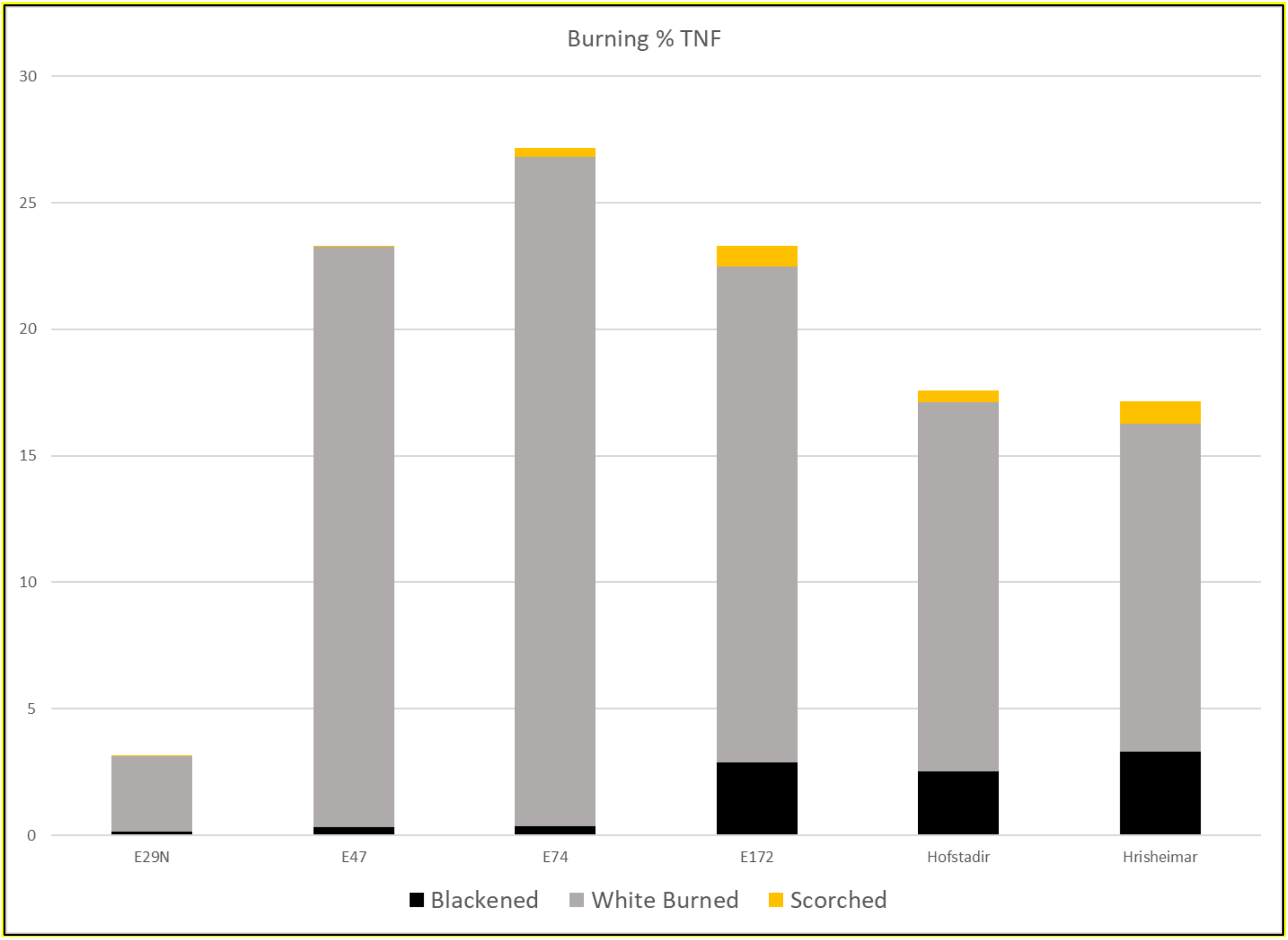


Figure 9 Total Number of Fragments (TNF) % of burnt bone.

Post Depositional Preservation and Recovery: As noted above, excavation conditions and recovery strategies directly affect the zooarchaeological record. Since 1975 systematic sieving has become standard in Greenlandic excavations, with 3-4 mm dry mesh sieves (backed by whole soil samples retained for flotation for insect and macrofloral analysis) increasingly supplemented by wet sieving using pumps. During the 1997-98 excavations by the Qaqortoq Museum at E34 wet bog conditions prevented sieving (Nyegaard 2018) but all post-2005 investigations have incorporated systematic 100% sieving.

A major result of the extensive site survey and testing work since 2000 has been the discovery of the widespread degradation of organic preservation due soil warming and loss of frozen ground. This means that recently excavated archaeofauna may have suffered some loss of organic preservation in comparison with bones excavated in the early-mid 20th century from the same sites. This is a significant problem for the future, and a major motivation for ongoing collaborative rescue work making use of the new scientific measurements of rates of decomposition by the REMAINS project (Hollesen et al. 2015, 2016; Matthiessen et al. 2021) and the ongoing US National Science Foundation project "Coproduction of Knowledge and the Building of Local Archaeological Capacity in Greenland" (NSF ASSP 18212184).

4.2 Laboratory Methods and Reporting

Analysis of the 2005-16 collections was carried out at the *Hunter College Zooarchaeology Laboratory* and made use of extensive comparative skeletal collections of the lab and the holdings of the *American Museum of Natural History*. Additional work on earlier excavated collections was carried out at the *University of Copenhagen Zoological Museum* with the kind cooperation of the Museum staff. Seal tooth sectioning was carried out under the supervision of Dr. James Woollett at the *Université Laval* in Quebec. Current analysis of collections excavated after 2016 are carried out at the *University of Bergen Zooarchaeology Laboratory.*

All fragments were identified as far as taxonomically possible (selected element approach not employed) but most land mammal ribs, long bone shaft fragments, and vertebral fragments were assigned to “Large Terrestrial Mammal” (cattle-horse sized), “Medium terrestrial mammal” (sheep-goat-pig-large dog sized), and “small terrestrial mammal” (small dog-fox sized) categories. Only elements positively identifiable as *Ovis aries* were assigned to the “sheep” category and *Capra hircus* to “goat” category, with all other sheep/goat elements being assigned to a general “*caprine*” category potentially including both sheep and goats.

Seal bones are likewise identifiable to species level only on a restricted range of elements (following the current NABO version of the seal identification manual by Møhl, posted on www.nabohome.org). This creates a substantial “phocid species” category comparable to the “caprine” category (which incorporates ribs, small cranial fragments, unidentifiable long bone elements and vertebrae). On some elements it is possible to distinguish “large seals” (either hooded *Cystophora cristata* or bearded *Erignathus barbatus*) from the three smaller species (common/harbor seals *Phoca vitulina*, harp seals *Pagophilus groenlandicus*, and ringed seals *Phoca hispida*). Most cetacean (whale) bone is highly fragmented and probably often represents craft debris, but it has been occasionally possible to distinguish bones of great (usually baleen) whales (“large cetacean”) from the bones of smaller whales (probably narwhal or beluga) or porpoise (“small cetacean”). In some cases, analysts have placed some smaller cetacean elements in a dual category (Pilot whale/ Orca, Narwhal/ Beluga). Some cetacean and seal bone from these sites has been studied by teams led by Dr. Vicki Szabo for collagen and ancient DNA and these results are presented below in Chapter 5.

Murre and Guillemot auks are not distinguishable on most bones and are presented together as *Uria species.* Where other auk species are possible the broader “*Alcid sp. indet.*” category has been employed. Similarly, general categories such as “Gull sp.” And “Duck sp.” have also been employed where species level identification is not possible.

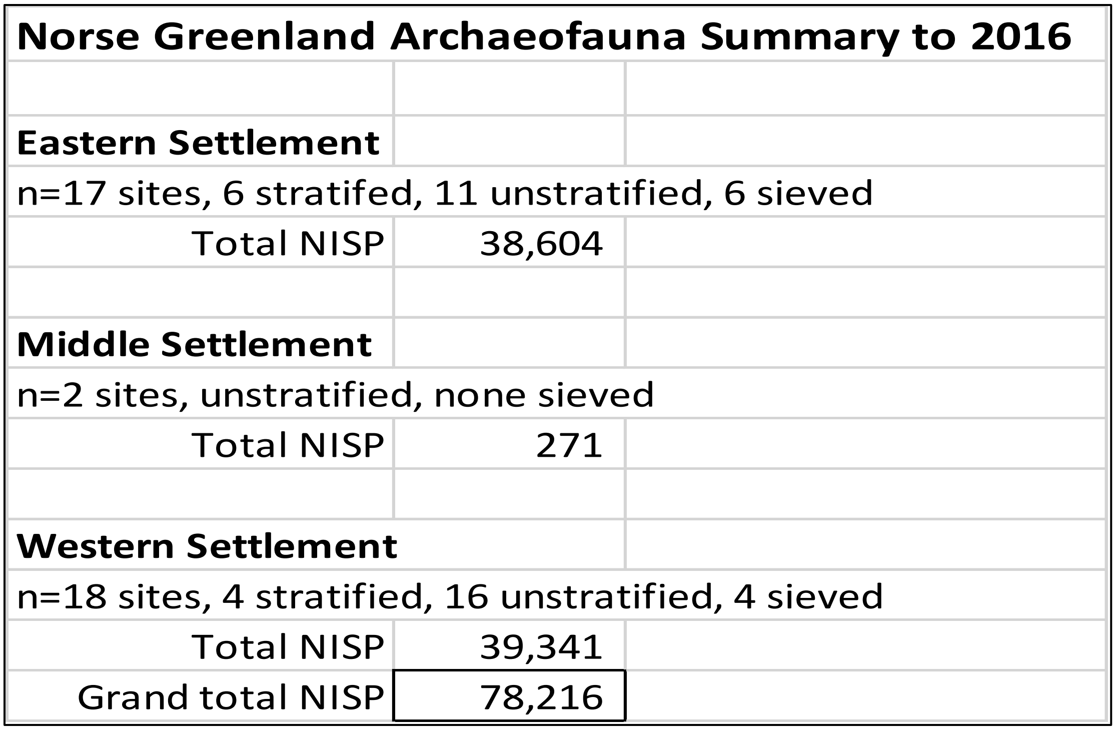
The data presentation thus attempts to reasonably reflect the different levels of accuracy possible in osteological identification, but creates some pooled categories at different taxonomic levels, which require some care in comparisons.

Following NABO Zooarchaeology Working Group recommendations and the established traditions of N Atlantic zooarchaeology we have made a simple fragment count (NISP) the basis for most quantitative presentation. Following widespread North Atlantic tradition, bone fragment quantification makes use of the Number of Identified Specimens (NISP) method (Grayson 1984). Sheep/goat distinctions follow Boessneck (1969), Mainland and Halstead (2005), Zeder and Lapham (2010), and Zeder and Pilaar (2010). Only positively identified fragments of fish bone were given species level identification, with those unidentifiable to species placed in the family category where possible, often *gadid*, while others were identified simply as fish. Measurements (Mitoyo digimatic digital caliper, to nearest mm) follow Von Den Driesch (1976), mammal tooth eruption and wear recording follows Grant (1982) and general presentation follows Enghoff (2003). Digital records of all data collected were made following the 9th edition NABONE recording package (Microsoft Access database supplemented with specialized Excel spreadsheets, see discussion and downloadable version at www.nabohome.org) and all digital records (including archival element by element bone records) and the bone samples will be permanently curated at the Greenland National Museum and Archives with full copies at the Zoological Museum of the University of Copenhagen, the NABO Project Management System, and the NSF Arctic Data Repository.

4.3 Data Summary - Taxa Present and Ubiquity Measures

Table 1 presents an overview summary of the available Norse archaeofauna from Greenland to 2016, with a total of 17 archaeofauna from the Eastern Settlement, two from the small Middle Settlement, and 18 from the Western Settlement for a grand total of 78,216 identified fragments.

Table 1 Summary of All Norse Greenland Archaeofauna to 2016



Norse Greenland Archaeofauna Summary to 2016		
Eastern Settlement		
n=17 sites, 6 stratifed, 11 unstratified, 6 sieved		
Total NISP	38,604	
Middle Settlement		
n=2 sites, unstratified, none sieved		
Total NISP	271	
Western Settlement		
n=18 sites, 4 stratified, 16 unstratified, 4 sieved		
Total NISP	39,341	
Grand total NISP	78,216	

Table 2 presents a summary with NISP (number of identified fragments) totals for the archaeofauna reported. The columns are sorted into the three phases now widely used in Greenlandic Norse archaeology (Greenland Isotope Project: Arneborg, Lynnerup and Heinemeier 2012, Madsen 2014). The Early phase (ca. 980-1160 CE) reflects the initial settlement ca. 985 CE and the gradual expansion. The Middle phase (ca. 1160-1300 CE) reflects the "high tide" of Norse settlement in Greenland with maximum settlement size. The Late phase (ca.1300-1450) reflects the end period of settlement contraction and eventual collapse. These phases represent temporal sorting "boxes" allowing aggregation along regularly recurring patterns of calibrated AMS Radiocarbon assays and not all the date ranges reported for each phased archaeofauna represent a perfect fit.

Table 2 Summary of Phased and Unstratified Archaeofauna until 2016

Phase	**c 980-1160**	**c 1160-1300**	**c. 1300-1450**		
Eastern Settlement	**Early**	**Middle**	**Late**	**Unstratified**	**Sieving**
Gardar E47		3664	541		Y
Brattahlid E29 N	54	1918	512		Y
E17a	1073		499		N
E68	257	230	75		Y
E64		342			Y
E74	165	202	1107		Y
E172	2218	773			Y
E28 River				136	N
E34				15777	N
E 64a				107	N
E 66				48	N
E68				45	N
E78a				56	N
E71N				827	N
E71S				5913	N
E149				610	N
E167				1455	N
	c 980-1160	c 1160-1300	c. 1300-1450		
Middle Settlement	**Early**	**Middle**	**Late**	**Unstratified**	**Sieving**
M15				229	N
M21				42	N
	c 980-1160	c 1160-1300	c. 1300-1450		
Western Settlement	**Early**	**Middle**	**Late**	**Unstratified**	**Sieving**
W54			2451		Y
W51 Sandnes	479	3133	4799		Y
W48	4788	6500	3811		Y
GUS	587	563	2893		Y
W16				39	N
W29				56	N
W35				903	N
W36				2	N
W44				8	N
W45				238	N
W50a				16	N
W52a				1734	N
W53a				32	N
W53c				1122	N
W53d				655	N
W59				4408	N
W63				123	N
W75				1	N

While several archaeofauna produce NISP counts in the thousands, many are far too small to reasonably quantify, but are presented here for completeness and in the hope that future work may add additional samples. It should be noted that most of the early 20th c collections in fact probably reflect the Middle and Late phases as early excavations tended to concentrate on house interiors (whose floor layers were rich in bone mainly dating to the final occupation) and in middens they were often stopped by then-frozen ground.

One approach to quantifying collections with very divergent sample sizes is to make use of a simple ubiquity (present/absent) measure to get a sense of the frequency with which different taxa appear in the record in all collections (Grayson 1984). Table 3 presents the ubiquity measures for the archaeofauna (total 59 all phases plus unstratified collections) for human bone and domestic mammals. The list is sorted by frequency (Cattle bones are most frequent, occurring in 57 of 59 collections, Cat bones are least frequent, occurring thus far only at E34).

Table 3 Presence of Taxa in Archaeofauna

UBIQUITY MEASURES	Sites in sample	59	8	13	11	27
Domestic Mammals	Phase	All Collections	EARLY PHASE	MIDDLE PHASE	LATE PHASE	UNSTRATIFIED
	Est.time range (CE)	980-1450	980-1160	1160-1300	1300-1450	?
Taxon						
Homo sapiens	Human	3	0	0	1	2
Domestic Mammals						
Bos taurus	Cattle	57	8	13	11	25
Ovis or Capra	Sheep or Goat	56	8	13	11	24
Ovis aries	Sheep	42	8	13	10	11
Capra hircus	Goat	41	7	13	10	11
Canis familiaris	Dog	28	3	5	9	11
Equus caballus	Horse	20	3	6	3	8
Sus scrofa	Pig	19	4	9	3	3
Felis catus	Cat	1	0	0	0	1

Table 3 indicates that even in small collections, some bones of cattle, sheep, goats, and caprines (both sheep and goat) are nearly universally present. This underlines the observation that cattle bones appear on virtually all sites, even poor ones with apparently marginal grazing potential. If specialized sheep/ goat herding farms without cattle existed, they do not seem to be reflected in the current zooarchaeological record. Domestic dog bones are somewhat surprisingly frequent (28 of 59 collections) given that dogs are usually rare in middens and seem to have been infrequently eaten by humans. The concentration of dog bone frequency (and absolute number of dog bones, some semi-articulated) in the later and unstratified (but probably mainly late interior) collections may reflect some "final days" scenarios suggested by Buckland et al. (1983). Horse bones occur regularly in low numbers and may reflect occasional human consumption or potentially craft working debris (horse metapodials were often sources for bone working). Pig bones in fact occur in sites of all phases, contrary to prior assumptions that they were restricted to early phases only (McGovern 1985). As in Iceland, it appears that some pigs continued to be kept on some farms down to the 15th century, but in low numbers. Cat bones are exceedingly rare, occurring thus far only at E34.

Table 4 presents the ubiquity measures for terrestrial and marine wild mammals. Caribou are found in nearly all collections (53 of 59) and occur in all phases. This pattern underlines the success of Norse managers in preventing local extinction of caribou, whose populations in the SW are particularly subject to crashes from range icing (Meldgaard 1986). Overhunting in the 19th century drove local caribou to extinction in the Eastern Settlement area, without substantial competition from grazing sheep, goats, and cattle present in the Norse period. House mice were imported from Europe via Iceland and seem to have inhabited many Norse buildings before the collapse of the settlement (Jones et al. 2012). Both arctic hare and fox seem to have been regularly taken in all phases.

Table 4 Presence of Wild Mammals in Norse Greenland Archaeofauna

Table 4						
UBIQUITY MEASURES	Sites in sample	59	8	13	11	27
Mammals	Phase	All Collections	EARLY PHASE	IDDLE PHAS	LATE PHASE	UNSTRATIFIED
	Est.time range (CE)	980-1450	980-1160	1160-1300	1300-1450	?
Taxon						
Wild Mammals Terrestrial						
Rangifer tarandus	Caribou	53	8	13	10	22
Lepus arcticus	Arctic hare	18	3	3	5	7
Alopex / Vulpes lagopus	Arctic Fox	17	3	6	4	4
Mus musculus	House mouse	5	1	1	2	1
Canid sp.	Dog or wolf	2	0	0	1	1
Mus sp..	Mouse sp.	1	0	0	1	0
Wild Mammals Marine						
Phocidae sp.	Seal sp. Indet.	54	7	13	11	23
Pagoph. groenlandica	Harp seal	53	6	13	10	24
Odobenus rosmarus	Walrus	50	6	13	11	20
Phoca vitulina	Common/ Harbor seal	42	5	10	9	18
Cetacea sp. Indet.	Whale sp. Indet	33	6	8	11	8
Cystophora cristata	Hooded seal	31	3	9	5	14
Erignathus barbatus	Bearded seal	28	5	6	6	11
Ursus maritimus	Polar Bear	23	3	5	7	8
Large Cetacea sp	Large whale sp. Indet.	21	2	5	5	9
Small cetacean sp.	Small whale/ porpoise	15	1	6	5	3
Phoca hispida	Ringed seal	14	2	0	1	11
E. barbatus or C. cristata	Large seal sp. Indet.	13	3	8	2	0
Delphinapterus leucas	Beluga whale	6	1	0	3	2
Lagenorhynchus albirostris	White sided porpoise	2	0	0	1	1
Phocoena phocoena	Common porpoise	2	1	0	1	0
D.leucas/Monodon m.	Beluga or Narwhal	1	0	0	0	1
Globicephalus melas	Pilot whale	1	0	0	1	0
Globicephalus melas/ Orcinus o.	Pilot/ Orca whale	1	0	0	1	0
Balaena australis/ Eubalaena australis	Southern Right Whale	1	0	0	0	1
Balaena mysticetus	Bowhead Whale	1	0	1	0	0

The most abundant marine mammals in all periods are seals, with Harp seals the most widespread of the identified species. Hooded seals do not normally reach the Western Settlement area, limiting their representation in this table mainly to the Eastern Settlement sites. Bearded seals are not uncommonly present in low numbers, while Ringed seal are both rare and low frequency. Walrus bones (mainly maxilla fragments associated with tusk extraction) are notably widespread (in 50 of 59 collections) in both settlement areas at all time periods, documenting the apparent importance of the walrus hunt and the widespread participation by most households (Frei et al. 2015). Polar bear bones are present on many sites of all periods in small numbers, often bones from the paw showing slice marks perhaps left by final finishing of hides taken elsewhere.

Small, toothed cetaceans (Porpoise, Beluga, and Narwhal) appear infrequently as identified elements, but whale bone is not uncommon on multiple sites, including bone osteologically identified as from Bowhead and Right Whale. Note that the single osteological identification of a Southern Right Whale bone was made by Degerbøl (1936) based on extensive comparative collections in the Zoological Museum and his publication insists on the accuracy of the identification, which has not yet been verified by aDNA or other analysis. As discussed more fully below in Chapter 5, a new collaborative project led by Dr. Vicki Szabo has opened new possibilities for identifying even small fragments of whale bone that are osteologically only identifiable as "cetacean sp." Bone from great whales was extensively used for artifacts and construction and may have been transported and deposited without much associated meat.

Table 5 presents the ubiquity measures for bird species in the available archaeofauna, ranked by ubiquity score (e.g., Ptarmigan are found in 22 of 59 collections). As several analysts have observed, the Norse Greenlandic bird archaeofauna is dominated by the auk (Alcid) family, mainly the mid-sized Murre and Guillemot. Unfortunately, most post-cranial bones of these species cannot be reliably distinguished, and they are often lumped under "Uria sp. Indet." These cliff nesting species are summer visitors and form substantial colonies (esp. the Black Guillemot) in several locations near both Eastern and Western Settlement farms (interactive maps available at Circumpolar Seabird Data Portal (http://axiom.seabirds.net). The non-migratory terrestrial Ptarmigan (grouse) is also common in the collections and as in Iceland it was probably taken with snares in all seasons. Somewhat surprising is the ubiquity of the white-tailed sea eagle which appears in 12 of 59 collections. Some of the elements suggest that whole wings were used as fire fans or brooms as in Iceland (Bovy 2002; Cesario 2021; Enghoff 2003). These impressive birds seem to have been taken in small numbers in all phases, possibly a stock protection measure. Domestic chicken is known only from the bishop's manor at Garðar E47.

Table 5 Presence of bird taxa in the Norse Greenland Archaeofauna.

UBIQUITY MEASURES	Sites in sample	59	8	13	11	27
Birds	Phase	All Collections	EARLY PHASE	MIDDLE PHASE	LATE PHASE	UNSTRATIFIED
	Est.time range (CE)	980-1450	980-1160	1160-1300	1300-1450	?
Taxon						
Birds						
Aves sp	Bird sp. Indet.	35	8	10	10	7
Uria sp.	Guillemot/Murre sp.ind	31	6	9	8	8
Lagopus muta	Ptarmigan	22	4	7	6	5
Haliaeetus albicilla	Sea Eagle	12	2	4	2	4
Uria lomvia	Brunnich's guillemot	7	1	1	2	3
Uria aalge	Common Guillemot/ Mu	6	1	2	2	1
Anas platyrhynchos	Mallard duck	4	1	1	1	1
Anatidae sp	Duck sp. Indet	4	0	2	1	1
Cygnus cygnus	Whooper Swan	4	1	1	1	1
Cygnus sp.	Swan sp. Indet.	4	1	2	1	0
Alca torda	Razorbill	4	1	1	0	2
Cepphus grylle	Black Guillemot	4	0	0	3	1
Alcidae sp.	Auk family sp. Indet	4	0	2	1	1
Larus glaucoides	Iceland gull	4	2	1	1	0
Somateria spectabilis	King Eider duck	3	0	0	1	2
Anser/Branta sp.	Goose sp. Indet.	3	0	1	2	0
Corvus corax	Raven	3	0	1	1	1
Cygnus musicus	Whooper Swan	2	0	0	1	1
Falco rusticolis	Gyrfalcon	2	0	0	2	0
Alle alle	Little Auk/ Dovekie	2	1	0	1	0
Larus sp.	Gull sp. Indet.	2	0	2	0	0
Carduelis flammea	Common Redpoll	1	1	0	0	0
Anas acutas	Northern Pintail duck	1	1	0	0	0
Somateria mollissima	Eider duck	1	1	0	0	0
Somateria sp.	Eider sp. Indet.	1	0	1	0	0
Mergus serrator	Red Breasted Merganser	1	0	1	0	0
Gavia immer	Common Loon/Diver	1	0	0	1	0
Gavia stellata	Red Throated Loon/Dive	1	0	0	0	1
Rissa trydactyla	Black-legged Kittiwake	1	0	0	0	1
Fratercula arctica	Puffin	1	0	1	0	0
Gallus gallus	Domestic Chicken	1	0	0	1	0

Table 6 Presence of fish, Mollusca, and Arthropods in the Norse Greenland Archaeofauna.

UBIQUITY MEASURES	Sites in sample	59	8	13	11	27
Fish & Mollusca	Phase	All Collections	EARLY PHASE	MIDDLE PHASE	LATE PHASE	UNSTRATIFIED
	Est.time range (CE)	980-1450	980-1160	1160-1300	1300-1450	?
Taxon						
Fish						
Pisces sp. Indet	Fish sp. Indet.	14	2	4	5	3
Salvelinus alpinus	Arctic char	9	2	2	3	2
Gadus morhua	Atlantic cod	4	0	1	1	2
Gadidae sp.	Cod family sp. Indet.	4	1	3	0	0
M. villosus	Capelin	2	0	1	1	0
Hippoglossus hippoglossus	Atlantic Halibut	2	0	1	1	0
Gadus aculatus/ogac	Greenland cod	1	0	1	0	0
Salmonid sp.	Trout/Char sp. Indet	1	0	0	1	0
Cottidae sp.	Sculpin sp. Indet.	1	0	0	1	0
Myoxocephalus scorpius	Shorthorn Sculpin	1	0	0	0	1
Cottus scorpius	Shorthorn Sculpin	1	0	0	1	0
Pleuronectidae sp.	Flatfish sp. Indet.	1	0	0	0	1
Lycodes sp. Eelpout	Eelpout	1	0	0	0	1
Mollusca						
Mytilus edulis	Common/ Blue Mussel	14	3	3	4	4
Mollusca sp. Indet.	Shellfish sp. Indet.	9	2	4	3	0
Panopeaea /Panomya norvegica	Arctic clam	3	1	1	0	1
Coronula diadema	Whale barnacle	1	0	0	0	1
Mya sp. Indet.	Clam sp. Indet	1	0	1	0	0

Table 6 presents the ubiquity data for fish, shellfish, and the single arthropod (barnacle) for the Greenlandic Norse archaeofauna. Fish of any kind are rare in Norse collections but do appear in many of the newer sieved collections in small numbers. The freshwater arctic char and the marine cod family fish are the most frequent species occurring, but only a few elements are present in any collection. Norse marine and freshwater fishing certainly occurred more often in Greenland than the zooarchaeological record indicates, but by comparison to other parts of the Norse North Atlantic (esp. Iceland) this seems to have been a minor contribution to subsistence and negligible item for trade. As discussed below (Chapter 5) contemporary Icelandic sites show far higher amounts of marine and freshwater fish bones from nearly all sites. Mollusca are regularly recovered, with the blue mussel appearing most frequently. The single whale barnacle is a species associated with the Humpback whale and does indicate that at least sometimes great whale skin and meat reached Norse farms.

4.4 Data Summary- Identified Fragment (NISP) Counts

Table 7 presents the NISP (identified fragment count) for the domestic mammals in the quantifiable stratified collections in the Early Phase (c. 980-1160 CE) for the Eastern and Western Settlements.

Table 7 NISP Counts for Domestic Mammals in Early Phase Quantifiable Archaeofauna.

EARLY PHASE	sites in sample	E17a	E29N	E74	E172	E68	GUS	Sandnes W51	W48
c 980-1160 CE	date	1976, 1983	2006	2006	2017	2007	2002	1984	1979
NISP Counts	Phase		IX	Phase 1 A	Phase 1	Phase 1	1	F I Midden	AU I
	est.time range	lower	early 11th	1040-1150	100-1100	985-1050	1000-1200	1025-1150	980-1160
Taxon	***notes***		*SMALL*					W51-1	
Homo sapiens	Human								
Domestic Mammals									
Bos taurus	Cattle	127	7	8	135	4	82	37	126
Equus caballus	Horse				5		1	1	
Canis familiaris	Dog	1			3	3			
Felis catus	Cat								
Sus scrofa	Pig	10			7			9	2
Ovis aries	Sheep	18	1	2	82	2	23	6	18
Capra hircus	Goat	6	1		59	4	18	1	23
Ovis or Capra	Sheep or Goat	219	6	32	403	138	107	31	436

Table 8 NISP counts for Wild Mammals for Early Phase Archaeofauna.

EARLY PHASE	**sites in sample**	**E17a**	**E29N**	**E74**	**E172**	**E68**	**GUS**	**andnes W5**	**W48**
c 980-1160 CE	**date**	**1976, 1983**	**2006**	**2006**	**2017**	**2007**	**2002**	**1984**	**1979**
NISP Counts	**Phase**		**IX**	**Phase 1 A**	**Phase 1**	**Phase 1**	**1**	**F I Midden**	**AU I**
	est.time range	**lower**	**early 11th**	**1040-1150**	**100-1100**	**985-1050**	**1000-1200**	**1025-1150**	**980-1160**
Taxon	***notes***		***SMALL***					**W51-1**	
Wild Mammals Terrestrial									
Rangifer tarandus	Caribou	**86**	**12**	**1**	**38**	**1**	**149**	**40**	**279**
Lepus arcticus	Arctic hare						**5**	**5**	**16**
Alopex / Vulpes lagopus	Arctic Fox	**4**			**6**				**5**
Mus musculus	House mouse								**5**
Mus sp..	Mouse sp.								
Canid sp.	Dog or wolf								
Wild Mammals Marine									
Pagoph. groenlandica	Harp seal	**19**	**1**		**37**		**3**	**9**	**105**
Phoca vitulina	Common/ Harbor seal	**37**			**9**		**3**	**9**	**74**
Cystophora cristata	Hooded seal	**4**			**17**	**2**			
Phoca hispida	Ringed seal	**1**							**1**
Erignathus barbatus	Bearded seal	**3**			**2**		**2**	**1**	**1**
E. barbatus or *C. cristata*	Large seal sp. Indet.		**24**		**92**	**1**			
Phocidae sp.	Seal sp. Indet.	**440**		**100**	**1271**	**96**	**147**	**144**	**3192**
Odobenus rosmarus	Walrus	**25**		**3**	**15**		**6**	**65**	***25***
Ursus maritimus	Polar Bear	**8**			**3**				***2***
Delphinapterus leucas	Beluga whale	**3**							
D.leucas/Monodon m.	Beluga or Narwhal								
Lagenorhynchus albirostris	White sided porpoise								
Phocoena phocoena	Common porpoise								***1***
Globicephalus melas	Pilot whale								
Globicephalus melas/ Orcinus	Pilot/ Orca whale								
Small cetacean sp.	Small whale/ porpoise							**4**	
Balaena australis/ Eubalaena a	Southern Right Whale								
Balaena mysticetus	Bowhead Whale								
Large Cetacea sp	Large whale sp. Indet.	**26**							**1**
Cetacea sp. Indet.	Whale sp. Indet	**5**	**1**		**13**	**2**		**15**	**17**

Table 9 NISP Counts for Early Phase Birds. E17a, W51, and W48 data by McGovern. GUS data by Enghoff, E74, E172, E68 by the author.

EARLY PHASE	sites in sample	E17a	E29N	E74	E172	E68	GUS	andnes W5	W48
c 980-1160 CE	date	1976, 1983	2006	2006	2017	2007	2002	1984	1979
NISP Counts	Phase		IX	Phase 1 A	Phase 1	Phase 1	1	F I Midden	AU I
	est.time range	lower	early 11th	1040-1150	100-1100	985-1050	1000-1200	1025-1150	980-1160
Taxon	***notes***		***SMALL***					**W51-1**	
Birds									
Lagopus muta	Ptarmigan	2		2			34		23
Carduelis flammea	Common Redpoll								1
Anas acutas	Northern Pintail duck								1
Anas platyrhynchos	Mallard duck								1
Somateria mollissima	Eider duck	1							
Somateria spectabilis	King Eider duck								
Somateria sp.	Eider sp. Indet.				1		1		
Anatidae sp	Duck sp. Indet								
Mergus serrator	Red Breasted Merganser								
Gavia immer	Common Loon/Diver								
Gavia stellata	Red Throated Loon/Diver								
Anser/Branta sp.	Goose sp. Indet.								
Cygnus musicus	Whooper Swan								
Cygnus cygnus	Whooper Swan								1
Cygnus sp.	Swan sp. Indet.	3							
Haliaeetus albicilla	Sea Eagle	1							3
Falco rusticolis	Gyrfalcon								
Corvus corax	Raven								
Rissa trydactyla	Black-legged Kittiwake								
Fratercula arctica	Puffin								
Alca torda	Razorbill	1							
Alle alle	Little Auk/ Dovekie	1							
Uria lomvia	Brunnich's guillemot								4
Uria aalge	Common Guillemot/ Murre								2
Cepphus grylle	Black Guillemot								
Uria sp.	Guillemot/Murre sp.indet	18		2		1	1	11	107
Alcidae sp.	Auk family sp. Indet								
Larus glaucoides	Iceland gull	3							1
Larus sp.	Gull sp. Indet.								
Gallus gallus	Domestic Chicken								
Aves sp	Bird sp. Indet.	1	1	1	11	3	5	12	171

Table 10 NISP fragment counts for the Early Phase fish and Mollusca collections. E17a, W51, and W48 data by McGovern. GUS data by Enghoff, E74, E172, E68 by the author.

EARLY PHASE	**sites in sample**	**E17a**	**E74**	**E172**	**E68**	**GUS**	**W51**	**W48**
c 980-1160 CE	**date**	**1976, 1983**	**2006**	**2007**	**2007**	**2002**	**1984**	**1979**
NISP Counts	**Phase**	**lower**	**Phase 1 A**	**Phase 1**	**Phase 1**	**1**	**F I Midden**	**AU I**
	est. time range	**10th-11th c**	**1040-1150**	**1000-1100**	**985-1050**	**1000-1200**	**1025-1150**	**980-1160**
Taxon	***notes***							
Fish								
Gadus morhua	Atlantic cod							
Gadus aculatus/ogac	Greenland cod							
Gadidae sp.	Cod family sp. Indet.		1					
Salvelinus alpinus	Arctic char		3	9				
Salmonid sp.	Trout/Char sp. Indet							
M. villosus	Capelin							
Cottidae sp.	Sculpin sp. Indet.							
Myoxocephalus scorpius	Shorthorn Sculpin							
Hippoglossus hippoglossus	Atlantic Halibut							
Pleuronectidae sp.	Flatfish sp. Indet.							
Lycodes sp. Eelpout	Eelpout							
Pisces sp. Indet	Fish sp. Indet.		2				1	
Mollusca								
Mytilus edulis	Common/ Blue Mussel		5				56	140
Panopeaea /Panomya norvegica	Arctic clam							4
Mya sp. Indet.	Clam sp. Indet							
Mollusca sp. Indet.	Shellfish sp. Indet.		3				22	

Table 11 NISP counts for domestic mammals for the Middle Phase (c.1160-1300).

MIDDLE PHASE	sites in sample	E47 Gardar	E172	E64	E29N	E29N	E29N	E68	E64	E74	GUS	W48	Sandnes W51	Sandnes W51
c 1160-1300 CE	date	2017	2017	2017	2006	2006	2006	2007	2007	2007	2002	1979	1984	1984
NISP Counts	Phase	Phase 1	Phase 2 & 3		VI-VIII	V	IV	Phase 2		Phase 2 A	2	AU II	F I Midden	F I Midden
Domestic Mammals	est.time range	1150-1250	1100-1300	1150-1265	I 11th-12th	1200-1250	1250-1300	1050-1350	1150-1265	1150-1300	1200-1300	1160-1300	1150-1200	1200-1250
Taxon					SMALL								W51-3	W51-4
Homo sapiens	Human													
Domestic Mammals														
Bos taurus	Cattle	120	28	45	38	64	94	6	45	16	50	100	81	112
Equus caballus	Horse	6			1	1	1				2		1	
Canis familiaris	Dog	68	1			1					2	1		
Felis catus	Cat													
Sus scrofa	Pig	2	2	2	1	2	5		2				8	3
Ovis aries	Sheep	26	13	4	6	20	19	2	4	3	32	21	17	15
Capra hircus	Goat	32	18	1	2	6	5	1	1	1	32	26	12	19
Ovis or Capra	Sheep or Goat	521	122	152	38	74	115	121	152	50	95	498	100	138

Table 12 NISP counts for wild mammals for the Middle Phase (c. 1160-1300).

MIDDLE PHASE	**sites in sample**	**E47 Gardar**	**E172**	**E64**	**E29N**	**E29N**	**E29N**	**E68**	**E64**	**E74**	**GUS**	**W48**	**Sandnes W51**	**Sandnes W51**
c 1160-1300 CE	**date**	2017	2017	2017	2006	2006	2006	2007	2007	2007	2002	1979	1984	1984
NISP Counts	**Phase**	**Phase 1**	Phase 2 & 3		VI-VIII	V	IV	**Phase 2**		**Phase 2 A**	2	AU II	F I Midden	F I Midden
Wild Mammals	**est.time range**	1150-1250	1100-1300	1150-1265	I 11th-12th	1200-1250	1250-1300	1050-1350	1150-1265	1150-1300	1200-1300	1160-1300	1150-1200	1200-1250
Taxon					***SMALL***								**W51-3**	**W51-4**
Wild Mammals Terrestrial														
Rangifer tarandus	Caribou	209	11	13	9	25	22	3	13	3	61	241	162	207
Lepus arcticus	Arctic hare										3		10	4
Alopex / Vulpes lagopus	Arctic Fox	9	4		2							5	2	1
Mus musculus	House mouse											8		
Mus sp..	Mouse sp.													
Canid sp.	Dog or wolf													
Wild Mammals Marine														
Pagoph. groenlandica	Harp seal	51	8	7	9	15	34	9	7	6	8	116	9	16
Phoca vitulina	Common/ Harbor seal	1	5	5		17	3		5		11	78	16	12
Cystophora cristata	Hooded seal	3	5	2	1	9	7	2	2	5				
Phoca hispida	Ringed seal													
Erignathus barbatus	Bearded seal	2	1								3	5	2	3
E. barbatus or *C. cristata*	Large seal sp. Indet.	6	23	4	3	9	8	2	4					
Phocidae sp.	Seal sp. Indet.	2441	483	100	97	360	640	79	100	101	147	3808	236	362
Odobenus rosmarus	Walrus	97	36	5	9	14	19	1	5	6	5	*11*	406	382
Ursus maritimus	Polar Bear	2									1	*1*	2	5
Delphinapterus leucas	Beluga whale													
D.leucas/Monodon m.	Beluga or Narwhal													
Lagenorhynchus albirostris	White sided porpoise													
Phocoena phocoena	Common porpoise													
Globicephalus melas	Pilot whale													
Globicephalus melas/ Orcinus o.	Pilot/ Orca whale													
Small cetacean sp.	Small whale/ porpoise	1		2	1		3		2					1
Balaena australis/ Eubalaena austr	Southern Right Whale													
Balaena mysticetus	Bowhead Whale										1			
Large Cetacea sp	Large whale sp. Indet.		1			1	3					2		3
Cetacea sp. Indet.	Whale sp. Indet	10	1			14	24			6		20	85	55

Table 13 Bird NISP counts for the Middle Phase (c. 1160-1300).

MIDDLE PHASE	sites in sample	E47 Gardar	E172	E64	E29N	E29N	E29N	E68	E64	E74	GUS	W48	Sandnes W51	Sandnes W51
c 1160-1300 CE	date	2017	2017	2017	2006	2006	2006	2007	2007	2007	2002	1979	1984	1984
NISP Counts	Phase	Phase 1	Phase 2 & 3		VI-VIII	V	IV	Phase 2		Phase 2 A	2	AU II	F I Midden	F I Midden
Wild Mammals	est.time range	1150-1250	1100-1300	1150-1265	11th-12th	1200-1250	1250-1300	1050-1350	1150-1265	1150-1300	1200-1300	1160-1300	1150-1200	1200-1250
Taxon					***SMALL***								W51-3	W51-4
Birds											1			
Lagopus muta	Ptarmigan		1				1			1	58	8	5	10
Carduelis flammea	Common Redpoll													
Anas acutas	Northern Pintail duck													
Anas platyrhynchos	Mallard duck											2		
Somateria mollissima	Eider duck													
Somateria spectabilis	King Eider duck													
Somateria sp.	Eider sp. Indet.		1											
Anatidae sp	Duck sp. Indet						1				1			
Mergus serrator	Red Breasted Merganser										1			
Gavia immer	Common Loon/Diver													
Gavia stellata	Red Throated Loon/Diver													
Anser/Branta sp.	Goose sp. Indet.										1			
Cygnus musicus	Whooper Swan													
Cygnus cygnus	Whooper Swan											1		
Cygnus sp.	Swan sp. Indet.					1						1		
Haliaeetus albicilla	Sea Eagle	1				1					8			1
Falco rusticolis	Gyrfalcon													
Corvus corax	Raven	3												
Rissa trydactyla	Black-legged Kittiwake													
Fratercula arctica	Puffin						1							
Alca torda	Razorbill											4		
Alle alle	Little Auk/ Dovekie													
Uria lomvia	Brunnich's guillemot											11		
Uria aalge	Common Guillemot/ Murre	24										2		
Cepphus grylle	Black Guillemot													
Uria sp.	Guillemot/Murre sp.indet	5			4	8	15	2			5	225	35	59
Alcidae sp.	Auk family sp. Indet										3			10
Larus glaucoides	Iceland gull											1		
Larus sp.	Gull sp. Indet.				1							1		
Gallus gallus	Domestic Chicken													
Aves sp	Bird sp. Indet.	23	9			18	16	2		2	15	516	100	76

Table 14   Fish and Mollusca NISP counts for the Middle Phase (c. 1160-1300).

MIDDLE PHASE	sites in sample	E47 Gardar	E172	E29N	E29N	E29N	E68	E64	E74	GUS	W48	W51-3	W51-4
c 1160-1300 CE	date	2017	2017	2006	2006	2006	2007	2007	2007	2002	1979	1984	1984
NISP Counts	Phase	Phase 1	Phase 2 & 3	VI-VIII	V	IV	Phase 2		Phase 2 A	2	AU II	F I Midden	F I Midden
	est.time range	1150-1250	1100-1300	l 11th-12th	1200-1250	1250-1300	1050-1350	1150-1265	1150-1300	1200-1300	1160-1300	1150-1200	1200-1250
Taxon				SMALL									
Fish													
Gadus morhua	Atlantic cod									**1**			
Gadus aculatus/ogac	Greenland cod									**1**			
Gadidae sp.	Cod family sp. Indet.	**1**							**1**		**1**		
Salvelinus alpinus	Arctic char									**1**	**2**		
Salmonid sp.	Trout/Char sp. Indet												
M. villosus	Capelin									**7**			
Cottidae sp.	Sculpin sp. Indet.												
Myoxocephalus scorpius	Shorthorn Sculpin												
Cottus scorpius	Shorthorn Sculpin												
Hippoglossus hippoglossus	Atlantic Halibut									**1**			
Pleuronectidae sp.	Flatfish sp. Indet.												
Lycodes sp. Eelpout	Eelpout												
Pisces sp. Indet	Fish sp. Indet.									**6**	**3**	**1**	**1**
	All fish	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**17**	**6**	**1**	**1**
Mollusca													
Mytilus edulis	Common/ Blue Mussel										**776**	**181**	**114**
Panopeaea /Panomya norvegica	Arctic clam										**5**		
Mya sp. Indet.	Clam sp. Indet											**1**	
Mollusca sp. Indet.	Shellfish sp. Indet.		**1**						**1**			**34**	**18**
	total all Mollusca	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**781**	**216**	**132**

Table 15   Late Phase (c 1300-1450) Domestic Mammal NISP Counts.

LATE PHASE	sites in sample	E47 Gardar	E29N	E68	E74	E17a		W48	W51	W51	W51	W54	GUS
c 1300-1450 CE	date	2017	2006	2007	2007	1976, 1983		1979	1984	1984	1935/81	1979	2002
NISP Counts	Phase	Phase 2	III	Phase 3	Phase 3 B			AU III	F I Midden	table Midde	use & Midd	house int.	3
	est.time range	1270-1320	1300-1450	1350-1450	1300-1400	upper		1300-1400	1250-1325	1200-1325	1300-1400?	1300-1400	1300-1400
Taxon				*SMALL*					W51-5	W 51-4/5			
Homo sapiens	Human					**5**							
Domestic Mammals													
Bos taurus	Cattle	**20**	**25**	**5**	**57**	**76**		**42**	**132**	**16**	**373**	**165**	**158**
Equus caballus	Horse					**2**						**1**	**21**
Canis familiaris	Dog	**3**	**1**			**1**		**1**	**2**	**2**	**36**	**7**	**17**
Felis catus	Cat												
Sus scrofa	Pig					**3**			**4**		**4**		
Ovis aries	Sheep	**3**	**9**		**5**	**10**		**8**	**10**	**2**	**37**	**30**	**85**
Capra hircus	Goat	**4**	**4**		**1**	**1**		**14**	**14**	**1**	**35**	**41**	**58**
Ovis or Capra	Sheep or Goat	**97**	**53**	**56**	**720**	**97**		**310**	**136**	**54**	**192**	**489**	**735**

Table 16 Wild Mammal NISP counts for the Late Phase (c.1300-1450).

LATE PHASE	sites in sample	E47 Gardar	E29N	E68	E74	E17a	W48	W51	W51	W51	W54	GUS
c 1300-1450 CE	date	2017	2006	2007	2007	1976, 1983	1979	1984	1984	1935/81	1979	2002
NISP Counts	Phase	Phase 2	III	Phase 3	Phase 3 B		AU III	F I Midden	table Midde	use & Midd	house int.	3
	est.time range	1270-1320	1300-1450	1350-1450	1300-1400	upper	1300-1400	1250-1325	1200-1325	1300-1400?	1300-1400	1300-1400
Wild Mammals Terrestrial												
Rangifer tarandus	Caribou	16	15		9	22	173	300	27	681	391	331
Lepus arcticus	Arctic hare	1						1		3	59	52
Alopex / Vulpes lagopus	Arctic Fox					2	2		1			1
Mus musculus	House mouse										1	58
Mus sp..	Mouse sp.											1
Canid sp.	Dog or wolf										1	
Wild Mammals Marine												
Pagoph. groenlandica	Harp seal	6	11		14	39	83	20	3	277	27	34
Phoca vitulina	Common/ Harbor seal		2		3	5	58	37	2	101	11	16
Cystophora cristata	Hooded seal		1	1	10	9						1
Phoca hispida	Ringed seal									8		
Erignathus barbatus	Bearded seal					1	9	3		17	4	6
E. barbatus or *C. cristata*	Large seal sp. Indet.	9		1								
Phocidae sp.	Seal sp. Indet.	356	360	8	280	199	2947	492	185	402	723	1058
Odobenus rosmarus	Walrus	5	7	2	4	3	7	612	8	165	17	11
Ursus maritimus	Polar Bear	1				1	*1*	2		8	1	1
Delphinapterus leucas	Beluga whale						*1*			4	5	
D.leucas/Monodon m.	Beluga or Narwhal											
Lagenorhynchus albirostris	White sided porpoise									1		
Phocoena phocoena	Common porpoise						*1*					
Globicephalus melas	Pilot whale									1		
Globicephalus melas/ Orcinu	Pilot/ Orca whale											1
Small cetacean sp.	Small whale/ porpoise		5		1	1		1		1		
Balaena australis/ Eubalaena	Southern Right Whale											
Balaena mysticetus	Bowhead Whale											
Large Cetacea sp	Large whale sp. Indet.		1			2	1	1		6		
Cetacea sp. Indet.	Whale sp. Indet	6	6	1	1	18	13	52	15	3	1	7

Table 17 Late Phase (c. 1300-1450) Fish and Mollusca NISP counts.

LATE PHASE	sites in sample	E47 Gardar	E29N	E68	E74	E17a	W48	W51	W51	W51	W54	GUS
c 1300-1450 CE	date	2017	2006	2007	2007	1976, 1983	1979	1984	1984	1935/81	1979	2002
NISP Counts	Phase	Phase 2	III	Phase 3	Phase 3 B		AU III	F I Midden	table Midde	use & Midd	house int.	3
	est.time range	1270-1320	1300-1450	1350-1450	1300-1400	upper	1300-1400	1250-1325	1200-1325	1300-1400?	1300-1400	1300-1400
Fish												
Gadus morhua	Atlantic cod											3
Gadus aculatus/ogac	Greenland cod											
Gadidae sp.	Cod family sp. Indet.											
Salvelinus alpinus	Arctic char						5				6	33
Salmonid sp.	Trout/Char sp. Indet											15
M. villosus	Capelin											1
Cottidae sp.	Sculpin sp. Indet.											1
Myoxocephalus scorpius	Shorthorn Sculpin											
Cottus scorpius	Shorthorn Sculpin						1					
Hippoglossus hippoglossus	Atlantic Halibut										4	
Pleuronectidae sp.	Flatfish sp. Indet.											
Lycodes sp. Eelpout	Eelpout											
Pisces sp. Indet	Fish sp. Indet.					1	2	1			1	23
Mollusca												
Mytilus edulis	Common/ Blue Mussel							31	5	8	106	
Panopeaea /Panomya norveg	Arctic clam											
Coronula diadema	Whale barnacle											
Mya sp. Indet.	Clam sp. Indet											
Mollusca sp. Indet.	Shellfish sp. Indet.			1				3	1			

Table 18 Domestic Mammals NISP Count from Eastern and Middle Settlement Unstratified Collections.

	sites in sample	M15	M21	E29 River	E64a	E64c	E66	E68	E78a	E34	E71N	E71S	E149	E167
Unphased Eastern Settlement	date	1979	1979	1934	1941	1941	1941	1979	1941	1997-98	1979	1979	1979	1979
NISP Counts	Phase	small	small	small	small	small	small	small	small					
	est.time range	?	?	?	?	?	?	?	?	mixed	?	?	?	?
Taxon														
Homo sapiens	Human												1	1
Domestic Mammals														
Bos taurus	Cattle	1	8	36	30	24	9	3	8	2453	126	564	100	321
Equus caballus	Horse					4				28	3	4	1	4
Canis familiaris	Dog			1			2	2		30		3	1	
Felis catus	Cat									21				
Sus scrofa	Pig									76				5
Ovis aries	Sheep				3	3				454	24	148		
Capra hircus	Goat				1					350	18	76		
Ovis or Capra	Sheep or Goat		5	22	16	19	11	3	5	4829	263	1942	98	545

Table 19 Wild Mammals NISP count from Eastern and Middle Settlement Unstratified Collections.

	sites in sample	M15	M21	E29 River	E64a	E64c	E66	E68	E78a	E34	E71N	E71S	E149	E167
Unphased Eastern Settlement	date	1979	1979	1934	1941	1941	1941	1979	1941	1997-98	1979	1979	1979	1979
NISP Counts	Phase	small	small	small	small	small	small	small	small					
	est.time range	?	?	?	?	?	?	?	?	mixed	?	?	?	?
Taxon														
Homo sapiens	Human												1	1
Wild Mammals Terrestrial														
Rangifer tarandus	Caribou	2	8	11	6	5			1	975	2	82	23	24
Lepus arcticus	Arctic hare									11		2		2
Alopex lagopus	Arctic Fox									23				
Mus musculus	House mouse											110		
Mus sp..	Mouse sp.													
Dog or wolf	Dog or wolf									2				
Wild Mammals Marine														
Pagoph. groenlandica	Harp seal	25	3	53	6	11	4	3	7	197	33	193	34	52
Phoca vitulina	Common/ Harbor seal	2		3			1			6	5	10	10	4
Cystophora cristata	Hooded seal	2	1	6	16	12		1	7	268	10	80	35	22
Phoca hispida	Ringed seal	1		2		1				8		1	2	2
Erignathus barbatus	Bearded seal			1						15	4	7	5	1
E. barbatus or *C. cristata*	Large seal sp. Indet.													
Phocidae sp.	Seal sp. Indet.	171	17		25	58	20	31	28	5562	329	1811	287	427
Odobenus rosmarus	Walrus	1			2	3				48	*5*	*1*	*1*	*11*
Ursus maritimus	Polar Bear			1		1				19			*4*	*1*
Delphinapterus leucas	Beluga whale									2				*1*
D.leucas/Monodon m.	Beluga or Narwhal									6				
Lagenorhynchus albirostris	White sided porpoise													*1*
Phocoena phocoena	Common porpoise													
Globicephalus melas	Pilot whale													
Globicephalus melas/ Orcinus o.	Pilot/ Orca whale													
Small cetacean sp.	Small whale/ porpoise							2		26		1		
Balaena australis	Southern Right Whale													
Balaena mysticetus	Bowhead Whale													
Large Cetacea sp	Large whale sp. Indet.				2					3	1	3	1	2
Cetacea sp. Indet.	Whale sp. Indet	6								43			4	3

Table 20 Bird NISP Count from Eastern and Middle Settlement Unstratified Collections.

	sites in sample	M15	M21	E29 River	E64a	E64c	E66	E68	E78a	E34	E71N	E71S	E149	E167
Unphased Eastern Settlement	date	1979	1979	1934	1941	1941	1941	1979	1941	1997-98	1979	1979	1979	1979
NISP Counts	Phase	small	small	small	small	small	small	small	small					
	est.time range	?	?	?	?	?	?	?	?	mixed	?	?	?	?
Taxon														
Birds														
Lagopus muta	Ptarmigan									14		6		5
Carduelis flammea	Common Redpoll													
Anas acutas	Northern Pintail duck													
Anas platyrhynchos	Mallard duck									1				
Somateria mollissima	Eider duck													
Somateria spectabilis	King Eider duck											2	1	
Somateria sp.	Eider sp. Indet.													
Anatidae sp	Duck sp. Indet													
Mergus serrator	Red Breasted Merganser													
Gavia immer	Common Loon/Diver													
Gavia stellata	Red Throated Loon/Diver													
Anser/Branta sp.	Goose sp. Indet.													
Cygnus musicus	Whooper Swan													
Cygnus olor	Whooper Swan													
Cygnus cygnus	Swan sp. Indet.													
Cygnus sp.	Sea Eagle													
Haliaeetus albicilla	Gyrfalcon									2		1		1
Falco rusticolis	Raven													
Corvus corax	Black-legged Kittiwake													
Rissa trydactyla	Puffin													
Fratercula arctica	Razorbill													
Alca torda	Little Auk/ Dovekie													5
Alle alle	Brunnich's guillemot													
Uria lomvia	Common Guillemot/ Murre						1							
Uria aalge	Black Guillemot													
Cepphus grylle	Guillemot/Murre sp.indet													
Uria sp.	Auk family sp. Indet									129	4	425	2	6
Alcidae sp.	Iceland gull									92				
Larus glaucoides	Gull sp. Indet.													
Larus sp.	Domestic Chicken													
Gallus gallus	Bird sp. Indet.													
Aves sp		18								75		441		4

Table 21 Fish and Mollusca NISP count from Eastern and Middle Settlement Unstratified Collections.

	sites in sample	M15	M21	E29 River	E64a	E64c	E66	E68	E78a	E34	E71N	E71S	E149	E167
Unphased Eastern Settlement	date	1979	1979	1934	1941	1941	1941	1979	1941	1997-98	1979	1979	1979	1979
NISP Counts	Phase	small	small	small	small	small	small	small	small					
	est.time range	?	?	?	?	?	?	?	?	mixed	?	?	?	?
Taxon														
Fish	Atlantic cod													
Gadus morhua	Greenland cod									5				
Gadus aculatus	Cod family sp. Indet.													
Gadidae sp.	Arctic char													
Salvelinus alpinus	Trout/Char sp. Indet													
Salmonid sp.	Capelin													
M. villosus	Sculpin sp. Indet.													
Cottidae sp.	Shorthorn Sculpin													
Myoxocephalus scorpius	Shorthorn Sculpin													
Cottus scorpius	Atlantic Halibut													
Hippoglossus hippoglossus	Flatfish sp. Indet.													
Pleuronectidae sp.	Eelpout									2				
Lycodes sp. Eelpout	Fish sp. Indet.									1				
Pisces sp. Indet										1				3
Mollusca	Common/ Blue Mussel													
Mytilus edulis	Arctic clam													2
Panopeaea norvegica	Whale barnacle													
Mya sp. Indet.	Shellfish sp. Indet.													

Table 22 Domestic Mammals NISP Count from Western Settlement Unstratified Collections.

Table 22	sites in sample	W16	W29	W36	W44	W45	W50a	W53a	W63	W75	W35	W52a	W53c	W53d	W59
Unphased Western Settlement	date	1936	1981	1981	1981	1981	1981	1941	1979	1981	1936, 1981	1936	1941	1941	1982
NISP Counts	Phase	small	small	small	small	small	small	small	small	small					Int & midden
	est.time range	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Taxon															
Homo sapiens	Human														
Domestic Mammals															
Bos taurus	Cattle	9	2	1		46	2	3	9		59	173	87	56	150
Equus caballus	Horse											7		3	
Canis familiaris	Dog										1	11	3	3	6
Felis catus	Cat														
Sus scrofa	Pig														2
Ovis aries	Sheep								2		8	62	15	10	13
Capra hircus	Goat	2				1					12	28	4	5	7
Ovis or Capra	Sheep or Goat	12	12			35	2	2	17	1	178	200	139	69	505

Table 23 Wild Mammals NISP count from Western Settlement Unstratified Collections.

Table 23	sites in sample	W16	W29	W36	W44	W45	W50a	W53a	W63	W75	W35	W52a	W53c	W53d	W59
Unphased Western Settlement	date	1936	1981	1981	1981	1981	1981	1941	1979	1981	1936, 1981	1936	1941	1941	1982
NISP Counts	Phase	small	small	small	small	small	small	small	small	small					Int & midden
	est.time range	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Taxon															
Wild Mammals Terrestrial															
Rangifer tarandus	Caribou	5	9			20	1	7	11		119	439	120	120	755
Lepus arcticus	Arctic hare	1							1			9			34
Alopex lagopus	Arctic Fox											3		1	15
Mus musculus	House mouse														
Mus sp..	Mouse sp.														
Dog or wolf	Dog or wolf														
Wild Mammals Marine															
Pagoph. groenlandica	Harp seal	5	1		1	4		2	7		38	255	99	63	55
Phoca vitulina	Common/ Harbor seal	1	1		1	3			2		15	103	42	15	77
Cystophora cristata	Hooded seal				3										1
Phoca hispida	Ringed seal										1	7	3		5
Erignathus barbatus	Bearded seal										4	26	18	11	3
E. barbatus or *C. cristata*	Large seal sp. Indet.														
Phocidae sp.	Seal sp. Indet.		29	1		117	10	15	69		447	316	585	289	2466
Odobenus rosmarus	Walrus	4	1		1	2	1	3	1		*4*	62	7	7	32
Ursus maritimus	Polar Bear										*1*	2			*1*
Delphinapterus leucas	Beluga whale														
D.leucas/Monodon m.	Beluga or Narwhal														
Lagenorhynchus albirostris	White sided porpoise														
Phocoena phocoena	Common porpoise														
Globicephalus melas	Pilot whale														
Globicephalus melas/ Orcinus o.	Pilot/ Orca whale														
Small cetacean sp.	Small whale/ porpoise														
Balaena australis	Southern Right Whale											3			
Balaena mysticetus	Bowhead Whale														
Large Cetacea sp	Large whale sp. Indet.										4	13		1	
Cetacea sp. Indet.	Whale sp. Indet				1	9						4			56

Table 24 Bird NISP Count from Western Settlement Unstratified Collections.

Table 24	sites in sample	W16	W29	W36	W44	W45	W50a	W53a	W63	W75	W35	W52a	W53c	W53d	W59
Unphased Western Settlement	date	1936	1981	1981	1981	1981	1981	1941	1979	1981	1936, 1981	1936	1941	1941	1982
NISP Counts	Phase	small	small	small	small	small	small	small	small	small					Int & midden
	est.time range	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Taxon															
Birds															
Lagopus muta	Ptarmigan								1						133
Carduelis flammea	Common Redpoll														
Anas acutas	Northern Pintail duck														
Anas platyrhynchos	Mallard duck														
Somateria mollissima	Eider duck														
Somateria spectabilis	King Eider duck														
Somateria sp.	Eider sp. Indet.														
Anatidae sp	Duck sp. Indet														3
Mergus serrator	Red Breasted Merganser														
Gavia immer	Common Loon/Diver														
Gavia stellata	Red Throated Loon/Diver														1
Anser/Branta sp.	Goose sp. Indet.														
Cygnus musicus	Whooper Swan											2			
Cygnus olor	Whooper Swan														
Cygnus cygnus	Swan sp. Indet.														3
Cygnus sp.	Sea Eagle														
Haliaeetus albicilla	Gyrfalcon														3
Falco rusticolis	Raven														
Corvus corax	Black-legged Kittiwake														1
Rissa trydactyla	Puffin														3
Fratercula arctica	Razorbill														
Alca torda	Little Auk/ Dovekie														1
Alle alle	Brunnich's guillemot														
Uria lomvia	Common Guillemot/ Murre											6			55
Uria aalge	Black Guillemot													2	
Cepphus grylle	Guillemot/Murre sp.indet														1
Uria sp.	Auk family sp. Indet				1				2		2				
Alcidae sp.	Iceland gull														
Larus glaucoides	Gull sp. Indet.														
Larus sp.	Domestic Chicken														
Gallus gallus	Bird sp. Indet.														
Aves sp						1			1		9				

Table 25 Fish and Mollusca NISP Count from Western Settlement Unstratified Collections.

	sites in sample	W16	W29	W36	W44	W45	W50a	W53a	W63	W75	W35	W52a	W53c	W53d	W59
Unphased Western Settlement	date	1936	1981	1981	1981	1981	1981	1941	1979	1981	1936, 1981	1936	1941	1941	1982
NISP Counts	Phase	small	small	small	small	small	small	small	small	small					Int & midden
	est.time range	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Taxon															
Fish	Atlantic cod														
Gadus morhua	Greenland cod														3
Gadus aculatus	Cod family sp. Indet.														
Gadidae sp.	Arctic char														
Salvelinus alpinus	Trout/Char sp. Indet										1				2
Salmonid sp.	Capelin														
M. villosus	Sculpin sp. Indet.														
Cottidae sp.	Shorthorn Sculpin														
Myoxocephalus scorpius	Shorthorn Sculpin														1
Cottus scorpius	Atlantic Halibut														
Hippoglossus hippoglossus	Flatfish sp. Indet.														
Pleuronectidae sp.	Eelpout														
Lycodes sp. Eelpout	Fish sp. Indet.														
Pisces sp. Indet															2
Mollusca															
Mytilus edulis	Common/ Blue Mussel		1									1			13
Panopeaea norvegica	Arctic clam											1			
Mya sp. Indet.	Clam sp. Indet														
Mollusca sp. Indet.	Shellfish sp. Indet.														
Arthropod															
Coronula diadema	Whale barnacle											1			

4.5 Data Summary- Relative Percentage Data (NISP%) and The Ratio Data

This section presents the archaeofauna from the phased sites in relative percentage format to make patterns more legible and to centralize tables that will appear in the interpretive chapters 5 and 6. These data are presented as relative percentage of major taxonomic groups (Domestic Mammals, Wild Mammals, Birds, Fish, Mollusca), Domestic Mammals, Seals Species. Ratio measures for cattle to caprine and sheep to goat bones are also presented here for reference.

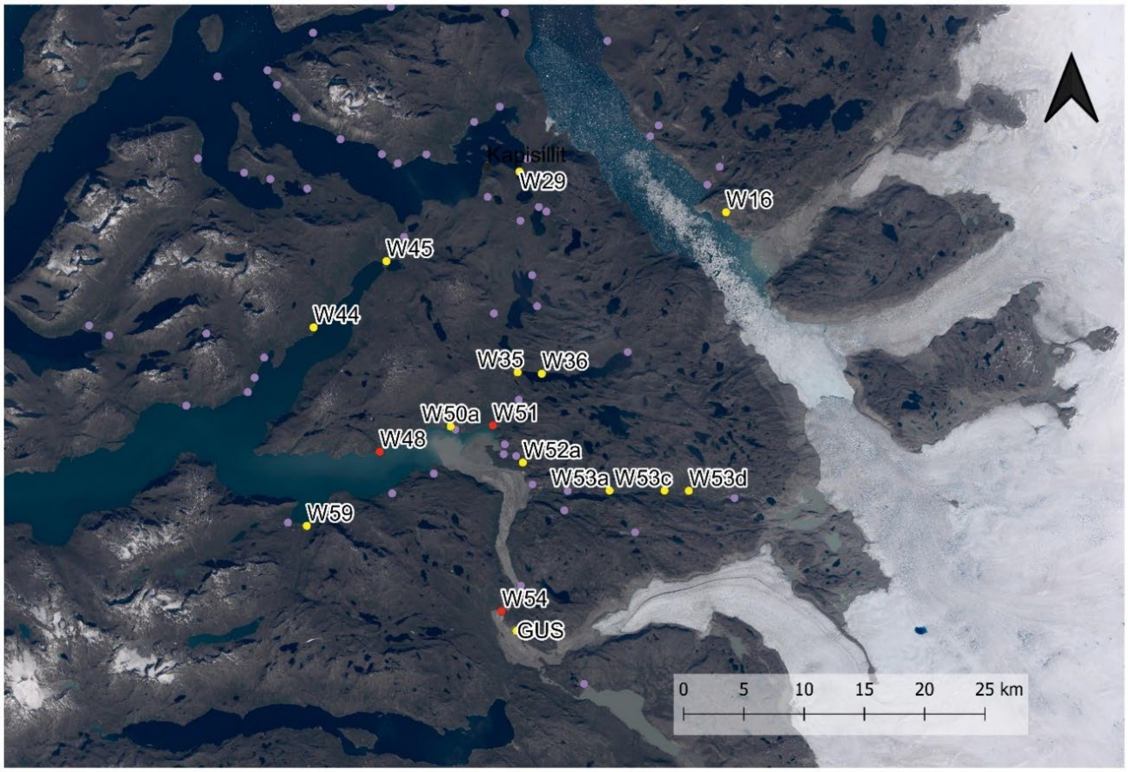


Figure 10 Central Western Settlement showing environmental setting of the key sites discussed. Map by Howell Roberts and the author (source: nunniffiit.natmus.gl and QGreenland (v2) .

Figure 11 Central Eastern Settlement showing environmental setting of the key sites discussed. Map by Howell Roberts and the author (source: nunniffiit.natmus.gl and QGreenland (v2).

Table 26 Major Taxonomic Groups for the Early Phase Archaeofauna.

n= 7	E17a	E74	E172	E68	GUS	W51-1	W48
date	1976, 1983	2006	2017	2007	2002	1984	1979
Phase	lower	Phase 1 A	Phase 1	Phase 1	1	F I Midden	AU I
est.time range	10-11th c	1040-1150	100-1100	985-1050	1000-1200	1025-1150	980-1160
notes		*SMALL*					
Domestic Mammals	35.64	25.45	31.37	58.75	39.69	17.93	12.70
Caribou	8.04	0.61	1.72	0.39	25.60	8.44	5.86
Seals	47.15	60.61	64.56	38.52	26.63	34.39	70.83
Walrus	2.34	1.82	0.68	0.00	1.03	13.71	0.52
Polar Bear	0.75	0.00	0.14	0.00	0.00	0.00	0.04
Cetacea	3.18	0.00	0.59	0.78	0.00	4.01	0.40
Birds	2.90	3.03	0.54	1.56	7.04	4.85	6.61
Fish	0.00	3.64	0.41	0.00	0.00	0.21	0.00
Mollusca	0.00	4.85	0.00	0.00	0.00	16.46	3.02

Table 27 Domestic Mammal Relative % (NISP) for the Early Phase Archaeofauna.

EARLY PHASE	n= 7	E17a	E74	E172	E68	GUS	Sandnes W51	W48
c 980-1160 CE	date	1976, 1983	2006	2017	2007	2002	1984	1979
% domesticates	Phase	lower	Phase 1 A	Phase 1	Phase 1	1	F I Midden	AU I
	est.time range	10-11th c	1040-1150	100-1100	985-1050	1000-1200	1025-1150	980-1160
Taxon								
	Domestic Mammals							
Bos taurus	Cattle	33.33	19.05	19.45	2.65	35.50	43.53	20.83
Equus caballus	Horse	0.00	0.00	0.72	0.00	0.43	1.18	0.00
Canis familiaris	Dog	0.26	0.00	0.43	1.99	0.00	0.00	0.00
Felis catus	Cat	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sus scrofa	Pig	2.62	0.00	1.01	0.00	0.00	10.59	0.33
Ovis aries	Sheep	4.72	4.76	11.82	1.32	9.96	7.06	2.98
Capra hircus	Goat	1.57	0.00	8.50	2.65	7.79	1.18	3.80
Ovis or Capra	Sheep or Goat	57.48	76.19	58.07	91.39	46.32	36.47	72.07
	total caprine	63.78	80.95	78.39	95.36	64.07	44.71	78.84

Table 28 Ratios of Caprine (Sheep, goat, and caprine indet.) to Cattle and Identified Sheep to Goat for the Early Phase archaeofauna.

EARLY PHASE	sites in sample	7	E17a	E74	E172	E68	GUS	andnes W5	W48
c 980-1160 CE	date		1976, 1983	2006	2017	2007	2002	1984	1979
Ratio Measure	Phase		lower	Phase 1 A	Phase 1	Phase 1	1	F I Midden	AU I
	est.time range		10-11th c	1040-1150	100-1100	985-1050	1000-1200	1025-1150	980-1160
	Caprine/Cattle		1.91	4.25	4.03	36.00	1.80	1.03	3.79
	Sheep/Goat		3.00	no goat	1.39	0.50	1.28	6.00	0.78

Table 29 NISP % of Identified Seals for the Early Phase Archaeofauna.

EARLY PHASE	n= 7	E17a	E172	E68	GUS	W51-1	W48
c 980-1160 CE	date	1976, 1983	2017	2007	2002	1984	1979
Identified Seal NISP %	Phase	lower	Phase 1	Phase 1	1	F I Midden	AU I
	est.time range	10-11th c	100-1100	985-1050	1000-1200	1025-1150	980-1160
Taxon	***notes***						
Wild Mammals Marine							
Pagoph. groenlandica	Harp seal	**29.69**	**23.57**	**0.00**	**37.50**	**47.37**	**58.01**
Phoca vitulina	Common/ Harbor seal	**57.81**	**5.73**	**0.00**	**37.50**	**47.37**	**40.88**
Cystophora cristata	Hooded seal	**6.25**	**10.83**	**66.67**	**0.00**	**0.00**	**0.00**
Phoca hispida	Ringed seal	**1.56**	**0.00**	**0.00**	**0.00**	**0.00**	**0.55**
Erignathus barbatus	Bearded seal	**4.69**	**1.27**	**0.00**	**25.00**	**5.26**	**0.55**
E. barbatus or *C. cristata*	Large seal sp. Indet.	**0.00**	**58.60**	**33.33**	**0.00**	**0.00**	**0.00**

Table 30 % NISP of major taxa for the Middle Phase Archaeofauna.

n= 13	E47 Gardar	E172	E64	E29N	E29N	E29N	E68	E64	E74	GUS	W48	W51	W51
date	2017	2017	2017	2006	2006	2006	2007	2007	2007	2002	1979	1984	1984
Phase	Phase 1	Phase 2 & 3		VI-VIII	V	IV	Phase 2		Phase 2 A	2	AU II	F I Midden	F I Midden
est.time range	1150-1250	1100-1300	1150-1265	I 11th-12th	1200-1250	1250-1300	1050-1350	1150-1265	1150-1300	1200-1300	1160-1300	1150-1200	1200-1250
Domestic Mammals	21.20	23.90	59.65	39.09	25.45	23.07	56.52	59.65	34.65	38.10	9.96	14.66	17.69
Caribou	5.72	1.43	3.80	4.09	3.79	2.12	1.30	3.80	1.49	10.91	3.72	10.84	12.76
Seals	68.51	68.18	34.50	50.00	62.12	66.80	40.00	34.50	55.45	30.23	61.77	17.60	24.23
Walrus	2.65	4.68	1.46	4.09	2.12	1.83	0.43	1.46	2.97	0.89	0.17	27.18	23.55
Polar Bear	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.02	0.13	0.31
Cetacea	0.30	0.26	0.58	0.45	2.27	2.90	0.00	0.58	2.97	0.18	0.34	5.69	3.64
Birds	1.53	1.43	0.00	2.27	4.24	3.28	1.74	0.00	1.49	16.46	11.90	9.37	9.62
Fish	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	3.04	0.09	0.07	0.06
Mollusca	0.00	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.00	12.04	14.46	8.14

Table 31 Relative % NISP for the Domestic Mammals for the Middle Phase Archaeofauna.

MIDDLE PHASE	**n= 13**	E47 Gardar	E172	E64	E29N	E29N	E29N	E68	E64	E74	GUS	W48	W51	W51
c 1160-1300 CE	**date**	2017	2017	2017	2006	2006	2006	2007	2007	2007	2002	1979	1984	1984
Relative %	**Phase**	Phase 1	Phase 2 & 3		VI-VIII	V	IV	Phase 2		Phase 2 A	2	AU II	F I Midden	F I Midden
	est.time range	1150-1250	1100-1300	1150-1265	l 11th-12th	1200-1250	1250-1300	1050-1350	1150-1265	1150-1300	1200-1300	1160-1300	1150-1200	1200-1250
Bos taurus	Cattle	15.48	15.22	22.06	44.19	38.10	39.33	4.62	22.06	22.86	23.47	15.48	36.99	39.02
Equus caballus	Horse	0.77	0.00	0.00	1.16	0.60	0.42	0.00	0.00	0.00	0.94	0.00	0.46	0.00
Canis familiaris	Dog	8.77	0.54	0.00	0.00	0.60	0.00	0.00	0.00	0.00	0.94	0.15	0.00	0.00
Felis catus	Cat	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sus scrofa	Pig	0.26	1.09	0.98	1.16	1.19	2.09	0.00	0.98	0.00	0.00	0.00	3.65	1.05
Ovis aries	Sheep	3.35	7.07	1.96	6.98	11.90	7.95	1.54	1.96	4.29	15.02	3.25	7.76	5.23
Capra hircus	Goat	4.13	9.78	0.49	2.33	3.57	2.09	0.77	0.49	1.43	15.02	4.02	5.48	6.62
Ovis or Capra	Sheep or Goat	67.23	66.30	74.51	44.19	44.05	48.12	93.08	74.51	71.43	44.60	77.09	45.66	48.08
	Total Caprine	74.71	83.15	76.96	53.49	59.52	58.16	95.38	76.96	77.14	74.65	84.37	58.90	59.93

Table 32 Ratio of All Caprine Bones to Cattle Bones and the Identified Sheep to Goat Ratio for the Middle Phase Archaeofauna.

MIDDLE PHASE	**n= 13**	E47 Gardar	E172	E64	E29N	E29N	E29N	E68	E64	E74	GUS	W48	W51	W51
c 1160-1300 CE	**date**	2017	2017	2017	2006	2006	2006	2007	2007	2007	2002	1979	1984	1984
Ratios	**Phase**	Phase 1	Phase 2 & 3		VI-VIII	V	IV	Phase 2		Phase 2 A	2	AU II	F I Midden	F I Midden
	Caprine/ Cattle	4.83	5.46	3.49	1.21	1.56	1.48	20.67	3.49	3.38	3.18	5.45	1.59	1.54
	Sheep/Goats	0.81	0.72	4.00	3.00	3.33	3.80	2.00	4.00	3.00	1.00	0.81	1.42	0.79

Table 33 NISP % of the Identified Seals for the Middle Phase Archaeofauna.

