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ORIGINAL ARTICLE

Fossil insect evidence for the end of the Western Settlement in Norse Greenland

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Abstract The fate of Norse farming settlements in southwest Greenland has often been seen as one of the great mysteries of North Atlantic colonization and expansion. Preservation of organic remains in the permafrost of the area of the Western Settlement, inland from the modern capital Nuuk, allowed very detailed study of the phases of occupation. Samples were taken from house floors and middens during the process of archaeological excavations and from insect remains were abstracted and identified in the laboratory. In this study, we present a new paleoecological approach principally examining the fossil fly faunas from house floors. The results of our study provide contrasting detailed pictures of the demise of two neighboring farms, Gården under Sandet and Nipaatsoq, one where abandonment appears as part of a normal process of site selection and desertion, and the other where the end was more traumatic. The level of detail, which was obtained by analysis of the dipterous (true fly) remains, exceeds all previous work and provides insights otherwise unobtainable.

Keywords Greenland · Norse · Diptera · Ectoparasites · Abandonment

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Introduction

Southwestern Greenland was settled by pastoral subsistence farmers from Iceland in the late 10–11th century (Jansen 1972; McGovern 2000; Seaver 1996). For more than three centuries farming continued. The more northerly Western Settlement (Fig. 1) was abandoned around the mid-14th century, and the Eastern perhaps 100 years later (Arneborg 2003; Arneborg and Gulløv 1998). The literary record is slight, and the only source that sheds light on the abandonment is Ívar Barðarsson, writing ca. 1346 (Jónsson 1930), who claims to have traveled to the Western Settlement and found no people, only domestic animals. A later source provides information for a witch burning in 1406 and an elite wedding in 1408 at Hvalsey in the Eastern Settlement (Halldórsson 1978). These are the last records until 1721 when Hans Egede began the modern European colonization; his search for Norse survivors proved futile (Egede 1925). Diamond (2005) has recently summarized the various models for the loss of this most remote outpost of Europe, which Lynnerup (1998) has estimated had a population of perhaps 2,000, although some archaeological estimates (e.g., Berglund 1986) are much higher.

The Norse farmhouses of Iceland and Greenland were similar in construction. They were built largely of turf, often on stone foundations, with wood used only for doors, frames, the trusses of roofs, and occasionally for paneling

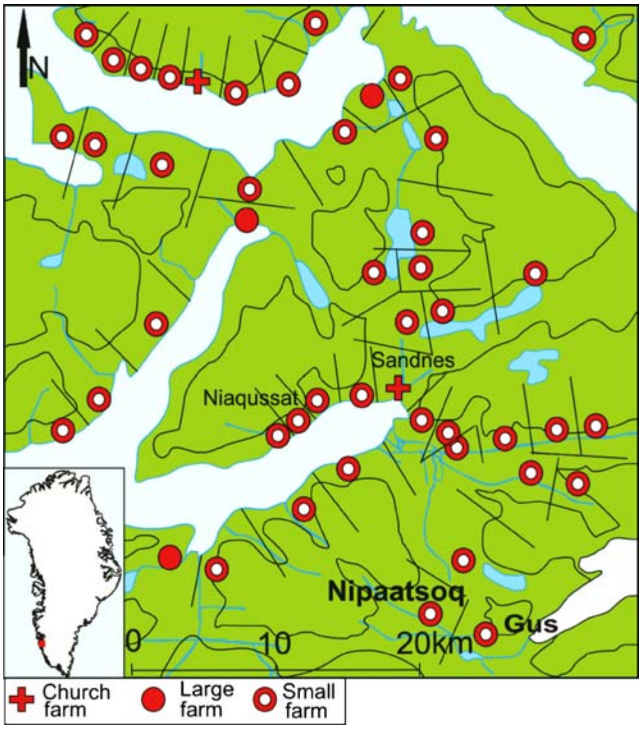

Fig. 1 The Western Settlement of Norse Greenland. The principal church farm lies at Kilaersavik (site V51, Sandnes) at the head of the fjord Ameralla. Note the regular spacing of settlements, and the larger territories of the major farms. All suitable sites for farms appear to have been occupied, and the only gaps occur where the shoreline is too steep for access. GUS lies toward the southern boundary of the Settlement, across the river from the smaller farm at Nipaatsoq (V54). Map and territories based upon McGovern and Jordan (1982) and Berglund (2000)

(Ágústsson 1983). While floors were usually of rammed earth spread with hay, animal byres were sometimes paved with stone flags and some living rooms had wooden floors. In the Western Settlement of Greenland, floors were carefully made of layers of twigs and wood chips as insulation over the permafrost (Buckland et al. 1994). This environment provided optimal conditions for a wide range of invertebrates from fleas to flies. The frozen ground also provides excellent preservation of all organic materials, crucial for detailed paleoecological research. This study uses insect remains preserved in the archaeological deposits to reconstruct living conditions on farms in the Western Settlement and examines the processes of abandonment of farms in the Western Settlement.

