The Norse *landnám* on the North Atlantic islands: an environmental impact assessment

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ABSTRACT. The Norse colonisation or *landnám* of the North Atlantic islands of the Faroes, Iceland, and Greenland from the ninth century AD onwards provides opportunities to examine human environmental impacts on 'pristine' landscapes on an environmental gradient from warmer, more maritime conditions in the east to colder, more continental conditions in the west. This paper considers key environmental contrasts across the Atlantic and initial settlement impacts on the biota and landscape. Before *landnám*, the modes of origin of the biota (which resulted in boreo-temperate affinities), a lack of endemic species, limited diversity, and no grazing mammals on the Faroes or Iceland, were crucial in determining environmental sensitivity to human impact and, in particular, the impact of introduced domestic animals. Gathering new data and understanding their geographical patterns and changes through time are seen as crucial when tackling fundamental questions about human interactions with the environment, which are relevant to both understanding the past and planning for the future.

Contents

Introduction

The absence of people using settled agricultural systems in the North Atlantic islands of the Faroes, Iceland, and Greenland before the European colonisation or *landnám* of the ninth century AD onwards provides opportunities to examine human environmental impacts on 'pristine' landscapes. From east to west, the Faroes–Iceland–Greenland 'transect' spans environments that are of an increasingly Arctic character, as they become colder and more continental in character as both the marine and atmospheric polar fronts are crossed (Fig. 1). Within this broad climatic range, there is a wealth of other variants imposed by biogeography, volcanism, and topography. As a result, in the process of expansion westwards, groups of Scandinavian settlers faced a variety of challenges with differing resources, constraints, and opportunities, and produced contrasting environmental impacts that have significant implications for the history of human settlement.

After the successful colonisation of the Faroes and Iceland, expansion to Greenland at the end of the tenth century brought Norse settlers closer to the limits of

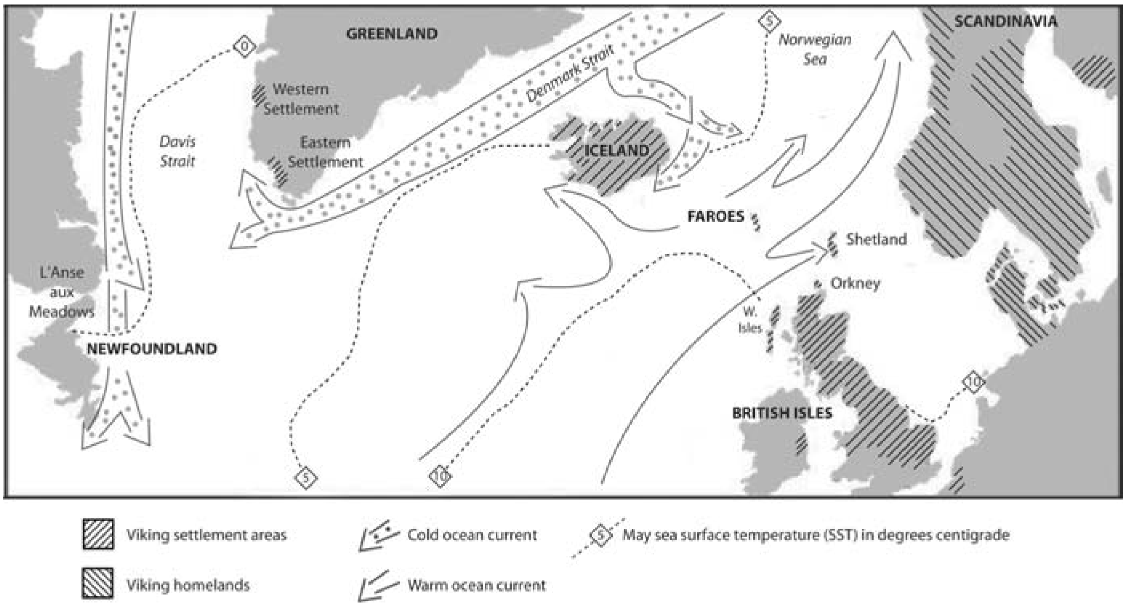

Fig. 1. The North Atlantic region showing the areas of Norse settlement and the major features of oceanic circulation that typify the environmental gradients across the region. The Norse settled limited areas of southern Greenland and all of Iceland save the interior highlands and glaciated areas (glaciers shown in Fig. 3). Virtually all the landscapes of the Faroes were utilised by the Norse, but actual settlement sites were near the coast.

their European-style agricultural systems. It was along this Arctic frontier that contact was made with other peoples, first with the Dorset palaeo-eskimo (Sutherland 2000) and later (probably after AD 1100) with the Thule culture, ancestors of the modern Inuit (McGhee 2000; Park 2000). Around AD 1000, the tide of European expansion was finally broken against the shores of Newfoundland. L'Anse aux Meadows on the northwest peninsula was probably only occupied for a few seasons at most (McGovern 1981; Wallace 2000; Davis and others 1988). Greenland saw a longer European settlement that lasted for at least 400 years, before climate change, perhaps coupled with cultural intransigence, forced retreat (Arneborg 1991; McGovern 1994; Barlow and others 1998).

This paper considers current knowledge of North Atlantic island environments before *landnám* and during initial settlement, in order to assess environmental impacts. This assessment highlights key environmental contrasts across the Atlantic, the significant variation in current knowledge, and the potential for developing further understanding.

Chronology

One of the key challenges for palaeoenvironmental reconstruction and the assessment of human impacts is integrating the various lines of evidence into a coherent chronological whole (Meese and others 1994; Edwards and others, in press). The two key environmental dating techniques employed in the North Atlantic region are radiocarbon dating and tephrochronology.

Despite its vital role, radiocarbon dating has a number of weaknesses, both inherent within the technique and also specific to the region. A number of these problems have long been acknowledged (Olsson 1982, 1986), causing detailed debate and controversy, for example over the dating of *landnám* in Iceland (Vilhjálmsson 1990, 1991; Hermanns-Auðardóttir 1991; Olsson 1992; Theodórsson 1998) and the Faroes (Jóhansen 1985; Debes 1993; Arge 1991, 1993; Hannon and Bradshaw 2000) (Fig. 2). The inherent problems include the precision and resolution of the technique, especially when considering detailed palaeoenvironmental trajectories at the time of *landnám* (Dugmore and others 2000). Perhaps of most relevance to radiocarbon dating *landnám* in the North Atlantic is the presence of a small but significant plateau within the calibration curve in the latter centuries of the first millennium cal AD. This means that *landnám* radiocarbon dates within this plateau can only produce a broad chronological resolution. A further plateau exists within the fifth and sixth centuries cal AD, which will impact on dating resolution when establishing environmental trajectories prior to *landnám* (Dugmore and others 2000). In addition, prior to the widespread availability of single entity AMS radiocarbon dating in the mid-1990s, the analysis of bulk samples potentially led to the incorporating of carbon from a variety of entities (Ashmore 1999). The use of AMS radiocarbon dating of small samples has, however, introduced new methodological and technical challenges that are only now beginning to be tackled (Wohlfarth and others 1998; Nilsson and others 2001).