MIDDLE PHASE	**n= 13**	**E47 Gardar**	**E172**	**E64**	**E29N**	**E29N**	**E29N**	**E68**	**E64**	**E74**	**GUS**	**W48**	**W51**	**W51**
c 1160-1300 CE	**date**	**2017**	**2017**	**2017**	**2006**	**2006**	**2006**	**2007**	**2007**	**2007**	**2002**	**1979**	**1984**	**1984**
Identified Seal NISP %	**Phase**	**Phase 1**	**Phase 2 & 3**		**VI-VIII**	**V**	**IV**	**Phase 2**		**Phase 2 A**	**2**	**AU II**	**F I Midden**	**F I Midden**
	est.time range	1150-1250	1100-1300	1150-1265	l 11th-12th	1200-1250	1250-1300	1050-1350	1150-1265	1150-1300	1200-1300	1160-1300	1150-1200	1200-1250
Wild Mammals Marine														
Pagoph. groenlandica	Harp seal	80.95	19.05	38.89	69.23	30.00	65.38	69.23	38.89	54.55	36.36	58.29	33.33	51.61
Phoca vitulina	Common/ Harbor seal	1.59	11.90	27.78	0.00	34.00	5.77	0.00	27.78	0.00	50.00	39.20	59.26	38.71
Cystophora cristata	Hooded seal	4.76	11.90	11.11	7.69	18.00	13.46	15.38	11.11	45.45	0.00	0.00	0.00	0.00
Phoca hispida	Ringed seal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Erignathus barbatus	Bearded seal	3.17	2.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	13.64	2.51	7.41	9.68
E. barbatus or *C. cristata*	Large seal sp. Indet.	9.52	54.76	22.22	23.08	18.00	15.38	15.38	22.22	0.00	0.00	0.00	0.00	0.00

Table 34 Relative % NISP Data for the Major Taxa for the Late Period.

LATE PHASE	**N= 11**	**E47 Gardar**	**E29N**	**E68**	**E74**	**E17a**	**W48**	**W51**	**W51**	**W51**	**W54**	**GUS**
c 1300-1450 CE	**date**	**2017**	**2006**	**2007**	**2007**	**1976, 1983**	**1979**	**1984**	**1984**	**1935/81**	**1979**	**2002**
Major taxa NISP %	**Phase**	**Phase 2**	**III**	**Phase 3**	**Phase 3 B**	**upper**	**AU III**	**F I Midden**	**Stable Midden**	**House & Midden**	**house int.**	**3**
	est.time range	**1270-1320**	**1300-1450**	**1350-1450**	**1300-1400**	**13-15th c**	**1300-1400**	**1250-1325**	**1200-1325**	**1300-1400?**	**1300-1400**	**1300-1400**
	Domestic Mammals	**23.52**	**17.97**	**81.33**	**70.73**	**38.23**	**9.85**	**14.41**	**21.37**	**28.51**	**30.67**	**38.62**
	Caribou	**2.96**	**2.93**	**0.00**	**0.81**	**4.43**	**4.54**	**14.51**	**7.69**	**28.67**	**16.36**	**11.90**
	Seals	**68.70**	**73.05**	**13.33**	**27.73**	**50.91**	**81.31**	**26.69**	**54.13**	**33.89**	**32.01**	**40.09**
	Walrus	**0.93**	**1.37**	**2.67**	**0.36**	**0.60**	**0.18**	**29.59**	**2.28**	**6.95**	**0.71**	**0.40**
	Polar Bear	**0.19**	**0.00**	**0.00**	**0.00**	**0.20**	**0.03**	**0.10**	**0.00**	**0.34**	**0.04**	**0.04**
	Cetacea	**1.11**	**2.34**	**1.33**	**0.18**	**4.23**	**0.42**	**2.61**	**4.27**	**0.67**	**0.25**	**0.29**
	Birds	**2.59**	**2.34**	**0.00**	**0.18**	**1.21**	**3.47**	**10.40**	**8.55**	**0.63**	**15.06**	**5.93**
	Fish	**0.00**	**0.00**	**0.00**	**0.00**	**0.20**	**0.21**	**0.05**	**0.00**	**0.00**	**0.46**	**2.73**
	Mollusca	**0.00**	**0.00**	**1.33**	**0.00**	**0.00**	**0.00**	**1.64**	**1.71**	**0.34**	**4.44**	**0.00**

Table 35 Relative NISP % of the Domestic Mammals for the Late Phase Archaeofauna.

LATE PHASE	n= 11	E47 Gardar	E29N	E68	E74	E17a	W48	W51	W51	W51	W54	GUS
c 1300-1450 CE	date	2017	2006	2007	2007	1976, 1983	1979	1984	1984	1935/81	1979	2002
Relative %	Phase	Phase 2	III	Phase 3	Phase 3 B		AU III	F I Midden	Stable Midden	House & Midden	house int.	3
	est.time range	1270-1320	1300-1450	1350-1450	1300-1400	upper	1300-1400	1250-1325	1200-1325	1300-1400?	1300-1400	1300-1400
Taxon				*SMALL*				W51-5	W 51-4/5			
Bos taurus	Cattle	15.75	27.17	8.20	7.28	40.00	11.20	44.30	21.33	55.10	22.51	14.71
Equus caballus	Horse	0.00	0.00	0.00	0.00	1.05	0.00	0.00	0.00	0.00	0.14	1.96
Canis familiaris	Dog	2.36	1.09	0.00	0.00	0.53	0.27	0.67	2.67	5.32	0.95	1.58
Felis catus	Cat	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sus scrofa	Pig	0.00	0.00	0.00	0.00	1.58	0.00	1.34	0.00	0.59	0.00	0.00
Ovis aries	Sheep	2.36	9.78	0.00	0.64	5.26	2.13	3.36	2.67	5.47	4.09	7.91
Capra hircus	Goat	3.15	4.35	0.00	0.13	0.53	3.73	4.70	1.33	5.17	5.59	5.40
Ovis or Capra	Sheep or Goat	76.38	57.61	91.80	91.95	51.05	82.67	45.64	72.00	28.36	66.71	68.44
	Total Caprine	81.89	71.74	91.80	92.72	56.84	88.53	53.69	76.00	39.00	76.40	81.75

Table 36 Ratio Data for Caprine to Cattle Bones and Identified Sheep to Goat Bones in the Late Phase Archaeofauna.

LATE PHASE	n= 11	E47 Gardar	E29N	E68	E74	E17a	W48	W51	W51	W51	W54	GUS
c 1300-1450 CE	date	2017	2006	2007	2007	1976, 1983	1979	1984	1984	1935/81	1979	2002
Ratios	Phase	Phase 2	III	Phase 3	Phase 3 B	upper	AU III	F I Midden	Stable Midden	louse & Midde	house int.	3
	est.time range	1270-1320	1300-1450	1350-1450	1300-1400	13th-15th c	1300-1400	1250-1325	1200-1325	1300-1400?	1300-1400	1300-1400
	Caprine/Cattle	5.2	2.64	11.20	12.74	1.42	7.90	1.21	3.56	0.71	3.39	5.56
	Sheep/Goat	0.75	2.25	no goats	5.00	10.00	0.57	0.71	2.00	1.06	0.73	1.47

Table 37 NISP % Data for Identified Seals in the Late Phase Archaeofauna.

LATE PHASE	N= 11	E47 Gardar	E29N	E68	E74	E17a	W48	W51	W51	W51	W54	GUS
c 1300-1450 CE	date	2017	2006	2007	2007	1976, 1983	1979	1984	1984	1935/81	1979	2002
NISP Counts	Phase	Phase 2	III	Phase 3	Phase 3 B	upper	AU III	F I Midden	Stable Midden	louse & Midde	house int.	3
	est.time range	1270-1320	1300-1450	1350-1450	1300-1400	13-15th c	1300-1400	1250-1325	1200-1325	1300-1400?	1300-1400	1300-1400
	comments			Small					Small			
Pagoph. groenlandica	Harp seal	40.00	78.57	0.00	51.85	72.22	55.33	33.33	60.00	68.73	64.29	59.65
Phoca vitulina	Common/ Harbor sea	0.00	14.29	0.00	11.11	9.26	38.67	61.67	40.00	25.06	26.19	28.07
Cystophora cristata	Hooded seal	0.00	7.14	50.00	37.04	16.67	0.00	0.00	0.00	0.00	0.00	1.75
Phoca hispida	Ringed seal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.99	0.00	0.00
Erignathus barbatus	Bearded seal	0.00	0.00	0.00	0.00	1.85	6.00	5.00	0.00	4.22	9.52	10.53
E. barbatus or *C. cristata*	Large seal sp. Indet.	60.00	0.00	50.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

CHAPTER 5: Economic Patterns in Norse Greenland

This chapter discusses patterns in the original data sets created by the author and presented in Chapter 4, placing the Greenlandic zooarchaeological record in a broader context of stable and changing economic patterns through time.

5.1 Initial Adaptations at Settlement

Both Iceland and Greenland were settled in the wave of sea-borne colonization that took European agricultural settlements to far offshore North Atlantic islands, reaching Iceland ca. 875 CE, Greenland ca. 985 CE, and briefly to Newfoundland by 1000 CE. Both modern and ancient DNA (aDNA) analyses (Helgason et al. 2000a, 2000b, 2001, Margaryan et al. 2020) confirm the strong British Isles genetic component of Icelanders, and aDNA from Greenlandic cemeteries (Lynnerup and Nørby 2004) provide confirmation of the traditional accounts of Greenlandic settlement from Iceland. These two island communities thus shared a great deal of cultural and biological heritage, and for nearly five centuries they represented the westernmost outposts of medieval Christendom. When Icelandic settlers crossed Denmark Strait in the late 10th century to found two communities on the west coast (Eastern Settlement in modern *Kujalleq* district, Western Settlement in *Nuuk* district further north) they crossed significant climatic and biological frontiers, though these may not have all been immediately apparent (Dugmore et al.2013). In Greenland they encountered caribou, polar bear, and huge populations of walrus as well as both familiar North Atlantic and unfamiliar Arctic seals and whales. Greenland was probably always beyond the reach of significant cereal agriculture (though flax and cereal pollen has been recovered, and there have been finds of carbonized barley discussion below in 5.10, also McGovern et al. 1996).

Table 38 Major Taxa from Early Phase Archaeofauna.

EARLY PHASE							
c 980-1160 CE							
Major Taxa NISP %							
n= 7	E17a	E74	E172	E68	GUS	W51-1	W48
date	1976, 1983	2006	2017	2007	2002	1984	1979
Phase	lower	Phase 1 A	Phase 1	Phase 1	1	F I Midden	AU I
est.time range	10-11th c	1040-1150	100-1100	985-1050	1000-1200	1025-1150	980-1160
notes		SMALL					
Domestic Mammals	35.64	25.45	31.37	58.75	39.69	17.93	12.70
Caribou	8.04	0.61	1.72	0.39	25.60	8.44	5.86
Seals	47.15	60.61	64.56	38.52	26.63	34.39	70.83
Walrus	2.34	1.82	0.68	0.00	1.03	13.71	0.52
Polar Bear	0.75	0.00	0.14	0.00	0.00	0.00	0.04
Cetacea	3.18	0.00	0.59	0.78	0.00	4.01	0.40
Birds	2.90	3.03	0.54	1.56	7.04	4.85	6.61
Fish	0.00	3.64	0.41	0.00	0.00	0.21	0.00
Mollusca	0.00	4.85	0.00	0.00	0.00	16.46	3.02

As table 38 above indicates early phase zooarchaeological collections from both settlement areas show a higher relative percentage of seal bones than any other Viking age sites in the North Atlantic region. We thus far do not see any transitional period when seal hunting was gradually introduced. As discussed in more detail below, while some of the hunted seals were the harbor/common seals (*Phoca vitulina*) familiar from the Eastern North Atlantic many of seal bones on the early sites are from the migratory harp seals (*Pagophilus groenlandicus*) with some hooded seal (*Cystophora cristata*) in the Eastern Settlement area (Hooded seals seldom appear in the Western Settlement area, which seems to be out of their normal migratory range). Some arctic bearded seal (*Erignathus barbatus*) and a very few ringed seal (*Phoca hispida*) bones appear in early archaeofauna, usually in comparatively small numbers (Table 39).

Table 39 Identified seal relative %. Note that E68 Timerliit is a small collection and the % data may not be representative.

EARLY PHASE						
c 980-1160 CE						
Identified Seal NISP %						
n= 6	E17a	E172	E68	GUS	W51-1	W48
date	1976, 1983	2017	2007	2002	1984	1979
Phase	lower	Phase 1	Phase 1	1	F I Midden	AU I
est.time range	10-11th c	100-1100	985-1050	1000-1200	1025-1150	980-1160
notes			small			
Harp seal	29.69	23.57	0.00	37.50	47.37	58.01
Common/ Harbor seal	57.81	5.73	0.00	37.50	47.37	40.88
Hooded seal	6.25	10.83	66.67	0.00	0.00	0.00
Ringed seal	1.56	0.00	0.00	0.00	0.00	0.55
Bearded seal	4.69	1.27	0.00	25.00	5.26	0.55
Large seal sp. Indet.	0.00	58.60	33.33	0.00	0.00	0.00

No other North Atlantic population consumed as much seal as the Norse Greenlanders, and their shift in adaptation seems to have happened rapidly- even early phase sites are high in seal bone by Icelandic, Faroese, Shetland or Orcadian standards. In the later phases of the settlements (especially after ca. 1250-1300 CE) the deposition of seal bones increased on many sites, and seal seems to have been particularly important on small farms.

Initially, the full Icelandic range of cattle, sheep, goats, dogs, cats, horses, and pigs appear in early Greenlandic collections (Smiarowski 2013a, 2014). Table 40 presents the relative percentages of domestic mammals from the early phase sites. Cattle bones are found on all early phase sites (and have a high ubiquity score in all collections), including the bones of neo-natal (newborn to a month old) individuals suggesting on site birth and a dairy focus in cattle management from the first settlement. Dog and horse bones are comparatively rare, though dog tooth marks are widely distributed on other species bone fragments. Pigs are present in several early phase sites and are most abundant at the chieftain's farm at W 51 Sandnes in the Western Settlement. As sheep and goat can only be distinguished to species level on a limited range of elements, and the Greenlandic archaeofauna are normally very highly fragmented, the "Caprine" category that includes bones that could come from either species is substantial, and the "total Caprine" category sums the sheep, goat, and caprine categories to allow for more realistic comparison to other taxa. Note that while small farms (W48, E172, E74) have the largest relative percentage of caprines, they were not specialized sheep and goat herding centers but instead appear to have maintained some cattle.

Table 40 Early Phase Domestic Mammal Relative %.

EARLY PHASE	**n= 7**	**E17a**	**E74**	**E172**	**E68**	**GUS**	**Sandnes W51**	**W48**
c 980-1160 CE	**date**	**1976, 1983**	**2006**	**2017**	**2007**	**2002**	**1984**	**1979**
% domesticates	**Phase**	**lower**	**Phase 1 A**	**Phase 1**	**Phase 1**	**1**	**F I Midden**	**AU I**
	est.time range	**10-11th c**	**1040-1150**	**100-1100**	**985-1050**	**1000-1200**	**1025-1150**	**980-1160**
Taxon								
	Domestic Mammals							
Bos taurus	Cattle	33.33	19.05	19.45	2.65	35.50	43.53	20.83
Equus caballus	Horse	0.00	0.00	0.72	0.00	0.43	1.18	0.00
Canis familiaris	Dog	0.26	0.00	0.43	1.99	0.00	0.00	0.00
Felis catus	Cat	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sus scrofa	Pig	2.62	0.00	1.01	0.00	0.00	10.59	0.33
Ovis aries	Sheep	4.72	4.76	11.82	1.32	9.96	7.06	2.98
Capra hircus	Goat	1.57	0.00	8.50	2.65	7.79	1.18	3.80
Ovis or Capra	Sheep or Goat	57.48	76.19	58.07	91.39	46.32	36.47	72.07
	total caprine	63.78	80.95	78.39	95.36	64.07	44.71	78.84

Greenlanders thus relied more heavily upon pastoralism combined with both marine and terrestrial (caribou) hunting than any of their contemporaries in the Norse North Atlantic world, and the strange lack of bread and beer in Greenland featured prominently in Icelandic sagas (mainly composed after ca.1150-1200, Hartman et al. 2017). The diet of the Norse Greenlanders (high in the food web), is reflected in N and C isotopic ratios in their bones (Arneborg et al. 1999, 2012) and in the notice taken by European writers like the apparently knowledgeable Norwegian mid-13th century author of the didactic text *King's Mirror:*

> *You ask what the inhabitants live on in that country since they sow no grain; but men can live on other food than bread. It is reported that the pasturage is good and that there are large and fine farms in Greenland. The farmers raise cattle and sheep in large numbers and make butter and cheese in great quantities. The people subsist chiefly on these foods and on beef; but they also eat the flesh of various kinds of game, such as reindeer, whales, seals, and bears. (*The King's Mirror-Speculum Regale-Konungs Skuggsjá Larsen trans. 1917, p 145)

The overview of all identified taxa from the early phase archaeofauna (Table 38) confirms the *King's Mirror* account, with all the species mentioned appearing in varied numbers. Caribou (*Rangifer tarandus*) appear on many sites but tend to be most common in Western Settlement collections, and drive systems and apparent hunting structures that appear to have both Norse and later Inuit components have been documented in the uplands in both settlement areas (McGovern and Jordan 1982). Walrus bones (as discussed below) tend to come from what appears to be final tusk extraction and it is not clear how much walrus meat contributed to the Norse diet beyond the early phases when walrus was probably accessible near the settlement areas. Polar bear bones are rare, and nearly all seem to come from final finishing of skins (metapodial and phalanges), but some skull fragments are also present, like at E172 Tatsipataa. Cetacean bone fragments are present on most sites, but in many cases seem to have been used for craft material and it is again uncertain how much whale meat was regularly consumed. Bird bones are comparatively rare, and nearly all come from the auk family (Alcidae) present in summer nesting colonies or Ptarmigan resident in the uplands year-round. Fish are exceedingly rare even on sieved sites, but a limited number of marine (mostly cod-family) and freshwater fish bones are now recorded. Mollusca are almost all mussels (*Mytilus edulis*) and are uncommon in the early phase collections except for W51 Sandnes.

The early phase archaeofauna thus support a scenario in which early Landnám settlers imported a domestic herding economy from Iceland that looks very much like contemporary Viking Age Icelandic archaeofauna (including pigs in the richer farms), while also rapidly adapting to the new wild resources available with a strong focus on migratory seals and caribou hunting. Sealing seems to have effectively and rapidly replaced the well-documented pattern of marine fishing and distribution of dried fish products in Viking Age Iceland, and fishing does not seem to have ever played the same role in Greenland as in Iceland and the other North Atlantic settlements. As discussed below, this pattern was to have significant impact upon the participation of Norse Greenland in the later medieval "proto-world system" after 1250. However, it is clear that the first generations of Norse settlers showed considerable skill in maintaining a herding economy in a significantly more difficult natural landscape and climate while demonstrating adaptive flexibility in rapidly re-aligning their maritime adaptations to sealing from marine fishing. The patterns established in the first generations of settlement were to persist in broad outlines down to the end of the settlement.

5.2 Was it for Walrus?

Recent comparative research has increasingly underlined the character of the Greenlandic settlements as always something of a specialized arctic resource extraction community, with export-orientated hunting for ivory and furs being supported by subsistence hunting and farming, rather than a farming community supplementing agriculture with subsistence hunting and fishing as in Iceland (Keller 2010, Dugmore et al. 2007). The Greenlandic walrus hunt seems to have been of a quite different character and intensity from the Viking Age exploitation of local walrus pods close to farming settlements that we can now document from early Iceland (Frei et al. 2015, Pierce

2009). Ancient DNA and isotopic studies now available (Keighley 2019) indicate that native Icelandic walrus populations were genetically separate from those in Greenland and Canada and suggest that overhunting by early Icelandic colonists probably drove this sub-population to extinction within a century of the first settlement ca. 875 CE. The exploration and colonization of Greenland by Icelanders ca. 980-1000 may have been initially driven by a desire to secure more walrus products.

While walrus today can be encountered in most parts of Greenland in small numbers, the historic concentration of walrus and walrus hunting as reported by both 18th-19th c Euro-American whalers and 20th century catch statistics has centered on Disko Bay on the central West coast (Madsen 2019, McGovern 1984, Vibe 1957). This seems to be the area the medieval Norse called the *Norðursetur* or northern hunting grounds (Gad 1970, Madsen 2019). Written sources from the 13th century onwards indicate that annual hunting trips were launched from both settlement areas to the Norðursetur, up to 800 km one way from the farming districts (Larsen trans 1917, Gad 1970). The 19th century find of a rune stone at Kingittorsuaq near Upernavik just north of Disko Bay dated to late April seems to suggest some hunters may have over-wintered. The runes were initially dated to ca 1300 but Stoklund (1993) convincingly argues for a date around 1200. The inscription is short and truncated:

> *"Erlingur the son of Sigvað and Baarne Þorðar's son and Enriði Ás's son, the washing day (Saturday) before Rogation Day (25 April), raised this mound and rode..."* (translation Stoklund 1993)

Lisbeth Imer (2017) offers two transcription of the text – here translated into English:

1. *"Erlingr Sighvatrs son and Bjarni þorðr´s son and Eindriði Oddr´s son, constructed these*

cairns the Saturday before Rogation Day, and …"

2. *"Erlingr Sighvatrs son carved and Bjarni þorðr's son and Eindriði Oddr's son constructed these cairns the Saturday before Rogation Day, and …"*

Rogation Day (gangdagen) was either: Litania maior (large gangdag) on April 25 or Litanae minores (small gangdage) that were on the Monday, Tuesday and Wednesday before Ascension Day (Imer 2017).

The zooarchaeological evidence for the hunt for walrus in Greenland has been found in virtually every archaeofauna from the home farms in the form of fragments of walrus maxilla from around the tusk root, left behind by careful extraction of the ivory. The dense maxillary bone (and probably some associated peg-like post-canine teeth) holding the valuable tusk ivory seem to have formed a butchery unit at the kill site that were transported south at the end of the hunt. The final extraction of the deeply rooted tusks (probably following some decomposition of connective tissue) seems to have taken place on the home farms with careful use of a chisel-like tool to break open the tooth root and extract the maximum amount of ivory without damage.

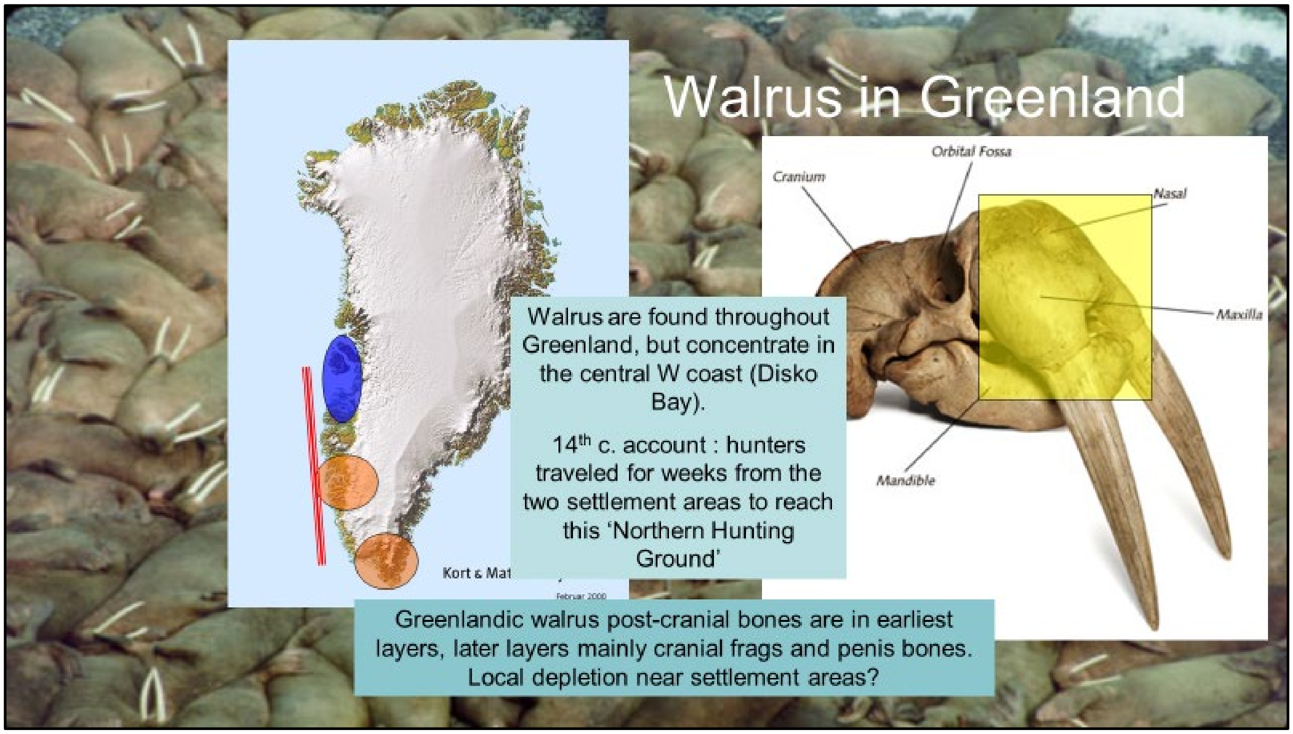
These dense walrus maxillary fragments are found on inland as well as coastal farms in both settlement areas and throughout the stratigraphic sequences, indicating the active participation of most of the community in the Norðursetur hunt and ivory preparation (McGovern 1984, McGovern et al. 1995). Tusk ivory or finished ivory pieces are rare on the home farms (though walrus penis-bone trophies and post-canines used for craftwork are not unusual, see figures below). Processing of the furs and hides mentioned in written sources is harder to document through zooarchaeology, but new collections from the Greenlandic Bishop's manor at Garðar / Igaliku in the Eastern Settlement have produced multiple polar bear third phalanges with cut marks suggesting on-site final finishing of bear skins (Smiarowski 2013a), a pattern also reported from W51 Sandnes in the Western Settlement (McGovern et al. 1996).

There are no concentrations of walrus post-cranial elements comparable to those found in the Reykjavik deposits in Iceland (Frei et al. 2015), but early phase midden deposits associated with farms in the Greenlandic settlement areas do contain some post-cranial bones suggesting some nearby kills and consumption of walrus meat. These post-cranial elements drop out in the upper layers and late phase walrus elements are virtually all maxillary fragments associated with final-stage tusk extraction, post-canines, and penis bones.

While there are significant sampling issues associated with quantifying walrus and polar bear bones from archaeofauna accumulated on the home farms (see discussion below) the walrus element distribution patterns suggest that the shift to the more distant hunting areas and the establishment of the long-range hunt happened early, probably within the first century of settlement. The trading contacts with Europe were clearly aware of the potential for profit at the Greenlanders expense, according to the Norwegian author of the *Kings' Mirror*:

> *But in Greenland it is this way, as you probably know, that whatever comes from other lands is high in price, for this land lies so distant from other countries that men seldom visit it. And everything that is needed to improve the land must be purchased abroad, both iron and all the timber used in building houses. In return for their wares the merchants bring back the following products: buckskin, or hides, sealskins, and rope of the kind that we talked about earlier which is called leather rope and is cut from the fish called walrus, and also the teeth of the walrus. (*Larsen trans. 1917*, The King's Mirror-Speculum Regale-Konungs Skuggsjá:142).*

The Norse Greenlanders could not have been dependent upon imported food, but iron was clearly valued and rare. A quantitative study by Aaron Kendall (2013) of modern excavations in Iceland and Greenland demonstrated that the most prominent difference was the relative lack of iron objects of any kind in the Greenlandic deposits, and most metallurgical studies suggest that (unlike their Icelandic contemporaries) the Greenlanders were probably not regularly smelting bog iron (Buchwald 1985). After full Christianization and the establishment of the bishop's manor at Garðar ca. 1125-50, the ritual needs of the mass (communion wafers and wine as well as vestments) and for effective Latin church rituals must have added an ideological as well as a technological importance to maintaining the contact with Bergen and Christendom. As suggested by Barrett et al. (2020) the establishment of the Episcopal seat at Garðar seems to correlate with an increase in walrus products from Greenland arriving in Europe, suggesting the role of ecclesiastical contacts and networks in facilitating the trade in the later Middle Ages. It is more likely however that Greenlanders had already established themselves in the profitable ivory trade, which attracted the Church.



Walrus in Greenland

Walrus are found throughout Greenland, but concentrate in the central W coast (Disko Bay).

14th c. account : hunters traveled for weeks from the two settlement areas to reach this 'Northern Hunting Ground'

Greenlandic walrus post-cranial bones are in earliest layers, later layers mainly cranial frags and penis bones. Local depletion near settlement areas?

Figure 12 Walrus hunting in Norse Greenland: Yellow box shows area of maxillary bone regularly appearing on home farms.

While most ivory seems to have been exported from Greenland, a few pieces of worked walrus ivory have been recovered (see 13 below, also Roesdahl 2005) but most craft items made of walrus tooth come from the peg-like post-canine teeth that may have traveled with the maxillary butchery unit containing the tusks. Partially finished post-canine carvings have been recovered from several sites (Figure 14). There are also a series of animal figures (bear, walrus, bird) that have suspension holes and may have been worn as decorations, trophies, or amulets (or perhaps served multiple functions). Figure 15 illustrates a unique bird carving from W 51 Sandnes, while Figure 16 illustrates two less well -preserved walrus and polar bear carvings from W 54. Chess and gaming pieces (all later medieval aniconic forms) were also produced from post-canines, making use of a lathe in fabrication (Figures 17 and 8 below). Small decorative buttons made from post-canines with carefully carved attachment loops are also recovered from several sites (Figures 19 and 20 below) as well as other decorative objects (Figure 21).

The penis bone finds and these varied post-canine carvings hint at the social role of participation in the northern hunt in Norse society in Greenland. The northern hunt may have been both something of both a rite of passage and a way for small holders to pay rent and tithe obligations. We should imagine that participation in the long -range summer hunt was embedded in a web of social connections and expectations beyond the need to produce marketable goods to attract merchants.

Figure 13 Walrus tusk fragment from Brattahlið North Farm E29N illustrates a portion of the very end of the tusk root, cut off with a backed bladed saw and showing marks of final tusk extraction just above the cut. This is a rare specimen compared to the substantial amount of maxillary bone fragments recovered, but it indicates some walrus tusk working took place in Greenland.

Figure 14 Worked walrus post-canine from W51 Sandnes. Possibly an unfinished preform. Photo Aaron Kendall.

Figure 15 Carved figurine made from Walrus post-canine tooth from W 51 Sandnes Midden 1984 (Phase 2). Several similar figurines have been recovered, all with suspension holes. Walrus and polar bear images are most common, this may be a Black Guillemot in a characteristic preening pose. Photo Claus Andreasen.

Figure 16 Walrus and bear figurines made from Walrus post-canines from W 54. Photo Aaron Kendall.

Figure 17 W48 Walrus post canine chess piece. Photo Aaron Kendall.

Figure 18 W48 chess piece showing lathe mark. Photo Aaron Kendall.

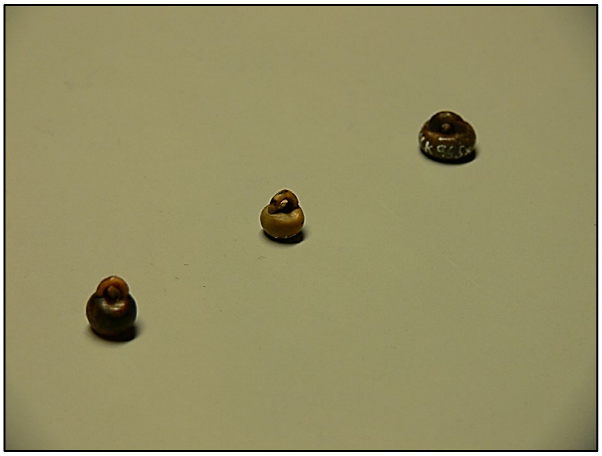


Figure 19 Three buttons made from walrus post-canines from W 48. Photo Aaron Kendall.

Figure 20 Six buttons made from walrus post-canines W 54. Photo Aaron Kendall.

Figure 21 Worked Walrus ivory object E 171. Photo by the author.

5.2.1 Zooarchaeological Evidence for Walrus Hunting

The current zooarchaeological data set for the Norðursetur hunt comes entirely from excavations on home farms hundreds of kilometers south of the probable hunting grounds. It is thus sourced from a very specialized type of deposit and may require some care in interpretation. While walrus and polar bear bones are typically large and robust (and attracted the attention of early zooarchaeologists) the nature of their deposition so far from probable kill sites means that their quantification is far less straightforward than the case for domestic mammals that were mainly killed, butchered, and consumed on the farms, or even than the hunted seals whose remains seem to have reached the home farms as more or less complete carcasses. Absence of walrus or polar bear bone from an existing archaeofauna thus may not imply their actual absence from the site, especially when the collection size is small. Despite these sampling issues, it is possible to provide some broad quantification of walrus and polar bear remains in the available collections. Table 41 below provides a simple ubiquity (presence/absence) measure of the distribution of walrus fragments in the available zooarchaeological collections. Walrus remains are present in 5 of 8 early phase (c 980-1150 CE) collections, in all the Middle (1150-1300) and Late (1300-1450) and 20 of the 27 unstratified collections (some of which are small).

Table 41 Ubiquity Measure of the distribution ow walrus fragments in Archaeofauna.

	EARLY PHASE	MIDDLE PHASE	LATE PHASE	UNSTRATIFIED
Ubiquity	980-1150	1150-1300	1300-1450	?
Walrus present	5	13	11	20
Total Collections	8	13	11	27

Relative percent of collection NISP provides a sense of relative abundance on sites, here presented by phase (Table 42).

Table 42 Relative % of Walrus bones in collections.

Walrus NISP %	E47 Gardar	E74	E17a	E172	E68	E64	E29N	W51	W54	GUS	W48
Late Phase	0.93	0.36	0.60		2.67		1.37	29.59	0.71	0.40	0.18
Middle Phase	2.65	2.97		4.68	0.43	1.46	2.68	25.36		0.89	0.17
Early Phase		1.82	2.34	0.68	0.00			13.71		1.03	0.52

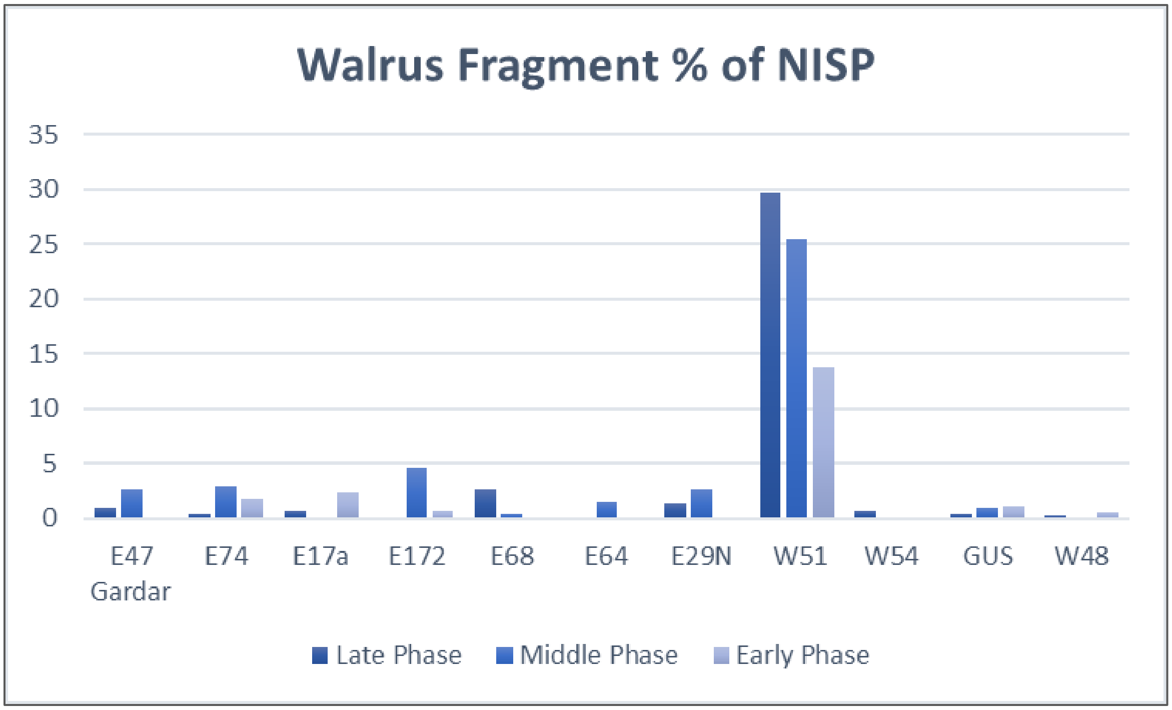


Figure 22 Walrus Fragment % NISP.

Figure 22 illustrates these relative percentage data and may underline the special importance of the chieftain’s farm at Sandnes W51 in the Western Settlement. While it may be unwise to read too much into the fluctuations of walrus relative NISP % given the depositional issues raised above, the W51 archaeofauna sample may allow further investigation. Table 43 presents a breakdown of the W51 walrus NISP % by sub-phase (the central sub – phases are both within the overall Greenland Middle Phase, for raw counts and further data discussion see chapter 4).

Table 43 Walrus Bone by Sub-Phase.

W51 contexts	% NISP
c 1250-1325	29.59
1200-1250	23.55
1150-1200	27.18
1025-1150	13.71

At W51 Sandnes, it appears that walrus maxillary fragment deposition rises from the early phase and seems to stabilize in the 20-30% range of total NISP in the later Middle Ages. The site was probably abandoned ca 1350-1400 AD and the available archaeofauna thus does not cover the final days of Norse Greenland, but from the evidence we have it would appear that:

1) The centrally located chieftain's farm at W51 Sandnes at the head of Ameralik fjord seems to have played an important role in the walrus hunt and processing of the transported butchery units. While the other Western Settlement archaeofauna (some from inland sites far from the fjord) also seem to have participated, this high- status site seems to have been a center in the network supporting the hunt and ivory processing. Sandnes plausibly could have been the manor of one of the "wealthy farmers" who were said to have sponsored the northern hunt in the 17th century Icelandic *Greenland Annals* (Halldórsson 1978, translation and full discussion in Madsen 2019: 123). The passage was written by Norwegian Haukr (born 1268) in his Hauksbók. Unfortunately, the pages about Greenland are lost. The author of Greenland Annals that was written in the beginning of the 1600s had access to the now lost pages.
2) Up to the mid-late 14th century there is no evidence at W51 Sandnes for a decline in walrus hunting effort. At the end of the Western Settlement the farmers were still very actively

engaged in walrus hunting and processing.

Polar bear bones are less widespread on Greenlandic home farm sites. Table 44 below presents the ubiquity (presence/absence) measure for the available collections. In the Early Phase polar bear appears in 3 of 8 collections, in Middle Phase in 5 of 13, in Late Phase in 7 of 11, and in the Unstratified collections (some small) in 8 of 27.

Table 44 Polar Bear ubiquity (presence/absence) measure for the available collections.

	EARLY PHASE	MIDDLE PHASE	LATE PHASE	UNSTRATIFIED
	980-1150	1150-1300	1300-1450	?
Polar Bear present	3	5	7	8
collections	8	13	11	27

As noted above, these bone elements are mostly from the feet (phalanges and metapodials) with at least two “point of the chin” mandibular fragments. These elements nearly all show slice marks and very probably represent pieces of the skeleton left with the hide after rough field skinning of the bear carcass.

5.2.2 Ancient DNA, Trace Element, and Stable Isotopic Evidence.

Collaborative work making use of lead isotopes and trace elements has recently allowed comparison of modern and archaeological walrus bone from arctic Canada, Greenland, Iceland, and the Barents Sea, opening an exciting new perspective on walrus exploitation by humans (Frei et al. 2015). This research has allowed a more systematic comparison of walrus finds in Viking Age to medieval Iceland and Greenland that has raised the real possibility that both Iceland and

Greenland were initially settled by walrus hunters. This is in line with Madsen's settlement model of "probe- burst- trickle" in which initial hunting and exploration parties preceded the better documented chiefly *Landnám* farming settlements (Madsen 2014, 2019). While in Iceland walrus seem to have been largely depopulated by ca. 1000 -1050 CE, the Greenlandic hunt continued right down to the end of the settlement.

As Frei et al. conclude:

> *"…Despite the realities of geography, by the end of the Viking Age c. 1050 CE, Greenland may have been paradoxically more tied to distant markets than was Iceland. Continuation of the Viking Age market production strategy of low-bulk/high-value exports in the high Middle Ages is one major point of contrast between the Greenlanders and their Icelandic kin and may well represent a critical point of pathway divergence* "(Frei et al. 2015:112)

Walrus in both North Pacific and North Atlantic are now subject of multiple new research projects, and new results making use of ancient DNA work is now serving to underline the impact of Greenlandic walrus ivory in Europe (Star et al. 2018, 2019, Barrett 2020). Especially after the establishment of the Episcopal seat at Garðar in the 12th century Greenlandic walrus products seem to have increasingly dominated the market, only being replaced by Barents Sea ivory after ca 1450 and the end of Norse Greenland.

As Star et al. 2018 note:

> *"The search for walruses as a source of ivory –a popular material for making luxury art objects in medieval Europe– played a key role in the historic Scandinavian expansion throughout the Arctic region. Most notably, the colonization, peak and collapse of the medieval Norse colony of Greenland have all been attributed to the proto-globalization of ivory trade. Nevertheless, no studies have directly traced European ivory back to distinct populations of walrus in the Arctic. This limits our understanding of how ivory trade impacted the sustainability of northern societies and the ecology of the species they relied on. Here, we compare the mitogenomes of 27 archaeological walrus specimens from Europe and Greenland (most dated between 900 and 1400 CE) and 10 specimens from Svalbard (dated to the 18th and 19th centuries CE) to partial mitochondrial (MT) data of over 300 modern walruses. We discover two monophyletic mitochondrial clades, one of which is exclusively found in walrus populations of western*

Greenland and the Canadian Arctic. Investigating the chronology of these clades in our European archaeological remains, we identify a significant shift in resource use from predominantly eastern sources towards a near exclusive representation of walruses from western Greenland. These results provide empirical evidence for the economic importance of walrus for the Norse Greenland settlements and the integration of this remote, western Arctic resource into a medieval pan-European trade network." Star et al.2018).

Keighley et al. (2019) reported a large scale aDNA study that demonstrated that Icelandic walrus were genetically distinct from any living walrus population, and they muster C14 and documentary evidence for the extinction event taking place within a century of the Icelandic Landnám in the late 9th century:

"Our results support the existence of a unique genetic lineage of walruses in Iceland hunted by the Norse until its local extinction sometime during the 11–12th centuries. As such, it is one of the earliest examples of a population collapse following commercialized European hunting, occurring centuries before the majority of documented large-scale marine population collapses resulting from industrialized exploitation. Our results suggest that commercial hunting and economic incentives as early as the Viking Age were of sufficient scale and intensity to result in significant, irreversible ecological impacts on the marine environment." (Keighley *et al.* 2019:15*)*

These findings lend support to the hypothesis posed in Hartman et al. (2017) that depletion of Icelandic walrus populations by the end of the 10th century could have been a major incentive for the exploration and colonization of Greenland. The role of the church and higher-ranking lineages in Greenland in maintaining the hunt and the connection to Europe it fueled, has likewise been noted as a factor increasing pathway dependence and possible loss of resilience in the face of late medieval climate change and increasing contact with the Thule people (Jackson et al. 2018, 2022 in press).

In 2020 another large -scale study was published using walrus fragments from Europe and the North Atlantic as sources for aDNA analysis mapping on the archaeological and museum specimens to the increasingly well-defined sub-populations in Iceland and the eastern Arctic (Barrett et al. 2020). This study built on prior work by the same and collaborating teams to indicate what the authors term “serial depletion” of walrus populations by the Norse Greenlanders. While earlier Greenlandic walrus maxillary fragments could be tied to the modern and historic Baffin-Disko Bay walrus populations, later fragments derived from the separate walrus population around the North Water Polynya in the Thule district. Barrett et al. (2020) argue that Norse walrus hunters depleted the Disko walrus before moving further north and seem to have taken more females in the later period as well. This perspective places medieval Norse walrus hunting firmly in the wider story of global resource depletion by market driven economic forces acting over thousands of miles.

All these new studies shed considerable new light on the interaction of Norse hunters and walrus populations. All the studies will benefit from larger sample sizes and more extensive sampling of actual walrus ivory artifacts from museum collections as well as archaeological sites, but the collective results seem to both confirm and expand the evidence of the osteological portion of the zooarchaeological record. Recent field survey and archival review by Madsen (2019) provides a comprehensive summary of the current archaeological site data for Norse marine shielings and provides a model for waystations and different kinds of structures in the Norðursetur and outer coast.

Walrus hunting seems to have been a core activity of the Norse Greenlanders, a major reason for the settlements’ establishment, and a central economic and social activity for multiple generations of Norse Greenlanders. The "white gold" of Greenland seems to have shaped Greenlandic society from its foundation down to the final days, and the interaction of humans, walrus, and distant markets must be seen as a key to the pathway divergence between Greenland and Iceland after ca. 1250.

5.3 Seal Hunting in Norse Greenland

The Greenlandic settlers' encounter with the immense populations of migratory harp and hooded seals (rare or absent in Iceland and the eastern North Atlantic) had immediate and lasting impact on their subsistence economy. The abundance of ice-riding seals in Greenland was noted as one of the characteristics of the country by the mid-13th c. author of the Norwegian *King's Mirror* text:

> *In those waters there are also many of those species of whales which we have already described. It is claimed that there are all sorts of seals, too, in those seas, and that they have a habit of following the ice, as if abundant food would never be wanting there. These are the species of seals that are found there. Once is called the "corse" seal; its length is never more than four ells. There is another sort called the "erken" seal, which grows to a length of five ells or six at the very longest. Then there is a third kind which is called the "flett" seal, which grows to about the same length as those mentioned above. There is still a fourth kind, called the bearded seal, which occasionally grows to a length of six ells or even seven. In addition, there are various smaller species, one of which is called the saddleback; it has this name because it does not swim on the belly like other seals but on the back or side; its length is never more than four ells. There remains the smallest kind, which is called the "short seal" and is not more than two ells in length. It has a peculiar nature; for it is reported that these seals can pass under flat ice masses four or even five ells thick and can blow up through them; consequently, they can have large openings wherever they want them.*
>
> *(*Larsen 1917, *The King's Mirror-Speculum Regale-Konungs Skuggsjá:*139–140.*)*

The generally well-informed author shows an awareness of the full set of seals in Greenlandic waters, including the "short seal" which must be the ringed seal (*P. hispida*). Although the ringed seal bones are very rare in Norse archaeofauna, Nordic observers were aware of its ability to make breathing holes and survive under fast "flat" ice even if they could not regularly hunt them.

As noted above, current zooarchaeological evidence from both the Western Settlement (McGovern 1985) and the Eastern Settlement (Smiarowski et al. 2007, Smiarowski 2012, 2013a, 2013b, 2014) dating to the early settlement period, indicates a rapid and radical shift in use of wild species by the original colonists. Marine fishing and dried fish production seem to have been immediately supplanted by large scale (probably communal) hunting of the newly encountered migratory seals, supplemented by seabird and caribou hunting.

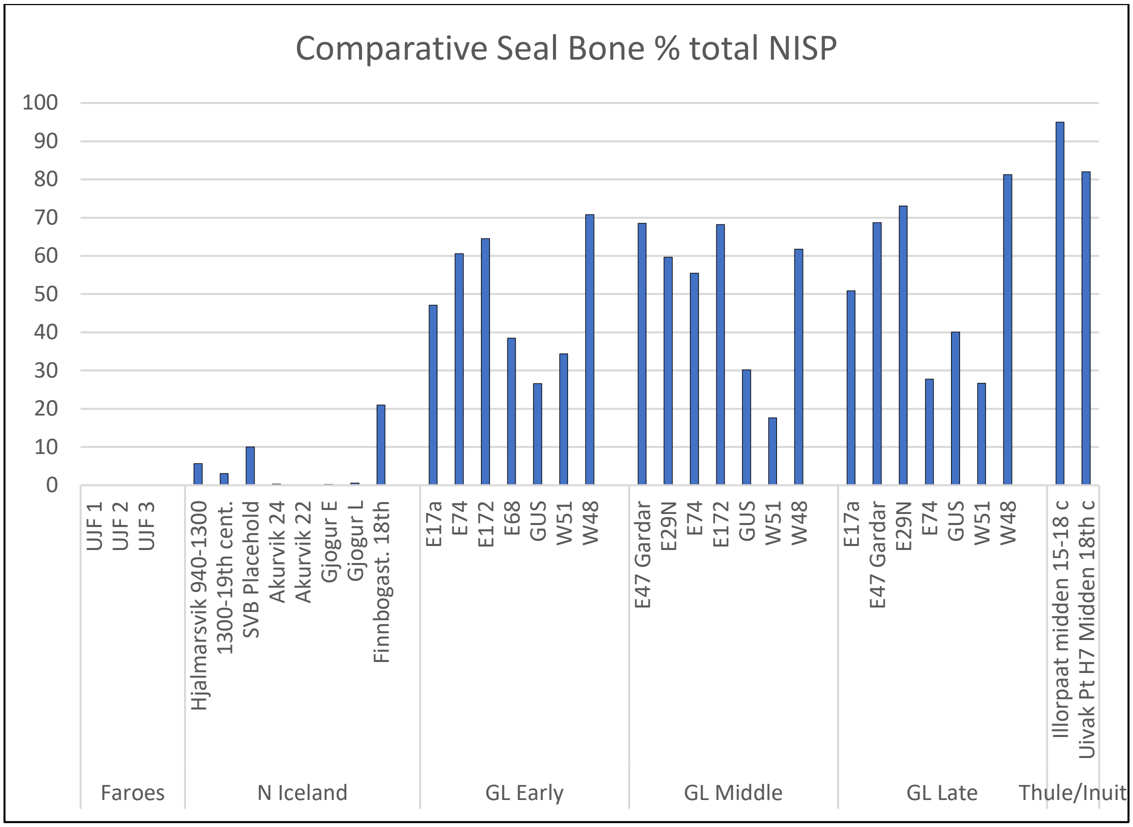
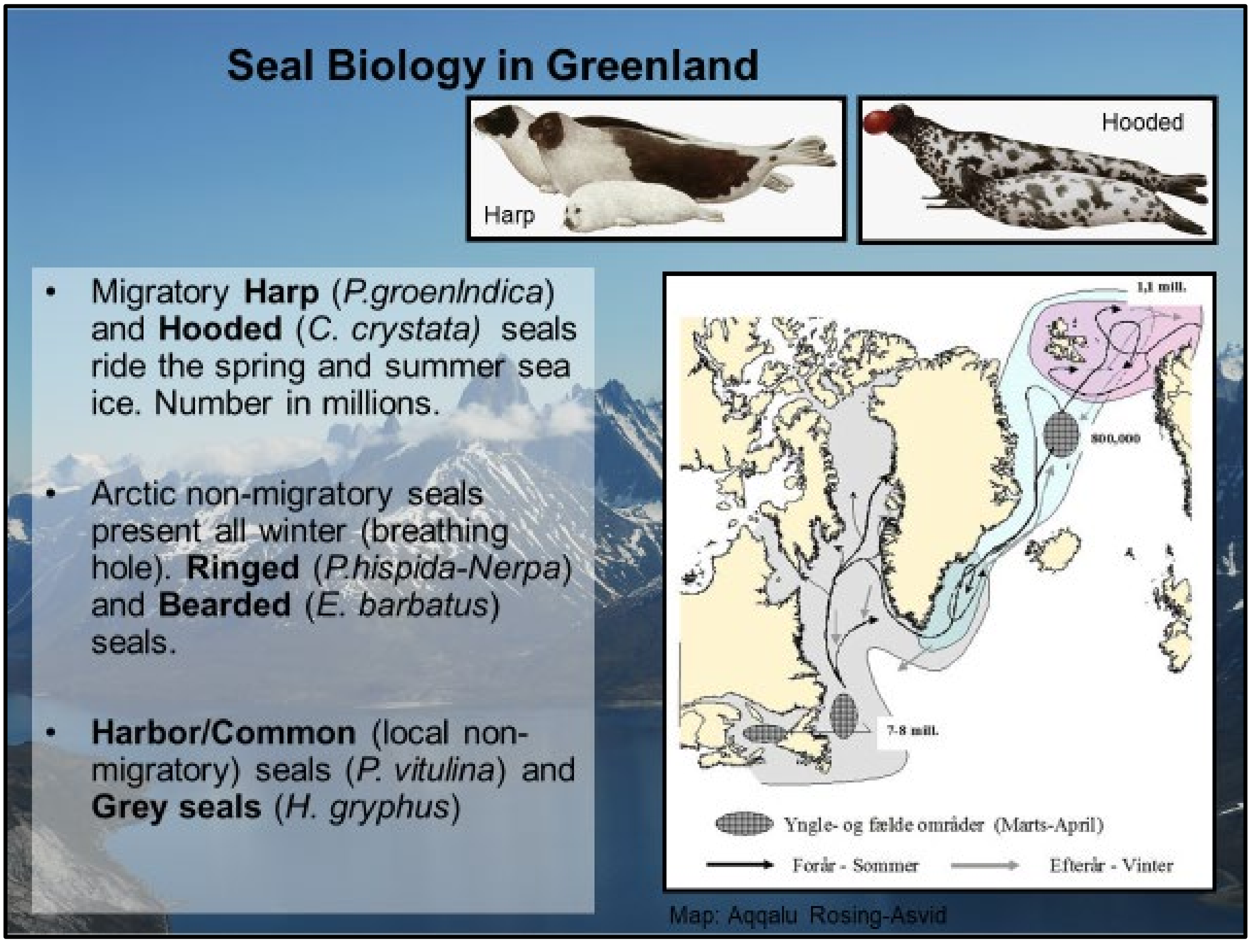


Figure 23 Comparison of seal bones as % of identified mammal in stratified sites in the N Atlantic.

Figure 23 above presents a comparative overview of seal bones in stratified North Atlantic and Eastern Arctic archaeofauna. Note that only the Thule/Historic Inuit sites generate a higher relative percentage of seal bones than the Norse Greenlandic archaeofauna.



Seal Biology in Greenland

- Migratory **Harp** (*P.groenlndica*) and **Hooded** (*C. crystata)* seals ride the spring and summer sea ice. Number in millions.
- Arctic non-migratory seals present all winter (breathing hole). **Ringed** (*P.hispida-Nerpa*) and **Bearded** (*E. barbatus*) seals.
- **Harbor/Common** (local non-migratory) seals (*P. vitulina*) and **Grey seals** (*H. gryphus*)

Map: Aqqalu Rosing-Asvid

Figure 24 Summary of seal biology in Greenland. Harp and Hooded seals migrate with the sea ice and Harp seals number in the millions. Arctic non-migratory Ringed and Bearded seals appear throughout Greenland, but Ringed seal bones are rare in Norse archaeofauna. North Atlantic temperate zone seals (Harbor seals and a few grey seals) also appear on the West coast but avoid areas with heavy summer drift ice. Hooded seals were seldom taken in the Western Settlement and are today rare in this part of West Greenland.

Tables 45, 46, and 47 below summarize the ratios of seal bone to domestic mammal bone and the seal % NISP for the major taxa for each major phase. Note that the similarity in overall mean seal % NISP in the three phases (early phase mean = 48.95, middle phase mean = 47.82, late phase mean = 48.85) masks a great deal of inter-site variability and some diverging patterns of seal consumption on sites of different size and status.

Table 45 Ratio of seal bones to domestic mammal bones and seal NISP% of major taxa from early phase archaeofauna.

EARLY PHASE	n= 7	E17a	E74	E172	E68	GUS	W51-1	W48
c 980-1160 CE	date	1976, 1983	2006	2017	2007	2002	1984	1979
	Phase	lower	Phase 1 A	Phase 1	Phase 1	1	F I Midden	AU I
	est.time range	10-11th c	1040-1150	100-1100	985-1050	1000-1200	1025-1150	980-1160
	Seals/Domestic	1.32	2.38	2.06	0.66	0.67	1.92	5.58
	Seal % of Major Taxa	47.15	60.61	64.56	38.52	26.63	34.39	70.83

Table 46 Ratio of seal bones to domestic mammal bones and seal % NISP of major taxa from middle phase archaeofauna.

MIDDLE PHASE	n= 13	E47 Gardar	E172	E64	E29N	E29N	E29N	E64	E74	GUS	W48	W51	W51
c 1160-1300 CE	date	2017	2017	2017	2006	2006	2006	2007	2007	2002	1979	1984	1984
	Phase	Phase 1	Phase 2 & 3		VI-VIII	V	IV		Phase 2 A	2	AU II	F I Midden	F I Midden
	est.time range	1150-1250	1100-1300	1150-1265	l 11th-12th	1200-1250	1250-1300	1150-1265	1150-1300	1200-1300	1160-1300	1150-1200	1200-1250
	Seal/Domestic	3.23	2.85	0.58	1.28	2.44	2.90	0.58	1.60	0.79	6.20	1.20	1.37
	Seal % Major Taxa	68.51	68.18	34.50	50.00	62.12	66.80	34.50	55.45	30.23	61.77	17.60	24.23

Table 47 Ratio of seal bones to domestic mammal bones and seal % NISP of major taxa from late phase archaeofauna.

LATE PHASE	N= 11	E47 Gardar	E29N	E74	E17a	W48	W51	W51	W51	W54	GUS
c 1300-1450 CE	date	2017	2006	2007	1976, 1983	1979	1984	1984	1935/81	1979	2002
	Phase	Phase 2	III	Phase 3 B	upper	AU III	F I Midden	Stable Midden	House & Midden	house int.	3
	est.time range	1270-1320	1300-1450	1300-1400	13-15th c	1300-1400	1250-1325	1200-1325	1300-1400?	1300-1400	1300-1400
	Domestic/Seal	2.92	4.07	0.39	1.33	8.26	1.85	2.53	1.19	1.04	1.04
	Seal % of Major Taxa	68.70	73.05	27.73	50.91	81.31	26.69	54.13	33.89	32.01	40.09

Table 48 Presence/absence (ubiquity) of seal taxa in the current archaeofauna.

UBIQUITY MEASURES	Sites in sample	59	8	13	11	27
Seals	Phase	All Collections	EARLY PHASE	MIDDLE PHASE	LATE PHASE	UNSTRATIFIED
Pagoph. groenlandica	Harp seal	53	6	13	10	24
Phoca vitulina	Common/ Harbo	42	5	10	9	18
Cystophora cristata	Hooded seal	31	3	9	5	14
Phoca hispida	Ringed seal	14	2	0	1	11
Erignathus barbatus	Bearded seal	28	5	6	6	11
Phocidae sp.	Seal sp. Indet.	54	7	13	11	23

In table 48 above, note that harp seals are the most widely represented and ringed seals are the least frequently represented in the 59 current archaeofauna. Hooded seals are not normally present in the Western Settlement area, so this ubiquity measure understates their actual high frequency in

Eastern Settlement collections.

Tables 49, 50, and 51 present the % of identified seal taxa for the phased collections.

Table 49 Presents the % of identified seal taxa for the phased collections.

EARLY PHASE						
c 980-1160 CE						
Identified Seal NISP %						
n= 6	E17a	E172	E68	GUS	W51-1	W48
date	1976, 1983	2017	2007	2002	1984	1979
Phase	lower	Phase 1	Phase 1	1	F I Midden	AU I
est.time range	10-11th c	100-1100	985-1050	1000-1200	1025-1150	980-1160
notes			small			
Harp seal	29.69	23.57		37.50	47.37	58.01
Common/ Harbor seal	57.81	5.73		37.50	47.37	40.88
Hooded seal	6.25	10.83	66.67			
Ringed seal	1.56					0.55
Bearded seal	4.69	1.27			5.26	0.55
Large seal sp. Indet.		58.60	33.33			

Table 50 Presents the % of identified seal taxa for the phased collections.

MIDDLE PHASE												
c 1160-1300 CE												
Identified Seal NISP %												
n= 13	E47 Gardar	E172	E64	E29N	E29N	E29N	E68	E74	GUS	W48	W51	W51
date	2017	2017	2017	2006	2006	2006	2007	2007	2002	1979	1984	1984
Phase	Phase 1	Phase 2 & 3		VI-VIII	V	IV	Phase 2	Phase 2 A	2	AU II	F I Midden	F I Midden
est.time range	1150-1250	1100-1300	1150-1265	l 11th-12th	1200-1250	1250-1300	1050-1350	1150-1300	1200-1300	1160-1300	1150-1200	1200-1250
Harp seal	80.95	19.05	38.89	69.23	30.00	65.38	69.23	54.55	36.36	58.29	33.33	51.61
Common/ Har	1.59	11.90	27.78		34.00	5.77			50.00	39.20	59.26	38.71
Hooded seal	4.76	11.90	11.11	7.69	18.00	13.46	15.38	45.45				
Ringed seal												
Bearded seal	3.17	2.38							13.64	2.51	7.41	9.68
Large seal sp.	9.52	54.76	22.22	23.08	18.00	15.38	15.38					

Table 51 Presents the % of identified seal taxa for the phased collections.

LATE PHASE										
c 1300-1450 CE										
N= 11	E47 Gardar	E29N	E74	E17a	W48	W51	W51	W51	W54	GUS
date	2017	2006	2007	1976, 1983	1979	1984	1984	1935/81	1979	2002
Phase	Phase 2	III	Phase 3 B	upper	AU III	F I Midden	Stable Midde	House & N	house int.	3
est.time range	1270-1320	1300-1450	1300-1400	13-15th c	1300-1400	1250-1325	1200-1325	1300-1400	1300-1400	1300-1400
Harp seal	40.00	78.57	51.85	72.22	55.33	33.33	60.00	68.73	64.29	59.65
Common/ Harbor seal		14.29	11.11	9.26	38.67	61.67	40.00	25.06	26.19	28.07
Hooded seal		7.14	37.04	16.67						1.75
Ringed seal								1.99		
Bearded seal				1.85	6.00	5.00		4.22	9.52	10.53
Large seal sp. Indet.	60.00									

The patterning of seal bones in Norse sites in Greenland underlines the unique importance of these marine mammals to the subsistence of the communities in both settlement areas, and substantial amounts of seal bone is found on inland farms several hours walk from the nearest landing point. Seal carcasses seem to have been transported nearly whole into these distant farms, as nearly all body parts are recorded in inland collections. The major exception is the male seal penis bone or baculum. These elements are common in Inuit archaeofauna but virtually absent in the Greenlandic Norse collections (McGovern 1985, Enghoff 2003). Inuit hunters regularly killed seals from kayaks or at ice edges and tended to bring the whole carcass home (sometimes inflated or frozen in the winter) for immediate butchery near the point of consumption and discard. If the Norse practiced mass kills in drives (perhaps based on outer fjord hunting farms and maritime shieling sites as suggested by Madsen 2019) they may have gutted the seal carcasses to slow decomposition during a longer period between kill and on-site consumption and discard. This pattern would regularly leave the bacula at the kill site. As will be discussed in more detail below, Norse seal hunting in Greenland was very different from most other circumpolar societies and seems to have emphasized community collaboration, collective drive hunting, and widespread dispersal (perhaps through a share system) throughout the community.

Figure 25 Simplified access to different seal species in the areas occupied by Viking Age and Medieval Scandinavians. Note that Harp and Hooded seals are exclusively hunted in large numbers in Greenland.

5.3.1. Reconstructing Norse Sealing Practice

Seals were regularly taken throughout the North Atlantic from prehistoric times, but the harbor (*P. vitulina)* and grey seals (*H. gryphus*) found in most of the Eastern North Atlantic form comparatively small non-migratory pods and are very vulnerable to over-hunting. In Iceland, law codes regulated sealing beaches and harbor and grey seal populations seem to have generally been harvested sustainably at a low level, with these non-migratory seal bones appearing as trace species in most archaeofauna from settlement onwards. In Greenland, harbor seal colonies were present, and the bones of this species appear regularly in Greenlandic archaeofauna as noted above (Ogilvie et al. 2009, McGovern 1985, Smiarowski 2013a). These non-migratory seals are greatly outnumbered by the bones of migratory harp seals (*P. groenlandicus,* both settlements) and hooded seal (*C. cristata*, Eastern Settlement only).

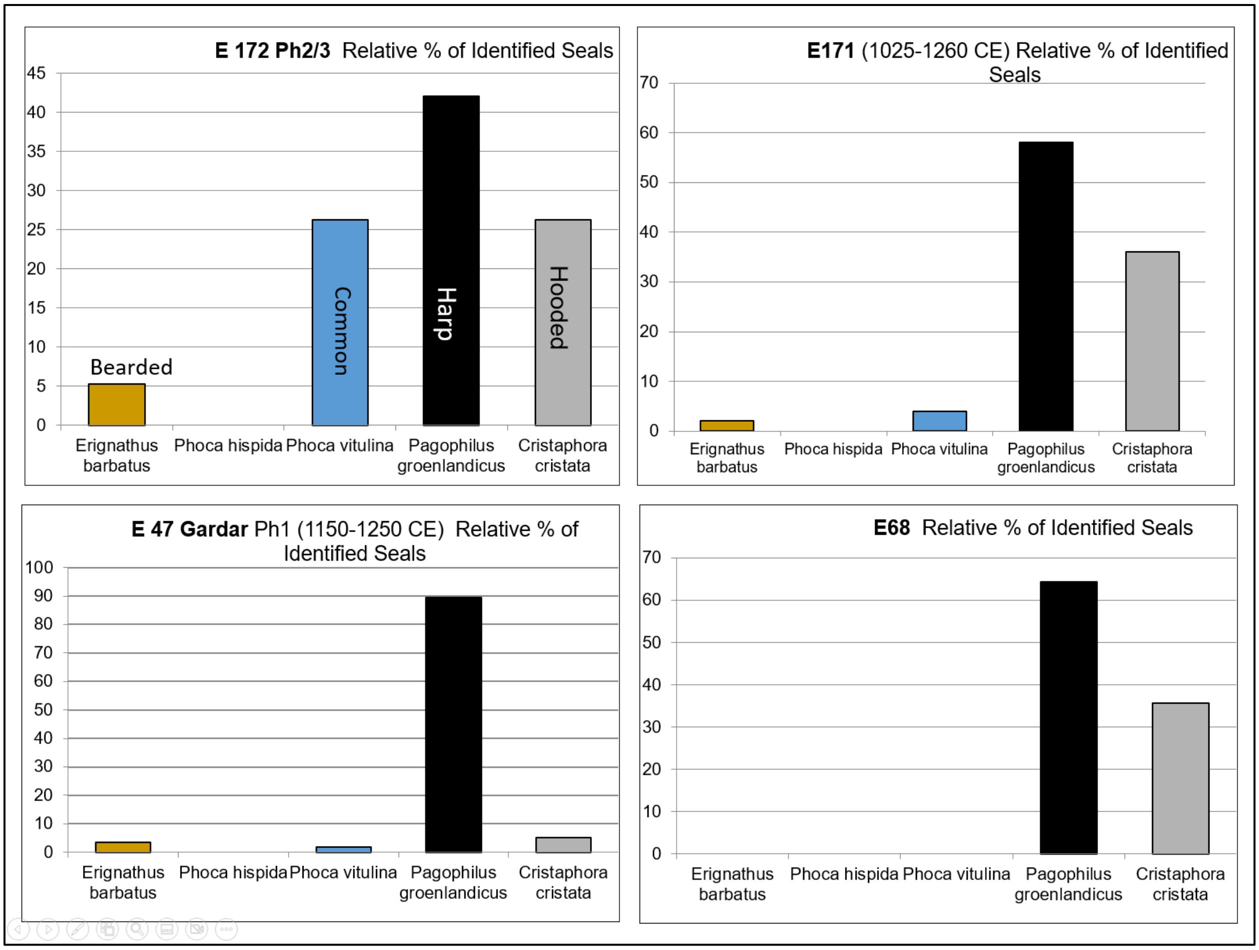


Figure 26 Relative percentage of identified seal bones at 4 sites in the Eastern Settlement. Note the uniform abundance of harp seals at all sites indicating communal hunt participation. Hooded seal relative absence at the high status E47 may indicate an additional side resource for the actual participants of the hunt (E171, E172, E68), rather than for the hunt organizers / managers who are getting the product as tribute (E47 Garðar).

Harbor seals seem to have become much rarer in the Eastern Settlement after ca. 1300 and the arrival of summer drift ice (Ogilvie et al. 2009, discussion below Chapter 6). Despite centuries of hunting, harp seals have made a total comeback, again number in the millions, and unlike the non-migratory harbor seals they could sustainably support a large-scale harvest. The bones of non-migratory arctic ringed (*P. hispida*) and bearded seals (*E. barbatus*), which make breathing holes in winter ice and have been staples for arctic adapted Inuit hunters down to the present are rare in

Norse collections from Greenland. These species are taken by Inuit hunters with specialized toggling harpoons and breathing hole and ice edge hunting in winter but are not so readily taken with boat drives and other communal hunting strategies apparently practiced by the Norse Greenlanders. Note that in tables 49-51 above Ringed seal bones never reach 2% of the identified seal bones though the *King's Mirror* account quoted above shows the Norse were aware of the presence and habits of this species.

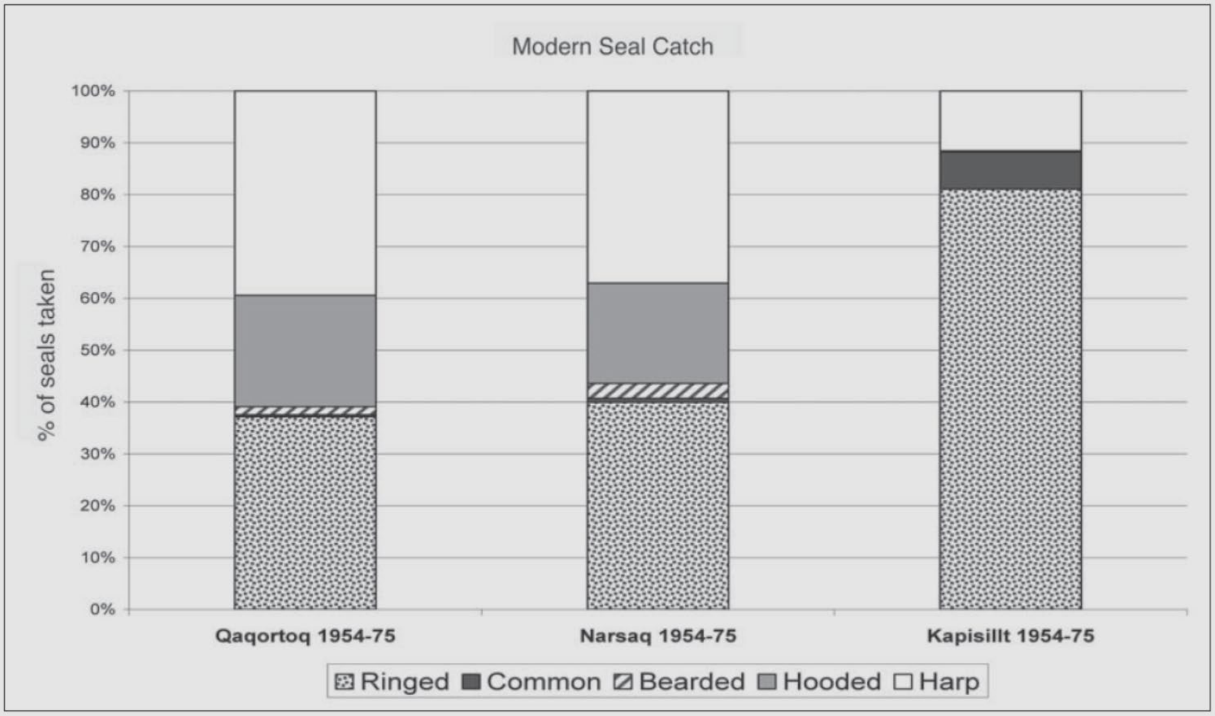


Figure 7. Modern catch records for Qaqortoq and Narsaq districts (covering the former Norse Eastern Settlement) and the village of Kapisillit (a small settlement in Nuuk Fjord) in the middle of the former Western Settlement.

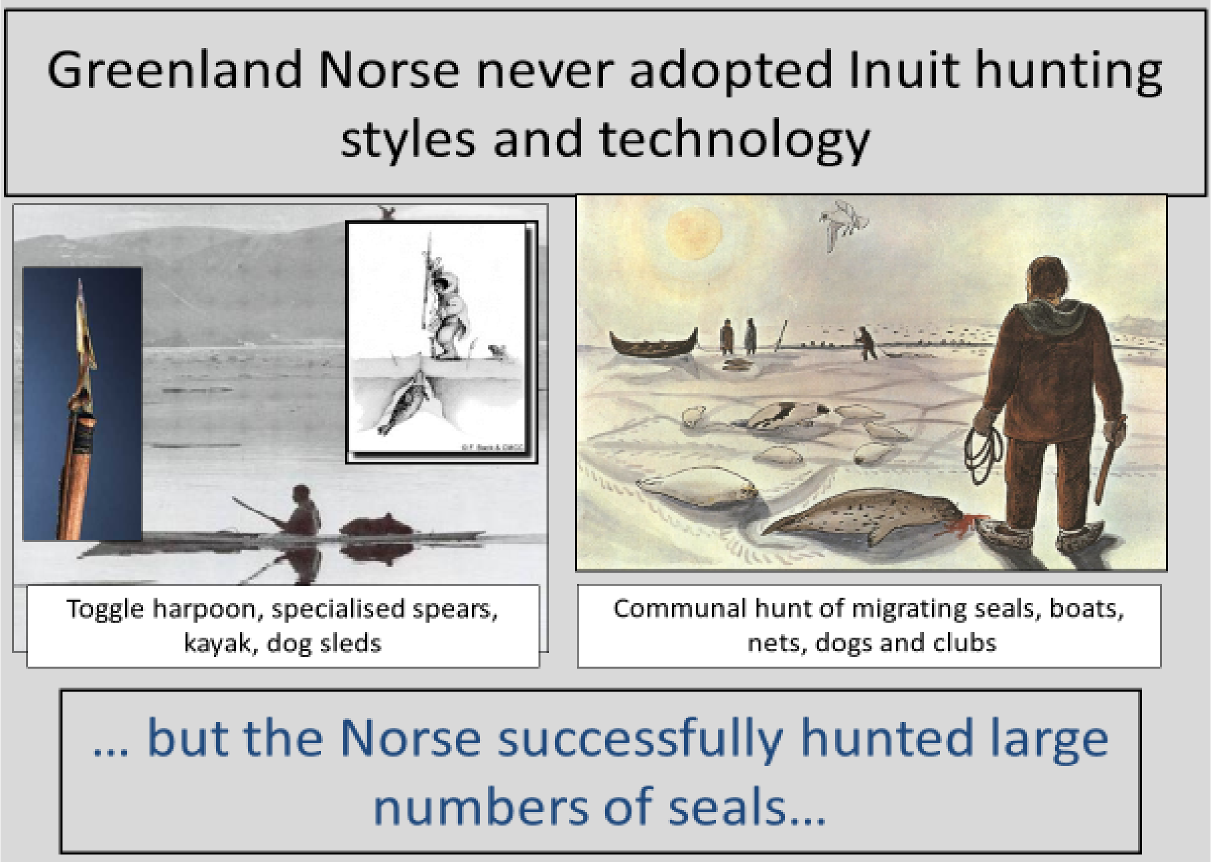
Figure 27 Illustrates 20th century seal catches as recorded in the Danish Fangslister statistics for two districts in the Eastern Settlement and one inner fjord community in the Western Settlement area. Figure from Ogilvie et al.2009.

