High Mobility or Gift Exchange – Early Mesolithic Exotic Chipped Lithics in Southern Finland

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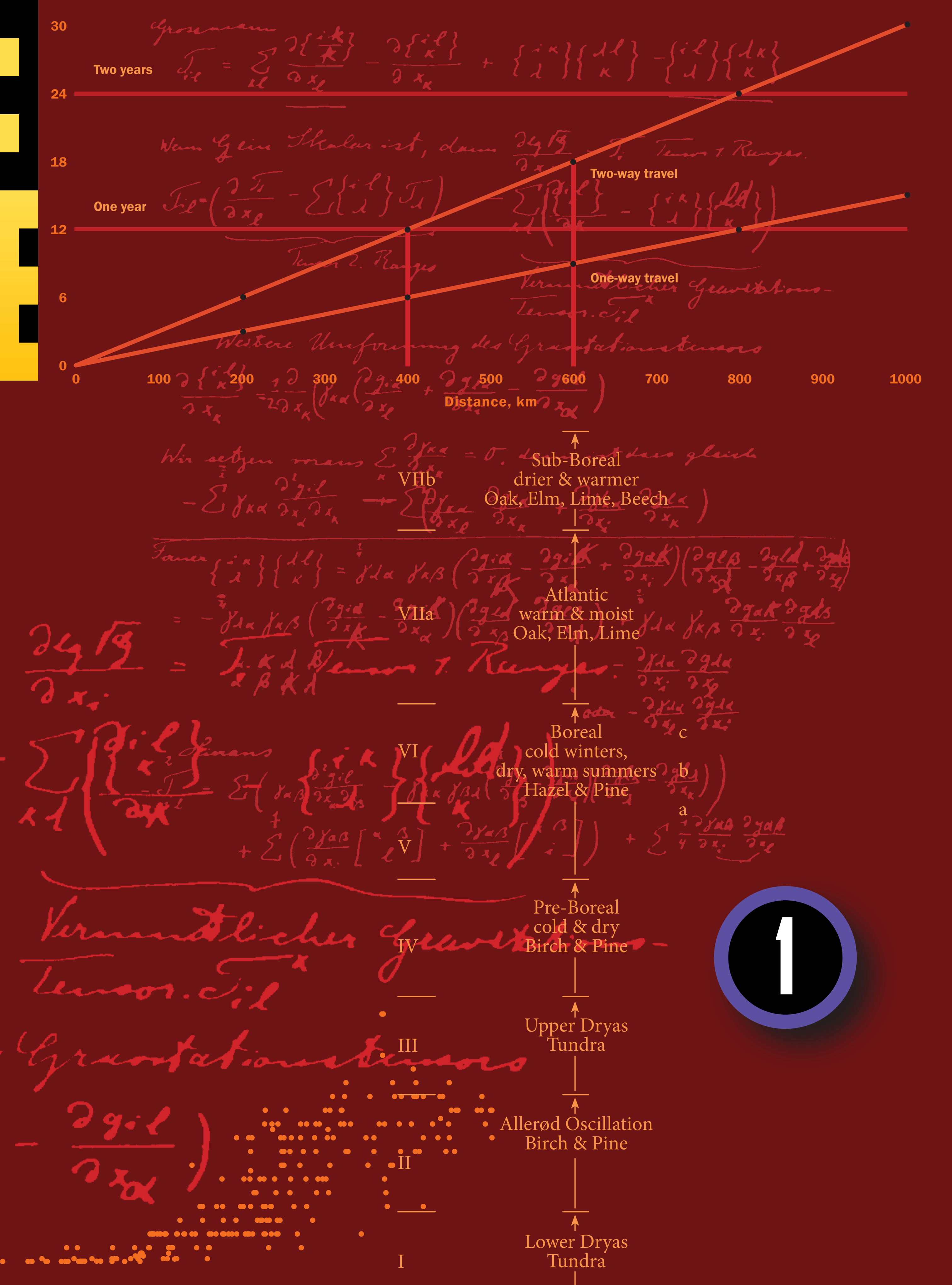
Two years
One year
Two-way travel
One-way travel
0
6
12
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200
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700
800
900
1000
Distance, km
VIIb
Sub-Boreal
drier & warmer
Oak, Elm, Lime, Beech
VIIa
Atlantic
warm & moist
Oak, Elm, Lime
VI
Boreal
cold winters,
dry, warm summers
Hazel & Pine
c
b
a
V
IV
Pre-Boreal
cold & dry
Birch & Pine
III
Upper Dryas
Tundra
II
Allerød Oscillation
Birch & Pine
I
Lower Dryas
Tundra
1

High Mobility or Gift Exchange – Early Mesolithic Exotic Chipped Lithics in Southern Finland

Esa Hertell & Miikka Tallavaara

ABSTRACT **Lithic materials have been distributed over considerable distances in many low-population-density demographic situations throughout the world. It has been suggested that this reflects either mobility or exchange, which have been explained by various mechanisms. In this paper, we discuss suggestions that have been put forth to explain the presence of exotic chipped lithics in southern Finland in the Early Mesolithic, and their subsequent disappearance from the archaeological record. Archaeologists have connected these exotic lithic materials to either high mobility, i.e., mainly migration, or exchange related to the colonisation process. Much of the discussion has been implicit. In this paper, we make these arguments explicit and formulate them as testable hypotheses with archaeological implications. We explore and discuss hunter-gatherer mobility, land use, and lithics use to understand the formation of the archaeological record and reveal the assumptions behind the high mobility argument. We further analyse the available data regarding exotic chipped lithic assemblages from southern Finland and show that different variations of mobility do not explain it well. Instead, we suggest that gift exchange is a better explanation for the observed patterns. On the basis of this observation, we formulate an evolutionary ecological model that explores hunter-gatherer mating behaviour during low-population-density dispersal. This mechanism explains the changes in the exchange network and, therefore, the presence and disappearance of the exotics from the archaeological record. To operationalise the abstract theoretical model, we present its archaeological implications and suggest some ways to test it. This paper helps archaeologists plan new research foci, generate a common language, and allow the collection of suitable datasets for testing mobility and exchange hypotheses in the future.**

KEYWORDS
Colonisation, hunter-gatherers, mobility, mating, exotic lithics, Early Mesolithic, Europe.

Introduction

In this paper, we shall study the mechanism through which exotic chipped lithics arrived in Finland within the context of the Early Mesolithic.[1] No flint is naturally available in Finland, and quartz was the dominant lithic material during the Stone Age. In eastern Fennoscandia, the first occurrence of exotic lithics in the archaeological record is associated with the earliest post-glacial sites and, therefore, with the post-glacial expansion of hunter-gatherers to the area. The existence of Mesolithic flint has not been recognised for very long. This has implications for the work that has been carried out concerning the issue. It is reasonable to say that, so far, there have been very few attempts to explain the Mesolithic exotic chipped lithics found in southern Finland. In the following, we shall review the detailed research history of the subject.

[1] Part of this work was originally presented as a poster at the 7th International Conference on the Mesolithic in Europe in Belfast in 2005. Here, we elaborate and present the ideas in full.

In general, there are two alternative explanations with regards to how flint arrived in Finland during the Stone Age. It was either brought to the area by individuals who could personally procure it from natural sources, or it was procured and used by different individuals and thereby distributed through exchange networks. These two forms of distribution can be expected to leave slightly different signatures on the archaeological record. Consequently, it ought to be possible to differentiate these signatures and determine the distribution mechanisms through which the lithics ended up in Finland. In this paper, we explore this issue. We discuss mobility, land use, and lithic assemblage formation and proceed to analyse available data from southern Finland. On this basis, we then formulate an explanation of the archaeological record.