Despite this, dating single entities produces more precise data than bulk dates on aggregate samples composed

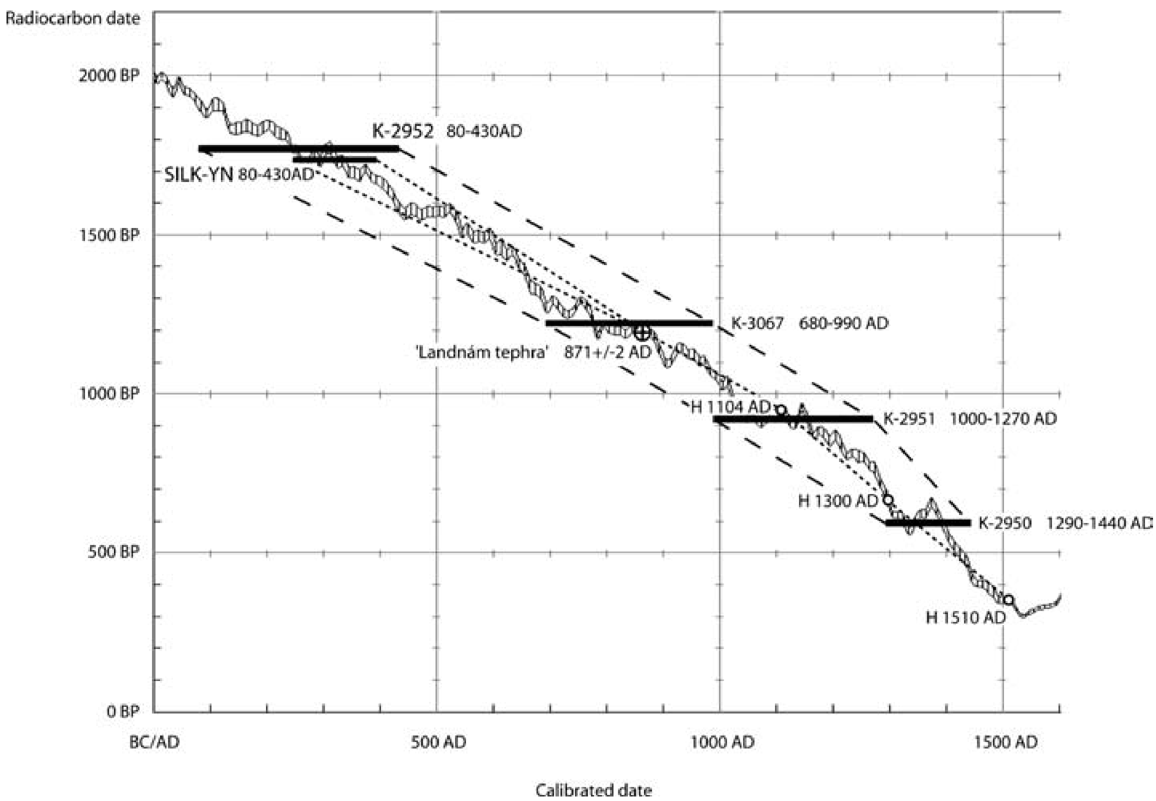

Fig. 2. Radiocarbon dates from a peat record spanning the period of Norse settlement and initial environmental impacts at Hov, Faroe Islands (Jóhansen 1982, 1985). In addition, key tephra isochrons from across the North Atlantic are shown to illustrate the complementary nature of the two dating techniques. The age of the SILK-YN tephra is derived from radiocarbon dating, the *landnám* tephra from correlations to the Greenland ice cores, and H1104, H1300, and H1510 are dated from historical records (Thórarinsson 1967). The laboratory codes denote the uncalibrated dates published by Jóhansen (1982). The calibrated date range of the radiocarbon dates at two standard deviations using OxCal v. 3.5 (Bronk-Ramsey 2000) is shown by the thick black lines. These data highlight key contrasts in resolution between radiocarbon dating and tephrochronology.

of a range of materials of slightly (or significantly) different ages. However, well-preserved single entities (such as plant macrofossils within a well-humified peat) may be discovered and not be of the same age as the surrounding material making up those strata. For this reason, a radiocarbon date on a discrete fraction (such as humic acid) may give more accurate ages for the formation of the actual matrix of a particular sediment than AMS dates on single entities within those strata.

Tephrochronology is the dating technique based on the identification and correlation of layers of volcanic ash (pyroclastic ejecta, most typically) that form time-parallel marker horizons (isochrons) (Thórarinsson 1944). An individual tephra layer can be used to define a precise spatial reconstruction of an environment at what is effectively a moment in time. Integration with other dating evidence (for example, historical records, data from ice cores, or radiocarbon dating) can enable this moment to be fixed to a specific date or age range (Fig. 2). Multiple tephra layers can be used to mark the passage of time, and the occurrence of tephra in a context that is of a different age (as may happen if the tephra is redeposited) can help to identify pathways followed by sediments through the environment (Dugmore and others 2000). Inter-site correlation of tephra isochrons provides a powerful framework for the high-resolution and large-scale analysis of the spatial and chronological dimensions of environmental change and human impact (Dugmore and others 2000). A very detailed tephrochronology has been established for Iceland (summarised by Hafliðason and others 2000) that contains almost 30 isochrons from AD 400 to 1510. For periods when appropriate historical records exist, these can be used to attach precise dates to tephra layers, data that are sometimes precise to within hours (for example, Thórarinsson 1967, 1975). Some of these isochrons have been identified across large areas of the North Atlantic, including the GISP2 and GRIP ice cores (Zielinski and others 1995; Grönvold and others 1995), marine cores (Eiríksson and others 2000), the Faroe Islands (Dugmore and Newton 1998), the British Isles (Dugmore and others 1995; Hall and Pilcher 2002) and even parts of northern Germany (van den Bogaard and Schmincke 2002). A set of isochrons occurs in the ninth and tenth centuries AD. Crucially these tephra include the '*Landnám* tephra' that covers much of Iceland, and has been identified in the Greenland ice and dated to AD

871 ± 2 (Grönvold and others 1995), and at a number of sites in the Faroes (Wastergård and others 2001). Originally identified by Thórarinsson (1944) as layer VIIa and VIIb, this tephra is found in the turves used to construct early settlements on Iceland and underlies major vegetation changes caused by people (Einarsson 1961; Hallsdóttir 1987). This tephra was produced by simultaneous activity in both the Veiðivötn and Torfajökull volcanic systems (Larsen 1984). Grönvald and others' (1995) dating of this tephra to AD 871 ± 2 resolved a number of debates about the timing of colonisation that could not be tackled with radiocarbon. It is consistent with a Norse settlement after AD 870, as recorded in *Íslendingabók* (*Book of Icelanders*).

This tephra distribution allows the environmental impact of *landnám* to be assessed against a very accurate chronological marker on a semi-hemispheric scale. With multiple isochrons covering the initial centuries of the *landnám*, especially in Iceland, this provides an excellent correlative tool for assessing local and regional landscape and geomorphic change. As with any dating technique, however, there are a number of limitations. The most important of these limitations is that the isochrons are limited to the areas covered by identifiable fallout and a depositional record (Dugmore and others 1995); in addition there is the potential for redeposition and winnowing of tephra in dynamic environments (Bierle and Bond 2002). Also, some indistinguishable geochemical signatures from different eruptions exist (Larsen and others 1999, 2001) and eruptions of prehistoric tephra can only be dated by radiocarbon techniques and so their numerical dating resolution and precision is dependent on what can be achieved through radiocarbon dating (compare SILK-YN tephra in Dugmore and others 2000). However, problems of equifinality can be tackled by considering the totality of information available (Westgate and Gorton 1981), and where radiocarbon dating is the only way to produce numerical dates, then at least the optimum location for the dating can be chosen from within the area covered by fallout, and this may be very extensive (Dugmore and others 1995).

In addition to providing chronological controls to date environmental change, tephra may also act as agents of environmental change. There has been much debate about putative environmental and cultural changes caused by volcanic impact on climate (for example, Buckland and others 1997), but in Iceland there are unambiguous effects caused by tephra directly (such as tephra fallout from Öraefajökull 1362 and Askjá 1875 directly onto settlements) and indirect effects, such as large-scale animal mortality and related famine caused by fluorosis following the eruptions of Katla 1755 and Laki 1783. In these cases, tephra may provide abrupt environmental 'shocks' that can be used to assess sensitivity and robustness within environmental and cultural systems.

Overall, tephrochronology provides a critical extra dimension to palaeoenvironmental studies in the North Atlantic region, and this, combined with the area's cultural history and island geography, gives it great potential for the studies of human–environment interactions and human impact.

