The Moose Trappers and Hunting Grounds of Vilhelmina

ABM-simulation of annual cycles during the Stone Age

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Abstract

Archaeological research in northern Sweden has customarily proposed models based on assumed migration patterns to portray resource utilization of prehistoric hunter-gatherers. An average hunting household needs about 500km² for its subsistence. This assumption, as well as the temporal and spatial distribution of animal resources available for hunting households in the interior of Northern Sweden, is investigated using Agent Based Modelling (ABM) with explicitly identified factors and conditions. ABM simulations were run in order to analyse the relationships between hunters, moose (*Alces alces*), predators, landscapes and how human migration patterns could be adjusted in order to coincide with moose migrations. The results suggest that wolves and human hunters could coexist if the landscape had a moose density of 0.6 moose/km² or more and if each hunting household possessed territories of 400–500km². In accordance with the model's parameters, the simulation identifies those factors that are particularly sensitive to change and those factors that are necessary in order to maintain an ecological balance between hunters and their prey.

Keywords: Norrland, Neolithic, social organization, subsistence strategies, Agent Based Modelling

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Introduction

Archaeology is a science and thus a creative and innovative endeavour. It takes an imaginative leap to envision hypothetical scenarios that contextualize scant remains from the pre-historic past. While inspired by observations, not all hypotheses are immediately falsifiable and/or testable, which some consider to be unscientific (Popper 1998:36). This is a hasty conclusion since additional and/or independent materials or observations unearthed at some later time may well support, weaken or repudiate said hypothesis. A case in point is migration of human and other animal species and climate change, two explanations once widely invoked that later fell into utter disrepute. Advances in DNA analysis and research into climate change on a global scale (Brooke 2014) have reinvigorated these explanations, now respectable again. An alternative to waiting for novel materials/observations in order to substantiate/reject hypotheses is model building.

Recently the Swedish University of Agricultural Sciences (SLU) has implemented an extensive program to map the migration patterns of moose and any variation in their behaviour due to the characteristics of the landscape (Swedish University of Agricultural Sciences n.d.). The latest surveys are based on GPS data captured every hour. The accuracy of this data is superior to that which was available in earlier research, in which pitfalls, settlements and moose migration was first presented (Spång 1997:66). Another addition to technical and scientific developments is the easy-to-use simulation programs for *Agent Based Modelling* (ABM). We realized the benefit of using this tool to simulate how a hunting household during different seasons might use the resources in a landscape. Simulation or model building is gaining increasing adherence in the natural and social sciences as well as in philosophy (Casti 1997; Williamson 2020:114). While ABM has been used by several other disciplines, interest within archaeology has continued to grow only during the last decade (Kowarik 2013; Wurzer et al. 2015; Barceló et al. 2016; Cegielski & Rogers 2016; Romanowska et al. 2021). In this study prehistoric pitfall traps and settlement sites as well as data on present day migration patterns of moose (*Alces alces*) are combined in order to explore the relationship between resource utilization vis à vis settlement and migration patterns of prehistoric hunter-gathers in the interior of northern Sweden.

Background

This study assumes that there was a territorial structure among Neolithic hunter-gatherers in the inland forest areas of northern Sweden as stipulated

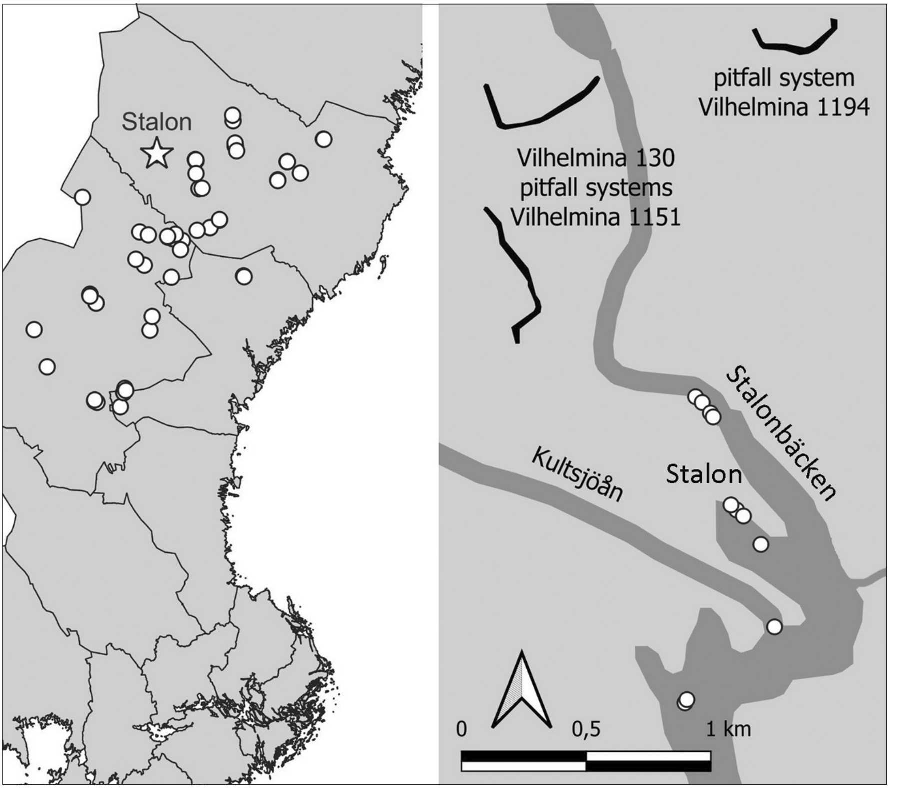

Figure 1. Left side: winter villages in northern Sweden according to Lundberg 1997. Right side: the Stalon winter village. One pitfall from the Raä Vilhelmina 130 system is dated to 4548–3797 BC two sigma, see Table 2.

in a previous study (Spång 1997:224). The thesis put forward then was based on analogies from Canada and Kemi Lappmark. The size and distribution of Sami hunting territories that were later turned into tax lands by the Swedish crown also contributed to the conclusion that a hunting/trapping/fishing economy in a boreal forest needs a territory between 100–700km² (Spång 1997:58). Neolithic winter villages with pit houses were spaced at regular distances from each other (Lundberg 1997:137). These houses are characterized by having the floor recessed a few decimetres below the surface of the ground and surrounded by an embankment consisting of gravel and waste. They are usually referred to as semi-subterranean houses or as pit houses and it is increasingly accepted that they were primarily used during the winter (Loeffler 2005:147). Lundberg mapped about 30 villages and concluded that they represented local bands. The villages were on average 35km apart and each had a territory of about 1000km² (Lundberg 1997:137).

The Stalon winter village

The Västerbotten Museum carried out excavations of the settlement at Stalon during 1979–1980 (Lundberg 1997:58). The winter village at Stalon consists of eleven pit houses. Dates from these excavations show that the round houses belong to an older group established around 4000 BC. Another group consisting of rectangular shaped houses is about 2000 years younger (Figure 1).

The material recovered in and around the pit houses consisted mostly of quartzite debitage and scrapers as well as fragments from a few slate artefacts. Stalon was inhabited both before and after the pit houses were in use. The winter village at Stalon could have simultaneously been home to at least five households between 4500–2500 BC. Here the simulation model is based on the territorial needs of a single household situated along the river Marsån. It is assumed that a household needed a territory of 500km^2 for its subsistence. The territory is assumed to coincide with a watershed which is one way of organizing land use between households, a theory explored earlier (Spång 1997:223) and is examined in more detail here.

Model building: analysing migration patterns and foraging strategies

Model building is a simplification of reality and thus necessarily involves choices. Certain parameters are deemed to be important, others less so. By tinkering with the parameters, connections are perceived, cause and effects discovered. Understanding the model's workings results in knowledge about the real world. In the methodology of model building, old models are replaced by another built on the insights of its predecessor while adding novel parameters (Williamson 2020:123–125). Current computational resources cannot model all aspects of the world, past or present. However, it is possible to model those parameters that are deemed most relevant to the hypothesis under review.