To contextualise and understand mobility and land use in the Early Mesolithic, we explore different varieties of forager mobility from an ecological perspective. The terminology used in the discussion concerning dispersal mechanisms and ways to move about the landscape, i.e., mobility, is variable in Finland. In this paper, we adopt the concepts common in New World archaeological literature, i.e., residential, logistic, and long-term mobility, and migration (Binford 1980; 2002; Kelly 1983; 1992; 1995). These different modes of mobility all have implications with regard to the archaeological record, e.g., in the form of exotic lithic assemblages, but also with respect to radiocarbon dates, refuse faunas, etc. In the mobility section, we discuss the different varieties of mobility in high-latitude environments and their implications. Throughout the discussion, we use ethnographic hunter-gatherer data to illustrate our points.[2]

To understand the effects of formation processes in the archaeological stone tool record, we explore the nature of chipped lithics and the way they are produced, used, and abandoned. We also discuss lithic reduction and curation, as they form the backbone for understanding Finnish lithic archaeological collections. Currently, the largest published dataset of exotic Early Mesolithic lithic materials in southern Finland comes from the Ristola site in Lahti (Takala 2004). We analyse this dataset and show that hunter-gatherer mobility accounts for it poorly and discuss why exchange explains the observed phenomena better.

To elaborate on exchange, we explore the issue of mate acquisition and suggest a mechanism that explains why and how flint arrived in Finland. We suggest that these archaeological exotics are physical remains of transactions between individuals who lived in conditions of low population density. The system of exchange was embedded in social relations that functioned to assist in mate search and acquisition, and therefore, the major driving force of this gift exchange was ultimately an attempt to maximise evolutionary success. We discuss the prerequisites of this mechanism and, subsequently, its implications for the archaeological record. This discussion should help archaeologists in planning new research and make it possible to collect suitable data for testing models in the future.

In Finland, the spread of exotics has been only a minor part of the discussion concerning the post-glacial colonisation of eastern Fennoscandia. Before the 1980s, the colonisation model involved Late Palaeolithic–Early Mesolithic reindeer hunters who followed the retreating ice and tundra zone northward (Luho 1957:129–133). Since the 1980s, Mesolithic colonisation has been seen as the result of the gradual dispersal of hunter-gatherers northwards in the birch-pine forest during the Boreal period (Siiriäinen 1981a; Nuñez 1987:6–7; Matiskainen 1989:67; Rankama 2003). This model has slight variations. Siiriäinen (1981a:25–26) suggested sealing opportunities as a pull mechanism into the area of present-day Finland. In his discussion of the Late Paleolithic–Early Mesolithic adaptive processes, Matiskainen (1989:67–68) also saw the adaptation to sealing as important in the Baltic Basin. Rankama (2003), discussing northern Lapland, stressed adaptation to inland environments and emphasised the difficulties related to adaptive changes when moving from one environment to another. Recent data from the 1990s and 2000s about the timing of the initial colonisation have pushed the earliest dates farther back in time, to the Preboreal (Jussila & Matiskainen 2003). It is now evident that the earliest sites associated with colonisation are found in a variety of environments. These range from birch-pine forest to the northern almost treeless subarctic zone. Consequently, refuse faunas vary from inland European elk, i.e., moose,

[2] There is a lot of variation in the estimates of different variables in the datasets as concerns e.g., the Nunamiut case, see Binford 2001: Table 5.01, Kelly 1983: Table 1, Kelly 1995: Table 4-1.

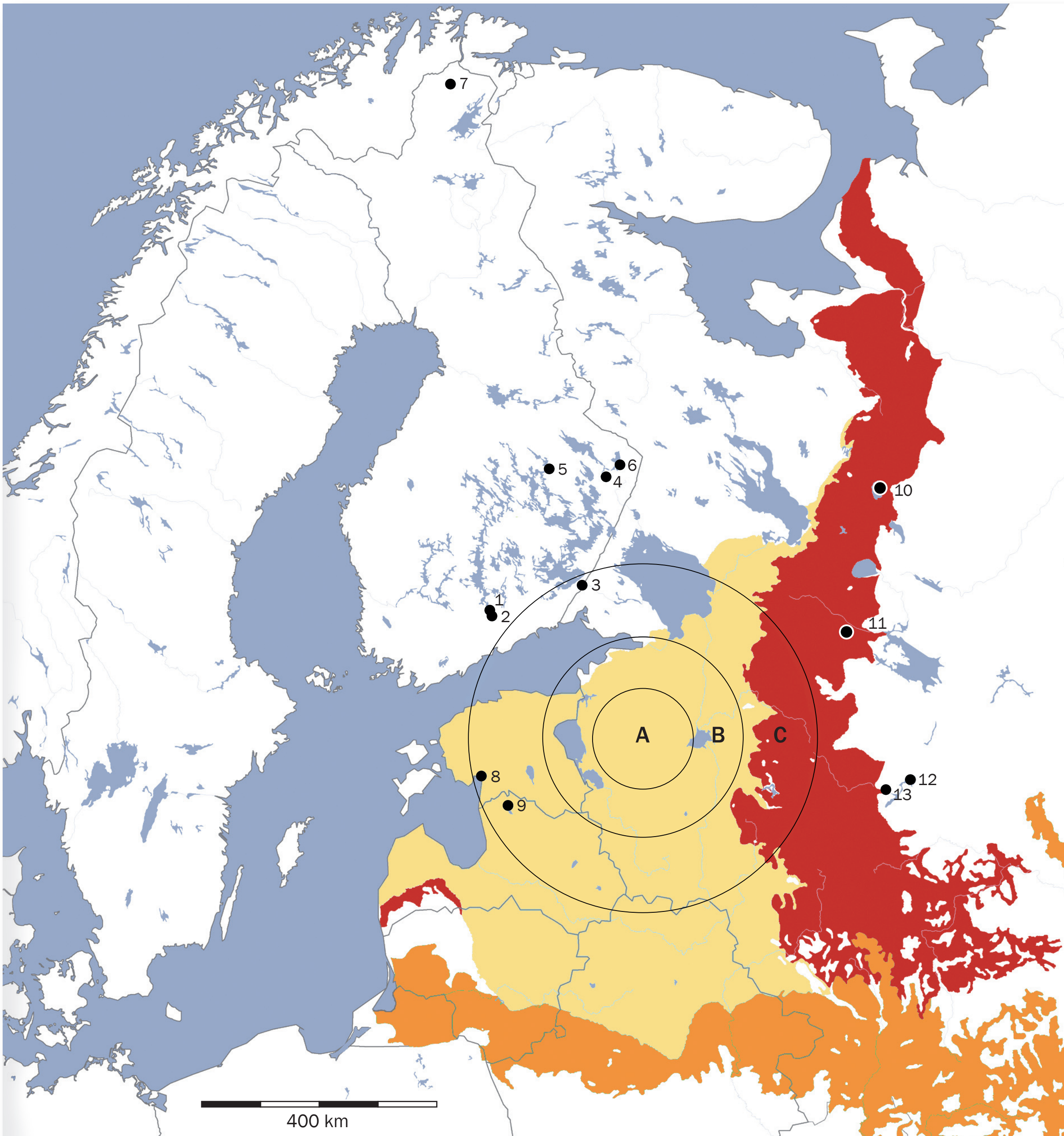

Figure 1. Map of the research area. Red = Carboniferous, orange = Cretaceous, yellow = Paleozoic (Devonian, Silurian & Ordovician) formations. **Key:** A) 25,000 km², B) 100,000 km², C) 300,000 km². **Sites:** 1. Ristola; 2. Myllykoski; 3. Kuurmanpohja/Saarenoja 2; 4. Rahakangas 1; 5. Helvetinhaudanpuro; 6. Syväys; 7. Sujala; 8. Pulli; 9. Zvejnieki; 10. Veretye I; 11. Kurevaniha; 12. Pekunovo , Prislon 1, Zaborovje 2; 13. Sukontsevo 3. Geological data from Persits *et al.,* 1997; Site locations from Latvia: Zagorska 1993, from Russia: Zhilin 2003; Koltsov & Zhilin 1999; Oshibkina 1997.

and beaver -dominated fauna in the south to reindeer-dominated fauna in the north. In a similar fashion, the use of other resources is diverse, e.g., lithic materials and technologies vary widely (e.g., Jussila *et al.* 2007; Rankama & Kankaanpää 2008; Takala 2004; Veski *et al.* 2005). To us, this demonstrates the adaptive flexibility of the Early Mesolithic foragers who spread into the north. We suggest that the explanation of the driving mechanism should be grounded in evolutionary theory and discuss the processes related to human dispersal explicitly from an evolutionary ecological perspective (Smith & Winterhalder 1992).

