# Cultural adaptation, compounding vulnerabilities and conjunctures in Norse Greenland

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**Norse Greenland has been seen as a classic case of maladaptation by an inflexible temperate zone society extending into the arctic and collapse driven by climate change. This paper, however, recognizes the successful arctic adaptation achieved in Norse Greenland and argues that, although climate change had impacts, the end of Norse settlement can only be truly understood as a complex socioenvironmental system that includes local and interregional interactions operating at different geographic and temporal scales and recognizes the cultural limits to adaptation of traditional ecological knowledge. This paper is not focused on a single discovery and its implications, an approach that can encourage monocausal and environmentally deterministic emphasis to explanation, but it is the product of sustained international interdisciplinary investigations in Greenland and the rest of the North Atlantic. It is based on data acquisitions, reinterpretation of established knowledge, and a somewhat different philosophical approach to the question of collapse. We argue that the Norse Greenlanders created a flexible and successful subsistence system that responded effectively to major environmental challenges but probably fell victim to a combination of conjunctures of large-scale historic processes and vulnerabilities created by their successful prior response to climate change. Their failure was an inability to anticipate an unknowable future, an inability to broaden their traditional ecological knowledge base, and a case of being too specialized, too small, and too isolated to be able to capitalize on and compete in the new protoworld system extending into the North Atlantic in the early 15th century.**

Vikings | marine mammals | Little Ice Age | rigidity trap

Although the term collapse has been widely used when referring to marked changes in social organization or cultural complexity, what is in reality meant is better captured by decline, a prolonged, decades- to centuries-scale process, which may differentially affect portions of societies or involve settlement reorganization rather than biological extinction. It is rare for a human society to collapse to the point of extinction (1). Many investigators of past human ecodynamics, thus, favor the idea of transformation over collapse and work to differentiate cases showing high human costs from cases of soft landings (2). In the few well-documented cases of painful transformation, where the end is absolute with no direct continuity with future settlement, there is a special need to better understand the factors leading to such changes, implied limitations to adaptation, and failed sustainability. In the case of the Norse, examples of profound change in Greenland can be considered alongside lesser changes elsewhere in the North Atlantic, where a range of Norse societies with both similarities and contrasts can be assessed and differences occurred in terms of geographical setting, pace of environmental change, use of ecological knowledge, social transformation, and choices about sustainable practice, trade, intensification, infrastructure, mobility, and social organization (3).

## Colonization of the Atlantic Islands

The late 10th century Norse settlement of Greenland was a part of a much wider pattern of Atlantic colonization (Fig. 1). Reasons for the Norse movement into the Atlantic between *ca*. A.D. 800 and A.D. 1000 are still debated (4, 5), but the push into the deep Atlantic was abrupt and large-scale.

The Norse had a broad-based subsistence system based on farming and the harvesting of wild resources. In the Faroe Islands, settlement nucleated into small clusters, whereas in Iceland and Greenland, it was characterized by more dispersed patterns (6, 7); however, everywhere, the annual subsistence round involved both multifarm collaboration and movement of products across multiple farm properties. The community rather than the individual farm was the basis of subsistence and survival. Settlers imported domestic animals, including cattle, sheep, goats, pigs, horses, dogs, and cats (8). Wherever possible, they supplemented pastoralism with barley and flax production. This approach was successful in the Faroes, small scale in Iceland until it disappeared in the 16th century, and barely possible in Greenland (9–11). Pastoralism was supported by a mix of farmyard infields, intensively cultivated for fodder, and communally managed upland grazing. Fodder maintained livestock through the winter, and this vital production was sometimes enhanced through manuring and irrigation (12, 13). Through the summer, shieling systems were used to manage the upland grazing of livestock and create dairy products while spreading grazing pressure more widely across the landscape (14).

The common practice of pastoralism meant that Norse settlement in Iceland and Greenland was strongly conditioned by available grazing, and there is a close correlation between the distribution of pasture plants and Norse farm sites in both areas. Production from imported domestic animals was supplemented by extensive hunting of seals and small whales, marine and freshwater fishing, wild fowling, egg collection, and in Greenland, caribou hunting (15–17). Large archaeofauna (animal bone collections) and a growing number of stable isotope measurements on Viking age and medieval human skeletons (15, 18, 19) show that these wild species (especially marine fish) provided storable buffers against terrestrial pasture productivity fluctuations and stock loss, and they constituted a regular part of the normal diet across the North Atlantic. In Greenland, the role of wild resources took on a unique importance, because Norse settlers exploited the huge populations of migratory harp and hooded seals that move along the southwest coast in spring (19).