ABM is a general tool for model building where an agent, an individual and/or a specific area are assigned different characteristics. The simulation is then run where agents interact over time depending on their characteristics. This interaction triggers changes in their characteristics and properties as well as changes in the relationships between agents, which is recorded and quantified during the course of the simulation. A common ABM tool is NetLogo which is relatively easy to work with even though it is a programming tool. NetLogo has undoubtedly contributed to the increased interest in ABM in archaeology. The program contains a built-in manual and an extensive library of sample models. A detailed guide for archaeologists has been published (Romanowska et al. 2021). Thus far, archaeological model building has focused on economic exchange relations and on migration and distribution patterns (Romanowska et al. 2021:71, 148). ABM studies similar to the present work have addressed relationships between hunting, mobility and the location of various other resources in Paraguay (Dean 2000; Janssen & Hill 2016) and Ireland (O'Brien & Bergh 2016). The model designed for this study is available at: https://ccl.northwestern.edu/netlogo/models/community/

PARAMETERS: TERRITORIALITY

It is assumed that waterways and lake systems have influenced the location of Neolithic winter villages and how hunting grounds were distributed among households. Waterways and drainage systems can and do form the basis for how territories are established (Brouwer 2011:128; Selsing 2020:6; Löwenborg 2007). Yet this connection might be too simplistic, other considerations besides geography may be more important (Jochim 2003:325; Lovis & Donahue 2011; Spång 1997:223). The territory of hunter-gatherers is also shaped, for example, by the type, distribution and abundance of predictable resources in the landscape and the extent to which the storage of resources is needed to cope with seasonal fluctuations (Dyson-Hudson & Smith 1978).

PARAMETERS: LOCATION-BOUND PREDICTABLE RESOURCES

An obvious example of a site-bound resource used during prehistoric times are stone quarries. Fishing is also of special importance because it is a rich and predictable resource located at specific places. To some extent the same conditions apply to beaver and moose. Beavers (*Castor fiber*) have specific territories within a lake system while moose (*Alces alces*) have specific migration trails used in the spring and fall. These practicable circumstances facilitate hunting and/or trapping strategies. The placement of pitfall systems shows where such trails are to be found. The investment of labour required to build and maintain a pitfall system inevitably leads to claims of ownership over the site and the game. There are historical documents that reveal property disputes concerning pitfalls (Manker 1960:11) that highlight the importance of these facilities as site-specific resources.

In boreal environments there is a need to store resources for the winter, such as dried meat and firewood. Storage and storehouses require safeguards from both animals and strangers, which in turn creates ownership claims to a place. Territories are maintained through different symbolic systems that outwardly indicate human occupation and activities within

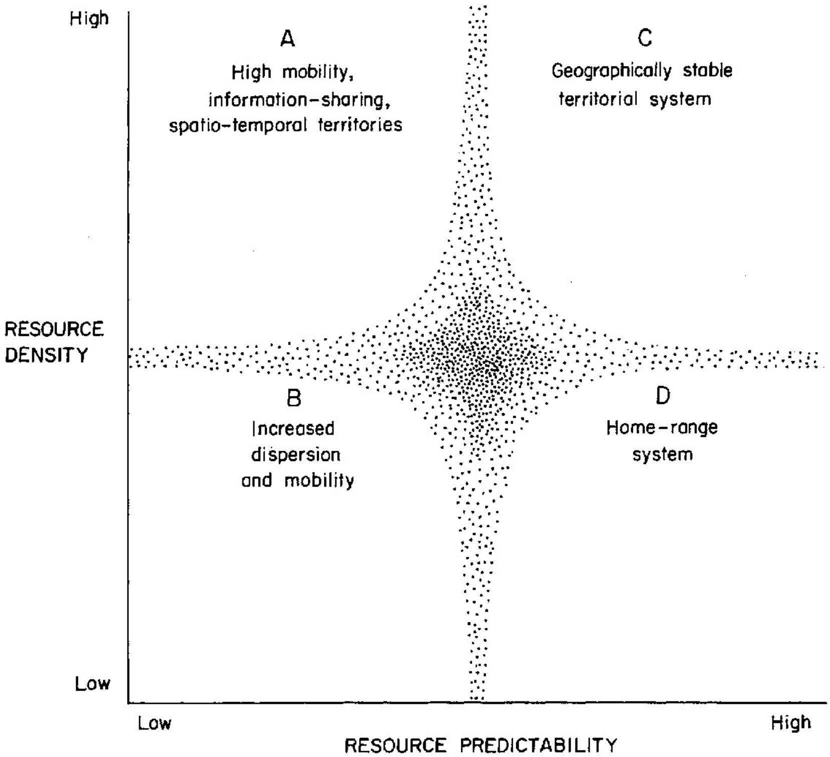

TABLE I. RELATIONSHIP BETWEEN RESOURCE DISTRIBUTION AND FORAGING STRATEGY.

	Resource Distribution	*Economic Defendability*	*Resource Utilization*	*Degree of Nomadism*
A.	Unpredictable and Dense	Low	Info-sharing	High
B.	Unpredictable and Scarce	Low	Dispersion	Very high
C.	Predictable and Dense	High	Territoriality	Low
D.	Predictable and Scarce	Fairly low	Home ranges	Low-medium

Figure 2. The relationship between resource distribution in a landscape and the hunting/trapping strategy employed. From Dyson-Hudson & Smith 1978.

each area (Grøn et al. 2008). Stories about places in the landscape internally strengthen the right to a territory. Religious factors and mental constructs drape the landscape (see the Siberian Khanty in Jordan 2003). Site-bound raw materials can also have an identifying function (Spång & Loeffler 2020). If they are evidence of long distance connections, such as flint, they can also have a status-enhancing effect. Rocks with a special appearance, such as red slate have had a broader meaning within and between groups to mark identity (Lundberg 1997:167; Cummings 2013:119).

In short, the driving force behind territoriality is the need of people to develop a system of coexistence where the community, within a given geo-

Figure 3. Outline of a possible annual cycle for a hunting household 4500–2500 BC based mainly on assumptions from ethnographic sources (Lundberg 1997:144ff).

graphical area, provides exchange, both economically and culturally, and where the relationship between neighbours is constantly renegotiated (Grøn et al. 2008:60).

PARAMETERS: SEASONAL HUNTING GROUNDS

This study investigates the seasonal use of hunting grounds following the seasonal distribution of prey (moose) assuming that the winter households gathered within a common area during the summer and thereafter dispersed to their respective winter villages. The archaeological indicators of winter occupation is the amount of fire-cracked stones and scrapers surrounding the pit houses, as well as the construction of the pit houses which take advantage of the earth's insulating properties. Furthermore, some of the pit houses in Stalon were flooded and uninhabitable during the spring. The amount of beaver bones also indicates seasonality, they are less abundant on winter sites as compared to spring and summer sites (Lundberg 1997:114).

Based on a comparison with the Cree Indians of Alberta, Canada, who subsisted on moose hunting (Lundberg 1997:144), a similar lifestyle is proposed for the prehistoric peoples of Stalon where different activities are linked to different seasons (Figure 3).

Ethnographic evidence shows that the moose was an important prey during autumn and winter when hides, meat, antlers and bones are of the best quality. The winter house needed to be prepared before the snow fell. This includes repairing the roof and insulation, collecting rocks and firewood and cleaning the floor. Storage pits had to be excavated before the frost sets in. Pitfalls and/or other traps also had to be prepared before the winter while fish needed to be caught and dried before the lakes froze. Winter was probably a quiet time when people could indulge in stories and keep traditions alive. Leather preparation was an important occupation during the winter, as evidenced by the many scrapers. Antler and bone crafts were certainly also important. Moose hunting might have been conducted on a smaller scale, but for the most part people relied on provisions in storage. This was probably in part due to the winter darkness and extremely short days, only three hours of sun in December. On the other hand fur animals are at their best in winter. Neighbours were important if stocks of food and fuel dwindled.

A critical season is the spring ice melt and flood. The pit houses could have been swamped and thus uninhabitable. Today the ice release takes place in the middle of May (Eklund 1999:17) but was much earlier during the Neolithic. Spring is and was the time of the beaver hunt. Their fur is at its best and the beavers are active outside their nests because their winter storage is now completely depleted. Birds could also be caught in the spring (Lundberg 1997:146). During the summer the different village households could have gathered in larger groups by a lake where fish, berries and game provided them with enough food. This gathering could last for two to three months. Before the ice settled, everyone would return to their winter villages. Nowadays the ice settles at the end of November, but somewhat later during Preboreal times when the climate was warmer.

It was certainly important to be on time and on station when the moose passed the pitfalls and/or other traps used to hunt them during their autumn migration. This onset is influenced by snow depth (Singh et al. 2012).

PARAMETERS: RESOURCES

The osteological material from the winter villages is dominated by moose (*Alces alces*). Beaver (*Castor fiber*) bones are also abundant, but not to the same extent as found on other inland settlements in Norrland. A few bones of reindeer (*Rangifer tarandus*), brown bear (*Ursus arctos*), marten (*Martes martes*), fish and birds have also been recorded, but their context is unclear (Lundberg 1997:114).