Geological settings and availability of flint

Modern-day Finland and the neighbouring region in north-western Russia form a part of the Fennoscandian Shield. The eastern part of the Fennoscandian Shield is largely devoid of flint and other high-quality raw materials for chipped lithic production. Because of this, other raw materials, mainly quartz, were used for chipped lithics in the area. However, there are a few small-scale occurrences of raw materials with better knapping qualities in Finland and in north-western Russia. In northern Finland, small sources of jasperoid are known (Kinnunen *et al.* 1985), and some pebble flint and silicified shales are found in the Kola Peninsula (Gurina 1987; Shumkin n.d.). To the south, east and north, the Fennoscandian Shield is surrounded by areas of sedimentary rocks where flint is locally present.

The distribution of sedimentary formations south and east of Finland is shown in **Figure 1**. Two main varieties of flint, Cretaceous and Carboniferous, are typically recognised in Finnish archaeological literature and are found in archaeological sites (Kinnunen *et al.* 1985). Geological formations bearing these varieties of flint extend from Lithuania to Belorussia and from Central Russia to the White Sea, respectively (Baltrūnas *et al.* 2006a; Persits *et al.* 1997; Zhilin 1997; Galibin & Timofeev 1993). Flint is also found in older Devonian and Silurian formations (henceforth, Paleozoic), e.g., in Estonia and Latvia, and was locally available and used in these areas during the Mesolithic (e.g., Baltrūnas *et al.* 2006b; Jaanits 1981:Fig.1; Jussila *et al.* 2006; 2007; Kriiska *et al. this volume*; Zagorska 1993:102). Paleozoic limestone is also found in the Baltic basin, for instance, in the bottom of the Gulf of Bothnia (Winterhalter 1972:30–33), but to what degree flint is present there and to what degree it has found its way to terrestrial till deposits remains to be demonstrated. Due to geology, therefore, it is reasonable to generalise that all flints found in the archaeological contexts of southern Finland must have been brought into the area by man one way or another.

From the perspective of a lithic user, the issue of flint availability is more complex, as the raw material availability and package size varies from one area to another. For example, in Estonia, the nodule size of Paleozoic flint materials is known to be relatively small (Kriiska *et al. this volume*). In the uppermost part of the River Volga, in Central Russia, the primary flint beds can be several hundred metres long with nodules of substantial size, whereas the quantity of flint in the secondary deposit decreases downstream (Zhilin 1997).

Research history and archaeological data

The Mesolithic period in Finland was long thought to have been devoid of exotic chipped lithics, i.e., flint (Vuorinen 1982:54). Although flint was occasionally found at Mesolithic sites, it was assigned to later intrusions or to younger phases of the same sites (Vuorinen 1982:38–39). However, since the 1960s, some flint artefacts have been attributed to the Mesolithic period. In 1964, Meinander (1964) reported tanged arrowheads that he dated on typological grounds to the Mesolithic and to the following Subneolithic period. In the middle of the 1980s, the flint finds from Lahti Ristola were dated to the Early Mesolithic (Edgren 1984; Kinnunen *et al.* 1985) and the presence of Mesolithic flint in Finland became widely acknowledged (see Hertell & Manninen 2006). Since the mid-1980s, Early Mesolithic flint has been mentioned in several publications (e.g., Matiskainen 1989; 1996; Schulz 1996).

The number of reported Mesolithic flint finds has grown in the 1990s and 2000s. New excavations in Lahti Ristola have yielded more flint (Takala 2003; 2004), and fieldwork in eastern and south-eastern Finland has also produced a number of new Mesolithic sites, some of which have also yielded new flint finds (Jussila *et al.* 2006; 2007; Jussila & Matiskainen 2003; Pesonen 2005:8). Most of the finds have been connected in the literature to the post-glacial colonisation phase of Finland (Edgren 1984; Jussila & Matiskainen 2003; Matiskainen 1996; Schulz 1996; Takala 2004).

Thus far, Lahti Ristola is the only Mesolithic site with a relatively large collection of exotic flint for which lithic data have been published (Takala 2004). Recent excavations at the Early Mesolithic Lappeenranta Saarenoja 2 site have also yielded a sizeable collection of exotics, but no published data exist as of yet.

So far, only small collections of Mesolithic flint are known from other sites, many of which are undated stray finds (Hertell & Manninen *this volume*). Nevertheless, these findings suggest an emerging pattern: early sites contain exotic lithic materials, and this requires systematic explanative work. Outside Finland, exotic lithic materials are also known from Early Mesolithic sites, e.g., in Pulli, Estonia, Zvejnieki, Latvia, and Veshevo 2 / Tarhojenranta in Russia near the Finnish border (Jussila *et al.* 2007:157; Jaanits 1981; 1990; Takala 2004:156; Zagorska 1993:102).

Ristola flint derives from Carboniferous and Cretaceous sedimentary formations (Edgren 1984; Kinnunen *et al.* 1985; Takala 2004). These sources of flint lie *c.* 400–600 km as the crow flies to the east and south, respectively (**Fig. 1**). Recent excavations at Helvetinhaudanpuro in eastern Finland produced a piece of black Cretaceous flint that has extended the linear distance from the source to 900 km (Jussila *et al*. 2007:157). Along the land route across the Karelian Isthmus, flint originating from the Cretaceous sediment area may have been carried *c.* 1000 km to Ristola.

These distances are considerable but not without parallels. In Finland, the same raw material types, especially Carboniferous flint, are generally found in Mid-Holocene assemblages (Kinnunen *et al*. 1985; Manninen *et al.* 2003; Vuorinen 1982) but in a completely different demographic and socioeconomic context. The long-distance spread of flint is also known from many other areas, especially in the context of Late Pleistocene and Early Holocene human dispersal and other situations characterised by low population density. In the European Upper Palaeolithic, exotic materials were spread over hundreds of kilometres, matching the distances involved in the present case (Rensink *et al.* 1991; Sulgostowska 2002:13–15). In North America, late Pleistocene foragers distributed lithic materials over extremely long distances that sometimes exceeded two thousand kilometres (Hofman 1991; Tankersley 1991). Arguments in favour of mobility – either migration or mobility inside a territory – or exchange have been presented in these and other cases (e.g., Gould & Saggers 1985; Janetski 2002; MacDonald 1998). The mechanisms to explain exchange networks often build on the idea that maintaining social contacts helps to reduce various forms of future risks, e.g., by facilitating access to other groups' territories (Gould 1980). What makes the situation archaeologically complex is that both mobility and exchange have operated simultaneously, at various levels, as exemplified, for example, by discussions on lithic and mollusc shell spread in Europe (Eriksen 2002; Rensink *et al.* 1991). These cases suggest that a single mechanism is unlikely to explain all of the distribution of exotic materials in northern Europe either. Instead, the cases need to be solved one by one or raw material by raw material, i.e., on a contextual basis. The present case study explores the spread of exotic lithics that correlates with population dispersal to uninhabited land and, therefore, studies the evolutionary strategies of hunter-gatherers who lived in conditions of low population density.