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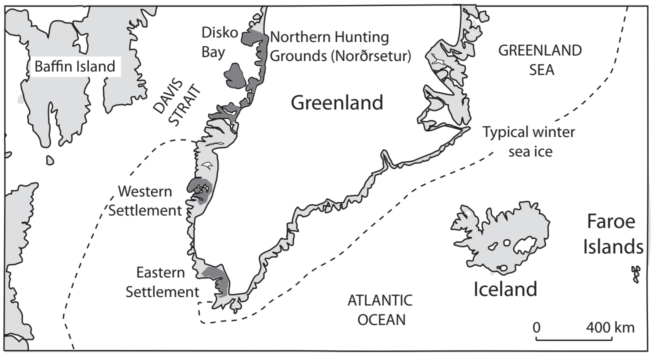


**Fig. 1.** The North Atlantic showing Norse settlement areas in Greenland and their northern hunting grounds.

For most North Atlantic settlers, survival and prosperity required a combination of pastoral farming (with a careful balance of stock and fodder production), use of a range of wild species, and exploitation of some source of trade goods to keep political, religious, and cultural connections open and maintain the flow of European artifacts. On small farms, people drew on more wild resources than those people on larger farms, and through time, they became increasingly dependent on magnate farmers who raised more cattle and actively participated in local and regional politics. All, however, shared a need to balance farming, hunting/fishing, and exchange. Common lands needed effective management, buffering had to be maintained against individual bad luck or short-term disaster, and communal labor required coordination to meet seasonal demands; thus, the medieval Norse island communities generated elaborate law codes and multitiered court systems well before their eventual integration into the Norwegian kingdom in the late 13th century (20). These records provide an invaluable insight into local environmental knowledge and adaptive management strategies, but their interpretation requires supplementary evidence from archeology and paleoecology.

## Evidence for Adaptative Management

A common theme in narratives of collapse is a lack of flexibility or maladaptations to local conditions. The establishment and endurance of Norse farms across the Atlantic islands show, however, the successful translocation of domestic animals, farming experience, and a very varied use of wild resources. Although the initial farm stock introduced by the Norse included a common package of domesticates, it was locally modified. Across the North Atlantic, pigs became very rare or totally extinct by the early 13th century, a change best explained by their propensity to damage grazing in a period of economic intensification and environmental fluctuation. The Atlantic island communities also diverged in terms of farming strategy. In Iceland after A.D. 1200, goats became rare, and sheep increased dramatically compared with cattle and other stock, possibly reflecting the intensification of wool production to produce an exchange commodity (16). In most Greenland archaeofauna, goats remain as common as sheep, suggesting a continued emphasis on food, especially dairy production, rather than surplus wool production (21). although cattle bones remain most common on magnate farms across the North Atlantic, the balance between the species varies considerably between districts and settlements. Barley production is harder to quantify directly, but some barley continued to be produced in specially sheltered spots well beyond the theoretical agroclimatic limits of medieval Iceland (22).

Wild birds (especially sea bird colonies and migratory waterfowl) were exploited universally, and in some cases, this natural capital may have been significantly drawn down by first settlers encountering unwary bird populations. However, stratified archaeological sites document the long-term sustainable exploitation of sea birds on both Sandoy in the Faroes (9, 23) and migratory waterfowl around Lake Mývatn in Iceland (15).

Although walrus may have been hunted to local extinction in Iceland during the initial settlement period, Icelandic colonies of nonmigratory harbor and gray seals have been sustainably managed through to present times. Walrus hunting was a key element of the Norse economy in Greenland. This importance is indicated by documentary sources telling of annual 800-km voyages from the settlement areas to the northern hunting grounds and finds within the settlements of abundant fragments of walrus bone generated by the extraction of tusks from skulls (24).

Norse hunters in Greenland responded to the presence of caribou by the development of cairn drives, creation of stone meat stores, and importation of large deer hounds (25). Although the west Greenland caribou has been vulnerable to climate fluctuation and overhunting in modern times (26), the Greenland Norse successfully managed these deer populations for nearly 500 y—perhaps an indication of vigorous top-down game management strategies familiar from medieval Europe.