Figure 27 above (from Ogilvie et al. 2009, fig 7) illustrates the pattern in seal catches from 20th century Kalaallit hunters in the two former Norse settlement areas based on the comprehensive (localized) catch statistics maintained by each community. The two-decade record during a period of sustained subsistence hunting spans a period of climate and catch instability in the 1960's but shows a consistent pattern of heavy reliance on Ringed seal (especially in the inner fjord community of Kapisillit in the former Western Settlement) mainly taken in winter. The near absence of Common seal in the former Eastern Settlement communities reflects its rarity under modern summer drift ice conditions and the presence of Common seal in the Western Settlement catch records indicate the continued survival of these seals beyond the reach of summer *stor-is* drift ice from East Greenland.

The Norse Greenlanders apparently adapted communal seal hunting techniques of the Eastern North Atlantic to the newly encountered migratory species and did not make extensive use of the sea ice sealing practices of either the Dorset or Thule peoples or of the Nordic ringed-seal hunters of the contemporary north Baltic (Storå, J. and Lõugas, L 2005). Communal hunting required close coordination of labor and scarce boats during the spring harp and hooded seal migration (probably like the traditional Faroese "*grind*" drives of pilot whales), and this probably both required and promoted community solidarity in both pooling labor and sharing meat (as in the modern Faroese community). Norse exploitation of resident harbor seal (*P. vitulina*) pods may well have been organized differently from the mass drives aimed at the migratory seals, and there are some indications in the archaeofauna that harbor seals may have been locally managed and distributed. The Ameralik sites W48, W59, GUS and W51 Sandnes are all near common/harbor seal pupping beaches mapped by Bruun (1917) and these sites show higher common/harbor seal bone % throughout their occupation (Tables 49-51 above), though some common seal bones also reach more inland farms and webs of social interaction and labor and resource exchange between farms were probably complex in all periods.

The account *Description of Greenland* (Halldórsson 1978, trans Mathers 2009) listing church properties by episcopal steward Ivar Bárðarson (probably present in Greenland c. 1341-50) notes that marine mammal hunters needed "the bishop's permission" for taking prey in the unsettled parts of East Greenland (trans Mathers 2009:71). As Madsen (2019) suggests this passage is unclear about details and degree of ownership and control, but it does suggest some attempt at top-down management. In Iceland, rights to productive sealing beaches by the 18th c were often owned by distant (often ecclesiastical) elites and local farmers doing the actual hunting had to reserve part of their catch as access payment (Pálsson 2019).

The seasonal spring mass hunt of harp and hooded seals was probably also an opportunity for interaction and collaboration among Norse households who might have been otherwise rather isolated during the rest of the seasonal round, and the pattern of harp seal carcasses appearing on far inland farms probably reflects the operation of a well-developed community-wide distribution network. Individualistic hunting using Thule- derived harpoons, sea ice hunting techniques, and one-person kayaks in a year- round hunt aimed at household (rather than community) provisioning thus would present major social as well as technological challenges to the Norse Greenlanders. After 1300, when cooling climate stressed Norse agriculture and Norse diets became increasingly marine, the mass seal hunt must have become even more important to both food security and social bonds. For better or worse, when under stress the Norse understandably chose to maintain their proven community-based hunting and distribution system of seal hunting.



Greenland Norse never adopted Inuit hunting styles and technology

Toggle harpoon, specialised spears, kayak, dog sleds

Communal hunt of migrating seals, boats, nets, dogs and clubs

… but the Norse successfully hunted large numbers of seals…

Figure 28 Norse and Inuit Sealing options and choices.

5.3.2. Seasonality of the Seal Hunt

The migratory seals would arrive in the outer fjords of the two Greenlandic settlements in late May and early June: before the probable start of the Norðursetur voyages and during the worst of and recurring late-winter household provisioning gap. Seasonality studies carried out in cooperation with Dr. James Woollett (U Laval) making use of cementum layers in seal teeth as part of this doctoral project all indicate a strong seasonal pattern suggesting a spring hunt. The seal teeth Sections were prepared at U. Laval IRIS microscopy laboratory (Figure 29) and followed these standardized procedures: teeth were decalcified in formic and nitric acids, and later diluted and buffered to produce a gentler effect. The teeth were decalcified thin sections about 15 microns thick. The teeth were placed in paraffin blocks and cut with a microtome. They were stained with toluidine blue, a standard microscopy stain and imbedded on slides. Photos taken at 40x and 100x magnification with transmitted light on an Olympus petrographic microscope. Readings of cementum primarily and dentine secondarily, then checked against each other, some readings of dentine were aided with a polarizing filter useful to emphasize the optical differentiation of translucent and opaque GLs.

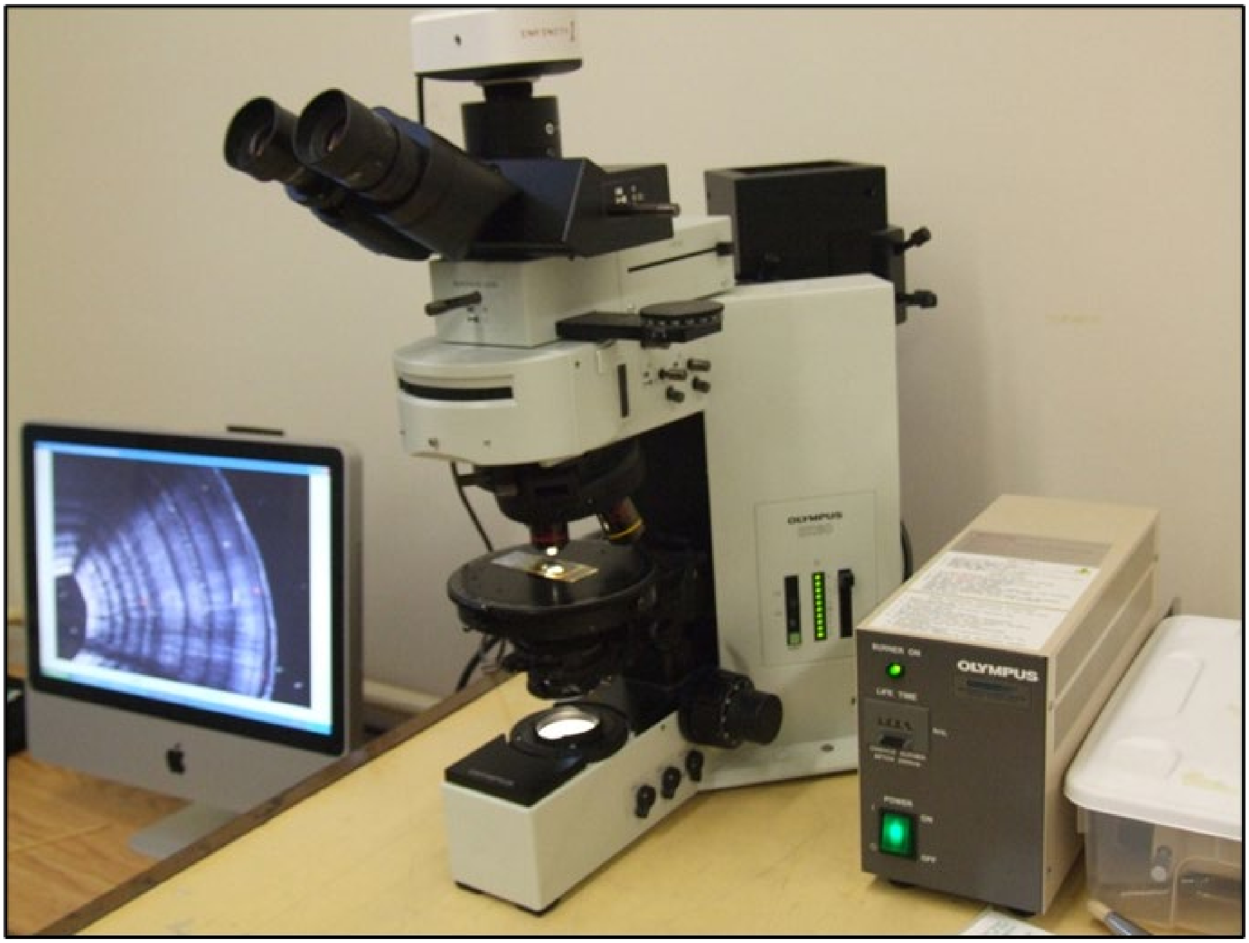
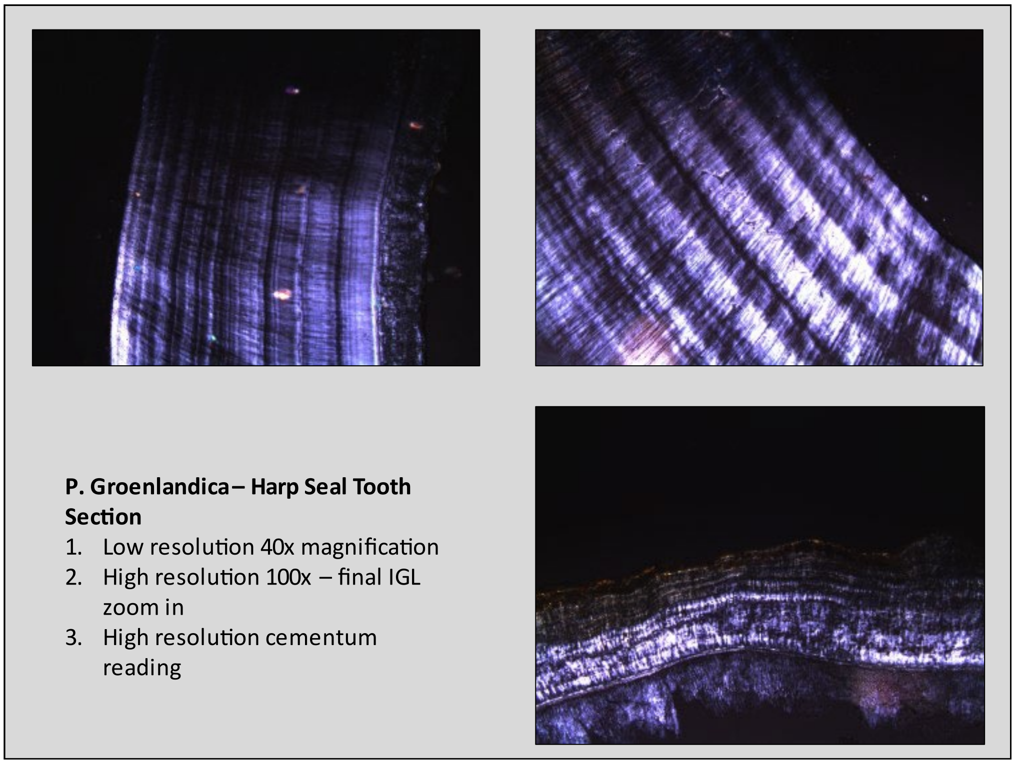


Figure 29 Laval University Zooarchaeology Laboratory Micro-analysis set up used by the author.



P. Groenlandica – Harp Seal Tooth Section

1. Low resolution 40x magnification
2. High resolution 100x – final IGL zoom in
3. High resolution cementum reading

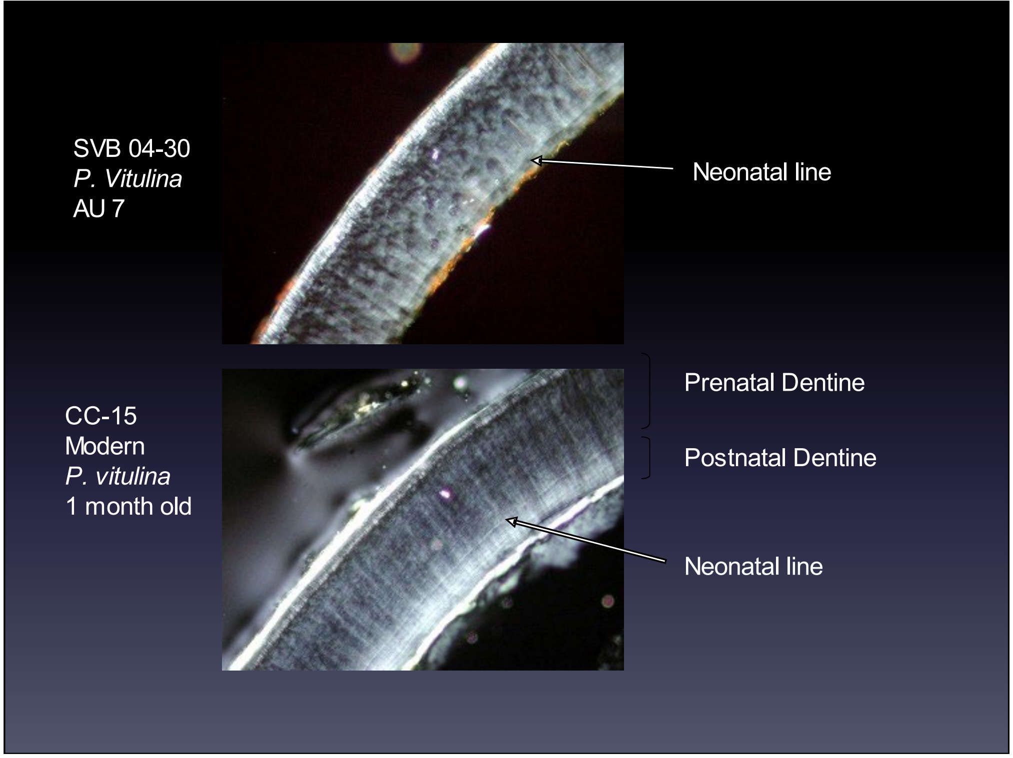
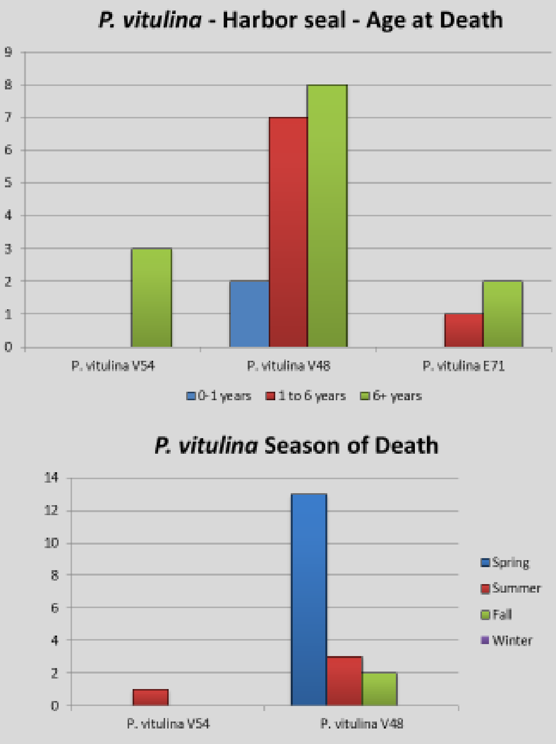


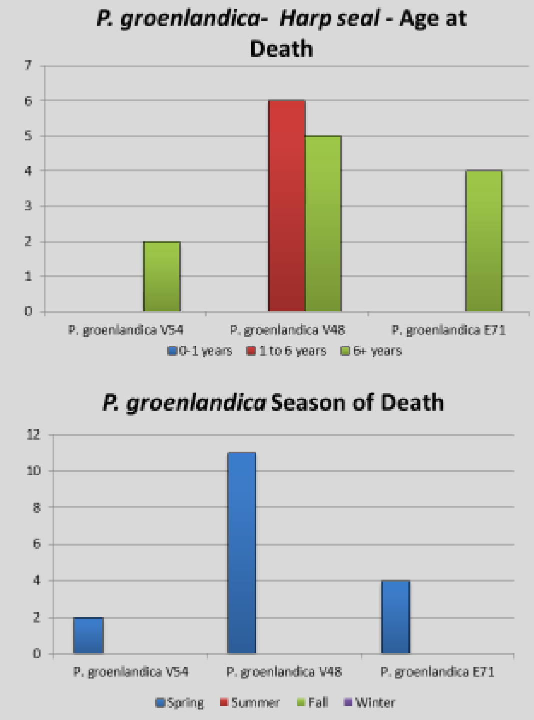
Figure 30 Thin sectioning and microscopy identify annual dental rings allowing reconstruction of age and season of death matched against known age modern specimens.



Local non-migratory Seals

- Adult seal consumption and small number of Harbor/Common seal pups indicates a seal management strategy aimed at preserving valued pupping beaches?
- Harbor seal colonies are land based, and land ownership was at the center of Norse hierarchy – who owns the pupping beaches and who has rights to harvest harbor seals? Only one harbor seal colony is left after firearms were introduced in GL in 18th -19th century.
- Most kills occur during spring, at the time the colonies come together on land, for breeding, molting and mating.

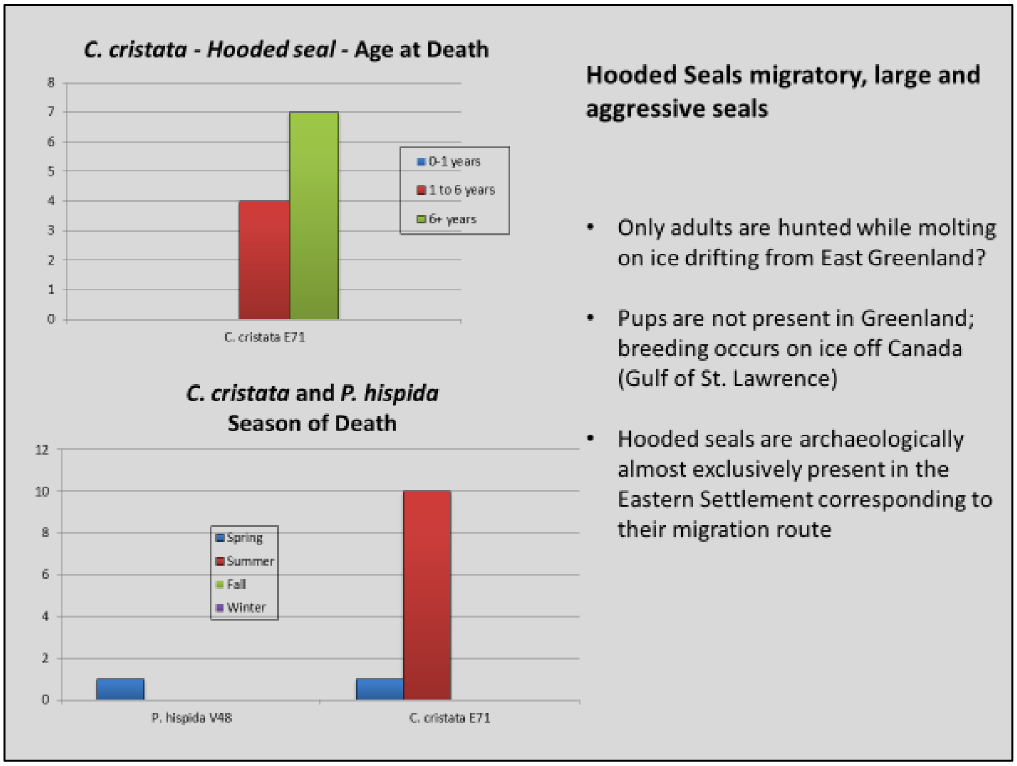
Figure 31 Phoca vitulina Harbor/Common Seal Age and Season of Death Assessment.



Harp Seal breeds on ice, migrates in packs, millions of animals annually.

- Mostly adults are hunted on the way north from the breeding colonies off Canada – early migrating young males? Post winter food source?
- These seals are present in GL waters most of the year, but only hunted in the spring, indicating communal effort to harvest this seasonally abundant resource, on a large scale, possibly involving labor and boats from ALL farms
- The same seasonality & age signatures for consumers on coastal and inland sites? How was labor recruited? How is the catch divided?

Figure 32 Pagophilus groenlandicus Harp seal Age at Death and Seasonality Assessment.



Hooded Seals migratory, large and aggressive seals

- Only adults are hunted while molting on ice drifting from East Greenland?
- Pups are not present in Greenland; breeding occurs on ice off Canada (Gulf of St. Lawrence)
- Hooded seals are archaeologically almost exclusively present in the Eastern Settlement corresponding to their migration route

Figure 33 Hooded seal Cystophora cristata Age and Season of Death, Ringed seal P. hispida from W 48 is a spring kill.

As figures 31, 32, and 33 indicate Norse seal hunting was highly seasonal, taking place in spring and summer. Thus far no winter kills have been identified, and the single Ringed seal tooth available for sectioning indicates a spring kill, potentially as by-catch during a communal hunt focused on Harp seals. The seasonality evidence thus far supports the model of Norse sealing targeting non-migratory and migratory seals in spring and summer and further supports evidence for deliberate sustainable management of Harbor/Common seal pupping beaches.

5. 4 Cetacea

Bones and baleen from large whales and teeth and bones from small (porpoise/beluga sized) cetacea are present in many Greenlandic Norse archaeofauna. Table 52 below summarizes the presence of different cetacean species bones in the current collections. As is usual with these species, most bones are not easily identifiable to species by osteological means (despite the excellent comparative collections housed at the University Zoological Museum in Copenhagen) and many fragments are identifiable only to broad categories like “large or small cetacean”, and many more fragments are identifiable only as whale bone. Note that the single identification of a Southern Right Whale (which would be far out of its modern range) was by Dr. Degerbøl who asserted a positive identification based on osteology.

Table 52 Ubiquity (presence/absence) of cetacean bone in Norse archaeofauna.

Cetacean Ubiquity from Osteology Identifications						
	Phase	All Collections	EARLY PHASE	MIDDLE PHASE	LATE PHASE	UNSTRATIFIED
	Est.time range (CE)	980-1450	980-1160	1160-1300	1300-1450	?
	Sites in sample	59	8	13	11	27
Delphinapterus leucas	Beluga whale	6	1		3	2
D.leucas/Monodon m.	Beluga or Narwhal	1				1
Lagenorhynchus albirostris	White sided porpoise	2			1	1
Phocoena phocoena	Common porpoise	2	1		1	
Globicephalus melas	Pilot whale	1			1	
Globicephalus melas/ Orcinus o.	Pilot/ Orca whale	1			1	
Small cetacean sp.	Small whale/ porpoise	15	1	6	5	3
Balaena australis/ Eubalaena australis	Southern Right Whale	1				1
Balaena mysticetus	Bowhead Whale	1		1		
Large Cetacea sp	Large whale sp. Indet.	21	2	5	5	9
Cetacea sp. Indet.	Whale sp. Indet	33	6	8	11	8

Fortunately, new potentials for species level identification are rapidly opening through ancient DNA and ZooMS analysis. An interdisciplinary NSF project led by Dr. Vicki Szabo with participation by the author is raising new possibilities about medieval Norse active hunting of great whales as well as providing identifications based on ZooMS Collagen and aDNA of Sperm, Fin, Gray, Humpback, Bowhead, and Blue Whale from Norse Greenland sites. Table 53 below presents the successful Greenlandic cetacean identifications available at present (data kindly supplied by Dr. Szabo). These identifications expand the list of cetacean species known from Norse archaeofauna in Greenland, adding Fin, Blue, Humpback, now-extinct Atlantic Gray, and Sperm whales to the species list. These analyses were all carried out on bone, as the baleen samples submitted did not retain enough aDNA for analysis. Seal bone analysis was generally not successful in separating common/harp/ringed seal species, except on the auditory bulla (which can be securely identified to species level on osteology), so no changes have been made in the seal NISP discussed in this chapter above.

Table 53 The aDNA and Collagen Cetacean identifications. data courtesy of Dr. Vicki Szabo.

Cetacea Identifications by aDNA and Collagen				
data courtesy of Szabo and McCloud 2021				
Site	aDNA	Collagen	Species	NISP
E172	x	*Balaenidae*	Baleen whale sp.	2
E74	x	*Balaenidae*	Baleen whale sp.	1
W48	x	*Balaenidae*	Baleen whale sp.	1
W48	*B mysticetus*	*B mysticetus*	Bowhead whale	2
E171	*B mysticetus*	*B mysticetus*	Bowhead whale	1
E74	*B. musculus*	*B. musculus*	Blue whale	1
GUS	*B. physalis*	*B. physalis*	Fin whale	2
GUS	*E. robustus*	*E. robustus*	Atlantic Gray whale	1
E171	x	*M.novaeangliae*	Humpback whale	1
E172	x	*M.novaeangliae*	Humpback whale	1
GUS	*M.novaeangliae*	*M.novaeangliae*	Humpback whale	1
E172	*x*	*P. macrocephalus*	Sperm whale	1

It is difficult to interpret the contribution that cetacea made to Norse diet in Greenland, as it is of course possible to bring back hundreds of kilos of boneless flesh and blubber without any bone, and likewise possible to scavenge bone from long dead beached skeletons without gaining any meat. It seems likely that the smaller toothed porpoise-sized cetacea might have been regularly taken during boat drives (as in the modern Faroese *grind* hunt for pilot whales), possibly as by-catch during the communal seal hunts.

While it is unclear how often larger whales were actively hunted prior to the Basque expansion in the later Middle Ages, the famous account of the North Norwegian chieftain Ottar in King Alfred's court implies active hunting of very large whales in the Viking Age (Whittaker 1981; Orosius

1984). Discussions with Icelandic scholars Vidar Hreinsson and Árni Daniel Juliusson during the collaborative sea mammal project provided strong medieval and early modern documentary evidence for active pursuit of the great whales in Iceland (probably including Blue Whale and other rorquals) and it is possible that Norse Greenlanders also hunted great whales at sea as well as making use of stranded carcasses. Prior to the "great whale massacre" of the 17th-19th centuries in the North Atlantic and the Arctic, whales were not uncommon and must have interacted with humans in many ways, with whale stranding certainly far more frequent and widespread than in recent centuries.

Whale bone and baleen were used for many purposes with vertebrae often serving as chopping blocks or occasionally as vessels as in Figure 34 below.

Figure 34 Site W 54 interior, large whale vertebra used as vessel. Photo Aaron Kendall.

Figure 35 Whale bone spade from W 51 Sandnes. Photo Aaron Kendall.

A common use for whalebone seems to be as a spade or shovel blade, and these seem to have often been used to clean byres and are often found inside these rooms (Figure 35).

5.5 Caribou Hunting

While reindeer hunting has been practiced since early prehistory in Norway and Red deer were hunted in Scotland since the Mesolithic, deer were not present in Iceland and the Greenlandic caribou (*Rangifer tarandus*) must have been a positive attraction for the first settlers. Survey work in the highlands of both Western and Eastern Settlement areas continues (Madsen personal communication August 15, 2021) but from existing data it appears that drive systems and probable meat caches plausibly connected to the Norse settlers were present in several parts of both Settlement areas. Caribou seasonal movement routes tend to be channeled by topography, and it appears that cairn and cache systems may have been re-used by successive hunting cultures from Saqqaq through Norse to Thule and modern hunters. The highland farm W35 just uphill from the chieftain’s manor at W51 Sandnes appears associated with a well-established caribou movement route and a multi-culture drive system with multiple cache and hunter’s shelter features illustrated in Figures 36 and 37 (McGovern and Jordan 1982). Caches and hunting shelters have also been reported in the highlands near the inland W54 site, again probably reflecting re-use over long periods (McGovern and Jordan 1982). Caribou drive systems are also now being documented in the Eastern Settlement highlands as in Figure 38 (Madsen 2019).

Figure 36 Photo of linear stone alignment near W35, looking NW. Probable caribou drive system potentially used by several cultures. Photo T.H. McGovern 1981.

Figure 37 2Cache and hunter's shelter features on ridgeline above W35, looking SE. Photo T.H. McGovern 1981.

Figure 38 Caribou drive system from Eastern Settlement. Photo Madsen 2019.

Caribou have been present in Greenland since early Holocene but have been subject to local extinction events and population crashes. Morten Melgaard's large-scale overview study divided Greenlandic caribou populations into 20 groups clustered in 5 larger regional groupings and discusses the long- term population dynamics of each group as impacted by climate and predation (Meldgaard 1985). Caribou remain common in the former Western Settlement area down to the present, but a combination of climate fluctuation (especially range icing events) and over hunting following the widespread introduction of firearms caused the extinction of the caribou in the Eastern Settlement area in the 19th century.

While extreme fragmentation limits metric reconstruction of body size, it is clear from the bone material overall that the Greenlandic caribou taken by Norse hunters were large robust animals like the present caribou herds in modern Nuuk district. They do not show the dwarfing "*kummerform*" characteristics of the prehistoric Saqqaq period caribou taken by hunters at the Itivnera site in the Western Settlement area (Møhl 1972). The antler fragments also suggest substantial racks rather than the reduced antlers of the NE Greenland populations. Enghoff (2003) makes similar observations concerning the GUS caribou.

Caribou antler was extensively used by the Norse Greenlanders for artifacts and craft work, including the characteristically Greenlandic forms of the double -sided composite combs fashionable after ca 1200 CE (Figure 39). Antler arrow heads and other tools were regularly produced and seem to have often substituted for metal. Caribou antler was worked using the "groove and splinter" technique for extracting the hard, outer surface from the cancellous antler core by burnination as well as the use of backed saw blades.

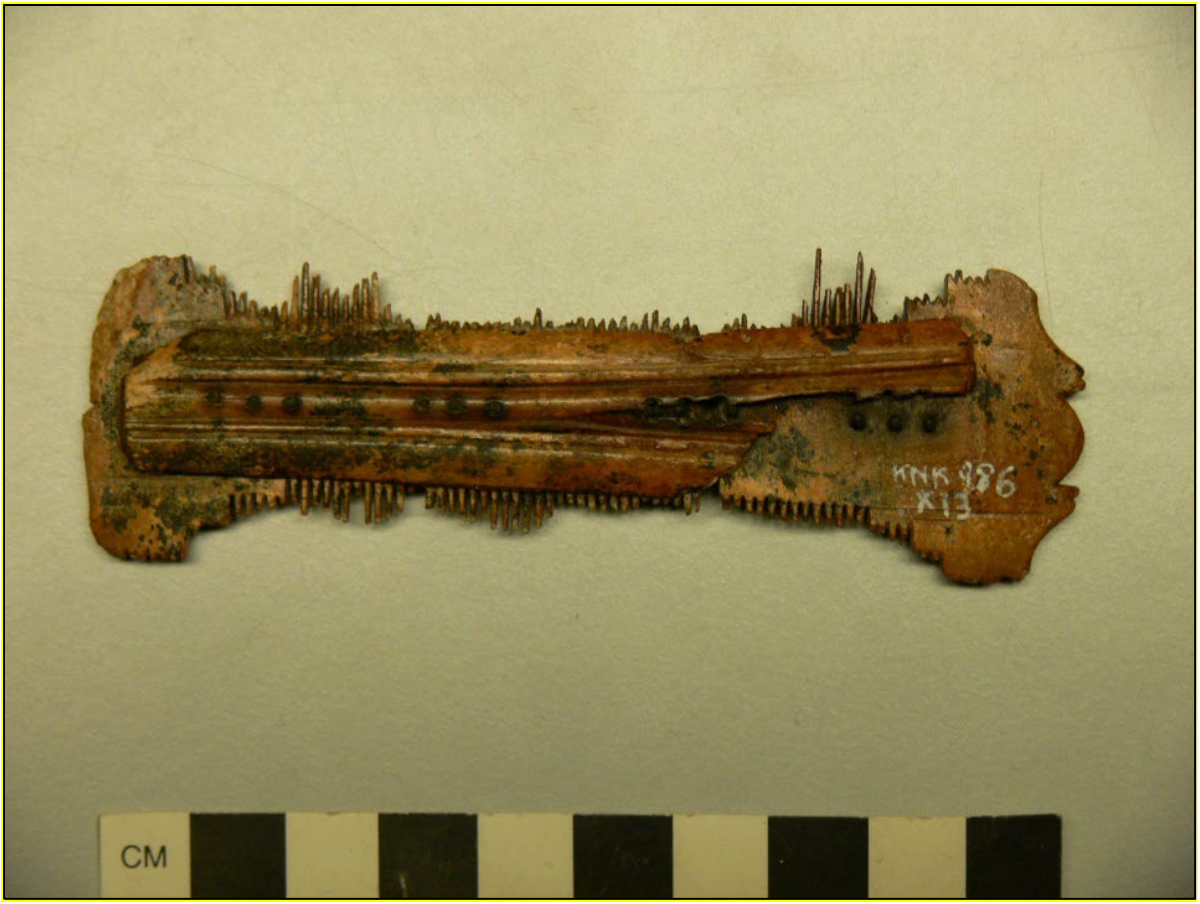


Figure 39 Composite antler comb from W 54. Photo Aaron Kendall.

Zooarchaeological evidence for Norse caribou hunting suggests that the communities in both settlement areas managed to take caribou throughout the period of settlement, apparently without causing localized extinctions. As table 54 below showing ubiquity of caribou bone by period indicates, some caribou bone is present in 53 of the 59 available Norse archaeofauna.

Table 54 Ubiquity of caribou bones in Norse Greenland sites.

Sites in sample	59	8	13	11	27
Phase	All Collections	EARLY PHASE	MIDDLE PHASE	LATE PHASE	UNSTRATIFIED
Est.time range (CE)	980-1450	980-1160	1160-1300	1300-1450	?
Caribou	53	8	13	10	22

Figure 40 below presents the NISP % of total collection for caribou in the quantifiable unphased collections from both settlement areas. The Western Settlement archaeofauna clearly have more caribou bones (ca. 10-25% of collection) but caribou do appear in smaller numbers in all the Eastern Settlement collections (ca. 1-4%). Note that W52a was probably a middle-high ranking farm near caribou migration routes while W35 is situated next to drive and cache ruins.

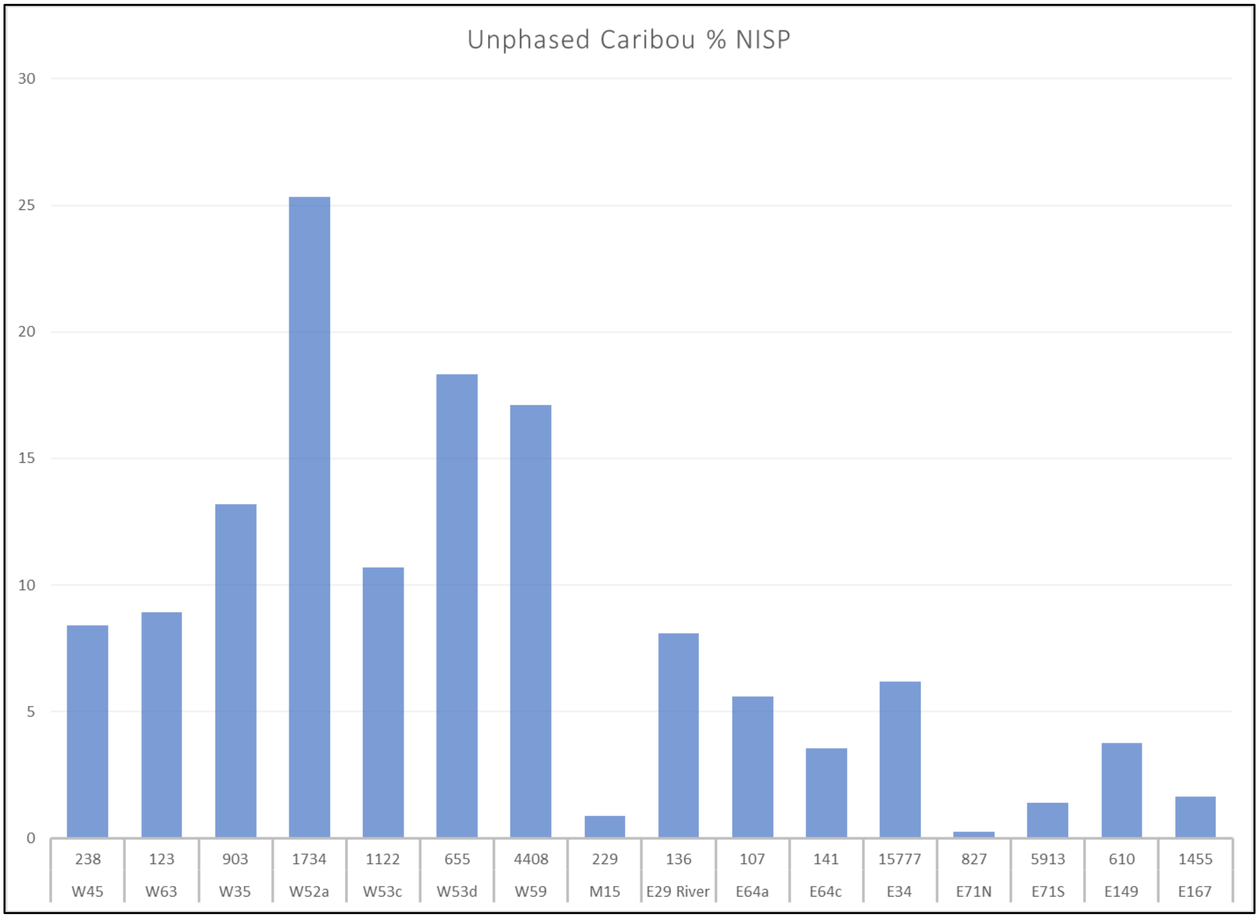


Figure 40 Caribou bone % of total NISP for quantifiable un-phased collections in Eastern and Western Settlements. NISP count is provided for reference.

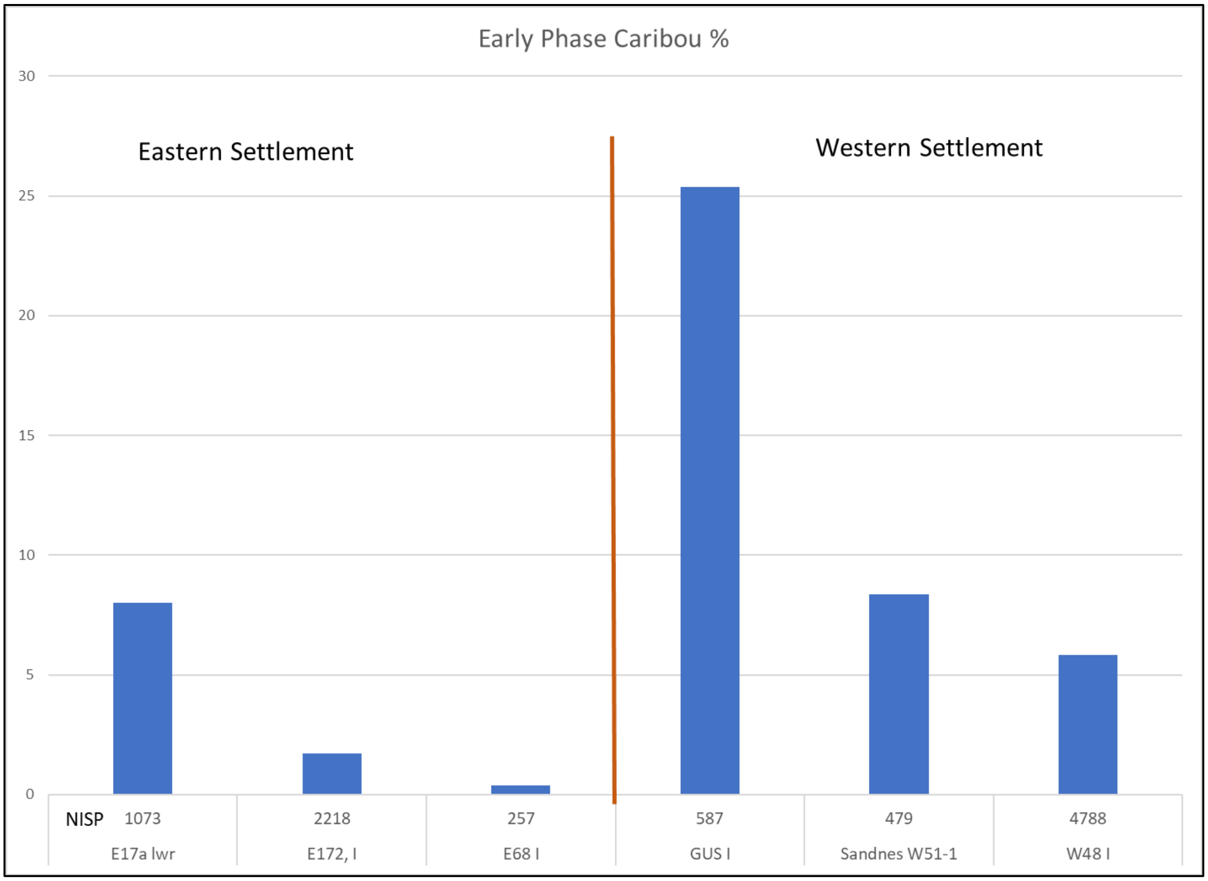


Figure 41 Caribou NISP % from phased archaeofauna dating to the Early Period. NISP count for each archaeofauna is provided.

Figure 41 presents the caribou % of total NISP (provided for reference) on the larger early phase collections. The high concentration of caribou at the inland GUS I site is notable. This is a location with excellent access to highlands to the south and west, with modern caribou movement pathways present in several parts of the inland valley system. The valley area around GUS is a major modern caribou hunting area for Greenlanders, and in fact the eroding site was first reported by a Greenlandic hunting party. Both W51 Sandnes (chieftains farm) and the small and probably always dependent W48 farm are coastal, with less direct access to the best highland hunting grounds.

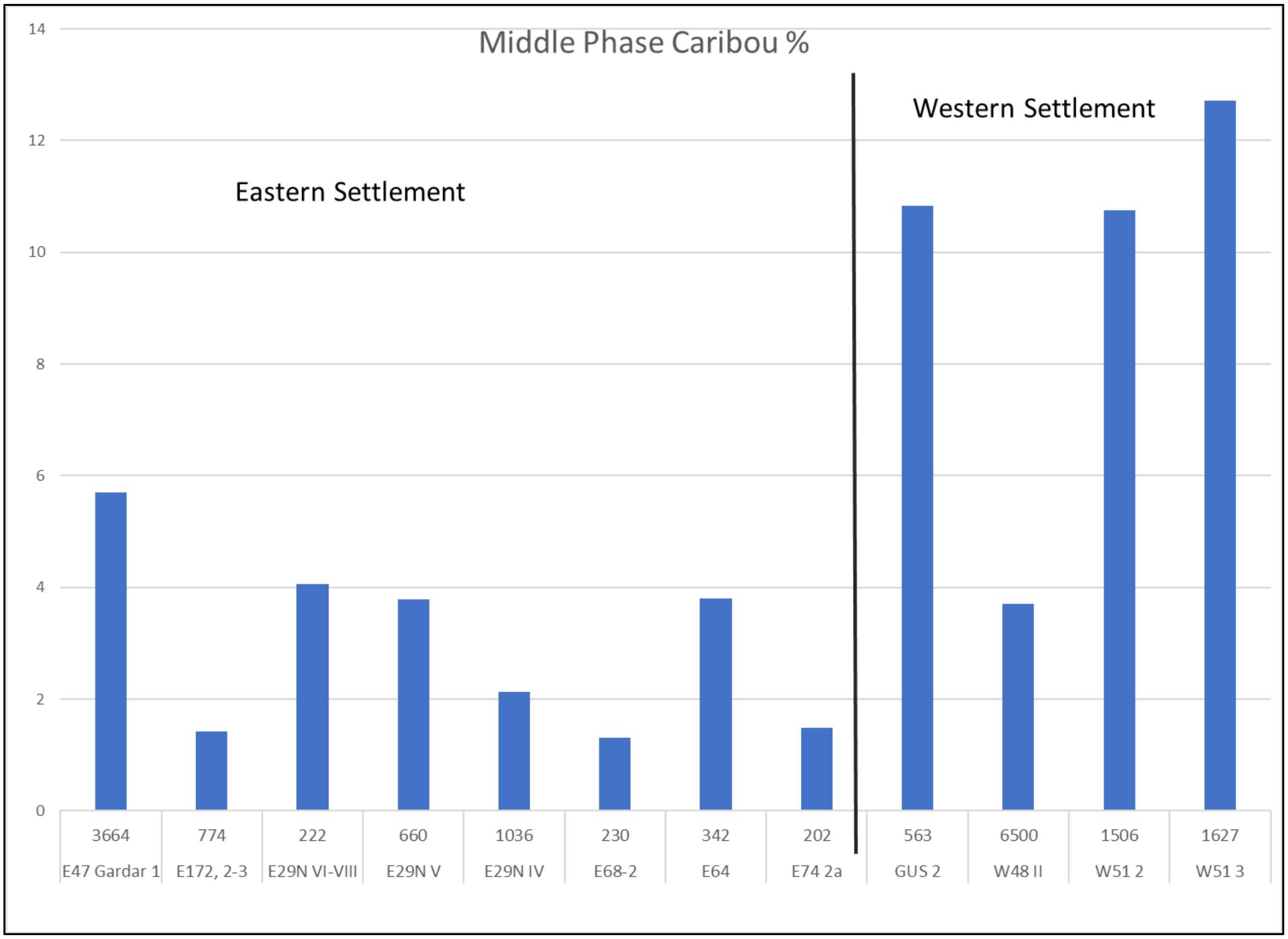


Figure 42 Caribou bone % of total NISP for Middle Phase collections. Western Settlement archaeofauna again show the most caribou, but the collection from the Bishop's manor at Gardar leads the Eastern Settlement collections.

Figure 42 presents the caribou NISP % of archaeofauna for the middle phase collections. In this phase the episcopal manor midden deposits sampled in 2012 enter the Eastern Settlement data set. While Garðar has some of the best pasture in Greenland that was heavily amended and equipped with an irrigation system (Adderley and Simpson 2006), it is not particularly well- sited for caribou hunting. However, the single surviving account of church properties by episcopal steward Ívar Bárðarson (probably present in Greenland c. 1341-50) describes the Garðar manor as owning the hunting on Renøe (Reindeer Island) which has been identified as modern Akia Island. As in the

Early Phase, Western Settlement farms at GUS and W 51 Sandnes show the greatest relative % of caribou bones, while the small coastal farm W48 falls into the Eastern Settlement range.

Figure 43 presents the Late Phase caribou relative % of collection (NISP) for the two settlement areas. The peak in caribou bones in the house interior at W51 Sandnes may possibly reflect some "final days" winter hunting, as the same layers produced the multiple semi-articulated dog skeletons noted by Degerbøl (1935), but in any case, the manor farm at Sandnes was drawing substantially on caribou hunting up to the end of the settlement in the last half of the 14th century.

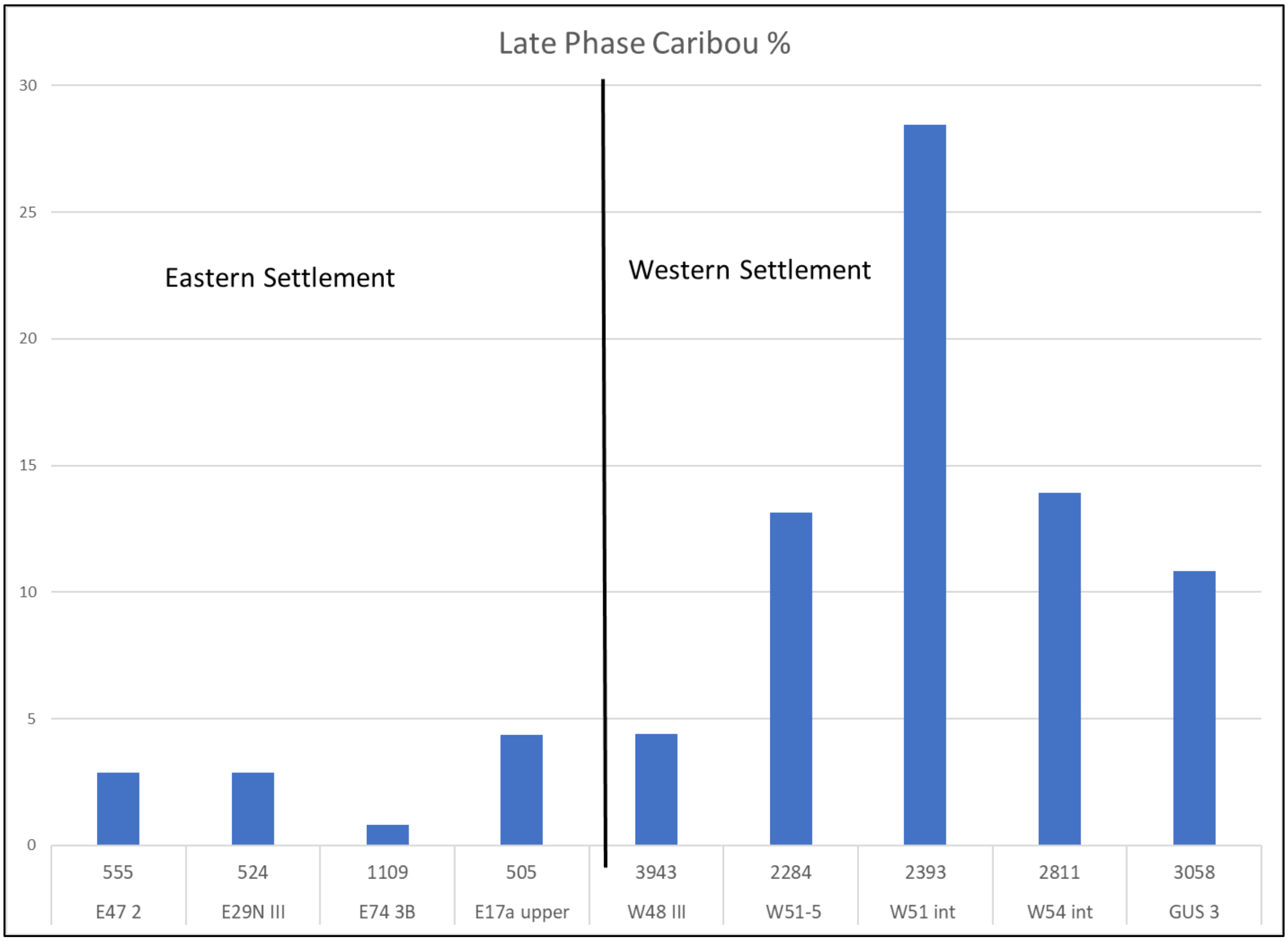


Figure 43 Late phase caribou NISP %, with Western Settlement collections again showing the greatest number of caribou bones. Interior collections at both W51 Sandnes and W54 may reflect "final days" scenarios.

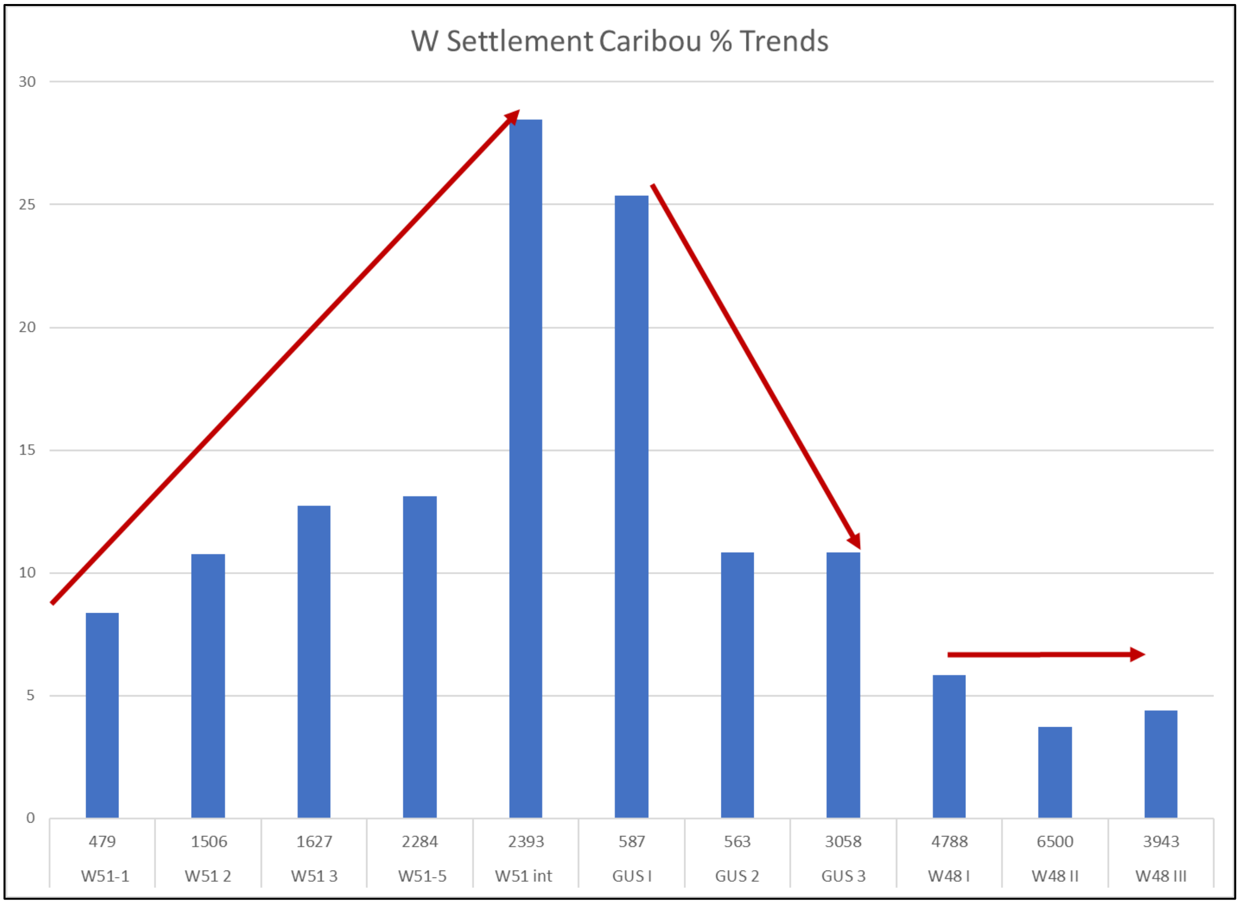


Figure 44 Trends in Western Settlement Caribou bone % over time in the stratified phased collections (W 51 Sandnes, GUS, and W48).

Figure 44 brings together the caribou % for the stratified sites to present trends in the abundance of caribou bone through time. Even if we somewhat discount the high % of the W51 interiors, the Sandnes manor seems to have been steadily increasing its consumption of caribou throughout the occupation. The pattern at GUS is apparently the reverse, with heavy caribou consumption in the first phase followed by a subsequent drop and stabilization. Enghoff (2003) notes this trend and provides a useful discussion of the possible factors (intense early hunting pressures, natural caribou population dynamics, climate change) responsible for the decline. The small W48 coastal farm shows a stable pattern of low-level caribou consumption throughout the occupation. While additional stratified collections from the Western Settlement would be desirable, one speculation may be that while GUS hunters had to draw on a single hunting area the manor at Sandnes might be receiving rents and tribute paid in caribou products from multiple catchments. If caribou meat consumption was associated with status (as was deer and hunted game in medieval Europe) then the status differential between the Sandnes manor, middle ranking GUS, and low ranking W48 may be reflected in their access to caribou.

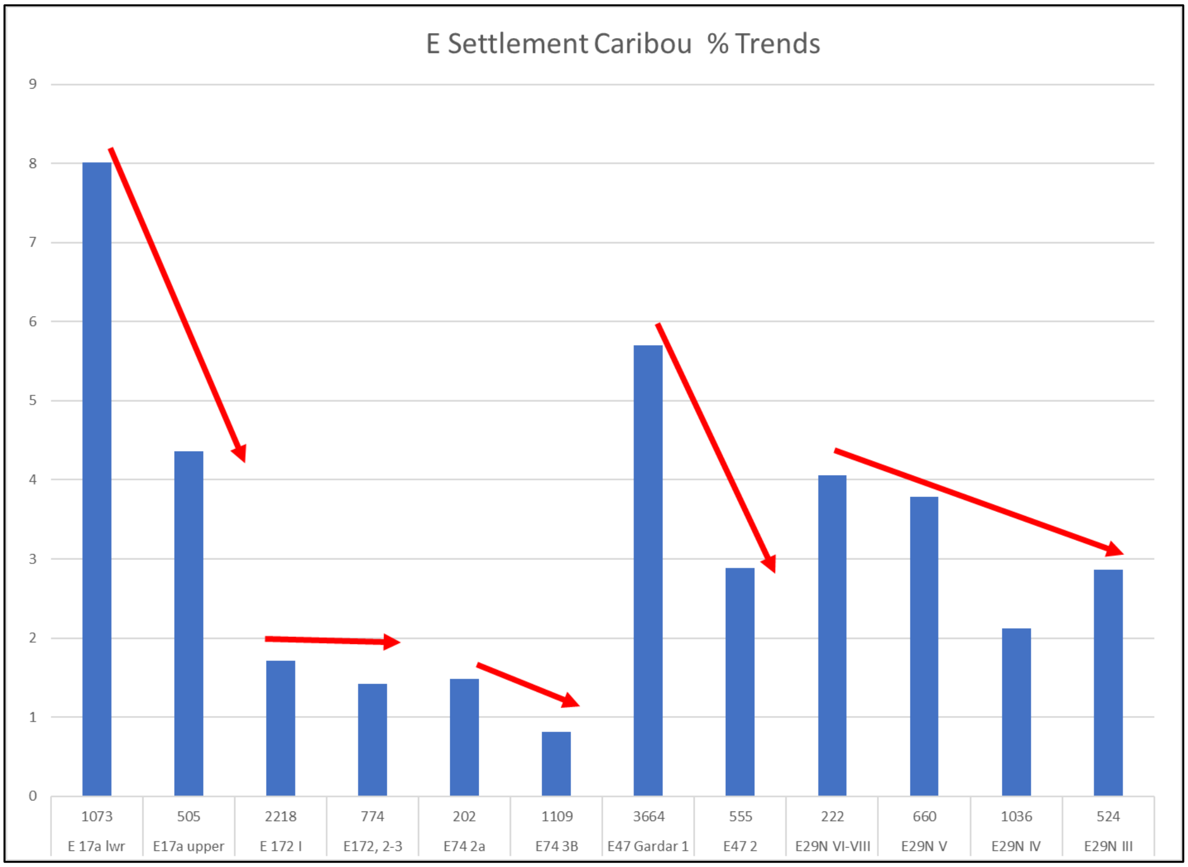


Figure 45 Eastern Settlement Caribou trends over time. Note that the "late phase" Eastern Settlement archaeofauna seem to show stability (at low frequency) or decline in caribou deposition.

Figure 45 presents the trends in caribou bone in the phased Eastern Settlement collections. In this case the pattern of decline (at E17a Narsaq, at Garðar E47 and Brattahlið N farm E29N) and stability or decline at the smaller farms E172 and E 74 may suggest something widespread happening in the region that impacted caribou access across social classes.

Element representation has been used by many authors documenting patterns of historic and prehistoric caribou/reindeer hunting, many following the Binford et al. (1975) classic Nunamiut study of caribou element transport decision making. While the Norse Greenland caribou bone collections are often too small to support a full body part analysis, the larger W 51 Sandnes caribou collection allowed some body part distribution analysis (McGovern et al. 1996). Figure 46 below presents a ratio (NISP) of upper limb bones (humerus, radius/ulna, femora, tibia) to lower limb bones (distal metapodials, phalanges). The upper limb bones are associated with high meat value in all scoring systems while foot bones are often discarded at the kill site. The chart indicates that the household at W51 Sandnes was regularly consuming high meat value caribou portions, and that this pattern of consumption was distinct from the pattern shown by the domestic stock. This suggests that Sandnes was being provisioned with high quality cuts of meat rather than whole carcasses, and that distant kill sites (perhaps associated with the drive systems just uphill at W35, which may well have been a client farm on a larger estate) were servicing the chieftains' farm.

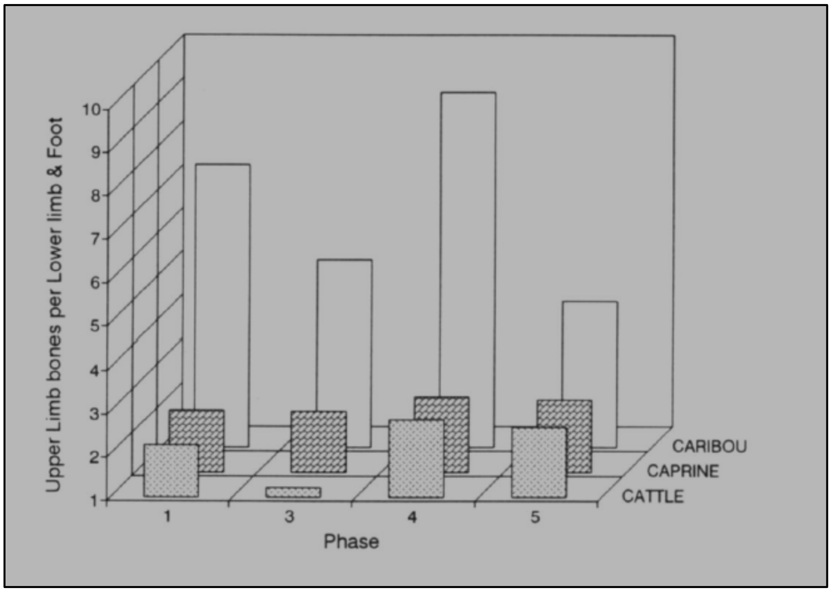


Figure 46 Distribution of upper (high meat value) and lower (low meat value) elements at W 51 Sandnes using the original 5 phase dating framework. Figure from McGovern et al. 1996.

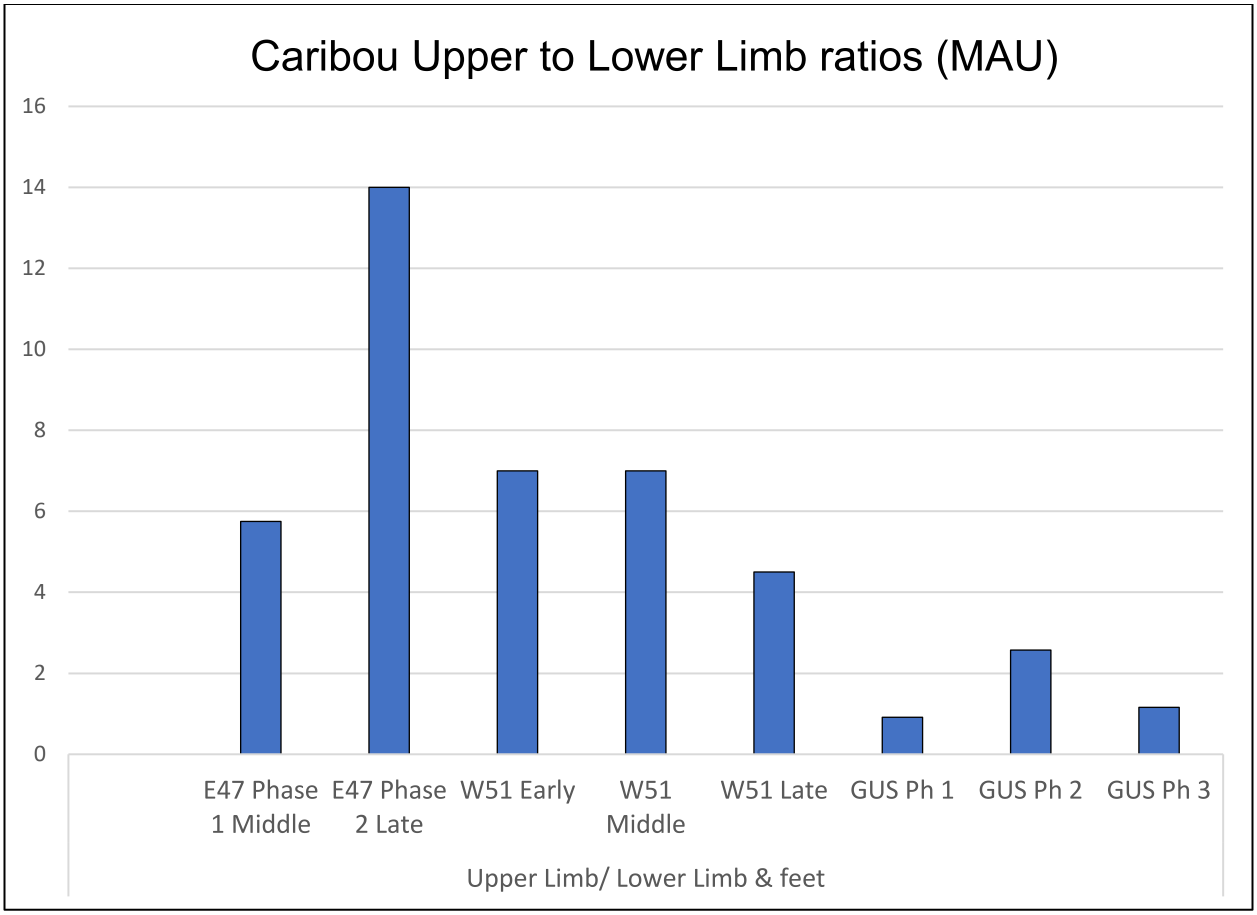


Figure 47 Comparison of E47 Garðar, W 51 Sandnes, and GUS Caribou element distribution over time.

Figure 47 above compares the E47 Garðar caribou upper limb to lower limb and feet ratio in the same format, and the figure compares these new data to the W51 Sandnes ratios, now placed in the three-phase analytic framework. The remarkably high ratio (14:1) of E 47 Phase 2 Late is an artifact of small caribou bone sample size, but the pattern of over-representation of meat rich upper limb bones seems clear at Garðar as well as at Sandnes. Both high-status sites seem to have been provisioned with high-meat-value cuts of meat as well as some occasional whole carcasses. Using similar metrics, Enghoff (2003) produced a lower ratio of upper to lower caribou limb bones from the well -preserved deposits at GUS in the Western Settlement. While some differential transport of meat rich elements from kill sites is indicated for this probably middle-ranking farm, the ratios suggest something else was happening in the provisioning of the elite households at Garðar and Sandnes. The other new Eastern Settlement archaeofauna from middle to lower ranking sites currently have too few caribou bones to reasonably quantify in this way, but an inspection suggests less marked element frequency patterns more like the GUS archaeofauna.

Butchery patterns often reflect both prey biology and cultural preferences, and both are evident in the butchery patterns that can be identified from the usually highly fragmented Norse caribou remains. Ulrik Møhl (1972) in his study of the Saqqaq caribou hunters at Itivnera (in the Western Settlement) noted that the Saqqaq used a characteristic method of breaking off both proximal and distal ends of the caribou metapodials, creating a "bone tube" effect allowing easy extraction of the rich metapodial bone marrow. As caribou metapodials are comparatively thin-walled and tend to break into sharp splinters when split longitudinally this was an efficient means to extract marrow. By contrast, the Norse treated caribou metapodials in the same way they butchered the thicker walled cattle and caprine metapodials by longitudinal splitting and endured the subsequent splintering. In the Faroes, Shetlands, and Iceland the later Middle Ages (after ca 1200) a distinctive method of cleanly extracting metapodial caprine marrow by dual perforation of both ends avoided splintering and preserved a usefully shaped bone for craftwork (and children's toys). This bi-perforation method seems to have spread to Iceland ca.1200 -1250 but did not reach Greenland where the Viking age pattern of longitudinal splitting remained constant (Bigelow 1984; Arge and Brewington 2009). One butchery pattern dating to the Viking Age (and still practiced in Iceland and Norway) was the creation of the "*svið*" dish of a split caprine cranium singed in fire and then consumed as a delicacy. In Greenland, this split cranium preparation was applied to both caprines and caribou, and split caribou *svið* have been identified at W 51 Sandnes (McGovern et al. 1996).

As noted above the comparative study by Alan Outram (1999) indicates the Norse seem to have regularly and intensively processed bone to extract collagen "bone grease", while the Saqqaq hunters mostly did not bother with this intensive process, leading to quite different caribou fragmentation patterns overall. Comparative caribou butchery and meat transport patterns may be a productive area for further research as sample sizes increase.

Seasonality indicators for Norse caribou hunting include shed vs. "massacred" (still attached to cranium) antlers, frequency of young (neonatal) calves, fusion of long bones, tooth sectioning and eruption and wear of tooth rows. While the heavy fragmentation of caribou bones noted above (including the regular breaking open of the mandible to extract the small marrow cavity) severely limits what can be said from tooth rows and long bone fusion states, some observations can still be made on season of death based on other indicators.

Neonatal bones have a characteristically rough outer texture in most mammals, reflecting the incomplete calcification of these rapidly growing structures. This also renders these neonatal bones of all species much more vulnerable to attrition of all kinds, including dog chewing noted in chapter 4. That said, caribou neonatal bones are rare compared to cattle, caprine, or seal newborns with only W 48 and W 51 showing any at all, and these ranging from 0.41 to 1.45 % of taxon. Caribou antler pedicles (attachment to the skull) are also only sporadically preserved, but McGovern et al. (1996) reported only two shed pedicles from W51 Sandnes vs. 15 massacred (attached) pedicles. Antler was extensively used for craft work, and shed antler was certainly collected so this ratio need not reflect much about seasonality of hunting, but it suggests that a substantial number of caribou were killed with mature antlers still attached. Since caribou shed antlers in late winter this would suggest autumn/ early winter hunting. Thanks to the kind collaboration of scholars at U Laval and the Zoological Museum of U Copenhagen the author was able to section some caribou teeth and perform an estimate of season of death based on annular dentine and enamel structure

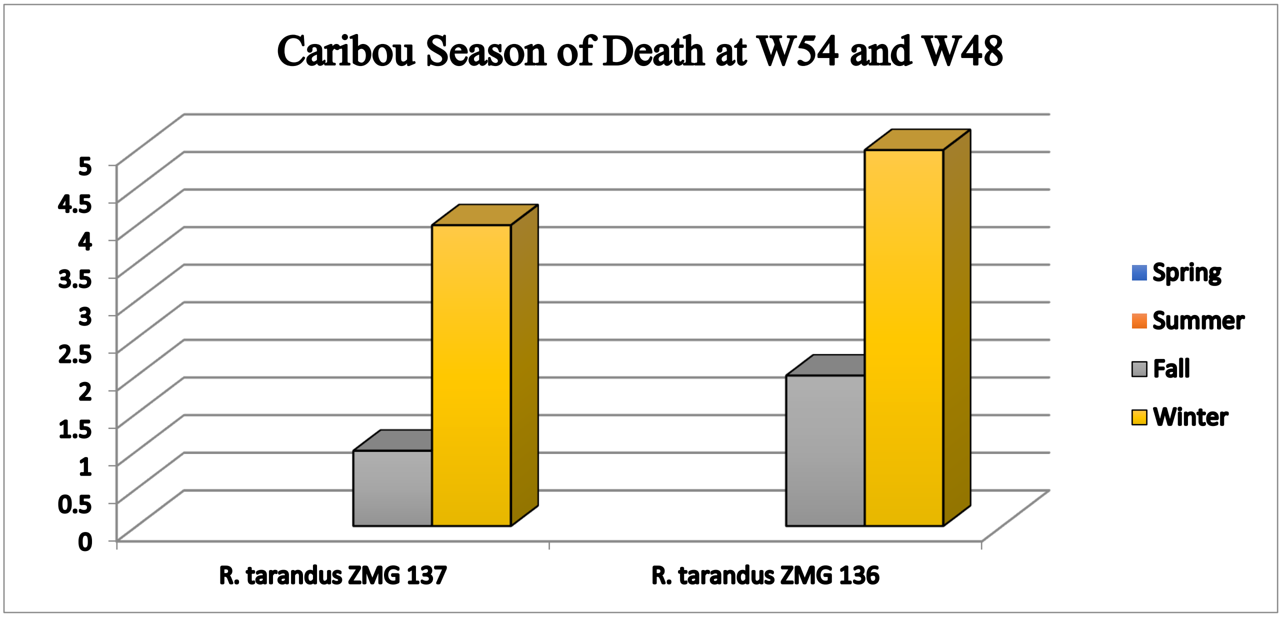


Figure 48 Season of death based on tooth annuli. ZMG 137 are from W54, ZMG136 are from W48. Note that all specimens indicate a fall/ winter death.

While more data will always be welcome, the overall impression is that Norse hunters in Western Settlement at W54 and W48 mainly targeted adult caribou in autumn to early winter, but occasionally making spring kills of calves and adults. As noted by Roussell (1936) cross bow bolt holes have been found in caribou crania in Norse middens, and we can suspect that cairn and drive systems and large dogs were also used as part of the hunt. There may have been a communal hunt in uplands managed as commons but the distribution of bones and indications of cuts of meat moving to higher status farms may indicate that some hunting areas may have been managed as part of a manorial system as suggested by Bárðarson's 14th century account of the bishops' holdings and rights to resources as “owning the hunting”. Despite the evidence for potentially intensive hunting and the competition for upland grazing with domestic sheep and goat flocks, some sort of sustainable management system limiting caribou hunting must have been in place in Norse Greenland. This may have been a top-down system controlled by elites with restrictions on commoner hunting (as was nearly universal in medieval Europe) but it does appear that most Greenlandic households did consume at least some caribou meat throughout the history of the settlements.

5.6 Arctic Fox, Arctic Hare, House Mice and Wolves

5.6.1 Arctic Fox and Hare

Besides caribou, a limited number of other wild terrestrial mammal species were sometimes taken by Norse hunters. Arctic fox (*Vulpes/Alopex lagopus*) was probably taken for fur and possibly for stock protection (as in Iceland, where bounties were offered for fox kills in medieval law codes). The arctic hare (*Lepus arcticus*) was also sometimes taken, possibly in snares in winter. The hare may have provided both fur and food. Both wild species are trace elements in the Norse archaeofauna, with fox bones appearing in 17 of the 59 total archaeofauna discussed in this thesis and hare bones appearing in 18 of 59 total vs. caribou which appears in 53 of 59 current archaeofauna (table 55 below). Fox and hare bones seldom top 1.00% of total identified bones. Both hare and fox are comparatively small animals with fragile bones and their remains were certainly regularly overlooked in older un-sieved excavations and were also differentially destroyed by dogs, burning, bone grease extraction and other forces of attrition. Their low frequency in the identified archaeofauna probably under-represents their actual role in Norse economy, but it still appears that fox and hare were minor elements in all periods.

Table 55 Presence of bones in archaeofauna (ubiquity) measures for wild land mammals.