The origins of the pre-*landnám* biota

The limited diversity of North Atlantic pre-*landnám* island biota, a reflection of the modes of origin, has major implications for the interpretation of evidence for environmental change both before and after the arrival of people. The relatively limited flora means that vegetational changes are less complex than in more temperate mainland regions with higher diversity. For example, in Iceland, there was typically birch (*Betula* sp.) and willow (*Salix* sp.) woodland/scrub or no woodland. Similarly, many heaths were dominated by a handful of species with quite similar climatic tolerances. In general the invertebrate faunas were also limited in diversity, deficient in host-specific species, and dominated by generalists. This is particularly true of the beetle and fly faunas, where pre-*landnám* changes probably reflected local edaphic events rather than climate change. Before the arrival of people there were no land mammals in the Faroes and likewise for Iceland, save for the Arctic fox (*Alopex lagopus* L.) and the polar bear (*Ursus maritimus* L.) that reached the island by crossing winter sea ice in the Denmark Strait. In contrast Greenland had, and has, indigenous populations of grazing mammals, for example caribou (*Rangifer tarandus* L.) and musk oxen (*Ovibus moschatus* Erchl.), as well as the marine mammals common to the shores of the other Atlantic islands.

The essentially European nature of the terrestrial and fresh-water aquatic flora and fauna of the Atlantic islands has been discussed for more than a century (Buckland 1988). Ostenfeld (1926) examined the Greenlandic flora, suggesting that many European taxa were anthropochores, and Iversen (1934) was early in the application of pollen analysis to this biogeographical problem. The origins of the insect fauna of Iceland, and by implication of the Faroes and Greenland, formed the core of Carl Lindroth's (1931) doctoral thesis. Yet despite his own early involvement in the study of fossil insects (compare Lindroth 1948), identifications of Quaternary insects from both the Faroes (Jessen and Rasmussen 1922) and Iceland (Thorkelsson 1935), and his own frequent return to the problems of the biota (for example, Lindroth 1960; Lindroth and others 1988), he never effectively utilised the fossil record to test his arguments for survival *in situ*, although he was aware that the virtual absence of endemics from the islands militated against his hypothesis of long-term survival in refugia. The nature of the baseline pre-*landnám* beetle faunas supports a model of virtual annihilation of pre-glacial biota and late-glacial or Early Holocene immigration (Buckland and Dugmore 1991; Buckland and others 1998a). Although the study of late-glacial plant macrofossils from Torfadalsvatn on the Skagi peninsula in the north of Iceland has recently been used to resurrect the refugia hypothesis (Rundgren and Ingólfsson

1999), it seems probable that the pre-*landnám* biota arrived largely by ice-rafting from Europe during the rapid warming that characterised the end of the last glaciation. Some elements may well have arrived either earlier or later than the main immigration event, as part of the aerial plankton, and occasional plant propagules could have survived for years in the Arctic pack in the cracks of driftwood (Johansen and Hytteborn 2001). However, the bulk of the fauna and flora, including relatively heavy flightless ground beetles and weevils, was probably dispersed to the islands during the breakup of the main north European ice sheet approximately 11,600 years ago. Although this does not preclude an earlier dispersal event after the glacial maximum, the boreo-temperate nature of the beetle fauna and the virtual absence of true Arctic elements suggest that many species could not have survived through the Younger Dryas cold stage.

The development of the pre-*landnám* biota is a key step in determining the potential impacts of *landnám* itself. The composition of the biota presented a range of constraints and opportunities for the early settlers that were different to similar climatic zones of the continental mainland, Britain, or Ireland. In addition, it created the potential for 'false analogy.' Early settlers found areas that appeared familiar and comparable to parts of their homelands, but despite some clear visual similarities (in the appearance of heathland or grassland, for example), these new lands of the Atlantic islands were fundamentally different. Profound contrasts in biomass productivity and its seasonal distribution, ecological resilience, and sensitivity to erosion could all have presented early settlers with unexpected challenges and potentially catastrophic changes.

Landnám

According to Dicuil's *De mensura orbis terrae*, written in approximately AD 825 at the court of Charlemagne's successors (Tierney 1967), Christian Gaels, monks, or hermits had settled on islands the description of which points to the Faroes, bringing with them at least sheep. Jóhansen's investigations at archaeological and field sites in the Faroes (Jóhansen 1985) led him to suggest that there were two settlement periods, the first, pre-Viking, between AD 600 and 700, and the second, Viking *landnám*, between 850 and 900. However, Buckland and others (1998b) challenged the validity of Jóhansen's dating at the key site of Lambi on Mykines, while Arge (1991) pointed out that Jóhansen's claim for an early settlement could not be supported by archaeological evidence, as there were very few artefacts dating from the first millennium. Subsequent excavations at Toftanes (Hansen 1989, 1991) have confirmed the presence of the later, Viking settlement, but currently there is still no definitive archaeological evidence for an earlier, pre-Viking settlement. Further pollen and macrofossil work at Tjørnuvík, Eiði and Korkadalur (Hannon and Bradshaw 2000; Hannon and others 1998, 2001), including new AMS dates, has been used to support Jóhansen's hypothesis that the first settlement occurred closer to 600 than 800. Unfortunately, the variability in the AMS dates and the presence of a radiocarbon plateau make it impossible to use this method alone to pin down accurately the date of the first palaeoenvironmental hints of settlement where these dates lie between AD 500 and 700 (Fig. 2). The *in situ* presence of the '*Landnám* tephra' of AD 871 ± 2 could help to resolve this issue definitively (compare Hannon and others 2001).

A number of written sources of varying reliability are available for the earliest settlement in Iceland. The suggestion that Irish monks occupied the country before the Norse settlers arrived is supported by Dicuil's *De mensura orbis terrae*, but this has not been supported by palaeoenvironmental or archaeological data (for example, Buckland and others 1995b; Sveinbjarnardóttir 2002). The main and most comprehensive historical sources for the settlement of Iceland are *Íslendingabók* (*Book of Icelanders*), written in the early twelfth century, and *Landnámabók* (*Book of Settlement*), also thought to have been originally written in the twelfth century, but only preserved in the form of later versions. Neither source is contemporary with the events they describe.

The early historical sources may be principally concerned with establishing the prior claims of the church and leading families to the land (Benediktsson 1974; Rafnsson 1974, 1976; Grímsdóttir 1996). Whilst the literary sources may reflect foundation myths rather than fact (Einarsson 1995), archaeology, palynology, and tephrochronology indicate that the dates are approximately correct (compare Thórarinsson 1944; Grönvold and others 1995; Hallsdóttir 1987), although there have been arguments for significantly earlier dates (compare Hermanns-Auðardóttir 1989, but see Sveinbjarnardóttir 1990; Vilhjálmsson 1990; and Hermanns-Auðardóttir 1991). It seems that the land was soon fully settled. Estimates for the initial size of the population at the end of the settlement period range from 40,000 to 100,000, depending on how the available sources are interpreted (Karlson 2000). Estimates of pasture productivity and stocking levels around the time of settlement have produced suggestions of between 70,000 and 80,000 as possible population levels at that time (Friðriksson 1972). A number of Viking-period sites have been excavated in Iceland, key examples being Herjólfsdalur in the Vestmanmaeyjar off the south coast (Hermanns-Auðardóttir 1989), Papey off the east coast (Eldjárn 1989), Granastaðir (Einarsson 1995) and Hofstaðir (Friðriksson and Vésteinsson 1997) in the north, Reykjavík (Nordahl 1988; Roberts 2002) and Grelutóttir (Ólafsson 1980) in the west, and Hvítárholt (Magnússon 1972) in the south.

For the Norse settlement of Greenland there are a number of relevant historical documents, but these vary greatly in their utility. The *Grœnlendinga saga* (*Greenlander's saga*) describes Erik the Red's journey to and settlement of Greenland, but it is from the early thirteenth century and is based on oral accounts. The same applies to *Eiríks saga rauða* (*Erik the Red's saga*), also written in the early thirteenth century. The two sagas seem to be written independently of each other, but based on the same oral accounts (Halldórsson 1978). They disagree on certain details and cannot be taken as historical fact, but some of the accounts have been supported by recent archaeological studies, such as those at L'Anse aux Meadows (Wallace 2000).