An adult member of a hunting and trapping household needs 1600–1920kcal/day (Speth & Spielman 1982:13). The carcass weight of a moose varies depending on age and gender. According to the County Administrative Board's moose statistics from 2020 for Västerbotten, an adult bull has a carcass weight of about 200kg, a cow of about 170kg and a calf of about 60kg (Länsstyrelsen n.d.). The carcass weight does not include the skull, lower legs, hide and intestines, but it does include the remaining parts of the skeleton, which make up about 25 percent of its body weight (Jordbruksverket n.d.). A moose steak prepared in a modern oven provides about 1300kcal/kilo of meat. With a few simple calculations one may conclude that a moose bull can fill the calorie requirement of a five person household for almost three weeks while that of a calf lasts a few days. It is estimated that a moose provided enough food for 30 people during one week among the Beaver Indians of Alberta, Canada (Lundberg 1997:136). This estimate corresponds to a five person household during six weeks.

It should also be noted that much more of the moose was considered edible as compared with today. A meat diet in large quantities also demands a balanced proportion between protein and fat, eating only lean meat can cause the nutritional deficiency known as rabbit starvation (Speth & Spielman 1982:3). A cookbook about traditional food among North American indigenous peoples (Anderson 1973) lists the mule, kidneys, rumen and liver as delicacies. The brain, however, was probably used for hide preparation (Rahme 1991:25). Some parts went to the dogs, which by now were probably members of the prehistoric household (Mannermaa et al. 2014). A lot of moose meat was dried before the winter, while the diet was supplemented with birds, fish and small game. Since the introduction of pots, provided by Europeans, the cooking habits changed among circumpolar indigenous people, favouring boiling (Eidlitz 1969). We can only guess the proportions between fish/fowl and moose, but if half of the calorie intake consisted of moose meat, a household would require about ten adult moose per year.

PARAMETERS: MOOSE MIGRATION AND TRAPS

Moose (*Alces alces*) are partially migratory, which includes different movement strategies and migratory distances within the same population (Singh et al. 2014). For any individual, however, a given strategy is relatively predictable (Bunnefeld et al. 2010). Migratory moose show regular annual migration patterns between their summer and winter ranges, often along the same migration trails, thus making the construction of pitfall traps along these migratory trails a worthy investment, especially within a landscape where the terrain funnels much of the movement. Migration patterns vary with latitude, with longer migration distances and a larger percentage of migrants in northern Sweden compared to the south (Singh et al. 2012; Allen et al. 2016). This variation depends on the different lengths of the growing season, forage accessibility and snow conditions. A warmer climate during Preboreal times in the north is expected to result in migration patterns similar to those currently found in southern Sweden which would suggest shorter migratory distances in the past than those recorded

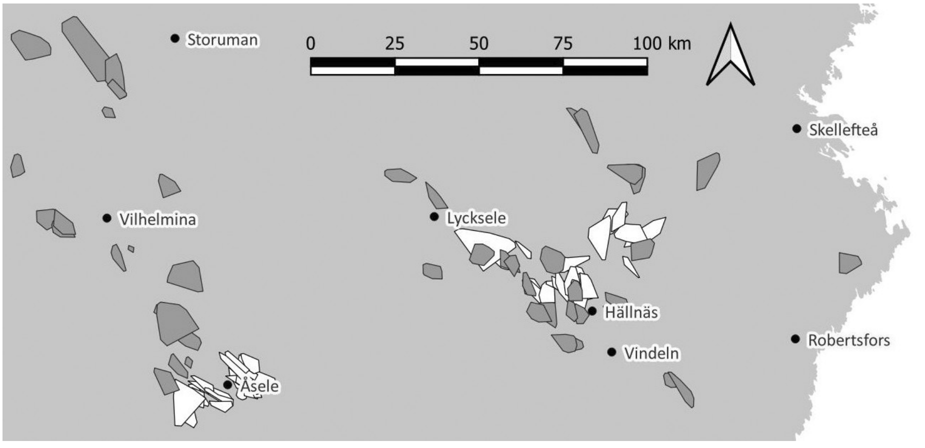

Figure 4. Each polygon is the summer (gray) and winter (white) home range of a single moose. Some home ranges overlap. The data from Åsele is from 2004 while the data from Hällnäs is from 2006. Note the differences between the two areas, where the Åsele moose migrate longer distances due to colder conditions. Data from Ericsson et al. 2004 & 2006.

in the study area today (Allen et al. 2016). Today the annual average temperature in Hällnäs is 1–2 degrees warmer than in Åsele (SMHI n.d.), a circumstance that seems to influence the migration distances between winter and summer ranges. The GPS data on the seasonal migration of moose available from Åsele Lappmark shows that the distance between the winter and summer ranges is over 200km for one bull and 100–120km for the cows (Neumann et al. 2018; Schön et al. 2007:20), see Figure 4 left side. The maximum migration distance between winter and summer ranges in Hällnäs is 83km while the average migration distance is only 19km (Ericsson et al. 2006:4), see Figure 4 right side. In our model we assume an average migration distance of 10–40km.

The bulls usually migrate to their summer ranges in May, just before the leaves sprout while cows migrate just before calving (Neumann et al. 2020; Singh et al. 2014). In contrast, the timing of the autumn migration back to the winter range is often less predictable, varying from year to year, depending on environmental conditions (Singh et al. 2012).

Pitfall systems are commonly located near winter villages. Radiocarbon dates show that pitfalls are occasionally contemporary with the pit houses (Table 1) but pitfalls may have been in use throughout most of prehistory and even later. One of the pitfalls in Stalon has been dated to about 4000 BC and is thus contemporary with the oldest dated pit houses. Radiocarbon dating and their presentation are highly problematic. This is exemplified by two flawed hypothetical scenarios that purport to place them in a prehistoric context. One is based on a fallacious mixing of both un-calibrated

Table 1. Newly calibrated ^{14}C dates 2 sigma (Stuiver et al. 2020) of pitfalls from 21 pitfall systems older than 4000 years within the Åsele Lappmark. Original material/dates from Selinge 2001:181 and Spång 1981:284 & 1997:77).

Lab no.	Raä no.	Sample location	BP	2 sigma BC	Source
Lu 1558	Vilhelmina 235:6	bottom	7280±75	6352–6005	Spång 1981:24
St 7402	Vilhelmina 573:32	wall	6250±100	5467–4963	Spång 1981:24
Lu 1562	Vilhelmina 235:18	embankment	6160±70	5300–4938	Spång 1981:24
St 11681	Fredrika 125:3	embankment	6090±265	5533–4402	Spång 1981:24
St 6335	Åsele 10:1	bottom	5835±95	4932–4465	Spång 1981:24
St 11680	Fredrika 125:3	bottom	5425±135	4525–3968	Spång 1981:24
St 8118	Vilhelmina 130	bottom	5380±170	4548–3797	Spång 1981:24
St 6585	Åsele 16:3	embankment layer 2	5210±95	4313–3795	Selinge 2001:181
St 6613	Åsele 17:21	embankment layer 3	4940±110	3972–3387	Selinge 2001:181
St 6611	Åsele 17:20	embankment layer 3	4855±310	4335–2888	Selinge 2001:181
St 6594	Åsele 16:10	embankment layer 2	4785±210	3982–2934	Selinge 2001:181
Lu 1563	Vilhelmina 235:18	bottom	4700±60	3634–3367	Spång 1981:24
St 11667	Fredrika 79:3	embankment	4680±170	3775–2928	Spång 1981:24
St 6583	Åsele 15:20	embankment layer 3	4650±175	3762–2912	Selinge 2001:181
St 11666	Fredrika 125:1	bottom	4540±75	3514–2944	Spång 1981:24
St 6580	Åsele 15:5	embankment layer 7	4410±245	3695–2458	Selinge 2001:181
St 6597	Åsele 17:11	embankment layer 2	4360±265	3652–2291	Selinge 2001:181
St 6586	Åsele 16:10	embankment layer 1	4145±295	3517–1931	Selinge 2001:181
St 6936	Vilhelmina 235:2	bottom	4020±95	2872–2298	Spång 1981:24
St 6584	Åsele 16:3	embankment layer 1	3930±125	2865–2041	Selinge 2001:181
St 7403	Vilhelmina 573:21	wall	3920±285	3317–1635	Spång 1981:24

and calibrated dates (sigma unspecified) resulting in erroneous conclusions (Larsson et al. 2012). The other is based on a covert sampling method that garbles all attempts to duplicate and verify the conclusions drawn from the sample (Ramqvist 2007:166).

PARAMETERS: HUNTERS AND PREDATORS, COOPERATION OR COMPETITION

Wolves (*Canis lupus*) are effective hunters of large prey as they usually hunt in packs. They typically hunt moose younger than two years of age (80 per cent) and cows older than 11 years. In the summer a wolf pack kills almost one moose a day and in the winter one moose every three days, in total circa 120 moose each year (Sand et al. 2011).