Existing explanations in Finland – mobility and exchange

Despite the growing awareness over the past two decades of the existence of Mesolithic flint in Finland, there have been very few efforts to explain the presence of these exotics. So far, two general propositions have been put forth to explain the situation. These parallel the explanations cited above. The first model suggests that migrating pioneers brought flint artefacts with them, and the second suggests distribution through exchange. These models are partly contradictory, and in many cases, they have not been expressed explicitly or elaborated upon.

The presence of exotic lithic material at Lahti Ristola has commonly been explained through the first model. According to this proposition, flint was brought to the site by foragers who migrated to the area from the south with their flint artefacts. Edgren (1984:22) originally suggested that the tools were the personal equipment of someone who immigrated from the south, i.e., Estonia.

More recently, it has been suggested that individuals who migrated to the site from the south, i.e., from the area of the Kunda culture, "*brought with them raw material for artefacts, such as flint cores and half-finished blades, and possibly also complete flint artefacts*." (Takala 2004:170; 2009:36). That the flint was brought to Ristola by pioneers was also emphasised by Zhilin (2003:692), who suggested that the pioneers were "*not familiar with local resources and had to carry necessary amount of flint over long distances*". We interpret this to imply that the pioneers came from areas where such flint was naturally available.

We shall call this the *high mobility* hypothesis. It states that flint was brought to Finland by individuals who carried the raw material, blanks, and tools with them. Although not stated explicitly in all of the cases, central to our new formulation of the hypothesis is that the raw material was procured, transported, used, and discarded by the same individuals. In other words, they came to southern Finland from areas where the flint was locally available. This was not originally argued by Edgren (1984) or Takala (2004); they only suggested that Estonia was the origin of the migrating individuals but did not really explain how the flint ended up there. The new formulation also widens the model to include different ways to move around the landscape and is not restricted to migration only.

Although the arguments on migrating or mobile individuals bringing flint material with them are scarce, these are still explicit. The suggestions of exchange are less clear and open to interpretation. Following Edgren's (1984) work, Matiskainen (1989:V,73) wrote that the exotic lithics in Ristola "*indicate a migration of settlers*" but then continued that "*once the former ties and contacts of this population were severed quartz became the sole material used in retouched artefacts*". For us, this seems to imply that two mechanisms were functioning behind the spread of exotics into Finland. In the first phase, individuals brought the flint with them, and later, it was distributed through exchange until these contacts were finally severed. Why such contacts were maintained and why they ended was not discussed.

Zhilin (2003) discussed the Early Mesolithic lithics in north-western Russia, the East Baltic countries, and Finland. He suggested two patterns: in Finland and the East Baltic, flint was carried along as a raw material supply as quoted above. The other pattern was that the single artefacts, tools, and blades of exotic materials found at sites in Estonia and Central Russia were either distributed by highly mobile people who carried their tools with them or exchanged between groups. The mechanism that produced both patterns was a *communication network* that was formed to create stable exogamic links because of low population densities among people with similar cultural traditions from the Early Mesolithic onwards (Zhilin 2003:692). Following Zhilin (2003), Takala (2004:169–170, 177; 2009:36) also noted the possibility of exchange or trade but did not elaborate on this.

Following the original work behind this paper, Hertell & Manninen (2006:45) stated that the Mesolithic flint collections in Finland consist of heterogeneous sets of artefacts whose character can best be explained through exchange rather than direct migration from flint source areas, but they did not clarify their argument. Jussila and associates (Jussila *et al.* 2007:159) also suggest exchange by remarking that "*through the help of direct and indirect contacts exotic raw material could drift hundreds of kilometres without major migrations*" but do not elaborate on the concepts or discuss the mechanism further.

To summarise the short review above, it can be said that most of the published works on the Early Mesolithic exotics in the study area operate on a very general level. Many of the remarks on the issue are implicit, and argumentation about the processes and the distribution mechanisms is largely absent. Furthermore, there has been little attempt to analyse the mechanisms through the lithic data.

How mobile were Mesolithic hunter-gatherers in northern Europe?

Following Binford (1980; 2002) and Kelly (1983; 1992; 1995), we divide hunter-gatherer land use and mobility into four models of moving around the landscape (residential, logistical, long-term, and migration). These types of mobility can be predicted to affect the lithic archaeological record differently, at least in part. Residential mobility refers to campsite shifts that the whole occupational unit carries out together. In logistical mobility, single individuals or groups operate from their residential sites. These trips can be mounted for the purposes of hunting, gathering, collecting firewood, or searching for spouses, etc. It is also possible to break migration down into residential moves. For foragers migrating from their original areas, the migration is necessarily the result of a number of consecutive residential moves. Long-term mobility means change in the size and location of the home range habitually used by foragers over long times, e.g., the lifetime of an individual. Other ways and reasons to move around the landscape have also been proposed. The landscape learning process is seen to be important in the colonisation process, and s*couting* of new areas can provide information and enhance learning (e.g., Kelly 2003, Rockman 2003).

Hunter-gatherers can also make *pilgrimages* or *journeys*, e.g., to visit other groups (Zedeno & Stoffle 2003, Whallon 2006). Boas (1964:166–7) for example, reports the Central Eskimo making journeys that may have lasted for a year or more.

For the sake of clarity, we shall discuss the different mobility patterns one by one. Mobility, by definition, always has a spatial dimension. Individuals move around in a landscape, not in random fashion and everywhere, but within a certain region. We shall consider this area, the home range, first, as this gives us a good starting point for the discussion of the scale of hunter-gatherer land use and, therefore, the scale of mobility required to cover the territory in an Early Mesolithic context.

Region	Size sq km
Finland	338,424
North Karelia	21,584
Estonia	45,228
Latvia	64,589
Russia	
Leningrad region	84,500
Pskov region	55,300
Republic of Karelia	180,500
Estonia, Latvia & Pskov	165,117
Estonia, Latvia, Pskov & Leningrad	249,617

Figure 2. Sizes of selected northern European states and regions. Data from
http://fi.wikipedia.org/wiki/Suomi
http://www.maanmittauslaitos.fi
https://www.cia.gov/library/publications/the-world-factbook/
http://en.wikipedia.org/wiki/Leningrad_Oblast
http://en.wikipedia.org/wiki/Pskov_Oblast
http://www.gov.karelia.ru/

Land use and home range

Reported hunter-gatherer land use can have extensive spatial coverage. Binford (2002:115), for example, reports that the lifetime travels of a Nunamiut male can cover an area of more than 300,000 sq km in size. This comes close to the size of modern-day Finland (see **Fig. 2**). In a similar fashion, E. Leacock's (1969:6–8) Montagnais informant was able to produce a map covering a large area of the southern Labrador, suggesting he had personal experience of it all. Lovis and co-workers (2005:674) estimate this area to be *c.* 240,000 sq km in size. Our estimate is somewhat smaller and is *c.* 200,000 sq km. The Central Eskimo knowledge of land is also known to be extensive. They produced maps that covered the southern part of Baffin Island (Boas 1964:236–239). Kelly (2003:45) estimates these to have covered 650,000 sq km in size. This estimate seems too large, given the size of the whole island. Our estimate is considerably smaller, *c.* 230,000 sq km. Despite the deviation in the estimates, the examples make it clear that some northern hunter-gatherers may have travelled over large areas during their lifetime.