Attempts have been made to estimate the Norse population of Greenland, basing it on number and size of farms correlated with a population size. Such estimates have ranged from 3000 to 6000 (Lynnerup 1998). The last record from the more southerly Eastern Settlement, in 1407, describes two activities, a marriage and a witch-burning; thereafter all is speculation (compare Seaver 1996).

Landscapes at *landnám*

What the first settlers saw as they skirted the coasts of the various islands is difficult to envisage. No such pristine, cool-temperate island habitats survived into the age of scientific investigation, and the surviving sources are all written long after the event, often with rather different motives.

There is debate over the extent of woodland in the Faroes during the Holocene. At present there are no trees outside of plantations, and shrub cover is restricted to juniper (*Juniperus* sp.), willow (*Salix* sp.), and dwarf shrubs such as Ling heather (*Calluna vulgaris* (L.) Hull) and crowberry (*Empetrum* sp.). Jóhansen (for example, 1985) detected considerable quantities of temperate tree pollen in peat and lake-sediment sequences, but dismissed this as representing long-distance transport, the effect of which is amplified in environments such as the Faroes, where pollen productivity is low (Fig. 3A). However, Hannon and Bradshaw (2000) challenged this assumption, citing the discovery (Malmros 1990) of a thick layer of Downy birch, dated to between 2460 BC and AD 770, beneath a Viking site at Argisbrekka, Eysturoy (Mahler 1993). Less dramatic macrofossil evidence of Downy birch and dwarf birch (*Betula nana* L.) is also known from Streymoy and Eysturoy (Hannon and others 2001). Hannon and Bradshaw's own study showed a decline in the pollen of juniper, birch, and willow at the time of the settlement. This range of evidence implies that Jóhansen's assumption that the Faroes were unwooded needs some reconsideration. It now seems certain that at least limited pockets of Downy birch occurred on the islands in sheltered locations, and that shrub cover was thicker before the settlers arrived than it is today.

The lowlands of Iceland, and regions up to 400 m asl, can be, and have been, classified as part of the sub-Alpine birch-forest belt of Fennoscandia, where birch woodland (*Betula pubescens* and *Betula pubescens* ssp *turtuosa)* with willow and juniper, is the potential climax vegetation; in addition the interior highlands generally above 400 m asl have been described as belonging to the Arctic zone (Sjörs 1963) (Fig. 3B). Although this classification is

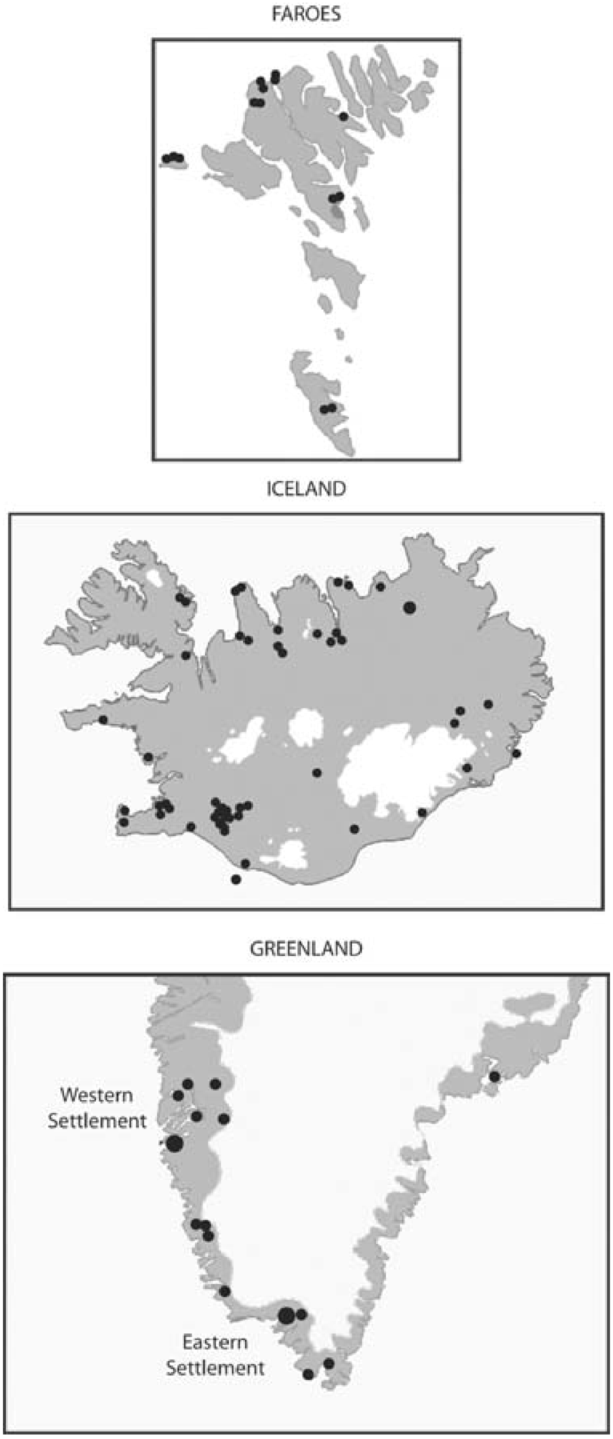

Fig. 3. Pollen sites in different locations in the North Atlantic region. 3A (top): the Faroes, based on Jóhansen (1971, 1979, 1982, 1985, 1989), Edwards and Craigie (1998), Hannon and Bradshaw (2000), and Hannon and others (2001, 2002). 3B (middle): Iceland, based mainly on Caseldine (2001), Hallsdóttir (1987, 1995), and Buckland and others (1995a). 3C (bottom): Greenland, based mainly on Fredskild (1973, 1978, 1983, 1985), Kelly and Funder (1974), Bick (1978), Böcher and Fredskild (1993), Eisner and others (1995), and Wagner and others (2000).

relevant for pre-*landnám* landscapes, today, after the environmental impact of the Norse settlement, these concepts are not regarded as useful by many authors (Hallsdóttir 1987; Ólafsdóttir 2001). Today the extent of birch forest is very limited — around 1100 km^2, or less than 1% of Iceland's 103,000 km^2 area (Ólafsdóttir 2001).

Both the Faroes and Iceland lacked indigenous mammalian grazers and the pre-*landnám* invertebrate faunas are deficient in litter-processing species. Whilst the wet climate leads to extensive peat accumulation, the result over several thousand years would be the accumulation of a deep litter layer in areas beyond the peatlands, and woody material significantly older than the time of settlement would inevitably have been available when people first arrived.

Greenland had herds of caribou (*Rangifer tarandus* L.), and these may have helped to maintain relatively permanent areas of open grassland, in part perhaps perpetuating sites once occupied as perennial hunting stations by Sarqaq eskimoes (compare Buckland and Edwards 1984). The former presence of what Icelandic sources call *Skræling* is noted in *Islendingabók*, in perhaps the first piece of archaeological deduction in the North Atlantic island record:

> Þeir fundu þar manna vistir, bæði austur og vestur á landi, og keiplabrot og steinsmíði það er af því má skilja, að þar hafði þesskonar þjóð farið, er Vinland hefir byggt og Grœnlendingar kalla Skrælinga' (Halldórsson 1978: 74). ('There they found human habitation sites, both in the east and west of the country, and fragments of boats made of hide and stone implements. From that can be inferred that the kind of people who were there were those who settled Vínland and the Greenlanders call *skrælingar*.')