Materials and methods

Archaeological excavations at the site of the Norse farm Gården under Sandet (GUS), the farm under the sands, in Ameralla were carried by an international team under the direction of the National Museums of Greenland and Denmark between 1991 and 1996, in advance of destruction by the changing course of a glacial outwash river (Arneborg and Gulløv 1998). The site was preserved within the frozen ground of the sandur, which, while it slowed down the process of excavation, reduced the problems of contamination and other mixing of sediments. The excavations defined eight structural phases, at each of which there was apparent replanning of the farm buildings (see S1). Careful sampling of all closely defined archaeological layers was carried out by the excavation team, and 5-l samples were collected directly into polythene bags, which were then sealed. The material was shipped to the UK for analysis. Faced with more than 120 archaeological contexts, with spatially discrete multiple samples from some, the authors initially selected material for insect analysis randomly, but additional samples were examined as soon as the details of the archaeological stratigraphy became available. This allowed any critical gaps in the sequence to be infilled and a total of 75 5-l samples was processed for insect remains, 60 of which could be placed in the archaeological matrix and therefore were used for the interpretation of the site. Each sample was gently disaggregated in water and washed out over a 300-μm mesh sieve. Material retained on the sieve was returned to the processing bowl, and a small quantity of kerosene (liquid paraffin) was added. The kerosene adsorbs onto fragments of insect cuticle and the material can be induced to float with the light oil by adding cold water (Panagiotakopulu 2004). The floatant was then decanted off and washed with a mild detergent and alcohol. The resultant subsamples were sorted under a low-power binocular microscope and the insect remains extracted with fine forceps. The insects, largely disconnected individual sclerites, were stored in alcohol before identification. Identification was achieved by use of the published literature and direct comparison with modern reference material. In some cases, it was possible to dissect out the unemerged imagines from within fossil puparia; this was particularly useful where the larval stages of some Diptera have still to be described (Skidmore 1992). The minimum number of individuals recovered from each context are listed in S2 and S3.

Discussion

Fossil insect faunas from farm sites in Greenland include large numbers of the puparia of true flies (Diptera). These assemblages are dominated by the troglodytic *Heleomyza borealis* Bohe. (Fig. 2), which thrives on foul, high protein materials, including feces. It is resistant to low temperatures, but when below zero, falls into diapause; the artificial warmth of Norse sod buildings allowed multiple annual generations. On farms, it is present in contexts