UBIQUITY MEASURES	Phase	All Collections	EARLY PHASE	MIDDLE PHASE	LATE PHASE	UNSTRATIFIED	
	Est.time range (CE)	980-1450	980-1160	1160-1300	1300-1450	?	
Taxon	Sites in sample	59	8	13	11	27	
Wild Mammals Terrestrial							
Rangifer tarandus	Caribou	53	8	13	10	22	
Lepus arcticus	Arctic hare	18	3	3	5	7	
Alopex / Vulpes lagopus	Arctic Fox	17	3	6	4	4	
Mus musculus	House mouse	5	1	1	2	1	
Mus sp..	Mouse sp.	1	0	0	1	0	
Canid sp.	Dog or wolf	2	0	0	1	1	

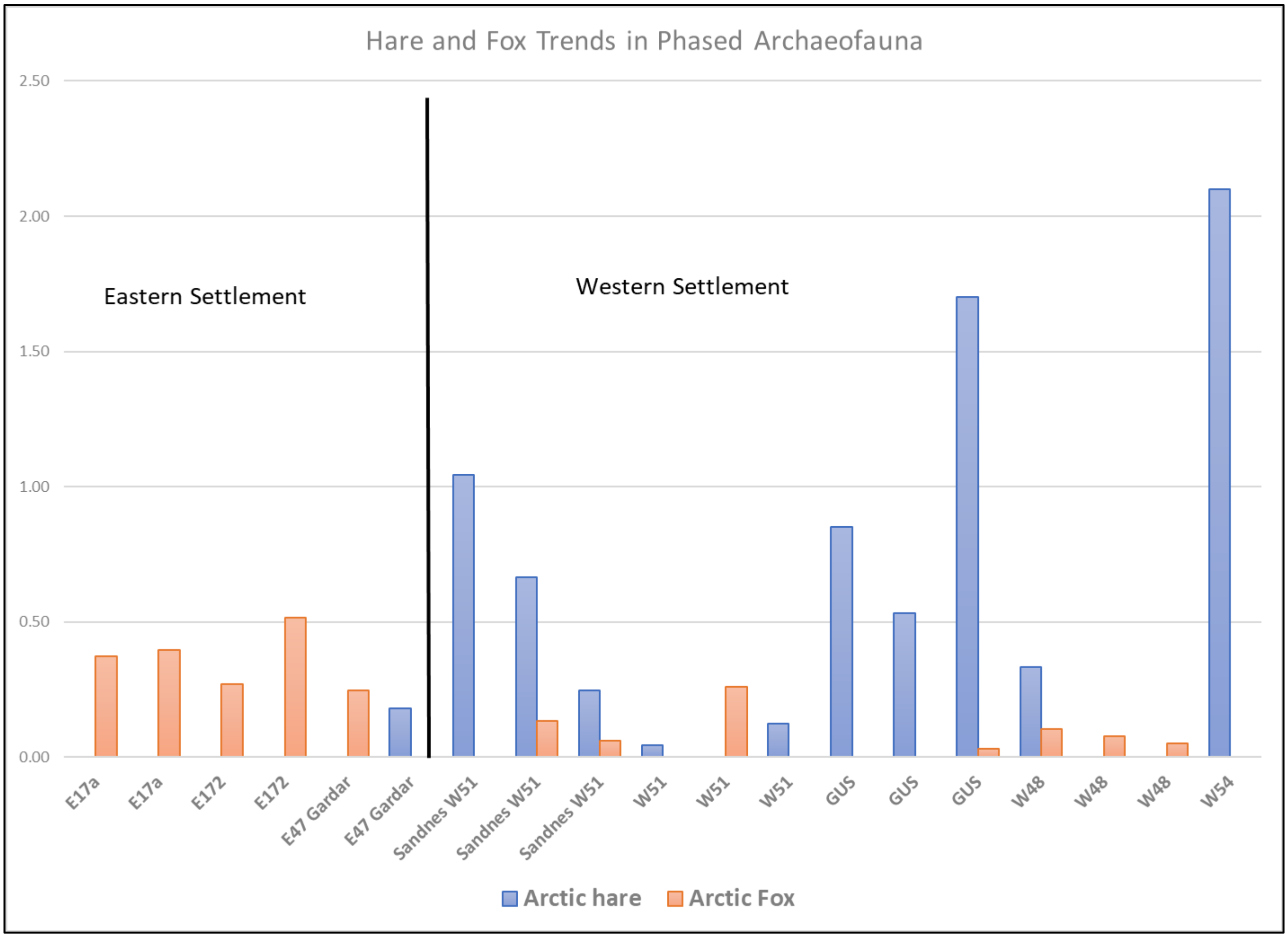


Figure 49 Arctic Hare and Fox bone % NISP total for the phased archaeofauna that have either species present. Archaeofauna are arranged by phase from left to right.

As figure 49 above indicates, hare bones are more common on Western Settlement sites, with the highest relative percentages of hare bones in the late phase interior deposits at GUS and W 54. The concentration of hare bones in the W 54 interior has been interpreted as a “final days” late winter provisioning effort (Buckland et al. 1983).

5.6.2 Mice

The presence of house mouse (*Mus musculus*) bones in Norse archaeofauna in both Iceland and Greenland has been regularly recorded, and their role as accidentally imported commensals along with a range of insects and weedy plants has been noted for some time. A comparative ancient DNA study demonstrated that the house mice in Viking age Iceland and Norse Greenland were closely related (Jones et al. 2012). Mice were able to survive inside the heated Norse farms, and in middens their bones are associated with twig-rich “floor cleaning layers” that appear to be flooring material that was dumped onto the midden as part of a cleaning episode (Buckland et al. 1994). At the Eastern Settlement Vatnahverfi site of E71S a dense concentration of partly articulated house mouse bones was recovered from the interior of a large, coopered tub in the storeroom. This assemblage came to a Minimum Number of Individuals of at least 110 mice both adults and juveniles, (McGovern 1992), and the excavator interpreted the collection as a group of mice attempting to consume the last of the preserved *skyr* who became trapped in the tub, perhaps and abandonment phenomenon (Vebæk 1992). This plausible explanation also offers a sense of how many commensal rodents shared space with Norse farmers, and ultimately became extinct when their indoor habitats went cold. Perhaps significantly, the meadow mouse (*Apodemus silvaticus*) which was also introduced to Iceland and survives there outdoors to the present is not found in any Norse archaeofauna from Greenland at present.

5.6.3. Wolves

Possible wolf bones have been reported as *Canid sp.* but given the potential size overlap of the larger breed of Norse hunting dogs and wolves it is probably best to leave the wolf question as a "case not proven" pending aDNA or ZooMS analysis.

5.7 Bird Hunting

Bird bones have been recovered from virtually all the larger Norse archaeofaunal collections, usually in small numbers. While the issues of recovery and preservation noted above for smaller mammals certainly also apply to bird bones, there do seem to be recurring patterns in the bird species presence and abundance in the quantifiable Greenland Norse sites. Table 56 presents the ubiquity (presence in collection) measures for the quantifiable archaeofauna, sorted by frequency of representation.

Table 56 Presence of Bird Bones in Norse Archaeofauna

Birds	Sites in sample	59	8	13	11	27
Ubiquity	Phase	All Collections	EARLY PHASE	MIDDLE PHASE	LATE PHASE	NSTRATIFIE
	Est.time range (CE)	980-1450	980-1160	1160-1300	1300-1450	?
Aves sp	Bird sp. Indet.	35	8	10	10	7
Uria sp.	Guillemot/Murre sp.indet	31	6	9	8	8
Lagopus muta	Ptarmigan	22	4	7	6	5
Haliaeetus albicilla	Sea Eagle	12	2	4	2	4
Uria lomvia	Brunnich's guillemot	7	1	1	2	3
Uria aalge	Common Guillemot/ Murre	6	1	2	2	1
Larus glaucoides	Iceland gull	4	2	1	1	
Cygnus sp.	Swan sp. Indet.	4	1	2	1	
Cygnus cygnus	Whooper Swan	4	1	1	1	1
Cepphus grylle	Black Guillemot	4			3	1
Anatidae sp	Duck sp. Indet	4		2	1	1
Anas platyrhynchos	Mallard duck	4	1	1	1	1
Alcidae sp.	Auk family sp. Indet	4		2	1	1
Alca torda	Razorbill	4	1	1		2
Somateria spectabilis	King Eider duck	3			1	2
Corvus corax	Raven	3		1	1	1
Anser/Branta sp.	Goose sp. Indet.	3		1	2	
Larus sp.	Gull sp. Indet.	2		2		
Falco rusticolis	Gyrfalcon	2			2	
Cygnus musicus/ cygnus	Whooper Swan	2			1	1
Alle alle	Little Auk/ Dovekie	2	1		1	
Somateria sp.	Eider sp. Indet.	1		1		
Somateria mollissima	Eider duck	1	1			
Rissa tridactyla	Black-legged Kittiwake	1				1
Mergus serrator	Red Breasted Merganser	1		1		
Gavia stellata	Red Throated Loon/Diver	1				1
Gavia immer	Common Loon/Diver	1			1	
Gallus gallus	Domestic Chicken	1			1	
Fratercula arctica	Puffin	1		1		
Carduelis flammea	Common Redpoll	1	1			
Anas acutas	Northern Pintail duck	1	1			

While a range of migratory waterfowl and a number of sea eagle bones appear in most of the current Norse archaeofauna, the non-migratory ptarmigan (grouse) and members of the auk (*Alcidae*) family of sea birds are the most common bird taxa in all periods. Enghoff (2003) illustrates a nearly complete articulated sea eagle wing from GUS, and Cesario (2021) reports a disproportionately large concentration of auk wings in Viking Age sites from Skagafjord in Iceland with ethnographic accounts of bird wings being used as brooms or fire-fans.

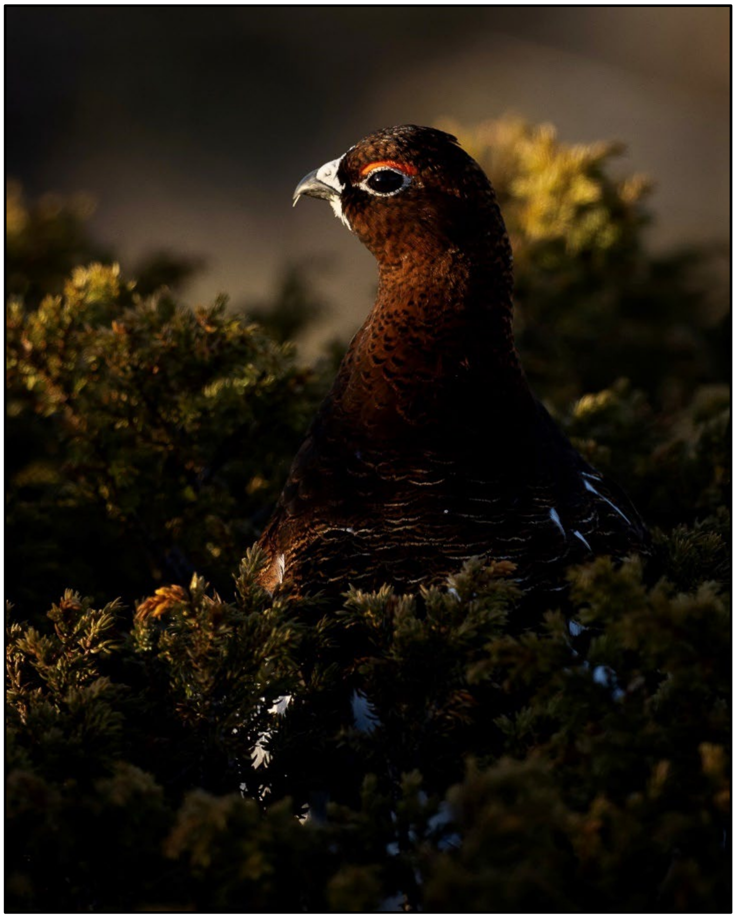


Figure 50 Ptarmigan. Photo by Leif Inge Åstveit.

Domestic chicken has thus far only been found at the episcopal manor at Garðar. Bird eggshell is frequently recovered in Iceland, especially from the Myvatn lakeshore sites (Hicks et al. 2021) but no bird eggshell has yet been recovered from Greenlandic Norse sites. While the Greenlandic sites show much higher pre-depositional attrition, it may also be the case that no similarly rich nesting areas were accessible to the Greenlandic settlers. Birds seem to have been a supplementary resource, with the auks and migratory waterfowl being hunted in summer and the ptarmigan potentially taken year-round. Birds in Greenland do not seem to have played the same role as in the Faroe Islands, where puffins and other auk bones regularly make up a majority of the archaeofauna (Brewington et al. 2013).

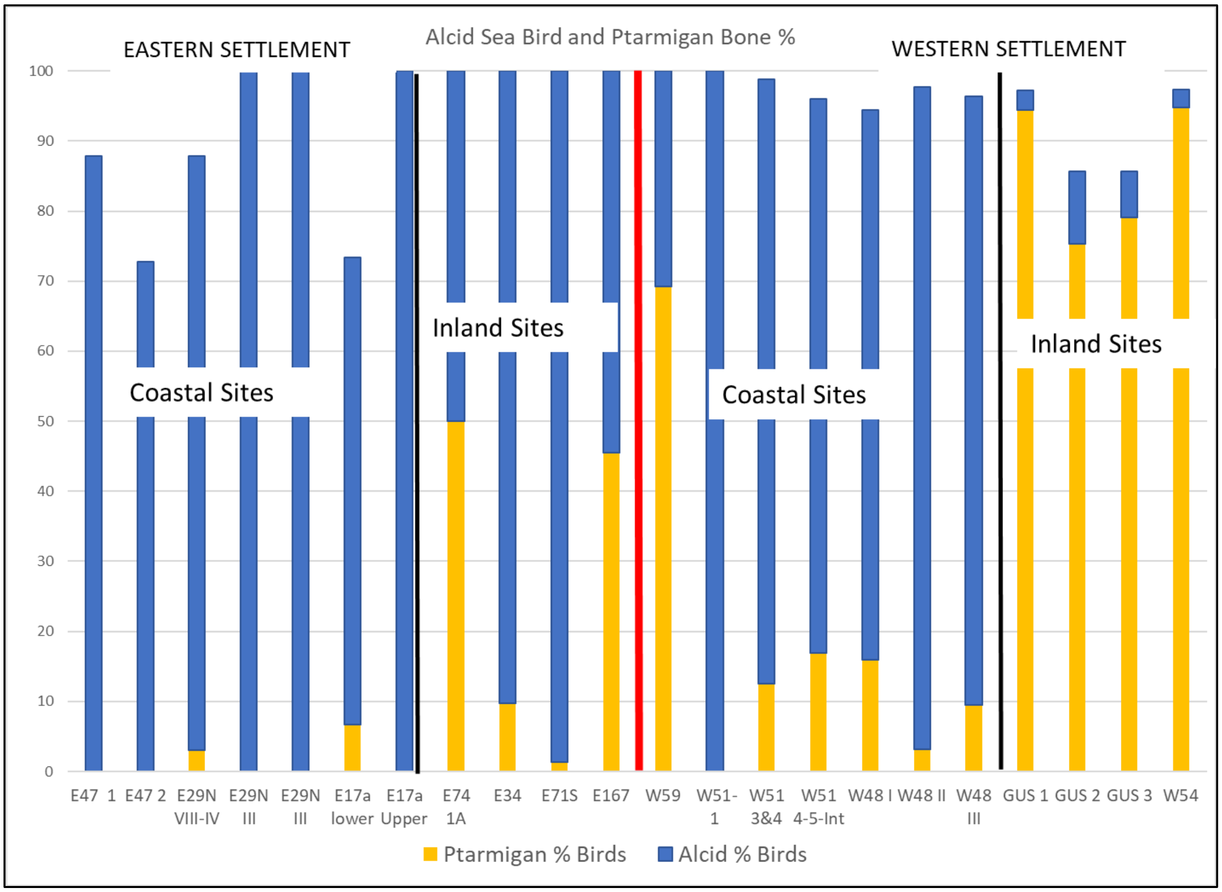


Figure 51 The distribution of the most common bird taxa as % of Bird identified NISP arranged by location (coastal/inland) and Settlement area. The site archaeofauna are arranged from early to late from left to right.

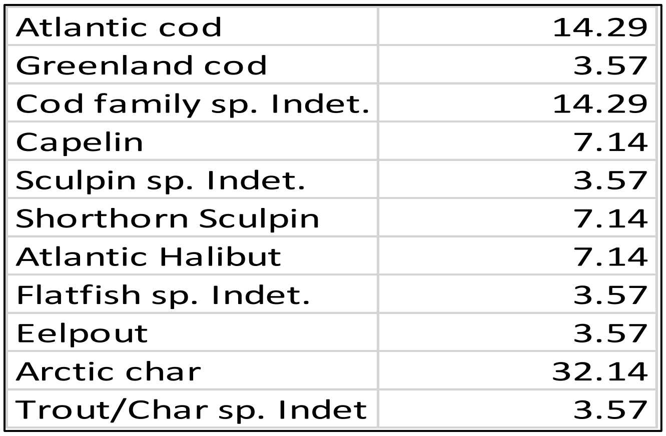
Figure 51 above displays the distribution of the most common taxa as % of identified bird bone in the phased archaeofauna. In both settlement areas there is a tendency for the marine auks (mainly murre/guillemot) to dominate the coastal collections, with non-migratory ptarmigan generally more common on inland farms. This pattern may reflect local hunting patterns with upland farms finding better ptarmigan hunting, but it is notable that all the inland sites have at least some auk present (an especially strong pattern in the Eastern Settlement sites). This suggests that the summer hunt for auks may well have had a communal pattern that drew upon the labor of the whole community and that auk carcasses then circulated to the inland farms. It seems less clear that any substantial exchange of ptarmigan took place, and these two resources may well have been managed differently. Cesario (2021) documents what appears to be a communal seasonal hunt of auks and distribution of carcasses in Skagafjord in Iceland that extends back to first settlement.

Figure 52   Guillemot colony on the outer coast. Photo by Kjærstin Åstveit.

5.8 Fishing

As noted in chapter 4 above, fish bones are exceedingly rare in Norse collections in Greenland, present in only 14 of the 49 currently available archaeofauna. Table 57 below presents the relative % of identified fish based on ubiquity in all current archaeofauna, with a total NISP of only 28 in total.

Table 57 Relative % of identified fish based on ubiquity in all current archaeofauna.



Atlantic cod	14.29
Greenland cod	3.57
Cod family sp. Indet.	14.29
Capelin	7.14
Sculpin sp. Indet.	3.57
Shorthorn Sculpin	7.14
Atlantic Halibut	7.14
Flatfish sp. Indet.	3.57
Eelpout	3.57
Arctic char	32.14
Trout/Char sp. Indet	3.57

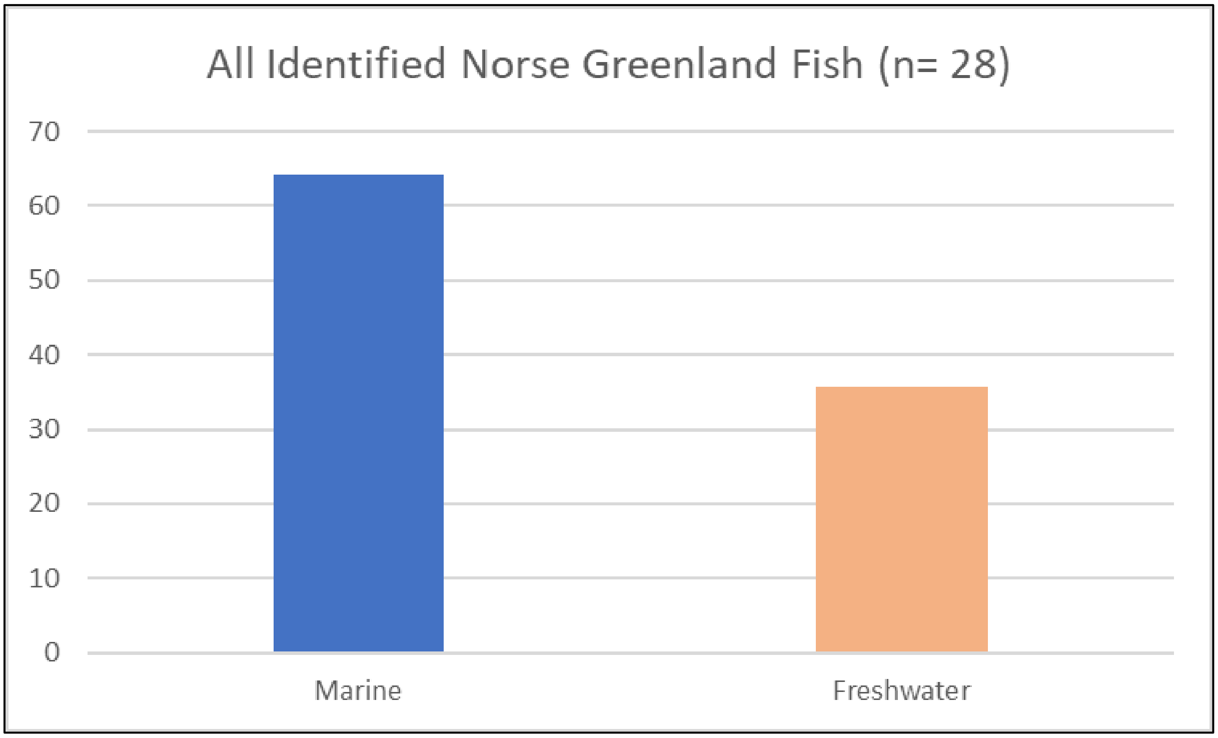


Figure 53 Relative proportions based on ubiquity of marine and freshwater fish bones from current Norse Greenlandic archaeofauna. NB: very small sample size.

Figure 53 above illustrates the ratio of marine to freshwater fish bones recovered thus far, but the pattern is very strongly affected by small sample size and beyond noting that the Norse took both marine (including some deep-water species) and freshwater fish (mainly Arctic char) on occasion we should not draw any broad conclusions.

In contrast, similar excavations in the Myvatn inland lake basin in Iceland carried out using the same techniques as the current Greenlandic projects generated very substantial amounts of both marine and freshwater fish. Table 58 below presents the current data from the small farm Sveigakót (SVK) and the chieftain farm Hofstaðir (HST) as an illustration of the numbers involved (data from Lucas 2008 Ch. 4). Both sites are dated by volcanic tephra and radiocarbon to ca 877-1050 CE and thus pre-date the Greenland Landnám.

Table 58 Viking Age Myvatn area fish NISP, illustrating use of both freshwater and marine fish at inland sites occupied before and during the Greenland Landnám.

Myvatn Iceland Viking Age					
Fish species identified, Major Archaeofauna					
Site	SVK 1	SVK 2	SVK 3	HST G3	HST G4
Atlantic cod	9	47	137	475	861
Haddock		41	28	202	248
Saithe		1	63	21	35
Ling			15		
Cusk					2
Gadid family	18	89	211	1,071	1,485
Halibut				2	3
Wolf fish				2	1
Arctic charr	15	227	341	693	1,409
Brown trout	8	94	111	3,413	4,058
Atlantic salmon			1		4
Salmonid family	114	967	893	2,082	3,329
Fish species	105	641	899	1,720	4,113
all fish	269	2,107	2,699	9,681	15,548

As has been discussed elsewhere (McGovern et al. 2006, Perdikaris et al. 2007, 2008) there is clear evidence of the transferal of both intensive fishing and large- scale production of a range of dried fish products from Arctic Norway to the Norse diaspora in the Faroes, Iceland, and Northern Isles.

The Icelandic record makes clear that an extensive artisanal fishery was active from first settlement and supplied dried fish products to inland farms like those in Myvatn, and that this fishery would intensify after ca. 1250 to serve fully commercialized international markets.

The lack of substantial fish bones in the Greenlandic Norse collections has been a concern for at least three generations of zooarchaeologists, and while lack of sieving in earlier excavations and the strong taphonomic attrition observed in all Greenlandic archaeofauna certainly has artificially reduced the frequency of fish bones these factors cannot fully explain the "missing fish problem". The results of ongoing work in Iceland, Faroes, and Scotland all have documented a pattern of heavy reliance on marine fish (and in Myvatn area on freshwater fish as well) that extends to the early Viking age and into prehistory. Evidence for an extensive pre-commercial exchange of processed (probably air dried) marine fish is simply absent in Greenland despite the direct lineal connection of the founding settlers to their Icelandic neighbors. Something clearly happened to replace the role of marine fishing and consumption of dried fish products in the first period of the Norse Landnám in Greenland.

Did highly abundant migratory seals replace fish? As noted above seal bones vary from about 25% of major identified taxa to nearly 80% on small farms with limited pasture and are common on far inland Greenlandic farms. Fish make up less than one percent, even when they are present (Smiarowski 2013a, 2014), far less than the staple represented by marine fish (25 to over 80%) in Viking and Early Medieval Icelandic archaeofauna (Hambrecht et al. 2018). Seals appear to have replaced marine fish almost entirely in subsistence strategy, and this seems to have happened in the very first years of settlement in Greenland. There has been extensive debate about the cause of this clear pattern, which seems strongly counter-intuitive given both the role of marine fisheries in modern Greenland and the now well-documented late 9th century Icelandic fishing record.

Scheduling issues, rather than ritual prohibitions (Diamond 2005), are likely at the core of this unexpected divergence. In Iceland and Norway, marine fishing was regularly practiced in winter, and the air drying of stockfish requires prolonged temperatures hovering around the freezing point for curing. Winter was also the farming slack season, and in later time periods Icelandic farm hands were regularly sent to sea in winter as fishermen. In Greenland, winter sea conditions even during a warmer climate are far more affected by sea ice, and winter temperature ranges for most of the SW of about −20 to −4 °C (−4 to 25 °F) tend to be too cold for effective stockfish curing. Greenlandic seagoing boats and labor were needed for most of the summer for the weeks-long voyages to the Norðursetur and the walrus hunt, which thus would compete directly with a summer fishing effort. On the other hand, the abundance of migratory seals in Greenland provided a resource that could sustain intensive exploitation without significant impact on the prey population (unlike the seal populations of the rest of the Norse North Atlantic). Harp seal migrations (especially with larger medieval seal populations) and potential in-fjord pupping areas may also have provided a more reliably scheduled target resource during periods of climate variability than the fluctuating cod stocks.

The Greenlandic choice of intensifying migratory seal hunting and de-emphasizing marine fishing thus appears rational, given the environmental conditions and the scheduling limitations imposed by the long-range Norðursetur hunt. The demands of production of walrus products for export may have limited the options for viable local subsistence strategies involving intensified summer fishing efforts, but intensifying spring sealing proved a strategy with potentially greater returns for subsistence, with a much higher yield of fat and protein alike.

5.9 Shellfish and Arthropod Use

Norse Greenlanders regularly collected mollusks as did their relatives in Iceland, Faroes, and the Northern Isles. However, shellfish remain comparatively rare in the Norse archaeofauna (table 59 below), and their distribution is probably heavily affected by taphonomy and recovery. These are not "shell middens" in terms of species composition and with a low density of shell even small fluctuations in soil pH will differentially remove shellfish. In addition, it is not clear that excavators in un-sieved pre-modern projects regularly collected shell as well as bone.

Table 59 Shellfish Ubiquity in all collections.

Shellfish Ubiquity	Sites in sample	59	8	13	11	27
	Phase	All Collections	EARLY PHASE	MIDDLE PHASE	LATE PHASE	UNSTRATIFIED
	Est.time range (CE)	980-1450	980-1160	1160-1300	1300-1450	?
Mollusca						
Mytilus edulis	Common/ Blue Mussel	14	3	3	4	4
Panopeaea /Panomya norvegica	Arctic clam	3	1	1	0	1
Coronula diadema	Whale barnacle	1	0	0	0	1
Mya sp. Indet.	Clam sp. Indet	1	0	1	0	0
Mollusca sp. Indet.	Shellfish sp. Indet.	9	2	4	3	0

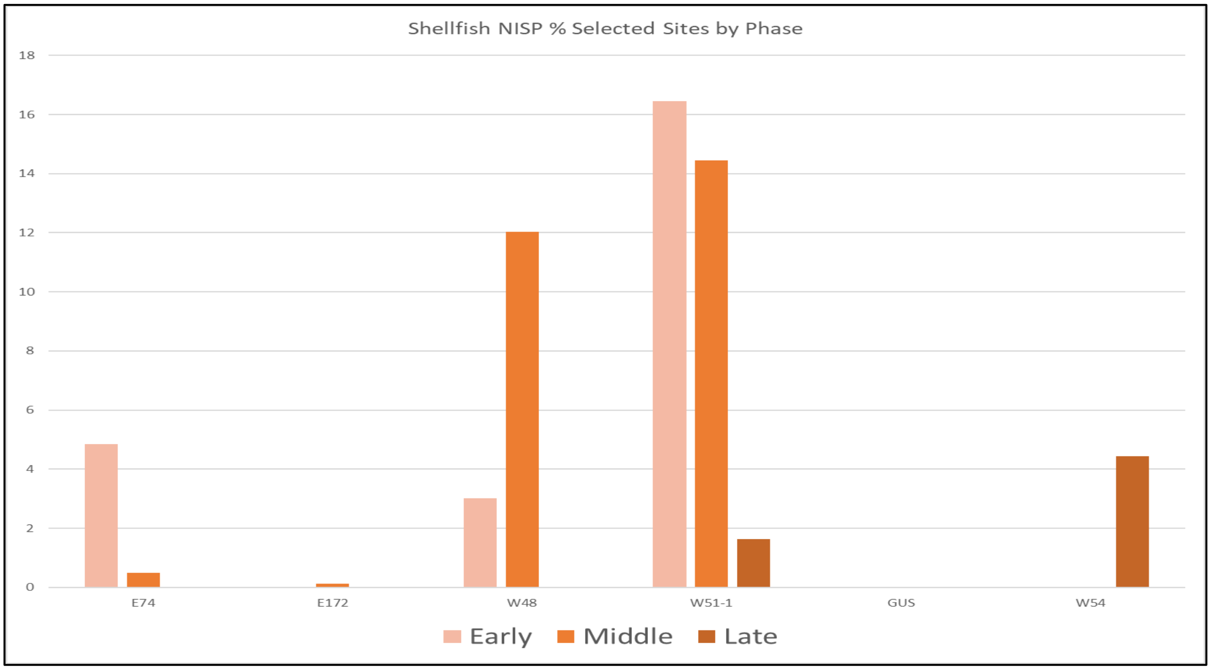


Figure 54 Shellfish Distribution in selected collections.

Figure 54 presents a limited quantification of shellfish for selected sites (phased modern sieved excavations). The main trend is a drop off in shellfish % (virtually all blue mussel) at the coastal Western Settlement sites W 48 and W 51 Sandnes which may be due to changing water conditions in the head of the Ameralik fjord, or simply preservation issues. Note that while the inland GUS site shows no shellfish remains some mussels did reach the neighboring farm W54 in the late phases. The mussels recovered were mainly unburnt full -sized adults probably collected from the inter-tidal zone, a pattern that contrasts with the deposition in the Icelandic Myvatn sites of very tiny 1-2 cm mussels (often burnt) that seem to have been taken inland attached to the root balls of *Laminaria sp.* seaweed that may have been burnt for salt extraction (McGovern et al. 2007). The arthropod whale barnacle (often associated with Humpbacks but present on some other species) provides evidence that some whale skin did reach the home farms and strengthens the case for consumption of whale meat.

5.10 Farming Strategies

On the Greenlandic home farms, short growing seasons and long winters constrained stock production and sharply limited the potential for cereal agriculture. Some pollen and macrofloral evidence have accumulated for local growing of flax and barley in the early phases of settlement and some use of local lyme grass and seaweed has been documented (Fredskild 1988, Fredskild and Humle 1991, Henriksen 2016, Schofield et al. 2013,). A deposit of carbonized barley in early layers at E35 in the Qolortup valley is reported by Henriksen (2016), and as Ledger et al. (2014) discusses in detail there is some pollen evidence for barley presence in some Vatnahverfi sites. Large indoor stoves have been interpreted as both grain drying ovens and sauna stoves (Vebæk

1943, 1992). Milling stones have been recovered from E66 and E64a (Nørlund 1930, Vebæk 1943) and at least two fragments of scored baking plates used in the production of flatbread have been recovered from E47 Garðar (Vésteinsson et al. 2013), E2 Tingimiut and GUS. These schistose baking plates may have been a Norwegian export, and their fragments are quite common finds on medieval sites of all sizes in Shetland and Orkney (Bigelow 1984), but the baking plate from GUS is made of local Greenlandic stone (J. Arneborg, personal communication, June 2nd, 2022). Widespread evidence of early barley production in Northern Iceland indicates that cereal agriculture was part of the farming strategies known to the Greenlandic Landnám settlers (Mooney and Guðmundsdóttir 2020).

However, the 13th century *King's Mirror* account cited above probably accurately characterized Norse agriculture in Greenland as overwhelmingly pastoral and focused on producing milk, meat, fiber, and hides from the imported cattle, sheep, pigs, and goats. This section will review the quantitative zooarchaeological evidence for domestic mammal management and integrate complimentary studies of tooth wear and landscape modification to place these archaeofauna in context.

5.10.1 Cattle

As noted in Chapter 4, cattle bones are present in virtually all quantifiable archaeofauna in our sample (present in 57 of 59 collections, and in all time periods). Multiple authors (Mulville et al. 2005, McGovern 1985, Enghoff 2003) have concluded that Norse cattle in most parts of the North Atlantic were managed primarily as dairy herds, with scattered evidence of exceptional production of prime beef aged animals for elite or merchant consumption as at Gásir in Eyjafjord (Harrison

2014a). In practice, it is hard to effectively manage cattle to produce both milk and meat optimally from the same herd, and modern farmers universally specialize in beef vs. dairy herding. Dairy herds produce close to four times the calories for human consumption as herds managed primarily for beef (even with pre-modern breeds, Outram and Mulville 2005), so this strategy seems highly rational given the shortage of fodder and the need to conserve small herds in Atlantic Island contexts. The Icelandic practice of storing milk products as cheese and yoghurt- like *Skyr* while also using *Skyr* tubs as pickling agents for meat seems to have been practiced in Greenland, as multiple excavations have reported the presence of characteristic large, coopered tubs built into the floors of larders (Vebæk 1992).

In Greenland, cattle probably spent nearly 9 months a year indoors being hand fed fodder harvested in autumn (McGovern 1992, Amorosi et al. 1988), and evidence of preserved dung concentrations suggests that at least some goats and sheep were also regularly stabled indoors in winter (Enghoff 2003). The specter of late winter shortfall in stored fodder and human provisions was a recurring threat to North Atlantic farmers, and cattle were substantially more demanding of winter feeding than sheep and goats (Amorosi et al. 1998). They would have needed high quality hay from the homefields, which would have been reduced while lower quality fodder would have been collected from the wider landscape. Nevertheless, cattle were still maintained on all farms and there are no current Greenlandic archaeofauna indicating specialized caprine herding, even on the smallest farms with poor pastures. Cattle clearly had a social as well as economic role in the North Atlantic diaspora, and Icelandic farm values were regularly given in "legal cow" values. The Icelandic early medieval law code *Grágás* provides a clear definition of cow value:

> "*Also of standard value is a cow three winters old or older, ten winters old or*

> *younger, capable of bearing calves, in milk, horned and free of defects, no worse than the average beast, fit enough to be driven from one district to another at the moving days and giving enough for a calf at milking*."
>
> *Grágás* MS later 13th century (trans. Dennis, Foote, and Perkins vol 2., 2000, p 208)

This definition is clearly referencing a dairy cow and assumes that cows might be kept to ten years or more (far older than modern dairy herding) so long as they stayed fertile.

The zooarchaeological evidence for cattle management comes from reconstruction of age at death (survivorship) profiles based on presence of young (neonatal) animals 1-2 months old, tooth eruption and wear, and the fusion of long bones. As discussed in Chapter 4.1 the heavy pre-depositional attrition notable in all Greenlandic Norse archaeofauna and the current problems with post-depositional decay sharply limits and probably skews these data away from younger animals and may over-represent the denser bones of adults. Reporting of neonatal fragments is also uneven in the early literature, though Degerbøl notes the presence of neonatal cattle bone in all his collections.

Figure 55 below presents the available cattle neonatal bone % (as % of Cattle NISP) for the

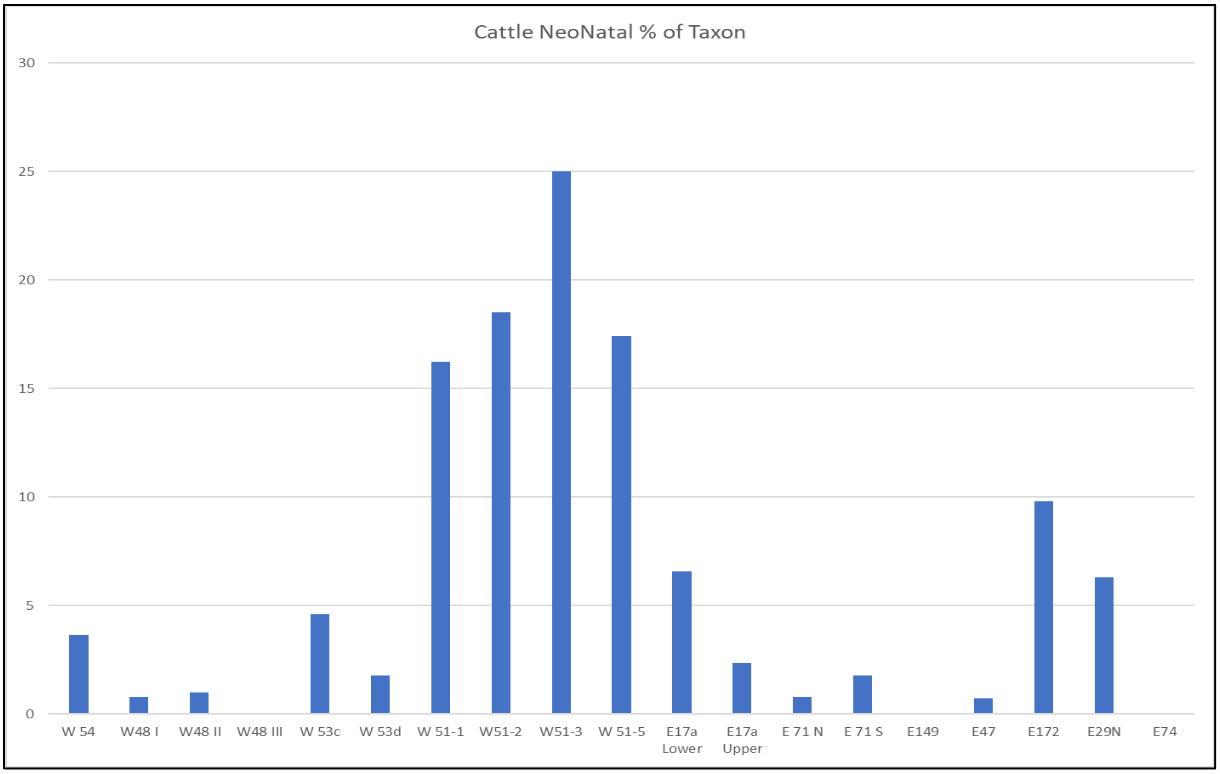


Figure 55 Cattle Neonatal bone % over time (left to right).

Greenlandic modern archaeofauna. The neonatal percentages vary between zero and about 25 % of the total cattle bones identified (some neonates in the Large Terrestrial Mammal category not counted here may also be cattle).

These cattle neonatal percentages are far lower than the range for Viking Age to Medieval Iceland (generally between 25 and 50% of the cattle bones, see Harrison 2013). It seems likely that this difference is directly related to pre-depositional attrition (especially bone grease extraction and dog gnawing) having a strong impact on the less calcified bones of the young animals. The Greenlandic neonatal data (for all taxa) thus should probably be read as a presence/absence (ubiquity) measure rather than as ratio scale data. While reporting issues make a numerical ubiquity score problematic for cattle neonatal bones, it appears that despite the taphonomic attrition they are present on the great majority of collections.

In North Atlantic zooarchaeology, the nearly universal presence of neonatal cattle bones in archaeofauna from Scotland, Iceland and Greenland has been interpreted as evidence for a strong dairy focus in challenging environments where nearly all the cow's milk production had to be reserved for human consumption and the occasional calf raised as a replacement milker. Most calves were killed and eaten very young, with farmers accepting the loss in body weight gain as the price of maximizing milk availability for humans in early spring (when provisions may have regularly been low). In Iceland, this pattern is well documented from Landnám onwards and the Greenlandic farmers seem to have maintained the same practices in a significantly more difficult cattle management environment.

Eruption and wear of mandibular (jaw) teeth is commonly used to reconstruct age of death of multiple species with scoring systems derived from Grant (1982) and Legge (1992). Greenlandic bone collections were exceptionally fully processed for recovering all edible marrow, and this regularly results in the breaking open of mandibles to extract the small amount of marrow within-usually destroying the tooth rows. In her comprehensive analysis of the GUS archaeofauna Enghoff provides an overview of both the small numbers of completed mandibles and the loose deciduous pre-molar 4 (dp4) and adult third molar (M3) (Enghoff 2003, Figure 38), here Figure 56.

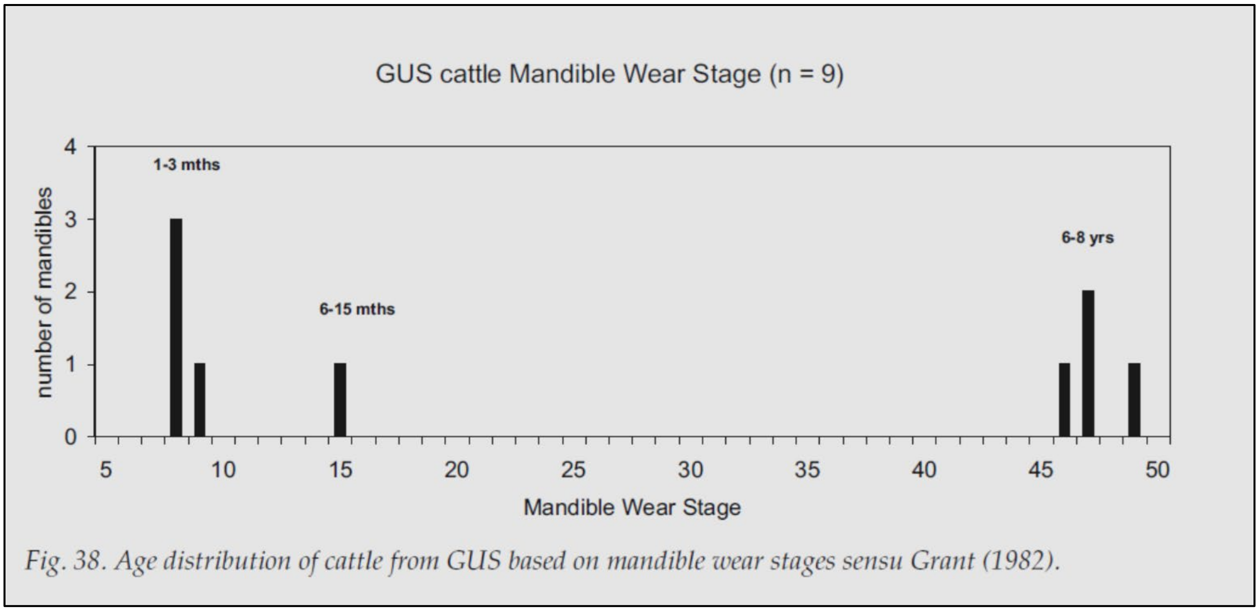


Fig. 38. Age distribution of cattle from GUS based on mandible wear stages sensu Grant (1982).

Figure 56 Cattle Mandibular Tooth Wear stages, Enghoff 2003

As Enghoff notes, while the sample size is small, the overall pattern suggests fairly old adults and young calves as expected in a North Atlantic dairy strategy with no young adults as would be expected in a beef production strategy. In an effort to increase sample size, Enghoff also made use of loose deciduous fourth premolar (dp4) and the last-erupting permanent third molar (M3) to attempt to further document herding strategies.

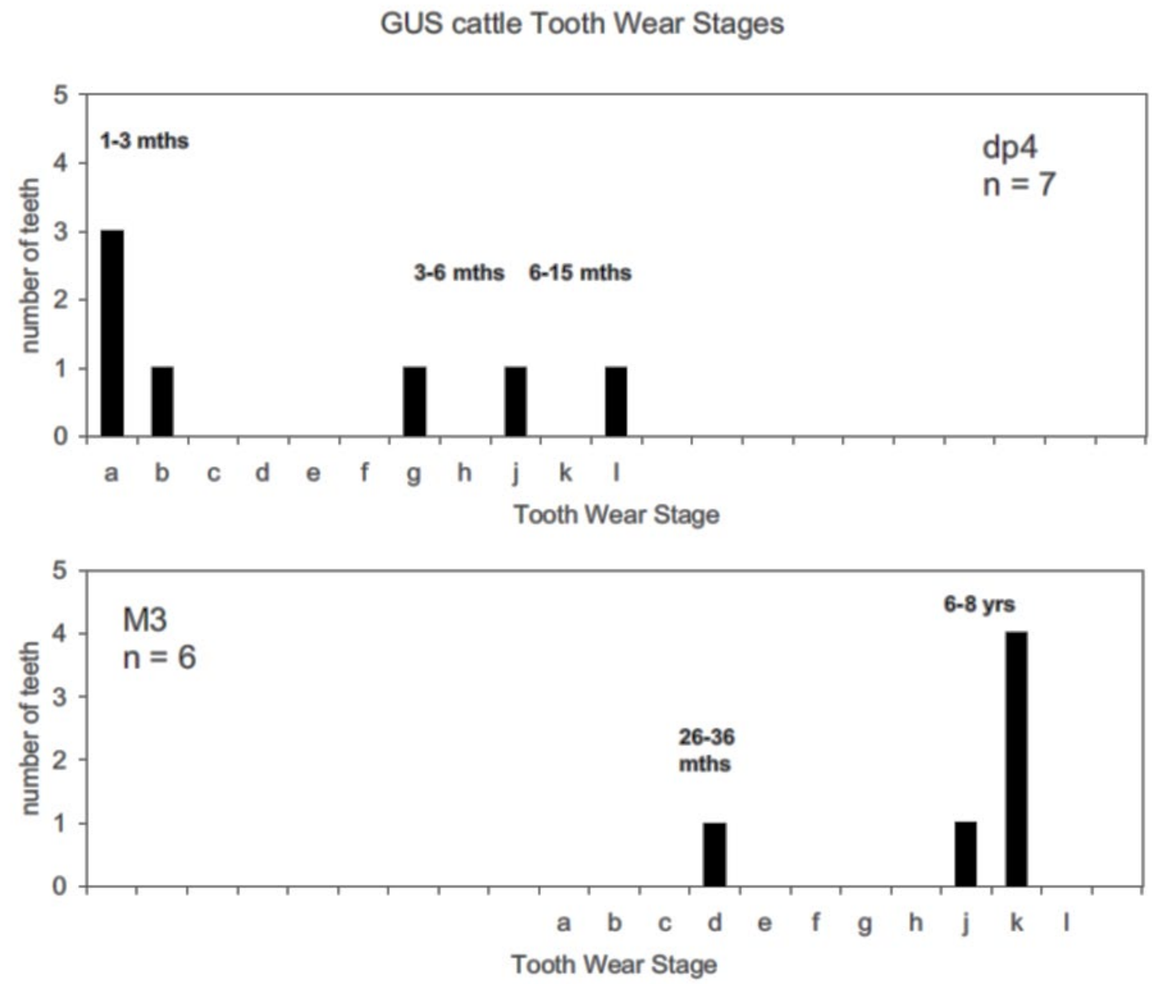


Fig. 39. Age estimates for cattle from GUS based on wear patterns sensu Grant (1982) for individual, mandibular dp_4 and M_3.

Figure 57 Wear patterns on loose deciduous premolars and adult third molar. Enghoff 2003.

While sample size is again very small, the dp4 pattern suggests most calves died very young (soon after birth) with a few surviving to the end of their first summer. The permanent M3 (last erupting tooth) shows a predominance of older adults with high rates of tooth wear. As Enghoff notes, age estimates based on tooth wear are always affected by different rates of tooth wear in different animals and different feeding patterns as well as age. Ingrid Mainland (2006) has documented high rates of wear on Greenlandic sheep and goats (see discussion below) which may also apply to cattle, thus potentially skewing wear-based age reconstructions.

In the new Eastern Settlement archaeofauna there are thus far no cattle mandibles complete enough to reasonably construct a full mandibular wear state (MWS) reconstruction following Grant (1982), but some scoring on isolated dp4 and M3 teeth is possible (following Enghoff 2003).

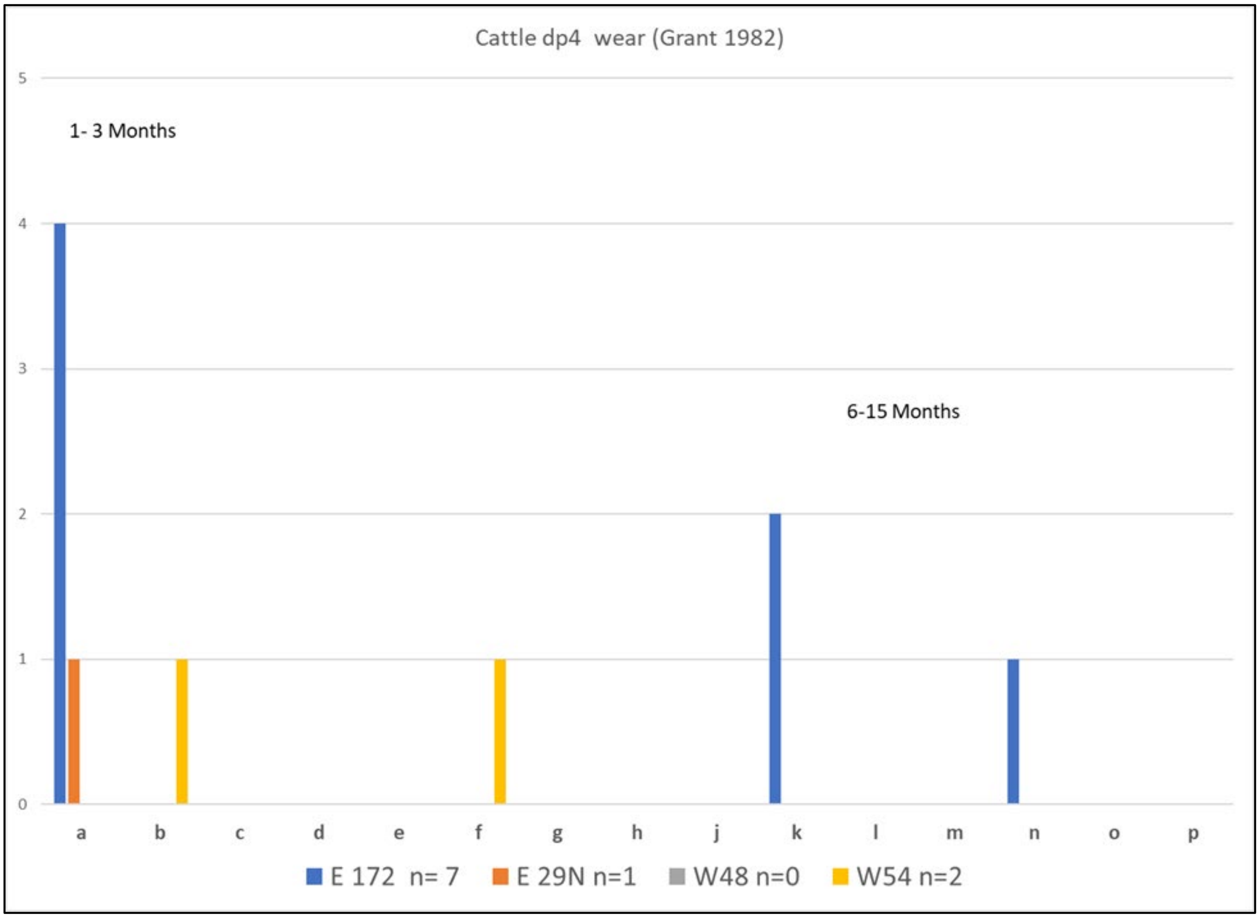


Figure 58 Wear on Cattle dp4, Note small sample sizes.

Figure 58 above presents the limited number of deciduous premolar (dp4) wear states available for cattle from the new Eastern Settlement archaeofauna and a re-analysis by the author of mandibles from W 48 and W 54 at the University Zoological Museum. Again, small sample size is a major problem, but the overall pattern fits the GUS model of many calves dying very soon after birth, and a few more surviving to the end of summer.

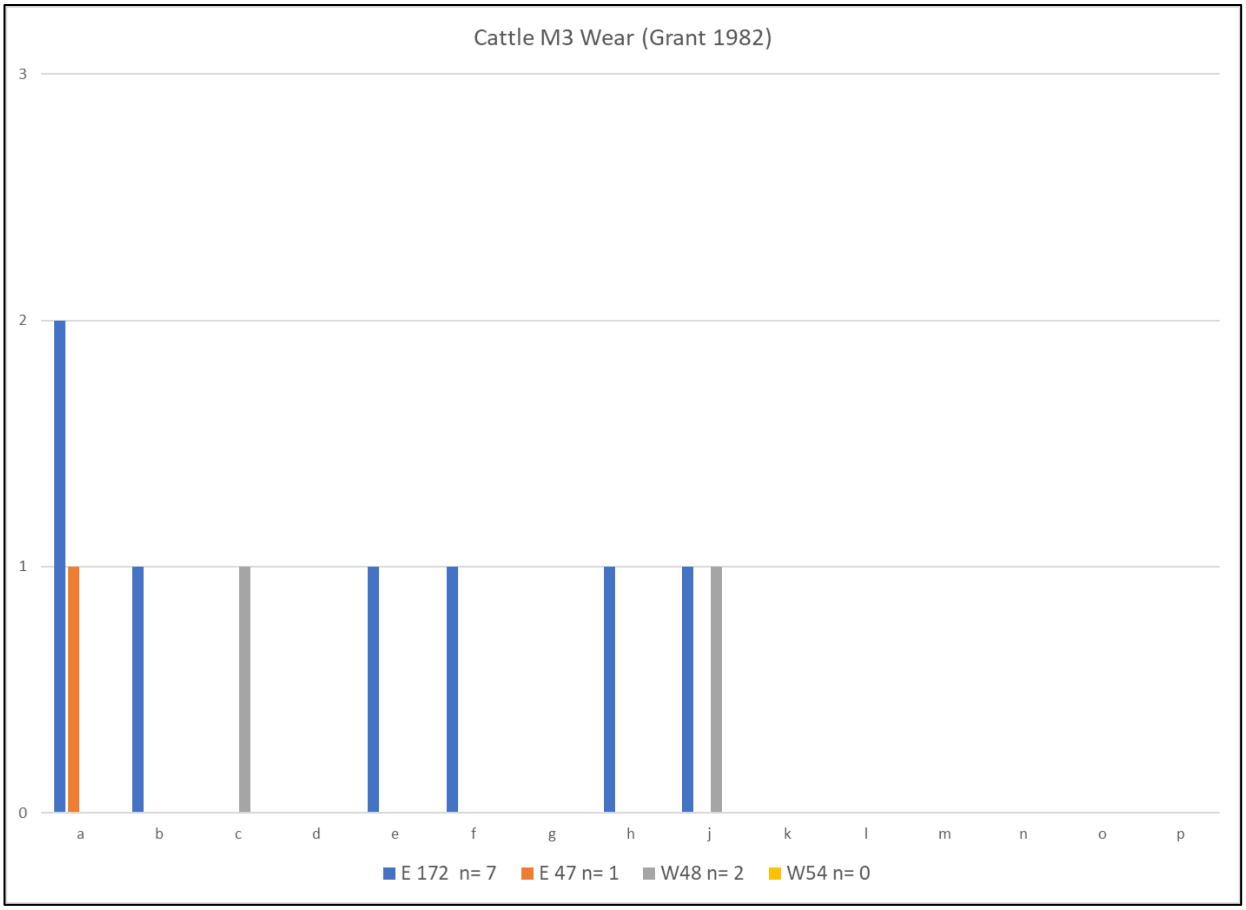


Figure 59 Cattle third molar (M3) wear. Note the small sample sizes.

Figure 59 presents the available cattle third molar scores for W 48, W 54, E 172 and E 47. While some younger animals seem to be represented at E172, it is probably unwise to draw any conclusions from such a small sample size (n=7). Most of the individual M3 cattle teeth come from older adults as at GUS.

Long bone epiphyseal fusion is regularly used as a secondary means for estimating age at death for domestic mammals. In most cases long bone fusion measures tend to be more biased against the survival of younger age classes with less fully calcified and dense bone, and in the harsh pre-depositional attritional conditions on Norse Greenland sites the number of surviving long bones is often too small to make this approach viable. Table 60 below presents the available fusion data for the available cattle long bones (E74 produced no usable cattle long bones). While sample sizes are far too small for effective quantitative analysis, the general trend for most cattle surviving their first months to live to the 3-4 year fully adult range (and possibly beyond).

Table 60 Cattle Long bone fusion data available from recent Eastern Settlement sites. Note that sample sizes are too small for extensive quantification.

Cattle		E29N		E172		E47	
	Age est.	F	U	F	U	F	U
Radius D	3.5-4 yr	2			1		
Femora D	3.5-4 yr	2	2	1	1		
Tibia D	2-2.5 yr	2		2		5	
Humerus D	1-1.5 yr	3		1		1	

Cattle size and conformation analysis is again impeded by extreme fragmentation, and the new data adds only modestly to the comprehensive study by Enghoff (2003), Degerbøl (1936), and an unpublished Hunter College MA thesis (Daniel Russell 1985). As these studies indicate, Greenlandic cattle seem to have had much the same conformation as their relatives in Iceland, small in stature, large headed, short horned, and stocky. Greenlandic cattle were smaller than their counterparts in Iceland and medieval Denmark, and the current study (based on a very small number of measurable fragments) seems to confirm this pattern. Table 61 below presents the withers height reconstruction based on cattle metatarsals (following von den Driesch and Boessneck 1974) comparing the single whole cattle metatarsal from E29N with the six from GUS (Enghoff 2003). The single E29N metatarsal falls well within the GUS range. The lower register of the table presents Viking Age cattle measurements from metatarsi from Hofstaðir and Sveigakót in the Myvatn area (McGovern et al. 2009) illustrating the somewhat larger size of these northern Icelandic cattle.

Table 61 Cattle stature reconstructions. NB: small sample size.

Cattle Metatarsals		
Withers Ht. Reconstruction		
(von den Driesch & Boessneck 1974, GL x 5.45)		
Greenland		Withers Ht. (cm)
E29 N (n=1)		108.51
GUS (n=6)	mean	107.93
	range	101.4 - 113.5
Iceland		
Hofstadir (n=2)	mean	188.36
	range	180.15-196.57
Sveigakot (n=2)	mean	199.85
	range	197.9-201.8

Table 62 below presents some comparative measurements of the distal tibia on cattle bone from E29 N and E 47 with the Icelandic Viking Age Hrísheimar archaeofauna. Again, sample sizes are too small for reasonable quantification, but the impression that Greenlandic cattle may have been varying close to the lower size range of their Icelandic relatives.

Table 62 Measurements of the distal tibia of cattle. Note the small sample size.

Cattle Distal Tibia (Von den Dreisch 1976 Bd)						
Iceland						
Site	Phase	Species	Bone	End	Ref#	Bd
Hrisheimar	4	Cattle	Tibia	Distal	40	5.04
Hrisheimar	3	Cattle	Tibia	Distal	2134	5.33
Hrisheimar	3	Cattle	Tibia	Distal	1011	5.50
Hrisheimar	3	Cattle	Tibia	Distal	1010	5.55
					n=	4
					mean	5.56
					max	5.55
					min	5.04
Greenland						
Site	Phase	Species	Bone	End	Ref#	Bd
E29N	81	Cattle	Tibia	Distal	3	5.57
E47	1	Cattle	Tibia	Distal	M11	5.41
E47	1	Cattle	Tibia	Distal	M14	4.19
E47	1	Cattle	Tibia	Distal	M30	5.45
E47	1	Cattle	Tibia	Distal	M31	5.59
					n=	5
					mean	5.24
					max	5.59
					min	4.19

As part of a Sr isotope- based study of human migration in the N Atlantic (Price and Arneborg 2018) the Hunter zooarchaeology lab provided cattle bone from W51 Sandnes and E29N as reference specimens to allow for calibration of the human cemetery samples. One of the cattle bones from W51 proved to have a Sr isotope ratio that demonstrated that the animal had been born and raised in Iceland. The other specimens were from cattle born in Greenland. Figure 60 illustrates this pattern (data and slide courtesy of Doug Price).

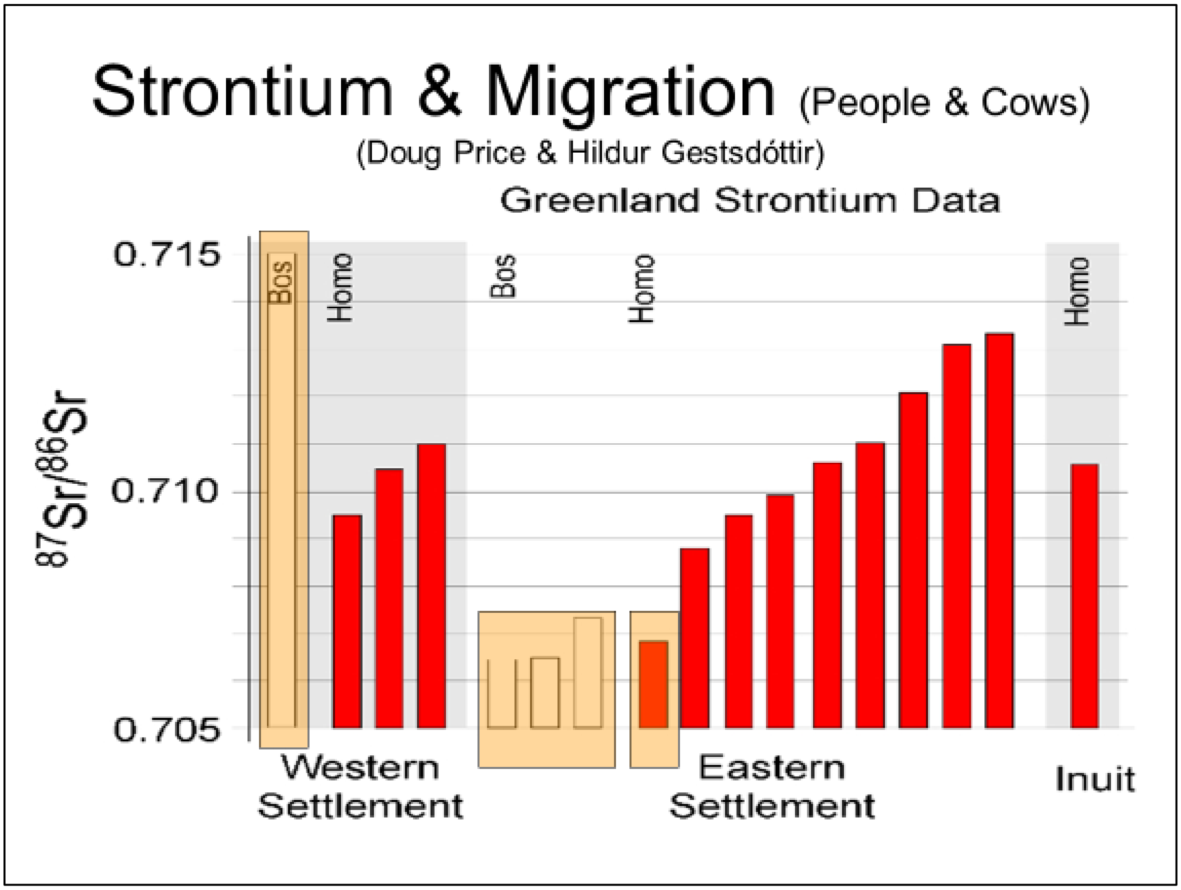


Figure 60 Cattle bone from W51 have strontium signatures indicating birth in Iceland.

5.10.2 Sheep and Goats

Sheep and goat bones (and the collective "Caprine" category for bones that cannot be distinguished between these related species) are usually the most common domestic mammal in Greenlandic archaeofauna and are found in 56 of the 59 currently known collections (Chapter 4). Goats were more numerous in the Greenlandic archaeofauna than in Iceland from first settlement onwards, and on some farms, they become relatively more common over time. Goats are more effective in metabolizing leaves and twigs, while sheep are preferentially grazers. Goat hair and hide were valued, and goat hair has been found incorporated into Greenlandic textiles mainly made of sheep wool (Hayeur Smith 2020). However, sheep produce the wool required for most clothing and furnishings, and woolen cloth and loom parts are common finds on Greenlandic sites (Østergård 2004, Hayeur Smith 2020, see also discussion in Chapter 6.3). In Iceland, goats were apparently always much less common than sheep, and after ca. 1100 their bones become increasingly rare, though some Icelandic goats have survived down to the present in a few parts of the Northeast (further discussion and comparative evidence is presented in Chapter 6.3).

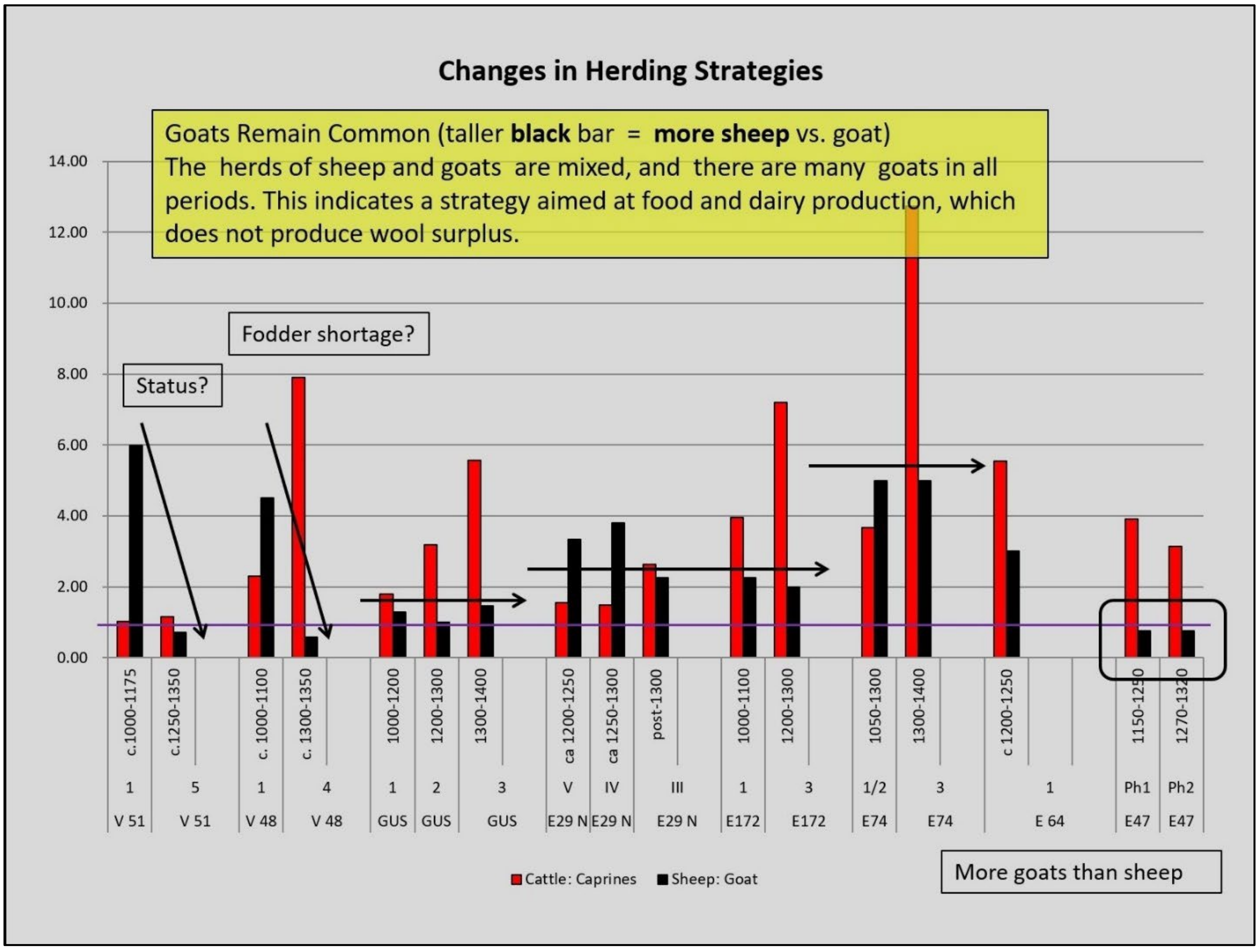


Figure 61 Changes in Caprine herding patterns in Phased Archaeofauna.

Figure 61 above illustrates changes in ratio of sheep to goat bones in the phased archaeofauna (taller black bar = more sheep). As the trend lines indicate, sheep do not increase relative to goats through time in Greenland, and on the manor farms of W 51 Sandnes, E29N Brattahlið, and E47 Garðar goats are particularly common relative to sheep. At W51 Sandnes and at the small farm W48 nearby there is a sharp decline in sheep relative numbers from early to late phases. In both settlement areas, goats retain or increase their numbers after ca. 1250 CE, even at the bishop's manor at E47 Garðar.

Unlike contemporary Iceland, as well as in much of Britain and mainland Europe, sheep and wool production do not seem to have been fostered by ecclesiastical and lay elites in response to growing market demand in the later Middle Ages. Hayeur Smith's comprehensive comparative study of Greenlandic and Icelandic textiles indicates that while Greenlandic weavers seem to have produced a characteristically dense and wind-resistant cloth in later periods, they did not produce the quantities of the standardized and commodified *vaðmál* cloth as produced by their relatives in Iceland (Hayeur Smith 2020). A study by McCooey (2017) of Icelandic documentary sources and available zooarchaeology shows a correlation between surviving goat herds and persisting native brushy woodlands in parts of Northern Iceland, suggesting both a role in initial forest clearance following the Icelandic Landnám and the continued economic linkage between goat keeping and scrub forest. In Greenland, current paleoecological evidence (discussed below) suggest that scrub forest may have been successfully conserved in some substantial areas after initial impacts.

Goats may have retained value in Greenland for their capacity to survive on rough grazing and twig-dominated winter feed, and they would have provided more milk than sheep, though some of our current evidence suggests a focus on goat meat production at least at the small W48 farm. The persistently high ratios of goats to sheep maintained in later medieval Greenland may be further evidence of a lighter environmental impact of Norse agriculture in Greenland than in most of Iceland. However, the persistently high ratio of goats to sheep also precluded the intensification of wool production and the generation of a significant wool surplus on most farmsteads, a sharp contrast to patterns in Iceland in the later Middle Ages and Early Modern periods (discussion in Chapter 6.3).

Zooarchaeological evidence for caprine husbandry again rests on tooth eruption and wear, long bone fusion, and the presence of neonatal animal bones. A key study remains that of Mainland and Halstead (2005) who applied then newly- developed methods for separating sheep and goat on their teeth (not available to McGovern or Enghoff) which allowed them to break down the lumped "caprine" category for the most critical age of death indicators in dental eruption and wear states by species. They worked on three of the larger pre-modern archaeofauna W51 Sandnes (1936), W52a, and E71S, with collaborative data provided for W48 and GUS. They confirmed the high ratio of goats to sheep and suggested that the earlier reports may have effectively under-counted goats. They applied the eruption and wear data to the reconstruction of survivorship curves after Payne (1973) intended to separate farming strategies focused upon meat, milk, or wool production. Milk production profiles tend to have high initial mortality in the first year as lambs and kids are culled to reserve milk for human consumption. Meat production profiles tend to show mortality peaks close to their growth peak at 12-18 months, while wool production profiles (often making use of castrated male wethers who produce the densest fleece) produce more older animals surviving beyond the ca 4–6-year-old threshold for optimum fertility (and thus dairy production). Mainland and Halstead note the taphonomic problem of under-representation of young animals' bones (thus skewing profiles away from the milk production pattern) but concluded the best fit was to Payne's meat production strategy and that there was no persuasive evidence of specialized wool production (Mainland and Halstead 2005: 117).

As part of the research for this thesis the author applied the modern standards for sheep/goat distinction on both the dental and post-cranial bones (Zeder and Lapham 2010) and with the kind assistance of the staff of the University Zoological Museum in Copenhagen he was able to re-analyze the early collections from E47 Garðar as well as W48 and W54. This expands our collection of sites with caprine dentition divided to species (though an indeterminate "caprine" category still exists) and may expand on the sheep and goat management model presented by Mainland and Halstead (2005).

Before presenting these data, it may be important to underline the taphonomic attrition patterns in the Greenlandic archaeofauna. As discussed above in Chapter 4, Norse Greenlandic archaeofauna are exceptionally fragmented and completely processed for marrow and bone grease extraction, and dog gnawing attrition also seems to have been widespread. We have seen that cattle neo-natal bone elements are much less common on most of the Greenlandic sites than collections from Iceland and Scotland. As discussed above we have good evidence that Greenlandic cattle were managed largely for dairy production, suggesting extreme attrition differentially removing neonatal cattle bones from the collections ***despite*** a strong dairy pattern. Given that calves are much larger than lambs (whose bones can easily be chewed up even by humans) we may need to be exceptionally careful of dismissing a sheep and goat dairy management strategy based upon low numbers of young lamb bones. Figure 62 below presents the relative % of young caprines for the available collections.

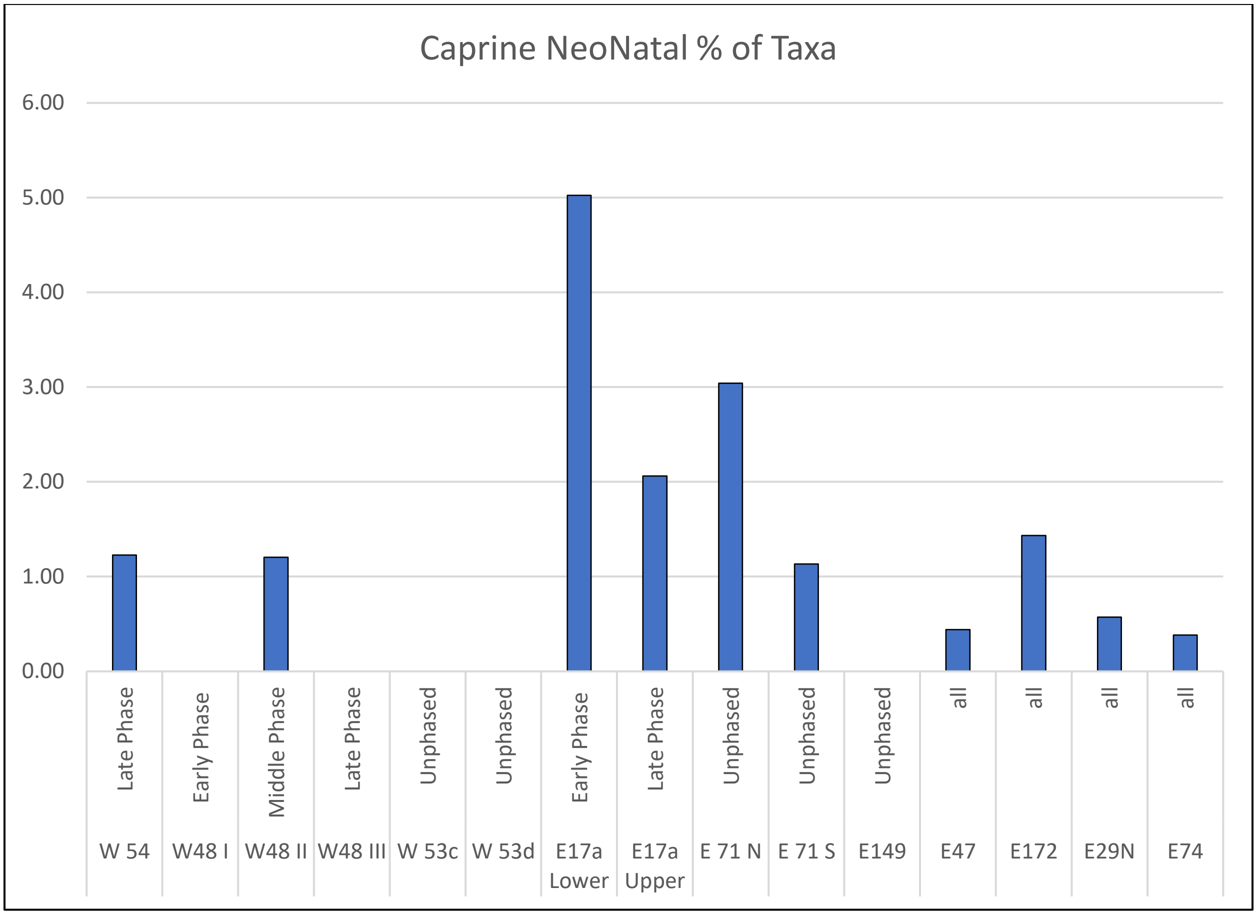


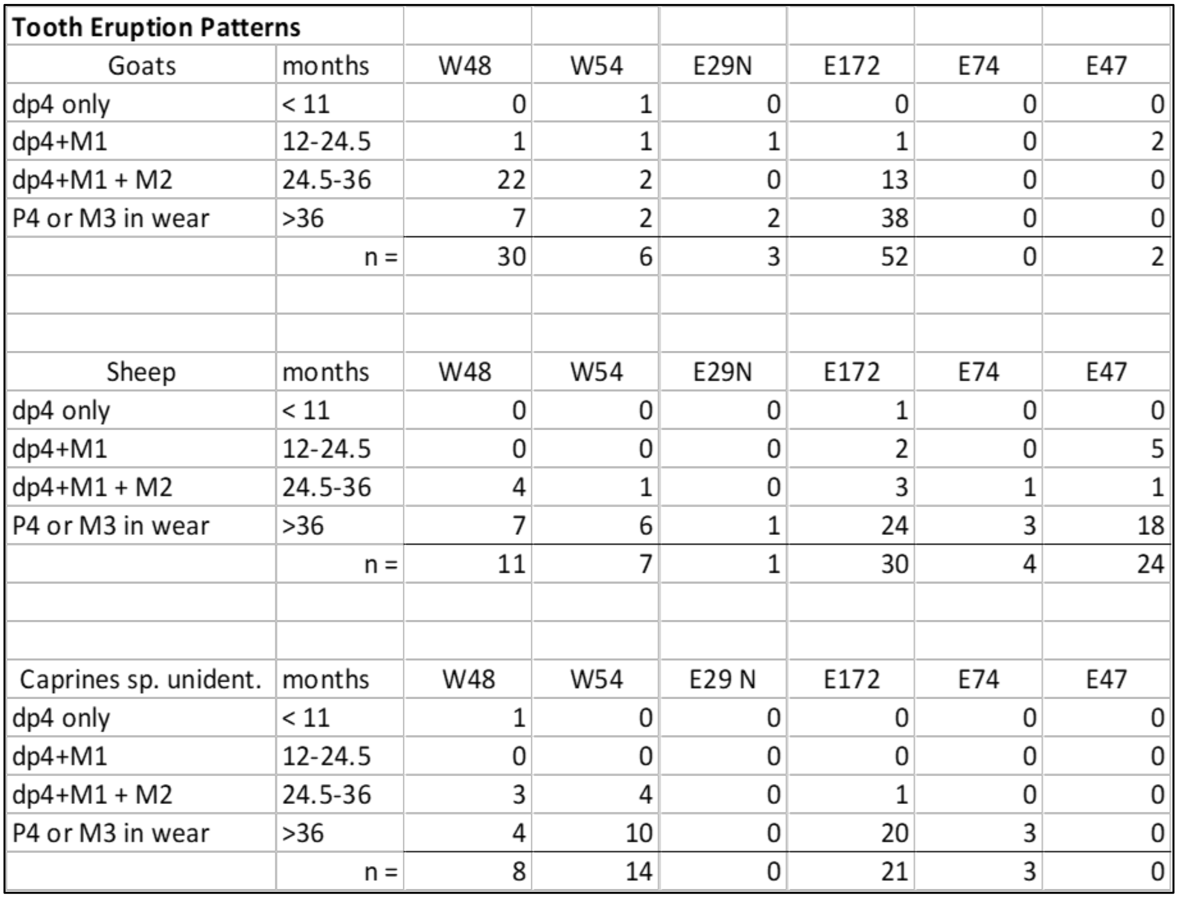
Figure 62 Caprine Neonatal Bones as % of Taxa.