In addition to adaptation that effectively harnessed wild animal resources, there is evidence for adaptative management of vegetation; in Iceland, large-scale woodland clearance progressed through the first five centuries of settlement but waned in the 14th century to be replaced by effective, long-term (>600 y) conservation of much of the remaining woodland for charcoal production (27–29). The drawdown of woodland in Iceland is mirrored by rangeland degradation, which has been extensive; some 20,000 $km^2$ of soil cover present before colonization have probably been eroded (30). This degradation has important qualifications: the overall availability of upland grazing has not been a constraint on livestock numbers and the highest animal numbers in Iceland's history developed in modern times when the cumulative losses of soil and vegetation were also at record levels. The drawdown of rangeland in Iceland has been associated with a persistence of settlement; arguably, one has been degraded to enable the survival of the other.

The most striking Norse adaptation of all seems to have been the immediate switch in emphasis in Greenland from sea fishing to the large-scale harvesting of migrating seals. In Iceland, multiple coastal and inland archaeofauna and a growing number of isotopic assays on human skeletons from both inland and coastal churchyards show that island-wide exchange of dried marine fish (mainly cod family) and substantial consumption of marine food by inland residents took place from first settlement (15, 16, 31, 32). Despite this early, large-scale use of marine fish in Iceland, the rarity of marine fish bones in any phase of Norse occupation—even recently excavated archaeofauna that have been carefully sieved for small bones—indicates that early settlers in Greenland decisively switched from cod to seal (32, 33). Although some explanations for this change invoke special pleading (34), it can be argued to be a pragmatic and effective adaptation driven by seasonal scheduling issues; the ice-riding harp and hooded seals arrived in the springtime, filling a potential late winter provisioning gap before the summer trips north for walrus hunting. Winter fisheries that did not compete with other subsistence were possible in Iceland but were less feasible in Greenlandic waters because of the formation of sea ice (35).

The Greenland Norse sealing techniques are likely to have been organizationally similar to historic and modern Faroese pilot whale drives in so much as they would probably have required most of the available boats and active crew. Communal action in the form of group clubbing attacks is also likely to have been used when the Greenland Norse took the familiar harbor seals, because this approach was used by the Norse in Iceland and the British Isles. The bearded and ringed seals that use winter breathing holes and do not form large seasonal concentrations are rare in Norse archaeofauna, but they are common in

Inuit sites alongside artifacts associated with elaborate sea ice hunting technology. Although Norse Greenlanders did not adopt these individualistic Inuit seal hunting techniques and technology and thus, had limited access to seals in winter, their strongly seasonal communal spring hunt effectively produced a large and seasonally critical supplementary food resource. Communal hunting of the effectively limitless stocks of migratory seals could be intensified significantly in ways that stock raising or hunting of caribou and harbor seals could not. This capability would be limited essentially only by labor supply, extreme weather, and transport capability, and it is likely to have played a critical role in the survival of Norse communities through climate shocks in the mid-13th and early 14th centuries.

## Connections, Integration, and Isolation

Changing political power and trade are key features of the Norse Atlantic communities through medieval to early modern times. Although the Faroes were integrated into the Norwegian kingdom from the 11th century, Iceland and Greenland remained separate polities until the A.D. 1260s. In both cases, there was a gradual increase in political ties with Norway through the 12th century, which is shown most clearly by the inclusion of the North Atlantic dioceses in the new archdiocese of Niðarós (Trondheim in Norway) established in A.D. 1156. It seems, however, that royal influence and involvement were considerably greater in Greenland than Iceland. This influence was partly because of differences in population size; Iceland, with a population 10–15 times greater than the population of Greenland (and the Faroes), was large enough to sustain its own local gentry. They turned out to be resilient enough to preserve their own influence even after unification, evidenced i.a. by the fact that, unlike the Faroes and Greenland, Iceland retained its status as a separate law district within the Norwegian kingdom.