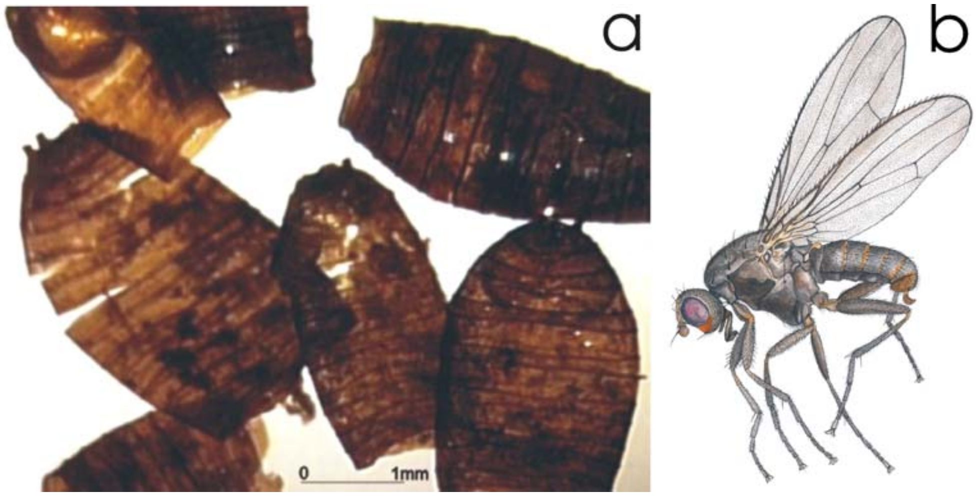

Fig. 2 Puparia (**a**) and a drawing by Pete Skidmore (**b**) of the adult fly *H. borealis* Fall. (Diptera: Heleomyzidae). The sample comes from the filling of a soapstone pot set into the floor of the latest phase of the farm at GUS, containing charred seaweed (*Fucus* sp.), probably a source of salt to preserve meat in the vessel (Buckland et al. 1999)

where there is activity by humans or domestic animals. While *H. borealis* is native to Greenland and we have found it on an earlier Sarqaq Paleo-Eskimo site, some puparia in the Greenland sites were well within the larger size range of *Heleomyza serrata* L., rather than *H. borealis*, although the critical characters to separate the taxa were not preserved. As this is the most abundant fly in samples from Icelandic farms, it is probable that it was introduced to Norse Greenland and became extinct with the demise of the settlements. The fellow travelers of the Norse included other flies. *Telomerina flavipes* (Meig.) and *Ischiolepta pusilla* Fall., the latter recovered in Greenland only from GUS, was probably imported in ships' dunnage. They have similar preferences to *H. borealis*, frequently breeding in urine-soaked feces, but need higher temperatures, relying on the artificial warmth provided by humans. They disappeared from Greenland with the farmers and other synanthropic insects during the late medieval period (Sadler and Skidmore 1995).

Preservation at GUS provides unique opportunities to study life during the farm's occupation. When founded ca. 1,000 A.D., the farm consisted of a longhouse, but later farms on the site had several rooms clustered together (Arneborg and Gulløv 1998). Both archaeological and paleoecological evidence indicate that room use changed between phases, according to the needs of the farm.

In the longhouse around the fireplace, large numbers of *H. borealis* puparia, human fleas, *Pulex irritans* L., human lice, *Pediculus humanus* L., and sheep lice, *Damalinia ovis* L. occurred. Delousing, next to the light of the fire, would have been an everyday activity, and sheep lice perhaps reflect the preparation of wool (Buckland and Perry 1989). In the adjacent animal houses, large numbers of ectoparasites are also present, both animal and human, and it is probable that the herdsman lived with his winter stalled stock. While many samples have extensive insect faunas associated with fodder, in some from the byres only the sheep ectoparasite *D. ovis* is present, sometimes with a few individuals of the fly genus *Agromyza* sp., an outdoor species probably brought in with hay. We recovered no flies signifying herbivore dung. This may relate to the accumulation of urine, which acts as a sterilizing agent to the accumulating dung and bedding; this is not an ideal environment for the dung fauna, and it is no surprise that during long-term stalling, there are few dung flies present. Foul material from the byre would have been ideal for manuring the nearby hay fields.

H. borealis puparia peak at disparate times in different parts of the house, signifying different activities or differing storage of materials. High numbers of this species appear connected with storage or processing of food, as for example in an area with seal bones during phase V, where the maggots were presumably feeding off protein residues on the bones, or other offal. *T. flavipes* was also found scattered in small numbers from a range of contexts from the different phases of the house. Surprisingly, the highest numbers of *T. flavipes* from GUS were recovered from an alcove containing sheep dung pellets, perhaps collected as fuel, belonging to phase VII–VIII. This fly likes warm environments and protein, and their occurrence may reflect the collection of fresh dung from sheep that had a more diverse diet than just plant fodder. Although research upon isotopic composition of bones suggests a largely terrestrial diet for the farm's herbivores (J. Arneborg, unpublished data), ethnographic sources, including the 16th century account of Olaus Magnus in Sweden, record the use of pounded fish and fish bones as sustenance for animals during winter (Magnus 1998); this could partly explain the virtual absence of even small fish bone fragments in all our samples from Norse Greenlandic farms. Isotopic studies of human bone suggest an increasing marine component in the diet through the medieval period (Arneborg et al. 1999), although bone evidence suggests that this is likely to have been via seal meat.