It is possible that some Early Mesolithic hunter-gatherers in northern Europe traversed areas as large as the Montagnais or Nunamiut during their lifetime. These figures make it clear that the archaeological record produced by a single Early Mesolithic individual extends over large areas and can be found over wide regions in Finland and neighbouring regions. Furthermore, these figures help to explain how knowledge and technological information, e.g., about lithics, pottery, housing, agriculture, and rituals, can spread over vast areas in the northern hemisphere in a short time on an archaeological time scale. Although impressive in size, these figures are of little use in explaining exotics in southern Finland, as hunter-gatherers did not cover areas of this size over short periods, although they may have gained the knowledge over a lifetime.

Instead of long-term mobility and the area covered in a lifetime, the home range, i.e., the area habitually used by an individual, is a more useful concept for the current analysis. In general, the home range size of a foraging animal is a function of the animal´s size and diet. The larger the size of the forager and the higher the trophic level, the larger the exploited area must be (Harestad & Bunnell 1979). Because this is a consequence of the structure of our ecosystem, it can be expected to hold true for all foragers, including humans past and present. This can be shown to be the case for ethnographically documented hunter-gatherers (Kelly 1983; 1995).

On a global scale, hunter-gatherer diet is known to be systemically related to the environment. Available plant foods decrease towards the poles and the hunter-gatherer use of plant food diminishes accordingly (Binford 1990; Kelly 1995). On the basis of contemporary hunter-gatherer datasets (Binford 2001), the amount of gathered food, which can be used as a rough proxy for plant food, for the boreal zone can be calculated to be generally below 30% of the diet (see **Fig. 3**). The rest of the food intake consists of foods hunted in either terrestrial or in aquatic environments. The ratio is not constant but situational, and foraging models predict

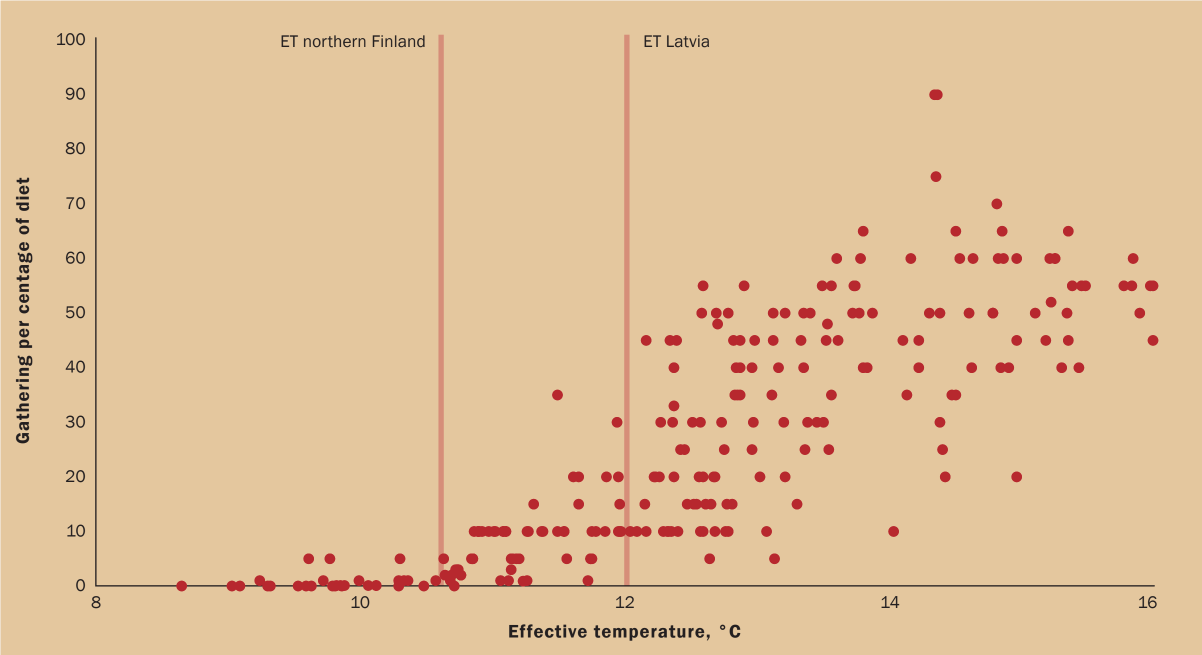

Figure 3. The relationship between effective temperature and gathered foods in the diet of ethnographic hunter-gatherers. Each red dot represents an ethnographic group. ET 8 = the poles, ET 10.6 = northern Finland, ET 12 = Latvia. Southern Finland is c. ET 11.9. Ethnographic data from Binford 2001: table 5.01; temperature data from Drebs *et al.* 2002.

diet composition change in relation to various factors, for example, resource availability (Kaplan & Hill 1992).

Early Mesolithic hunter-gatherers in north-eastern Europe subsisted heavily on large- and medium-sized terrestrial mammals. In the forested zone, European elk and beaver were the main prey species, and in the treeless zone in the north, reindeer were targeted (e.g., Jussila *et al.* 2007; Rankama & Kankaanpää 2008; Veski *et al.* 2005; Zagorska 1993; Koltsov & Zhilin 1999; Oshibkina 1997). The composition of terrestrial diets changed during the Mesolithic in the study area: the percentage of elk decreased in the refuse faunas, and the percentage of smaller mammals increased after the Early Mesolithic (**Fig. 4**). This implies that later foragers targeted elk less often and had a wider diet breadth than their predecessors in northern Europe. We suggest that this process was related to population growth in northern Europe (Hertell 2009; Tallavaara *et al.* 2010). Population growth reduced the amount of available habitats, restricted options for mobility and, therefore, generally diminished the size of the home ranges. Since large animals provide higher rates of return than smaller ones (Kelly 1995:Table 3–3; Ugan 2005), targeting elk in the Early Mesolithic, thus, probably provided higher average hunting returns from a terrestrial environment than did the fauna hunted in the later Mesolithic.

As illustrated in **Figure 3**, the average amount of gathered foods was *c.* 10% for the hunter-gatherers who lived in the areas that equal the area between northern Finland and Latvia. It is reasonable to assume that the percentage of plant food was also equal in the Early Mesolithic. If we assume that the non-plant food fraction of the diet was based on hunted terrestrial foods, we can then explore the size of the home range required by Early Mesolithic foragers.

The hunter-gatherer space requirement can be first illustrated by the Nunamiut case. With an estimated 90% terrestrial meat diet, the Mesolithic foragers' percentage of hunted foods approximates ethnographic estimates of the diet of the Nunamiut, who consume *c.* 87–89% terrestrially hunted foods (see Binford 2001: Table 5.01, Kelly 1995:Table 3–1). At first, it seems reasonable to note that the Nunamiut example is rather extreme when considering northern European Mesolithic foragers. This is suggested by the difference in the environment in which the Nunamiut and Early Mesolithic hunters lived. The late Preboreal environment in northern Europe was clearly more productive than that of northern Alaska. For example, the effective temperature values that approximate environmental produc-

Elk percentage			
	Meso 1	Meso 2	Meso 3
Russia, Ivanovskoje 7			
IF %	38	16	17
MNI %	10	6	5
Latvia			
IF %	92	77	21
Finland, coastal			
IF %	16	14	2

Figure 4. The percentage of elk bones in Mesolithic refuse faunas from Finland (burnt bone fragments), Latvia and Russia. The periodization is relative and as in original publications. IF = identified fragments, MNI = minimum number of individuals. Data from Zhilin *et al*. 2002; Zagorska 1993; Ukkonen 2001.

tivity fall below 10 for the Nunamiut home area (Binford 2001:Table 4.01). According to Heikkilä & Seppä (2003), the Early Mesolithic annual mean temperature in southern Finland was around 1° C, which translates to ET value of 11.1 (see Hertell 2009). This implies that survival by foraging required less space in northern Europe than in northern Alaska. The percentage of large terrestrial game in the diet of the Mesolithic hunters was probably smaller, as indicated by the refuse faunas in which beaver and other small mammal bones are common. This implies that there was less emphasis on large land mammals in northern Europe than among the Nunamiut. Despite this, the Nunamiut case provides an idea of the space that hunter-gatherers need and use.