Although neither the Faroes nor Iceland produced much in terms of prestige goods, the Greenlandic economy seems from the outset to have been geared to obtaining and exporting rare and prestigious commodities such as walrus tusk and hide, narwhal teeth, and live polar bears. It is likely that the Norwegian kings were in control of this trade from early times; control is certainly evident by the early 14th century when written sources become available (36). In contrast, Greenland had no part in the increasingly significant bulk trade in dried fish that the other North Atlantic communities vigorously embraced from the 13th century on. When the Kalmar Union was established in A.D. 1397, the focus of the Norwegian crown shifted south and east, and its Greenlandic province became doubly marginalized: first, because it ceased to be of concern to king and court and second, because it had no role in the developing trade in bulk commodities.

## Traditional Ecological Knowledge

Over multiple generations, the Norse North Atlantic island communities became well-established and accumulated island-specific reserves of what anthropologists call traditional ecological knowledge (TEK) (37). This knowledge encompasses worldview and accumulated knowledge of environmental variability, resource fluctuation, the nature of interactive relationships and the temporal and spatial patterning of these dynamics on the local scale. This TEK provides an understanding of likely seasonal variability in resources, ranges of expected weather and farming productivity on the decadal scale, best use of wild resources as sustainable supplements, and alternate strategies for survival in hard times and good. In the terms of McIntosh et al. (38), TEK is the practical "schemata" that provide the tertiary interface between the deep reservoirs that provide cultural legitimacy for action and the store of social memory that informs and provides context for social action (Fig. 2). We can identify the development of TEK in many aspects of Norse settlement from the successful long-term use of both domesticated and wild resources to details such as drive lines for caribou.

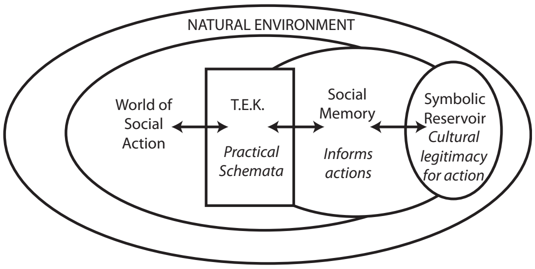


**Fig. 2.** Cultural schemata: filtering experience and legitimizing action using the work of McIntosh et al. (38).

Human societies (including our own) engage with natural environments through their accumulated TEK (which now includes science and engineering) mediated by deeper cultural traditions, core ideology, and belief systems. By A.D. 1200 and before the onset of a series of major climate perturbations, the communities of the North Atlantic had practical schemata in place that were reinforced by accumulated century-scale TEK and underpinned by a common Nordic Latin Christian ideology and symbolic reservoir.

## Discussion

**Environmental Change, Conjuncture, Collapse, and the Limits of TEK.** Although Norse settlement in Greenland came to an end, Norse settlement across the Atlantic as a whole is characterized by endurance and resilience. In Iceland, for example, the population has shown remarkable resilience in the face of short-lived demographic shocks created by disease, famine, bad weather, sea ice, or volcanic impacts acting both alone and in combination (20, 39, 40).

In Greenland, key themes of local adaptation and century-scale sustainability can be identified in common with other Norse colonies: the combination of terrestrial and marine resource use, farming infrastructure improvements (e.g., fertilization, fencing, and drainage/irrigation), and the successful communal organization of labor despite highly dispersed settlement patterns. The simple fact of a settlement's extinction implies, however, that there were limits to its adaptive management. In the case of Norse Greenland, numerical modeling has been used to explain these potential constraints. The FARMPACT simulation of Norse farming, which broadly quantifies fodder production, consumption, and provisioning constraints on Norse Greenlandic households of different scales, serves to highlight some of the limits to the intensification of domestic stock production (41). Under all realistic scenarios, the modeled dairy and meat production (based on size of byres, barns, and pens combined with medieval stock productivity estimates) fails to meet minimum household provisioning requirements (based on hall floor area measurements and early modern Icelandic analogs) and requires the supplement of marine wild resources apparent in the zooarchaeological and isotopic record.

According to the FARMPACT model, stock culling would have been forced by periods of extended winter feeding or periods of reduced pasture productivity caused by reduced summer temperatures, shortened growing season, or loss of pasture area to erosion or sea-level change. If interannual variation in fodder production levels requires repeated stock culling in closely spaced bad years, there is a tendency (especially on smaller farms) for herds and flocks to fall below minimal biological replacement levels. This finding suggests a key role for the larger magnate farms, with their richer pastures and larger total stock numbers, in maintaining the long-term viability of the whole farming system. This finding also offers a likely explanation for the recurring historical tendency for small farmers to become tenants of larger farms. High interannual variability in summer growing season and winter duration also produces a tracking problem; farmers who heavily culled their stock to survive a cold period are likely to have needed 3–5 y to rebuild herds to take advantage of a subsequent run of warm summers. FARMPACT results indicate the constraints on farming expansion in Greenland, highlight the tendency of the overall farming system to foster interdependency, and through time, they show an increase in collective reliance on better-situated magnate farms. These factors, coupled with the topographic constraints of Greenland's glaciated landscape, limit the potential for either the maintenance or intensification of domestic stock production through periods of climate fluctuation and cooling.