Insect faunas from samples from the turf walls from the first phases of the building consist largely of natural assemblages, pointing to the use of turves collected from adjacent open grassland areas, perhaps areas naturally kept clear of scrub by grazing caribou. Later structures produce a strong synanthropic signal, probably because turf was obtained from overgrown and grazed areas of the farm's midden. Phases with an absence of synanthropic insects provide evidence for breaks in the occupation of the farm. At the end of structural phase II, the longhouse was burnt, and turf grew over the site. The limited fly faunas consist of outdoor species, a few *Scatophila cribrata* Sten., *Scatella stagnalis* Fall., and anthomyids, whose larvae mine in grass stems. That stock were still present is evident from numbers of *Scatophaga furcata* Say, a predator in herbivore dung, probably indicating visits by either feral or domestic sheep from still occupied farms. Another gap is evident between phases IV and V. The pattern of the house being empty of synanthropes and cold, and sheep coming back for shelter is repeated, represented in the flies by the dominance of outdoor species, in particular the algaecols, *Scatella* sp. and *S. cribrata*, and where there are herbivores, *S. furcata*. Sealed by a collapsed roof between phases VI and VII, was a goat. The fact that it had not been processed by the indoor carrion fauna points to the absence of this element, a result of low temperatures (Panagiotakopulu 2004). In most circumstances, the carrion would have been sensed and processed by the flies in the building; the implication is that the goat had returned to an abandoned farm. There were at least three phases of abandonment (end of phase II, between phases IV and V, and between VI and VII) before the final one (after VIII) (see S4). Mobility, the temporary abandonment of sites, was a way in which the Norse coped with adverse conditions, from overgrazing (cf. Fredskild 1992) to climate change (cf. Barlow et al. 1998). Abandonment of outlying farms or relocation of the farm, provided there was space available in the area, could have been an effective solution for small-scale problems, but this would not have been an effective measure to tackle any regional environmental crisis. With limited communal infrastructure to cope with such an event, perhaps outmigration would have been the only option.

After the farm was abandoned, our insect evidence shows that a small pool formed over the collapsed roof, and sheep kept coming back for shelter and water. From each phase of abandonment at GUS, we have evidence for the presence of sheep in the farm. Sheep, and perhaps goat, cattle, and horses, have social memories and become attached to their pens and pastures (Thórhallsdóttir and Thorsteinsson 1993). They would have returned to the abandoned farmhouse, and as a result, their offspring would also have recognized it as a familiar place. How long this continued after the last farmers departed cannot be estimated, but sheep introduced into adjacent Austmannadal during the 1950s still manage to survive, despite hunting pressure (C. Andreasen, personal communication).

On the other side of Ameralla fjord, a few kilometers from GUS, lies Nipaatsoq (site V54, Fig. 1). Excavated by Andreasen (1982), the farm consisted of rooms built around a central passage and its main entrance looked south, away from the river (Fig. 3). All samples came from the terminal phase from rooms interpreted as larder (room IV), living room, (III), and bedroom (VI). The insect faunas are strongly synanthropic, similar to those from other sites in the Western Settlement. Although there is evidence of later occupation (J. Arneborg, personal communication), insect faunas associated with the Inuit and their hunter-gathering sites are different (compare Böcher and Fredskild 1993; Buckland et al. 1983). Animal bones show the remains of five cattle, butchered in the larder, and many bones of ptarmigan *Lagopus mutus* L., and arctic hare *Lepus arcticus* L., in both larder and hall. There are also the bones of a large dog, scattered between the hall and bedroom (Buckland et al. 1983). It could be argued that the farm was abandoned with a full larder, but it is more probable that the occupants were hostages inside their own house during a long cold winter, and forced to butcher their livestock and eat small game, eventually eating their dog. Did they survive the adverse winter? Flies throw light on this question. Large numbers of *T. flavipes* (see S3 and S5) are characteristic of all assemblages, except those from the larder, which must have been a much colder place. The frequencies of this animal are abnormally high, indicating