The wolf certainly constituted a major intrusion into the Stone Age hunting economy since both wolves and hunters were dependent on the same prey. Traces of wolves are however unusual in the archaeological record in

Norrland. Of the 59 settlements that were investigated in connection with the hydro-electric development of the Ångermanälven River, bones from wolf were only found on one site (Ekman & Iregren 1984:60). Maybe the wolf was not hunted. Maybe it was considered to have supernatural powers as envisioned by the Dene in Alberta (Moore & Wheelock 1990) and treated in a way that left no traces. Among hunter-gatherers it is also possible that the relationship between humans and wolves was mutually beneficial rather than competitive, a situation which eventually leads to domestication of the latter (Pierotti & Fogg 2017:270).

Bears are omnivores and usually prey on recently calved juvenile moose, only rarely do they kill an adult moose (Swenson et al. 2007). Bears can take over the prey of wolves, but meat is not their main diet. In Scandinavia plants and berries comprise a large part of their food (Swenson et al. 1999; Stenseth et al. 2016). Adult bears kill 7–8 moose calves per year (Sand et al. 2011). Bones from bears are rare on archaeological sites in Norrland even though this environment is natural for them. Within the Ångermanälven river system, bones from bears have been found on 7 of 59 sites (Ekman & Iregren 1984:12). Many bear graves have been found along the coast of northern Norway, as well as in the mountain regions and in the forested interior of northern Sweden. Dated to historical times it is a ritualistic act that clearly belongs to the Sami cultural sphere (Jennbert 2003:142). It is possible that the bear also held a special position during the Stone Age since the oldest unburnt bear bones are 3000 to 5000 years old (Iregren 2023:554). Bears have been a sacred animal for several cultural groups in northern Eurasia. Bears are depicted in the rock-art of the northern Scandinavian dating to the Stone Age (Hellskog 2012). The bear head sculptures from Arnäs and Bodum in Northern Sweden also date to the Stone Age (Baudou & Selinge 1977:91). The wolf however, is seldom, if at all, depicted.

PARAMETERS: THE LANDSCAPE

Pollen analyses from lake sediments in Stalon revealed that the winter pit houses were established after the postglacial thermal maximum when the climate was up to 3.6 degrees warmer than today and the forest included significantly more deciduous trees. From the glacier at Tärna, for example, the remains of trees have recently been recovered from beneath the melting and retreating ice-sheet. This shows that the tree line was up to 700m higher than it is today. Within the present study area, the highest peak, Marsfjället, reaches 1590m.a.s.l. while the tree line is now between 700–800m.a.s.l., which means that during the Subboreal period most of the mountains were covered with forest (Öberg & Kullman 2011; Kullman 2017).

The pit houses are a response to a gradually cooling climate, but it was still slightly warmer than today, since deciduous trees grew in the area.

Table 2. Settings of the simulation.

Hunters	
Onset to spring camp	123 Julian days
Onset to summer camp	153 Julian days
Onset to fall camp (trap location)	300 Julian days
Onset to winter camp	365 Julian days
Speed	0.7km/day
Trap radius	1km
Moose	
Onset to summer range	121 Julian days
Onset to winter range	304 Julian days
Speed	0.2–0.4km/day
Distance between summer and winter range	20–40km
Birth of calves (60% of moose females yrs >2)	50 Julian day
Wolves	
Kill radius (selection of prey)	0.8km
Speed	0.6km/day
Bears	
Active moose kill (only calves <1 yrs)	120–160 Julian days
Speed	0.6km/day
Hibernation	300–120 Julian days

Some lakes had already turned into bogs. According to the pollen analysis, bogs were formed before the Subboreal period, namely before the pit houses were established (Wallin 1986).

Setting up the simulation

In the simulation program NetLogo (Wilensky 1999) we specified conditions during the Neolithic. The model created here focuses on the spatial interaction between predators-hunters-moose. Our intention was to discover when this interaction becomes sustainable based on the migration model proposed for the hunting households in relationship to the migration patterns of the moose accompanied by the assumed presence of predators.

Our simulation emphasizes the importance of setting the daily movement correctly for both the human hunters, the predators and the moose (Table 2). Parameters, such as departure, arrival and speed were adjusted so that hunters would reach their traps when the moose were in the area. For

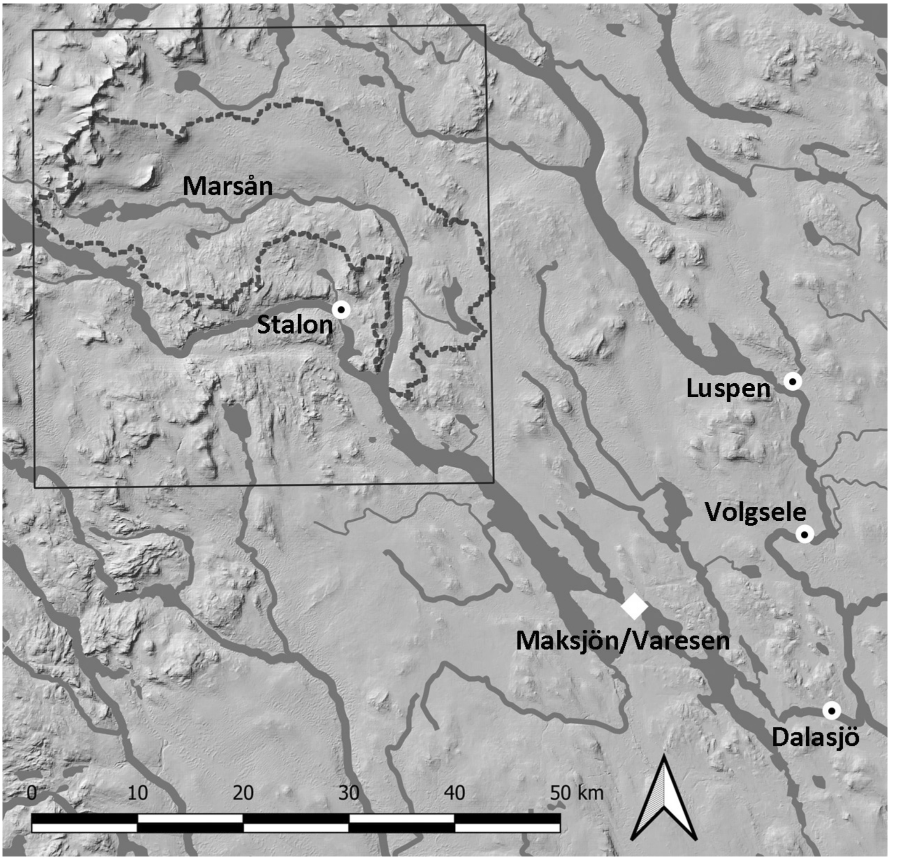

Figure 5. The frame around Stalon is equivalent to the map in figure 6. All winter camps with pit houses are marked with a white dot, their common summer area (Maksjön and Varesen) marked with a white diamond. The Marsån hunting territory, belonging to one household from Stalon, is marked with a dotted line.

example, if the daily movement was set too low, households did not reach their base camp and traps in time. If the movements of the predators were too slow then they did not catch up with their prey. The daily movement of the moose also needed to be set so that most of them reach their summer and winter destinations within a specific time period.

A simulation run in the study area will furnish varying results depending on where traps and base camps are located and where the winter and summer ranges of the moose are situated. After having reached their base camps, households move randomly in the vicinity of the camp. Likewise, moose move randomly within their seasonal home range.

Household base camps were located according to certain principles. The winter base camp includes pit houses while the summer camps are located at lakes Maksjön and Varesen (Figure 5) which is believed to have been a common summer residence used by several winter villages (Lundberg 1997:138). The spring camps were located along the river Marsån, where beaver trapping is believed to have been most lucrative. The pitfalls are located near the winter range of the moose, taking into account that transport by boat/sledge to the winter village would be possible. The winter range was placed close to the fall camps while the summer ranges were initially placed randomly (Figure 5).

GEOGRAPHICAL PARAMETERS

Using real terrain data and archaeological documentation within the area under study, we simulated the Neolithic environmental conditions as closely as possible. Terrain properties are created using digital elevation maps (DEM) with waterways and lakes. In this model we assume that all land has equal properties and is not affected, for example, by overgrazing or forest fires.

Rivers and lakes are obstacles for the migration of animals, but only to a certain extent. Both wolves and moose swim long distances, whereas in the winter the ice facilitates movement. Rivers and lakes are impossible to cross during some weeks when ice formation and break-up occurs, but these factors are excluded in the model.

ANNUAL CYCLE OF THE HOUSEHOLD

We divided the household annual cycle into four seasons, winter, spring, summer and autumn with each season having one base camp. We specified the day of the year when households move to a new seasonal encampment, the arrival at the summer camp is 1 June. During our simulation, we adjusted distances travelled in a day so that the households would reach their base camps in time to intercept the moose. Households have probably travelled according to certain preferences, for example via lakes and rivers or by land, topography permitting. In the model households move in a straight line between seasonal camps.