The first Norse settlers may have been initially attracted to these grassy places. Certainly this would explain the occurrence of occasional Sarqaq pieces on Norse sites (McGovern and others 1996). The nature and degree of Norse contact with the Dorset successors of the Sarqaq remains unclear, but it is probable that the Dorset had abandoned southwest Greenland before the Norse *landnám*. Much of the remaining area suitable for potential settlement in southwest Greenland, however, must have consisted of dense birch and willow, and in the Western Settlement of alder scrub, only penetrable along rare caribou trails, much like the areas outside the sheep rangelands at the present day (Fig. 3C). Böcher and others (1968) defined three major vegetational belts: (a) 'a subarctic belt in the inland parts of the warmest valleys in S. and S.W. Greenland, where the summer temperature is high enough to support low woodland'; (b) 'a low arctic belt, extending northwards to c. lat. 72°N' (willow scrub); and (c) 'a high arctic belt including northernmost Greenland and cold, outer coastal areas southwards to c. lat. 60°N' (*Cassiope* heaths and tundra). Only a handful of species can be found in all three belts. Successful, regular ripening of cereals is impossible.

Zooarchaeological evidence for the *landnám* economies: the basis of human environmental impact

Zooarchaeological evidence for both the mix of European domestic animals imported to the North Atlantic islands and for the settlers' use of wild mammals, birds, and fish has grown steadily during the past two decades (McGovern and others 2001; Enghoff 2003). While the Faroes thus far lack published archaeofauna (animal bone collections) from the settlement period, there are now several settlement-age archaeofauna of quantifiable size and broadly comparable excavation methods from Iceland and Greenland. While more large collections from well-dated contexts are urgently needed in all three island groups (particularly from the Faroes), it is possible to make some general comments about the patterns of early Scandinavian economy in Iceland and Greenland based on the zooarchaeological record of *landnám* as it now exists. This gives a key insight into mechanisms of human impacts on the environment.

Figure 4 presents an overview of the major domestic mammals from these collections dating to the settlement period (ninth through eleventh centuries in Iceland, eleventh through twelfth centuries in Greenland) and includes for reference an archaeofauna from a high status farm in southern Norway at Aaker (Perdikaris 1990). In the archaeofauna from Aaker in Norway, cattle (*Bos* sp.) bones predominate, followed by pig (*Sus* sp.) bones and by caprines, both sheep (*Ovis* sp.) and goat (*Capra* sp.) together. This pattern probably represented an 'ideal farm' in the minds of would-be chieftains of the *landnám* era in Iceland. The archaeofauna from Tjarnargata 4 under central Reykjavík, with its large number of cattle and pig bones, illustrates how closely this ideal was followed in the richer districts of the south. The archaeofauna from the settlement period long hall at Aðalstræði, recently excavated close to Tjarnargata 4, is too small and too heavily skewed by post-depositional attrition to be fully quantifiable, but it does contain pig remains as well as cattle and caprine bones and teeth (Tinsley and McGovern 2002). The other early archaeofauna from the Vestmanmaeyjar off the south coast (Herjolfsdalur) and from the Kraká river drainage south of Myvatn in the north (Sveigakot, SVK) appear somewhat less successful in mirroring the patterns of ancestral southern Norway, but the high percentage of cattle and the substantial presence of pig bone is notable. In contexts from northern Iceland dated by radiocarbon and tephra to the tenth century, archaeofauna present a varied pattern but all are comparatively high in cattle (Selhagi, SLH), or pig (Hrísheimar, HRH), or both (Granastaðir, GST). In these early northern sites, the 'caprine' category is in fact made up of both sheep and substantial numbers of goats judging by the elements that can be speciated. As the Icelandic *landnám* period closed in the mid-tenth century, many farms of different size were apparently still struggling with varied success to maintain the farming patterns of the ancestral homelands' economy against a background

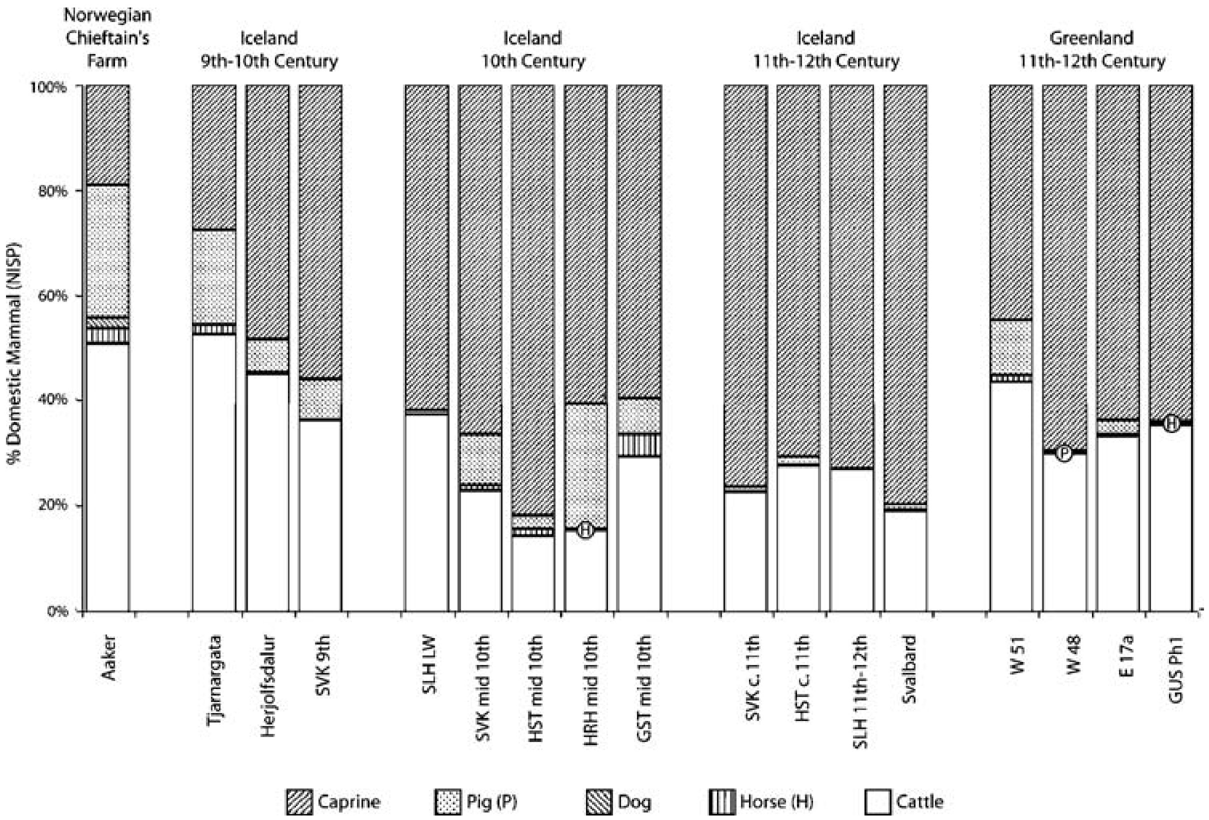

Fig. 4. Data derived from the zooarchaeological record on settlement phase domestic mammals in Iceland and Greenland, compared with data from Norway. Domestic mammals in the North Atlantic islands were first introduced by people and were the key agents of environmental impact.

of rapid environmental change. By the eleventh through twelfth centuries in Iceland, farming strategies seem to have altered, largely omitting pigs and goats and often (although not always) shifting the balance of cattle and sheep. The outline of a later medieval and early modern sheep-and-cattle-based economy better suited to the deforested landscape of later Iceland was beginning to emerge soon after AD 1000. In all periods, dairy production appears to have been the main objective of cattle husbandry, while the different roles of sheep in production of milk, meat, and wool remains an active research question.

In Greenland the later *landnám* of around AD 985–1000 again transferred northwest European domestic stock to a new set of North Atlantic landscapes, moving this farming strategy farther into the low Arctic. Interestingly, it would appear that high status Greenlandic *landnám* settlers at W51 Sandnes in the northern (and more Arctic) Western Settlement, did not apparently attempt to duplicate the contemporary stock-raising pattern of contemporary Iceland, but instead the option of a pig and cattle-rich farmyard, reminiscent of Norway or northern Britain. Pigs in Greenland rapidly disappeared, although goats remained common throughout the rest of the settlement period (McGovern and others 1983; McGovern 1985; Enghoff 2003).