As the figure indicates, newborn lamb and kid bones are rare or absent in the available archaeofauna, and taphonomic attrition certainly has differentially removed these bones prior to deposition. The presence of lamb and kid bones at all in the total taxa NISP count (distributed across the whole skeleton) does suggest a pattern of early mortality consistent with a dairy strategy that may not be reflected in the less commonly occurring intact tooth rows and long bones.

Exceptionally complete processing of carcasses and resulting fragmentation also results in a shortage of intact tooth rows for conventional age assessment based on eruption and wear patterns across a nearly complete dental arcade. While tooth rows are usually the best indicators of age at death (less influenced by taphonomic attrition and nutritional variation than long bone fusion), the extreme fragmentation pattern in Greenland extends to even the dense and usually frequently surviving mandibles. Sample sizes tend to be too small to effectively break down patterns by phase, and we are thus forced to lump by site collection in most cases. Even in large archaeofauna, it is thus often difficult to reach the ca 30 mandible threshold for effective quantification of tooth row series. Enghoff addressed this problem in her analysis of the GUS archaeofauna by also scoring the eruption and wear patterns on loose teeth for the deciduous fourth premolar (dp4) and the adult third molar (M3). The dp4 is the last shed of the deciduous dentition and thus accumulates wear up to the eruption of the permanent P4 premolar and the third M3 molar in caprines. Heavily worn dp4 thus are probably associated with animals close to their maximum growth and thus in prime meat age range. The M3 is the last erupting tooth, and its wear state thus reflects the age at death of fully adult animals. While tooth eruption schedules are usually consistent despite environmental conditions (Popkin et al. 2012), tooth wear is very subject to acceleration by grit in fodder and soil ingestion on degraded pastures. Both patterns have been observed on Greenlandic caprine tooth surfaces by Mainland's microwear analysis (2006) on collections from both settlement areas and all periods. We should thus probably assume that the wear-to-age assessments presented (following Enghoff 2003) may in fact be somewhat over-estimating age based on dental wear.

Table 63 below presents the eruption patterns broken down to Goat, Sheep, and Caprine (still unidentifiable). The general pattern of a shortage of very young animals is evident across species, but again may partially reflect taphonomic attrition.

Table 63 Eruption patterns broken down to Goat, Sheep, and Caprine.



Tooth Eruption Patterns							
Goats	months	W48	W54	E29N	E172	E74	E47
dp4 only	< 11	0	1	0	0	0	0
dp4+M1	12-24.5	1	1	1	1	0	2
dp4+M1 + M2	24.5-36	22	2	0	13	0	0
P4 or M3 in wear	>36	7	2	2	38	0	0
	n =	30	6	3	52	0	2
Sheep	months	W48	W54	E29N	E172	E74	E47
dp4 only	< 11	0	0	0	1	0	0
dp4+M1	12-24.5	0	0	0	2	0	5
dp4+M1 + M2	24.5-36	4	1	0	3	1	1
P4 or M3 in wear	>36	7	6	1	24	3	18
	n =	11	7	1	30	4	24
Caprines sp. unident.	months	W48	W54	E29 N	E172	E74	E47
dp4 only	< 11	1	0	0	0	0	0
dp4+M1	12-24.5	0	0	0	0	0	0
dp4+M1 + M2	24.5-36	3	4	0	1	0	0
P4 or M3 in wear	>36	4	10	0	20	3	0
	n =	8	14	0	21	3	0

The W48 (very small coastal site) and E172 (medium Vatnahverfi site) collections provide enough tooth rows to reasonably quantify further, and figure 63 presents the relative % of eruption states for goat mandibles at the two sites.

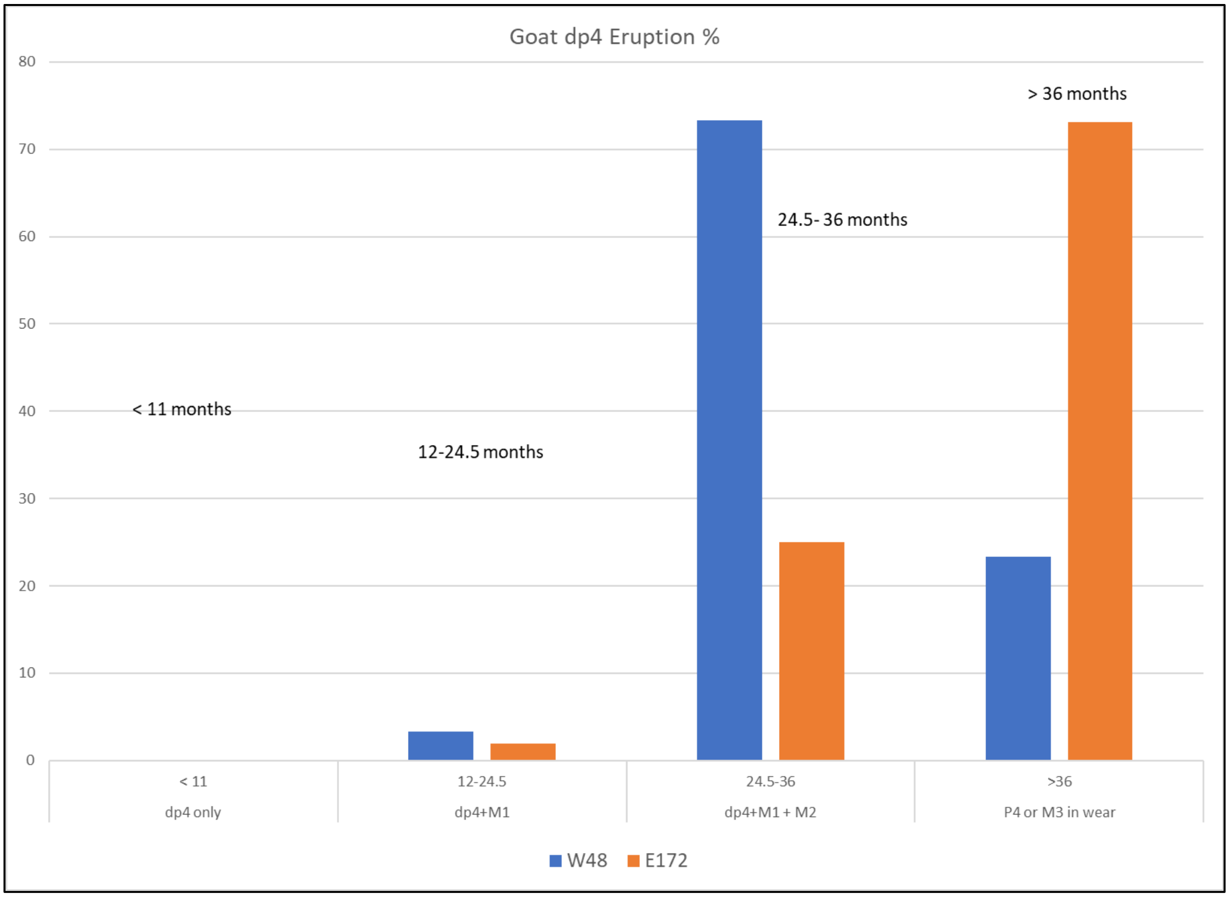


Figure 63 Relative % of Eruption States for goat Mandibles.

The absence of very young goats is clear at both sites, but most notable is the very different mortality patterns for the nearly full grown 2–3-year-old goats. At E172 most goats seem to have survived to full adult status, while the majority of W48 goats seem to have been culled just at growth peak. Allowing for the potential taphonomic removal of the very young mandibles, this pattern still suggests a significant meat production strategy at W48 and probably a different goat raising strategy at E172 (perhaps in fact a dairy pattern).

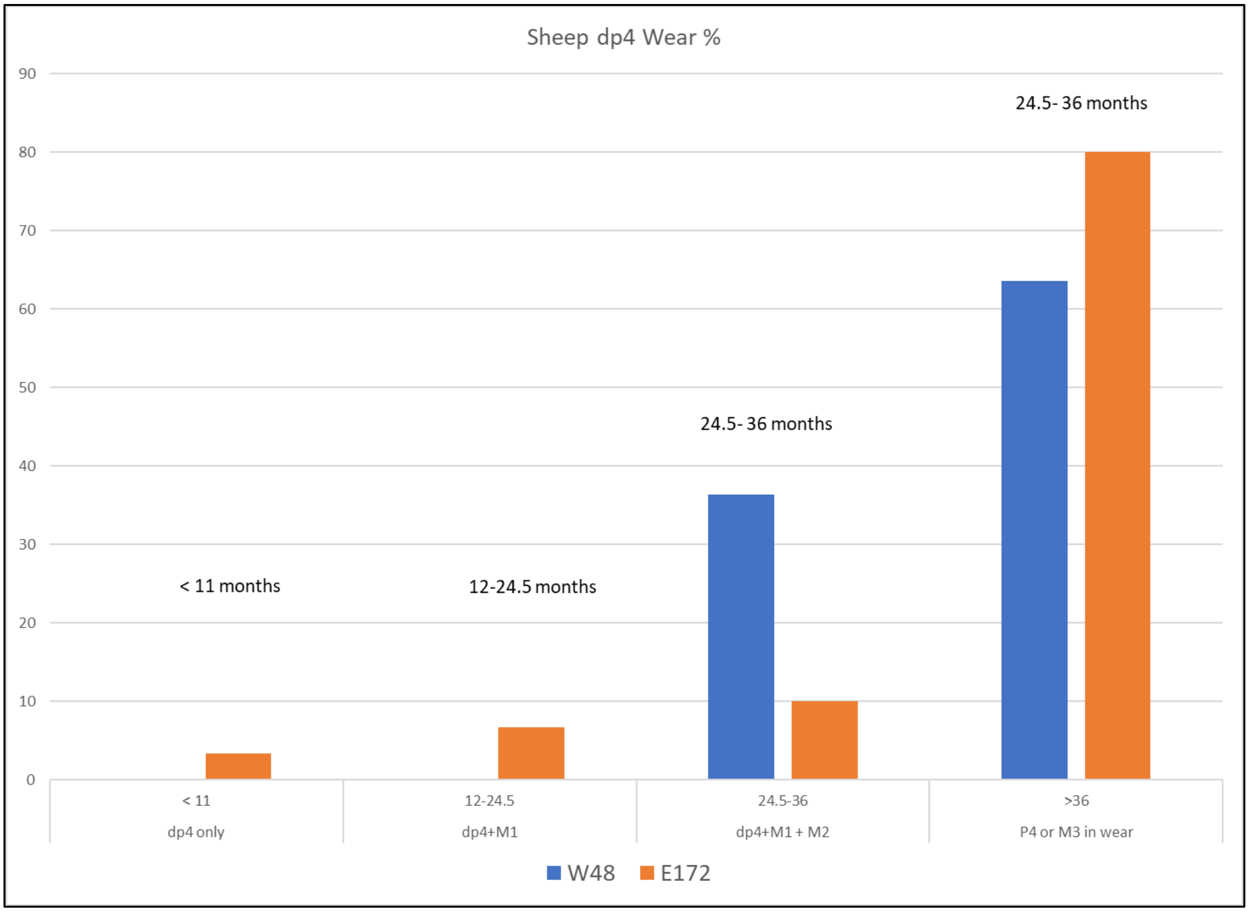


Figure 64 Comparative % dp4 eruption state for sheep from W 48 (n= 11) and E172 (n= 30).

Figure 64 above presents the same tooth eruption % data for the sheep from W48 and E172. There is again an apparent divergence in flock management, with a substantial cull at W48 near the growth peak but with most sheep in the sample surviving to adulthood on both farms. The eruption patterns at these two sites suggest that goats and sheep may have been managed differently on different farms, and that the small W48 household was consuming more of their sheep and goat stock as meat than the E172 household. It may be worth noting here that W48 also shows the highest %NISP of seal bones in our current collection of archaeofauna, and it is possible that some lower-ranking Greenlanders may have been consuming more meat (more desired in colder climate) and less dairy produce than higher ranking households (a reversal of normal European patterns).

Figure 65 below presents Enghoff's scoring of the individual dp4 and M3 teeth of all Caprines (sheep and goats together) for the GUS site.

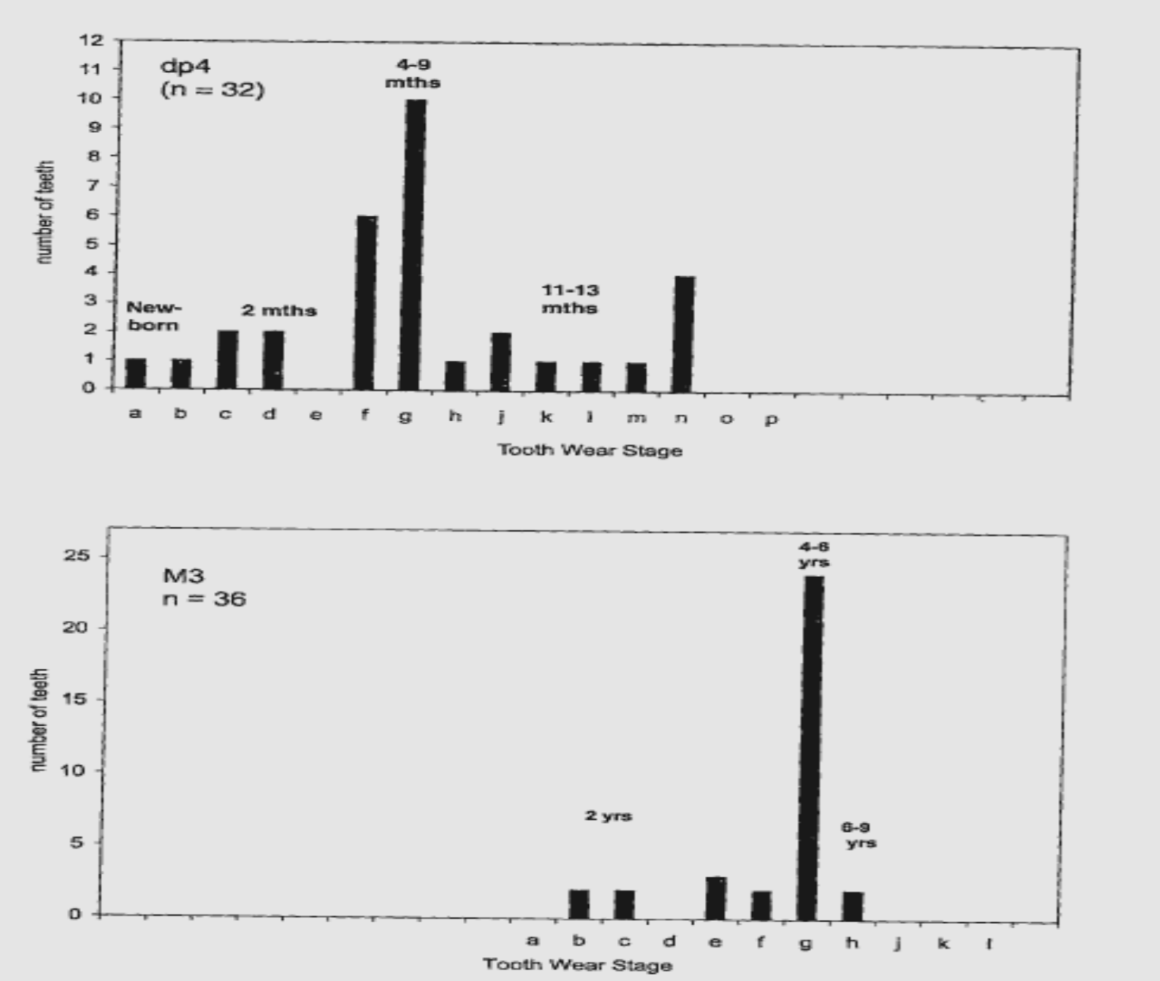


Fig. 25. Age estimates for sheep/goat from GUS based on wear patterns sensu Grant (1982) for individual, mandibular dp₄ and M₃.

Figure 65 Distribution of wear patterns on deciduous 4th premolar (dp4) and permanent third molar (M3) for GUS caprines (combined). Enghoff 2003, p 55.

The upper dp4 pattern indicates some animals dying very young (supporting a dairy pattern) and a peak in juvenile mortality at the end of the first summer (as farmers culled animals before winter feeding). Some juveniles were culled in the beginning of their second year, potentially a meat production indicator. The lower M3 pattern shows some mortality in the second to third years (again potentially meat production indicator) but the mortality peak is clearly in the 4-to-6-year range as sheep and goats begin to become too old to reliably reproduce. Very old animals are rare, suggesting that wool production was not a priority at GUS.

Table 68 below presents the tooth wear states (following Grant 1982) for E47 (all collections), E29N, E172, W48 and W54 divided by species where possible. Again, wear states will be affected by grit consumed and probably are accelerated in the Greenlandic samples.

Table 64 Tooth Wear States (following Grant 1982) for E47 (all phases), E29N, E172, W48 and W54.

	Grant Wear States															
Goats		**a**	**b**	**c**	**d**	**e**	**f**	**g**	**h**	**j**	**k**	**l**	**m**	**n**	**o**	**p**
dp4	E47							3	1							
	E29N							1								
	E172				1			1	2	2	1			2		
	W48							1	1		3	2		4		
	W54						1	1						2		
Sheep		**a**	**b**	**c**	**d**	**e**	**f**	**g**	**h**	**j**	**k**	**l**	**m**	**n**	**o**	**p**
dp4	E47							4	1			1		1		
	E172				1	2	1	1	2				1	1		
	E74						1									
	W48							2	1			1				
	W54									1						
Caprine		**a**	**b**	**c**	**d**	**e**	**f**	**g**	**h**	**j**	**k**	**l**	**m**	**n**	**o**	**p**
dp4	E47							1	2							
	E172							1								
	W48	1												3		
	W54							1	1					1		

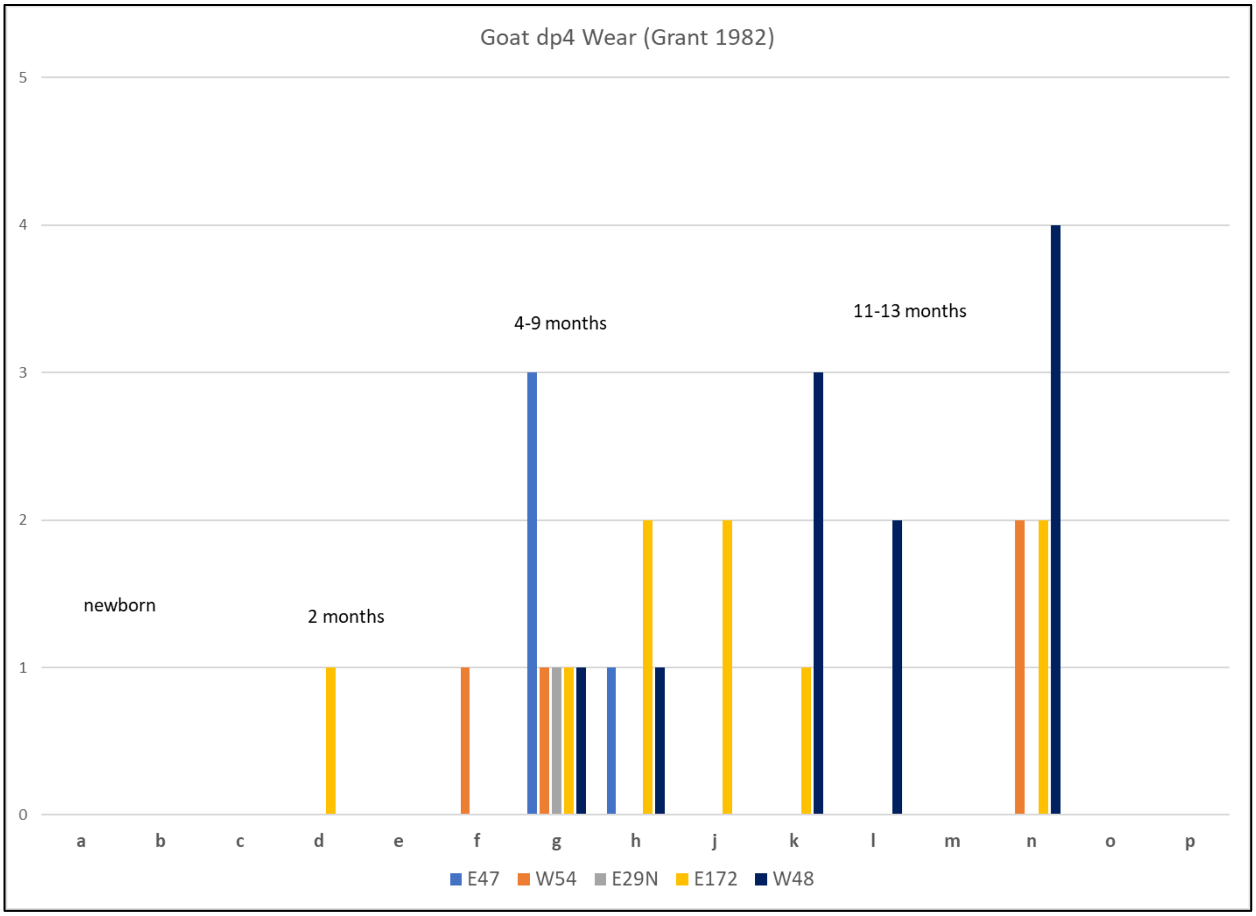


Figure 66 Tooth wear on dp4 Goat teeth with general age assessments following Enghoff 2003.

Figure 66 above graphs the goat dp4 wear states for the different sites. Sample size is again a major issue, but the general pattern of wear supports the model for a meat-production goat raising strategy at W48, with the dp4 wear patterns suggesting maximum mortality near the end of the growth period. The E172 goat mortality seems to be more evenly distributed and follows the general pattern of the other sites with an apparent culling at the end of the first summer.

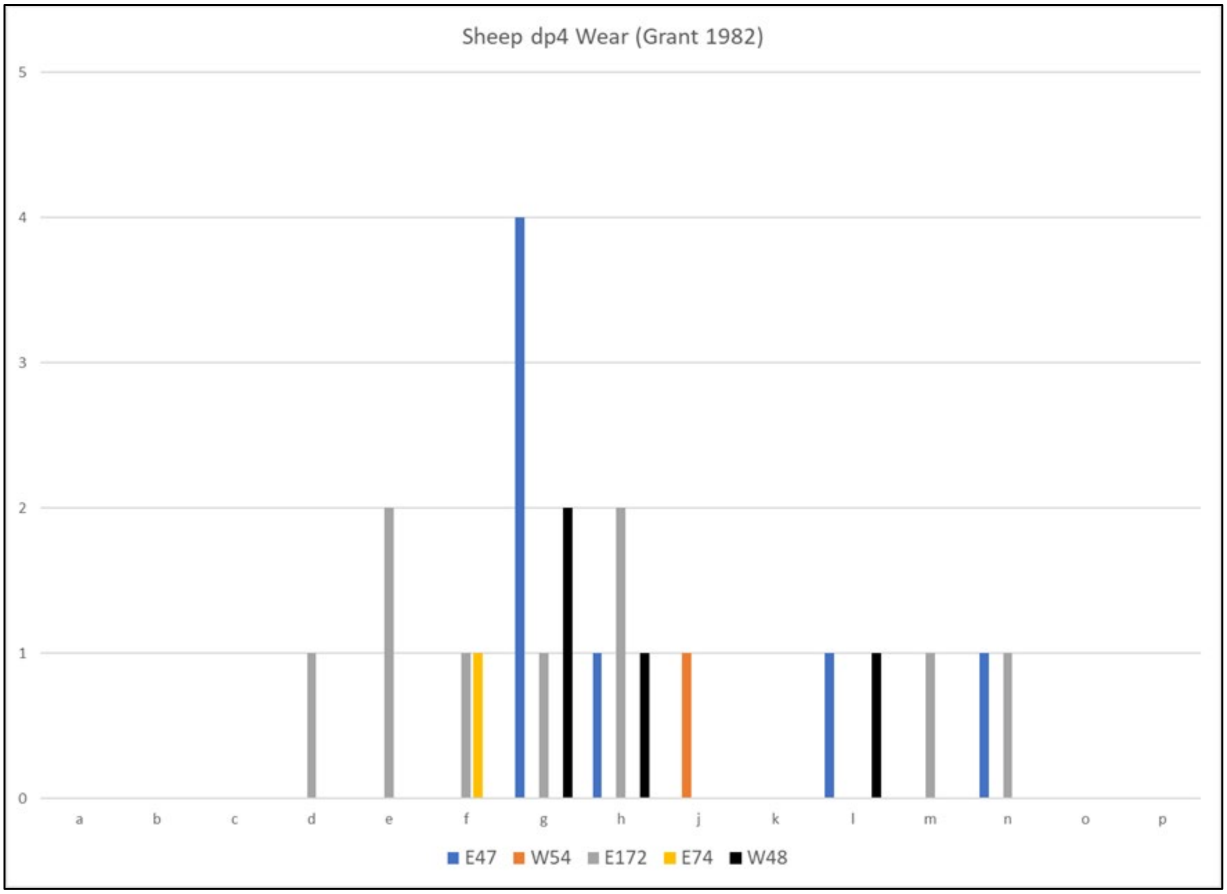


Figure 67 Sheep dp4 Tooth Wear.

Figure 67 above presents the dp4 wear analysis for the sheep teeth from the same sites. In this case the patterning suggests most of the pre-adult culling took place at the end of the first summer, with comparatively less mortality near the growth peak. This suggests that at W48 at least sheep were being managed differently from goats and underlines the contrast with the E172 management pattern.

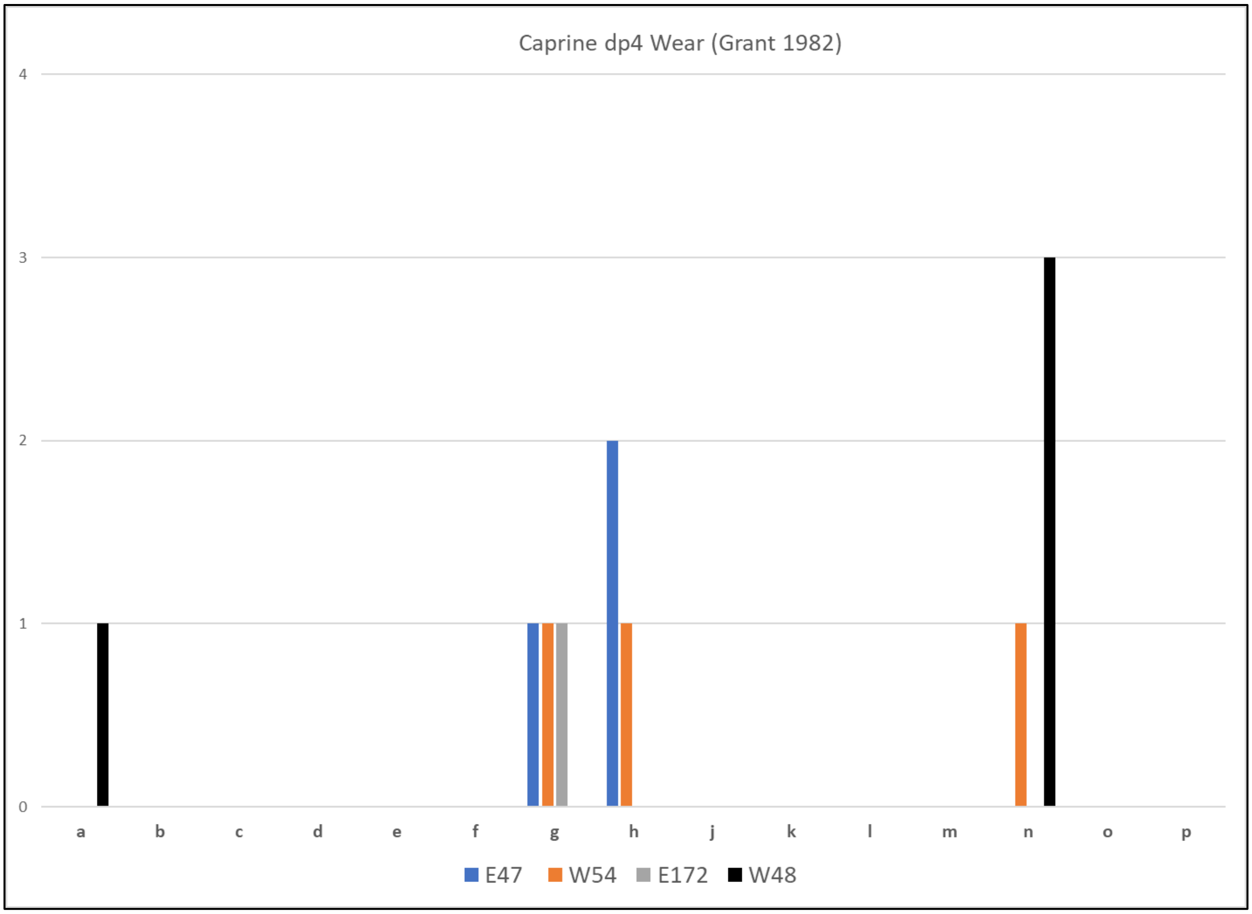


Figure 68 The dp4 wear patterns for the mandibles too fragmentary to be securely identified to species level and reported only as Caprines.

Figure 68 above presents the dp4 wear patterns for the mandibles too fragmentary to be securely identified to species level and reported only as Caprines. These less- identified specimens support the general patter of an end of summer cull and (at W48) a spike in mortality near the growth peak. Note that one very young caprine mandible does appear in the W48 collection.

Table 65 below presents the wear data using the Grant (1982) scoring system for the adult third molar (M3) for the same sites broken down to goat, sheep, and remaining caprine categories. Sample sizes again are small, but some general patterns are emerging.

Table 65 Grant tooth wear states for adult third molar (M3) for goats, sheep, and caprines.

	Grant Wear States															
Goats		**a**	**b**	**c**	**d**	**e**	**f**	**g**	**h**	**j**	**k**	**l**	**m**	**n**	**o**	**p**
M3	E47		1	1	1			1		1						
	E29N			1			1									
	E172			2	1	2	2	10	1							
	W48		1					1	1							
	W54							2								
Sheep		**a**	**b**	**c**	**d**	**e**	**f**	**g**	**h**	**j**	**k**	**l**	**m**	**n**	**o**	**p**
M3	E47		1			1		11	2							
	E172	1		1	1	4	3	3	2							
	E74															
	W48		1					3	1							
	W54		1	1			1						1			
Caprine		**a**	**b**	**c**	**d**	**e**	**f**	**g**	**h**	**j**	**k**	**l**	**m**	**n**	**o**	**p**
M3	E47															
	E172	3	2	2				6								
	W48							1								
	W54		1	2				5		1						

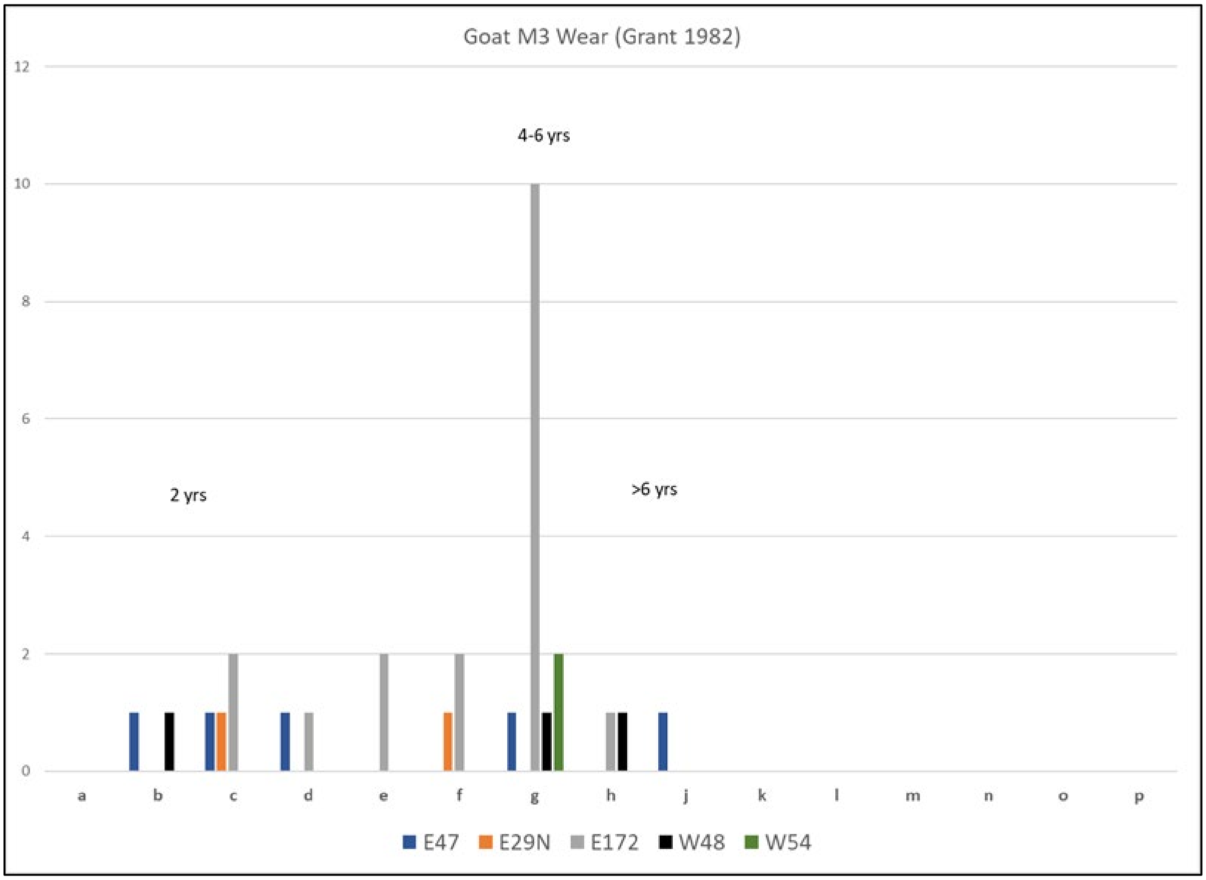


Figure 69 Goat M3 wear pattern, with age estimates again following Enghoff (2003).

Figure 69 above presents the goat M3 wear pattern, with age estimates again following Enghoff (2003). Some adult goats are being culled in their second year and there is an apparent peak in mortality around 4-6 when fertility drops off. A few individuals may have survived beyond this point, but there are no very old goats in this sample.

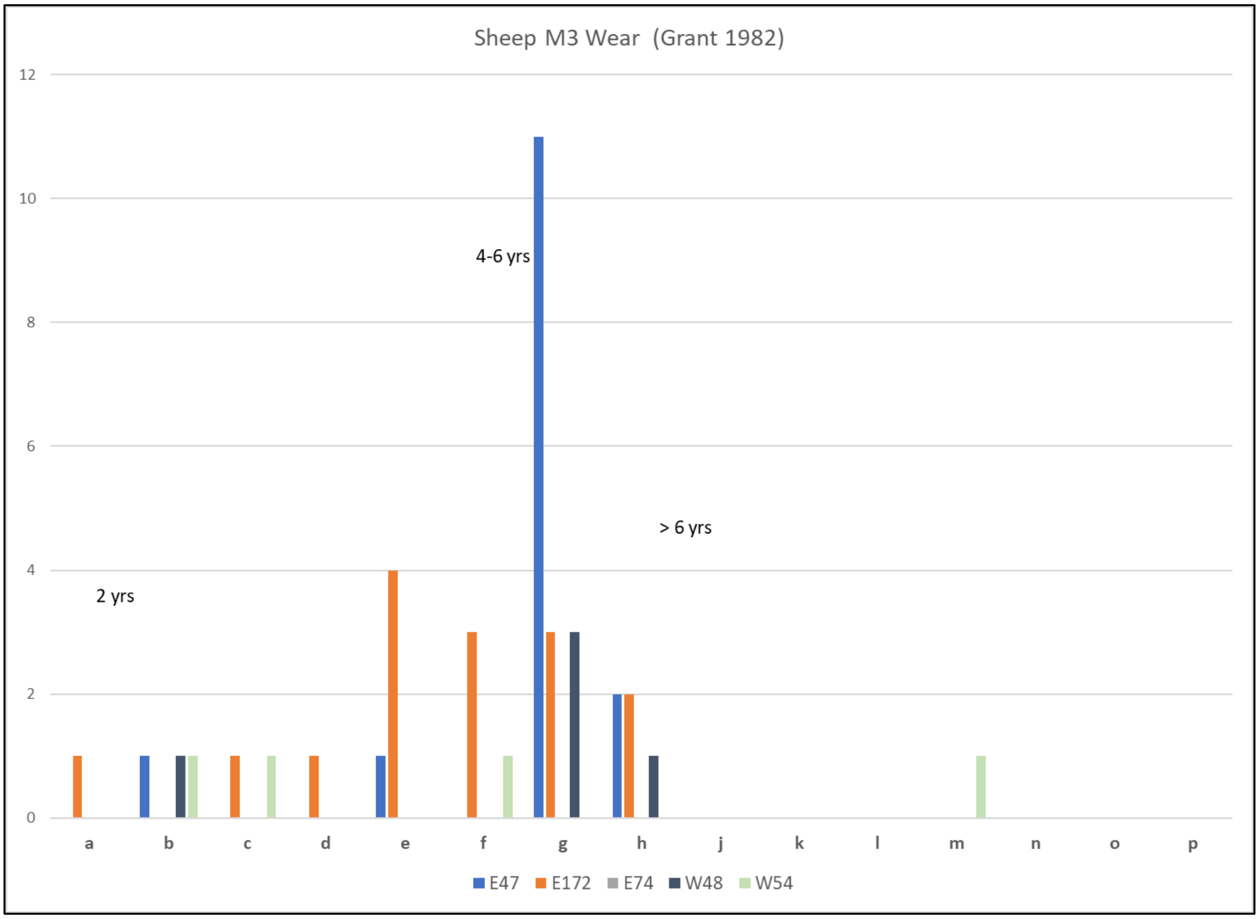


Figure 70 sheep M3 wear patterns with age assessment again following Enghoff (2003).

Figure 70 above presents the sheep M3 wear patterns with age assessment again following Enghoff (2003). The patterning suggests an occasional cull in the second to third year, followed by a peak in mortality in the 4–6-year range. Note that a few sheep seem to have survived well past their reproductive period, and thus may represent the old ewes or wethers associated with wool producing patterns in Iceland.

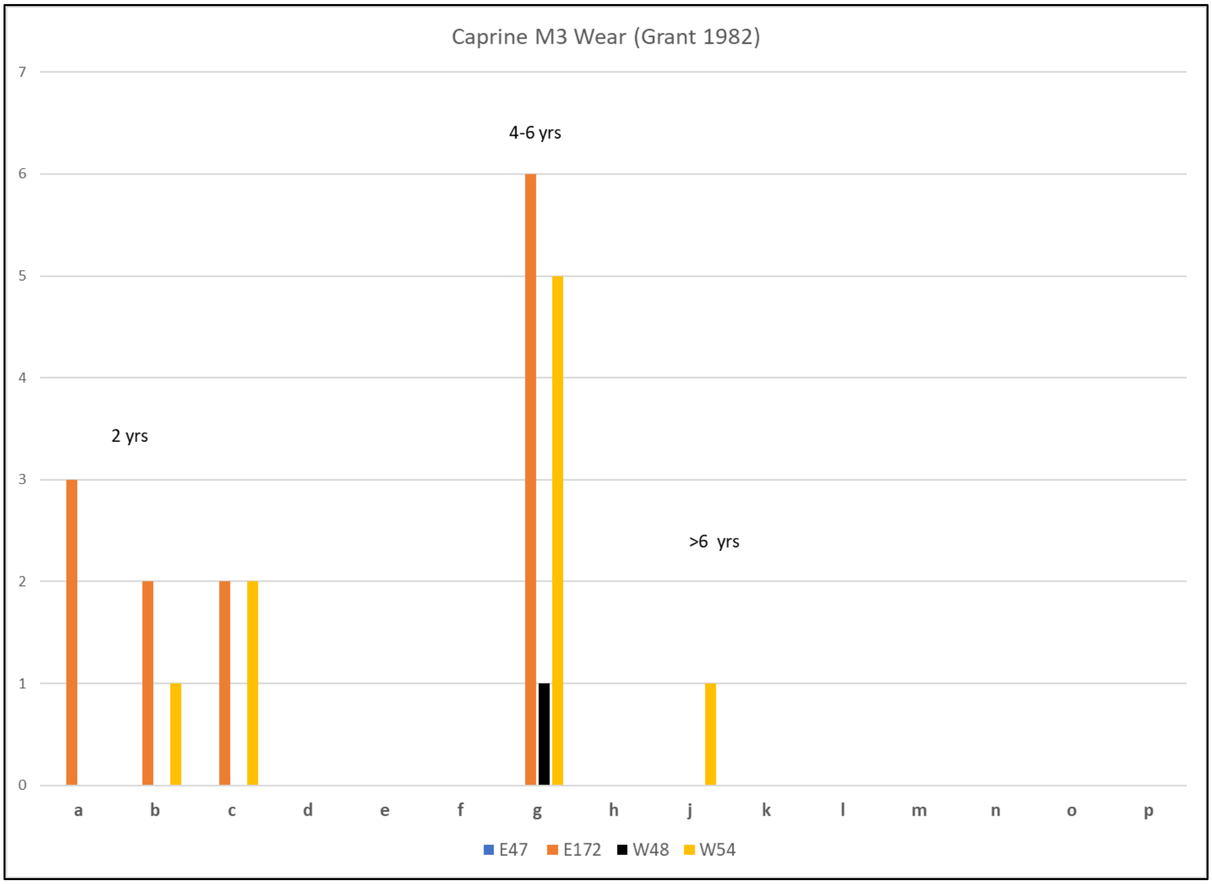


Figure 71 M3 wear patterns that could only be identified as Caprine, with age assessments following Enghoff (2003).

Figure 71 presents the wear patterns for the M3 that could only be identified as Caprine, with age assessments again following Enghoff (2003). As in the teeth identifiable to species, there is indication of a ca 2–3-year cull and a major mortality peak at 4-6 years, with a few individuals surviving past reproductive age.

Table 67 below presents the Caprine long bone epiphyseal fusion data for the newly analyzed Eastern Settlement archaeofauna, broken down where possible into Sheep (O), Goats (C) or

Caprine sp. Indeterminate (O/C). Pre-depositional attrition again sharply limits what can be done with these data to reconstruct age at death of sheep and goats in our sample, and none of the collections reaches quantifiable limits for this approach.

However, the general pattern of early fusing and later fusing elements supports the model of most caprines surviving their first 6-12 months, but with significant mortality peaking in the 3.5-4-year range. Age estimates for element fusion follow Enghoff (2003) with modifications from Popkin et al. 2012.

Table 66 Caprine long bone epiphyseal fusion data for the newly analyzed Eastern Settlement archaeofauna, broken down into Sheep (O), Goats (C) or Caprine sp. Indeterminate (O/C).

		E29N		E172		E47		E74	
Element	age est.	F	U	F	U	F	U	F	U
D Radius O	4-4.5 yrs	1	4	5					
D Radius C	4-4.5 yrs				2				
D Radius O/C	4-4.5 yrs			4		1	4	1	
D Femora	3.5 yrs	4	2	2	6	4	2	1	1
P Tibia	30-48 months			7	12			1	2
D Tibia	2 yrs	7	5	3	2	7	5		
D Metatarsus C	15-30 months					2	2		1
D Metatarsus O	15-30 months			4		1			
D Metatarsus O/C	15-30 months			1		2	4		
D Metacarpus C	15-30 months					1			
D Metacarpus O	15-30 months			1		2	3		
D Metacarpus O/C	15-30 months			1	4	1	4		
D Humerus O	6 -12 months	7		12	1	7		1	
D Humerus C	6 -12 months	1		3		1		1	
D Humerus O/C	6 -12 months	2	2	3	1	2	2	5	
O= sheep									
C= goat									
O/C= Caprine									

Due to the heavy pre-depositional fragmentation and very complete processing of long bones for marrow extraction (compounded by the Greenlanders failure to adopt the Shetland, Orcadian, Icelandic, and Faroese pattern of biperforating metapodials ca. AD 1150-1200, which preserves key measurable elements) there are very few measurable elements to report. Even normally durable and dense elements like distal humeri were regularly shattered during marrow and bone grease extraction, a pattern also observed by McGovern (1985) and Enghoff (2003). The surviving sheep and goat distal humerus breadth (Bd, all metrics follow Von den Driesch 1976) is presented in table 67 below.

Table 67 Sheep and goat distal humerus breadth (Bd, metrics follow Von den Driesch 1976).

Goat	Distal Humerus (Bd)					
Site	Phase	Species	Bone	End	Ref #	Bd
E 172	3	Goat	Humerus	distal	48	2.44
E 172	3	Goat	Humerus	distal	49	3.22
E47	1	Goat	Humerus	distal	M28	2.83
E47	1	Goat	Humerus	distal	M21	2.51
					mean	2.75
					range max	3.22
					range min	2.44
Sheep	Distal Humerus (Bd)					
Site	Phase	Species	Bone	End	Ref #	Bd
E47	1	Sheep	Humerus	distal	M7	2.66
E47	1	Sheep	Humerus	distal	M29	3.05
E 172	1	Sheep	Humerus	distal	41	3.65
E 172	1	Sheep	Humerus	distal	33	2.88
E 172	1	Sheep	Humerus	distal	34	3.18
E 172	1	Sheep	Humerus	distal	35	3.62
E 172	1	Sheep	Humerus	distal	36	2.79
E 172	1	Sheep	Humerus	distal	37	3.30
E 172	1	Sheep	Humerus	distal	38	2.59
E 172	3	Sheep	Humerus	distal	47	2.83
E 172	1	Sheep	Humerus	distal	52	2.81
E 172	1	Sheep	Humerus	distal	53	3.76
					mean	3.09
					range max	3.65
					range min	2.59

Table 68 below presents a comparison between the sheep and goat distal humerus Bd measure between the newly reported Greenlandic archaeofauna and a large Viking Age Icelandic archaeofauna from Hrísheimar in the Myvatn district (McGovern et al. in progress). While small sample sizes again limit conclusions, the Greenlandic sheep and goat metrics fall within the range of the Icelandic sheep and goat on this element.

Table 68 Sheep and goat distal humerus Bd.

Sheep			
Distal Humerus (Bd)		mean	3.09
E47 & E172 (Greenland)		range max	3.65
		range min	2.59
		n=	12
Distal Humerus (Bd)		mean	2.84
Hrisheimar (Iceland)		range max	3.43
		range min	2.27
		n=	106
Goat			
Distal Humerus (Bd)		mean	2.75
E 172 & E47		range max	3.22
		range min	2.44
		n=	4
Distal Humerus (Bd)		mean	3.06
Hrisheimar (Iceland)		range max	3.42
		range min	2.30
		n=	5

Table 69 below presents the six metapodials (metatarsus and metacarpus) that allow calculation of the live withers height (Teichert 1975, following Enghoff 2003).

Table 69 Metapodials (metatarsus and metacarpus) that allow calculation of the live withers height (Teichert 1975, following Enghoff 2003).

Sheep Metacarpus		n =3							withers ht.
Site	Phase	Species	Bone	Ref#	Bd	SD	GL	Bp	(GLx4.89)
E29N	22	Sheep	Metacarpus	2	2.56	1.48	12.29	2.30	60.10
E 172	1	Sheep	Metacarpus	12	2.40	1.12	11.21	1.96	54.81
E 172	1	Sheep	Metacarpus	7	2.60		10.48		51.27
Sheep Metatarsus		n =3							withers ht.
Site	SU	Species	Bone	Ref#	Bd	SD	GL	Bp	(GL x 4.54)
E 172	1	Sheep	Metatarsus	15	2.12	0.99	11.82	1.82	53.67
E 172	1	Sheep	Metatarsus	16	2.15	0.99	11.61		52.70
E 172	1	Sheep	Metatarsus	17		1.11	13.64	2.07	61.93

Table 70 below presents a comparison between reconstructed withers heights for two Viking Age sites in the Myvatn district in Iceland with the new Greenlandic sample and the GUS sheep (Enghoff 2003).

Table 70 Reconstructed withers heights for two Viking Age sites in Myvatn district in Iceland with the Greenlandic sample.

Sheep Withers Ht. Measure (Teichart 1975)						
Metatarsus Withers Ht. (cm)						
		n	mean	range max	range min	data
Iceland	Sveigakot 3	28	63	70	57	McGovern et al. 2009
	Sveigakot 1	2	63	64	62	McGovern et al. 2009
	Hofstadir II-III	21	60	69	54	McGovern et al. 2009
	Hofstadir I	8	62	68	58	McGovern et al. 2009
		n	mean	range max	range min	
Greenland	E 172	3	56	62	53	this thesis
	GUS	7	60	67	53	Enghoff 2003
Metacarpus Withers Ht. (cm)						
		n	mean	range max	range min	
Iceland	Sveigakot 3	24	60	70	56	McGovern et al. 2009
	Hofstadir II-III	12	61	68	57	McGovern et al. 2009
	Hofstadir I	6	62	67	58	McGovern et al. 2009
		n	mean	range max	range min	
Greenland	E 172	2	53	55	51	this thesis
	E29N	1	60			this thesis
	GUS	8	59	62	56	Enghoff 2003

Enghoff (2003) again presents a very thorough discussion and documentation of comparative size of sheep in the two settlement areas and draws some comparisons with then available Icelandic and Danish data sets. Her main conclusions that Greenlandic sheep and goats tended to fall within the lower size range of contemporary Scandinavian caprines seem to be supported by the smaller new samples presented here.

5.10.3 Pigs

As noted above pigs were part of the domestic mammal "Landnám package" that crossed from Iceland to Greenland. Pigs are present in 19 of the 59 current collections, and as table 71 below indicates they do not become extinct in the later phases (contrary to prior assumptions).

Table 71 Ubiquity Measures of Pigs at all Greenlandic sites.

Sites in sample	59	8	13	11	27
Phase	All Collections	EARLY PHASE	MIDDLE PHASE	LATE PHASE	UNSTRATIFIED
Est.time range (CE)	980-1450	980-1160	1160-1300	1300-1450	?
Pig	19	4	9	3	3

In Iceland, pigs are strongly associated with the Viking Age period, and do become rare in archaeofauna from later time periods, though documentary sources refer to late medieval pigs on some manor farms (Árni Daniel Juliusson pers. Com. 2019). Pigs require either extensive woodlands or wetlands for free range pannage or resources for stall feeding, and in practice most European pig raising strategies combined pannage and stall feeding (Kreiner 2020). While pig keeping may have initially been a low-cost way of rapidly producing meat in a forested environment, by the time the early medieval Grágás law code was written in Iceland pigs were clearly seen as "problem animals" prone to damage crops and infield grazing and likely to cause friction between neighbors.

In Iceland, accounts of feral pigs surviving on their own in the early settlement period are known in several stories apparently recognizing post-settlement environmental change (Vidar Hreinsson, pers com), but in Greenland it is harder to imagine even tough and agile medieval pigs surviving outdoors in winter. As part of the Comparative Island Ecodynamics project in 2006 five pig bone samples from E29N were submitted for C and N isotopic analysis to the Scottish Environmental Research Center (SUERC) in East Kilbride. The results of the SUERC analyses are presented in table 72 below (data courtesy of Kerry Sayle) and combined with the analysis results from four pigs conducted by Nelson et al. (2012) as part of the large Greenland Isotopes Project. As Nelson et al. note, the dC13 scores of most of the pigs seem to indicate at least partly marine diet, though some of the E29N pigs seem somewhat more in the terrestrial food web. These findings are similar to stable isotope work on the Faroese and Icelandic pigs (Ascough et al. 2006), which also showed a mix of marine and terrestrial food web with some individuals clearly being fed fish or marine mammal waste. Pig keeping in Greenland probably involved substantial stall feeding and given the absence of cereal agricultural waste and evidence for very complete processing of meat residue by humans this would seem something of a status/ luxury strategy for most households.

Table 72   Pig Carbon and Nitrogen Isotope Measurements from new sites.

Pig Stable Isotopic Data			
Source	Site & Sample	d13C(cf)	d15N(cf)
SUERC	E29N 81	-21.6	3.4
SUERC	E 29N 063	-20.8	12.5
SUERC	E29N 1 061	-19.5	11.6
SUERC	E29 N 2 061	-18.9	12.3
SUERC	E29R 3 061	-18.9	12.3
Nelson et al. 2012	E17a 80	-17.2	11.7
Nelson et al. 2012	E167 81	-17.2	9.2
Nelson et al. 2012	E47 308	-17.2	11.6
Nelson et al. 2012	E47 309	-16.2	12.3

Figure 72 below presents the pig % of domestic mammal NISP for the phased collections in the three time periods. Pigs are present on a range of sites (not all high status), but the early and middle phase collection from W51 Sandnes at present seems unique in terms of pig consumption.

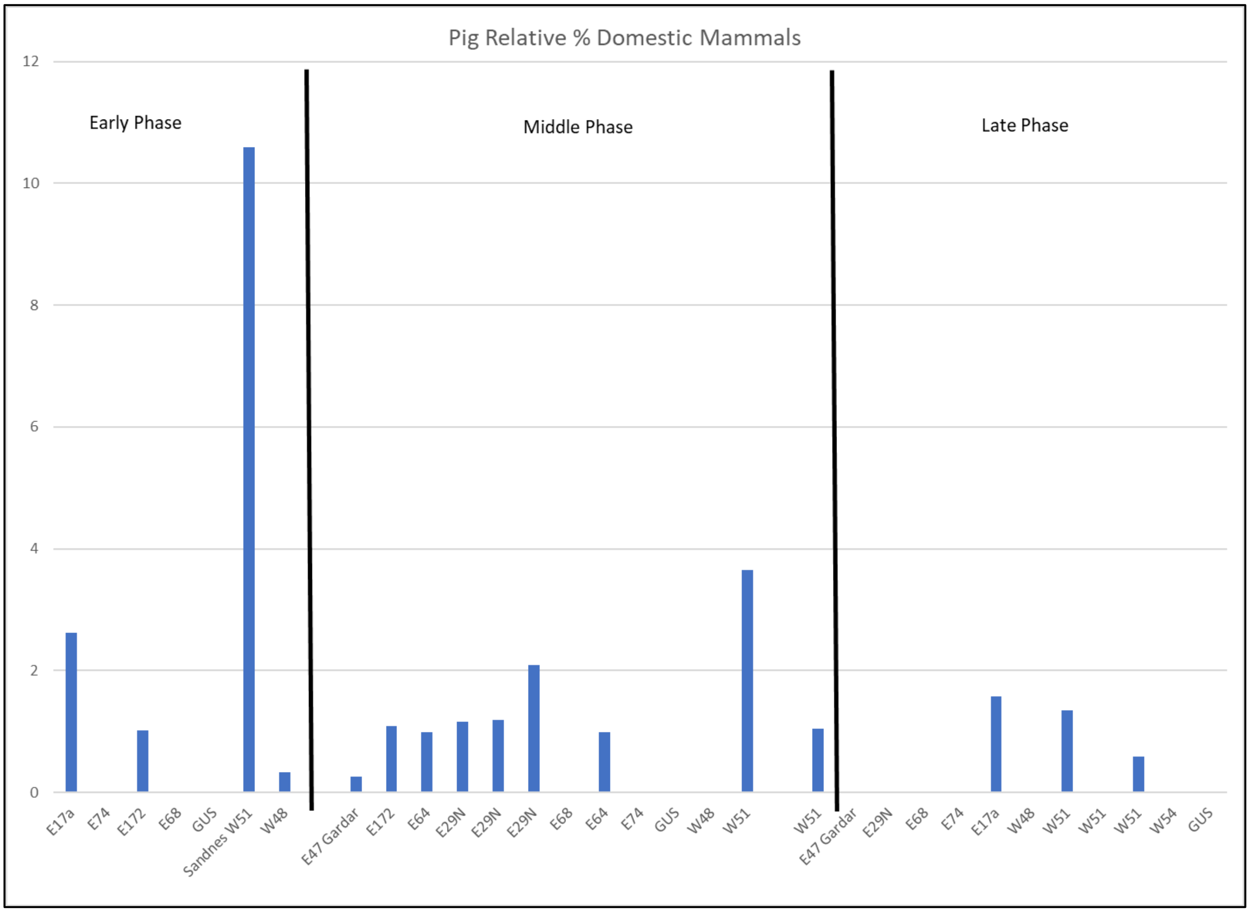


Figure 72 Pig % of domestic mammal NISP for the phased collections in the three time periods.

As observed by Degerbøl (1936) pig bones in Greenland come from cranial as well as post-cranial elements, suggesting local pig keeping rather than the importation of pork with bones. The available age at death data further suggests local pig rearing in Greenland. Neonatal (suckling) pig bones are found in three collections W51 Phase 1 (30% of pig bones), E17a Lower (40% of pig bones) and E17a Upper (20% of pig bones). As noted above, the harsh pre-depositional attrition on Greenlandic Norse sites would strongly select against the survival of these small and less completely calcified bones, so these figures probably under-estimate the proportion of pigs consumed as very young animals. Tooth rows are exceptionally rare, with one specimen (# 588) from E172 showing an adult premolar in wear (Grant stage b) and the first molar at stage e, indicating a younger mature adult. The other fragments recovered mainly suggest a mix of adult and juvenile pigs. No measurable fragments have been recorded, but the general conformation is very like the Icelandic Viking Age pigs- relatively small, long snouted, long-legged animals similar to other NW European breeds. When some Greenlandic and Icelandic pig bones were submitted as part of a large-scale ancient DNA project focused upon pig domestication and spread, the two were seen as genetically indistinguishable (Frantz et al. 2019).

Pig keeping in Greenland was expensive in comparison with Iceland or Scotland, and while summer pannage may have been possible in and around wooded areas pigs would also represent a threat to fertilized infields, nesting birds, and any attempts at cereal agriculture. Even more than in medieval Iceland, Greenlandic pigs would appear to be "problem animals" capable of generating both prestige and conflict for their owners. Given the availability of fat-rich seal carcasses the survival of piggery in Greenland appears to be more about status and prestige markers rather than nutrition or effective land use.

5.10.4 Horses

Horse bones are present in low frequency on many Norse Greenlandic collections, as table 73 below indicates. The largest number of horse bones currently come from the GUS site in the Western Settlement (NISP 26), and as Enghoff suggests these may come from partial articulations, one of which showed signs of skinning (Enghoff 2003:75). As demonstrated by Enghoff (2003) and Degerbøl (1936) on larger samples the Greenlandic horses are very similar to their Icelandic relatives and are almost certainly direct descendants. The newly available horse remains from E47, E 172 and E29N are mostly loose teeth, one premolar from E172 Phase 1 showing bit wear from harnessing. The teeth are generally heavily worn, suggesting fairly old animals at the end of their service. An unfused femora and tibia from E172 Phase 1 indicate young adult animals were also sometimes culled. Unlike some of the Viking Age horse remains from Iceland there are no signs of butchery for consumption.

Table 73 Horse Ubiquity Measures at all Greenlandic sites.

Sites in sample	59	8	13	11	27
Phase	All Collections	EARLY PHASE	MIDDLE PHASE	LATE PHASE	UNSTRATIFIED
Est.time range (CE)	980-1450	980-1160	1160-1300	1300-1450	?
Horse	20	3	6	3	8

5.10.5 Dogs and Cats

Dogs were also kept by both the Icelanders and Greenlanders, and some cat remains have also been recovered from Iceland (Prehal 2015, 2021, McGovern et al. 2013). Their remains are rare in most midden deposits, and it would appear that they were only occasionally eaten by Norse Greenlanders, if at all.

A significant exception are the repeated finds of partially articulated dog skeletons in the terminal floor deposits in multiple Western Settlement sites that appears to be an abandonment phenomenon (McGovern 1982, McGovern et al. 1983, Buckland et al. 1995). Dogs in Iceland in the Viking age were closely similar in size and conformation to the modern Icelandic sheep dog, but there was apparently a brief fashion for small lapdogs in the high Middle Ages (Harrison 2015).

In Greenland Degerbøl identified both sheep dog sized, and much larger dog remains and suggested that the larger dogs (in conformation probably similar to modern Irish wolfhounds) would have been used as hunting aids for caribou or possibly walrus (for an imaginative reconstruction of a dog-aided walrus hunt see the *Scientific American* cover, Zorich 2015). Large dogs would be expensive to maintain, and in Iceland dogs were apparently sometimes killed to free provisions for humans during times of famine (Hreinsson pers.com. 2013, McGovern et al. 2013). Both dogs and horses were certainly working animals in Norse Greenland and must have justified their consumption of meat and fodder.

Figure 73 Artist representation of the Norse walrus hunt, using dogs. Painting by Tyler Jacobson.

5.11 Comparative Interdisciplinary Evidence for Norse Farming

Beyond the zooarchaeological bone data we are now able to integrate a range of studies including tooth micro-wear (Mainland 2005), stable isotopes (Arneborg et al. 2012), soil science, palaeoentomology, and geoarchaeology (Adderley and Simpson 2006, Simpson et al. 2002, 2005, Buckland et al. 2009, Panagiotakopulu and Buckland 2012, Panagiotakopulu et al. 2012) local and regional scale paleoecology (Bishop et al. 2013; Guillemot et al. 2015; Fredskild 1973, 1983, Schofield and Edwards 2011, Schofield et al. 2008, 2010, Ledger et al. 2013, 2014a, 2014b, Massa et al. 2012) and increasingly complete survey of Norse ruins and landscape features (Madsen 2014, 2019). These sources have greatly extended the debates on Norse farming practices in Greenland and especially on the level of environmental impact these may have caused over time.

It is clear that early models (e.g., McGovern et al. 1988, Vebæk 1943) that assumed a widespread grazing and rangeland degradation pattern in Norse Greenland comparable to medieval and early modern Iceland are in need of revision, and the zooarchaeological evidence needs to be considered in the light of these additional data sets. While there is definite evidence of intense erosion in the E64c/ Igaliku Kujalleq area due to strong foehn winds from the inland ice, this now appears to be a somewhat limited phenomenon. As noted by Guillemot et al. (2015), Ledger et al. (2014), Perrin et al. (2012) and Massa et al. (2012) the expanded pollen, spore, and microcharcoal record from several new lake and bog cores do show a clear Landnám impact in the reduction of arboreal pollen (suggesting some deforestation) and an uptick in coprophilic spore deposit (suggesting increased herbivore presence) and grass pollen. However, there is also evidence for continued shrub cover (that may have been maintained to manage snow cover / accumulation of snowbanks for irrigation water in summertime) and relatively limited soil erosion impacts in the immediate vicinity of the Norse farmsteads in most cases.

As Bishop et al. (2013) summarize:

> *Moreover, close examination of the local and regional pollen evidence from South and West Greenland, reveals that woodland/ scrub destruction was not widespread at landnám and that a complex pattern of vegetation changes occurred between landnám and the present day. Recent pollen analyses of peat profiles and lake sequences with high-resolution radiocarbon dating have shown that woodland/scrub clearance at landnám was rapid around the Norse farm site of E2 (Edwards et al., 2008) and in the surrounding region of Lake Igaliku in the Norse Eastern Settlement (Gauthier et al., 2010), suggesting a direct human cause for woodland/scrub decline. In contrast, a small reduction in birch woodland/scrub around the Norse farm at E39 at landnám, was followed by an increase in birch, which was sustained at a relatively high level throughout the Norse settlement, suggesting that woodland/scrub may have been deliberately preserved by the Norse settlers* (Schofield and Edwards, 2011). Bishop et al. (2013: 3895-3896)

Norse settlers in Greenland, like their Icelandic contemporaries, managed surviving woodlands and that the use of woodlands for fodder and fuel was probably actively regulated. The account of Ívar Bárðarson lists a woodland near the bishop's manor as part of church property and probably reflects a pattern of resource ownership better documented in medieval to early modern Iceland (Guðmundsdóttir 2022; Pinta 2021).

These findings connect to geoarchaeological work focusing on Norse homefield management through both irrigation and soil amendment (Adderley and Simpson 2006) and Panagiotakopulu and Buckland (2012a, 2012b) indicate a major investment in both water control and homefield soil amendment at the bishop's manor at Garðar E47. Norse farmers (perhaps especially ecclesiastical elites) seem to have been willing and able to invest considerable labor in vegetation and soil conservation around the farmstead.

Archaeological excavation in both settlement areas have documented thick mats of willow and birch twigs used as floor covering within Greenlandic Norse houses in human spaces as well as in stock rooms, and these are regularly recovered in midden deposits outside (often containing mouse and insect remains from indoor habitats, Buckland et al. 1994). These twig floors were regularly renewed and were *in situ* at abandonment in most excavated sites (Roussell 1941) providing further evidence of surviving scrub woodlands accessible to the Norse householders, and perhaps casting doubt on the assumption that an increase in scrub means farm abandonment.

These new perspectives on Norse woodland and landscape management require some re-evaluation of the zooarchaeological evidence for stocking, and especially caprine management. Ingrid Mainland's (2006) dental microwear analysis on a large sample of Greenlandic sheep and goat tooth rows indicates considerable grit and soil ingestion from ca. 1150 CE onwards, and she concludes that:

> *It is argued that these results provide further evidence that maladaptive grazing practices led to a decline in the viability of pastoral farming in Greenland, and, moreover, that overgrazing did not merely occur towards the end of the settlement as a consequence of the worsening climate of the "Little Ice Age" but rather was present in both Western and Eastern Settlement from a relatively early date.* Mainland (2006:238)

As noted above, a large- scale analysis of sheep and goat husbandry in Greenland by Mainland and Halstead (2005) indicated that the overview by McGovern (1995) tended to under-estimate the actual proportions of goat relative to sheep, underlining the potential for goat-induced deforestation impacts. As Mainland and Halstead note, the FARMPACT model (McGovern 1995) estimates of actual numbers (rather than relative proportions of identified bones) of cattle, sheep, and goats (ultimately based on byre capacity) by status modeled a flock of ca 30 sheep and goats for low-ranking farms and ca 55-60 for middle ranking farms. If we assume that most or all known

Norse sites are in fact full farmsteads occupied by up to 5,000 humans, the modeled numbers of Norse livestock begin to look potentially unsustainable. However, Madsen (2014) has demonstrated that many registered sites are in fact probably seasonal shielings of one type or another, and we should thus revise our modeled total human population and livestock estimates significantly downwards. The current landscape use model suggests very high summer mobility for caprine flocks, probably with extensive movement away from homefields and often into highlands and more marginal grazing away from the managed hay fields and perhaps managed woodlots.

In this landscape management model, caprines will be moved well away from managed homefields and woodlots in summer and probably kept in one or more upland or distant shielings. This may regularly have exposed the sheep and goats to thin soils and patchy vegetation cover leading to soil ingestion and abrasive grazing conditions without necessarily impacting the homefield or woodlot areas. With close shepherding and regular movement, it may also have been possible to reduce permanent damage to the more marginal upland areas and exploit extensive areas of limited vegetation cover if sheep and goat flocks were in fact small enough to be moved from one summer grazing area to another. In this modeled system, managed infields (sometimes irrigated and heavily amended), conserved woodlots, and carefully balanced upland grazing areas would all form part of a seasonally adjusted system requiring considerable labor investment and understanding of local landscape potentials and resilience. Climate fluctuation (especially shortened summer growing season) would certainly impact this system and may have been another critical point for the disruptive effects of increasing climate variability on local and traditional knowledge systems (Jackson et al. 2018).

CHAPTER 6: Interpreting Change in Norse Greenland Paleoeconomy

6.1 Climate Change and Zooarchaeology in Norse Greenland

The aim of this chapter is to present and interpret current zooarchaeological evidence for Norse human ecodynamics, and thus it will only present what appears to be a broad consensus view of climate change in the Norse period while focusing on zooarchaeological evidence for Norse adaptive responses

The climate of SW Greenland is subject to changes in the volume of warm North Atlantic drift water reaching the Northern North Atlantic and associated thermohaline circulation patterns as well as atmospheric fluctuations in the North Atlantic Oscillation (NAO) (see Dawson et al. 2007 for description of relevant ocean-atmosphere-cryosphere interactions). The multiple Greenland Ice cores now supplemented by a range of multi-proxy indicators has allowed a set of high-resolution reconstruction of climate fluctuation on the "human scale" of years and decades (Dugmore et al. 2007, 2013; Miller et al. 2012).

Key economic and food security variables for the Norse communities that would be affected by climate change would have been summer temperatures, length of growing season, length of winter feeding of stock, persistence of winter snow cover, sea ice conditions, and changing storminess. While all of these factors are impacted by climate fluctuation, current research indicates that the statement "it got cold, and they died" is far too simple to account for the complex patterns of shifting vulnerability, differential impact, and societal response in Norse Greenland. Early applications of climate determinism to the case of Norse Greenland have been fully critiqued (Arneborg 2003, McGovern 1992) and focus has shifted towards understanding Norse social and economic adaptation to Greenland's always fluctuating climate as a complex story of long-term human ecodynamics.

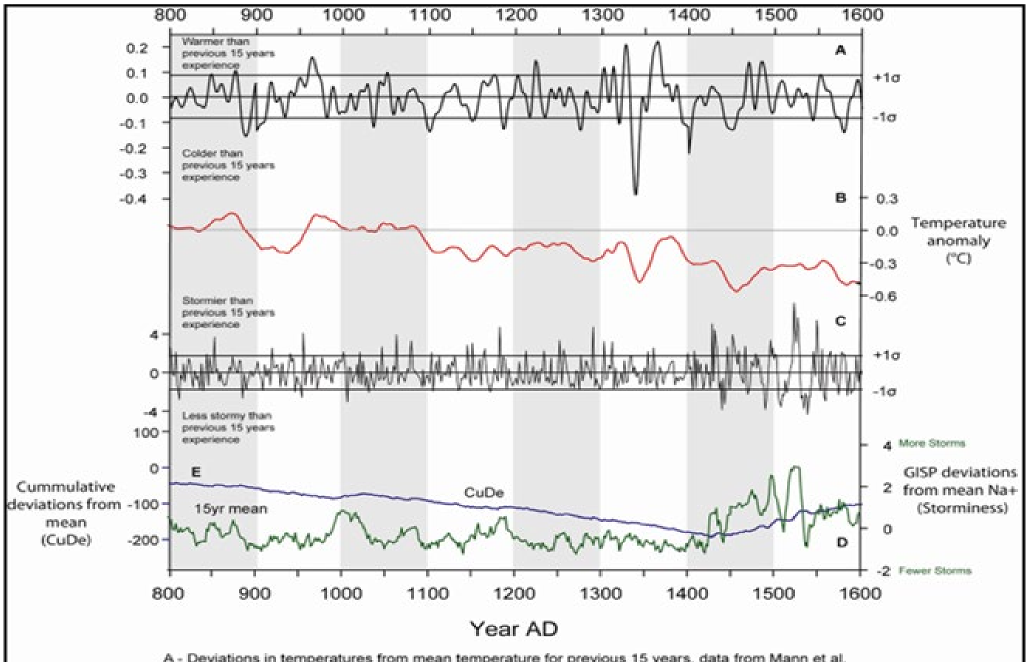
The first centuries of Norse settlement in Greenland saw some climate variability but did not see significant summer drift ice in the Denmark Strait area, and sea ice was probably rare in Iceland in the Viking age (Ogilvie et al. 2008). In 1257 a major volcanic eruption of the Samalas volcano on Lombok in modern Indonesia seems to have set in motion a series of changes in North Atlantic temperature and circulation systems that would ultimately mark the transition between the "Early Medieval Climate Anomaly (aka Medieval Warm Period, MWP)" and the "Little Ice Age LIA" (Miller et al. 2012). As Dawson et al. (2008) stress, current evidence indicates a two-step process with rapid cooling at the end of the 13th century into the early 14th century followed by a significant increase in storminess ca 1425-50. It should be noted that neither the MWP or the LIA were periods of uniform warm or cold conditions, and both periods showed considerable inter-annual variability (Ogilvie et al. 2009). Norse settlers in the Viking Age and early Middle Ages thus had to immediately adapt to longer colder winters than their relatives in Iceland, and their economy had to have been resilient in the face of significant inter-annual and inter-decadal fluctuations even before the changes at the end of the 13th century.

The period ca. 1260-1300 seems to mark a major transition in both temperature and sea ice in SW Greenland, with the first onset of summer sea ice and increase in ice in all seasons in Denmark Strait. The mid-13th century *King's Mirror* account again provides information on the impact on navigation:

As soon as one has passed over the deepest part of the ocean, he will encounter such masses of ice in the seas, that I know of no equal of it anywhere else in all the earth. Sometimes these ice fields are as flat as if they were frozen on the sea itself... There is more ice to the northeast and north of the land than to the south, southwest, and west; consequently, whoever wishes to make the land should sail around it to the southwest and west, till he has come past all those places where ice may be looked for and approach the land on that side. It has frequently happened that men have

> *sought to make the land too soon and, as a result, have been caught in the ice floes. Some of those who have been caught have perished; but others have got out again, and we have met some of these and have heard their accounts and tales. But all those who have been caught in these ice drifts have adopted the same plan: they have taken their small boats and have dragged them up on the ice with them, and in this way have sought to reach land; but the ship and everything else of value had to be abandoned and was lost. Some have had to spend four days or five upon the ice before reaching land, and some even longer. (*Larsen 1917, *The King's Mirror-Speculum Regale-Konungs Skuggsjá:*138–139.)