In Norse Greenland, interannual buffering from stored food was limited by the absence of grain or dried fish. In these circumstances, necessity would dictate the increased use of other resources. Intensification of caribou or harbor seal hunting was, however, also limited by climate impacts on caribou grazing and harbor seal reproduction and the need to avoid their overhunting and local extinction. These limitations left the migrating seal populations in general and harp and hooded seals in particular as a truly vital source of food in the form of air-dried meat. The Norse seasonal round in Greenland, thus, represented something of a balancing act, requiring considerable skill, deep reserves of TEK, and substantial resilience to not only get the community from year to year on current account subsistence but to also produce the surpluses that supported construction of the still impressive stone churches of the Eastern Settlement.

In the later Middle Ages, the balance between terrestrial farming and marine hunting began to shift decisively in Greenland. The increased use of marine mammals through time is shown by two independent lines of evidence. The C and N isotope records from human skeletal material change from ∼40% to ∼80% marine, and this finding mirrors changes in the faunal assemblages in middens, where seal bones increase to similar levels of abundance over the same time period (18, 24). We argue that this shift represents an initially successful response to climate change and an initially resilient modification and intensification of sealing TEK by the Greenlanders.

Climate variability always provided challenges to Norse Greenland's TEK, and the notion of a uniform medieval warm period has long been replaced by the realization that even the earliest periods of settlement saw considerable variability requiring effective coping strategies. The Norse Greenlanders survived many hard years before the 13th century and not only persevered but prospered. However, in the late 13th to mid-14th centuries, the effects of processes operating on different temporal and spatial scales began to coincide, producing unprecedented challenges.

Sea-level rise operating over century time scales destroyed significant areas of lowland pasture and maritime infrastructure such as boat houses (42). Cooling trends on decadal scales coincided with climate fluctuations expressed on annual scales, which are shown in ice cores and multiproxy climate reconstructions (43–46). Add to the mix low-frequency, high-magnitude volcanic impacts on climate—the global climate perturbation caused by low latitude volcanism in A.D. 1257–1259 (47)—and the circumstances were created for transformative change (Fig. 3).

Summer sea ice increased around the Eastern Settlement, with direct impacts on navigation, harbor seals, and quality of pasture along shores (48). The increasing sea ice would also have affected the coordination of communal labor during the vital summer months. The cumulative effects of reduced summer growing seasons (sometimes occurring in strings of successive summers) (43) and rising sea levels (42) would have both reduced grazing and fodder production and increased winter byring time and overall fodder need. Increased North Atlantic storminess (especially after A.D. 1425) would have increased hazards to sailing, threatening voyages to the Northern hunting grounds for walrus and the vital communications with Norway, the lifeline for both exports and imports.