According to Binford (2002:110), a Nunamiut group of five families resides on an area of approximately 5000 square kilometres during one year. Trips are made outside this residential core area, and the area exploited may total up to 25,000 square kilometres during one year. If we compare the size of this range to different areas of northern Europe, it can be seen that during one year a single Nunamiut band could have subsisted in and around the area of North Karelia in Finland **(cf. Fig. 2)**. Two such bands might have lived in Estonia and another two in Latvia, etc. A hypothetical Nunamiut group living in southern Finland, or in any other nearby area, then, would not have encountered Carboniferous or Cretaceous lithic sources during their annual trips.

To move beyond a single example, foragers' need for space can be studied through comparative animal ecology and ethnography. On the basis of the known correlation between animal body weight and home range size (Harestad & Bunnell 1979), Cashdan (1992:260) calculated the home range for a 65-kg hunter-gatherer. The predicted home range for a carnivorous hunter-gatherer with a diet of which more than 90% consists of meat, is *c*. 3900 square kilometres. From this, we estimate *c*. 97,000 square kilometres for a band of 25 persons. This size approximates the combined area of Estonia and Latvia, or with small additions, the area known as the Leningrad region (**Fig. 2**). This suggests that a home range of this size might just about be large enough to have provided Cretaceous flint from Lithuania to, for example, Pulli in Estonia or Carboniferous flint from Russia to Ristola, Finland but not both varieties of flint to southern Finland at the same time.

To evaluate the estimate derived from comparative animal ecology, it can be compared with ethnographic hunter-gatherer data. Kelly (1983) studied the relationship between diet and size of the home range and found that these are strongly correlated for hunter-gatherers. A linear model based on re-tabulated ethnographic datasets (Kelly 1995:Table 3–1, 4–1) gives the equation $\log_{10}y = 0.0282x + 2.0333$ ($R^2 = 0.5565$) for diet and home range size (**Fig. 5**).[3] From this we estimate a home range of 37,265 square kilometres for a group (25 individuals) with 90% hunted food in their diet. This implies that it is reasonable to question whether Early Mesolithic home ranges actually were of the magnitude of *c*. 100,000 square kilometres and extended from, for example, the Carboniferous formation to Finland.

Residential mobility

The shape and orientation of home ranges in the landscape can and do vary. Therefore, it is possible to explore the distances hunter-gatherers move inside their home range in another way. An increase in the dependence on hunted foods and in the associated range size will necessarily also increase the distances travelled in the course of residential moves. The total distance travelled during a year should, therefore, be a function of the percentage of hunted terrestrial food in the diet. This is illustrated in **Figure 6** for contemporary hunter-gatherers (Binford 2001:Table 5.01). It is possible to use this interdependence as a model for all hunter-gatherers.

[3] The original model ($\log_{10}y = 0{,}024x + 2{,}06$, Kelly 1995:130) gives 16 596 square kilometres, but it does not seem to agree with the original graph (Kelly 1995: fig 4-8).

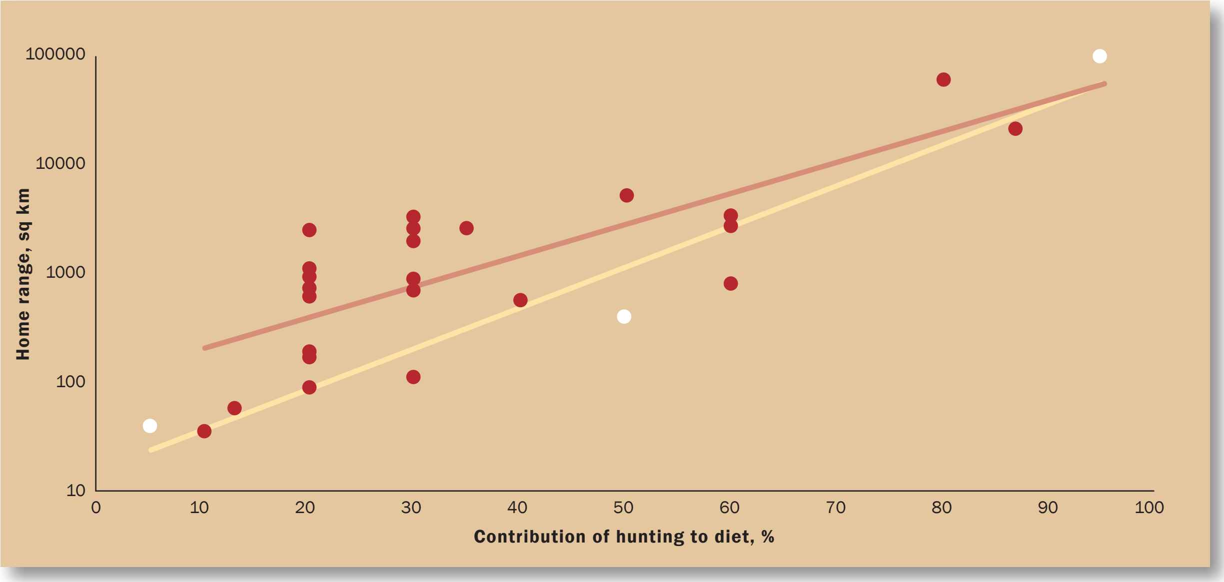

Figure 5. Comparison of diet and range size. White dots: range size estimates for a band of 25 hunter-gatherers (65 kg) based on Harestad & Bunnel (1979); red dots: ethnographic hunter-gatherer cases (Kelly 1995).

To study the relationship between the distances travelled in annual residential moves and the distances from flint source areas, we developed a simple model (**Fig. 7**). It illustrates the time needed to travel the distance from flint source areas to southern Finland in the course of annual residential moves by ethnographic foragers.

Of all of the non-mounted hunter-gatherers listed in comparative ethnographic datasets (Kelly 1995, Binford 2001), the Nunamiut travel annually the longest distance in the course of their residential moves (**Fig. 6**). Binford estimates the total distance travelled by the Nunamiut to be 806 km, while Kelly's estimate is 725 km. Therefore,