While the farming strategy of the *landnám* era settlers drew on millennia of farming experience in northwest Europe and perhaps inevitably showed a recurring tendency to impose familiar patterns on unfamiliar landscapes, the use of wild species reflected in the settlement era archaeofauna shows far greater flexibility. Figure 5 illustrates the balance of wild and domestic animal bones from the same set of early sites from Norway, Iceland, and Greenland. The role of wild birds, including some great auk (*Alcus impennis* L.), in early subsistence in southern Iceland is striking, and evokes saga accounts (written down centuries after *landnám*) of 'unwary,' easily hunted wild animals during the Settlement period (Vésteinsson and others 2002). A few walrus (*Odobenus rosmarus* L.) bones found in the Tjarnargata 4 collection included animals too young to swim, and the recent Aðalstræti collection nearby contained three entire walrus tusks (Woollett and McGovern 2002). Place-names along the Reykjanes peninsula in the southwest also suggest the presence of resident Icelandic walrus populations at *landnám*. In northern Iceland, fresh-water fish, including trout (*Salmo trutta*) and charr (*Salvelinus alpinus*), provided a major supplement to domestic animal production. Analysis of marine fish bones, recovered from all the inland Myvatn sites by Perdikaris (McGovern and others 2001; McGovern and Perdikaris 2002a, 2002b), indicates that ninth- through tenth-century inland sites were being provisioned with preserved marine fish caught and processed elsewhere. A few fragments of sea-mammal bone, including seal (*Phocidae* sp.) and porpoise

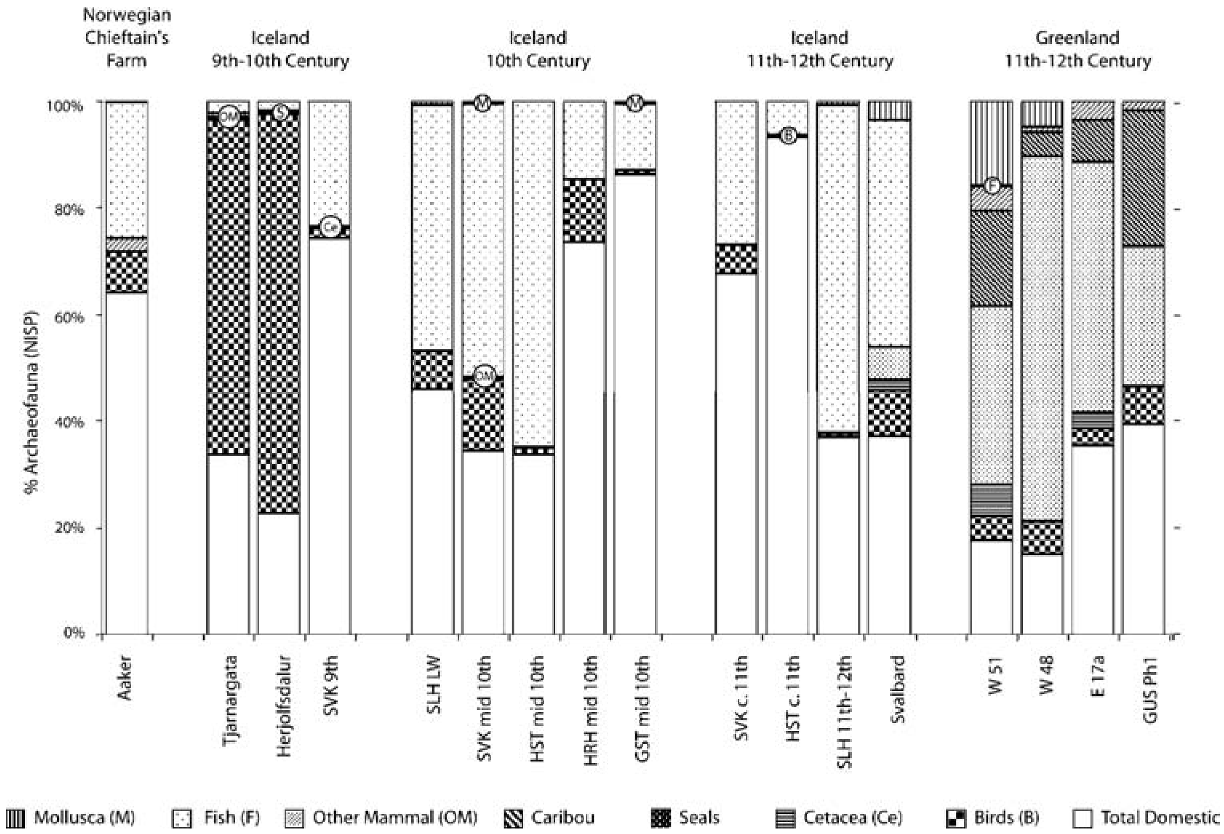

Fig. 5. The relative importance of domestic mammals and the non-domesticated biota in the archaeofaunal record.

(*Phocaena* sp.), were recovered from the late ninth- to early tenth- century layers at Sveigakot (70 km from the sea), further illustrating the interconnected web of economic relationships present even during first settlement. This internal trade or long-distance provisioning appears to pre-date the large-scale commercial fisheries of the fourteenth through twentieth centuries, which served the requirements of external trade and tribute as well as domestic consumption (Amundsen and others, in press). While all the collections from the Myvatn area include quantities of egg shell, probably duck (*Anatidae* sp.), the few bird bones recovered are mainly ptarmigan (*Lagopus mutus*) and sea birds, rather than the adult migratory waterfowl common to the lakeshore. In later historic times, Myvatn farmers have managed a sustained yield of 10,000 eggs per year by taking a single egg from each nest and leaving adults undisturbed.

In Greenland, seals (*Phocidae* sp.) and caribou (*Rangifer tarandus* L.) rather than fish provided the main supplement to the farming economy, and even inland sites many hours' walk from salt water (like Gård under Sandet [GUS]; Enghoff 2003) seem to have participated in communal sealing (see McGovern 1985 for overview). Smaller farms like W48 became increasingly dependent upon sealing, mainly targeting common seals (*Phoca vitulina*) and migratory harp seals (*Pagophilius groenlandicus*), but their extensive hunting began with first settlement.

Environmental impacts of the Norse *landnám*

The introduction of domestic mammals (as well as the accidental introduction of the mouse (*Mus musculus*) in archaeofauna from Iceland and Greenland) had profound impacts on vegetation, soils, and landscapes while dramatically boosting the animal biomass of the offshore Atlantic islands. Although all the island groups have produced evidence for extirpations in their insect faunas within the last 1000 years (Buckland and others 1983, 1998b; Buckland and Wagner 2001), it is difficult to be certain whether these reflect simple climate change or the environmental changes initiated by the arrival of humans and their domestic animals. Habitats that were once rare became common, new, broadly synanthropic environments were created, and others, more natural, were largely destroyed. Some local populations of sea mammals were probably immediately disrupted, and the scale of sea-bird predation suggested by the southern Icelandic archaeofauna may well have altered the composition of nesting colonies. However, the example of the apparent conservation of Myvatn waterfowl suggests that initial human impact on wild species may have been a more complex story than first imagined, and the arrival of humans and their domesticates may not always have been an unmitigated disaster for resident or migratory island species.

Using the Mutual Climatic Range method, it was possible to show that the small water beetle (*Hydraena britteni*) was sufficiently marginal in southern Iceland for a 1°C fall in summer temperatures to lead to its extinction (Buckland and others 1983). The disappearance of *H. britteni* in the late fourteenth century suggests that it could have been a victim of 'Little Ice Age' cold periods; however, the destruction of sheltering birch woodlands may also have played a key role. The main indications of the Norse *landnám* in Icelandic pollen records are a substantial and rapid decline in birch pollen abundance, and the expansion of grasses (Gramineae or Poaceae) and sedges (Cyperaceae) together with weeds such as docks (*Rumex* spp.) and members of the carrot family (Umbelliferae or Apiaceae) (Hallsdóttir 1987). In some deposits — for example, at Holt (Buckland and others 1991a) — the *landnám* coincides with a layer of Downy birch wood and charcoal. In short, the main vegetational impact at *landnám* was the destruction of large areas of woodland, presumably to clear land for grazing, as well as for structural timber and wood for fuel and charcoal.