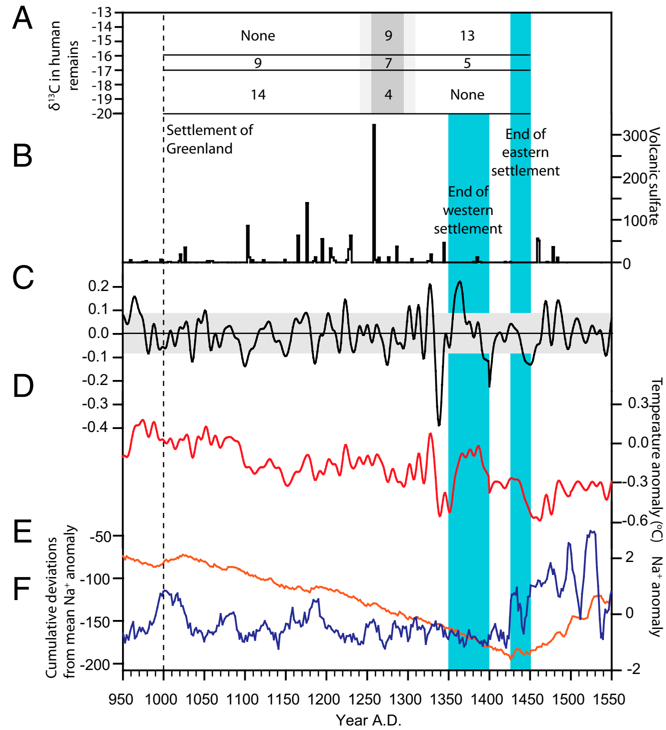


**Fig. 3.** Isotope records from Norse human remains in Greenland (*A*) indicate changes in diet (18). Volcanic sulfate records (*B*) from Greenland Ice Sheet Project 2 (GISP2) show the unusual scale of the A.D. 1257 volcanic eruption (47). Multiproxy records of climate (44) (*D*) also indicate potential unpredictability, shown in *C* as the deviation of each year from the mean of the previous 15 y. Proxy records of storminess (46) (*E* and *F*) show stepwise changes that contribute to the conjunctures of the 15th century.

A general reduction in summer temperatures would have had adverse impact on stock survival, while sharpening vertical zonation effects to the disadvantage of all upland farms, especially those farms in the more arctic Western Settlement. As Fig. 3 indicates, in the early 14th century, the overall cooling trend was associated with alternating extremes of warm and cold that far exceeded the range of the prior decadal-scale experience and therefore, fell outside the expected range of Norse TEK.

Collectively, these environmental changes would have degraded subsistence flexibility, decreased environmental predictability, and driven threshold crossing in the marine ecosystems related to the Eastern Settlement. The small Western Settlement (with a maximum likely population of 600–800) failed sometime in the late 14th century. Although the end of the Western Settlement is not completely understood, a likely proximate cause was isolation combined with late winter subsistence failure, plausibly connected to climate change (25, 43).

The much larger Eastern Settlement did not go extinct along with the Western Settlement, enduring until the mid-15th century. Despite the multiple assaults on their subsistence system and the apparent devaluation of centuries of accumulated TEK, the Eastern Settlement mobilized community resources and intensified exploitation of what was arguably the only resource open to them—the migratory seals. In combination, these data present a clear picture of significant climate challenge and flexible human response. Norse Greenland did not succumb entirely to the massive and unprecedented environmental challenges of the 14th century but instead, drew on its depth of TEK and its cultural reservoirs to produce an impressively successful intensification of their communal sealing effort.

This adaptive success was not without tradeoffs, and increased reliance on what had been only part of a multistranded subsistence system worsened some critical vulnerabilities. The seal cull took place offshore at a significant distance from the farms of the inner fjords. After the cull had taken place, the task of shifting carcasses from killing grounds to communities began. In the Faroe Islands, the distribution of meat from similar episodic culls of marine mammals—in that case, the pilot whale—can be done over comparatively short distances and without exposure to drift ice. In Greenland, however, distances were much greater, and the volume of seal meat to be shifted was much larger. Thus, the intensification of the spring seal hunt raised risks of potentially catastrophic loss of life in boating accidents, especially as frequency and intensity of storms increased beyond the limits expected by generations of seafaring TEK.

In addition to adverse climate impacts, the Norse Greenlanders were subject to other historical cultural conjunctures deriving from both Europe and North America. In the 15th century, economic transformations swept Europe in the aftermath of the plagues (49). After A.D. 1400, the Norwegians ceded control over the North Atlantic trade to the Hansa. They were primarily interested in securing supplies of North Atlantic fish and were locked in competition with the English, who were increasingly active in the North Atlantic from the early A.D. 1400s on. To these merchants, profits came from providing large quantities of fish and fish oil to growing urban markets in Europe, not distributing prestige items. This change no doubt devalued the Norðrsetr walrus hunt, which had been one of the mainstays of Greenlandic social and economic organization and contributed to the growing isolation of the Greenlandic settlements (50). Regular shipping between Norway and Greenland ceased after the A.D. 1370s, the last written record of contact occurred in A.D. 1408, and the last navigation between Greenland and Norway was about A.D. 1420 (51).