Figure 74 below created by Dugmore (Dugmore et al. 2007) makes use of climate multi-proxy data sets (Mann et al. 2009) to display changing temperature variability and changes in sea-salt Sodium record (proxy for storminess) with a filter showing periods colder or warmer than the previous 15 years' experience as a measure of the impact on local and traditional management and human adaptation strategies. The cooling combined with increased inter-annual variability after ca. 1300 is evident, as is the increase in storminess after ca. AD 1425.



A - Deviations in temperatures from mean temperature for previous 15 years, data from Mann et al. 2009. B - Multi-proxy weighted reconstructed SST from North Atlantic Region, Mann et al. 2009. C - Deviations in storminess from mean of previous 15 years of storminess from Na+ in GISP. D - Records of North Atlantic storminess (Na+) from the GISP ice core E - Cummulative deviations from the mean of storminess from the GISP ice core, Dugmore et al 2007.

Figure 74 Potential effect of changing temperatures (B) on human LTK memory (A) as reflected as years warmer or colder than the past 15 years. The lower graph C and D reflect the Sea Salt Sodium proxy record of changing storminess with similar 15-year deviations from the mean. Figure from Dugmore et al. 2007

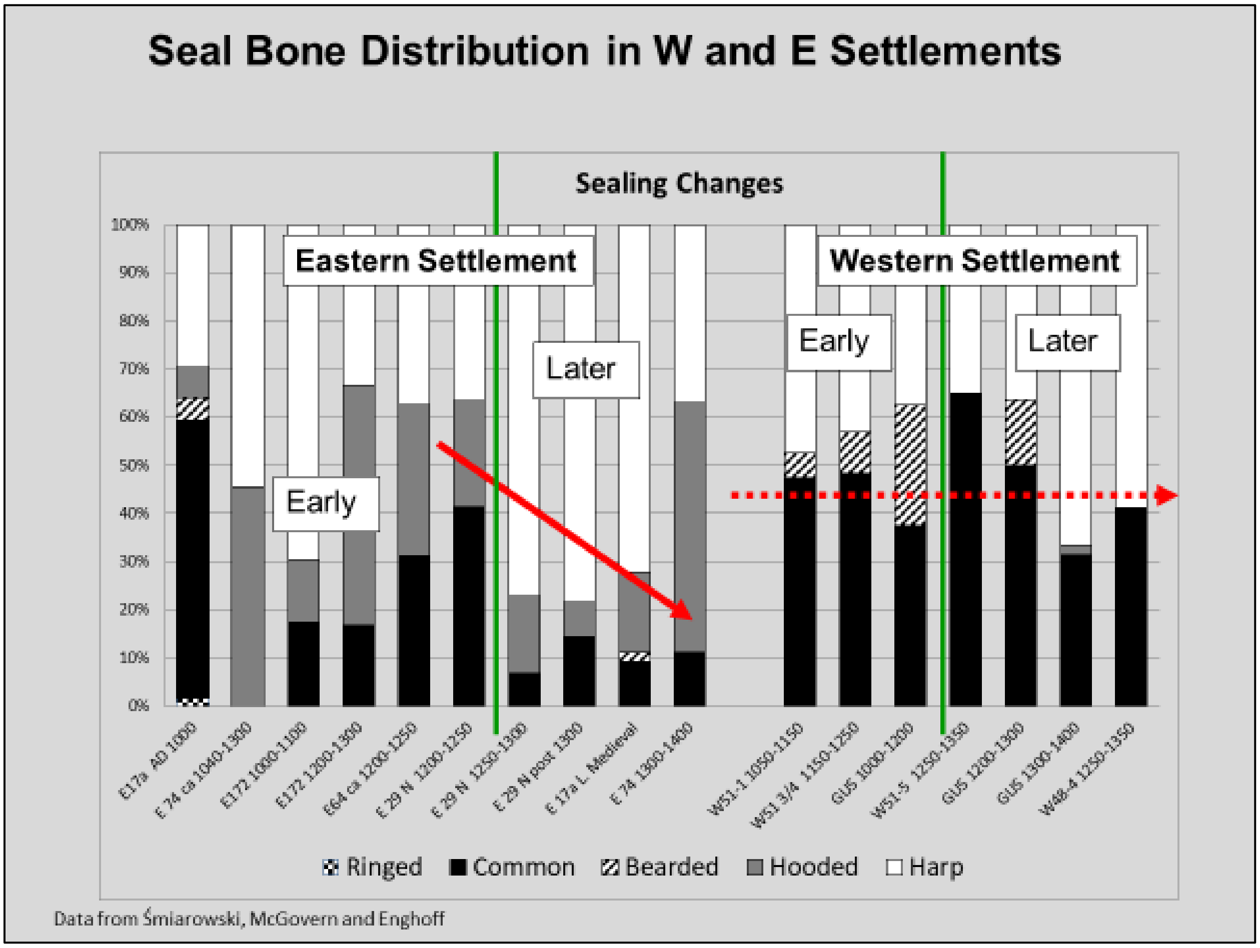
In terms of the three-part phasing model used in this thesis, the critical shift in climate would thus begin at the end of the Middle Phase and intensify in the second half of the Late Phase. While different parts of the current zooarchaeological record arguably reflect Norse adaptation to climate impacts, probably the clearest direct zooarchaeological evidence for change ca 1300 AD is in the shifting patterns of seal hunting in the Eastern Settlement (Ogilvie et al. 2009).

6.2 Seals and Climate Change: The Zooarchaeological Evidence

Seals respond to changes in marine and near shore climate conditions and a key variable for Greenlandic seals is the presence or absence of summer drift ice. Harbor / Common (*P. vitulina*) seals are near the northern limits of their range in Greenland. Adults are capable of withstanding winter icing and cold, but pups are vulnerable to sea ice in summer, so the onset of the current pattern of summer *stor-is* drift ice coming into the Eastern Settlement area from East Greenland should have had an impact on these seals. As discussed in chapter 5 above, 20th century seal catch records (*Fangslister*) from the former Eastern Settlement area in fact show only small numbers of harbor/common seals taken under the recent regime of extensive summer drift ice.

Figure 75 Harbor/Common seal. Photo by Leif Inge Åstveit.

Changes in frequency of bones from Common/Harbor seals in the Eastern and Western Settlement phased collections is illustrated in Figure 76 below (updated from Ogilvie et al. 2008). The red trend line indicates the reduction in Common seal proportions in the post-1300 Eastern Settlement collections. The Western Settlement archaeofauna (not affected by summer drift ice at any period) do not show a comparable reduction in Common seals. These patterns suggest that while Norse management of the pupping beaches may have remained successful (note that Common seals do not become extinct in the Eastern Settlement), but the impact of climate change on summer sea ice seems to have put these seal colonies under stress. Late phase Eastern Settlement hunters thus probably had to concentrate even more fully on the migratory Harp and Hooded seal populations probably less impacted by sea ice. After the abandonment of the Western Settlement ca 1350-1400 Norse sealing was increasingly dependent upon the migratory Harp and Hooded seals.



Data from Śmiarowski, McGovern and Enghoff

Figure 76 Changing seal bone NISP % in the two settlement areas after ca. 1300 AD.

6.3 Comparative Evidence for Diet and Climate Change Adaptations

While zooarchaeology can provide proxy evidence for past human diet, nutrition, and food security, the most direct evidence comes from human bioarchaeology and especially the newly available ancient DNA, biomolecular, and stable isotopic studies that have been applied to Norse Greenlandic human skeletal populations. This area of research is ongoing under the leadership of Jette Arneborg and Niels Lynnerup (overview in Arneborg et al. 2012) and this section provides a working summary of a rapidly expanding research area as it relates to the current zooarchaeological record. The author is grateful to these scholars for sharing and updating data on the project.

Human osteological research on Norse Greenlanders extends back to the early 20th century and generated controversy over supposed "degeneration" of the population through time (see discussion of research history in Lynnerup 2014). Lynnerup's doctoral thesis (1998) provided a still invaluable overview of then-accessible Norse human skeletal material and noted that many skeletons showed evidence of a life of hard labor and probably occasionally significant impairment by injury and arthritis, but little evidence of severe malnutrition or developmental issues. Halfmann et al. (1992) reported marked maxillary hypertrophy and formation of "tori" around both mandibular and maxillary tooth rows. Scott et al. (2008) documented wear patterns on Norse teeth indicative of use of teeth in yarn production or other line working that left characteristic wear patterns. This pattern of hypertrophy was more like Inuit populations than contemporary medieval Icelanders and seems to be related to significant biomechanical stresses from eating tough food and potentially regularly using teeth as tools (Scott et al. 2016, Baumann et al. 2017). McGovern (1985) speculated that the use of dry-stone storage structures (*skemma*) probably for creating air-dried meat that are common on Greenlandic farm sites but absent in Iceland may have produced hard dried seal and caribou meat for winter consumption that placed greater biomechanical stress on Greenlanders jaws. Ruins of these structures (now coded type 3c and 3d in Madsen's system) have been reported in the coastal shieling sites probably associated with seasonal sealing, and they are very common on home farms (Madsen 2014, 2019). These structures have the potential to mass-produce a dried (and possibly also smoked) meat like the traditional Icelandic *Hangikjöt* that could be consumed through the winter. The older traditional *Hangikjöt* or the fully wind dried *Skerpikjøt* was a much tougher hard dried product than the modern product and was known to occasionally break consumers' teeth (Vidar Hreinsson, pers. com.). If hard dried mammal meat products provided a winter staple in Greenland rather than the softer dairy and dried fish products that made up much Icelandic winter food this might explain the difference in observed biomechanical stress response. Further work perhaps involving comparative micro-wear analysis on human teeth might be a productive way of investigating some of these differences in diet.

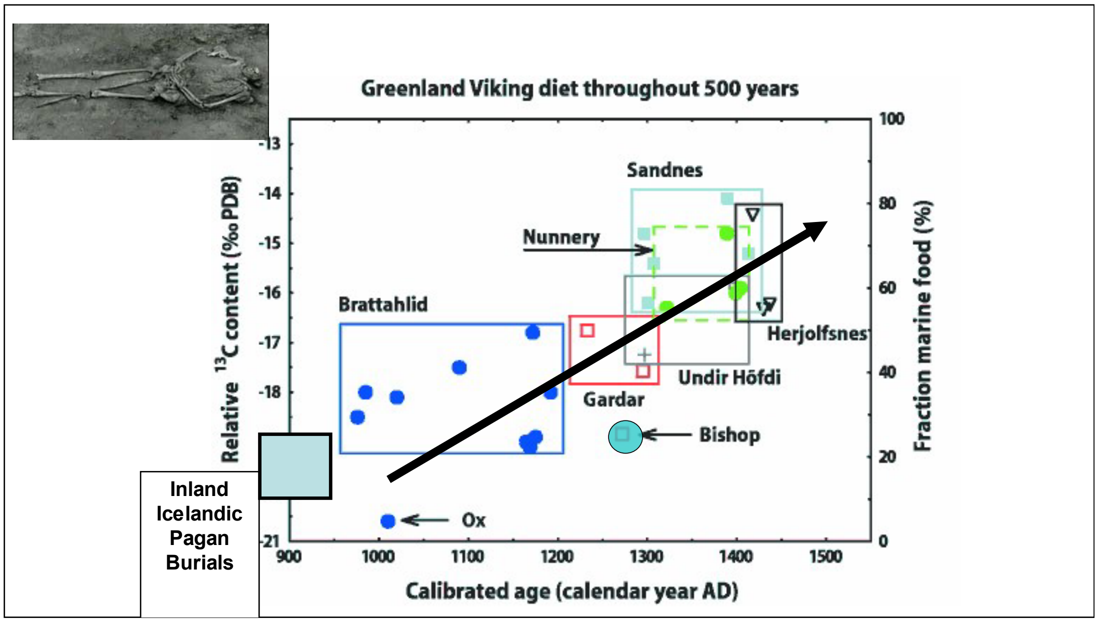


Figure 77 Graphic overview of several dated churchyard populations (courtesy of Jette Arneborg).

The ongoing *Greenland Isotope Project* has greatly expanded our understanding of changing diet in Greenland by combining Nitrogen and Carbon stable isotope analysis with systematic AMS radiocarbon dating to provide a growing record of dietary change through time. Figure 77 above presents an interim graphic representation of the relative position of skeletal populations from Viking age Iceland and progressively later Greenlandic cemetery populations. As the graphic illustrates an outlier is the bishop's skeleton (possibly Jón *Smyrill* Árnason) from beneath the cathedral floor at Garðar which was far less within the marine food web than most contemporary Greenlanders.

Figure 78 below presents a fuller data set (courtesy of Dr. Arneborg) arranged to show the approximate point where more than 50% of the reconstructed diet probably came from marine sources. The Greenlandic and Icelandic patterns are broadly similar before ca. 1300 CE (though the Icelanders were probably mainly consuming fish, and the Greenlanders were mainly consuming seals), but after ca. 1250 there is a marked shift into the marine food web in Norse Greenland.

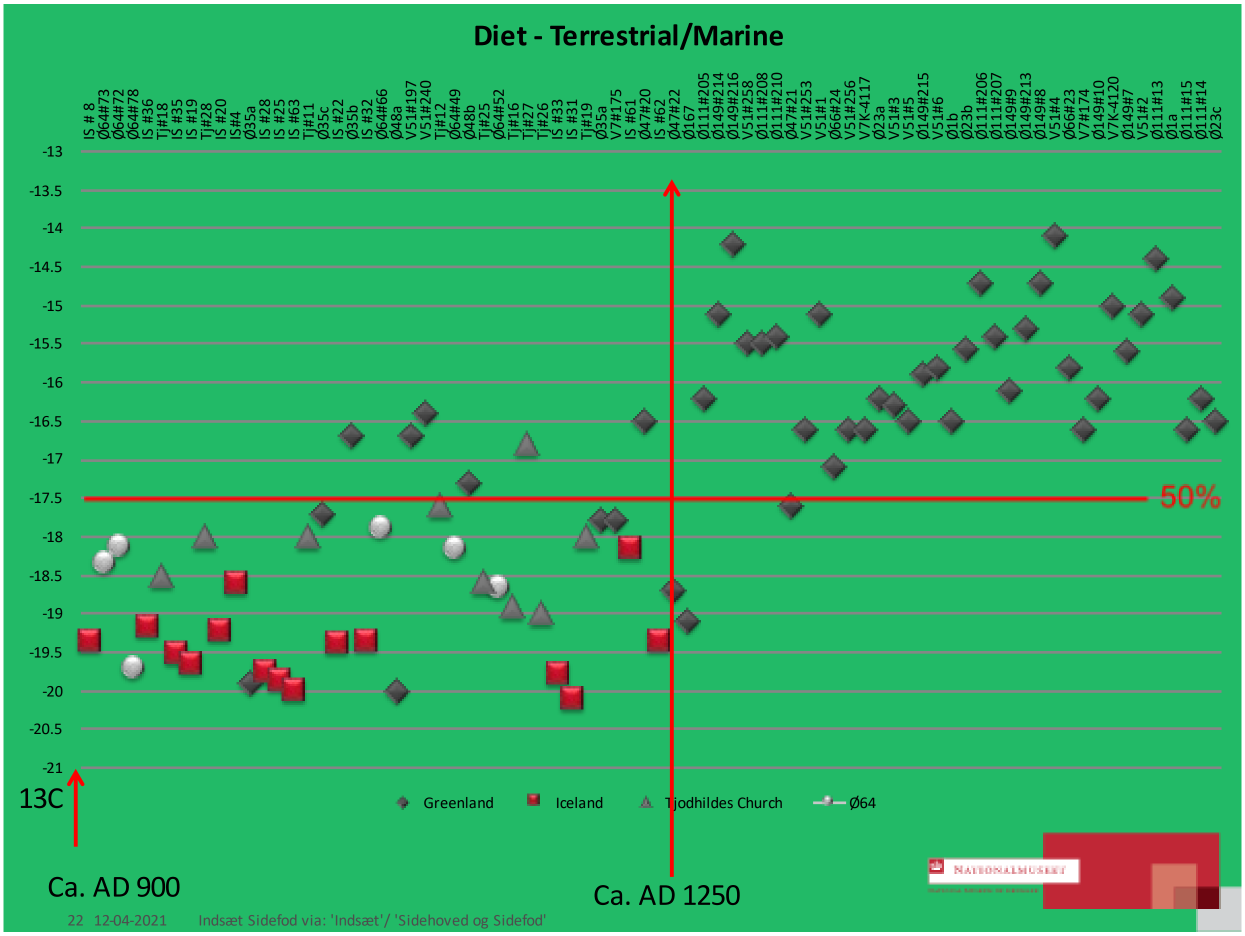


Figure 78 Shifting stable isotope ratios indicate strong shift to marine diet ca 1250-1300. Data Arneborg 2015.

Figure 79 from Warinner et al. (2014) compares the BLG spectra from human dental calculus (a proxy for dairy consumption) to the N/C stable isotope scores from the same individuals. The early Tjodhilde's Church burials show both lower consumption of marine food and a much higher consumption of dairy products. The authors interpret this pattern as evidence of declining success in Norse farming (and dairy production) and increasing use of marine resources to compensate.

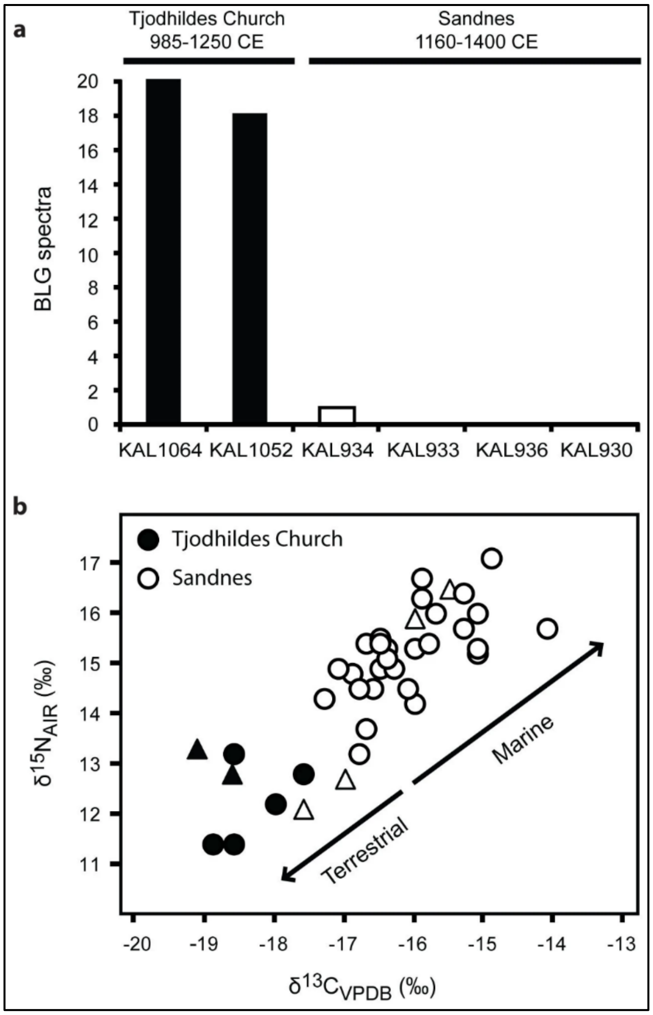


Figure 79 Comparison of BLG pattern in dental calculus and N and C stable isotope ratios from the same individuals in two Greenlandic cemeteries. Figure 3 in Warinner et al. 2014

As discussed above in Chapter 5, one of the major overall trends in the phased Norse archaeofauna is an increase in relative % of seal bones in most (but not all) archaeofauna. Figure 80 below illustrates trends in the ratio of marine mammal bone to terrestrial mammals (domesticates and caribou) in the phased archaeofauna from the Eastern Settlement. The midden at E 29N Brattahlið shows a clear trend of increasing marine consumption after ca 1250, with a similarly sharp increase at E172 and a steady but less dramatic increase a E17a. The exceptions are trends at the small upland site of E74 (probably converted from farm to shieling, see section 6.2 below) and the current archaeofauna from the bishop's manor at E47 Garðar.

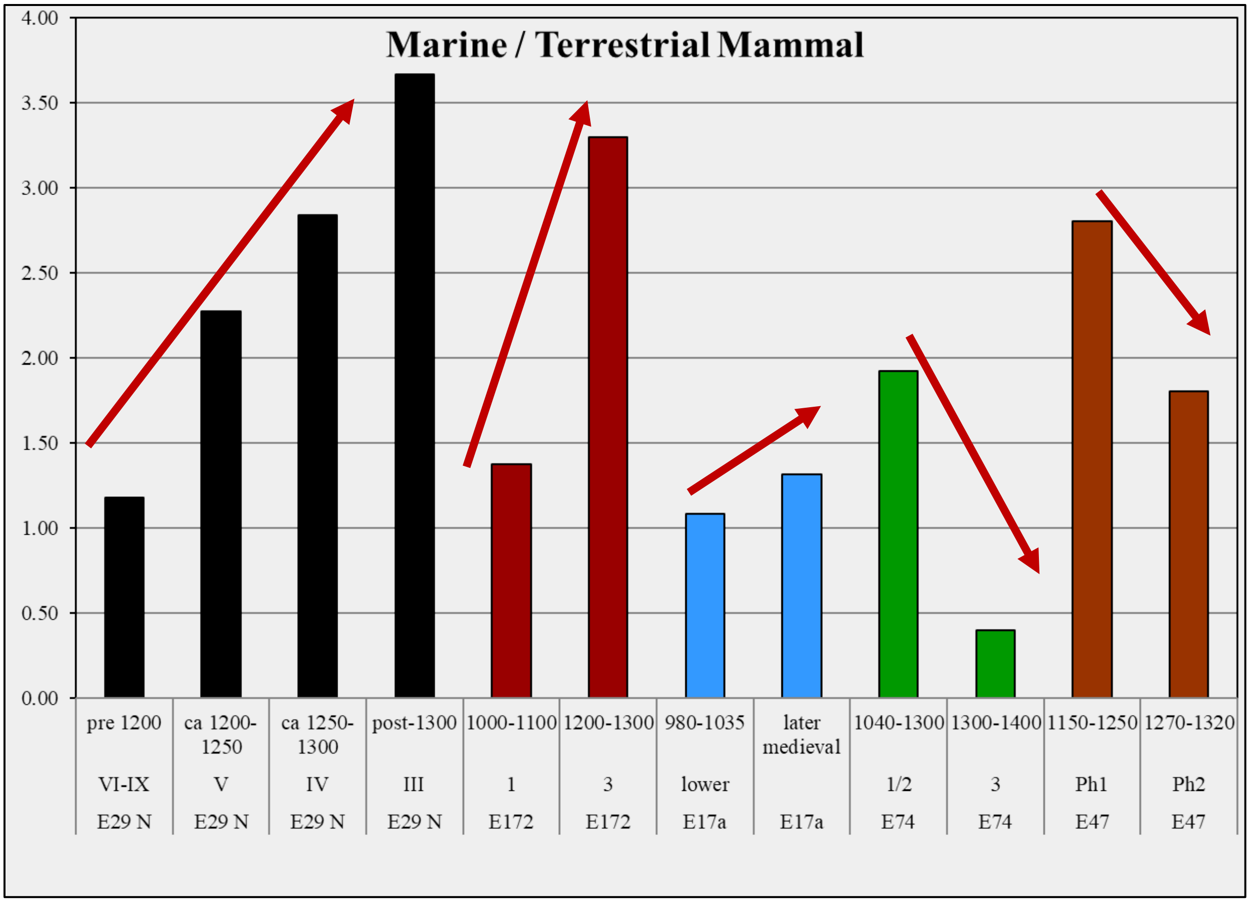


Figure 80 Ratios of marine mammal bone to terrestrial mammals (domesticates and caribou) in the phased archaeofauna from the Eastern Settlement.

Figure 81 below illustrates the changing ratios of marine/ terrestrial mammals in the phased Western Settlement collections. The small coastal site of W48 (probably one of the smallest and lowest-status site archaeofauna we now have) shows a high ratio of marine consumption growing steadily greater through time. The probably middle-ranking inland GUS site also shows an increase in marine consumption on a more modest scale. The high- status manor farm of W51 Sandnes by contrast shows no noticeable increase in marine consumption through time.

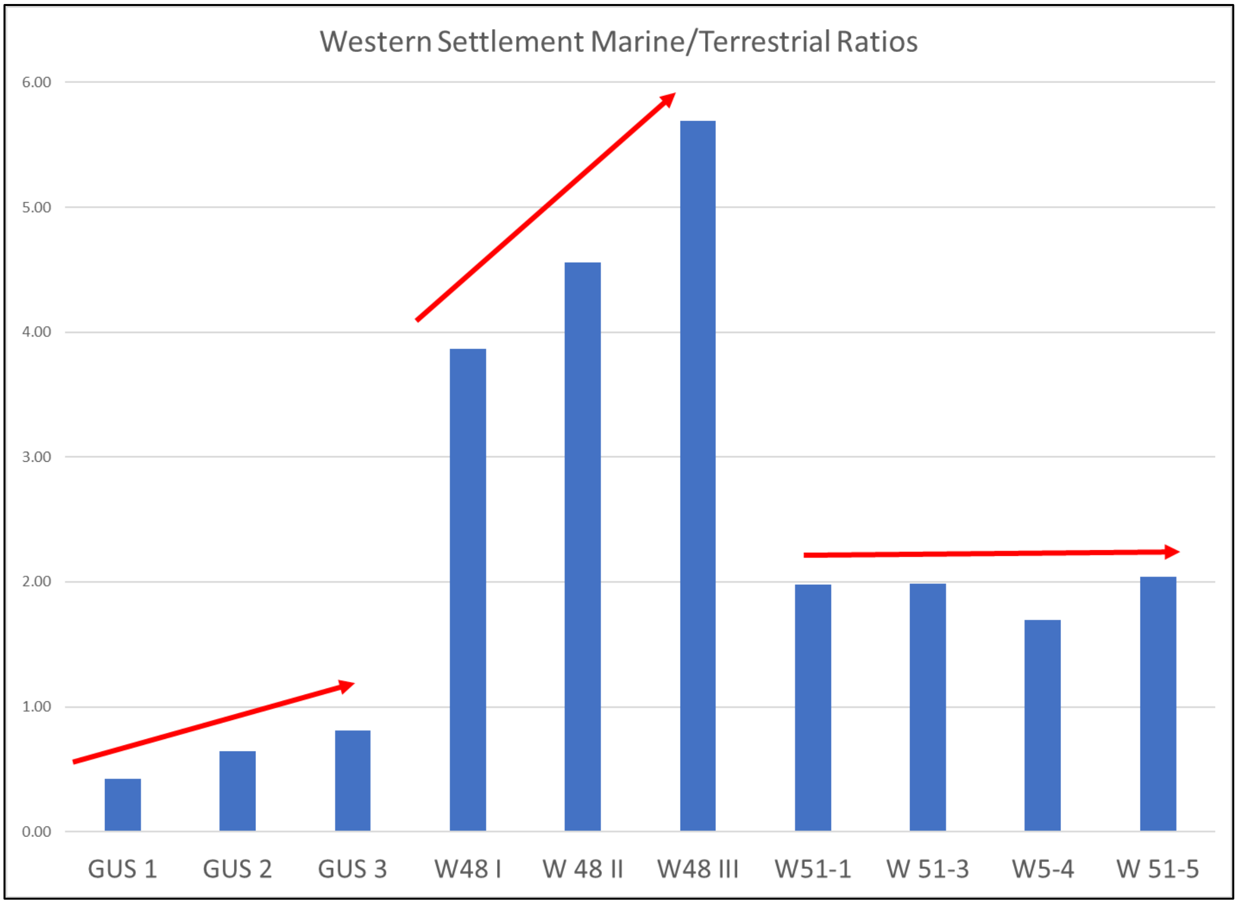


Figure 81 Marine vs. Terrestrial Mammal Bone Ratios from Phased Western Settlement Sites Over Time (left to right).

The current zooarchaeological data thus supports the broad patterns of the human stable isotope analyses and the calculus biomarker work in documenting a widespread shift away from domestic mammals and caribou and into the marine food web (mainly seals but also sea birds, cetacea, and some marine fish and shellfish). However, as the figures above suggest the consumption of seals vs. domestic mammals and dairy may always have had a class/status component. The issues of elite consumption vs. overall household provisioning (where debris from meals consumed by servants and masters alike probably ended up in the same middens) complicate the status- based consumption hypothesis (E29N Brattahlið was probably a chieftain farm throughout its occupation). Note that all Norse Greenlandic archaeofauna contain far more seals than contemporary collections in Iceland or Scotland so all Greenlandic households were committed to seal hunting and marine mammal consumption to a considerable degree.

However, the zooarchaeological evidence suggests that some Greenlandic households were able to continue provisioning from non-marine sources even after the climate impacts of 1250-1300 while others became nearly entirely dependent upon marine food. As low and middle-ranking settlers probably make up the great majority of the human skeletons analyzed, class-based differences in diet may be somewhat masked in the bioarcheological data sets. An area for further cooperative research might be an attempt to tease out status differences among the human skeletons (often challenging for Christian cemeteries) to investigate inter-group differences in diet among contemporaries.

6.4 Climate Related Farm-to-Shieling Transition at E74 Qorlortorsuaq[i] - Case Study

The archaeology of summer transhumance is a relatively undeveloped field in Norse Greenland. Albrethsen and Keller, when discussing shielings in Greenland, cite the lack of survey in upland areas and the lack of excavation and scientific investigation of the sites in question, as major obstacles to research (Albrethsen and Keller 1985; Albrethsen 1991). They presented a model based on Reinton's work in Norway (Reinton 1959) and applied it to the sites in the Qordlortoq Valley near E29N Brattahlið, where they identified full, milking and hay saeters (shielings). Though this original work has been greatly modified by 20 years of continued research, the original still remains the foundation of the study of shielings in the Eastern Settlement.

This case study of Human Ecodynamics presents zooarchaeological and architectural evidence from the small inland site of E74 Qorlortorsuaq (also referred to in this thesis by its site registry number: E74) in the former Norse Eastern Settlement in Greenland. The archaeofaunal collection, new radiocarbon dates from excavated floor and midden layers, and the archaeological architectural data reported from the survey in 2004 and the excavation in 2005, indicate a major site reorganization that occurred broadly contemporaneously with the onset of the period of cooling at the end of the 13th century. The combination of these datasets demonstrates a changing site history at E74 as it traces its functionality from site establishment during the early phases of the settlement of Norse Greenland, down to its final abandonment in the early to mid-15th century. New, and combined archaeological research methods show that E74 probably started as a low status small farm (or a shieling that developed into a small farm rather quickly), but after the main dwelling was abandoned during the late 13th century, the site was converted to a seasonally occupied shieling, specializing in sheep and goat herding. The environmental and climate changes of the Little Ice Age (Dugmore et al. 2015), which influenced other aspects of the Norse settlement in Greenland, were at least partially responsible for a restructuring of the site economy.

Due to the small number of large-scale open area excavations, and the fact that studies of shieling systems are mostly conducted through analysis of surface survey data, such transitions were not previously documented by archaeological investigations in Greenland. The recent zooarchaeological analysis of the stratified bone collection from E74, combined with the other archaeological data presented in this chapter, are key to identifying and understanding the site's economy and functionality through the *longue durée*, especially during its final occupation phase affected by the changing environment and landscape. This analysis can be applied to help explain shifting settlement patterns in the Eastern Settlement on a broader scale and provides a valuable contribution to the archaeology of summer transhumance in Norse Greenland. It is a significant step in the understanding of past and present issues of Human Ecodynamics in this part of the arctic island, where both sheep husbandry and climate change still take place today.

Vatnahverfi is one of the most successful sheep farming areas in Greenland today, and archaeobotanical analyses demonstrate that this was also the case during the Norse settlement (Ledger 2013). The lush grasslands, meadows and fens created rich pastures and allowed for relatively dense settlement. The higher elevated, inland part of the peninsula located closer to the Greenlandic Ice Sheet has a shorter vegetation growing season and is less productive than the Norse farming areas located more coastally. That area is much more suited for summer grazing of the sheep and goat flocks, than for sustainable operation of a full-scale farmstead. Successful modern Greenlandic farmers, who started to raise sheep in the area in the early 20th century, placed their farms near the ruins of the substantial, high status Norse farms that had good areas for hay production in the past, and still have them today. Many modern farmers who settled in the less favorable locations, where medium and low status Norse farms used to be located, have not made it through the challenging weather conditions in the 1950's, and their farms are abandoned today. The successful farmers today, regularly herd their sheep during summer months in the more remote (by today's standards) inland parts of the Vatnahverfi peninsula, where the small Norse farms and shielings were located in the Middle Ages. Qorlortorsuaq Valley is one of those areas, and it is therefore not surprising that the site has a rich history, affected by changing climatic and environmental conditions.

This section investigates a Norse site that was established in the early 11th century as a small farmstead operation and changed its function and status the in late 13th – early 14th century to a shieling, a seasonally occupied sheep and goat herding station. This event was probably a response to deteriorating climatic and environmental conditions during the late 13th century, the beginning of the Little Ice Age, which severely altered the economy and settlement pattern of the Norse colony, and eventually contributed to its demise in the mid-15th century AD. The zooarchaeological patterns are in direct contrast to all other Greenlandic farm sites, where post c. AD 1300 archaeofauna usually reflect an increase in seal hunting and a decrease in livestock herding due to harsher environmental conditions affecting the terrestrial resources. The Qorlortorsuaq pattern demonstrates a very different economic practice, not observed anywhere else in Greenland, and can be explained as adaptation to changing environmental conditions, and economic reorganization.

6.4.1. The Environmental and Climatic Context

Climate change impacted both Greenland and Iceland when in AD 1258 a massive volcanic eruption on Lombok (Indonesia) triggered an immediate cooling across the North Atlantic. Between AD 1275 and AD 1300 a threshold-crossing increase in summer sea ice occurred in southwest Greenland (Miller et al. 2012). Pasture productivity in the low-lying coastal Norse communities was adversely affected, and the summer drift ice impacted transatlantic voyages to Greenland, local travel, and the viability of valuable harbor seal colonies in the Eastern Settlement area (Ogilvie et al. 2009). As noted above, Greenlandic archaeofauna dated after c. AD 1275-1300 suggest a marked intensification of the communal harp seal hunt, a pattern mirrored by the human stable isotope data that indicate Norse Greenlanders moved decisively into the marine food web after c. AD 1250 (Arneborg et al. 2012; Nelson et al. 2012) The combined zooarchaeological and bioarchaeological record indicates that the Norse Greenlanders successfully survived the climate shocks of AD 1275-1300 by intensifying their communal seal hunting strategies to compensate for the stress on the farming economy. Around AD 1425, a second climate shock impacted the whole region, this time in the form of a dramatic increase in storminess (Dugmore et al. 2007a). The successful Greenlandic response to the initial climate impact may have rendered this small community tragically vulnerable to loss of life at sea in a radically stormier North Atlantic, and by around AD 1450, with the combined impacts of a series of other socio-politico-economic-demographic and environmental stressors Norse Greenland was extinct.

6.4.2. The Site Background

E74 Qorlortorsuaq, is located in the Kujalleq municipality of southwest Greenland. This inland farm is a part of the historic Norse Vatnahverfi district (Lake Region), east of Qorlortorsuup Lake and approximately 10 km from the Amitsuarssuk fjord. The first archaeological work on the site was carried out in the form of a survey by Daniel Bruun in 1894 (Bruun 1895), and a successive survey in 2004 identified more ruins at the site, counting a total of seven buildings (Kapel et al. 2004). In 2004 a long sondage trench (10x1 m) and three small trenches (1x1 m) were excavated by the Greenland National Museum, to gather chronological information and to learn as much as possible about the site during one short field season, as it was unclear if it would be possible to conduct a large -scale excavation there before the site was going to be flooded by the dam construction project (Kapel et al. 2004).

A large-scale open-area rescue excavation of E74 Qorlortorsuaq was conducted in April and May of 2005, where multidisciplinary, international team (NABO cooperative collaboration with the Greenlandic National Museum and Archives and the National Museum in Copenhagen) excavated the main dwelling (structure 2), an adjacent building (structure 3), and the midden associated with the occupation of the site (Edvardsson et al. 2010; Edvardsson 2013). Since E74 was in the immediate flood-zone, the team had only four weeks to complete the excavation before it was submerged. The site, including the two structures and the midden, was excavated using a modified single-context open area excavation, following standard practices employed on all NABO projects (Edvardsson et al. 2010). All bone-yielding structural contexts and floor layers, and all contexts in the midden were 100% sieved through a 4mm mesh for optimal bone recovery. These excavation methods made the site directly comparable with all other NABO sites excavated in Iceland and the Faroe Islands (Smiarowski et al. 2007; Smiarowski et al.2013).

6.4.3. The Archaeological Data

The case study presented here integrates current zooarchaeological data from Norse Greenland. The site of E74, and all other sites used for the comparison, provided a faunal assemblage count much higher than the minimum sample size of Number of Identified Specimens (>300 NISP for major taxa) required by the NABO protocol. All of the material comes from at least partially sieved contexts which can be dated by radiocarbon and artifacts, and most were analyzed using the common NABONE recording, and data management system first developed by the NABO cooperative in 1997.

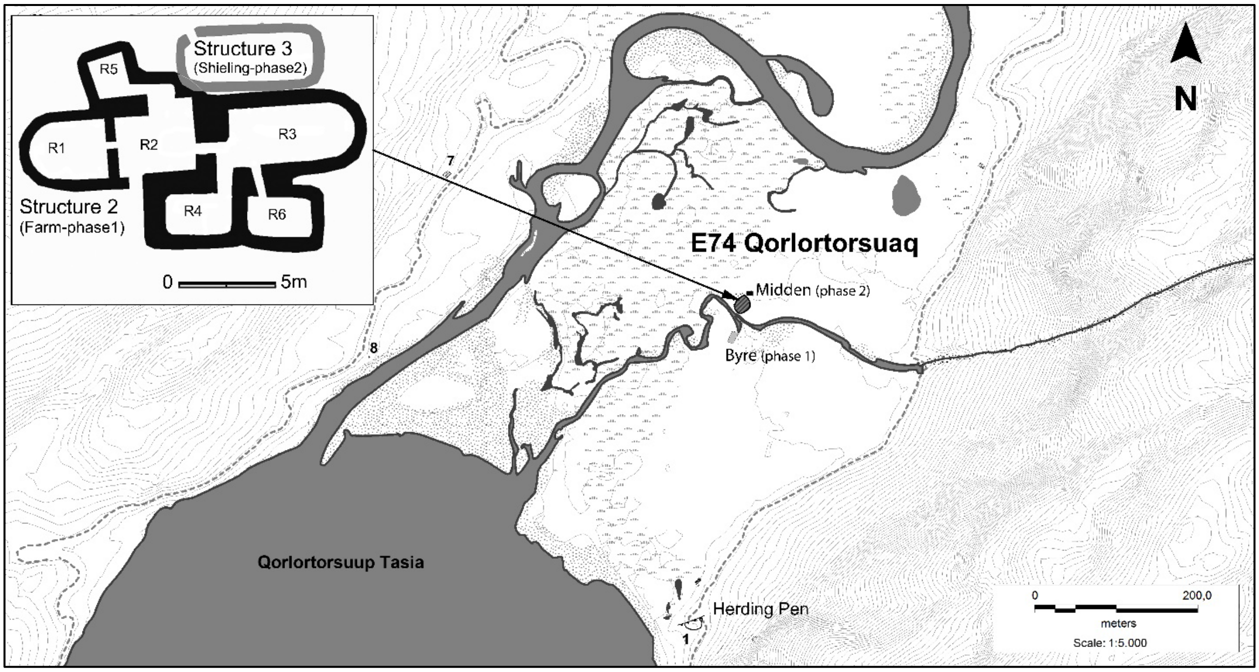


Figure 82 E74 Site and Area Plan.

AMS C14 dates of cattle bone collagen analyzed at the Scottish Universities Environmental Research Centre (SUERC) provide the first step in interpreting the economy of the site and divide it into two occupational phases: Phase 1 and Phase 2. Phase 1 at E74 is represented by a small, farm building (structure 2) that did not house livestock, and a contemporary small byre located c. 30 m south of that dwelling (Fig. 10.1). Three AMS dates (SUERC 17585, 17589, 17590) from the floor layers of the farm building (structure 2) excavated in 2005, indicate its occupation in the early 11th to mid-13th century. One radiocarbon date from the byre, sampled in 2004, places it in the same time frame (Kapel et al. 2004; Arneborg unpublished data). The bones from the floor layers of the centralized farm building comprise the E74 Phase 1 in this chapter.

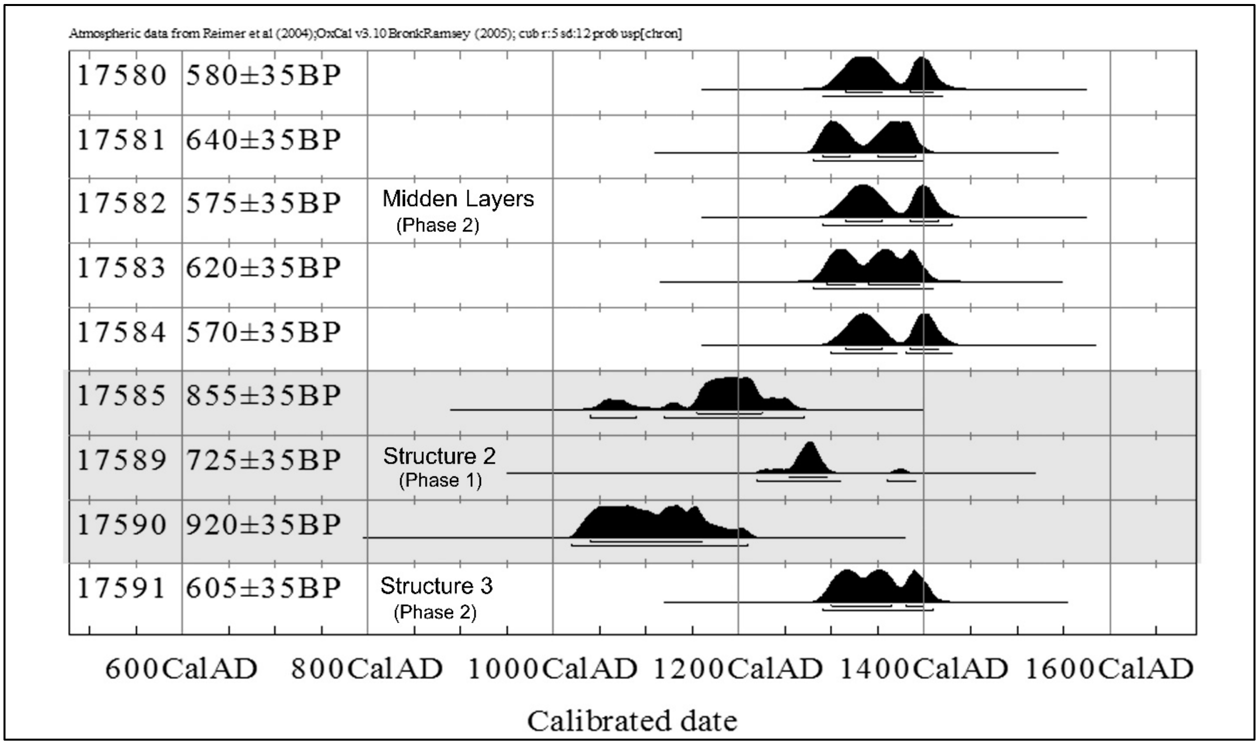


Figure 83 Calibration of AMS C14 from E 74.

The midden produced samples for five very consistent AMS C14 dates (SUERC 17580, 17581, 17582, 17583, and 17584) from four separate contexts indicating that all layers from this c. 50 cm deep household refuse area are contemporary with each other and were deposited during the mid-14th to early 15th century. These dates indicate that the excavated midden must be associated with another, later dwelling, not structure 2. The two-sigma date range c. AD 1290-1410 of the floor layer of structure 3 (SUERC 17951) seems to place it in the same time period with the midden. Simple, small, and only containing a single 3x10 m room, it may be a shieling whose inhabitants occupied the site during its later phase. All bones from the midden contexts and the structure 3 floor layers have been combined, and for the purpose of the zooarchaeological analysis in this chapter, are referred to as Phase 2 of the E74 occupation.

6.4.4. Site Settlement, Abandonment, and the change of use over time

The E74 farm was always a low status holding, that was temporarily abandoned in the 13th century, and resettled shortly after as a sheep and goat herding station, a shieling. The farm's low status in the Vatnahverfi social hierarchy was probably impossible to improve economically. Due to its unfavorable location that could not support high quality grass for haymaking and grazing, it was not able to sustain the cattle that would have been necessary to improve the social status of the site. People most likely settled there ca. AD 1050, during the second or even third generation since the initial settlement of Greenland, at the time of increasing human population on the island. By then, the preferred farming locations were probably already claimed, and the people moving in to the Qorlortorsuaq Valley had to settle for this marginal location with its low quality and low hay production potential, suitable mostly for the less demanding caprine herding.

The farm dwelling (structure 2) probably started as a small, long hall, originally comprising rooms 1-3 of the abandonment phase represented in Fig. 6.9. At some point this hall was divided into three rooms, and subsequently three other rooms were added to it (Edvardsson 2013), creating a small, multi roomed farm dwelling; however, none of these rooms seem to have housed the livestock over the winter. The initial size of the hall and the small dimensions of all the rooms indicate that the farm was a low status holding throughout its occupation period. For example, the kitchen area in room 2 was only 3.5x3.5 m, and the hall floor area, before the partition, would have only been c. 3x12.5 m, which is in the smaller range, at least according to Icelandic standards (Edvardsson et al. 2010; Edvardsson 2013). The small byre/animal shelter building that housed the farm's livestock over the winter, was radiocarbon dated to the mid-12th to early 13th centuries AD, without evidence of continuation of its use into Phase 2 (Arneborg, unpublished C14 data).

From the beginning, this Phase 1 farm was a small, low status site that never achieved elite or even middle-ranking status before it was abandoned at the end of the 13th century AD.

E74 was occupied during the Medieval Warm Period (c. 9th to 13th centuries AD), when the favorable climatic conditions made the fodder resources in this remote area of the Eastern Settlement favorable enough to raise livestock successfully. Sometime after c. AD 1350 people returned to E74, as is demonstrated by the midden that dates to the mid-14th to early 15th centuries. This seems to have happened shortly after the most severe years of the environmental changes that influenced livestock husbandry and caused the intensification of the use of marine resources throughout both Greenlandic Settlements (Ogilvie et al. 2009; Arneborg et al. 2012). The new radiocarbon date indicates that structure 3 was also occupied during that period, therefore the Phase 2 midden deposits were likely produced by the inhabitants of that building, located approximately 5 m southeast of the midden. To add another line of evidence for the contemporaneous character of these two features, it would have been optimal to divide the Phase 2 archaeofauna from these two areas, the midden and structure 3, and to directly compare their zooarchaeological patterns for consistency. However, the assemblage from the floor of structure 3 cannot be used in such intra-site comparison due to its very small sample size (Smiarowski et al. 2007). Nonetheless, the six corresponding radiocarbon dates and the direct proximity of the midden to structure 3 should be sufficient to associate these two features with Phase 2 at E74.

The small size of structure 3, the poorly preserved construction of its walls, and the incorporation of the NW wall of structure 2 into the SE wall of structure 3 (Edvardsson et al. 2010) indicate that this building may have been erected as a temporary shelter, or a shieling after the abandonment of structure 2. Its inhabitants probably occupied the site seasonally in the summer, to take care of the sheep and goat flocks while these were kept on pastures, away from their main farmsteads and hay fields. The absence of permanent animal shelters, such as byres, during Phase 2 and the presence of a herding enclosure by the lake (Fig. 10.1) confirm the seasonal nature of this site. The function of this building cannot be assessed with full certainty based on the scarce excavation finds from the fully excavated main floor deposit at structure 3 (Edvardsson et al. 2010). However, the lack of artifacts in the usually finds-rich Greenlandic floor deposits supports the claim of the seasonal shieling occupation, where herders traveled annually with everything necessary to spend the short summer at the site. The large herding pen by the lake (feature 1 in Fig. 6.9) points to a shieling that specializes in seasonal caprine herding, but the milking enclosure (*lambakró*) incorporated into the eastern wall of the pen, indicates that some ewes and does (female sheep and goats) were present, and the shieling was also involved in producing cheese and other milk products as well.

The described buildings, pens and enclosures would classify this as a full shieling according to Albrethsen and Keller's classification based on Reinton's work (Albrethsen 1991). People and animals occupied such a shieling all summer, with all necessary supplies, and did not return to the farm until the autumn. Apart from the summer herding, people would process milk, produce cheese, and store the dairy products for use at the farm in the winter months. Some full shielings also harvested hay, willow and birch as winter fodder that was brought back to the farm at the end of the season. The extensive vegetation in the Qorlortorsuaq Valley could have been used in this way, but we do not have firm evidence of that at E74.

The timing of the settlement of E74 in the mid-11th century, and small size of the dwelling and the byre, indicate that the site started as a small farm, or a full shieling that became a full farm rather quickly. The abandonment of the farm and its later reorganization into a shieling in the 14th century is traced by radiocarbon dates and is reflected in the architectural changes at the site and the deposition of the midden.

The settlement dynamics at E74 in the Qorlortorsuaq Valley represents a climate -influenced economic transition, and a human response to environmental stress in the subarctic environment. This case study of Human Ecodynamics in the Vatnahverfi region of Norse Greenland is investigated with proxy climatic data reference, and zooarchaeological analysis on a site, regional and Trans-Atlantic level. The transition from farm to shieling at E74 was likely not an isolated circumstance, and more sites located in disadvantaged areas may have been subjected to similar changes at some point during environmentally strenuous times.

The changes in growing season, pasture plant productivity, and depth and duration of winter snow cover in the second half of the 13th century all would have posed challenges to Greenlandic farming, perhaps especially to small inland farms at higher elevations such as E74, which is located at c. 125 m. above sea level. While more research (including regional climate impact modeling) is needed, occupation Phase 1 at E74 was associated with the comparatively warm and stable conditions of the early medieval warm period; however, Phase 2 activities took place after the late-13th century transition to much less favorable farming conditions in the early portion of the Little Ice Age. The abandonment of the original small farm and its replacement with a much smaller and probably seasonally occupied shieling thus played out against a background of significant climate changes, almost all posing increasing challenges to farming in Greenland.

6.4.5. The Zooarchaeological Evidence

At E74 Qorlortorsuaq zooarchaeological evidence shows significant changes in the economy of the site that occurred at the time of the global cooling and may be associated with this transition. The Phase 1 archaeofauna is much more varied than that of Phase 2 and includes not only local domesticates such as cattle and caprines, but also a range of wild marine resources (Fig. 6.11 see also Chapter 4). This is a characteristic of a Greenlandic year-round occupation, where seal meat and other marine products taken at different seasons of the year (seals taken in spring, caribou likely in autumn, sea birds in spring to summer) provisioned households living both on the coast and at inland farms (McGovern 1985; Smiarowski 2013; Smiarowski et al. 2017). The change to a much less varied animal bone assemblage in Phase 2 indicates a shift in provisioning strategy.

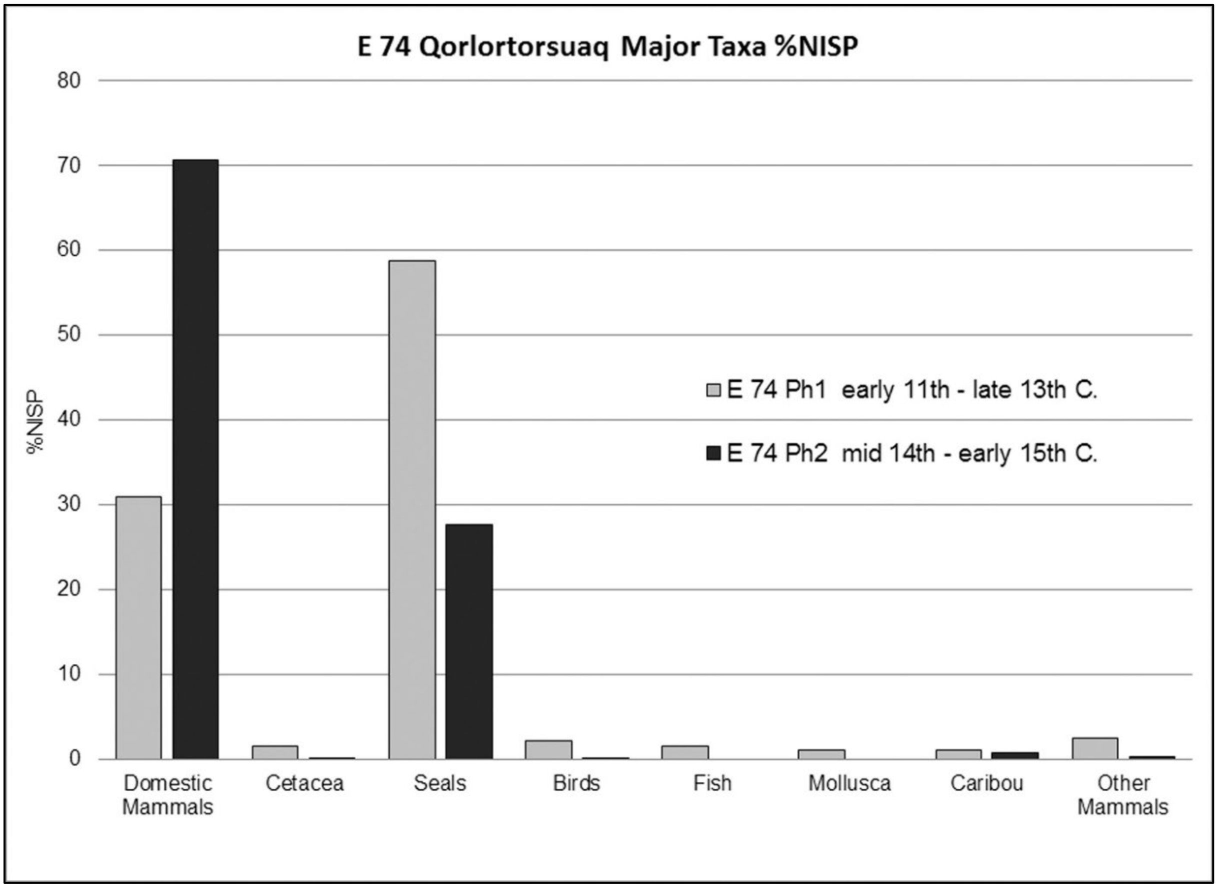


Figure 84 Major Taxa Relative % NISP at E74.

Seal bones in the Greenlandic faunal assemblages generally vary from about 25% of the major identified taxa to nearly 80% on small farms with limited pasture; and are common on far inland farms (Smiarowski 2013; Smiarowski 2014). The Norse Greenlanders adapted communal seal hunting techniques to the newly encountered migratory species and took large numbers of harp and hooded seals from the coastal locations, to then be distributed to all the inland farms, including E74. As discussed above, large specialized dry-stone storage buildings (*skemma*) are very common on Greenlandic farms (but absent on contemporary sites in Iceland, where storage buildings were constructed differently), and it is widely suspected that these were used to prepare hard-dried meat jerky from seals and probably caribou (McGovern 1985; Smiarowski et al. 2017). The spring seal-hunt catch could thus be spread throughout the year, and hard dried seal meat probably substituted for the hard dried cod-family fish products consumed in Iceland and other parts of the North Atlantic for both late winter consumption and provisioning of work groups and sailors (Smiarowski et al. 2017). Marine fish bones are very rare in Greenlandic sites (Smiarowski 2013), and it is likely that such dried seal meat provided the dietary equivalent of the Icelandic dried cod and haddock. While seal bones are much more commonly found in lower status sites, substantial amounts of seal were also consumed on medium and high-status Greenlandic farms, suggesting its key provisioning role for the whole Norse colony. This is evident in Phase 1 at E74, where close to 59% of the faunal remains at the site were seals, which in combination with its architectural scale and layout, and small size of the byre, places the farm household in the lower-status range.

The seal bone percentage dropped to c. 28% in Phase 2 when the very small and apparently specialized household associated with structure 3, was set up. The occupants of the Phase 2 dwelling may well have represented a working party detached from other household, possibly E91 based on the topographic location of both sites (Christian Madsen, pers. comm. 2014) rather than a farm household with the full range of access to resources available to even small tenant-family farm. The herders may have brought some fresh or dried seal meat with them, but if they were not present for either the sealing season in the early spring or the long winter, their on-site consumption of seal meat may well have been proportionately lower. The site of E74 is the only Norse site in Greenland where zooarchaeological analysis identified a pattern of decreased seal meat consumption post late-13th century climatic events. All other Greenlandic sites in both the Eastern and Western Settlements; including small, medium and magnate farms such as W51 Sandnes and E29N Brattahlið, display an increase in seal consumption at this time (McGovern et al. 1995; McGovern et al. 2007; Smiarowski et al. 2017, see above Chapter 4). This pattern emphasizes the uniqueness of the E74 archaeofaunal collection and shows the importance of including a range of sites, which reminds us that even in small communities there can be significant variation.

The consumption of domestic animals, mostly sheep and goats, increased from c. 31% in Phase 1 to c. 71% in Phase 2. This change reflects on the food source available at a sheep and goat herding station, where mostly meat of these animals is available during the summer months. An increase of domestic mammal meat during this time period at Greenlandic sites usually reflects an increase in status and was only thus far recorded at E47 the Bishop's estate at Garðar (Smiarowski 2013). The dramatic 40% increase of consumption of domesticates at E74 does not indicate a rise in status, but rather the complete reorganization of animal husbandry. Phase 2 at E 74 Qorlortorsuaq was almost exclusively dedicated to herding sheep and goats during the summer months.

Cattle are the domestic animals that can be utilized as high-status indicators at Norse farms in Greenland, and the rest of the North Atlantic. The caprine to cattle ratio is one of the key indicators of the status of the site, and a changing ratio in favor of caprines usually indicates harder times (e.g., McGovern et al. 2007). This is an almost universal pattern at all Norse sites post AD 1270-1300 environmental destabilization, but at E74, the ratio increases from 3.57 caprines to 1 cow bone (no known site prior to c. AD 1270 ratio higher than 4:1) to 12.74 caprines to 1 cow bone in Phase 2 (Fig. 10.4). This is a record high caprine ratio, and the closest contender is the small low status farm at W48 Niaqussat (McGovern et al. 1983) with a post AD 1300 caprine to cattle ratio of 8:1. High status farms tend to have a ratio below 3:1, while medium and low status farms are 4:1 or above (Smiarowski et al.2017).

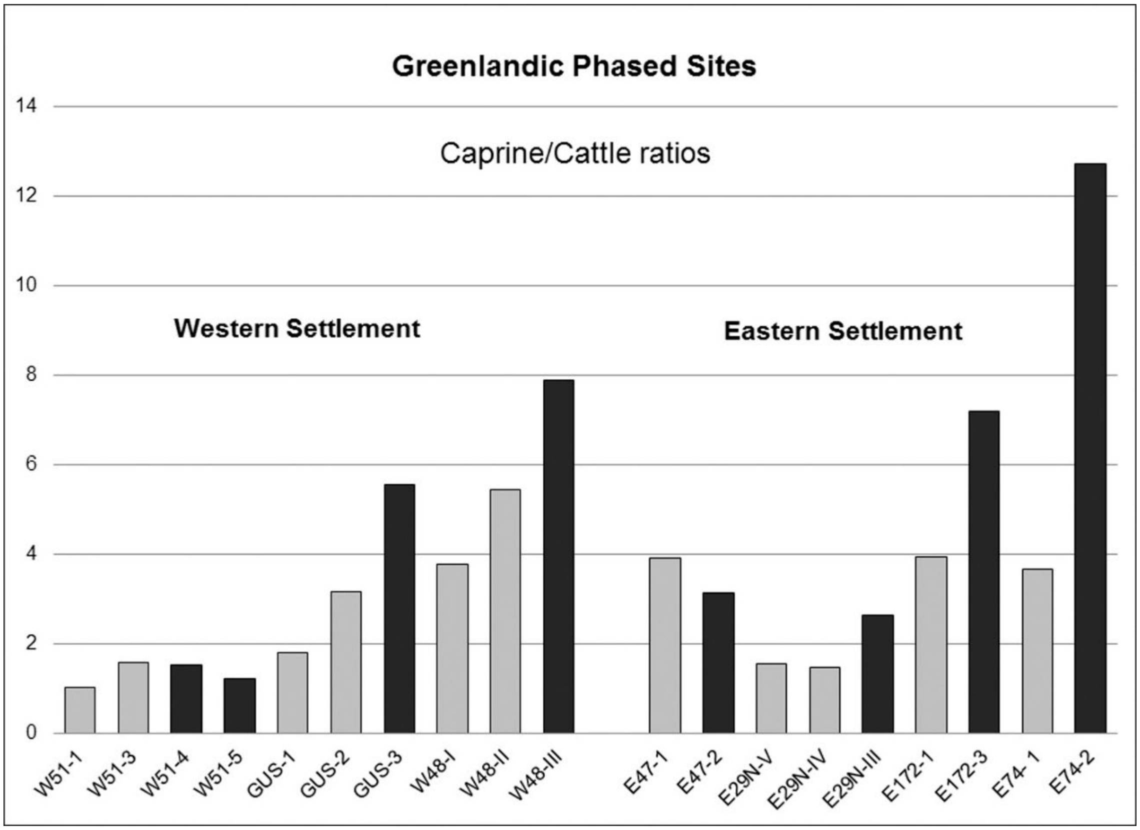


Figure 85 Caprine vs. Cattle Bone Ratios in Major Greenlandic Collections.

The E74 Qorlortorsuaq zooarchaeological patterns are in direct contrast to all other Greenlandic sites, where post c. AD 1300 archaeofauna usually reflect an increase in seal hunting and a decrease in livestock herding due to harsher environmental conditions affecting the terrestrial resources. The Qorlortorsuaq pattern clearly demonstrates a very different economic practice not observed anywhere else in Greenland and illustrates a seasonal occupation and diet.

6.4.6. Case Study Conclusions

Several lines of evidence reported in this case study show that E74 Qorlortorsuaq was established as a small farm and continued to operate as such until its abandonment or direct transformation into a full-time shieling in the 14th century AD. The Phase 2 dwelling (structure 3) was both smaller and far simpler than the small multi room farm structure from Phase 1 that it replaced. AMS C14 dates indicate that this small building was occupied at the same time in which the midden was deposited, and it seems reasonable to connect this structure to the midden. Zooarchaeological analysis of the major taxa distribution at the site demonstrates that caprines significantly increased in numbers right after the transition period during which the settlement use changed, and that seal consumption decreased at the same time. The record high increase of caprine to cattle ratio between Phases 1 and 2 demonstrates that focus was placed on herding sheep and goats at the site during the later phase.

The mixture of sheep and goats indicates that meat, milk and hide production were major objectives leading to the increased proportion of caprines relative to cattle, as the E74 archaeofauna does not show the shift to nearly all sheep caprine flocks aimed at wool production as occurred in Iceland at the same time (McGovern et al. 2014). The shift from cattle to caprines thus allowed for an effective substitution of goat and sheep milk for cattle dairy produce. This measure may be seen as a focus on animals more tolerant of lower-quality grazing in an attempt to continue patterns of domestic mammal dairy and meat production rather than an intensification of wool production for local consumption or export. Unlike shielings and the specialized sheep houses developed in Iceland after c. AD 1200 as part of an intensified wool trade, this Greenlandic shieling model would appear to have been aimed at maintaining food production in highland areas that could no longer support full year-round farm households (Smiarowski et al. 2017). This pattern provided by the archaeofauna and architecture at E74 demonstrates a major reconfiguration of the economy of the site, and a transition from a full farm economy to a distinctively Greenlandic pattern of a shieling system, at least partially in response to the conditions brought about by the Little Ice Age, appears to be a plausible explanation.

The occupants of E74 abandoned the site during the period of the first onset of the Little Ice Age, as the higher elevation area close to the Greenlandic Ice Sheet probably did not produce enough hay surpluses to maintain a working farm. The re-occupation during Phase 2 may represent an effort to at least maintain grazing in the Qorlortorsuaq Valley by herding sheep and goats during the summer months, but this more specialized land use strategy was aimed at food production rather than intensified wool production. This case study of Human Ecodynamics in Norse Greenland is thus also a contribution to the study of summer transhumance in the northern landscapes and has a potential to grow to a regional-scale study at least in Vatnahverfi or even in the broader Eastern Settlement. The site of E74 Qorlortorsuaq is probably not the only site to go through such drastic changes caused by climatic and environmental conditions, but more research, modeling, and excavation is needed to bring this work to a regional perspective.

6.5 Diverging Pathways in Medieval Iceland and Greenland

Both island communities were settled in the Viking Age, both participated to some degree in international trade from Landnám onwards, both were integrated into a common Norwegian Realm by the mid-13th century, and by the early 14th century both endured significant climate change. Iceland survived the Middle Ages to eventually become a vibrant, urbanized, modern Scandinavian society but Norse Greenland did not survive the mid-15th century. Since 2012 the NABO *Comparative Island Ecodynamics Project* (NSF ASSP 1202592) has focused specifically on cases of long-term human-landscape-climate interactions in Viking Age and medieval Iceland and Greenland, to better understand the points of divergence that led these two closely related societies to such different historical pathways. One aspect of the divergence between the two communities, centers on management of sheep and goats.

6.5.1 High Medieval Conjunctures

As noted above, the 1257 Lombok eruption arguably triggered an abrupt cooling across the North Atlantic region and began onset of summer sea ice in the Denmark Strait between Iceland and Greenland c. AD 1275-1300. The changes in temperature, precipitation, and growing season impacted communities across Atlantic NW Europe, where cereal farming populations had expanded into uplands and previously marginal areas, creating potential vulnerabilities while lessening the buffering effects of lower intensity land use (woodland and marsh products, pannage, grazing, hunting). The early 14th century saw what historians have described as the "Great Famine" across much of Atlantic Europe ca. 1314-22 when heavy and prolonged summer precipitation and shortened growing season in successive summers that resulted in widespread crop failure and animal disease. The cumulative impact of successive "ill years" eventually overwhelmed local resilience and prolonged famine ensued causing population loss estimated at 5-12% from the 1300 peak (Jordan 1998). These impacts were particularly intense in upland and newly settled areas most subject to reduced accumulated temperature and flooding.

In Iceland and Greenland climate changes were intensified by the direct impact of summer drift ice that stressed farming economies with shortened growing seasons and lowered productivity of shoreside pastures, impacted seal populations, and affected navigation during the late 13th and early 14th centuries (Ogilvie et al. 2008). Around the same time, geoarchaeological evidence and the *CENTURY* agro-ecology model (e.g., Simpson et al. 2001; Adderley et al. 2008; Brown et al. 2012) suggest that the 13th century probably saw the peak effect of infield soil amendment and fertilization in Iceland, with declining returns on additional amendments thereafter.

In the same decades, expanding trade networks and inter-regional exchange associated with the trans-Eurasiatic *Pax Mongolica* and increasing market demand in Western Europe c. AD 1250-1350 created what has been described as a medieval proto-world system (Abu-Lughod 1989; Marks 2005), raising demand for bulk goods like woolen cloth and dried fish. This same period c. AD 1200-1350 marked the emergence of Norwegian royal authority from a long period of civil war, reaching its maximum territorial expansion AD 1254-55 with the successful incorporation of the Northern Isles, Iceland, and Greenland and an ultimately failed military intervention at Largs in mainland West Scotland (Imsen 2010). The period between the onset of the "Little Ice Age" c. AD 1250-1300 and the impacts of the Black Death in continental Scandinavia and Britain after AD 1348 thus represents the conjuncture of multiple natural and social forces operating over different time scales. Coming together these factors presented a set of challenges and opportunities to the island communities of Iceland and Greenland.

In Iceland, by the 14th century specialized sheep herding structures (arranged as winter sheep housing with some human occupation) appear to replace mixed farming households in at least some valleys in North Iceland (Harrison 2013). After ca AD 1450 specialized communal sheep corral structures (*rettir)* associated with intensified upland summer grazing become widespread in Iceland (Aldred 2004). These sorting pen structures remain in use as a way of sorting multiple farms' sheep at end of summer when they are brought down from largely unsupervised grazing in the uplands, and seem to be often associated with both marked intensification of wool production and increasing erosion impacts inland in late medieval to early modern times (Hicks et al. 2016, Sigurðardóttir et al. 2019)

As noted above herding structures in Greenland have been intensively studied in the past decade and many ruins previously thought to represent full farms are now recognized as seasonal herding centers of different kinds (Madsen et al. 2009, Madsen 2014, 2019). The example of E74 discussed above illustrates a pattern of replacement of full-scale farms with shielings that is also known from parts of Iceland (Gísladóttir 2013). The archaeological evidence thus demonstrates a complex pattern of shieling use in Greenland that seems to have been aimed at moving caprines away from managed home fields (and possibly managed wood lots) in summer and making full use of every pocket of pasture in the uplands and coastal strip. These ruins indicate a well-developed caprine management strategy probably aimed at both food and fiber production but at present their patterning does not indicate the same restructuring of caprine management in the later Middle

Ages as in Iceland. Structures like *rettir* associated with managing large free ranging flocks appear to be rare or absent in Greenland though large pens with milking enclosures as at E74 that imply close human contact and supervision are well documented. As we have seen above, there is also far less evidence for widespread rangeland overgrazing and degradation in Greenland than in Iceland.

While wild species (waterfowl, sea birds, sea mammals, and fish) were exploited from first settlement onwards in Iceland, by later medieval times marine fish became the major supplement to farm produce in provisioning. After c. AD 1250 evidence for standardization and commoditization associated with an expanded dried fish trade becomes increasingly archaeologically visible (Perdikaris and McGovern 2008; Feeley 2012; Harrison 2014; Smiarowski et al. 2017). The first unambiguous written records of commercial export of dried fish from Iceland to Britain likewise date to the end of the 13th century (Boulhousa 2010). As we have seen (Chapter 6) the Greenlanders did not expand fishing but seem to have significantly intensified their hunt for migratory seals, which had an increasingly key role in household provisioning on many farms but did not generate a marketable product for overseas trade.

As noted above (Chapter 6), Hayeur Smith's study of surviving woolen cloth from later medieval Greenland indicates some local developments of a denser (and perhaps a more weather-proof) weave, but not the same evidence for the production of standardized legally defined *vaðmál* that could serve as a unit of value in transactions and a commodity for overseas trade as in later medieval Iceland (Hayeur Smith 2014, 2020). The weaving traditions (highly female gendered) of the two communities thus diverged markedly just as both Scandinavian settlements were becoming integrated into the same Norwegian Atlantic Realm. The Icelandic weavers were producing a standardized commodity that could be bought and paid for sight unseen by distant merchants while their Greenlandic relatives continued an artisanal tradition apparently aimed at local consumers. Diverging household production modes and diverging use of marine resources is one clear outcome of the response to the conjunctures of the late 13th century in the two communities.

In both Iceland and Greenland, the later Middle Ages saw some parallel changes in the domestic mammal bones in the phased archaeofauna. In both communities, pigs were increasingly rare, and become trace species rarely occurring in most collections. In both communities, horse, dog, and cat bones rarely occur in refuse contexts, suggesting that they rarely played any role in human diet. In both communities, cattle remain present in all archaeofauna, though their relative numbers vary considerably between sites of different status (and in Iceland between Northern and Southern regions). The major difference in the zooarchaeology is in the diverging pattern of caprine bone deposition. As we have seen, goats were common in Greenlandic farming in all periods, becoming more common with time in some archaeofauna. Unlike in Iceland, goats did not become rare in the later Middle Ages, and the caprine herds continued to be very mixed until the disappearance of the colonies in the early 15th century AD (McGovern 1985a; Mainland and Halstead 1995; Smiarowski et al. 2017).

Contact with the immigrating Thule Inuit seems to have accelerated after AD 1300, generating some scattered records of conflict in a still poorly-understood story of culture contact (Gulløv 2008). The smaller and more northern Western Settlement appears to have been abandoned in the mid-14th century, but the much larger Eastern Settlement clearly survived into the mid-15th century (Arneborg 2003). Current evidence suggests that there may have been a realignment of farms in the final century, with more marginal farms being abandoned in favor of a core constructed around the larger manors of the inner fjords and farms being converted to seasonal shielings as at E74. The 15th century in Norse Greenland seems to have been a story of ultimately fatal settlement contraction and population decline and loss of contact with Europe, while late medieval Iceland was recovering from the plague years of the early 15th century and hosting increasing numbers of English, German, and Basque fishermen, traders, and whalers and becoming increasingly drawn into European commerce and politics.

As discussed in Smiarowski et al. (2017) the transition period between the Middle and Late phases ca. 1300 was thus a period of conjuncture of a number of forces acting on different temporal and geographic scales coming together to provide a critical turning point for these two closely related Scandinavian settlements. While this thesis is based on animal bone deposited as refuse on Greenlandic Norse farms, the patterns documented in Chapter 4 and discussed in more detail in Chapter 5, these analyses need to be placed in this wider context of these social/economic/ environmental conjunctures and set in more detailed comparison with contemporary zooarchaeological patterns across the Scandinavian North Atlantic.

Farming decisions in both Iceland and Greenland were driven by a need to balance different human needs; including basic household provisioning with food and woolen cloth needed for immediate survival; production of goods that could be mobilized for rent, tribute, or market sale; and maintenance of household prestige, social capital, and biological reproductive capacities.

Household decisions on caprine management were thus always embedded in a wider matrix and could be impacted by both local environmental factors (rangeland productivity changes, soil erosion, and vegetation changes) and by social factors (changing demands for rent or tribute). Another factor would be the ongoing critical zero-sum calculations of winter fodder consumption by different stalled domestic animals during the long winters, (ability of the livestock to 'fatten' over the summer for winter – meaning less fodder requirement over winter) and the availability of wild food to supplement domesticates' milk and meat (Amorosi et al. 1997). As both Iceland and Greenland were socially stratified medieval societies by the 13th century, the different economic and social positions and objectives of magnate households, middle ranking independent farmers, and poorer tenants or subsidiary farmers would have major impact on the respective farm herding strategies and the resulting midden contents that provide the proxy evidence we have today.

This section works to integrate current zooarchaeological data from fifteen archaeofauna from Iceland and Greenland. All are above a minimum sample size of Number of Identified Specimens (NISP) (> 300 NISP for major taxa), all come from at least partially sieved contexts which can be dated by radiocarbon, volcanic tephra, and artifacts, and most were analyzed using the common NABONE recording, and data management system developed by the NABO cooperative since 1997 (NABONE 9th edition). Older, un-sieved (and often not well dated) archaeofauna are referenced in the presentation but are not included in the graphs or summary tables.

One major inherent limitation in the comparison of archaeofauna from Icelandic and Greenlandic sites is particularly important to re-emphasize in this comparative study: there is a great difference in the pre-depositional taphonomy in most Greenlandic and Icelandic archaeofauna. As noted in

Chapter 4 Greenlandic archaeofauna are heavily fragmented and fully processed for maximum marrow extraction and often for 'bone grease' to a degree seen very rarely in Icelandic archaeofauna (Outram 2003; Smiarowski et al. 2017). As a result, measurable fragments, intact tooth rows, and whole bones are much rarer in the Greenlandic archaeofauna, rendering problematic many otherwise useful zooarchaeological comparisons (e.g., fusion rates on long bones, stature reconstruction). In this study we have thus largely restricted the cross-island comparisons to simple but generally robust relative species abundance NISP-based measures.