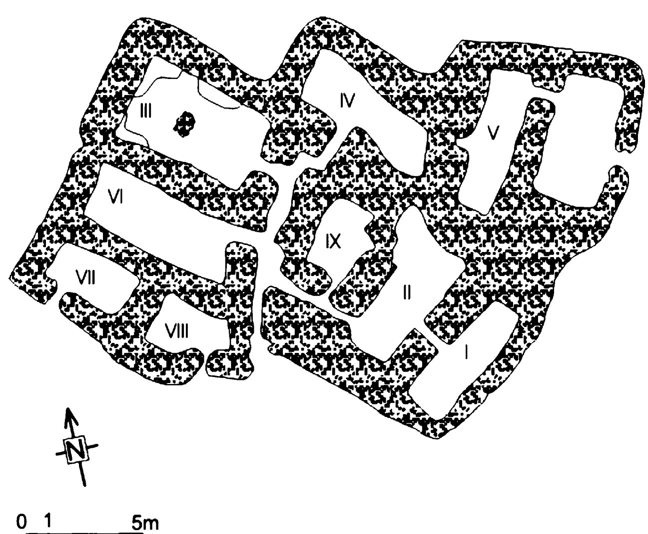

Fig. 3 Plan of the final phase of the farm at Nipaatsoq. Samples for environmental analysis were taken from rooms III, interpreted as the living room (skáli), IV the larder, and VI the bedroom. Room III has a central hearth, while IV contained the butchered remains of the farm's cattle and VI has much feather down and moss in the samples. Two samples (VIa and VIb) were taken in a vertical succession from room VI detailing the final occupation of the farm

decaying materials high in protein, probably feces. In Iceland, inside farms, we do not find this species in particularly high numbers, apart from in atypical situations, such as the drains beneath the farm at Stóraborg on the south coast (Buckland et al. unpublished data). High numbers (54% of the whole fauna) also occur in the midden of the elite farm at Bessastaðir, where the imported grain pests *Sitophilus granarius* (L.) and *Oryzaephilus surinamensis* (L.) were also recovered (Amorosi et al. 1992). *T. flavipes* indicates high protein concentrations, and probably the midden contains much human feces, which would include the grain beetles (cf. Osborne 1983), as opposed to cereal debris. In medieval Icelandic farms, *T. flavipes* forms 0–7% of the fossil dipterous faunas, 7% being the frequencies from Stóraborg, including the material from the drains. The picture is also consistent in Greenland, where *T. flavipes* frequencies range from 20% of the dipterous fauna in the midden at Niaqussat (site V48) to 2.5% from the house at GUS. The exception to this rule of thumb is seen at V54. *T. flavipes* was present all over this farm in much higher frequencies, reaching a high of 78%.

Nipaatsoq has unique faunas in its final phase—it is a place more similar to a latrine than living quarters. Evidence implies a farm under severe stress. Samples from around the fireplace in the living room contain *H. borealis* and high numbers of *T. flavipes*; this must have been extremely squalid, high in protein waste. The larder, on the other hand, has an assemblage comprising *H. borealis*, a few *T. flavipes*, and few individuals of the necrophagous *Scoliocentra fraterna* Loew; the butchered cattle would explain the presence of carrion species. The first sample from the bedroom presents a similar picture to the living room. The high counts of *T. flavipes* are not comparable to anything found on other farms, and *H. borealis* is also present. During the last phase of the bedroom, numbers of *T. flavipes* crash, probably because the temperature drops, and they are replaced by *H. borealis* and *S. fraterna*, the latter probably moving from the larder with the chance of a meal. In addition, a few puparia of two light-requiring carrion species appear. Adults of *Cynomya mortuorum* L. and *Protophormia terraenovae* Rob.-Des., two of the most frequent open air sarcophagous species from the subarctic (Rognes 1991), entered the bedroom, perhaps as an opening appeared in the roof, and found a suitable pabulum for oviposition.

Our evidence from Nipaatsoq bears few similarities with the other farms excavated. It was a warm, extremely foul place, and during the last phase of the bedroom there is evidence for carrion, presumably the last inhabitants. This is the only evidence we have for death in situ in Norse Greenland. The most likely scenario is that, after a long cold winter, the inhabitants had had to consume their milk cows and finally eat their dog. They may have teased their hunger with ptarmigan and hare, but lack of fat in the diet would have been lethal (Cordain et al. 2000; Speth 1983). The Icelandic explorer Vilhjalmur Stefansson observed that eating large quantities of arctic hare without accompanying it with oil or fat does not stop hunger, and he named this condition, very commonly encountered with Arctic explorers, “rabbit starvation.” He noted that eating lean meat and no extra fat intake was followed by illness. After several days of a no fat diet, the main symptom is diarrhea (Steffansson 1956). The need for fat is well known among Inuit, and it is evident that it was recognized as an essential part of the Norse diet, to the extent that they were breaking animal bones to extract all available fat and marrow (Outram 2003). We have found that piophilid flies, specialist feeders on fat and marrow, are virtually absent from most middens studied in the Western Settlement, indicating the extent to which the farmers utilized all available fat.