MOOSE MOVEMENT AND REGROWTH

We controlled moose migration through several parameters. Two variables control the direction; the destination parameter and a variable that drives the moose towards valleys. The start of the migration towards the summer areas was set to 1st April and back towards the winter areas on the 1st November. The map frame sets the limit for the distance between winter and summer areas to a maximum of 60km (Figure 5).

In the spring cows give birth to one or two calves (Neumann et al. 2020). The calves inherit migration trails from the cow. In our simulation, we simplified moose fertility which decreases after ten years (Sand 1997; Ericsson et al. 2001) by assuming that 60 percent of all cows older than 2 years give birth to a calf (Sand 2007). The quota is based on the County Administrative Board's statistics from this area between 2009–2019 that show a fertility rate of 0.6 calves per cow (Länsstyrelsen n.d.).

Home range size varies individually according to GPS documented movement, about 2700ha in Hällnäs and 1300ha in Nordmaling (Ericsson et al. 2006; Neumann et al. 2018). Here, each moose is assigned a home range covering on average 2000ha for both summer and winter.

EFFICIENCY OF THE TRAPS

Ethnographic sources show that trapping moose in a pitfall is one of many possible hunting methods. Snares and self-triggering spears have also been employed as well as hunting by boat at fords and pursuit hunting through heavy snow on skies (Spång 1997:55). In this model we do not distinguish between pitfalls or other methods used to hunt or trap moose but we assume that the trap is only active when the household is in place.

A radius was created around each trap. Only when the household and moose are simultaneously within this radius does the trap become functional and moose is caught. The trap should not be too far from the winter village, where the prey is to be stored. Several factors determine the difficulty of transporting the prey, such as snow and ice conditions, as well as topography, none of which is specified in this model.

Unlike the predators, the household does not select calves. Calves were probably not attractive from a nutritional point of view, but they do provide the best hides (Rahme 1991:39). In the model, however, only moose older than one year are killed, a parameter chosen because it simplifies keeping track of nutritional needs, which is ten moose per year for each household.

The moose density in Sweden is very high relative to other countries globally (Jensen et al. 2020). This is in part caused by extensive forestry that generates large areas of young successional forest and in part by selective hunting practices that cull the low reproductive members of the moose population, were calves are shot before the female (Lavsund et al. 2003). Thus moose density today likely differs from Stone Age conditions. Today the population is estimated to be 230–360 thousand in the summer when the calves are born (Jagareförbundet n.d.). With 28 million hectares of forest in Sweden (Skogen n.d.) there is an average of about one moose per km^2 of forest. Today, during the annual moose hunt from autumn to winter, between 80,000–90,000 moose are killed, equivalent to 29 per cent of the population. The moose population is less dense within Åsele Lappmark where in 2019 a total of 2200 moose were killed in a hunting area of 14,700km^2 (Länsstyrelsen n.d.). This corresponds to about 0.15 moose per km^2 and a density before the hunting season of 0.45 moose per km^2. Stalon, the area under study, is 1849km^2 in size. If moose density in the past was equivalent to that of today, the study area would have supported about 700 moose.

WOLVES AS PREDATORS

A pack of wolves normally consists of a family of about six with a territory of about 900–1200km^2 (Sand et al. 2007:27). In our model, the size of the wolf pack does not increase and the pack only hunts moose calves younger than two years and moose cows older than 11 years (Sand et al. 2007:33). To survive, wolves require a large number of moose, but wolves and humans could coexist if the moose population was large enough, to be exact, over 0.5 moose per km^2. Sand et al. (2007) have calculated different scenarios concerning culling rates and concluded that a density of 0.5 moose per km^2 together with a wolf pack with a territory of 1000km^2 would entail that both wolves and human hunters would be able to meet their needs without endangering the regeneration of the moose population. However, if the territory of the wolf is less than 1000km^2 then the moose population risks extinction. The predation rate of wolves is regulated by two variables, mobility and radius. Mobility controls the speed at which the wolf pack moves towards the prey and the radius indicates the distance to the prey. When a wolf targets a prey that meet the criteria (calf <2 years and cow >11 years) it is followed and killed. The radius is adjusted so that the wolf pack kills approximately 100 moose per year.

Results of the simulation

Eight different scenarios were simulated, based on the parameters described above but with varying moose density, number of predators and traps (Figure 6). A period of ten years was simulated during which the different outcomes are compared (Table 3).

The speed of the moose was set so that most of them reached their summer range during the spring. The human hunters/household needed to travel 700m/day to reach their destinations on time. The number and efficiency of the traps was set so that each household harvested ca 10 moose/year. The speed and radius of the wolves was set so that each wolf pack would harvest circa 100 moose each year. A bear only kills juveniles during spring and its speed and radius was the same as the wolves. The result of the bear's harvest was rather unpredictable, but their impact on the population was minimal.

Our simulation suggests that when the moose population falls below 0.6 moose per km^2 while both predators and hunters kill their share of the

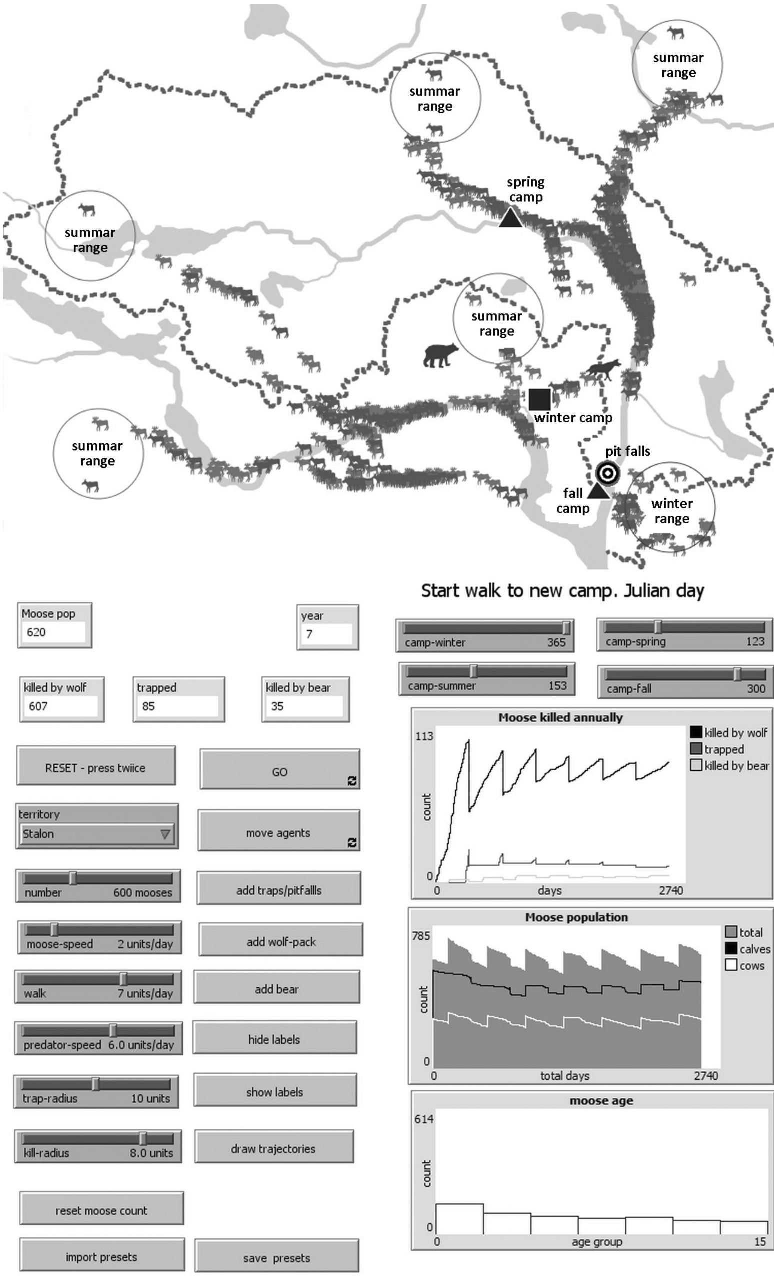

Figure 6. Snapshot of the simulation model running according to scenario 2 (Table 3). The hunting territory, Marsån, belonging to one household from Stalon is marked with a dotted line. The moose migrate between five summer ranges and one common winter range. The household has its fall camp near the moose's winter range, where pitfalls are placed (marked with a target symbol). The summer camp is located at Maksjön-Varesen outside the map. One unit equals 100m.

Table 3. Variations in the densities of the moose population as a result of different hypothetical scenarios based on the settings for departure, speed, trap-radius et cetera, as shown in Table 2.