6.5.2. Icelandic Archaeofauna in this Study

In Iceland, faunal collections from Eyjafjörður and Mývatnssveit in the North and Northeast of Iceland contribute new data sets covering the time span between c. AD 875-1400. Eyjafjörður is a deep fjord system marked by steeply incised side valleys and comparatively rich farmland in the lower elevations. The major archaeofauna come from excavations at Gásir, located at the coast, as well as Möðruvellir, whose land is situated in the low-lying estuarine zone of the Hörgá river and the two upland sites Skuggi and Oddstaðir, located between 150 and 200 meters above sea level further up the Hörgárdalur valley (Vésteinsson 2001; Harrison 2013).

The Gásir site was not a farmstead but a seasonally occupied trading center, specialized in structure and layout, and functioned as a collection point and possibly as place of on-site finishing of Icelandic (and other North Atlantic) products for export and import (Harrison et al. 2008; Harrison 2013; Harrison 2014). The 2002-05 open area excavation of the Gásir trading site and its Merchant Church in 2004 and 2005 had as a goal the recovery of a broad synchronic picture of site conditions

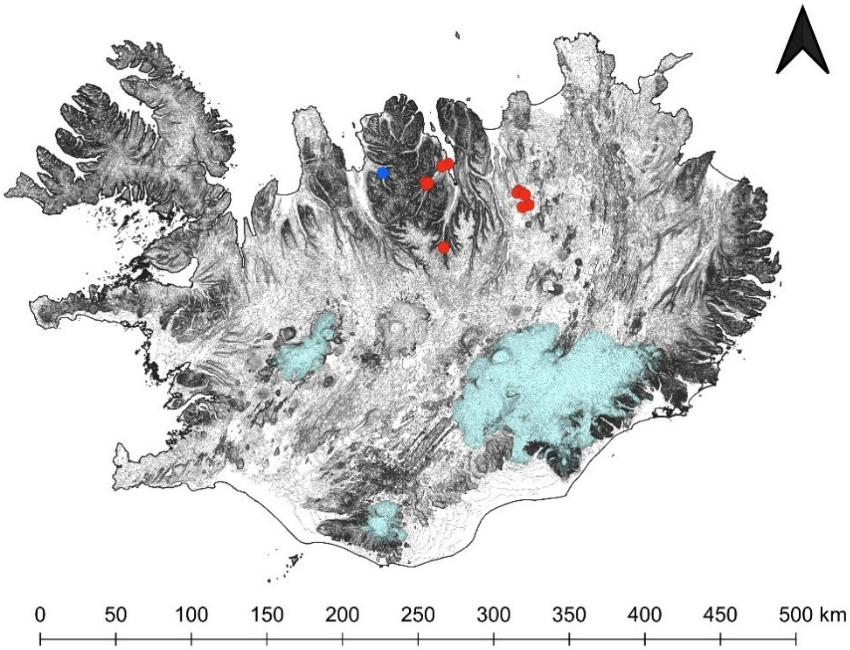


Figure 86 Icelandic sites discussed in this thesis. Map by Howell Roberts and the author. Base map from Anon, Is 50V Vatnafar/ISN2016.

during its later and possibly terminal activity phases (14th to early 15th century). Artifacts, and ecofacts, with special focus on the faunal remains are thus all from the same time period, dated by volcanic tephra and radiocarbon analyses to the 14th century.

Möðruvellir was an early chieftain's farm that became an ecclesiastical institution by the mid-12th century. It became an Augustinian House of Canons in AD 1295, operated under the control of the northern bishopric at Hólar (Harrison 2014). This high-status site drew resources from a wide area of Eyjafjörður and Hörgárdalur, interacted with the seasonal trading center at Gásir, and in early modern times was a major administrative center. Möðruvellir seems to represent a node in what

Júlíusson (2007) has characterized as an early Icelandic manorial system that integrated multiple outlying farms of varied status into a functional economic and social unit.

Skuggi was an upland Hörgárdalur farm established some time in the late 9th or early 10th century, and was probably always a fairly small and lower-status holding. Available radiocarbon and tephra evidence suggest an abandonment of the site some time in the 12th century. The site was likely a subsidiary farm and Skuggi represents a small farming establishment probably linked to larger holdings such as the Möðruvellir manor down valley. The abandonment of Skuggi may be associated with the establishment of a large specialized sheep herding structure at Klausturhús less than a kilometer away, which may have effectively replaced the farm household at Skuggi with a smaller staff of specialized herders tied to the Möðruvellir estate (Harrison 2013).

Oddstaðir is the second medieval non-elite Hörgárdalur farmstead investigated as part of the Gásir Hinterlands Project. It is located on the land owned by Öxnhóll, and was likely a subsidiary holding on the Öxnhóll estate where there had been a parish church since medieval times (Hreiðarsdóttir, pers. comm. 2008). The Oddstaðir data sets from the associated midden deposits give a chronology of activities spanning several centuries, from the farm´s likely establishment in the late 9th or early 10th century, through to farm abandonment in the late 14th century, around the same time when Gásir's use as harbor area and place of exchange seems to have come to an end. Just like Skuggi, Oddstaðir could have been a subsidiary farm; however, its faunal remains and its size based on its visible archeology hint towards a farm of higher economic standing than the one at Skuggi (Harrison 2013).

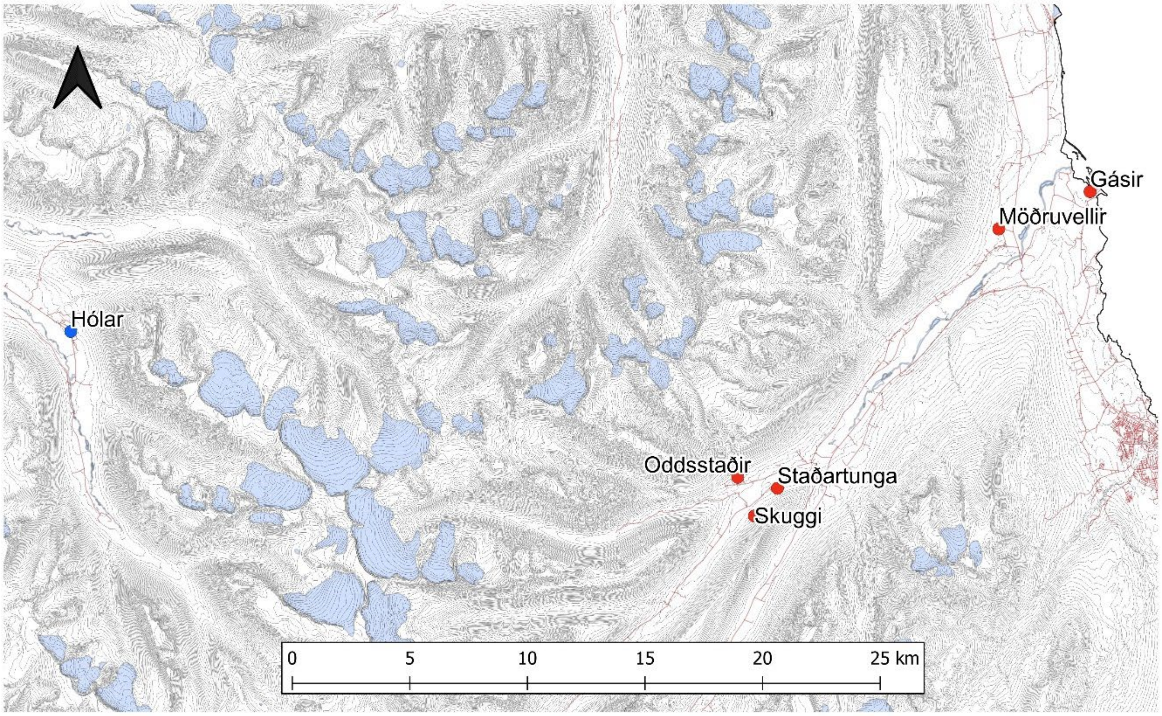


Figure 87 Eyjafjörður sites discussed in this thesis. Map by Howell Roberts and the author. Base map from Anon, Is 50V Vatnafar/ISN2016.

The Mývatn lake basin is one of the furthest inland areas of Iceland that was continuously occupied, with many farms above 200 meters above sea level and 50-50 km from the coast to the north. Zooarchaeological research in the Mývatn district (*Mývatnssveit*) extends over a century to the pioneering work of Herluf Winge and the 1907 excavations at the Viking Age great hall at Hofstaðir (Bruun and Jónsson 1911). Since 1995 the region has become a NABO long-term research area with international, interdisciplinary survey and excavation projects carried out nearly every summer down to the present (interim summary in McGovern et al. 2007). Major archaeofauna datable by radiocarbon and tephra to the initial settlement (c. AD 875-940) and later

Viking Age (c. AD 940-1050) include the middens and structural deposits associated with the great hall and ritual center at Hofstaðir, middens from the probably middle ranking site of Hrísheimar, and middens and structural deposits at the low-ranking site of Sveigakót (e.g., McGovern et al. 2009). Later medieval archaeofauna from the small site of Steinbogi*,* from c. AD 1200 (summary in McGovern et al. 2007) and later medieval deposits at Hofstaðir from c. AD 1250-1300 (McGovern et al. in press) are also reported here.

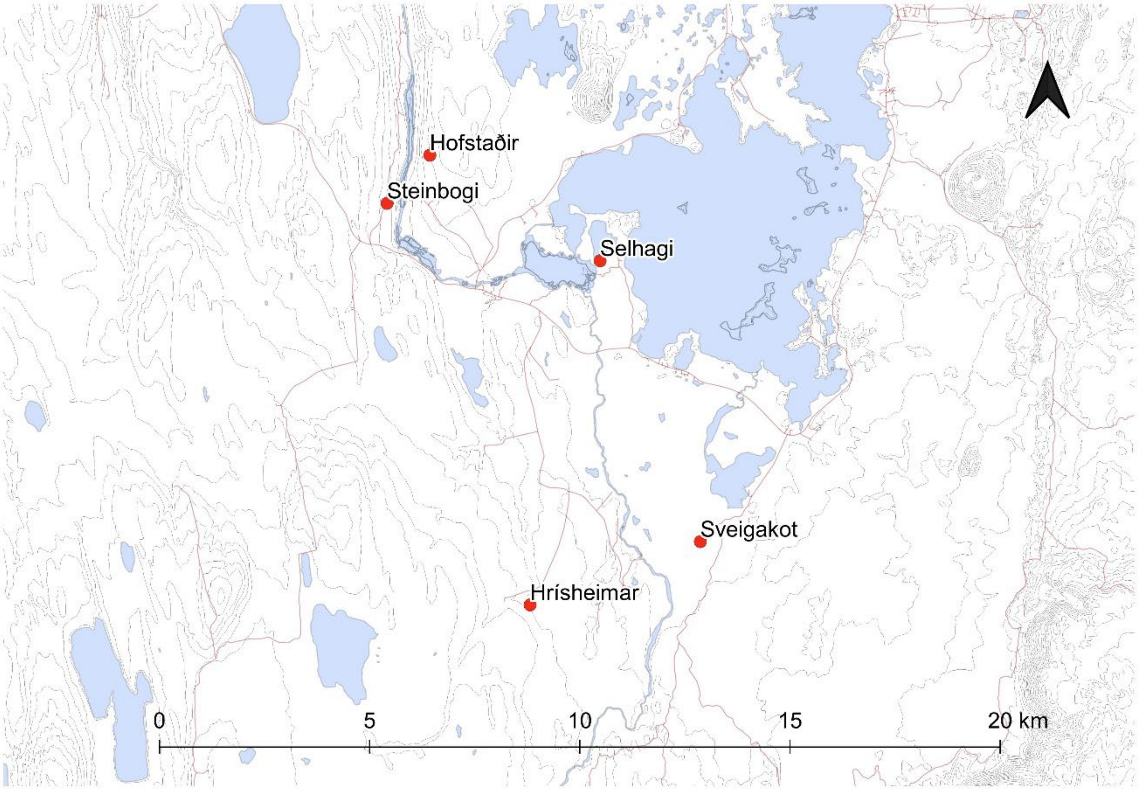


Figure 88 Myvatn area sites discussed in this thesis. Map by Howell Roberts and the author. Base map from Anon, Is 50V Vatnafar/ISN2016.

6.5.3. Greenlandic Archaeofauna in this Study

The stratified Greenlandic archaeofauna were collected from both the Western and Eastern Settlement sites on the west coast of the island. The Western Settlement collections come from the chieftain's farm at W51 Sandnes from a very small farm at W48 Niaqussat in the same Ameralla fjord (McGovern et al. 1996), and from the middle-ranking 'Gården under Sandet' GUS in a nearby inland valley (Enghoff 2003). All these Western Settlement archaeofauna are from the same settlement unit, a parish/district probably centered upon the elite church farm at Sandnes.

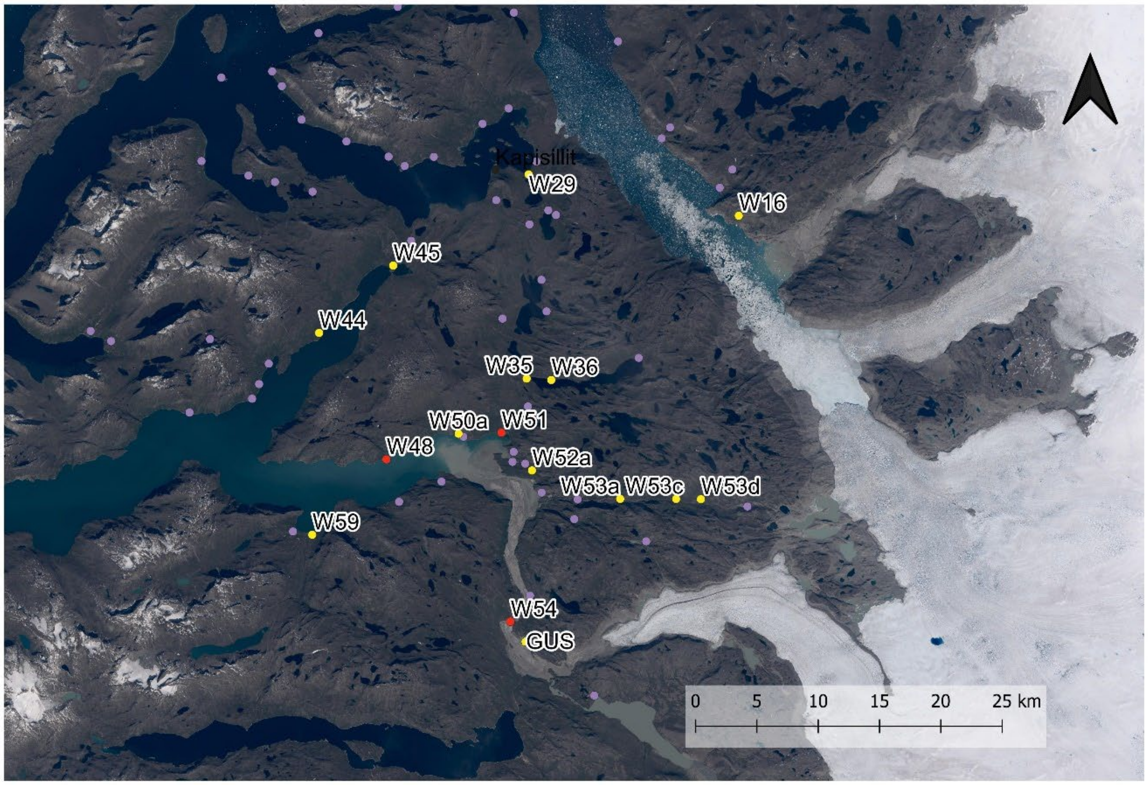


Figure 89 Western Settlement sites discussed in this thesis. Map by Howell Roberts and the author (source: nunniffiit.natmus.gl and QGreenland (v2).

The newer stratified archaeofauna from the Eastern Settlement come from extensive excavations from 2005-2012. Research focus has been placed on the inland district of Vatnahverfi, where Danish, Greenlandic and United States researchers collaborated on *The Vatnahverfi Project* from 2005-2011(Madsen et al. 2009; Smiarowski 2012). E172 Tatsipataa and E74 Qorlortorsuaq are in Vatnahverfi, while E29N Brattahlið and E47 Garðar are both in the central part of the Eastern Settlement area.

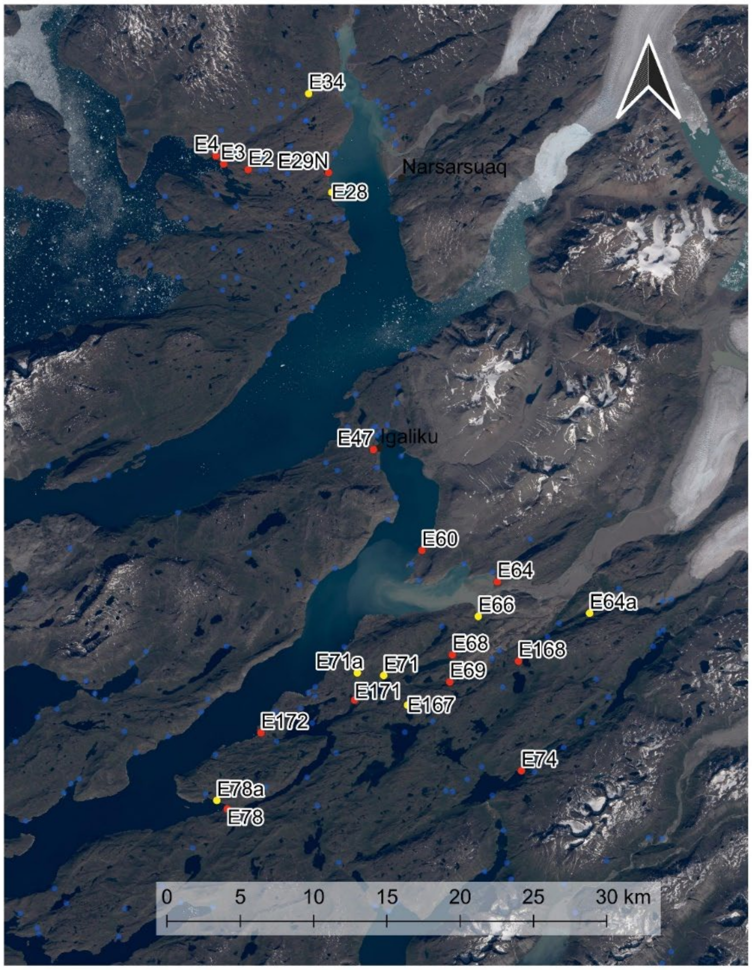


Figure 90 Eastern Settlement sites discussed in this thesis. Map by Howell Roberts and the author (source: nunniffiit.natmus.gl and QGreenland (v2).

The farm site E172 Tatsipataa is located on the eastern shore of Igaliku Fjord and is a typical mid-sized inner fjord farm, without a church or other evidence of high status or economic specialization. During the Vatnahverfi Project survey, 21 separate ruins were registered as part of this farmstead (Madsen et al. 2009). The site rests on a gentle and damp slope, has a substantial home field area and decent productivity of the vegetation. The site has a good landing area, a somewhat protected harbor, and a stream where boats could be overwintered.

The closest early parish churches are located at E78 Eqaluit, E64 Innoquassaq, and E66 Igaliku Kujalleq; and the site may have belonged to any of them during the early settlement stages. After abandonment of the small churches E64 Innoquassaq and E78 Eqaluit in the late 13th century, the site probably belonged to a parish at E66 Igaliku Kujalleq. Radiocarbon dates for the midden excavated at the site in 2007-2010, date the occupation of this site to the early 11th -early 15th century.

The E47 Garðar farmstead, located in the modern settlement of Igaliku, was a Landnám site that became the Greenlandic bishopric in AD 1127, and current evidence suggests that it developed into, by far, the largest manor and elite center in Greenland (Smiarowski 2012). It was a local chieftain's farmstead in the early stages of the settlement and became a localized center of power for all of Norse Greenland once the bishopric was established. The site is placed at the head of Igaliku Fjord, with a well-protected harbor. The farm and ecclesiastical buildings are roughly centered on a large, flat, irrigated meadow, which is the largest home-field in Norse Greenland. Monumental architecture at the site, especially the St. Nicolas cathedral, large warehouses and the sheer number of ruins (c. 35 registered, but most have been removed during 18th-19th century resettlement) during the last occupation period, leaves no doubt about its prime role as a magnate estate with far reaching influence and control in the Eastern Settlement, and the whole of Norse Greenland. Cattle byres were capable of housing nearly a hundred cattle, in contrast to the 3-5 stalls usually encountered on smaller farms (Roussel 1941). This site also contains the largest concentration of caribou bone in the Eastern Settlement, further indicating the high status of its inhabitants (Smiarowski 2013). The zooarchaeological collection, excavated in 2012 dates to roughly AD 1150-1390, and does not represent the whole occupation history of the site.

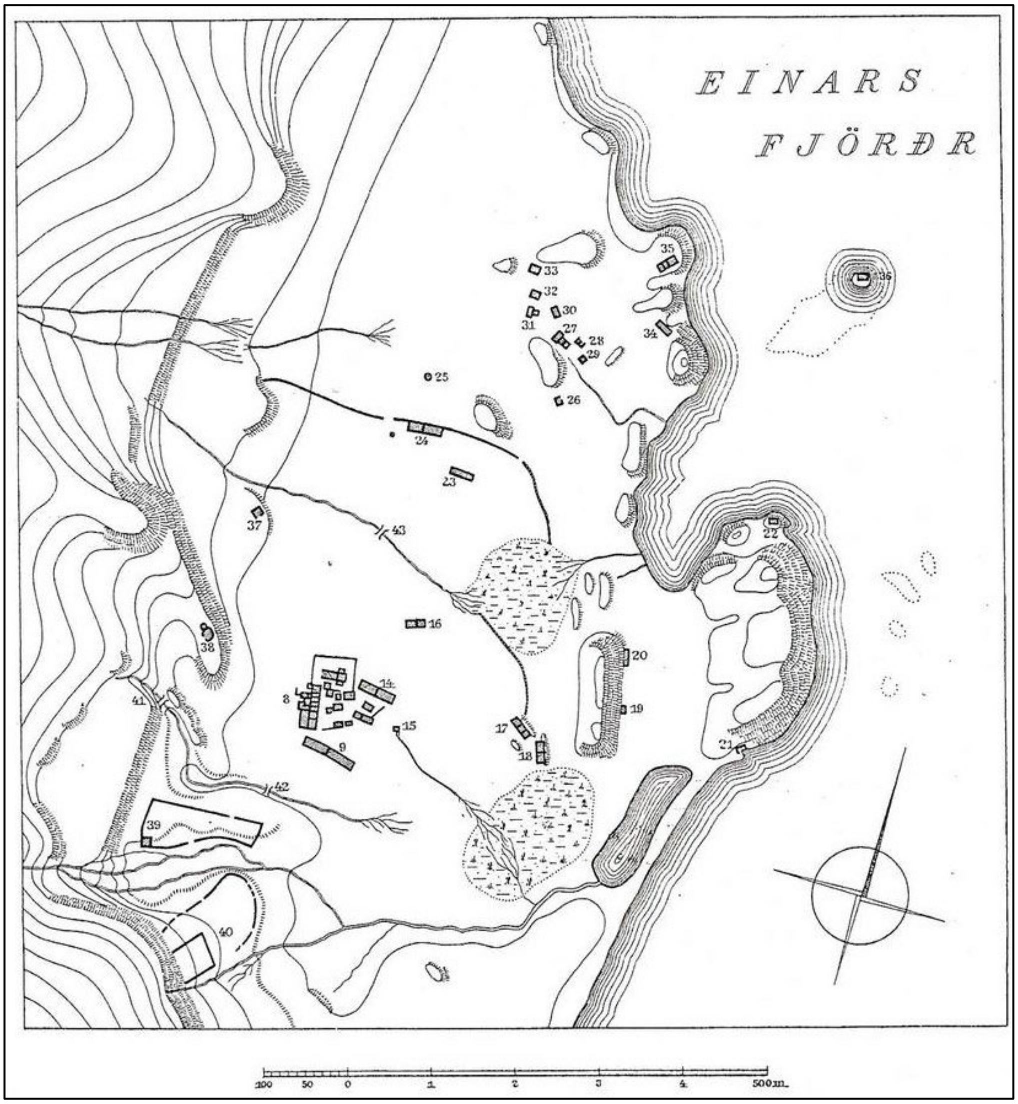


Figure 91 Plan of E47 Garðar (Nørlund 1929)

The site of E64 Innoquassaq is a medium sized site located at the head of a large bay in the Igaliku Fjord. This is probably a Landnám site where excavations of an early medieval churchyard cemetery and midden deposits identified two major occupation phases. The midden located next to the dwelling has been partially excavated in 2008 (e.g., Paulsen et al. 2009) but the preservation conditions completely ravaged the bones, and the collection is unfit for any analysis. The organic preservation was too poor to provide even a few terrestrial mammal bones suitable for radiocarbon dating. The archaeofauna presented in this chapter comes from a house midden deposited in the upper layers of the churchyard, collected during excavation of the underlying graves in 2007-2008. The dates for this deposit range between AD 1150-1250, dating the abandonment of the church and the graveyard to that time period.

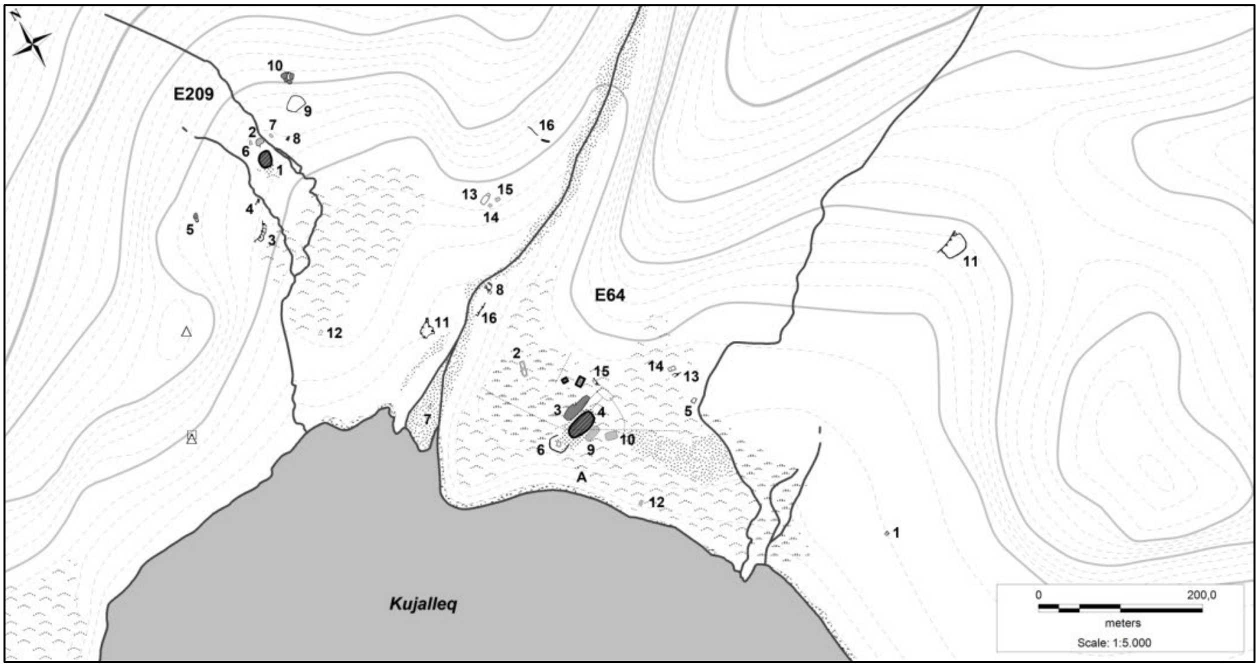


Figure 92 Site Plan of E64 Innoquassaq (Madsen 2014). The dwelling is ruin no. 4, and the excavated midden is the shaded area next to it.

Brattahlið (E29N) was a high-status chieftain's farm during the settlement period, located northwest of the Vatnahverfi district on Tunulliarfik Fjord, and is widely considered to be the farm of Eric the Red. It had an early, small turf church associated with the Settlement occupation. The small church was replaced by two larger churches. First one was a church with Romanesque ground plan that around AD 1300 was replaced by a rectangular, stone-built church. The site has been identified by later medieval written sources as home of the local law-speaker, or head of the assembly (Gad 1970). E29N Brattahlið was probably occupied until the abandonment of the area in early 15th century, but the C14 AMS dates obtained from the midden material excavated in 2005-2006 date the zooarchaeological collections to c. AD 1000-1300 (Edvardsson et al. 2010).

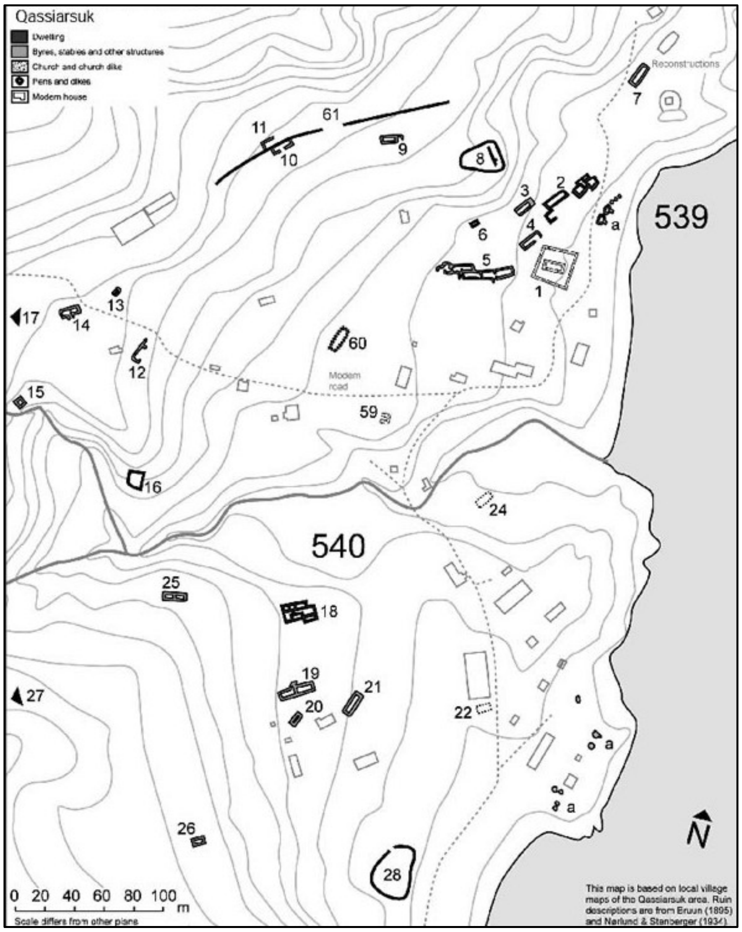


Figure 93 Site Plan of E29N (539) and E29 (540) in Qassiarsuk. The Dwelling is indicated as partial ruins 2 and 4 here, and the excavated midden is just SE and adjacent to them (Goldager 2002).

E74 Qorlortorsuaq was a small farm located in the inland part of the Vatnahverfi area. In the second half of the 13th century the site was transformed into a shieling, specializing in caprine herding. Midden and structural excavations in 2005 produced an archaeofaunal collection and radiocarbon dates ranging from c. AD 1020-1420, which most likely represents the whole occupation period at this site (Smiarowski 2014). This site has been used in the case study of climate related farm to shieling transition (section 6.3).

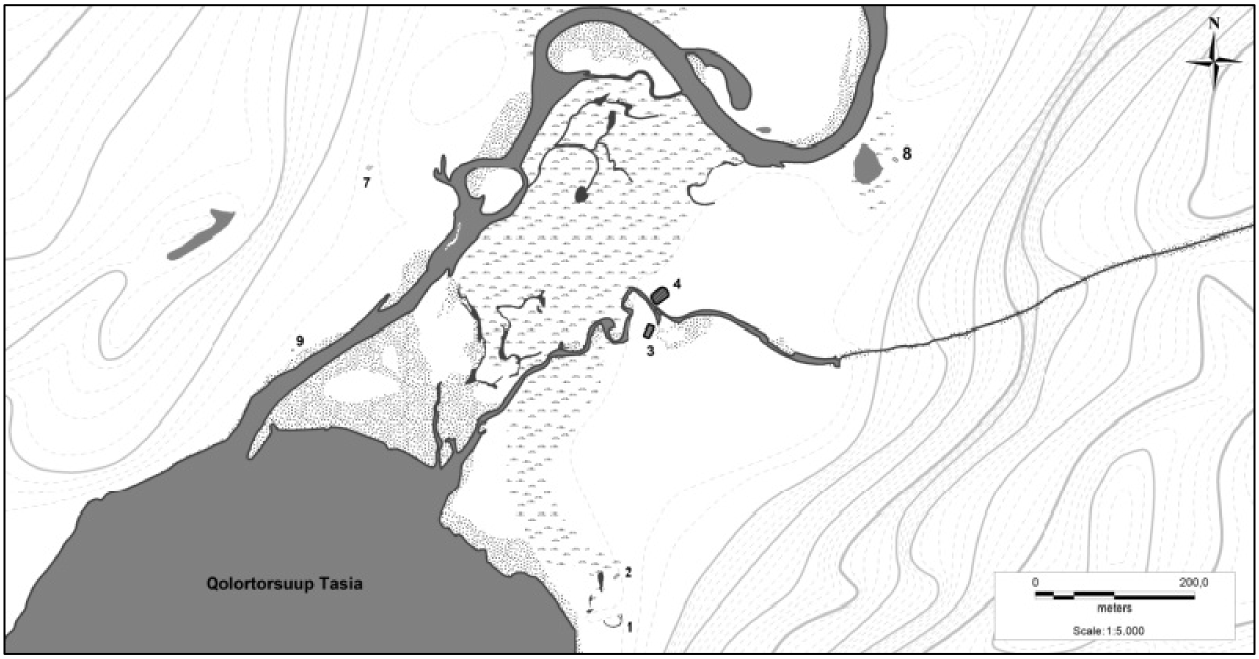


Figure 94 Site Plan of E74 Qorlortorsuaq (Madsen 2014). The dwelling is ruin no. 4 here, and the excavated midden is just NW and adjacent to it.

6.5.4. Discussion on Livestock Management Strategies

A first stage comparison of the relative proportions of the major domestic taxa, cattle and caprines in the phased archaeofauna may be helpful. As presented in figure 95, the data for our stratified, sieved collections from Iceland and Greenland, grouped the archaeofauna into two broad periods: Viking Age to c. AD 1200, and AD 1200 and later.

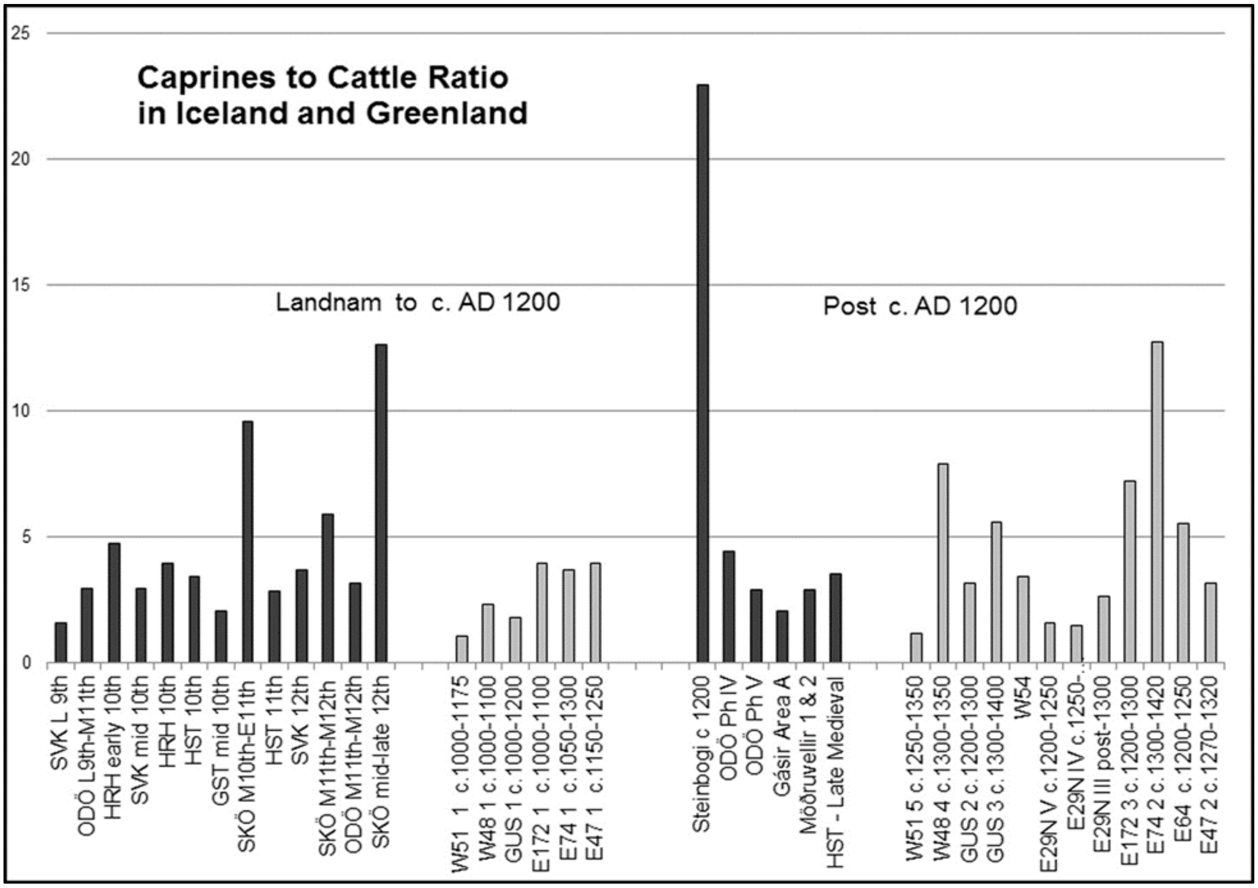


Figure 95 Caprine to Cattle Ratios at Icelandic and Greenlandic sites in two broad periods.

This division should capture the potential shifts associated with the hypothesized second major pathway juncture of the High Middle Ages. Within the two broad periods, archaeofauna are loosely grouped in approximate chronological order within their respective islands. It can be seen that during the Viking Age, both Icelandic and Greenlandic archaeofauna show a fairly low ratio of caprine bones (both sheep and goat together) relative to cattle; with a fairly consistent ratio below the one cow to five caprine limit. The exceptions are all from the small site of Skuggi (SKO) in Hörgárdalur. Current evidence suggests that it was always a small farm on a steep hillside and very likely a tenant farm for its entire existence. Skuggi was apparently replaced by a specialized sheep herding complex at Klausturhús just 500 m away sometime after AD 1200 (Harrison 2013).

In the post- AD 1200 collections, the very high ratio of caprines to cattle (23:1) at the small Mývatnssveit site of Steinbogi (SBO) is immediately apparent. A similar high ratio (above 1:20) is also present in the later medieval-early modern layers of the Icelandic Svalbard site (e.g., Smiarowski et al. in press). Interestingly, although the high-ranking site of Hofstaðir (with a private chapel) is in direct line of sight with Steinbogi across the Laxá river in Mývatnssveit, the medieval Hofstaðir archaeofauna from c. AD 1275-1310 displays much the same 1:3 - 1:4 ratio of cattle to caprine bones as the Viking Age Hofstaðir archaeofauna associated with the great hall (McGovern et al. 2009; McGovern et al. in press). The preliminary later medieval cattle to caprine ratios from the upper ranking church farm at Skútustaðir in Mývatnssveit (Hicks 2010) likewise do not show a ratio comparable to the > 20:1 Steinbogi pattern.

The post- AD 1200 Eyjafjörður/Hörgardalur collections do not contain an archaeofauna as caprine-rich as Steinbogi in Mývatnssveit, but by AD 1200 small farms like Skuggi had been abandoned and apparently replaced by specialized sheep herding structures tended by a few hired hands rather than a small farm household. The high ranking (at this point monastic) site of Möðruvellir shows a low caprine to cattle ratio similar to the higher ranking Mývatnssveit sites. The mid-ranking farm at Oddstaðir (directly across the Hörgá river from the site of Skuggi) actually shows a relative increase in cattle bones relative to caprines after c. AD 1250, but this may be associated with this farm's potential involvement in an area-wide provisioning system geared to the seasonal trading center at Gásir with beef; Oddstaðir also shows an anomalous beef vs. dairy signature in its site archaeofauna (e.g., Harrison 2013).

In the phased Greenlandic collections graphed in figure 95, there is no collection comparable to the Steinbogi caprine to cattle ratio either before or after AD 1200, but three Greenlandic sites do show significant increases in caprines relative to cattle: W48 in the Western Settlement and E74 Qorlortorsuaq and E172 Tatsipataa in the Eastern Settlement (McGovern 1985a; Smiarowski et al. 2017). The W48 site is one of the smallest and probably lowest status site yet excavated in Greenland, and like Skuggi in Iceland it may have been a dependent tenant farm for much or all of its existence. The E172 Tatsipataa was a mid-ranking farm founded in the Viking age, but one which may have been abandoned prior to the final end of Norse Greenland c. AD 1450. The site of E74 Qorlortorsuaq was always a small farm, and by the 13th century it may have been converted to a seasonal herding station (Smiarowski this volume). This later phase at E74 Qorlortorsuaq shows the highest proportion of caprines in the current Greenlandic archaeofaunal data set, but note that its c, 13:1 ratio is comparable to the c. 13:1 ratio in the final phase of Skuggi in Iceland over a century before.

As presented in figure 96 the ratio of sheep bones per goat bone for the same set of archaeofauna in the Icelandic and Greenlandic collections before and after c. AD 1200 (taller bar = more sheep relative to goats). Note that the Greenlandic archaeofauna are goat-rich throughout the entire period of the colony in both settlement areas. While comparably high ratios of goats to sheep are visible in many of the Icelandic Viking Age-early medieval archaeofauna, there is a general tendency for goats to decline relative to sheep in the Icelandic collections through time. The terminal Skuggi archaeofauna identified caprine category is entirely made up of sheep, as is the high medieval Hofstaðir archaeofauna; while the caprine rich Steinbogi archaeofauna has only a single goat bone (the actual 1:153 ratio is truncated in the graph of figure 96 to enhance legibility).

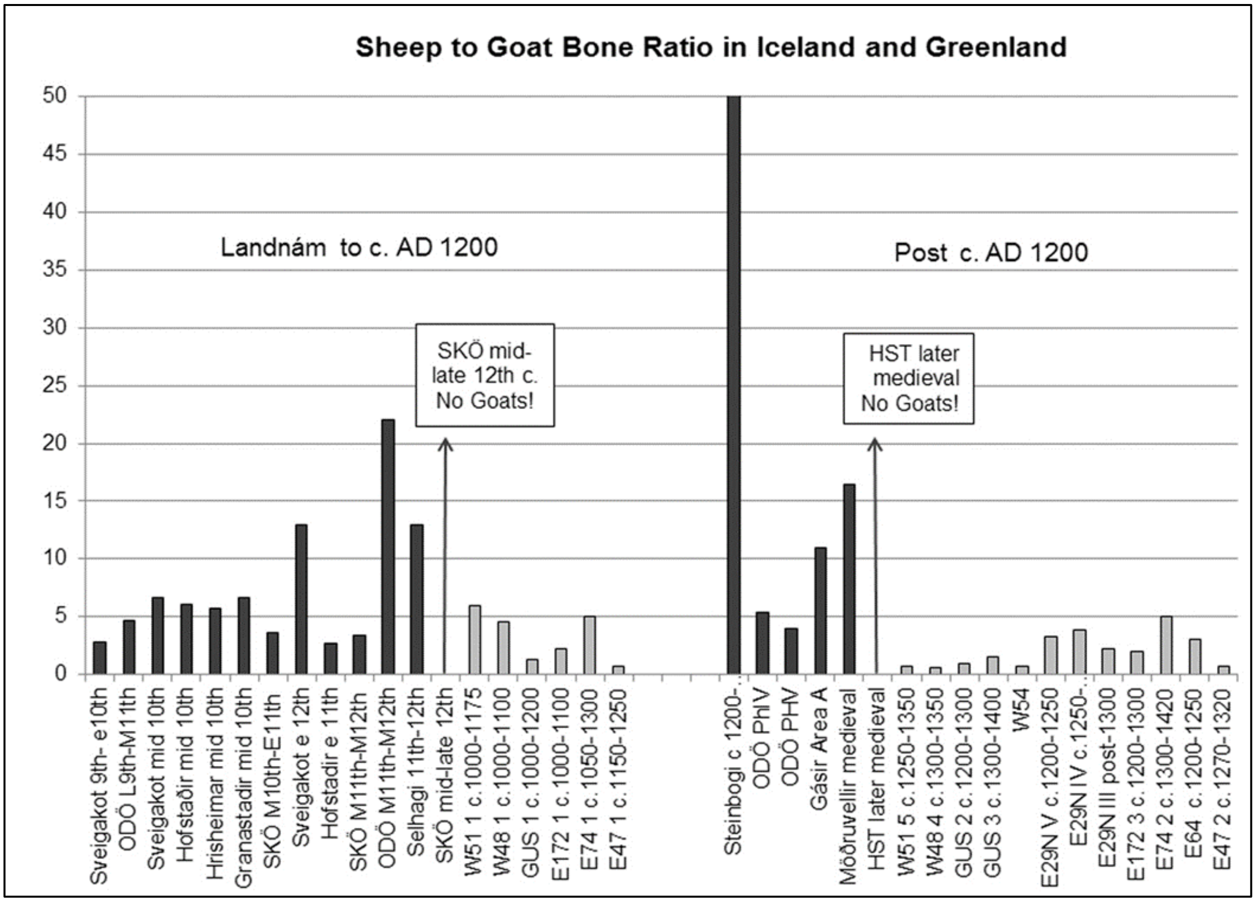


Figure 96 Sheep to Goat Ratios in Iceland and Greenland.

It may be helpful to bring together these two ratios where stratified collections from the same sites allow a direct comparison of caprine/cattle and sheep/goat ratios through time. In figure 97 below, these patterns for Mývatnssveit and Eyjafjörður in Iceland are presented.

In the Viking Age high status collections from Hofstaðir (HST) the cattle to caprine ratio is stable, but goats increase slightly relative to sheep into the early 11th century abandonment of the great hall and pagan ritual center (Lucas 2009). The medieval (c. AD 1275-1310) archaeofauna from just outside the Christian cemetery at Hofstaðir maintains a high proportion of cattle to caprines,

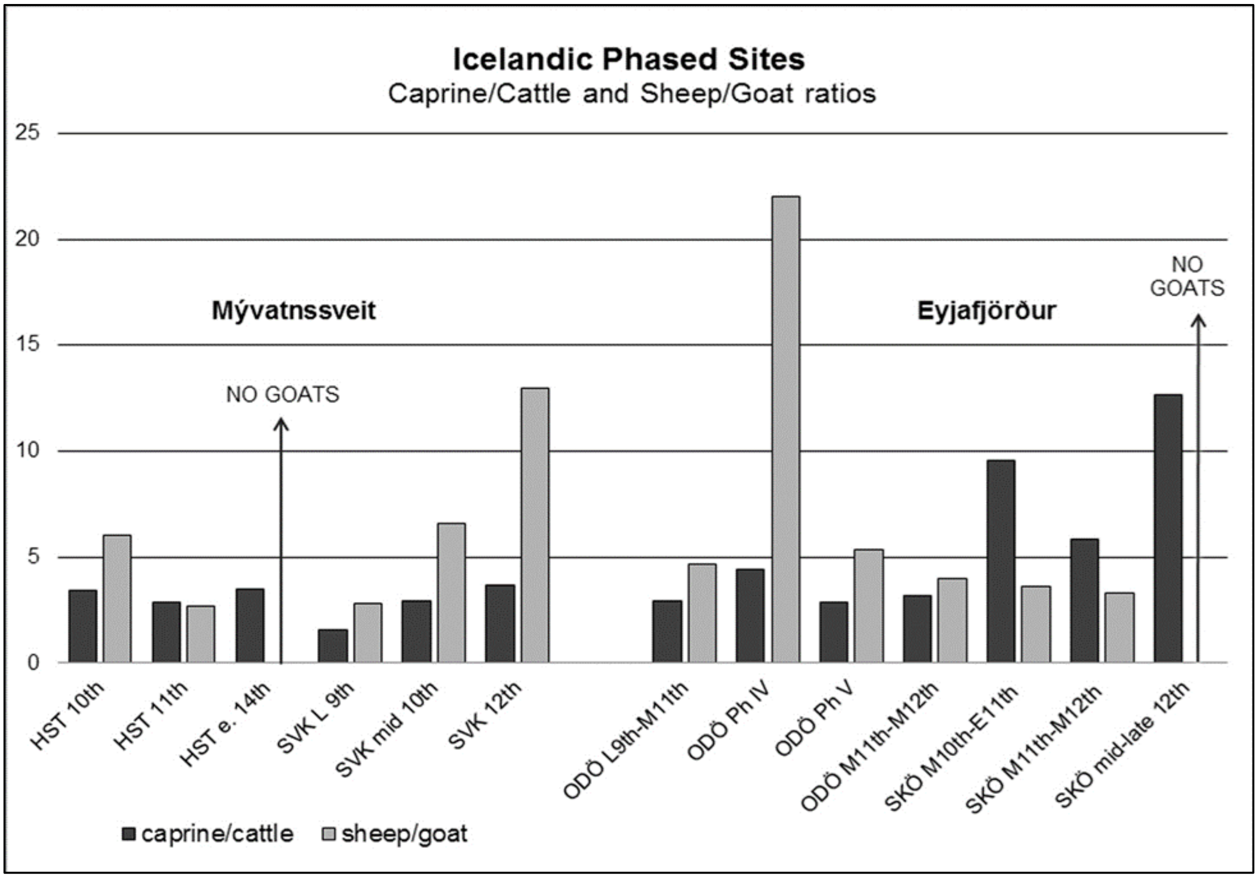


Figure 97 Caprine / Cattle and Sheep / Goat Ratios at Icelandic Phased Sites.

but the 185 caprine bones that could be identified to species level were all sheep (McGovern et al. in press). While the Hofstaðir high medieval archaeofauna does not show any shift away from a focus on cattle husbandry, it does show an apparent trend towards wool production within the caprines, a pattern reinforced by the available age/size reconstruction data indicating a higher percentage of larger older adults (probably mainly wethers) than in the Viking Age. The small farm of Sveigakót (SVK) was probably always a dependent farm from its late 9th century founding down to is abandonment c. AD 1200, shows a steady pattern of increasing caprines relative to cattle, and these caprines increasingly are sheep rather than goats. Available age/size data from Sveigakót suggests a multiple-use caprine herding strategy throughout, but with a trend towards older and larger individuals in the later phases. In Eyjafjörður, the small Skuggi (SKO) site shows a Viking Age pattern of a very mixed caprine flock in its initial phases but appears to combine an increase in relative proportion of caprines with a conversion to an all-sheep flock in the final phase before abandonment c. AD 1200. The nearby middle-ranking site of Oddstaðir (ODO) again begins with the Viking Age pattern of a fairly small and very mixed caprine flock that converts towards a sheep-heavy flock in the early medieval period after AD 1200. As noted above the Oddstaðir farm economy seems to have become engaged in supplying Gásir (or a similarly profitable partner site) with beef, impacting the provisioning of its own household with dairy products as its cattle management strategy shifted towards beef production. This may explain the shift within the caprines back towards dairy goats, but clearly more work on this site is needed to better understand these patterns (Harrison 2013). Farm status seems to be involved in the trajectories of stock management in later medieval Iceland, but different strategies for market production may also be in play in what appears to be an increasingly complex Icelandic economy after AD 1200.

A comparison of the stratified Greenlandic archaeofauna combined ratios (Figure 98 below) also suggests the interplay of site status and farm husbandry strategies, but with some important differences from Iceland.

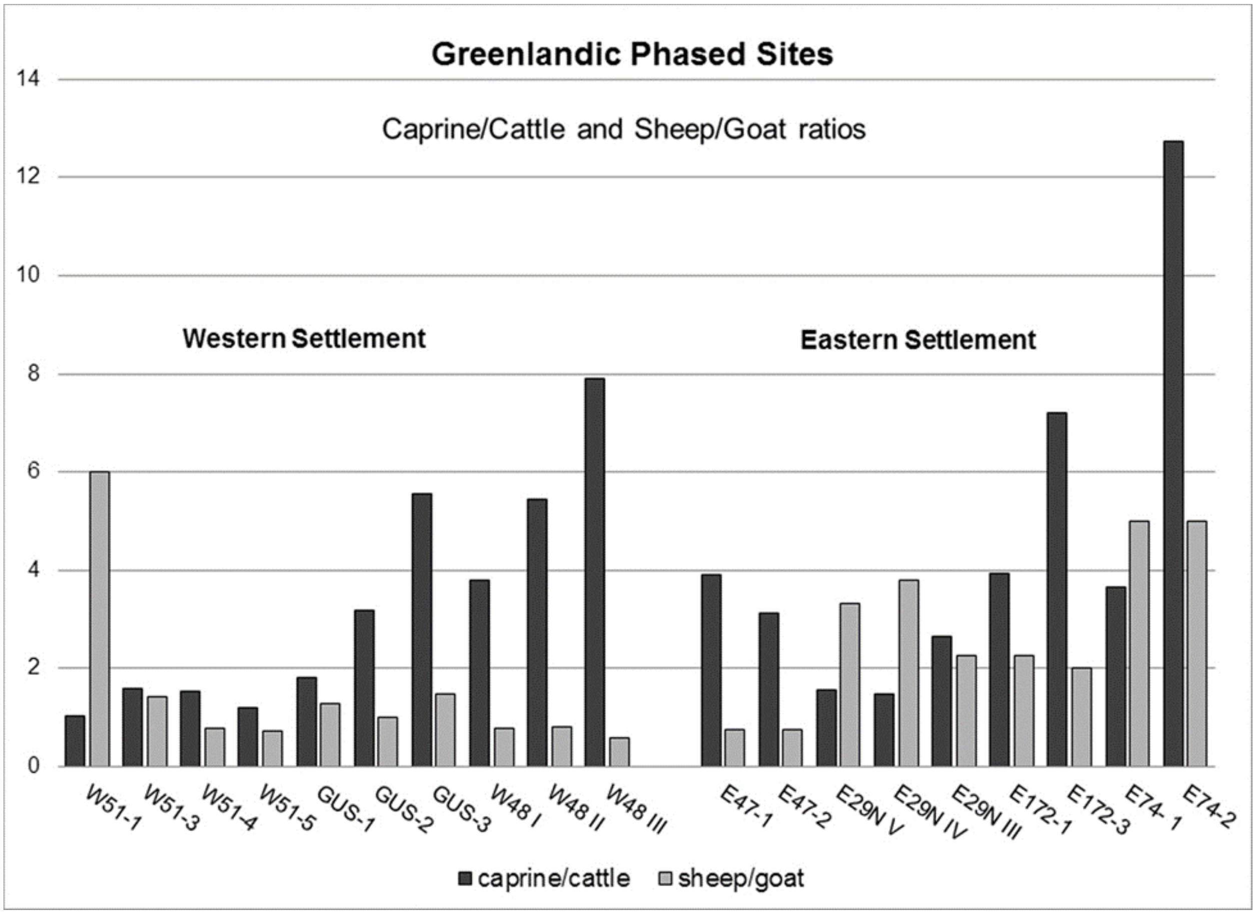


Figure 98 Caprine / Cattle and Sheep / Goat Ratios at Greenlandic Phased Sites.

In the Western Settlement, the chieftain (and later church) farm at W51 Sandnes maintained a high ratio of cattle to caprines throughout its occupation from late 10th to mid-14th centuries. Like contemporary elites in Iceland, the Sandnes estate-maintained cattle keeping as a key farming strategy, but the sheep to goat ratio moves away from more sheep in the late Viking Age towards a pattern of more goats in the later Middle Ages. Both the middle ranking GUS site and the very small W48 site archaeofauna show a steady increase of caprines relative to cattle, but stable or declining ratios of sheep to goats. Goat-keeping clearly remained very important in the farming strategies of all classes in the Western Settlement down to its abandonment in the mid-14th century.

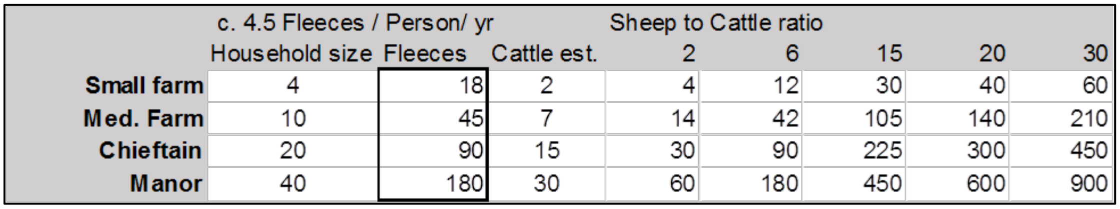
At the bishop's manor at E47 the current stratified collections show a stable or declining ratio of caprines to cattle, and a consistently high ratio of goats to sheep. This elite central place does not seem to have emphasized wool production, at least not on its home manor farm. The later phase at E29N shows a slight increase in caprines in the uppermost layers as well as a somewhat higher (if variable) proportion of sheep to goats. The mid-ranking E172 Tatsipataa and low ranking E74 Qorlortorsuaq archaeofauna both show a common pattern similar to the GUS and W48 collections from the Western Settlement: steady increase in caprines relative to cattle without a corresponding increase in sheep relative to goats.

The current stratified domestic stock data for Iceland and Greenland thus provide some similarities in animal husbandry (especially in the Viking Age and early medieval period), but increasingly contrast after c. AD 1200 as the Icelanders generally replaced their food producing goats with food and wool producing sheep. In both communities, elite farms maintained substantial cattle herds, and even small households apparently maintained at least a few cattle to supplement increasingly caprine-dominated domestic stock. In both communities, there are clear indications of the sort of landscape-scaled elite manorial management systems suggested by Júlíusson (2007) based on the documentary record. The presence of marine fish and marine mammal bones on inland farms in both communities may serve as a reminder that the individual farm and its immediate site territory was not the fundamental unit of adaptation in either Greenland or Iceland during the Middle Ages. Elite farms were legally able to dictate animal production strategies to tenants, and they received rents, tithes, and other tribute in wool, dairy products, and labor thus underwriting animal management strategies on the home manor with the production of multiple dispersed tenant holdings.

Divergence in caprine management strategy between Iceland and Greenland c. AD 1200 seems increasingly well documented by a range of archaeological indicators. A key question remaining is associated with the production of a significant surplus of woolen cloth above the immediate needs of the farm households (Ingimundarsson 1995). What stocking level and mix of caprines will allow for a significant wool surplus to be produced for external or internal trade, rent or tribute payment?

Vésteinsson (pers. comm.) and Thorláksson (1991) have done considerable documentary research on medieval Icelandic sheep raising, consulting law codes, sagas, and later management literature to address some of these key questions about production and consumption of woolen cloth. Their research indicates a consistent figure of about three to five fleeces worth of sheep wool per year to adequately clothe an individual and provide some allowance for bedding and other fabric needs. Using this consumption estimate (here set at about 4.5 fleeces/ person/ year) and broad estimates of human population and cattle herd size (based upon both documents and floor area metrics of excavated halls and byres; McGovern 1985b), we can generate a crude model for potential fleece production/consumption on four classes of farm holding (Table 74 below) with possible maximum fleece production provided for five scenarios of sheep per cattle ratios (from 1:2 to 1:30). The *small farm class* has a small household and a few cattle and will consume around 18 fleeces annually.

Table 74 Calculation of Estimated Fleece Production at Various Site Types.



	c. 4.5 Fleeces / Person/ yr			Sheep to Cattle ratio				
	Household size	Fleeces	Cattle est.	2	6	15	20	30
Small farm	4	18	2	4	12	30	40	60
Med. Farm	10	45	7	14	42	105	140	210
Chieftain	20	90	15	30	90	225	300	450
Manor	40	180	30	60	180	450	600	900

At a low ratio of caprines to cattle (1:2-1:5), this scale of farm will generate fewer fleeces than it can consume, therefore a small farm with a caprine ratio in this range is highly unlikely to generate any surplus wool, even if all the caprines are in fact sheep and all sheep are shorn each year. On the other end of the scale, a major magnate farm with a large household (and more cattle) will be about at the break-even point for woolens around the 1:5 cattle to caprine ratio, but below this point it will need to acquire fleeces from tenants or on the open market to clothe and equip its household.

In her extensive re-analysis of North Atlantic wool and wool production Hayeur Smith (2020:99-100) critiques the production/ consumption figures of Vésteinsson (pers. com.) and Thorláksson (1991) that underlie the model presented above (first appearing in 2014), Making use of experimental spinning and weaving data collected from the Danish Historical and Archaeological Experimental Center at Lejre (Andersson Strand 2007) she argues that the time required to produce this volume of woolen cloth of all sorts is simply too high to be realistic, allowing farm women no time for their many other tasks. She argues that most households made do with old cloth and supports her argument with analysis of the multiply patched woolen garments from the Herjolfsnes cemetery. The startling results of successive AMS radiocarbon assays run on different parts of the famed "Burgundian Cap" indicate both that it was at least 200 years older than Poul Nørlund´s stylistic data (Nørlund 1924) and that parts of the cap were woven as much as centuries apart. This cap was probably part of a woman's dress, and the re-use of legacy cloth may have had a ritual component in this case, but Hayeur Smith convincingly argues for pervasive recycling and re-use of textile fragments in both Greenland and Iceland (Hayeur Smith 2020:80-100).

Extensive re-use and long-term curation of woolen cloth probably brings the production/ consumption figures used in Table 74 above down significantly. Below is the same table as in Table 75 above re-calculated at 3 fleeces/person/ year to allow for more curation and re-use.

Table 75 Recalculation at 3 fleeces per person per year.

	c. 3 Fleeces / Person/ yr			Sheep to Cattle ratio				
	Household size	Fleeces	Cattle est.	2	6	15	20	30
Small farm	4	12	2	4	12	30	40	60
Med. Farm	10	30	8	14	42	105	140	210
Chieftain	20	60	18	30	90	225	300	450
Manor	40	120	36	60	180	450	600	900

This recalculation still suggests that a 5-6: 1 ratio of sheep to cattle will be needed for a breakeven point, which is still higher than most of the Greenlandic archaeofauna.

A second re-calculation at 1 fleece/person/year provides the results below (Table 76).

Table 76 Recalculation at 1 fleece per person per year.

	c. 1 Fleece / Person/ yr			Sheep to Cattle ratio				
	Household size	Fleeces	Cattle est.	2	6	15	20	30
Small farm	4	4	2	4	12	30	40	60
Med. Farm	10	10	8	14	42	105	140	210
Chieftain	20	20	18	30	90	225	300	450
Manor	40	40	36	60	180	450	600	900

At this point Hayeur Smith's worktime calculations suggest that available woman power on the farms might have been able to keep up with household demand on all site classes with a very low 2:1 ratio of sheep to cattle. This does suggest that if households could get by with heavily worn and patched clothing and household furnishings, they could have fulfilled these needs with some of the very low ratios of sheep to cattle observed in the Greenlandic record, while potentially creating a very small surplus to periodically meet other obligations.

These scenarios of course assume that the caprines are all sheep, and that everyone in the society was willing to be equally ragged, but they most definitely underline the heavy labor burden that large scale surplus wool production would put upon a small community. In practice, we know from Icelandic documentary sources that elites regularly wore fine and fashionable new clothing (and occasionally attracted negative ecclesiastical attention as a result) and that some manor farms (including monastic centers like Möðruvellir) maintained teams of women who specialized in weaving as their major labor service. We also should assume that some goat hair was incorporated into clothing along with other fiber and that caribou and seal skins were also used for outer clothing in Greenland. Hayeur Smith reports that aDNA analysis indicates use of arctic hare fur along with wool in some cloth fragments but has not yet confirmed goat hair presence in existing samples (Hayeur Smith 2020 :102-103). However, the addition of these other species hair would not qualify as legal woolen cloth for currency or exchange in Iceland nor would they have been regularly accepted in the growing European textile markets.

The calculations can be tweaked to produce different model outcomes, but the overall conclusion that low caprine to cattle ratios (below ca 5:1) will make it difficult to produce a wool surplus. The labor estimates likewise suggest that a small farm with limited weavers might struggle to produce woolen cloth as tithe and tribute payments even if the household mainly lived in rags. Flocks managed with significant numbers of goats are also very unlikely to have been able to generate significant wool surplus on a regular basis. These observations have implications for our currently observed cattle/caprine and sheep/goat ratio zooarchaeological patterns:

1) For all farm classes, caprine to cattle ratios in the 2:1 to 5:1 range were probably aimed at providing for household wool consumption needs rather than surplus generation (especially

if the caprines were a mix of sheep and goats). The widespread Viking Age pattern of caprine to cattle bones thus does not support a scenario of very large-scale surplus woolen cloth production, at least not based upon normal household productivity.

2) Small farms with caprine to cattle ratios substantially above 10 to 1 with a strong predominance of sheep over goats were potentially producing a wool surplus. Caprine to cattle ratios above 1:15 (especially when caprines are mostly sheep) were very likely associated with wool surplus production efforts for any farm class. The 1710 *Jarðabók* (Magnússon and Vídalín 1943) stock census returns for Mývatn farms indicates just such a wool surplus production pattern (mean caprine to cattle ratio is 27:1, range 49:1 to 13-1, n= 19, data from Edvardsson 2010), which is also attested by contemporary documentary evidence.

3) Greenlandic farms in our current sample were very unlikely to have ever produced a significant woolen cloth surplus above household consumption needs. Caprine to cattle ratios are low, and goats equal or outnumber sheep in most flocks. Increasing caprine numbers appear to reflect an effective substitution of goats and sheep for cattle in dairy and meat production. Greenlandic elites as well as commoners had significant goat flocks on their home farms and all Greenlandic farms seem to have been engaged in food production rather than wool production as a primary objective. This subsistence-orientated pattern seems if anything to have intensified after c. AD 1200.

4) Economic divergence in farming objectives between Greenland and Iceland across the High Medieval conjunctures of climate, politics, and local and regional exchanges is broadly supported by the current stratified zooarchaeological collections. While the

increasingly complex later medieval Icelandic economy appears to have been generating a woolen surplus as one of a set of interlocking farming objectives, the Greenlandic farming economy did not. Surplus woolen cloth production was not an option for later medieval Greenland.

CHAPTER 7: Conclusion

7.1 Major Findings

This section summarizes the major findings of this thesis as presented in the chapters above.

1) **Adapting to new environment at Landnám:** The first generation of settlers brought with them the mixed Nordic/European suite of adaptations to life based around domestic livestock and associated foddering to the Atlantic islands, but rapidly transformed them to adjust to the limits and opportunities provided by the new environment. The post 2005 archaeofaunas analyzed by the author, clearly demonstrate that the marine fishing was immediately supplanted by intensive seal hunting (perhaps taking small cetaceans as well) that involved both the non-migratory harbor seals and the amazingly abundant migratory harp and hooded seals. Caribou hunting was rapidly organized, probably always dominated by elite managers but providing some meat, antler, and hide to the whole community. Barley production on a large scale was probably difficult or impossible, and Greenlanders learned to live without beer or bread. Expanding from core areas in the inner fjords, farmers adapted to less productive pastures as the community expanded, developing a complex network of shielings and seasonally occupied sites.

2) **Early and prolonged Norðursetur commitment despite potential rising costs**: Walrus and other arctic mammals were a major factor in Norse Greenlandic economy and society from the initial Viking Age settlement down to the end of the Eastern Settlement ca. 1450. Zooarchaeological evidence broadly supports the model of "serial overexploitation" proposed by paleogenetic and stable isotope researchers, with post-cranial bones of walrus appearing mainly in early phases, and later phase archaeofauna composed of maxillary tusk extraction debris and occasional bacula indicating distant kill sites and limited transport capacity. There is no evidence

for a reduction in the Norðursetur hunting effort after the ca. 1300 climate impacts.

3) **Climate impact on sealing visible in zooarchaeology**: onset of summer drift ice impacting the Eastern Settlement area is visible in the changing proportions of seal bones deposited, through the new archaeofauna excavated and analyzed by the author. In the Western Settlement outside the range of the summer drift ice non-migratory harbor seal bones remain common, but the Eastern Settlement phased collections show a universal decline in this ice-vulnerable species in all new, post 2005 collections.

4) **Farming Strategies and sustainability**: Norse farmers imported the full range of domesticates and accidentally transported commensal mice and insects from Iceland. The domestic mammals were all within the size and conformation range of contemporary Icelandic stock. While pig keeping became less common through time, some pigs were maintained on a highly marine diet into the last phases of the community. While more cattle were kept on larger farms with better pastures, all archaeofauna have at least some cattle bones. Despite the rise in sheep and goat keeping on small farms in later phases there are no current examples of all-caprine archaeofauna. While proportions of sheep and goats varied by site and period, at no time were there the large all-sheep flocks needed for substantial wool production beyond household consumption as is visible in later medieval and early modern Icelandic archaeofauna. The paradox of heavy adult caprine tooth wear visible in micromorphology vs. lack of widespread soil erosion probably reflects careful sustainable shieling management that moved sheep and goat flocks away from vulnerable and valuable home fields into areas where grit and soil ingestion may have been more common. In later phases some permanent farms may have regularly been converted to seasonal shielings as at E74 to keep other farms active as the shieling system evolved to respond to climate change. Overall

Norse domestic mammal management in Greenland showed remarkable ability to maintain animals far outside the natural range in an environment significantly more hostile than Iceland.

5) **Different trajectories for large and small farms through time**: larger farms associated with larger agricultural buildings and better pasture show different economic trajectories through time. While seals become more important for the whole community after ca. 1300, small holdings were particularly dependent on seals while at least some of the larger farms were able to maintain more domestic stock, and perhaps benefit disproportionately from the caribou hunt. Small farmers must have become increasingly dependent on the larger chieftain farms and the bishop's manor for maintaining livestock numbers during periods of stress. The zooarchaeological data support the model of "hostile takeover" by elite lineages in Greenland after c 1250 and support the comparison to late medieval Icelandic patterns of many poor tenants and a few large manorial holdings. Late medieval Greenland was a fully hierarchical society, and this is reflected in the archaeofauna.

6) **Norse-Thule contact**: The zooarchaeological record from the Norse farm middens provides virtually no evidence of acquisition of Thule culture hunting techniques. Ringed and Bearded seal bones remain very rare, and the available seasonality data indicate a focus on spring rather than all- winter hunting. While the Norse potentially could have expanded their marine resource base by acquiring Inuit marine mammal hunting gear and expertise, there is no evidence that they did so.

7) **Climate adaptation options:** the current zooarchaeological data indicate that while the Norse Greenlanders were successful in maintaining some caribou in the Eastern Settlement in the latest phases, there was little potential for increasing the catch to supplement farming production. Bird

colonies likewise provided seasonal supplements but with little potential for intensification. If conditions for farming worsened after 1300, there was scope for intensification of the migratory seal hunt beyond anything possible on land or sea cliffs. Faced by food security challenges intensified by medieval climate change, the Norse Greenlanders seem to have made the rational decision to increase their sealing effort and move their society further into the marine food web,

7.2 Suggestions for Future Research

The once rich Norse zooarchaeological record is gravely endangered by rising soil temperatures. As the REMAINS project and multiple NABO excavations and field survey test pits have demonstrated, organic preservation is rapidly disappearing across Southern Greenland and progressively endangered further north as climate change in the arctic accelerates. There is urgent need to excavate additional collections before they are lost forever, and to create analytic backlogs if necessary. Fortunately, there is a growing international response to this threat to both science and heritage with major funding from the Carlsberg Foundation and US NSF Arctic Social Sciences program. Despite the limitations of the Covid19 pandemic, these new projects are working to identify and rescue sites of all periods in South Greenland. Soon there will be excavations at the Norse Vatnahverfi sites of E171 and NKAH 5500, with a potential for follow-up excavations of remaining midden deposits at E29N, and others. While conditions of preservation seem to remain relatively good in the Western Settlement area in the Nuuk district, there is a need for additional work to secure archaeofauna in the near future.

7.3 Contributions

This thesis provides a comprehensive overview of the current state of Zooarchaeological knowledge about Norse Greenland, bringing together all available archaeofaunal data from the late

19th century to 2016. New collections excavated by the author have been reported, and the results of special studies of legacy collections carried out at the University Zoological Museum in Copenhagen and Dr. Jim Woollett's laboratory at Université Laval in Quebec. These have allowed better understanding of patterns of seasonality in Norse exploitation of sea mammals, caribou and management of domestic stock. The thesis has been able to draw upon the new radiocarbon - supported chronological framework established by NABO research projects since 2005 that allows for the first comprehensive attempt to document the changes in Norse economy through time.

This thesis provides evidence for multiple taphonomic processes affecting the Greenlandic Norse archaeofauna that limit analysis and prevent the effective use of many techniques that can be applied to less fragmented and damaged collections. Despite these clear limitations to metrical analysis and reconstruction of age profiles, the presentation also provides some approaches to working quantitatively and qualitatively with what are often large archaeofauna. While taphonomic attrition will always be a major limiting factor for Greenlandic Norse zooarchaeology, clear patterns remain identifiable across sites and periods.

This thesis provides a new overview of the interaction of the special Greenlandic subsistence economy and its unprecedented use of marine mammals and caribou to support an Atlantic Norse farming system with the remarkable long-range hunt for walrus and arctic products. It contributes to the ongoing "green gold and white gold" debates about the relationship between the quest for new farmland and the demands of distant markets in the initial settlement of Greenland and its apparent pathway dependence in the face of increasing costs and declining returns of the northern hunt and the transatlantic links it supported. It may serve to flag up the areas of conflict between market and subsistence economy in annual round scheduling, labor, and scarce boats.

While noting areas of vulnerability, this thesis also documents substantial robustness and resilience in Norse adaptation to Greenlandic conditions. The Norse farmers apparently managed their mixed domestic stock without triggering widespread soil erosion and provided continued access to the milk, meat, hide, and wool needed to support their European lifestyle in conditions significantly harsher in all periods than experienced by their relatives in Iceland, Faroes, or Northern Isles. Despite a very dispersed settlement pattern with significant barriers to overland travel the Norse were able to organize annual communal hunting of seals and sea birds (and their distribution to inland farms) and pooled participation in the hunting and final processing of walrus and polar bear products on multiple farmsteads. Norse management of non-migratory harbor seals (*P. vitulina*) preserved colonies in both Eastern and Western settlements, despite the impact of summer drift ice post-1300 CE in the south. Norse managers were also able to maintain access to Greenlandic caribou throughout the period of settlement, despite fluctuating climate and potential range competition with domestic stock. At its height, this small community was able to erect large stone churches whose ruins remain impressive in an arctic landscape. Faced with an existential threat by climate changes after ca. 1300, the Norse were able to mount a successful economic reorganization involving major increases in sea mammal consumption by most of the population that bought the community another century or more of survival. Far from being a maladapted and inflexible failure, the Norse Greenlanders now appear to have been resilient and resourceful with the limits of their core culture but succumbed anyway to multiple converging threats.

While focusing on Norse Greenland, this thesis has made systematic comparison to contemporary economic patterns in Iceland and documented patterns of diverging pathways at first settlement and in the later Middle Ages between these two closely related island communities. The thesis has also worked to place Norse Greenland's case of long-term human ecodynamics in the broader context of the contribution of Historical Ecology to global change research and the grand challenges facing archaeology in this century.

New and ongoing research by the author and colleagues is already adding new data of many types to our new understanding of changing Norse economic adaptations in Greenland. These new results and findings will certainly cause revision of some of the conclusions presented in this thesis, but it can be hoped that this summary of our current state of knowledge will remain useful into the future as research accelerates in response to climate change impacts.

REFERENCES

Abu-Lughod, J., (1981) *Before European Hegemony: The World System A.D. 1250-1350*. Oxford University Press, Oxford.

Adderley, W.P., Simpson, I. (2006) Soils and palaeo-climate based evidence for irrigation requirements in Norse Greenland, *Journal of Archaeological Science*, 33 (12), 1666-1679.