A malnutrition scenario, leading to the death of the farm’s occupants could be the explanation for the large numbers of *T. flavipes* and the carrion-feeding species in the bedroom at Nipaatsoq, indeed the apparently full larder would have had little nutritional value to the inhabitants. No bodies were found the farm or on any abandoned farm in Greenland (contra Vebæk 1992), and the assumption is that there were still people around at a later stage to bury the dead.

McGovern (1979) has pointed out that if the Norse had adapted Thule technology, they would have been able to hunt seals on the ice all year round and that would have made them more flexible in terms of resources during bad years. Refusal to embrace innovation may have cost them survival. However, the Norse of the Western Settlement were an unusual group of farmers. Compared with the Eastern Settlement, further south in Greenland, their reliance on hunting seals and caribou appears greater, although it is difficult to assess just how much of the diet was provided by milk products from sheep, goats, and cattle. The farms had less space for storage, less domesticates, and a larger intake of caribou (McGovern 2000). Diet-wise their practice translates into the need to balance proteins and, more importantly, fats in their diet, from three different sources, two thirds, if not more, coming from hunting.

The Norse seasonal round as reconstructed by McGovern (2000) included seal hunting from March to July, caribou from August to November, a grazing and milk production season during the summer, haymaking from August to September, and a dead season during the winter, when they were confined in their houses using their stored supplies. An early summer hunt for prestige commodities, walrus ivory, and hide and polar bear skins, would also have reduced labor for farming. In terms of balancing their diet, part of the year was dedicated to obtaining seal fat, another to feeding animals to have enough fat to survive the winter, and another to hunting caribou with enough fat on their backs. In the Norse socially stratified world, bone research (McGovern 2000) shows that the poor farms were eating more seal and the rich more caribou. Seal fat was probably the fat of the poor and caribou fat the fat of the rich.

Farming communities are sedentary, having exchanged the flexibility of following game for land. The Norse of the Western Settlement were partly mobile, with designated hunts during different seasons of the year, according to the migratory cycles of the animals involved. Because of the nature of their lives, they were almost as vulnerable and dependent upon hunting resources as hunting and fishing communities. Livestock was an additional resource, but this was balanced out by lack of mobility during winter months. Sometimes they were forced to abandon their farms for greener pastures, as the evidence for periodic abandonment at GUS demonstrates. Preoccupation had to be food for themselves and their animals, as opposed to long-term occupation of a particular piece of land. Their ways of life were culturally constrained and different from the Inuit, but very much in line with the environment they were living in. The diverse lifestyle that sustained this farming/hunting community for more than 300 years failed them at the end. When things went wrong they moved out of the area leaving some of their animals behind, as in the case of GUS, or they died, as at Nipaatsoq.

It is not cold that is obstructive for the modern Greenlandic farmers, but variable, unpredictable weather. It is possible that extreme climate variability is what led to the final abandonment, although the precision of dating is insufficient to indicate which farm was abandoned first. Nipaatsoq, on the other side of the river from GUS, was not affected by the same immediate environmental processes; Schweger (1998) showed that the pasture and hayfields at GUS were destroyed by the moving pattern of distributaries from the glacial river. Keller (1991) has argued that the farmers were far from independent, and that their economy was based on concentration of resources and specialization. If we accept this, the failure of one or more households must have had a knock-on effect on the viability of communities. When these reached critically low numbers, then abandonment became inevitable (Lynnerup and Nørby 2004).

Ívar Barðarsson's account of his visit to the Western Settlement is not easily interpreted (Jónsson 1930), and it was suggested that cattle could not survive outdoors under severe arctic conditions (Diamond 2005), yet the Yakut cattle of Siberia, which are a similar small size to the Greenland Norse cattle, survive in equally harsh conditions (http://www.sitc.ru/konkurs/Cattle/Html/cattleng.htm), and the last Norse Greenlandic stock must have been equally hardy animals. Our archaeoentomological results confirm the survival of sheep after the abandonment of GUS, but the question of cattle remains open. The landscape was empty of people, and the only creatures in the farm after abandonment were the livestock and their insect fauna. Archaeoentomology supports history.

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