Scenario	Initial moose population	Moose mortality rate and population level after 10 years				
		old age	wolf	bear	trapped	remaining
1	600 (0,38 moose/km²)	333	0 (no wolfs)	61	209	3959
2	600 (0,38 moose/km²)	217	900	40	109	861
3	600 (0,38 moose/km²)	101	778*	22	66	217
4	600 (0,38 moose/km²)	227	868	101	86	1303
5	1000 (0,6 moose/km²)	359	1858*	40	131	1262
6	1000 (0,6 moose/km²)	175	887	28	333	513
7	1000 (0,6 moose/km²)	218	905	106**	105	689
8	1000 (0,6 moose/km²)	258	1026	65	722	947

*two wolf packs *two bears

moose population, then the moose population will decrease every year until completely depleted. This is consistent with the data reported by Sand et al. (2007). The results from simulating eight different scenarios are presented in Table 3.

Row 1. With no wolves and only one bear in the area the moose population grows over six times its original size, even if the human household traps twice as much as it needs.

Row 2. With one wolf pack in the area the moose population still grows.

Row 3. Two wolf packs in the area cause a sharp decline in the moose population after six years, since all juveniles are killed.

Row. 4. In this scenario predators and hunters meet their needs while the moose population more than doubles.

Row 5. If the moose population is initially set to 1000, two wolf packs and one household can all meet their needs while the moose population grows slightly.

Row 6. In this scenario the household extends its hunting range and traps three times more moose than previously. The wolves meet their needs, but the moose population drops to half of the initial population after ten years.

Row 7. Bears have minor impact on the system. Two bears and one wolf pack in the area cause a drop in moose population after ten years, but afterwards the population starts to grow again.

Row 8. This scenario is rather stable albeit the hunters are active with three traps at different places. By focusing on moose all year round and following the moose migration, they achieve the needs of seven households. One wolf pack and one bear are also present. This simulation was run to analyse the possibility of hunting for trade.

Summary

After running a number of alternative sets, we noticed that if a household fully utilizes its territory, one consequence will be a relatively longer walk to the local gathering at the summer meeting place. Thus the question is whether the utilization of the entire territory required participation of all members of the household. It is most likely that households moved between two base camps, the Stalon winter village in autumn-winter-spring and the Maksjön-Varesen area in summer. The full extent of the household territory was probably only used in the autumn and spring by individuals or task-groups, that is to say, for hunting birds, beavers and quarrying. Moose hunting, however, required the entire household to be gathered at the fall camp.

Moose cows pass on their migration route to their offspring. In our model, we assume that moose follow their traditional migration trails generation after generation as any given moose is quite consistent in its movement strategy (Bunnefeld et al. 2010). However, if a majority of traps had only been placed in the summer range of, for example, the simulation in Table 3 row 8, then the moose population of that particular group will decrease. We assume that this was obvious to the households and that the traps had to be built at several alternatives places in order to increase hunting success as well as to spread hunting pressure across the area. It is possible that the territory was used all year round for moose hunting and that the summer gathering took place for a short time at a marketplace, as was the case during historic times, where any surplus could be traded. This scenario is plausible in following periods after 2000 BC.

However, moose were probably caught in the summer during the time before 2000 BC as well. Two of the pitfalls at Varesen (Raä Vilhelmina 235, see Table 1) are contemporary with the winter villages but since there are no pit houses at Varesen we assume that the drying of moose meat and the processing of hides was also carried out during the summer.

Logistics regarding winter storage in collaboration with all households within a winter village would seem to be important. The prey could be slaughtered at the kill-site, but since almost the whole carcass was used, its weight did not decrease. Thus in one form or another the entire carcass had to be transported to the winter village and distributed among the different households where the skin was stretched for processing while the meat was cut into pieces and dried. In some places the prey could be moved by boat, but otherwise some form of sledge was probably necessary for transportation.

Conclusion and beyond

This study was intended to evaluate the models presented in previous research (Lundberg 1997) regarding winter and summer residence among hunter-gatherers during the Neolithic in Lapland. The intention was also to see how moose migration patterns interacted with the proposed migration between summer and winter settlements for a single household and if it was possible for wolves and bears to live in harmony with this economy. When the SLU mapped moose migration patterns and the predatory rate of wolves and bears, the opportunity to go deeper into this issue was made possible. In addition, a simulation tool was available that could process and animate migration patterns and how they evolved depending on geophysical conditions.

We applied a simple model that is limited to a few factors in the ecosystem; terrain, moose, wolves, bears and one household. We have not considered the occurrence of beavers, vegetation, poultry or fish, all of which would have been equally important for human subsistence. Neither has the availability of raw materials for tools, clothing and building been taken into account.

The social need for local meeting places for larger gatherings of people is a topic in archaeology (Käck 2009:7; Whallon et al. 2011). Lakes Maksjön and Varesen have been designated as an area that could have supported a local gathering of inhabitants from several winter villages during the summer (Lundberg 1997:141). There was probably also a need for more extensive networks reaching beyond these local meetings. Exactly how much larger these networks might have been is still under discussion (Käck 2009:154). In the model outlined here, social networks beyond the winter-summer settlements are ignored.

We cannot go back in time. But we can hypothetically model those parameters that would have been of great concern for prehistoric peoples and thereafter test the model. Testing models has the added advantage that others can duplicate and thus confirm the validity of the model and the suitability of the materials/variables/parameters used in its creation.

The results obtained here lend credence to previously proposed archaeological models concerning human migration, seasonality, subsistence strategies, size of territories and their geographic determinants (Lundberg 1997; Spång 1997). But like most hypothetical models, its creation and testing has required a considerable amount of speculation and simplification. An ecosystem with human occupants is enormously complex and grasping all parameters requires more than can be achieved in an overview such as this. Perhaps the most valuable result from this project has been that insight. It is easy to suggest different migration models based on the sparse facts archaeologists have access to, but how much of an ecosystem can we expect to reconstruct?

Agent Based Modelling is a powerful tool and it has a wider potential than this example shows. Perhaps a more extensive simulation, involving more parameters, would lead to better predictability. Extending the model could involve attributing soil variables to the terrain, so that when moose graze an area it needs time to recover thus addressing the risk of over browsing. It would also be interesting to calculate the number of beaver that could be harvested within a territory and what effects a declining beaver population would have on the environment. Forest fires fundamentally change both the environmental preconditions and productivity of an area, which in turn affects species composition and resource distribution (Brown et al. 2018; DeMars et al. 2019; De Jaeger et al. 2017a; De Jaeger et al. 2017b; Neumann et al. 2023: Fredriksson et al. 2024). Forest fires in Norrland have occurred frequently during history and prehistory (Spång 1997:63), some perhaps deliberately set by hunters as a form of wildlife management, an aspect which would also be interesting to include in a model.

Our simulation reveals the complexity of hunters' dependence on an ecosystem where some resources are predictable and stationary while others are on the move according to certain annual patterns. The impact of competing predators disrupts the equilibrium of the system, but this can also be monitored in a simulation. First and foremost we found that the simulation reveals the importance of specifying which parameters are predictable and which are random and/or unpredictable. When these and other factors are also accounted for, then Agent Based Modelling will facilitate an ever increasing range of insights.

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References

Allen, A.M., Månsson, J., Sand, H., Malmsten, J., Ericsson, G. & Singh, N.J. 2016. Scaling Up Movements: From Individual Space Use to Population Patterns. *Ecosphere*. Vol. 7(10).

Anderson, A. 1973. *The Great Outdoors Kitchen. Native Cook Book. With recipes and sketches*. Edmonton: Cree Productions.

Barceló, J.A., Del Castillo, F., […], Poza, D. & Vilà, X. 2015. Simulating Patagonian Territoriality in Prehistory: Space, Frontiers and Networks Among Hunter-Gatherers. In: Wurzer, G., Kowarik, K. & Reschreiter, H. (eds), *Agent-based Modeling and Simulation in Archaeology: Advances in Geographic Information Science*, pp. 217–256. Heidelberg: Springer.

Baudou, E. & Selinge, K-G. 1977. *Västernorrlands förhistoria*. Härnösand: Västernorrlands läns landsting.

Brooke, J.L. 2014. *Climate Change and the Course of Global History: A Rough Journey*. New York: Cambridge University Press.

Brouwer, M.E. 2011. *Modeling Mesolithic Hunter-Gatherer Land Use and Post-Glacial Landscape Dynamics in the Central Netherlands*. East Lansing, MI: Michigan State University.

Brown, C.L., Kielland, K., Euskirchen, E.S., Brinkman, T.J., Ruess, R.W. & Kellie, K.A. 2018. Fire-Mediated Patterns of Habitat Use by Male Moose (*Alces alces*) in Alaska. *Canadian Journal of Zoology*. Vol. 96(3), pp.183–192.