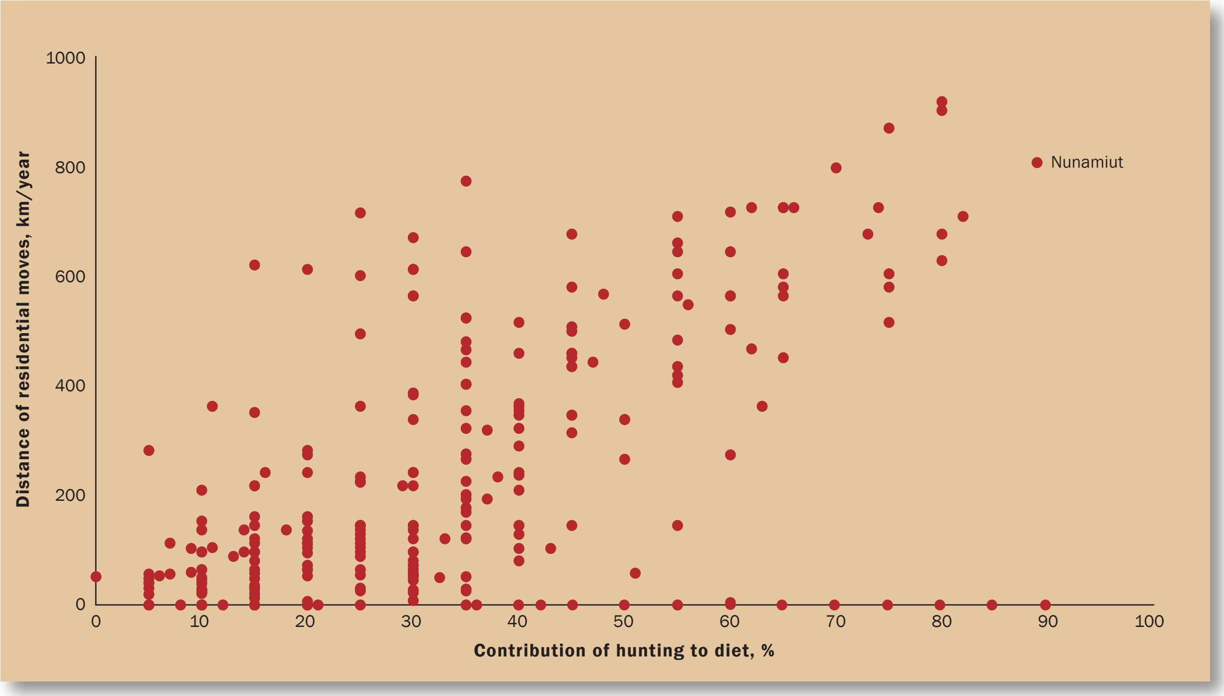

Figure 6. The contribution of hunting to diet (%) and the total distance of residential moves (km/year) for ethnographically documented hunter-gatherers. Data from Binford 2001.

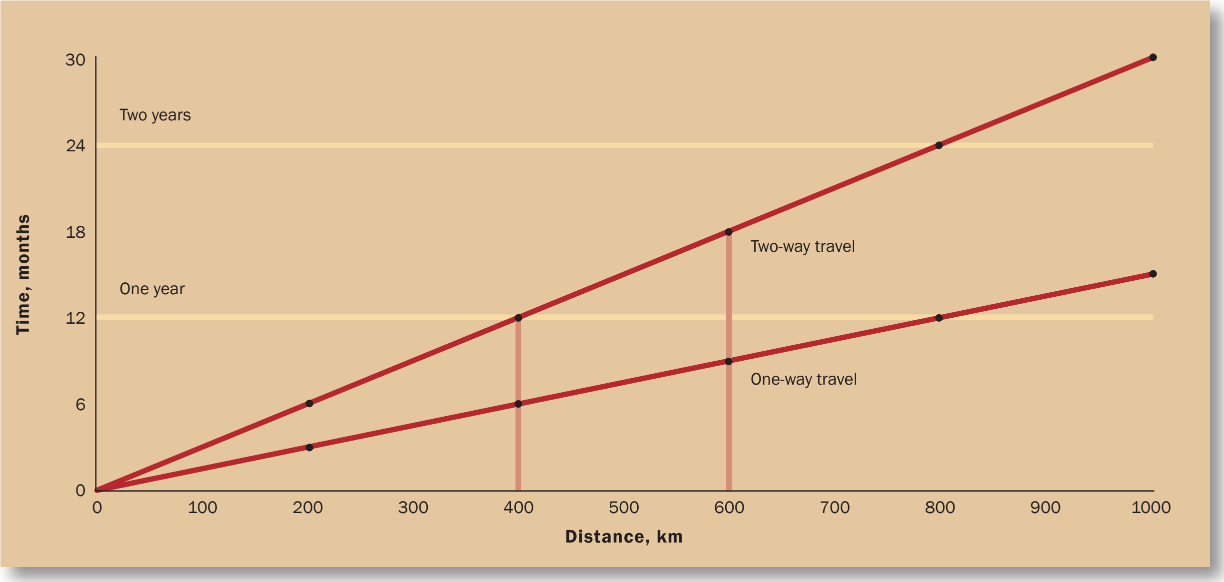

Figure 7. The time required to travel the distances from Carboniferous (400 km) and Cretaceous (600 km) formations to Ristola, southern Finland in the course of residential moves (residential speed 800 km/year).

of all of the non-mounted cases, the Nunamiut would take the least time to travel the distance from known flint sources to southern Finland in the course of their annual residential moves. By using Binford's estimate, we can determine the maximum speed (800 km/year) for our model hunter-gatherers (**Fig. 7**).

For the sake of simplicity, let us assume that southern Finland and a flint source were both within the same residential core area and, therefore, used within a hypothetical annual round by Early Mesolithic foragers. The closest Carboniferous flint sources to Ristola, for example, are c. 400 kilometres away. Cretaceous sources lie farther away and are located some 600 km south as the crow flies. As illustrated in the model (**Fig. 7**), if the Nunamiut equivalent model foragers started from these flint sources, they would travel 400 km in six months, assuming they were moving in one direction only. After this, they would still have another half a year to return back to the sources and complete their annual round, so to speak. If they started from flint sources that were even farther away, e.g., the source areas of Cretaceous flint, it would take nine months to get to southern Finland following a straight line. Naturally, it would take much longer if they did not follow the straight line, e.g., if they did not cross the Gulf of Finland.

As this model illustrates, the distance the model foragers travel in the course of their residential moves could just about take them to southern Finland from Carboniferous sources and back in one year. From Cretaceous sources, our model hunter-gatherers could not reach southern Finland and return in one year. Furthermore, to reach Finland, their residential sites should form a linear pattern. This seems an unlikely presumption for hunter-gatherers who lived in the late Preboreal environment, which was a mosaic of resource patches, rivers, and lakes, etc. The nature of the local geography and environment suggest that in southern Finland, the East Baltic, and adjacent areas of Russia, there was no large-scale zonation of resources. This implies that the settlement systems were unlikely to be like the ones documented for contemporary pastoral groups, with long annual shifts from one environment to another, e.g., from arctic coasts to forested inland areas. This lack of linearity in the settlement pattern is supported by the refuse faunas that show the use of a diversity of resources at many sites but little evidence for spatial patterns that could support distinctive environmental zones in the area (e.g., Koltsov & Zhilin 1999; Ukkonen 2001; Veski *et al.* 2005).

On the basis of the hunter-gatherer dataset (**Fig. 6**), it is possible to project additional paces for the model (**Fig. 7**). For example, assuming 100% hunted food, visual inspection of the graph (**Fig. 6**) gives a maximum total travel distance of around 1200 km a year. This is a very large increase (50%) with respect to the Nunamiut distance. With this maximum speed, the hunters would reach southern Finland in half a year if they started from Cretaceous sources and some months earlier if they started from Carboniferous sources. To summarise, an ethnographic dataset of contemporary hunter-gatherers that mirrors multiple physical and social environments indicates that the total travel distance of annual residential moves should not exceed this, and it is not easy to see a reason why prehistoric foragers might have deviated markedly from this pattern. However, this issue can be studied further in future studies, for example, by building separate models for the pedestrian foragers and hunter-gatherers who use other means of transportation, i.e., dog sledges or horses. By using these data, it should be possible to model residential mobility in varying situations and take into account the availability of resources, presence of competitors, etc. It suffices to say here that even with the maximum speed, it takes a relatively long time for our model foragers to reach southern Finland from the flint sources in the course of their annual residential moves. This has implications for the lithic collections that we will elaborate below in the lithic section.

If the exotic lithic materials found in Finland were personally and habitually procured by the inhabitants who resided in southern Finland, e.g., Ristola, then their annual range would have been much larger than that documented for the Nunamiut. A circular home range would have equalled the size of Estonia, Latvia, much of Lithuania or Belarus, Leningrad and Pskov regions, and parts of southern Finland put together (see **Fig. 1**). This means that the area would have totalled more than 400,000 square kilometres. This is more than ten times the size documented for the Nunamiut home range and many times larger than the areas documented for even the mounted foragers of other areas in North America. The area is also much larger than the prediction derived theoretically from comparative ecology i.e., 97,000 sq km. In principle, an elongated 1000-kilometre-long and 100-kilometre-wide stretch of land could be as large as the predicted home range, cover both flint formations and reach to southern Finland at the same time. However, a home range of this kind seems rather unlikely in the local environment, as discussed above. It is more likely that an elongated home range extending from the Cretaceous formation through the Carboniferous belt to southern Finland would have been somewhere between 200,000 and 400,000 square kilometres in size. Given the discussion on lifetime ranges of arctic hunter-gatherers it can be questioned whether most Early Mesolithic individuals living in southern Finland would have encountered both flint sources during their whole lifetime.