At the same time as the Norse faced environmental, economic, and political challenges, the Thule Inuit were moving into the outer fjords of the Norse Settlement areas. Despite ongoing research (52), we do not understand this complex culture contact, but Norse references after the early 13th century suggest growing conflict with people that they called Skrælings. The mid-14th-century report by Ívar Bárðarson enigmatically states that "[n]ow the Skrælings have desolated the whole of the Western Settlement" (53), and in A.D. 1379, the Icelandic annals note that "the Skrælings attacked the Greenlanders, killed 18 men and captured two boys and made them slaves" (53). The A.D. 1379 reference could be interpreted as the loss of three or four of the boats used for sealing and voyaging, and if accurate, this account would suggest that a single raid cost the Norse Greenlanders as much as 5% of their active adult hunters. Even just sporadic conflict with the maritime-adapted Thule Inuit would substantially increase the hazards of the annual sealing effort and daily life in this dispersed community.

Perhaps significantly, there is no osteological or ancient DNA evidence that the Norse Greenlanders and the Thule Inuit intermarried to any appreciable extent, and there is no evidence of a métis community of the sort that developed in 18–19th century colonial Greenland and was such a major force encouraging cultural and linguistic transfers. Despite the growing role of seal meat in the Norse diet, they did not include the common ringed seal. Providing appropriate sea ice hunting technology could be acquired, this animal could have been taken in winter at ice edge or breathing hole without conflicting with the rest of the Norse seasonal round. Inuit sea ice hunting gear is complex and requires a special set of hunting skills very different to those of the communal harp seal drives. Its successful adoption would probably have required close cooperative interaction between Norse and Inuit hunters. Were the heathen Skrælings simply too alien from the standpoint of the core values and symbolic reservoir of medieval Christianity to serve as acceptable role models? The community solidarity and cohesion required to make Norse Greenlandic society successful in its own TEK of communal sealing, walrus hunting, and wooden boat seafaring may well have worked against the adoption of such alien expertise, especially if it was held by increasingly dangerous competitors.

**Conclusions.** Enhanced datasets and new conceptual insight provide a changing view of collapse in the North Atlantic. Perhaps the greatest irony of Norse settlement in Greenland is that it survived the challenges of the 13th and 14th centuries but in surviving, created vulnerabilities to later changes. In isolation these later changes perhaps were no greater than those changes of previous centuries, but combined, they had greater overall impact. The coincidence of processes operating over a range of different temporal and spatial scales led to circumstances that drove transformative change. The choices made by the Norse in Greenland, to invest in fixed resource spaces and social and material infrastructure and intensify marine resource use, increased the effectiveness of adaptation and minimized landscape impacts but at an apparent cost of reduced resilience in the face of 15th century conjunctures. In effect, their concentration on certain marine mammals for subsistence and a highly integrated communal approach to both subsistence and economic activity (the focus on the spring seal hunt and the harvesting and processing of prestige goods, particularly ivory) were effective in the short term; they could be refined to cope with a degree of change over centennial time scales but developed into a rigidity trap on the millennial scale that ultimately lacked resilience in the face of the changing world system and conjunctures. In this respect, the seeds of the 15th century collapse of Norse Greenland were sown in the successful adaptations of the 13th and 14th centuries.

Conceiving the end of Norse Greenland as a case of maladaptation by an inflexible society in the face of climate change allows neither justice to their innovation nor appropriate lessons to be drawn from that completed experiment. Their skillful intensification of their own style of seal hunting made use of one of the few avenues for intensified subsistence production open to them. Their failure to adopt Inuit ice hunting technology was likely tied to the same social values that mobilized their community for such successful collective response to major climatic challenge. The Norse Greenlanders were ultimately as much victims of conjunctures of global economic change, regional political change, culture contact, and major environmental change as the victims of any individual threat.

Surviving climate change is a current cultural, economic, and technological challenge and one that the Norse Greenlanders met for nearly 500 y. Our own global society uses hugely greater resources than medieval arctic farmers but has yet to show greater resilience or more willingness to expand sources of TEK or the ability to resolve conflicts between climate change and core social ideology. The case of Norse Greenland's collapse and extinction, thus, remains a major interdisciplinary research topic of wide relevance. With other well-developed cases of long-term human ecodynamics, Norse Greenland may serve to broaden the perspectives and knowledge base of modern planners seeking sustainable futures in a contemporary world affected by rapid climate change and the historical conjunctures of economic stress and culture conflict.

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