Ólafsdóttir (2001) presented evidence to challenge the long-held assumption, based largely on a brief comment by Ari the Wise, that at *landnám* Iceland was thickly forested, with woodland extending from the mountains to the sea. Quite where the mountains should be taken to begin is clearly open to debate. Ólafsdóttir (2001) suggested that, in fact, forest cover began to diminish from 3000 BP onwards, probably through climate change. Her view is that, although *landnám* did exacerbate the ongoing degradation of vegetation, it was not the primary agent of change. In fact, tephrochronological study of sediment accumulation rates in Myvatnsheiði (Ólafsdóttir and Guðmundsson 2002) suggests that the major post-settlement decline in vegetation cover did not occur until around 1500 AD, and that overgrazing only contributed to a problem caused essentially by climate change and, possibly, the major tephra fall of 1477. This is consistent with the conclusions of Simpson and others (2001), who identified the key role played by unpredictable environmental changes that result in a mismatch between cultural systems and environmental carrying capacity.

Crucially, soil erosion does increase soon after *landnám*. Thórarinsson (1961) presented some of the first convincing evidence, based on tephrochronology, that the soil erosion, so typical of the modern landscape, accelerated at the time of Norse colonisation. There is widespread evidence of major changes in soil stability at *landnám*. These range from Haraldsson's (1981) data on an abrupt increase in the inorganic content of peat across Landeyjar, south Iceland, to Dugmore and others' (2000) observation of spatially varied changes of sediment accumulation rates during the first century of settlement. Rates of sediment accumulation across this period can change by more than an order of magnitude and are tightly constrained for the crucial phase of initial settlement by tephra layers dated to around AD 870, 920, and 935, which are clearly separated by intercalated aeolian silts. As wind erosion is a key process in Iceland post-*landnám*, and soil erosion generally takes the form of a loss of area rather than quality, sediment accumulation rates in areas of surviving soil and vegetation can be used as an effective proxy for post-*landnám* rates of erosion. A crucial difference before *landnám* is that before human settlement the very much lower rates of aeolian sediment accumulation are unlikely to represent a simple proxy for soil erosion; they are likely to include significant, if not dominant, contributions from glacial erosion and, most importantly, tephra formation. The long-term reworking of tephra layers deposited in the central highlands will have provided much material for the pre-*landnám* soil formation. For example, three large plinian eruptions of just one volcano, Hekla, created in excess of 25 km^3 of sediment (Larsen and Thorarinsson 1977), a volume similar to the soils eroded in southern Iceland since *landnám*. (This estimate is based on average soil thickness recorded in logged profiles and the erosion area calculations of the Iceland Soil Conservation Service.) In this respect, *landnám* resulted in a fundamental change in the process of sediment accumulation, making it a process dominated by the reworking of soils. In addition, the pattern of soil distribution changed in both a reduction in overall extent and the creation of mosaics of soil and exposed substrate.

The Norse settlers were responsible for the introduction of numerous species to the flora of Iceland, and in this way they increased floral diversity. Although they are not known to have brought about any extinctions amongst the flora, the settlers did have a negative impact on biomass. Before the settlement, soils were much more widespread than at present; copious evidence exists to show that farming could take place in areas that are now semi-desert, with minimal plant cover consisting of a few species of grass and small herbs. Relatively high-biomass woodland was replaced by heath, grassland, or eroded patches. Biodiversity suffered in the sense that, although the absolute number of species in Iceland as a whole probably increased, the impoverishment of many habitats probably led to a decrease in the average number of species in a given area of land.

In Iceland and Greenland it is probable that the initial reaction of incoming farmers, faced with deep litter, dead wood, and limited grass hay, would be to burn in order to extend areas of grass growth. The impact of its burning can be found as a thin black line in the peat bogs of the Western Settlement. At many sites in Greenland the vegetational response to *landnám* appears very muted. To some extent this may reflect the fact that sample sites, even if situated close to former Norse settlements, are often lakes with moderately large pollen catchments. The local changes happening at the farms themselves are masked by the signature from the regional vegetation, which appears to have been less drastically affected than in Iceland or the Faroes. The most important exception to this is a bog at Ujaragssuit, Godthåbsfjord (Iversen 1934; Fredskild 1972, 1973), the site of a Norse farm and church, where *landnám* is marked by a layer of wooden chips and charcoal. Pollen data from this site show an expansion of docks (*Rumex* spp.) and grasses (Gramineae or Poaceae). Similarly, at Lake Tugtuligssuag (Iversen 1953; Fredskild

1973), close to a Norse farm site, the beginning of settlement is marked by the appearance of docks and a decline in some shrubs including willow (*Salix* sp.) and alder (*Alnus* sp.). Again, a layer of charcoal is visible in the soils of the infield. Two Greenlandic insect extirpations, *Euaesthetus laeviusculus* and *Phratora polaris*, may reflect climate change (Buckland and Wagner 2001).

Timber was a valuable resource, and burning would have had to be carefully constrained. In Þórsmörk in southern Iceland, pits with the remains of charcoal formed from birch show the utilisation of woodland within a hundred years of *landnám*. As some pollen evidence clearly shows (Hallsdóttir 1987), woodland rapidly became a more limited resource in Iceland; however, more than half of Iceland's farms still had access to woodland in the eighteenth century. Coppice had probably rapidly replaced impenetrable wildwood. Fragments of these coppiced landscapes remain in the south in Þórsmörk, in the east in Hallormsstaður, and in the north in Fnjóskadalur (Bjarnason 1980), but for the most part Iceland's forests have gone, replaced initially by grassland and later by bare rock as the soil cover was stripped away (Thórarinsson 1961; Arnalds 2000). This part of the story lies more with the subsequent grazing history and woodland mismanagement (Dugmore and Buckland 1991; Simpson and others 2001) than with any initial burning. The situation in the Faroes was somewhat different, as the islands lacked any primary woodland cover except in the few most sheltered areas. Evidence from Mykines suggests that bird cliffs would have been covered with lush growth of grass (Buckland and others 1998b). Such coastal landscapes would also have been widespread in Iceland, where the abundance of birds and sea mammals was enough to seduce one of the island's first attempted Norse settlers, Flóki, into thinking that he would need no hay to overwinter his livestock. Their death, and the subsequent coining of the name 'Iceland', is probably again to be treated as a foundation myth, like the counterpoint name of 'Greenland,' but the didactic message is clear — no hay to overwinter stock, no farm. In contrast with Iceland, the small amount of archaeologically related palaeoenvironmental evidence from the Faroes (Edwards and others 1998) suggests that winter productivity may have been sufficient for stock to be over-wintered without stalling. In southern Iceland, only the core stock was normally stalled; into the early nineteenth century, the remainder was hazarded outside (Mackenzie 1842). Elsewhere, in the more Arctic environments of the north of Iceland and of Greenland, stalling of most if not all animals was probably essential to their survival.

The pattern that emerges in Greenland is one of an initial clearance of shrubs by burning and manual clearance, an expansion of grassland at the expense of the shrubs, and the appearance of a few weed species, most notably common/sheep's sorrel (*Rumex acetosa*/*acetosella* L.), but also yarrow (*Achillea millefolium* L.), knotgrass (*Polygonum aviculare* L.) and possibly autumn hawkbit (*Leontodon autumnalis* L.). The end of the settlement period saw a recovery of shrub taxa. A mineral magnetic study by Sandgren and Fredskild (1991) showed that, at Tasiussaq in southern Greenland, the Norse period saw increased rates of soil erosion, although there was a considerable lag between the first signs of vegetation disturbance and the onset of detectable soil erosion. It seems to be genuinely the case that the Norse settlers did not have such a devastating impact on the soils and vegetation of Greenland as they did in Iceland, although why this should be is not clear, particularly as the twentieth-century rise in sheep farming had considerable environmental consequences.