Adderley, P.W., I.A. Simpson, and O. Vésteinsson (2008)." Local-Scale Adaptations: A Modeled Assessment of Soil, Landscape, Microclimatic, and Management Factors in Norse Home-Field Productivities." *Geoarchaeology: An International Journal* 23(4):500–527.

Aðalsteinsson, S. (1991) Importance of Sheep in Early Icelandic Agriculture. *Acta Archaeologica* 61:285–291.

Albrethsen, S. E. (1991) "Saeters in the Norse Eastern Settlement of Østerbygden in Southwest Greenland." *Acta Borealia* 8: 15–28.

Albrethsen, S. E., and C. Keller, C. (1986) "The Use of the Saeter in Medieval Norse Farming in Greenland." *Arctic Anthropology* 23(1/2): 91–107.

Aldred, O. (2004) Réttir in the landscape. A study on the context of focal points; Dynamics of Northern Societies: Proceedings of the SILA/NABO Conference on Arctic and North Atlantic Archaeology, Copenhagen Volume10. Pages: 353-63

Amorosi, T., P.C. Buckland, K. Edwards, I. Mainland, T.H. McGovern, J. Sadler and P. Skidmore (1998) They did not live by grass alone: the politics and paleoecology of animal fodder in the North Atlantic region, *Environmental Archaeology* (1)41-55

Amorosi T., Buckland P., Dugmore A., Ingimundarsson J. and McGovern T.H. Raiding the Landscape: Human impact in the North Atlantic, (1997) in: B. Fitzhugh and T. Hunt (eds.) *Island Archaeology*, special edition of *Human Ecology*,25(3):491-518.

Anon, Is 50V Vatnafar/ISN2016. Available at: http://data.europa.eu/88u/dataset/https-kort-lmi-is [Accessed September 13, 2022].

Appelt, M., and H. C. Gulløv (2009) Tunit, Norsemen, and Inuit in Thirteenth-Century Northwest Greenland - Dorset between the Devil and the Deep Sea. *In The Northern World, AD 900–1400.* Herbert Maschner, Owen Mason, and Robert McGhee, (eds.) Pp. 300–320. Salt Lake City: University of Utah Press.

Armstrong, C. G., A. C. Shoemaker , I. McKechnie, A. Ekblom, P. Szabó, P.l J. Lane, Alex C. McAlvay, O.J. Boles, S. Walshaw, N. Petek, K. S. Gibbons, E. Q. Morales, E. N. Anderson, A. Ibragimow, G. Podruczny, J.C. Vamosi, T. Marks-Block, J. K. LeCompte, S. Awâsis, C.Nabess, P. Sinclair, and C. L. Crumley. (2017) Anthropological contributions to historical ecology: 50 questions, infinite prospects. *PLoS ONE* 12(2): e0171883.

Arneborg, J. (2005) Greenland irrigation systems on a west Nordic background. An overview of the evidence of irrigation systems in Norse Greenland c. 980-1450 AD. *Pamatky Archeologicke Supplementum* 17 *Ruralia* V: 137-45.

Arneborg, J (2006) *Saga trails – Brattahlið, Garðar, Hvalsey Fjord's Church and Herjolfsnes: four chieftain's farmsteads in the Norse settlement of Greenland. A visitor's guidebook.* National Museum of Denmark, Nanortalik Museum, Narsaq Museum and Qaqortoq Museum.

Arneborg, J. (2003) "Norse Greenland: Reflections on settlement and depopulation." In *Contact, Continuity, and Collapse: The Norse Colonization of the North Atlantic. Studies in the Early Middle Ages* 5, edited by James H. Barrett, 163–181. Brepols, Turnhout, Belgium.

Arneborg, J., J. Heinemeier, and N. Lynnerup, (eds.) (2012) "Greenland Isotope Project: Diet in Norse Greenland AD 1000–AD 1450." *Journal of the North Atlantic 3.* Maine: Eagle Hill.

Arneborg, J., (2012) Churches, Christianity, and magnate farmers in the Norse Eastern Settlement. In: Gulløv, H.C., Toft, P.A., and Hansgaard, C.P. (eds.), *Challenges and Solutions: Northern Worlds*. National Museum of Denmark, Copenhagen, 167-170.

Arneborg, J., Nyegaard, G., Vésteinsson, O., (eds.) (2009) Norse Greenland: Selected papers from the Hvalsey Conference 2008, *Journal of the North Atlantic*, Special Volume 2, Eagle Hill Publications, Steuben, ME.

Arge, S.V., Church, M.J., and Brewington, S.D. (2009) Pigs in the Faroe Islands: An Ancient Facet of the Islands' Paleoeconomy. *Journal of the North Atlantic* 2:19—32.

Ascough, P.L., G. T. Cook, M. Church, A.J. Dugmore, T. H. McGovern, E. Dunbar, A. Einarsson, A. Fridriksson, and H. Gestsdottir (2007) Reservoirs and radiocarbon. 14C dating problems in Mývatnssveit, Northern Iceland. *Radiocarbon* 49:947–961.

Ascough, P. L., G. T. Cook, M. J. Church, A. J. Dugmore, S.V. Arge, and T.H. McGovern (2006) Variability in North Atlantic marine radiocarbon reservoir effects at c. AD 1000. *The Holocene* 16(1):131–136.

Balée, W. (2006) The research program of historical ecology. *Annual Review of Anthropology* 35(5):15-24.

Balée, W. (ed.) (1998) *Advances in Historical Ecology*. New York: Columbia University Press.

Balée, W., and C. Erickson, (eds.) (2006) *Time and Complexity in Historical Ecology: Studies in the Neotropical Lowlands.* New York: Columbia University Press.

Baumann, M., N. Lynnerup, and G. Richard Scott (2017) "Stable isotopes and oral tori in Greenlandic Norse and Inuit." *International Journal of Osteoarchaeology* 27, no. 2: 312-319.

Berglund, J.(2009) Did the Medieval Norse Society in Greenland Really Fail? In: McAnany, P.A. and N. Yoffee: Questioning Collapse. Cambridge University Press, pp. 45 - 70

Bigelow G.F. (1985) Sandwick Unst and the Late Norse Shetlandic Economy, in B. Smith (ed) *Shetland Archaeology, New Work in Shetland in the 1970's*, Shetland Times Press, Lerwick, pp 95-127.

Binford, L. R. (1978). *Nunamiut ethnoarchaeology*. New York: Academic Press.

Bolender, D., J., John M. Steinberg, and E. Paul Durrenberger (2008) Unsettled Landscapes: Settlement Patterns and the Development of Social Inequality in Northern Iceland. In *Economies and the Transformation of Landscape*, edited by Lisa Cliggett and Christopher A. Pool, pp. 217–238. Altamira Press.

Bolender, Douglas J., John M. Steinberg, and Brian N. Damiata. (2011) "Farmstead Relocation at the End of the Viking Age; Results of the Skagafjörður Archaeological Settlement Survey." *Archaeologica Islandica* 9:77-101

Bolender, D. J. (2013) "Dividing Land and Creating Class: the Development of a Landlord-Tenant Political Economy in Medieval Iceland." In E. Paul Durrenberger (ed.) *The Anthropological Study of Class and Consciousness*:65-83. Boulder, CO: University of Colorado Press.

Brewington, Seth, Megan Hicks, Ágústa Edwald, Árni Einarsson, Kesara Anamthawat-Jónsson, Gordon Cook, Philippa Ascough, Kerry Sayle, Símun V. Arge, Mike Church, Julie Bond, Steve Dockrill, Adolf Friðriksson, George Hambrecht, Árni Daniel Juliusson, Vidar Hreinsson, Steven Hartman, Thomas H. McGovern (2015) Islands of Change vs. Islands of Disaster: Managing Pigs and Birds in the Anthropocene of the North Atlantic. In: Arlene Rosen (ed.) *The Anthropocene in the Longue Durée* special issue of *The Holocene* 25 (10): 1676-1725.

Bruun, D. (1918) "Oversigt over Nordboruniner i Godthaabs og Frederikhaabs Distrikter."

Bruun, D. (1904) "Arkæologiske Undersøgelser i Godthaabs og Frederikshaabs Distrikter i Grønland foretagne i Aaret 1903." *Geografisk Tidskrift* 17: 187-206.

Bruun, D. (1902) Det høje Nord. Færøernes, Islands og Grønlands Udforskning*,* København.

Bruun, D. (1895) "Arkaeologiske Undersøgelser i Julianehaabs Distrikt." *Meddelelser om Grønland* 16: 171-462.

Bruun, D. (1895) "Arkaeologiske Undersøgelser i Julianehaabs Distrikt" *Meddelelser om Grønland* 16, 171-462

Bruun, D. (1896) Arkæologiske Undersøgelser I Julianehaabs Distrikt. *Meddelelser om Grønland* 16(1).

Bruun, D. (1899) Arkæologiske Undersølgelser paa Island. *Geografiske Tidsskrift* Bind 15.

Bruun, D. (1896) "Arkæologisk Undersøgelsesrejse til Færøerne og Island 1896", *Geografisk Tidskrift* 13, 175-77.

Bruun, D. (1900) "Arkæologiske undersøgelser paa Island foretagne i sommeren 1898", *Geografisk Tidsskrift* 15, 71 87.

Bruun, D. (1902) *Det høje Nord. Færøernes, Islands og Grønlands Udforskning*, København.

Bruun, D. (1903) “Arkæologiske Undersøgelser i Godthaabs og Frederikshaabs Distrikter i Grønland foretagne i Aaret 1903”, Geografisk Tidskrift 17, 187-206.

Bruun, D. (1904) “Udgravninger paa Island” *Geografisk Tidsskrift* 17, 13 25.

Bruun, D. and F. Jónsson, (1911) Finds and excavations of Heathen Temples in Iceland. *Saga Book of the Viking Club* VII :25–37.

Bruun, D. (1917) Oversigt over Nordboruniner i Godthaab og Frederikshaabs Distriker. *Meddelelser om Grønland* 56(3).

Bruun, D. (1918) “Oversigt over Nordboruniner i Godthaabs og Frederikhaabs Distrikter”, *Meddelelser om Grønland* 56, 55-148

Bruun, D. (1928) *Fortidsminder og Nutidshjem paa Island*, København

Buckland, P.C., Gudrun Sveinbjarnardottir, Diana Savory, T.H. McGovern, Peter Skidmore, and Claus Andreasen (1983) Norsemen at Nipaitsoq, Greenland: a paleoecological investigation, *Norwegian Archaeological Review* 16(2):86

Buckland, P.C., T. Amorosi, L.K. Barlow, A.J. Dugmore, P.A. Mayewski, T.H McGovern, A.E.J. Ogilvie, J.P. Sadler and P. Skidmore (1996) Bioarchaeological and climatological evidence for the fate of the Norse farmers in medieval Greenland, *Antiquity* 70(1):88-96.

Buckland, P.C. McGovern T.H., Sadler, J.P. and Skidmore P. (1994)Twig layers, floors and middens: recent paleoecological research in the Western Settlement, Greenland, in B. Ambrosiani and H. Clarke (eds) *Proceedings of the 22nd Viking Congress*, Stockholm, Birka Studies 3 : 132-143.

Buckland, P.C., Edwards, K.J., Panagiotakopulu, E. and Schofield, J.E. (2008) Land management at the bishop’s seat, Garðar, medieval Greenland. *Antiquity* 82.

Buckland, P.C., Edwards, K.J., Panagiotakopulu, E., Schofield, J.E. (2009) Palaeoecological and historical evidence for manuring and irrigation at Garðar (Igaliku), Norse Eastern Settlement, Greenland. The Holocene 19: 105-116.

Butzer, K.W. and Endfield, G.H., (2012) Critical perspectives on historical collapse. *Proceedings of the National Academy of Sciences 109*(10): 3628-3631.

Boivin, N. L., Zeder, M.A., Fuller, D.Q., Crowther, A., Larson, G., Erlandson, J.M., Denham, T. and Petraglia, M.D. (2016) Ecological consequences of human niche construction: Examining long-term anthropogenic shaping of global species distributions. *Proceedings of the National Academy of Science* 113(23): 6388-6396.

Bostrom, N. and M. Cirkovic (eds.) (2008) *Global Catastrophic Risks*, Oxford University Press.

Boessneck, J. (1969) Osteological differences between sheep (Ovis aries Linne) and goats (Capra hircus Linne). In *Science in Archaeology*, edited by D. Brothwell and E. Higgs, pp. 331–358. Thames and Hudson, London, UK.

Boulhosa, P. (2010) "Of Fish and Ships in Medieval Iceland. " In *The Norwegian Domination and the Norse World c. 1100-c. 1400, Trondheim Studies in History*, edited by Steinar Imsen, 175-194. Trondheim: Tapir Press.

Bovy, K. M. (2002) Differential Avian Skeletal Part Distribution: Explaining the Abundance of Wings. *Journal of Archaeological Science* 29(9):965–978.

Buchwald, V. F. (1985). *Meteoritic iron, telluric iron and wrought iron in Greenland* (Vol. 9). Museum Tusculanum Press.

Cesario, G.M., "Marine Resource Specialization in Viking Age Iceland: Exploitation of Seabirds and Fish on Hegranes in Skagafjörður" (2021). *CUNY Academic Works.*

Church, M.J., S. Arge, S. Brewington, T.H. McGovern, J Woollett, S. Perdikaris, I. T. Lawson, G. C. Cook, C. Amundsen, R. Harrison, Y. Krivogorskaya (2005) 'Puffins, pigs, cod and barley: paleoeconomy at Undir Junkarinsfløtti, Sandoy, Faroe Islands', *Environmental Archaeology* 10, 2: 198-221.

Coleman, W. K.(2019) *Hrísheimar: Fish Consumption Patterns*. Master's Thesis, Hunter College, New York, NY.

Commisso, R.G. and Nelson, D.E. (2007) Patterns of plant δ15N values on a Greenland Norse farm. *Journal of Archaeological Science* 34,440–50.

Costanza, R., L. Graumlich, W. Steffen, C. Crumley, J. Dearing, K. Hibbard, R. Leemans, C. Redman, and D. Schimel (2007) Sustainability or Collapse: What Can We Learn from Integrating the History of Humans and the Rest of Nature? *Ambio* 36 (7): 522-527.

Constanza R., L.J. Graumlich, and W. Steffen (eds.) (2007). *Sustainability or Collapse? An Integrated History and Future of People on Earth,* MIT Press Cambridge Mass

Crumley, C. (ed.) (1994). *Historical Ecology.* Santa Fe, New Mexico: School of American Research.

Crumley, C.L. (2007) Historical Ecology: Integrated Thinking at Multiple Temporal and Spatial Scales. The World System and The Earth System: Global Socio-Environmental Change and Sustainability Since the Neolithic. Alf Hornberg and Carole Crumley, (eds.), pp. 15-28. Walnut Creek CA: Left Coast Press.

Crumley, C. L. (2012). A Heterarchy of Knowledges: Tools for the Study of Landscape Histories and Futures. *Resilience and the Cultural Landscape: Understanding and Managing Change in Human-Shaped Environments*, edited by Tobias Plieninger and Claudia Bieling, 12-64. Cambridge: Cambridge University Press.

Crumley, C. L., T. Lennartsson, and A. Westin, (eds.) (2018) Issues *and Concepts in Historical Ecology: The Past and Future of Landscapes and Regions,* Cambridge, UK: Cambridge University Press.

Crumley, C.L. (2018a) Historical Ecology and the Longue Durée. Paul Sinclair, Jon Moen, and Carole L. Crumley. Crumley, Carole L**.**, Tommy Lennartsson, and Anna Westin, (eds.) Issues and Concepts in Historical Ecology: The Past and Future of Landscapes and Regions, pp. 13-40. Cambridge GB: Cambridge University Press.

Crumley, C.L. (2018b) New Paths into the Anthropocene: Applying Historical Ecologies to the Human Future. The Oxford Handbook of Historical Ecology and Applied Archaeology, C. Isendahl and D. Stump, (eds.), pp. 6-20. Oxford: Oxford University Press. Online 2015, published 2018.

Dawson, A. G., K. Hickey, P. A. Mayewski, and A. Nesje (2007) "Greenland (GISP2) ice core and historical indicators of complex North Atlantic climate changes during the fourteenth century." *The Holocene* 17, no. 4: 427-434.

Dawson, T. (2015) Eroding Archaeology at the Coast: How a Global Problem is Being Managed in Scotland, with Examples from the Western Isles. *Journal of the North Atlantic* 9: 83-98.

Dawson, T., Hambly, J., Kelley, A., Lees, W. and Miller, S. (2020) Coastal heritage, global climate change, public engagement, and citizen science. *Proceedings of the National Academy of Sciences* 117(15): 8280-8286.

D'Alpoim G., J., Crabtree, S.A., Bocinsky, R.K. and Kohler, T.A. (2016) Twenty-first century approaches to ancient problems: Climate and society. *Proceedings of the National Academic of Sciences* 113(51): 14483-14491.

Degerbøl, M. (1929). Animal bones from the Norse ruins at Gardar, Greenland. *Meddelelser om Grønland* vol. 76: 183-192.

Degerbøl, M. (1934). Animal bones from the Norse ruins at Brattahlið. *Meddelelser om Grønland* vol. 88: 149-155.

Degerbøl, M. (1936). Animal remains from the West Settlement in Greenland with special reference to livestock. *Meddelelser om Grønland* vol. 88(3): 1-54.

Degerbøl, M. (1939). Nogle bemærkninger om husdyrene pa Island i Middelalderen. In: *Forntida gardar i Island. Nordiska arkeologiska undersokningenni Island* 1939: 261-268.

Degerbøl, M. (1940). Mammalia. – Zoology of the Faroes 3(2) 65: 1-132.

Degerbøl, M. (1941). The osseous material from Austmannadal and Tungmeralik. *Meddelelser om Grønland* vol. 89: 345-354.

Dennis, A., P. Foote, and R. Perkins, trans. (1993) *Laws of Early Iceland, Grágás: The Codex Regius of Grágás with Material from other Manuscripts 2 vols.* Winnipeg: University of Manitoba Press

Diamond, J., (2005). *Collapse: How Societies Choose to Fail or Succeed*, Viking, New York.

Dugmore, A J, Church, M J, Buckland, P C, Edwards, K J, Lawson, I, McGovern, T.H, Panagiotakopulu, E, Simpson, I.A, Skidmore, P. and Sveinbjarnardottir, G. (2004) "The Norse *landnám* on the North Atlantic islands: an environmental impact assessment", *Polar Record* 41, 1-17.

Dugmore A. J, Douglas, M. Borthwick, M. J. Church, A. Dawson, K. J. Edwards, C. Keller, P. Mayewski, T.H. McGovern and K. Mairs and G. Sveinbjarnardottir (2007). 'The Role of Climate in Settlement and Landscape Change in the North Atlantic Islands: An Assessment of Cumulative Deviations in High-Resolution Proxy Climate Records', *Human Ecology* (2007) 35:169–178

Dugmore, A. J., C. Keller, T.H. McGovern, A.F. Casely, and K. Smiarowski (2009). "Norse Greenland Settlement and Limits to Adaptation." In *Adapting to Climate Change,* edited by Neil W. Adger, Irene Lorenzoni, and Karen L. O'Brien, 96–113. Cambridge: Cambridge University Press.

Dugmore, A.J., C. Keller and T. H. McGovern (2007) 'Reflections on climate change, trade, and the contrasting fates of human settlements in the North Atlantic islands', *Arctic Anthropology* 44(1): 12-37.

Dugmore, A. J., T. H. McGovern, R. Streeter, C. K. Madsen, K. Smiarowski, and C. Keller (2013) "'Clumsy Solutions' and 'Elegant Failures': Lessons on Climate Change Adaptation from the Settlement of the North Atlantic Islands." In *A Changing Environment for Human Security: Transformative Approaches to Research, Policy and Action*, edited by Linda Sygna, Karen L O'Brien, and Johanna Wolf, 435-450. London: Routledge.

Dupont-Hebert, C. (2013) Zooarchaeology and Climate Change in Northeast Iceland: Expectation, Identification, and (Mis)Interpretation. In *GHEA Open Workshop, Nov 4-6, 2013.* University of Maryland.

Dupont-Hebert, C. (2017) *Preliminary zooarchaeological perspectives from Hjálmarvík, Northeast Iceland*. Université Laval, Quebec, Canada.

Dupont-Hébert, C. (2020) *Dynamic of change: economic landscape of rural settlements in Northeast Iceland, from Landnám to the 19th century*, doctoral thesis U Laval.

Dussault, F., Forbes, V., Bain, A. (2014) Archaeoentomology at Tatsip Ataa : evidence for the use of local resources and daily life in the Norse Eastern Settlement, Greenland. *Journal of the North Atlantic* 6: 14-28.

Edwards K. J., Schofield J. E., Kirby J. R., Cook G. T. (2011) Problematic but promising ponds? Palaeoenvironmental evidence from the Norse Eastern Settlement of Greenland. *Journal of Quaternary Science* 26, 854-865.

Edwards K. J., Schofield J. E, Mauquoy D. (2008) High Resolution Palaeoenvironmental and Chronological Investigations of Norse *landnám* at Tasiusaq, Eastern Settlement, Greenland. *Quaternary Research* 69, 1–15.

Edvardsson, R. (2013) "Qorlortorsuaq, fornleifarannsóknir í Vatnahverfi á Suður-Grænlandi vorið 2006." *Árbók hins íslenska fornleifafélags* 5–21.

Edvardsson, R., Thomas McGovern, Caroline Paulsen, Konrad Smiarowski, and Albina Palsdottir (2010) "Archaeological Excavations at Qorlortorsuaq 2006 - Field Report."

Enghoff, I.B. (2003) *Hunting, Fishing and Animal Husbandry at The Farm Beneath the Sand, Western Greenland: An Archaeozoological Analysis of a Norse Farm in the Western Settlement.* Copenhagen: Danish Polar Center.

Erlandson, J. M., and Braje, T. J. (2013). Archeology and the Anthropocene. *Anthropocene*, *4*, 1-7.

Fitzhugh, B., Butler, V., Bovy, K., Etnier, M. (2019) Human ecodynamics: A perspective for the study of long-term change in socioecological systems, *Journal of Archaeological Science:* Reports, Volume 23: 1077-1094.

Forbes, V., Dussault, F. and Bain, A. (2013) Contributions of Ectoparasite Studies in Archaeology with Two Examples from the North Atlantic Region. *International Journal of Paleopathology* 3: 158-164.

Forbes, V., Dussault, F. and Bain, A. (2014) Archaeoentomological Research in the North Atlantic: Past, Present and Future. *Journal of the North Atlantic* 26: 1-24.

Frantz, L. A., Haile, J., Lin, A. T., Scheu, A., Geörg, C., Benecke, N., and Larson, G. (2019) Ancient pigs reveal a near-complete genomic turnover following their introduction to Europe. *Proceedings of the National Academy of Sciences*, *116*(35), 17231-17238.

Fredskild, B. (1973) Studies in the vegetational history of Greenland. Palaeobotanical investigations of some Holocene lake and bog deposits. Meddelelser om Grønland 198: 1-245.

Fredskild, B. (1988) Agriculture in a marginal area – south Greenland from the Norse landnám (985 AD) to the present (1985 AD). In Birks, H.H., Birks, H.J.B., Kaland, P.E. and Moe, D., editors*, The cultural landscape – past, present and future.* Cambridge University Press,381–93.

Frei, K. M., Ashley N. Coutu, K. Smiarowski, R. Harrison, C. K. Madsen, J. Arneborg, R. Frei, G. Guðmundsson, S. M. Sindbæk, J. Woollett, S. Hartman, M. Hicks and T. H. McGovern (2015) 'Was it for walrus? Viking Age settlement and medieval walrus ivory trade in Iceland and Greenland', *World Archaeology*.

Gísladóttir, G. A., James M. Woollett, Uggi Ævarsson, Céline Dupont-Hébert, Anthony Newton and Orri Vésteinsson (2013). The Svalbard Project, *Archaeologica Islandica* 10: 69-103.

Goldager O., S. Stummann Hansen, and S. Gleie (2002) Medieval farmsteads in Greenland : The Brattahlið Region 1999-2000. Danish Polar Centre, Copenhagen.

Golding, K.A., Simpson, I.A., Wilson, C.A., Lowe, E.C., Schofield, J.E. and Edwards, K.J. (2015). Europeanization of sub-Arctic environments: Perspectives from Norse Greenland's outer fjords. *Human Ecology* 43, 61-77.

Golding, K. A., Simpson, I.A. Schofield, J.E. and Edwards, K.J. (2011). Norse – Inuit interaction and landscape change in southern Greenland. A geochronological, pedological and palynological investigation. *Geoarchaeology* 26, 315-345.

Gad, F. (1971) *The History of Greenland: Earliest Times to 1700, Vol. 1* (Vol. 1). McGill-Queen's Press-MQUP.

Grant, A. (1982) The Use of Tooth Wear as a Guide to the Age of Domestic Ungulates. In *Ageing and Sexing Animal Bones from Archaeological Sites*, edited by R Wilson, C Grigson, and S Payne, pp. 91–108. BAR British Series 109. Oxford, UK.

Grayson, D. K. (1984) *Quantitative Zooarchaeology*. Academic Press, Orlando, FL.

Guðmundsdóttir L. (2022) The Utilization of Native Woodland in Norse Greenland, Environmental Archaeology.

Guillemot, T., Renata Zocatelli, Vincent Bichet, Jérémy Jacob, Charly Massa, Claude Le Milbeau, Hervé Richard, and Emilie Gauthier (2015) "Evolution of pastoralism in Southern Greenland during the last two millennia reconstructed from bile acids and coprophilous fungal spores in lacustrine sediments." *Organic Geochemistry* 81: 40-44.

Gulløv, H. C. (1995) " Olden Times" in Southeast Greenland: New Archaeological Investigations and the Oral Tradition." *Études/Inuit/Studies* (1995): 3-36.

Gulløv, H. C. (2000) Natives and Norse in Greenland. *In Vikings: The North Atlantic Saga*. William W. Fitzhugh and Elisabeth I. Ward, (eds.) Pp.318–327. Washington, D.C.: Smithsonian Institution Press.

Gulløv, H. C. (1997) *From Middle Ages to Colonial Times: Archaeological and Ethnohistorical Studies of the Thule Culture in South West Greenland 1300-1800 AD*. Copenhagen: Meddelelser om Grønland

Gulløv, H. C., and H. Kapel.(1979) *Haabetz Colonie 1721-1728: A Historical-Archaeological Investigation of the Danish-Norwegian Colonization of Greenland*. 1 Vol. Copenhagen: National Museum of Denmark,

Haldon, J., Mordechai, L., Newfield, T.P., Chase, A.F. Izdebski, A., Guzowski, P., Labuhn, I. and Roberts, N. (2018) History meets palaeoscience: Consilience and collaboration in studying past societal responses to environmental change. *Proceedings of the National Academy of Sciences* 115(13): 3210-3218.

Halldórsson, Ó. (1982) Gömul Grænlandslýsing. *Gripla*, *5*, 148-161.

Halffman, C. M., G. Richard Scott, and P. O. Pedersen. (1992) "Palatine torus in the Greenlandic Norse." *American Journal of Physical Anthropology* 88, no. 2: 145-161.

Hambrecht, G. (2020) Crashes and Collapse in Northern Archaeology. In *Arctic Crashes: People and Animals in the Changing North*, edited by Igor Krupnik and Aron L. Crowell, pp. 100–118. Smithsonian Institution Scholarly Press, Washington, D.C.

Hambrecht, G., Frank Feeley, Konrad Smiarowski, Megan Hicks, Ramona Harrison, Seth Brewington, Grace Cesario, and Kevin Gibbons (2019) A millennium of Icelandic archaeological fish data examined against marine climate records. *Quaternary Research*:1–17.

Harsgor, M. (1978) 'Total History: The Annales School', *Journal of Contemporary History*, 13(1), pp. 1–13.

Henriksen, Peter S. (2016) Norse Agriculture in Greenland? Farming in a remote medieval landscape. in: *Agrarian Technology in the Medieval Landscape* J Kapista (ed), Brepols, pp 237-241

Harmsen, H., J. Hollesen, C. K. Madsen, B. Albrechtsen, M. Myrup, and H. Matthiesen. (2018) "A Ticking Clock? Preservation and Management of Greenland's Archaeological Heritage in the Twenty-First Century." Conservation and Management of Archaeological Sites 20 (4): 175–198.

Hambrecht, George, Anderung, C., Brewington, S., Dugmore, A., Edvardsson, R., Feeley, F., Gibbons, K., Harrison, R., Hicks, M., Ólafsdóttir, G., Rockman, M., Smiarowski, K., Streeter, R., Szabo, V**.,** McGovern, T.H. (2018), "Distributed Observation Networks of the Past.' *Quaternary International*.

Harrison, R. (2005) Faunal analysis results from the 2004 Excavations at Gásir, Eyjafjörður, N Iceland in: Excavations at Gásir 2004: An Interim Report. Howell Roberts (ed.). 2005. CUNY Northern Science and Education Center; FSI (Fornleifastofnun Íslands, Icelandic Archaeological Institute), FS280-01076, June 2005, Reykjavík, Iceland.

Harrison, R. (2006) The medieval trading station at Gásir, Eyjafjörður, N Iceland: Interim Report of faunal analysis from the 2006 Excavations. NORSEC lab report # 30.

Harrison, R. (2009) The Gásir Area A Archaeofauna: An Update of the Results from the Faunal Analysis of the High Medieval Trading Site in Eyjafjörður, N Iceland. March 2009, NORSEC lab report Nr. 44.

Harrison R. (2011a) Myrkárdalur in Hörgárdalur, N. Iceland: Brief Summary of the 2008/2009 Archaeofauna. NORSEC and HERC Zooarchaeology Laboratory Report No. 57.

Harrison R. (2011b) Möðruvellir in Hörgárdalur, N. Iceland: General Overview of the Faunal Remains Analyzed from the 2006-08 Midden Mound Excavations. NORSEC/HERC Zooarchaeology Laboratory Report No. 59.

Harrison R. (2011c) Skuggi in Hörgárdalur, N. Iceland: Preliminary report of the 2008/2009 archaeofauna. August 2010, NORSEC lab report Nr. 50.

Harrison, R. (2011d) Oddstaðir in Hörgárdalur, N. Iceland: Preliminary Report of the 2009 Archaeofauna. NORSEC/HERC Zooarchaeology Laboratory Report No. 58.

Harrison, R. (2013) "World Systems and Human Ecodynamics in Medieval Eyjafjörður, North Iceland: Gásir and Its Hinterlands." Ph.D. Diss., Graduate School and University Center of the City University of New York.

Harrison, R., (2014a) Gásir Archaeology – International Exchange and Eyjafjörður Ecodynamics in Medieval Iceland. In: Harrison, R., Maher, R. (eds.). Long-Term Human Ecodynamics in the North Atlantic: An Archaeological Study. Lexington Publishers, Lanham, Maryland, 10-35.

Harrison, R., (2014b) Connecting the Land to the Sea at Gásir. In: Harrison, R., Maher, R. (eds.), *Long-Term Human Ecodynamics in the North Atlantic: An Archaeological Study*. Lexington Publishers, Lanham, Maryland, 117-136.

Harrison, R (2015) Gásir Archaeology – International Exchange and Eyjafjörður Ecodynamics in Medieval Iceland. In Harrison, R. and Maher, R. (eds.). *Long-Term Human Ecodynamics in the North Atlantic: An Archaeological Study*. Lexington Publishers, Lanham, Maryland.

Harrison, R., H. M. Roberts, and P.W. Adderley (2008) "Gásir in Eyjafjörður: International Exchange and Local Economy in Medieval Iceland*." Journal of the North Atlantic* 1(1): 99-119.

Harrison, R, and R. A. Maher (eds.) (2014) *Human Ecodynamics in the North Atlantic*. Lexington Books, Maryland.

Hartman, Steven, Astrid Ogilvie, Jon Haukur Ingimundarsson, Andrew J Dugmore, George Hambrecht**,** Thomas H. McGovern (2017), 'Integrated Environmental Humanities: Medieval Iceland, Greenland, and the New Human Condition', *Global and Planetary Change* Volume 156, September, Pages 123-139, Hayeur -Smith, M (2014) “Dress, Cloth, and the Farmer’s Wife: Textiles from Ø 172 Tatsipataa, Greenland with Comparative Data from Iceland.” In *In the Footsteps of Vebæk: Vatnahverfi Studies 2005–2011. Journal of the North Atlantic Special Volume 6, edited by* J. Arneborg, T. H. McGovern, and G. Nyegaard

Hayeur-Smith, M. (2020) *The Valkyries' Loom: the archaeology of cloth production and female power in the North Atlantic*, U Press Florida, Gainesville.

Hayeur -Smith, M., Smith, K. P., and Nilsen, G. (2018) Dorset, Norse, or Thule? Technological transfers, marine mammal contamination, and AMS dating of spun yarn and textiles from the Eastern Canadian Arctic. *Journal of Archaeological Science* 96: 162–174.

Hegmon, M. (ed.) (2017). *The Give and Take of Sustainability: Archaeological and Anthropological Perspectives on Tradeoffs*. United Kingdom: Cambridge University Press.

Hegmon, M., J. Arneborg, A. J. Dugmore, G. Hambrecht, S. Ingram, K. Kintigh, T. H. McGovern, M. C. Nelson, M. A. Peeples, I. Simpson, K. Spielmann, R. Streeter, O. Vésteinsson (2014) The Human Experience of Social Change and Continuity: The Southwest and North Atlantic in “Interesting Times” ca. 1300. In *Climates of Change: The Shifting Environments of Archaeology*, edited by Sheila Lacey, Cara Tremain, and Madeleine Sawyer. Proceedings of the 44th Annual Chacmool Conference, University of Calgary.

Hegmon, M., Peeples, M.A. and LTVTP-NABO (2018) The human experience of social transformation: Insights from comparative archaeology. *PLOS ONE* 13(11): e0208060

Helgason A, Sigurðardóttir S, Gulcher JR, Ward R, Stefansson K (2000a) mtDNA and the origin of the Icelanders: deciphering signals of recent population history. *American Journal of Human Genetics* 66:999–1016

Helgason A, Sigurðardóttir S, Nicholson J, Sykes B, Hill EW, Bradley DG, Bosnes V, Gulcher JR, Ward R, Stefansson K (2000b) Estimating Scandinavian and Gaelic ancestry in the male settlers of Iceland. *American Journal of Human Genetics* 67:697–717

Helgason A, Hickey E, Goodacre S, Bosnes V, Stefansson K, Ward R, Sykes B (2001) mtDNA and the islands of the North Atlantic: Estimating the proportions of Norse and Gaelic ancestry. *American Journal of Human Genetics* 68:723–737

Høegsberg, M.S. **(**2007) A reassessment of the development of the cathedral at Garðar, Greenland. *Archaeologia Islandica* 6, 74–96.

Hicks M., Á. Einarsson, K. Anamthawat-Jónsson, Á. Edwald, A. Friðriksson, Æ. Þ. Þórsson, T. H. McGovern (2016) Community and Conservation: Documenting Millennial Scale Sustainable Resource Use at Lake Mývatn Iceland. in C. Isendahl and D. Stump (eds.) *Handbook of Historical Ecology and Applied Archaeology* Oxford University Press

Hoffman, R. C. (2014) *An Environmental History of Medieval Europe*, Cambridge U Press. ISBN 978-0-521-70037-5

Holm, P., Adamson, J., Huang, H., Kirdan, L., Kitch, S., McCalman, I., Ogude, J., Ronan, M., Scott, D., Thompson, K.O. and Travis, C., (2015) Humanities for the environment—A manifesto for research and action. *Humanities* 4(4): 977-992.

Holm, G.F. (1883): Beskrivelse af Ruiner i Julianehaabs Distrikt. *Meddelelser om Grønland* 6, 57–145.

Hollesen, J., Matthiesen, H., Moller, A.B., Elberling, B., (2015) Permafrost thawing in organic Arctic soils accelerated by ground heat production, *Nature Climate Change* 5, 574-578.

Hollesen, J., Matthiesen, H., Moller, A.B., Wastergård-Nielsen, A., Elberling, B., (2016) Climate change and the loss of organic archaeological deposits in the Arctic, *Scientific Reports* 6, 28690.

Hornberg A., J.R. McNeill, and J. Martinez-Alier (eds.) (2007) *Rethinking Environmental History: World System History and Global Environmental Change*. Altamira Press.

Imer, L. (2017). *Peasants and Prayers: The Inscriptions of Norse Greenland*. University Press of Southern Denmark. Publications from the National Museum / Studies in archaeology and history Bind 25

Iversen, J. (1934) Moorgeologische Untersuchungen auf Grönland. *Meddelelser fra Dansk Geologisk Forening* 8, 341-358.

Jensen, E. L., H. C. Gulløv, and K. Raahauge (2011) *Cultural Encounters at Cape Farewell: The East Greenlandic Immigrants and the German Moravian Mission in the 19th Century*. Vol. 38. , 2011 Museum Tusculanum Press.

Jackson, R., J. Arneborg, A. Dugmore, C. Madsen, T. McGovern, K. Smiarowski and R. Streeter (2018) 'Disequilibrium, Adaptation and the Norse Settlement of Greenland, *Human Ecology (2018) 46:665–684*

Jackson, R.C., Dugmore, A.J. and Riede, F. (2018) Rediscovering lessons of adaptation from the past. *Global Environmental Change* 52: 58-65.

Jackson, R.C., Arneborg, J., Dugmore, A., Harrison, R., Hartman, S., Madsen.C., Ogilvie.A., Simpson. I., Smiarowski, K. and McGovern, T.H (2022) Success and Failure in the Norse North Atlantic: Origins, Pathway Divergence, Extinction and Survival in; Zdebski A., Filipkowski P., Haldon J. (eds.). *Perspectives on public policy in societal-environmental crises. What the future needs from history*. Risks, Systems, Decisions. Cham: Springer Nature.

Jesch, J. (2015). *The Viking Diaspora,* Routledge, New York.

Jones, G. (1986). *The Norse Atlantic Saga: Being the Norse Voyages of Discovery and Settlement to Iceland, Greenland, and North America*. Oxford, University Press.

Jones E.P., K. Skirnisson, T.H. McGovern, M Y P Gilbert, E. Willerslev, J.B. Searle, (2012) Fellow travelers: a concordance of colonization patterns between mice and men in the North Atlantic region*. BMC Evolutionary Biology* 3.70 12:35

Jordan, William C (1998) *The Great Famine: Northern Europe in the Early Fourteenth Century* Princeton U Press.

Júlíusson, Árni D. (2007) Peasants, aristocracy and state power in Iceland 1400-1650. *The CAHD Papers 2*.

Kapel, H, J. H. Jønsson, and N. A. Møller (2004) "Vandkraftværket ved Qorlortorsuaq - Kulturhistoriske Interesser - Rapport Om Arkæologiske Undersøgelser Udført for Grønlands Nationalmuseum and Arkiv Sommeren 2004." *Nunatta Katersugaasivia Allagaateqarfialu.*

Keller, C. (2010) Furs, Fish, and Ivory: Medieval Norsemen at the Arctic Fringe. *Journal of the North Atlantic* 3(1):1–23.

Keller, C., and Perdikaris, S. (2016). The northern frontier – North Atlantic farming during the Viking and Middle Ages. In Retamero, F., Schjellerup, I., and Davies, A. (eds.), *Agricultural and Pastoral Landscapes in Pre-Industrial Society: Choices, Stability and Change*, Oxbow Books, Oxford, pp. 88–114.

Keighley, X., Pálsson, S., Einarsson B.F., Petersen, A., Fernández-Coll, M., Jordan, P., Tange Olsen, M., Malmquist, H.J. (2019) Disappearance of Icelandic Walruses coincided with Norse Settlement. *Molecular Biology and Evolution* 36(12): 2656–2667.

Keighley, X., M. T. Olsen, P. Jordan, and S. Desjardins (eds.) (2021) *The Atlantic Walrus: Multidisciplinary Insights into Human-Animal Interactions*, Elsevier, London.

Kendall, A. (2014) Material Culture and North Atlantic Trade in Iceland and Greenland. *Human Ecodynamics in the North Atlantic: A Collaborative Model of Humans and Nature through Space and Time*, *101*.

Kintigh ,Keith W., Jeffrey H. Altschul , Mary C. Beaudry, Robert D. Drennan, Ann P. Kinzig, Timothy A. Kohler, W. Fredrick Limp, Herbert D. G. Maschner, William K. Michener, Timothy R. Pauketat, Peter Peregrine, Jeremy A. Sabloff, Tony J. Wilkinson, Henry T. Wright, and Melinda A. Zeder (2014) Grand challenges for archaeology*, PNAS,* January 21, 2014| vol. 111 no. 3 879–880.

Kintisch, E. (2016) Why did Greenland's Vikings Disappear? *Science News* Nov 10th 2016 http://www.sciencemag.org/news/2016/11/why-did-greenland-s-vikings-disappear

Kolbert, E. (2016) Greenland is Melting, *The New Yorker* Oct 24 2016 http://www.newyorker.com/magazine/2016/10/24/greenland-is-melting

Kreiner, J. (2020) *Legions of pigs in the early medieval west*. Yale University Press.

Krogh, K.J. (1967) *Viking Greenland*. National Museum of Denmark.

Krogh, K.J. (1974) Kunstvanding – hemmeligheden bag Grønlandspispens hundrede køer. Nationalmuseets Arbejdsmark, 71–79.

Krogh, K.J. (1982) Erik den rødes Grønland. Nationalmuseets Forlag.

Larson, L. M. (1917) (trans.). *The King's Mirror* New York, Twayne Publishers.

Ledger, P. M. (2013) "Norse Landnám and Its Impact on the Vegetation of Vatnahverfi, Eastern Settlement, Greenland." Ph.D. Diss., University of Aberdeen.

Ledger P.M., Edwards K.J. and Schofield J.E. (2013) Shieling activity in the Norse Eastern Settlement: palaeoenvironment of the 'Mountain Farm', Vatnahverfi, Greenland. *The Holocene* 23: 810-822.

Ledger P.M., Edwards K.J., Schofield J.E. (2014a) Vatnahverfi: a green and pleasant land? Palaeoecological reconstructions of environmental and land-use change. *Journal of the North Atlantic* 6: 29-46.

Ledger P.M., Edwards K.J., Schofield J.E. (2014b) A multiple profile approach to the palynological reconstruction of Norse landscapes in Greenland's Eastern Settlement. *Quaternary Research* 82: 22-37.

Ledger P.M., Edwards K.J., Schofield J.E. (2015) Taphonomy or signal sensitivity in palaeoecological investigations of Norse landnám in Vatnahverfi, southern Greenland? *Boreas* 44: 197-215.

Ledger P.M**.**, Edwards K.J., Schofield J.E. (2017) Competing hypotheses, ordination and pollen preservation: landscape impacts of Norse *landnám* in southern Greenland. *Review of Paleobotany and Palynology* 236: 1-11.

Legge, A.J. (2013) "Practice with Science": Molar Tooth Eruption Ages in Domestic, Feral and Wild Pigs (Sus scrofa). *International Journal of Osteoarchaeology (Online)*.

Lemoine, X., M. A. Zeder, K. J. Bishop, and .J. Rufolo (2014) A new system for computing dentition-based age profiles in Sus scrofa. *Journal of Archaeological Science* 47:179–193.

Lozny, L. and T.H. McGovern (eds) (2019) *Global Perspectives on Long Term Community Resource Management.* Springer Nature Co Bern Switzerland

Lucas G. (ed.) (2009) *Hofstaðir: Excavations of a Viking Age Feasting Hall in North Eastern Iceland* , Inst. Of Archaeology Reykjavik Monograph 1, Reykjavik

Lund, J. and S. M. Sindbæk (2021) 'Crossing the Maelstrom: New Departures in Viking Archaeology', Journal of Archaeological Research

Lundqvist, F. C. (2005) The significance of remote resource regions for Norse Greenland. *Scripta Islandica*, *56*, 13-54.

Lyman, R. L. (1994) *Vertebrate taphonomy*. Cambridge University Press.

Lynnerup, N. (1998) *The Greenland Norse: a biological-anthropological study.* Man, and Society 24: Copenhagen.

Lynnerup, N. (2014) End period demographics of the Greenland Norse. In Price, T. D. (ed.), *Viking Settlers of the North Atlantic: An Isotopic Approach*, JONA Special Volume **7**: 18–24.

Lynnerup, N. and S. Nørby (2004) The Greenland Norse: bones, graves, computers, and DNA, *Polar Record*, Volume 40, issue 2 (April 2004), p. 107-111.

Madsen, C.K. (2014) Pastoral Settlement, Farming, and Hierarchy in Norse Vatnahverfi, South Greenland. Unpublished PhD thesis. University of Copenhagen, Denmark.

Madsen, Christian Koch (2019) 'Marine Shielings in Medieval Norse Greenland', *Arctic Anthropology. vol. 56 no. 1 119-159*

Madsen, C., J. Arneborg, P. B. Heide, and Konrad Smiarowski (2009) "Norse Coastal Farms - Field Report of a Survey in the Southwest 'Vatnahverfi Peninsula' - Summer 2009." *National Museum of Denmark*, Department of Danish Middle Age and Renaissance

Massa, C., V. Bichet, É. Gauthier, B. B. Perren, O. Mathieu, C. Petit, F. Monna, J. Girardeau, R. Losno, and Hervé Richard (2012) "A 2500-year record of natural and anthropogenic soil erosion in South Greenland." *Quaternary Science Reviews* 32 (2012): 119-130.

Magnússon, Á. and P. Vídalín, (eds.) (1943) *1712. Jarðabók Árna Magnussonar og Páls Vídalíns.* Copenhagen: Íslenska fræðafelag í Kaupmannahöfn.

Mainland I. (2006) Pastures lost? A dental microwear study of ovicaprine diet and management in Norse Greenland. Journal of Archaeological Science 33: 238-52.

Mainland, I., and P. Halstead (2005) "The economics of sheep and goat husbandry in Norse Greenland." *Arctic Anthropology* 42:103-120.

Matthiesen, Henning and Eriksen, Anne Marie and Hollesen, Jørgen and Collins, Matthew (2021) Bone degradation at five Arctic archaeological sites: Quantifying the importance of burial environment and bone characteristics. Journal of Archaeological Science.

Marks, R. B. (2015) *The Origins of the Modern World: A global and environmental narrative from the fifteenth to the twenty-first century.* London: Rowman and Littlefield.

Margaryan, A., Lawson, D.J., Sikora, M. (2020) 'Population genomics of the Viking world.' *Nature* 585, 390–396

McAnany, P.A. and Yoffee, N. (2010) *Questioning Collapse: Human Resilience, Ecological Vulnerability, and the Aftermath of Empire.* Cambridge: Cambridge University Press.

McCooey, B. (2017). *Farming practices in pre-modern Iceland* (Doctoral dissertation, University of Birmingham).

McGlade, J. (1995). Archaeology and the ecodynamics of human-modified landscapes. *Antiquity, 69*(262), 113-132.

McIntosh, R. J., J. A. Tainter, and S. K. McIntosh (eds), (2000). *The Way the Wind Blows: Climate, History, and Human Action*. Historical Ecology Series, Columbia U P. NYC.

McGovern, T.H. (1985a). "Contributions to the Paleoeconomy of Norse Greenland." *Acta Archaeologica* 54: 73-122.

McGovern, T.H. (1985b). "The Arctic frontier of Norse Greenland. In *The Archaeology of Frontiers and Boundaries.* edited by S. Green and S. Perlman, 275 323, New York: Academic Press.

McGovern, T.H. (1991) Climate, Correlation, and Causation in Norse Greenland, *Arctic Anthropology* 28(2):77-100.

McGovern, T.H. (1992a) Zooarchaeology of the Vatnahverfi, in: C.L. Vebæk, *Vatnahverfi*, *Meddelelser om Grønland Man and Society,* 17:93-107.

McGovern, T.H. (1992b) Bones, Buildings, and Boundaries: Paleoeconomic approaches to Norse Greenland, in: C.D. Morris and James Rackham (eds), *Norse and later Settlement and Subsistence in the North Atlantic G*lasgow U. Press pp 157-186.

McGovern, T.H. (1994) Management for extinction in Norse Greenland in: C. Crumley (ed.) *Historical Ecology: Cultural Knowledge and Changing Landscapes,* School of American Research Monograph, Santa Fe NM. pp 127-154

McGovern, T. H. (2000) "The Demise of Norse Greenland. " In *Viking Voyagers*, edited by W.W. Fitzhugh and E. Ward, 327-430, Washington: Smithsonian Institution Press.

McGovern, T.H., (2014). North Atlantic Human Ecodynamics Research: Looking forwards from the past. In: Harrison, R., Maher, R., (eds.). Long-Term Human Ecodynamics in the North Atlantic: An Archaeological Study. Lexington Publishers, Lanham, Maryland, 213-222.

McGovern, T.H. (2018), 'Burning Libraries: A Community Response', *Conservation and Management of Archaeological Sites* vol 20, 2018: 165-174.

McGovern, T.H. and R. H. Jordan (1982) Settlement and land use in the inner fjords of Godthab District, West Greenland *Arctic Anthropology* 19(1):53-80.

McGovern, T. H., Paul C. Buckland, Guðrún Sveinbjarnardóttir; Diana Savory, Peter Skidmore, and Claus Andreasen. (1983). "A Study of the Faunal and Floral Remains from two Norse Farms in the Western Settlement, Greenland." *Arctic Anthropology* 20(2):93-120.

McGovern, T.H., G.F. Bigelow, T. Amorosi and D. Russell (1988) Northern Islands, Human Error, and Environmental Degradation: a Preliminary Model for Social and Ecological Change in the Medieval North Atlantic *Human Ecology* 16(3):45-105.

McGovern, T.H., G.F. Bigelow T. Amorosi, J. Woollett and S. Perdikaris (1993) Animal bones from Ø17a Narsaq, in: C.L. Vebæk Narsaq- A Norse Landnám Farm. *Meddelelser om Grønland Man and Society,* 18 pp 134-47.

McGovern T.H., Amorosi, T., Perdikaris, S., Woollett, J.W., (1996). Zooarchaeology of Sandnes V51: Economic Change at a Chieftain's Farm in West Greenland. Arctic Anthropology 33 (2), 94-122.

McGovern, Thomas H., Sophia Perdikaris, Ingrid Mainland, Philippa Ascough, Vicki Ewens, Arni Einarsson, Jane Sidell, George Hambrecht, and Ramona Harrison, Chapter 4 : The archaeofauna (2009), in: Gavin Lucas (ed.) Hofstaðir: Excavations of a Viking Age Feasting Hall in North Eastern Iceland , Inst. of Archaeology Reykjavik Monograph 1, Reykjavik. Pp 168-252.

McGovern, T.H., R. Harrison, K. Smiarowski (2014). Sorting Sheep and Goats in Medieval Iceland and Greenland: Local Subsistence or World System? In Harrison, R. and Maher, R. (eds.).). *Long-Term Human Ecodynamics in the North Atlantic: An Archaeological Study*. Lexington Publishers, Lanham, Maryland.

Meldgaard, M. (1986) 'The Greenland caribou – zoogeography, taxonomy, and population dynamics', *Meddelelser om Grønland, Bioscience* **20**, 1–88.

Meyer, W.J. and Crumley, C.L. (2011) Historical Ecology: Using what Works to Cross the Divide. Atlantic Europe in the First Millennium BC: Crossing the Divide. Tom Moore and Lois Armada, (eds.), pp. 109-134. Oxford: Oxford University Press.

Mikkelsen, N., A. Kuijpers, and J. Arneborg (2008) The Norse in Greenland and Late Holocene Sea-Level Change. *Polar Record* 44(228):45–50.

Miles, M.W., Divine, D.V., Furevik, T., Jansen E., Moros, M., Ogilvie, A.E.J. (2014). A signal of persistent Atlantic multidecadal variability in Arctic Sea ice. *Geophysical Research Letters*, 41.

Miller, G.H., Gestsdóttir, Á., Zhong, Y., Larsen, D.J., Otto-Bliesner, B.L., Holland, M.M., Bailey, D.A., Refsnider, K., Lehman, S., Southon, J., Anderson, C., Björnsson, H., Thordarson, T. (2012). 'Abrupt Onset of the Little Ice Age Triggered by Volcanism and Sustained by Sea-Ice/ocean Feedbacks.' *Geophysical Research Letters* 39, no. 2.

Moon, T., Fisher, M., Harden, L., Simonoko, H., and T. Stafford (2022). QGreenland (v2.0.0) [software], National Snow and Ice Data Center.

Mooney D.E. (2021) Charred *Fucus*-Type Seaweed in the North Atlantic: A Survey of Finds and Potential Uses, Environmental Archaeology, 26:2, 238-250.

Mooney, D.E. and Guðmundsdóttir, L. (2020) ' Barley cultivation in Viking Age Iceland in light of evidence from Lækjargata 10–12, Reykjavík'. in: Santeri Vanhanen and Per Lagerås (eds.) *Archaeobotanical studies of past plant cultivation in northern Europe* , Barkhui Press (pp.5-20)

Moran, N. C, and T. P. O'Connor (1994) Age attribution in domestic sheep by skeletal and dental maturation: A pilot study of available sources. *International Journal of Osteoarchaeology* 4(4):267–285.

Mulville J., J. M. Bond, and O. Craig (2005) "The white stuff: milking in the outer Scottish Isles." In *The zooarchaeology of fats, oils, milk and dairying,* edited by Jacqui Mulville and Alan K. Outram, 167-182, Oxford: Oxbow.

Møhl, U. (1972) Animal Bones from Itivnera, West Greenland: A Reindeer Hunting Site of the Saqqaq Culture. Meddelelser om Grønland 191(6).

Nelson M.C. · S.E. Ingram · A.J. Dugmore · R. Streeter · M.A. Peeples · T. H. McGovern · M. Hegmon · J. Arneborg · K.W. Kintigh · S. Brewington · K.A. Spielmann · I.A. Simpson, C. Strawhacker · L. Comeau · A. Torvinen · C. K. Madsen · G. Hambrecht · K. Smiarowski (2016). 'Climate challenges, vulnerabilities, and food security'. *PNAS* 113(2):298-303.

Nelson, M.C., Kintigh, K.W., Arneborg, J., Streeter, R. and Ingram, S.E. (2017) 'Vulnerability to Food Insecurity: Trade-offs and Their Consequences' in Hegmon, M. (ed.) *The Give and Take of Sustainability: Archaeological and Anthropological Perspectives on Tradeoffs*. Cambridge: Cambridge University Press

Nelson, E. D., J. Heinemeier, N. Lynnerup, Á.E. Sveinbjörnsdóttir, and J. Arneborg. (2012) "An Isotopic Analysis of the Diet of the Greenland Norse." *Journal of the North Atlantic* 3 (sp3): 93–118.

Nørlund, P. (1924) Buried Norsemen at Herjolfsnes: An Archaeological and Historical, Study. Publisher, C. A. Rietzel.

Nørlund, P. (1929) Norse ruins at Gardar: the episcopal seat of mediaeval Greenland. *Meddelelser om Grønland* 76, 1–171.

Nørlund, P. (1936) *Viking settlers in Greenland and their descendants during five hundred years*. Cambridge University Press.

North Atlantic Biocultural Organization Zooarchaeology Working Group (2010) *NABONE Zooarchaeological Recording Package 9th edition*. New York: City University of New York

Nordic Seabird Colony Databases (2006) Results of a Nordic project on seabird breeding colonies in Faroes, Greenland, Iceland, Jan Mayen and Svalbard ,Tema Nord 2006:512 ISBN 92-893-1301-3

Nunniffiit (the Greenland National Database of Cultural Heritage) nunniffiit.natmus.gl

Nyegaard, G. (2018) Dairy Farmers and Seal Hunters: Subsistence on a Norse Farm in the Eastern Settlement, Greenland, *Journal of the North Atlantic* 2018(37), 1-80.

Ogilvie, A.E.J. (1991) Climatic changes in Iceland A. D. c. 1500 to 1598. (In) *The Norse of the North Atlantic* (Presented by G.F. Bigelow), *Acta Archaeologica Vol. 61-1900,* Munksgaard, Copenhagen, 233-251.

Ogilvie A.E.J., James M. Woollett, K. Smiarowski, J. Arneborg, S. Troelstra, A. Kuijpers, A. Pálsdóttir, and T.H. McGovern, (2009) 'Seals and Sea Ice in Medieval Greenland', *Journal of the North Atlantic,* Volume 2 (2009): 60–80.

Østergård, E. (2003) *Woven into the earth: textiles from Norse Greenland*. ISD LLC.

Orosius, P. (1984) *Two Voyagers at the Court of King Alfred: The Ventures of Ohthere and Wulfstan, Together with the Description of Northern Europe from the Old English Orosius*. Sessions.

Outram, A.K, and J. Mulville (2005) The Zooarchaeology of fats, oils, milk, and dairying: an introduction and overview, in J Mulville and A. Outram (eds) *The Zooarchaeology of fats, oils, milk, and dairying*, Oxbow Books Oxford. Pp 1-8.

Outram A.K. (1999), Comparison of Paleo-Eskimo and Medieval Norse Bone Fat Exploitation in Western Greenland *Arctic Anthropology* Vol. 36, No. 1/2 pp. 103-117.

Outram A. K. (2003) Comparing Levels of Subsistence Stress amongst Norse Settlers in Iceland and Greenland using Levels of Bone Fat Exploitation as an Indicator, Environmental Archaeology, 8:2, 119-128.

Pálsdóttir, L. and F. Feeley (2017) Gufuskalar: a medieval commercial fishing station in Western Iceland. In *Public Archaeology and Climate Change*, edited by Tom Dawson, Courtney Nimura, Elias Lopez- Romero, and Marie-Yvane Daire, pp. 109–116. Oxbow Books.

Paulsen, C, J. Arneborg, M. Hebsgaard, N. Lynnerup, C.K. Madsen, and K. Smiarowski (2009) "Resources, Mobility, and Cultural Identity in Norse Greenland, Vatnahverfi Project." *NABO International Polar Year Report*.

Panagiotakopulu, E. and A. L Buchan (2015) 'Present and Norse Greenlandic hayfields – Insect assemblages and human impact in southern Greenland'. *The Holocene* 2015, Vol. 25(6) 921–931.

Panagiotakopulu, E., Greenwood, M.T. and Buckland, P.C.,(2012). Insect fossils and irrigation in medieval Greenland. *Geografiska Annaler*: Series A, Physical Geography.

Patterson, W.P., K.A. Dietrich, C. Holmden, J.T. Andrews (2010) 'Two millennia of North Atlantic seasonality and implications for Norse colonies' *Proceedings of the National Academy of Sciences* Mar 2010, 107 (12) 5306-5310.

Perdikaris S. and T.H. McGovern (2008), 'Codfish and Kings, Seals and Subsistence: Norse Marine Resource Use in the North Atlantic', in: Torben Rick and Jon Erlandson (eds) *Human Impacts on Marine Environments*, UCLA Press Historical Ecology Series pp 157-190.

Perren, B., C. Massa, V. Bichet, É. Gauthier, O. Mathieu, C. Petit, and H. Richard (2012) "A paleoecological perspective on 1450 years of human impacts from a lake in southern Greenland." *The Holocene* 22, no. 9: 1025-1034.

Pierce, E. (2009). “Walrus hunting and the ivory trade in early Iceland.” *Archaeologia Islandica 7*: 55–63.

Pinta Elie (2021) Norse Management of Wooden Resources across the North Atlantic: Highlights from the Norse Greenlandic Settlements, *Environmental Archaeology*, 26:2, 209-221.

Prehal, Brenda (2015) Freyja’s Cats: Perspectives on Recent Viking Age Finds in Tegjandadalur North Iceland. Master’s Thesis, Hunter College, New York, NY.

Prehal, B. (2021) "Handbook for the Deceased: Re-Evaluating Literature and Folklore in Icelandic Archaeology". *CUNY Academic Works.*

Price, N. (2018). Viking phenomena. *SAA Archaeological Record* 18: 10–14.

Price, N. (2020) *History of the Vikings: Children of Ash and Elm,* Basic Books New York.

Price, N., and J. Arneborg (2018) The Peopling of the North Atlantic: Isotopic Results from Greenland. Viking Settlers of the North Atlantic: An Isotopic Approach. Journal of the North Atlantic Special Volume 7:164–185

Popkin, P., P. Baker, F Worley, S Payne, and A. Hamilton (2012) The Sheep Project (1): determining skeletal growth, timing of epiphyseal fusion and morphometric variation in unimproved Shetland sheep of known age, sex, castration status and nutrition, *Journal of Archaeological Science* 30(2012:1775-1792.

Redman C.L. Steven R. James, Paul R. Fish, and J Daniel Rogers (eds) (2004) *The Archaeology of Global Change*, Washington DC, Smithsonian Press.

Rick, T.C. and J.M. Erlandson (eds) (2008) *Human Impacts on Ancient Marine Ecosystems: a Global Perspective,* U California Press Berkeley.

Ritchey, Melissa M. (2019) Regional Variation in Grass, Sedge, and Cereal Cultivation During the Viking Age in Skagafjörður, North Iceland. University of Massachusetts, Boston, Boston, MA.

Roberts H. M. (2002) Archaeological Investigations at Gásir 2002, a preliminary report. Fornleifastofnun Norðurlands,FS180-01072, Reykjavík, September 2002.

Roberts H.M. (ed.) and C. Batey. (2003) Excavations at Gásir 2003 – A Preliminary Statement. Fornleifastofnung Norðurlands, FS210-01074, September 2003.

Roberts, H.M. (ed.), C. Batey, N, Mehler, E. Ó. Hreiðarsdóttir, B. Lárusdóttir, R. Harrison, S. Brewington, J. Woollett, T.H. McGovern, W. P. Adderley and I. A. Simpson. (2004) Excavations at Gásir 2003 An Interim Report, Fornleifastofnun Norðurlands, FS-238-01075, April 2004.

Roberts, H. M. (ed.), G. A. Gísladóttir, R. Harrison and O. Vésteinsson. (2005) Excavations at Gásir 2004: An Interim Report. Fornleifastofnun Íslands, FS280-01076, Reykjavík, June 2005.

Roberts, H. M. (ed.), O. Vésteinsson, T. Brorsson, H. Konráðsdóttir, R. Harrison, S. Ólafsson, G. A. Gísladóttir and M. Snæsdóttir. (2009) Gásir Post Excavation Reports – Volume 1. 2009, FS423-010712, Fornleifastofnun Íslands, Reykjavík.

Roberts, H. M. (ed.), O. Vésteinsson, S. Guðmundsdóttir Beck, Q. Mould, H. Konrádsdóttir and S. C. J. Hansen. (2010) Gásir Post Excavation Reports - Volume 2. 2010, FS450-010713, Fornleifastofnun Íslands, Reykjavík.

Roesdahl, E. (2005) Walrus Ivory—Demand, Supply, Workshops, and Greenland. *In Viking and Norse in the North Atlantic*: Select Papers from the Proceedings of the Fourteenth Viking Congress, Torshavn, 19–30 July 2001. Andras Mortensen and Simun V. Arge, (eds.) Pp. 182–207. Torshavn:

Roussell, A. (1934) Building Customs in the Scottish Isles. Munksgaard, Copenhagen.

Roussell, A. (1936) Sandnes and the neighboring farms. Meddelelser om Grønland 88(3).

Roussell, A. (1941) Farms and churches in the medieval Norse settlements of Greenland. Meddel. om Grønland 86(1).

Russell, D. (1985) *A Biogeographical Model for Island Dwarfism of Domestic Livestock in the Scandinavian North Atlantic: A Comparative Metrical Analysis of Bos and Ovicaprid Metapodials*. M. A. thesis, Hunter College, New York.

Schofield, J.E. (2008): Land management at the bishop's seat, *Garðar*, medieval Greenland. *Antiquity* 82.

Schofield J.E., Edwards K.J., Erlendsson E., Ledger P.M. (2013) Palynology supports 'Old Norse' introductions to the flora of Greenland. Journal of Biogeography 40: 1119-1130.

Schofield, J.E., Edwards, K.J. and McMullen, A.J. (2007) Modern pollen–vegetation relationships in subarctic southern Greenland and the interpretation of fossil pollen data from the Norse *landnám*. *Journal of Biogeography* 34, 473–88.

Schledermann, P. (2000) Ellesmere: Vikings in the Far North. *In Vikings: The North Atlantic Saga.* William W. Fitzhugh and Elizabeth I. Ward, eds Washington, D.C.: Smithsonian Institution Press. pp. 248–256.

Schledermann P. and K. M. McCullough (2003) Inuit-Norse Contact in the Smith Sound Region. *In* Contact, Continuity, and Collapse: The Norse Colonization of the North Atlantic. James Barrett, (ed.) pp. 183–207. Turnhout: Brepols.

Schmid, M. M., Dugmore, A. J., Vésteinsson, O., and Newton, A. J. (2017). Tephra isochrons and chronologies of colonization. *Quaternary Geochronology* 40: 56–66.

Schmid, M. E., A.J. Dugmore, A.J. Newton, and O. Vésteinsson (2021) “Multidisciplinary Chronological Data from Iceland Indicate a Viking Age Settlement Flood, Rather Than a Flow or Trickle.” The Archaeology of Island Colonization, 132–79.

Scott, G.R. and Jolie, R.B. (2008) Tooth-tool use and yarn production in Norse Greenland. *Alaska Journal of Anthropology*, *6*(1-2), pp.253-264

Scott, C.R., R. Schomberg, V. Swenson and D. Adams (2016) Northern exposure: Mandibular torus in the Greenlandic Norse and the whole wide world. American Journal of Physical Anthropology pp. 1-9.

Sigurðardóttir, R., A. Newton, M.T. Hicks, A.J. Dugmore, V. Hreinsson, A.E.J. Ogilvie, Á.D. Júlíusson, Á. Einarsson, S. Hartman, I.A. Simpson, Orri Vésteinsson**,** T.H. McGovern (2019) Trolls, Water, Time, and Community: Resource Management in the Mývatn District of Northeast Iceland in Ludomir Lozny and Thomas McGovern (eds) *Global Perspectives on Long Term Community Resource Management* Springer Co NY pp 77-101.

Simpson, I.A., Dugmore, A.J., Thomson, A.M., and O. Vésteinsson (2001) Crossing the thresholds: human ecology and historical patterns of landscape degradation. Catena 42:175-192.

Simpson, I.A., Adderley, W.P., Guðmundsson, G., Hallsdóttir, M., Sigurgeirsson, and Snæsdóttir, M. (2002). Soil limitations to agrarian land production in pre-modern Iceland. *Human Ecology* 30, 423-443.

Simpson, I.A., Vésteinsson, O., Adderley, W. P., and T.H. McGovern (2003) Fuel resources in landscapes of settlement. *Journal of Archaeological Science* 30:1401-1420.

Simpson, I.A., Guðmundsson, G., Thomson, A.M., and J. Cluett (2004) Assessing the role of winter grazing in historic land degradation, Mývatnssveit, north-east Iceland. *Geoarchaeology* 19:471-503.

Simpson, I.A., A. J. Dugmore, A. Thomson, and O. Vésteinsson (2001) “Crossing the Thresholds: Human Ecology and Historical Patterns of Landscape Degradation.” *Landscape Sensitivity: Principles and Applications* 42(2–4): 175–92.

Sinclair, P., Moen, J. and Crumley, C.L. (2018) Historical Ecology and the Longue Durée. In” Crumley, Carole L., Tommy Lennartsson, and Anna Westin, (eds.) *Issues and Concepts in Historical Ecology: The Past and Future of Landscapes and Regions,* pp. 13-40. Cambridge, UK: Cambridge University Press.

Smiarowski, K. (2007) Greenland 2007 Field Season Preliminary Report. NORSEC IPY Report.

Smiarowski, K. (2008) Archaeological Investigations in Vatnahverfi, Greenland 2008 Season Preliminary Report. NORSEC IPY Report.

Smiarowski Konrad. (2012). E172 Tatsip Ataa Midden Excavation. 2009 and 2010 Preliminary Excavation Report, NABO field report series.

Smiarowski K. (2013a) Preliminary Report on the 2012 Archaeofauna from E47 Gardar in the Eastern Settlement, Greenland, HERC- NORSEC Laboratory Report No. 61.

Smiarowski K. (2013b). Zooarchaeological Analysis of E168 Midden Test Trench – a Norse Shieling Site in Eastern Settlement, Greenland. HERC- NORSEC Laboratory Report.

Smiarowski, K. (2014) 'Climate related farm-to-shieling transition at E74 Qorlortorsuaq in Norse Greenland', in Harrison, R. and Maher, R. (eds) Human Ecodynamics in the North Atlantic: A Collaborative Model of Humans and Nature through Space and Time, pp. 177–94. Lanham: Lexington Publishers.

Smiarowski, K., Pálsdóttir, A., McGovern, T.H. (2007) Preliminary assessment report of the archaeofauna from KNK 203 (E 74), a Norse Farm in the Eastern Settlement, Greenland. NORSEC Laboratory Report 39.

Smiarowski, K., R. Harrison, S. Brewington, M. Hicks, F. Feeley, C. Dupont-Herbert, G. Hambrecht, J. Woollett, T.H. McGovern (2017) 'Zooarchaeology of the Scandinavian Settlements in Iceland and Greenland: diverging pathways', in: Umberto Albarella, Mauro Rizzetto, Hannah Russ, Kim Vickers, and Sarah Viner-Daniels, *Oxford Handbook of Zooarchaeology* ISBN: 9780199686476.

Spielmann, K., Peeples, M.A., Glowacki, D.M. and Dugmore, A. (2016) Early Warning Signals of Social Transformation: A Case Study from the US Southwest *PLoS ONE* 11(10): 1-18.

Storå, J., and Lõugas, L. (2005) Human exploitation and history of seals in the Baltic during the Late Holocene. In: Monks, G.G. (ed.), *The Exploitation and Cultural Importance of Sea Mammals*. Oxbow Books, Oxford, pp. 95-106.

Sutherland, P. (2009) The question of contact between Dorset Paleo-Eskimos and early Europeans in the eastern Arctic. In Maschner, H. D. G., Mason, O., and McGhee, R. (eds.), *The Northern World AD 900–1400*, University of Utah Press, Salt Lake City, pp. 279–299.

Star, B., J.H. Barrett, A. T. Gondek, and S. Boessenkool (2018) Ancient DNA Reveals the Chronology of Walrus Ivory Trade from Norse Greenland. *Proceedings of the Royal Society B: Biological Sciences* 285(1884).

Stoklund, M. (1993) "Greenland runes. Isolation or cultural contact?" in *The Viking Age in Caithness, Orkney and the North Atlantic*, pp. 528–543. ISBN 0748505327.

Þorláksson, H. (1991) Vaðmál og Verðlag: Vaðmál í utanlandsviðskiptum og búskap Íslendinga á 13. og 14. öld. Reykjavík: Háskóli Íslands.

Van der Leeuw, S. and C. Redman (2002) Placing archaeology at the center of socio-natural studies. *American Antiquity* 67: 597–605.

Van der Leeuw, S., R. Costanza, S. Aulenbach, S. Brewer, M. Burek, S. Cornell, C. Crumley, J. A. Dearing, C. Downy, L. J. Graumlich, S. Heckbert, M. Hegmon, K. Hibbard, S. T. Jackson, I. Kubiszewski, P. Sinclair, S. Sörlin, and W. Steffen (2011) Toward an integrated history to guide the future. *Ecology and Society* 16(4): 2

Vebæk, C.L. (1943a) Inland farms in the Norse East Settlement, Meddelelser om Grønland, 90(1)

Vebæk, C.L. (1943b) Nordboforskningen i Grønland, Geografisk Tidskrift, 46: 101–28.

Vebæk, C.L. (1952) Vatnahverfi, Nationalmuseets Arbejdsmark, 101–114. 1952:

Vebæk, C.L. (1953a) Klostre i de Grønlandske Nordbobygder, Tidsskriftet Grønland, 5

Vebæk, C.L. (1953b) Nordbobygdernes Kirker, Tidsskriftet Grønland, 8

Vebæk, C.L. (1953c) Vatnahverfi, Tidsskriftet Grønland, 6

Vebæk, C.L. (1956a) Mellembygden, Tidsskriftet Grønland, 3

Vebæk, C.L. (1957) Ten years of topographic and archaeological investigations in the medieval Norse settlements in Greenland. 32nd Intl. Congress of Americanists. Copenhagen. pp.733–743.

Vebæk, C.L. (1958) "Topographical and archaeological investigations in the medieval Norse settlements in Greenland: a survey of the work of the last ten years". In Third Viking Congress Reykjavik

Vebæk, C.L. (1991). *The Church Topography of the Eastern Settlement and the Excavation of the Benedictine Convent at Narsarsuaq in the Uunartoq Fjord*. Denmark: *Meddelelser om Grønland: Man and Society* 14.

Vebæk, C.L. (1992) Narsaq - A Norse Landnám Farm *Meddelelser om Grønland Man and Society,* 18

Vésteinsson, O. (2010) 'Parishes and Communities in Norse Greenland. *'Journal of the North Atlantic* 2(sp2):138–150.

Vésteinsson, O., T.H McGovern and C. Keller (2002) 'Enduring Impacts: Social and Environmental Aspects of Viking Age Settlement in Iceland and Greenland *Archaeologica Islandica 2* 98-136.

Vésteinsson, O., and T. H. McGovern (2012) "The Peopling of Iceland." *Norwegian Archaeological Review* 45(2): 206-218.

Vésteinsson, O. (2013) "Collapse or resilience? Archaeology, metaphor, and global warming" In Sabatini, S. and Bergerbrant, S. (eds.) *Counterpoint: Essays in Archaeology and Heritage Studies in Honour of Professor Kristian Kristiansen.* Bar Publishing.

Vésteinsson, O. (ed.) (2013) Rescue excavations at the Bishop's Manor at Gardar/ Igaliku in 2012: project report on file Greenland National Museums and Archives and on NABO Project Management system.

Vésteinsson, O., Hegmon, M., Arneborg, J., Riche, G. and Russell, W.G. (2019) Dimensions of inequality. Comparing the North Atlantic and the US Southwest. *Journal of Anthropological Archaeology* 54: 172-191.

Vibe, C. (1967) Arctic animals in relation to climatic fluctuations. *Meddelelser om Grønland* 170(5).

Vickers, K., and Panagiotakopulu, E. (2011) Insects in an abandoned landscape: late Holocene palaeoentomological investigations at Sandhavn, southern Greenland. Environmental Archaeology 16: 49-57.

Von den Driesch, Angela (1976) *A Guide to the Measurement of Animal Bones from Archaeological Sites*. Peabody Museum Bulletin 1. Peabody Museum of Archaeology and Ethnology, Harvard University, Cambridge, Massachusetts.

Warinner, C., Hendy, J., Speller, C., Cappellini, E., Fisher, R., Trachsel, C., Arneborg, J., Lynnerup, N., Craig, O.E., Swallow, D.M., Fotakis, A., Christensen, R.J., Olsen, J.V., Liebert, A., Montalva, N., Fiddyment, S., Charlton, S., Mackie, M., Canci, A., Bouwman, A., Rühli, F., Gilbert, M.T.P. and Collins, M.J. (2014) Direct evidence of milk consumption from ancient human dental calculus. *Scientific Reports* 4:7104.

Whitaker, I. (1981). Othere's account revisited, *Arctic Anthropology*, 18(1): 1–12.

Zeder, M. A. (2006) Reconciling rates of long-bone fusion and tooth eruption and wear in sheep (Ovis) and goat (Capra). In *Recent Advances in Ageing and Sexing Animal Bones*, edited by Deborah Ruscillo, pp. 87–118. Proceedings of the 9th Conference of the International Council of Archaeozoology, Durham, August 2002. Oxbow Press, Oxford, UK.

Zeder, M.A., and H.A. Lapham (2010) Assessing the reliability of criteria used to identify postcranial bones in sheep, Ovis, and goats, Capra. *Journal of Archaeological Science* 37(11):2887–2905.

Zeder, M.A., X. Lemoine, and S. Payne (2015) A new system for computing long-bone fusion age profiles in Sus scrofa. *Journal of Archaeological Science* 55:135–150.

---

[i] Portions of this section have been published in Smiarowski 2014