Bunnefeld, N., Börger, L., […], Solberg, E.J. & Ericsson, G. 2010. A Model-Driven Approach to Quantify Migration Patterns: Individual, Regional and Yearly Differences. *Journal of Animal Ecology*. Vol. 80(2), pp. 466–476.

Casti, J.L. 1997. *Would be Worlds: How Simulation is Changing the Frontiers of Science*. New York: John Wiley & Sons.

Cegielski, W.H. & Rogers, J.D. 2016. Rethinking the Role of Agent-Based Modeling in Archaeology. *Journal of Anthropological Archaeology*. Vol. 41, pp. 283–298.

Cummings, V. 2013. *The Anthropology of Hunter-Gatherers: Key Themes for Archaeologists*. London: Bloomsbury Academic.

DeMars, C.A., Serrouya, R., Mumma, M.A., Gillingham, M.P., McNay, R.S. & Boutin, S. 2019. Moose, Caribou, and Fire: Have We Got it Right Yet? *Canadian Journal of Zoology*. Vol. 97(10), pp. 866–879.

De Jager, N.R., Jason, J., […], Fox, T.J. & Romanski, M.C. 2017a. Modelling Moose–Forest Interactions Under Different Predation Scenarios at Isle Royale National Park, USA. *Ecological Applications*. Vol. 27(4), pp. 1317–1337.

De Jager, N.R., Drohan, P.J., […], Gustafson, E.J. & Romanski, M.C. 2017b. Simulating Ungulate Herbivory Across Forest Landscapes: A Browsing Extension for LANDIS-II. *Ecological Modelling*. Vol. 350, pp. 11–29.

Dean, J.S., Gumerman, G.J., […], Parker, M.T. & McCarroll, S. 2000. Understanding Anasazi Culture Change Through Agent-Based Modeling. In: Kohler, T.A. & Grummerman, G.G. (eds), *Dynamics in Human and Primate Society: Agent-Based Modeling of Social and Spatial Process*, pp. 179–205. Oxford, UK: Oxford University Press.

Dyson-Hudson, R. & Smith, E.A. 1978. Human Territoriality: An Ecological Reassessment. *American Anthropologist*. Vol. 80(1), pp. 21–41.

Eidlitz, K. 1969. *Food and Emergency Food in the Circumpolar Area*. Studia Ethnographica Upsaliensia XXXII. Uppsala: Uppsala University.

Eklund, A. 1999. Isläggning och islossning i svenska sjöar. *Hydrologi*. Nr 81. Norrköping: SMHI.

Ekman, J. & Iregren, E. 1984. *Archaeo-Zoological Investigations in Northern Sweden*. Early Norrland 8. Stockholm: Vitterhets Historie och Antikvitets Akademien.

Ericsson, G., Wallin, K., Ball, J.P. & Broberg, M. 2001. Age-Related Reproductive Effort and Senescence in Free-Ranging Moose, *Alces alces*. *Ecology. Ecological society of America*. Vol. 82(6), pp. 1613–1620.

Ericsson, G., Dettki, H., Edenius, L., Ball, J. & Andersson, E. 2004. *Förvaltning av älg i Västerbotten: Märkning av älg som en del av viltövervakningen. Delrapport märkning Åsele 2003/2004*. Umeå: Institutionen för skoglig zooekologi, Sveriges Lantbruksuniversitet. Unpublished report.

Ericsson, G., Dettki, H., Neumann, W., Andersson, E., Nordström, Å. & Edenius, L. 2006. *Förvaltning av älg i Västerbotten: Märkning av älg som en del av viltövervakningen. Delrapport märkning Hällnäs 2005/2006*. Umeå: Institutionen för skoglig zooekologi, Sveriges Lantbruksuniversitet. Unpublished report.

Fredriksson, E., Cromsigt, J.P.G.M. & Hofmeester, T.R. 2024. Wildfire Influences Species Assemblage and Habitat Utilization of Boreal Wildlife After More Than a Decade in Northern Sweden. *Wildlife Biology*. https://nsojournals.onlinelibrary.wiley.com/doi/10.1002/wlb3.01296

Grøn, O., Turov, M. & Klookkernes, T. 2008. Settling in the Landscape – Settling the Land: Ideological Aspects of Territoriality in a Siberian Hunter-Gatherer Society. In: Olofsson, A. (ed.), *Archaeology of Settlements and Landscapes in the North. Vuollerim Papers on Hunter-gatherer Archaeology* Volume 2, pp. 57–80.

Hellskog , K. 2012. Bears and Meanings among Hunter-fisher-gatherers in Northern Fennoscandia 9000–2500 BC. *Cambridge Archaeological Journal*. Vol. 22, pp. 209–236.

Iregren, E. 2023. Sámi Bear Graves: Results From Archaeological and Zooarchaeological Excavations and Analyses in the Swedish Part of Sápmi. In: Grimm, O. (ed.), *Bear and Human: Facets of a Multi-Layered Relationship from Past to Recent Times, with Emphasis on Northern Europe*, pp. 547–586. Turnhout: Brepols.

Jagareförbundet. n.d. https://jagareforbundet.se/vilt/vilt-vetande2/artpresentation/daggdjur/alg/alg-population/ [Accessed 21 January 2024]

Janssen, M.A. & Hill, K. 2016. An Agent-Based Model of Resource Distribution on Hunter-Gatherer Foraging Strategies: Clumped Habitats Favor Lower Mobility, but Result in Higher Foraging Returns. In: Barceló, J. & Del Castillo, F. (eds), *Simulating Prehistoric and Ancient Worlds*, pp. 159–174. Cham: Springer.

Jennbert, K. 2003. Animal Graves: Dog, Horse and Bear. *Current Swedish Archaeology*. Vol. 11, pp. 139–152.

Jensen, W., Rea, R.V., […], Veeroja, R. & Widemo, F. 2020. *Review of Circumpolar Moose Populations with Emphasis on Euroasian Moose Distributions and Densities*. https://www.researchgate.net/publication/343787598 [Accessed 9 May 2024]

Jochim, M. 2003. Regionalism in the Mesolithic of Southern Germany. In: Larsson, L., Knutsson, K., Loeffler, D. & Akerlund, A. (eds), *Papers presented on the sixth international conference on the Mesolithic in Europe, Stockholm 2000*, pp. 323–330. Oxford: Oxbow Books.

Jordan, P.D. 2003. Investigating Post-Glacial Hunter Gatherer Landscape Enculturation: Ethnographic Analogy and Interpretative Methodologies. In: Larsson, L., Knutsson, K., Loeffler, D. & Akerlund, A. (eds). *Papers Presented on the Sixth International Conference on the Mesolithic in Europe, Stockholm 2000*, pp. 128–138. Oxford: Oxbow Books.

Jordbruksverket. n.d. https://djur.jordbruksverket.se/ [Accessed 22 January 2024]

Kowarik, K. 2013. *Agents in Archaeology: Agent-based Modelling (ABM) in Archaeological Research*. http://gispoint.de/fileadmin/user_upload/paper_gis_open/Muenchner_Fortbildungsseminar_Geoinformationssysteme_2012/537514019.pdf [Accessed 9 May 2021]

Kullman, L. 2017. Further Details on Holocene Treeline, Glacier/Ice Patch and Climate History in Swedish Lapland. *International Journal of Research in Geography*. Vol. 3(4), pp. 61–69.

Käck, J. 2009. *Samlingsboplatser? En diskussion om människors möten i norr 7000 f.Kr.–Kr.f. med särskild utgångspunkt i data från Ställverksboplatsen vid Nämforsen*. Umeå: Institutionen för idé- och samhällsstudier, Umeå Universitet.

Larsson, T.B., Rosqvist, G., Ericsson, G. & Heinerud, J. 2012. Climate Change, Moose and Humans in Northern Sweden 400 cal. Yr BP. *Journal of Northern Studies*. Vol. 6(1), pp. 9–30.

Lavsund, S., Nygrén, T. & Solberg, E.J. 2003. Status of Moose Populations and Challenges to Moose Management in Fennoscandia. *Alces*. Vol. 39, pp. 109–130.

Loeffler, D. 2005. *Contested Landscapes/Contested Heritage: History and Heritage in Sweden and their Archaeological Implications Concerning the Interpretation of the Norrlandian Past*. Umeå: Institution för Arkeologi och Samiska Studier, Umeå Universitet.

Lovis, W.A. & Donahue, R.E. 2011. Space, Information, and Knowledge: Ethnocartography and North American Boreal Forest Hunter-Gatherers. In: Whallon, R., Lovis, W.A. & Hitchcock, R. (eds), *Information and Its Role in Hunter-Gatherer Bands*. Pp. 59–84. The Cotsen Institute of Archaeology, University of California.