The apparent disappearance of three insect species from natural habitats in the Faroes (*Calathus micropterus, Coelostoma orbiculare*, *Ochthephilus omalinus* [grp.]) is less easily explained (Buckland and others 1998b), and human impact, particularly eutrophication of aquatic and riparian habitats, may be partly to blame. The common denominator of the palynological signature of settlement on the Faroes is the first appearance of cereal-type pollen. At Lambi (Jóhansen 1979, 1985), these cereals comprise first oats (*Avena* sp.) then barley (*Hordeum* sp.). In most cases, this is accompanied by an expansion of arable weeds, especially various types of dock (*Rumex acetosa, R. longifolius, R. obtusifolius*) and plantains (*Plantago maritima* on Mykines, *P. lanceolota* elsewhere). At Tjørnuvík, juniper disappeared, perhaps used for fuel and for charcoal production and *Dryopteris*-type spores also declined dramatically, possibly reflecting trampling by people and livestock. At Hov, a pre-existing tall herb flora, comprising meadowsweets (*Filipendula* sp.), marsh marigolds (*Caltha* sp.), stonecrops (*Sedum*/*Rhodiola* spp.), the carrot family (Umbelliferae), and the polypody family (Polypodiaceae), disappeared, possibly as a result of grazing by sheep (Jóhansen 1985). At Tjørnuvík, Hannon and Bradshaw (2000) noted that the disturbance signature in the pollen record was strong owing to the small size of the islands and the likely pollen catchment areas. Hannon and others (2001) showed that microscopic charcoal was not present in sediments before the settlement, as indicated by pollen, and that charcoal occurred in small amounts after *landnám*. In the wet, cool climate of the Faroes, where natural fires are extremely unlikely, charcoal is thus perhaps one of the clearest indicators of human activity.

Sailing across the North Atlantic inevitably provided numerous opportunities for hitchhikers and uninvited guests (Sadler and Skidmore 1995), ranging from the ectoparasites of the people and their domestic animals to the flora and fauna accidentally carried in ballast and dunnage in the hulls of the boats and in the necessary fodder, carried to keep domestic animals alive. On landfall, the thin-walled clinker-built ships needed to be beached and cleaned out to avoid rotting, and the resultant midden provided a beachhead from which the introduced biota could disperse. It is hardly surprising therefore that the dung beetle (*Aphodius lapponum*) was the earliest widespread anthropochore in both the Faroese and Icelandic landscapes (Buckland 1992). What is surprising, particularly in view of the dung faunal footprint that appeared later across North America (Buckland and others 1995a), is the failure of the dung fauna to establish itself in the settlement areas of Norse Greenland. This may be a reflection of the general paucity of dung processors in the real Arctic, but equally it may be indicating that the winter stalling of animals, or the utilisation of dung as fuel, was more complete in the harsh environment of southwest Greenland. It should be noted, however, that fossil insect work on farms in the Eastern Settlement is currently limited, with one site E34, close to Qagssiarssuk (Brattahlíð) currently under investigation. The fodder and dunnage fauna appears to have rapidly established itself in the farms of the *landnámsmenn*. At Holt, on the south coast of Iceland, faunas that are characteristic of farms and barns through to the last century were established shortly after *landnám* (Buckland and others 1991a), although differences from the modern, pre-plastic roll silage faunas have been the source of some discussion (Buckland and others 1991b). These faunas are dominated by the processors of hay, largely feeding on the fungi on the decaying plants, and their predators. The faunas include the beetles *Laemostenus terricola, Omalium rivulare, O. excavatum, Xylodromus concinnus, Philonthus politus, P. cephalotes, Quedius mesomelinus, Cryptophagus* spp., *Atomaria* spp., *Lathridius minutus* and *L. pseudominutus*. This fauna appears to be largely absent in the one *landnám* farm examined on the Faroes, at Toftanes, perhaps a reflection of the lack of stored hay for the winter (Edwards and others 1998). Part of this synanthropic fauna reached Greenland, and became extinct along with their involuntary hosts (Böcher 1988). In the more foul residues, including house floors in Greenland, the carrion-feeding fly, *Heleomyza serrata*, is so common that it has been christened the 'Viking Housefly' — the true housefly, *Musca domestica*, is a much later emigrant across the North Atlantic (Skidmore 1996). In Greenland, the fly *Telomarina flavipes* is also an occupant of house floors (Buckland and others 1994), introduced at *landnám* and destined for extinction as the farms cool down on abandonment and the outdoor fauna moved in.

In terms of the balance book of species, human introductions, both temporary and more permanent, wholly outweigh extinctions, and the present landscapes of all island groups reflect the large-scale impact of introduced herbivores. Dugmore and Buckland (1991) coined the term 'ovigenic landscape' to describe these essentially artificial landscapes that are the consequence of human environmental impact.

Conclusions

The limited diversity of North Atlantic island biota pre-*landnám* and the domination by generalist and/or more eurytopic species is a reflection of their modes of origin. It means that ecological changes are less complex than in more temperate mainland regions with higher diversity, and that climate change may not always produce a response beyond ecotonal areas. A major ecological impact of *landnám* on the Faroes and Iceland was the introduction of grazing mammals that rapidly came to create new, eroded landscapes. Habitats that were once rare became common, new, broadly synanthropic environments were created, and others, more natural, were largely destroyed. Biodiversity suffered in the sense that, although the absolute number of species on the islands as a whole probably increased, the impoverishment of many habitats probably led to a decrease in the average number of species in a given area of land, away from that directly impacted by farms and hayfields. Effective chronologies can be constructed to correlate pre-settlement and settlement period events across the Atlantic islands, through a combination of archaeological, palaeoecological, historical, radiocarbon, and tephrochronological methods. Each approach has strengths and limitations but in combination they may be used to produce an unusually strong chronological framework founded on the widespread dispersal of *landnám* tephra erupted in AD 871 $\pm$ 2.

Progress in understanding requires both new data and modified approaches to data integration and analysis. One challenge is simply to add key data sets to existing studies. For example, the addition of pollen-based reconstructions of vegetation history to detailed excavation survey and zooarchaeological data in the Myvatn region of Iceland will enable a range of key ideas on landscape change and sustainability to be tested. Wholly new data are also needed for key areas that have currently received little attention. Thus, well-dated, archaeologically related palynology and geomorphology, coupled with quantified zooarchaeological and archaeobotanical assemblages from the Faroe Islands, would permit direct and effective comparisons to be made between the Faroes, Iceland and Greenland. Likewise, extension of research on the Norse Western Settlement in Greenland to the Eastern Settlement would provide crucial additional geographical dimensions to current knowledge. To date, the Western Settlement in general (and one community within the Western Settlement in particular) has received most attention. This is significant because the population of the Western Settlement probably peaked at about 1000 people, whereas the Eastern Settlement probably reached a maximum of about 5000. Crucial to the understanding of both *landnám* and, in the case of Greenland, the ultimate failure of *landnám*, are the major centres of population, as these were the probable centres for the decision-making processes, power, and prosperity and probably marked the positions of the ultimate end of the settlement.

In addition to substantially or completely new data, existing information can be extended, integrated, and analysed in new ways. In Iceland, for example, glaciers and their forelands have been well-studied, with the construction of detailed glacier histories based on tephrochronology. In key areas, geomorphological assessments of glacier forelands could be extended into neighbouring farm lands, integrated with land-boundary and farm-site data to test ideas of the interaction of land management (from historical and environmental archaeological data), climate (from glacier histories and palaeoclimate data), and landscape change (geomorphological and pollen data). All of these records may be potentially integrated using tephrochronology, and/or an intensive use of radiocarbon dating.

The authors see geographical patterns of change through time across the Atlantic islands as crucial to the effective understanding of environmental sensitivity to, and change as a result of, human settlement. Integrated multidisciplinary research holds the prospect of providing suitable data for assessing natural capital and its change through time, and as a result offering effective insight into the sustainability of long-term settlement.

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