Lundberg, Å. 1997. *Vinterbyar: Ett bandsamhälles territorier i Norrlands inland, 4500–2500 f.Kr.* Umeå: Arkeologiska institutionen, Umeå Universitet.

Länsstyrelsen. n.d. https://algdata-apps.lansstyrelsen.se/algdata-apps-stat. [Accessed 12 January 2022]

Löwenborg, D. 2007. Watersheds as a Method for Reconstructing Regions and Territories in GIS. In: Clark, J.T. & Hagemeister, E.M. (eds), *Digital Discovery: Exploring New Frontiers in Human Heritage. CAA 2006 Computer Applications and Quantitative Methods in Archaeology. Proceedings of the 34th Conference, Fargo, United States, April 2006*, pp. 143–149. Budapest: Archaeolingua.

Manker, E. 1960. *Fångstgropar och stalotomter: Kulturlämningar från lapsk forntid*. Acta Lapponica XV. Stockholm: Nordiska museet.

Mannermaa, K., Ukkonen, P. & Viranta, S. 2014. Prehistory and Early History of Dogs in Finland. *Fennoscandia Archaeologoica*. No. XXXI, pp. 25–44.

Moore, P.J. & Wheelock, A. 1990. *Wolverine Myths and Visions: Dene Traditions from Northern Alberta*. Lincoln, NE: University of Nebraska Press.

Netlogo. n.d. http://ccl.northwestern.edu/netlogo/ [Accessed 17 January 2024]

Neumann, W., Stenbacka, F., […], Singh, N. & Cromsigt, J. 2018. *Årsrapport GPS-märkta älgarna och rådjur i Nordmaling 2017–2018: Rörelse, reproduktion och överlevnad*. Rapport 1. Umeå: Institutionen för Vilt, Fisk och Miljö, Sveriges Lantbruksuniversitet. Unpublished report.

Neumann, W., Singh, N. J., […], Ball, J.P. & Ericsson, G. 2020. Divergence in Parturition Timing and Vegetation Onset in a Large Herbivore: Differences Along a Latitudinal Gradient. *Biology Letters*. Vol. 16(6).

Neumann, W., Stenbacka, F., Malmsten, J., Johansson, A. & Ericsson, G. 2023. *Slutrapport. GPS-märkta älgar i brandområdet och i interaktioner med rovdjuren: Fördelning, livsmiljö, bärris och spillning*. Umeå: Institutionen för Vilt, Fisk och Miljö, Sveriges Lantbruksuniversitet. Unpublished report.

O'Brien, Y. & Bergh, S. 2016. Modelling Routeways in a Landscape of Esker and Bog. In: Barceló, J. & Del Castillo, F. (eds), *Simulating Prehistoric and Ancient Worlds*, pp. 199–217. Cham: Springer.

Pierotti, R. & Fogg, B.R. 2017. *The First Domestication: How Wolves and Humans Coevolved*. New Haven, CT: Yale University Press.

Popper, K.R. 1998. *Conjectures and Refutations: The Growth of Scientific Knowledge*. London: Routledge.

Rahme, L. 1991. *Skinn: Garvning och beredning med traditionella metoder*. Stockholm: LT.

Ramqvist, P.H. 2007. Fem Norrland: Om norrländska regioner och deras interaktion. *Arkeologi i Norr*. Vol. 10, pp. 153–180.

Romanowska, I., Wren, C. & Crabtree, S.A. 2021. *Agent-Based Modeling for Archaeology: Simulating the Complexity of Societies*. Santa Fe: Santa Fe Institute.

Sand, H. 1997. Reporduktion hos älgkor: Har storleken någon betydelse? *Fakta skog*. Vol. 2, 1997. Umeå: Sveriges Lantbruksuniversitet.

Sand, H., Liberg, O., [...], Frank, J. & Ahlqvist, P. 2007. *Vargen: Artfakta, en sammanställning av data från det skandinaviska vargforskningssprojektet SKANDULV 2007 på uppdrag av utredningen om de stora rovdjuren*. Unpublished report.

Sand, H., Andrén, H., Swenson, J.E. & Kindberg, J. 2011. Adaptiv älgförvaltning nr 16. Flera jägare på älgpopulationen: Predationsmönster hos varg och björn. *Fakta Skog*. Vol. 25, 2007. Umeå: Sveriges Lantbruksuniversitet.

Schön, M., Ericsson, G. & Dettki, H. 2007. *Slutrapport Älg i Mittskandia 2004–2007*. Umeå: Sveriges lantbruksuniversitet. Unpublished report.

Selinge, K-G. 2001. Fångstgropar i Nämforsens upland. *Tidsspår. Forntidsvärld och gränslöst kulturarv*, pp. 153–186.

Selsing, L. 2020. Main Territories in South Norway in the Mesolithic. *Environmental Archaeology*. Vol. 26(1), pp. 75–98.

Singh, N.J., Börger, L., Dettki, H., Bunnefeld, N. & Ericsson, G. 2012. From Migration to Nomadism: Movement Variability in a Northern Ungulate Across its Latitudinal Range. *Ecological Applications*. Vol. 22(7), pp. 2007–2020.

Singh, N.J. & Ericsson, G. 2014. Changing Motivations During Migration: Linking Movement Speed to Reproductive Status in a Migratory Large Mammal. *The Royal Society. Biology Letters*. Vol. 10(6).

Skogen. n.d. https://www.skogssverige.se/skog/fakta-om-skog [Accessed 28 January 2024]

SMHI. n.d. https://www.smhi.se/data/meteorologi/kartor/normal-arsmedeltemperatur [Accessed 10 May 2024]

Speth, J.D. & Spielman, K.A. 1983. Energy Source, Protein Metabolism, and Hunter-Gatherer Subsistence Strategies. *Journal of Anthropological Archaeology*. Vol. 2, pp. 1–31.

Spång, L.G. 1981. Fångstgropar: Lämningar efter forntida älgfångst. *Västerbotten*. 1981(4), pp. 282–290.

Spång, L.G. 1997. *Fångstsamhälle i handelssystem: Åsele lappmark neolitikum–bronsålder*. Umeå: Arkeologiska institutionen, Umeå Universitet.

Spång, L.G. & Loeffler, D. 2020. *Rapport över inventering: Lämningar efter stenålderns barmarksaktiviteter inom Marsåns och Gråtanån/Vojmåns avrinningsområde, Vilhelmina kn och sn, Västerbottens län*. Umeå: Västerbottens museum. Unpublished report.

Stenseth, N.E., Nilsen Lutnæs, P., [...], Brunberg, S. & Swenson J.E. 2016. Seasonal and Annual Variation in the Diet of Brown Bears Ursus Arctos in the Boreal Forest of South-central Sweden. *Wildlife Biology*. Vol. 22, pp. 107–116.

Stuiver, M., Reimer, P.J. & Reimer, R.W. 2020. CALIB 8.2 http://calib.org [Accessed 9 May 2024]

Swedish University of Agriculturral Sciences n.d. https://www.slu.se/en/departments/wildlife-fish-environmental-studies/moose-slu/ [Accessed 5 June 2024]

Swenson, J.E., Jansson, A., Riig, R. & Sandegren, F. 1999. Bears and Ants: Myrmecophagy by Brown Bears in Central Scandinavia. *Canadian Journal of Zoology*. Vol. 77, pp. 551–561.

Swenson, J.E., Dahle, B., [...], Wallin, K. & Cederlund, G. 2007. Predation on Moose Calves by European Brown Bears. *The Journal of Wildlife Management*. Vol. 71, pp. 1993–1997.

Wallin, J-E. 1986. Naturgeografisk och paleobotanisk undersökning vid Vojmsjön. In: Lundberg, Å., Rydström, G. & Spång, L.G. (eds), *Studier i norrländsk forntid II*, pp. 9–19. Umeå: Västerbottens museum.

Whallon, R., Lovis, W.A. & Hitchcock, R.K. (eds). 2011. *Information and Its Role in Hunter-Gatherer Bands*. Los Angeles: The Cotsen Institute of Archaeology, University of California.

Wilensky, U. 1999. *NetLogo: Center for Connected Learning and Computer-Based Modeling*. Evanston, IL: Northwestern University. http://ccl.northwestern.edu/netlogo/ [Accessed 9 May 2021]

Williamson, T. 2020. *Philosophical Method: A Very Short Introduction*. Oxford: Oxford Books.

Wurzer, G., Kowarik, K. & Rechreiter, H. (eds). 2015. *Agent-Based Modeling and Simulation in Archaeology*. Heidelberg: Springer.

Öberg, L. & Kullman, L. 2011. Recent Glacier Recession: A New Source of Postglacial Treeline and Climate History in the Swedish Scandes. *Landscape Online. Journal of the International Association for Landscape Ecology*. Vol. 26(1), pp. 1–38.