If these areas seem rather large, how large home ranges might the Early Mesolithic hunter-gatherers in northern Europe then have had? We suggest that the estimates derived from ethnographic data and comparative ecology give us a good framework and help to understand the magnitude of the Mesolithic home ranges in north-eastern Europe. Obviously, this discussion does not mean that some Early Mesolithic home ranges could not have been occasionally *c.* 100,000 square kilometres or larger, even though a few ethnographic cases imply it was unlikely. Nevertheless, the discussion above implies that we need theoretically strong and sound argumentation and detailed analyses of archaeological data to support ultrahigh mobility inside an enormous home range, which deviates from the ethnographic and ecological data, to explain the exotics in southern Finland.

Logistical mobility, scouting and journeys

Long-distance trips from base camps or beyond the residential core area are well known in the ethnographic record. For example, a combination of both ethnohistorical and archaeological data indicates that the North American Pawnee transported lithics hundreds of kilometres while on bison hunting trips (Holen 1991). Long-distance trips have also been proposed to explain the presence of exotics in southern Finland (Zhilin 2003). However, in the Early Mesolithic context long-distance hunting trips are not theoretically predicted. In the Early Mesolithic northern European boreal forest, the anticipated returns from hunting were likely to be relatively small. Even the highest ranked resources are found in relatively small aggregates. The main targeted large mammal species and probably the only one available at the time in southern Finland was European elk (see Rankama & Ukkonen 2001). Elk is found either alone or in small herds, and although the species is widely dispersed, the mosaic-like nature of the environment means that suitable patches to locate elk are found generally everywhere on a large scale.

From an evolutionary perspective, long-distance hunting does not represent good tactics in such a situ-

Borough	Site	Lab code	BP	Std	calBC (1 sigma range)	Median	Km	Flint
Orimattila	Myllykoski	Hela-552	9480	90	9119–8637	8829	218	No
Lappeenranta	Saarenoja 2	Hela-728	9350	75	8735–8490	8614	169	Yes
Joensuu	Rahakangas 1	Hela-882	9405	80	8787–8567	8693	300	Yes
Juankoski	Helvetinhaudanpuro	Hela-918	9200	75	8532–8306	8425	370	Yes
	Pulli	TA-245	9600	120	9183–8823	8987	0	Yes
	Veretye I	Le-1469	9600	80	9173–8837	8995	0	Yes
	Baseline	Combined	9600	67	9158–8837	8995	0	

Figure 8. Earliest dates from selected Early Mesolithic finds from southern Finland, Estonia and Russia (**see also fig 9**). Dates are calibrated using OxCal4.1 and IntCal09 calibration curve (Bronk Ramsey 2009; Reimer *et al*. 2009).

ation. The longer the distance, the higher the travel and transportation costs, and inversely, the closer to home the hunting took place, the higher the total efficiency, all else being equal. This implies to us that long-distance hunting is unlikely to explain Early Mesolithic exotics in southern Finland. In the future, we need to attempt to model logistical mobility in relation to residential mobility and address questions such as: how long distances were beneficial to travel for hunting purposes, and how might these trips have enhanced fitness in the Early Mesolithic context. It is reasonable to suggest that as the population density in relation to available resources was relatively sparse in the Early Mesolithic, the options to move around were not restricted by the presence of other groups (see Kelly 1995). Given the small number of human foragers, the availability of high-ranking food patches was relatively high. Therefore, mobility is likely to have been organised around residential mobility, as predicted by the marginal value theorem (Charnov 1976; Hanski *et al.* 1998), rather than long-distance logistical trips from more stable residential camps. Therefore, we suggest that Early Mesolithic hunter-gatherers made frequent residential moves, spent only a relatively short time in a patch, and used only a fraction of the resources available in the patch in contrast to their successors. This should be readily detectable in the archaeological record.

Related to the special long-distance logistical trips, it is worth considering scouting activity and journeys beyond the home range. Information and knowledge of new areas and environments helps in planning the future and, therefore, reduces uncertainty and makes life less risky. From an evolutionary perspective, this means that it is worthwhile to invest time and energy to gain experience and information of new areas. To understand the role of scouting activity in relation to the spread of exotics, we need to address the magnitude and the effects of this kind of mobility. If exotics begin to be increasingly found in most or many early sites, as it now seems, scouting activity may not be a good basis for explaining the exotics. Furthermore, if the sites that contain exotics are separated by hundreds of years, as it now seems, the scouting of uninhabited land may not be a good explanation (see **Fig. 8**). If scouting was the cause for the exotics, one would expect to see relatively homogenous site assemblages, for example, a small number of raw material varieties at each site. These sites can also be expected to have sparse distribution over the landscape. These are the results of small parties of hunter-gatherers scouting the vast areas and carrying around a minimum amount of tool stone to minimise travel costs.

Special long-distance journeys to visit other groups might leave another kind of sign in the archaeological record. For example, Boas (1964:167) remarks that the Central Eskimo journeys may cover 800 km back and forth. These trips would be long enough to spread exotic materials to camp sites far away from the sources, for example, to southern Finland from a Carboniferous formation. Furthermore, a long-distance journey offers a physical mechanism for the movement of exotic stone between parties living far away from each other. This may lead to site assemblages where a small amount of exotics is found among a larger set of local lithic materials. However, special journeys alone cannot explain why the exotic lithics in Finland are found at the earliest sites, and we need a mechanism that can explain the beginning and the end of the spread of flint at the same time.

Migration and long-term mobility

Direct migration as a main distributive mechanism behind the exotics in Finland is favoured in many discussions reviewed above. If we simplify, two options for human dispersal into Finland exist: the colonisation was either a slow process in which new areas were gradually settled, or it involved long-distance migrations northwards from flint source areas to form new home ranges. The former case could have been possible in the course of long term mobility as home and lifetime ranges gradually shifted towards the north. The migration hypothesis put forth to explain the exotics implicitly suggests the latter. As we will elaborate below, the high mobility hypothesis implicitly argues that the pioneers must have migrated long distances very quickly without depleting their flint tool kits.

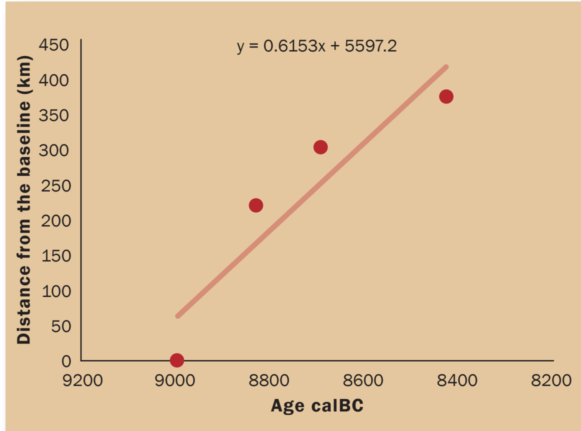

Figure 9. Analysis of colonization front line speed in southern Finland (y=0.6153x + 5597.2). Data from Carpelan 1999; Pesonen 2005; Takala 2004.

Modelling hunter-gatherer migration to an unknown destination obviously does not match any historic case, but ethnographic data can, nevertheless, be utilised to learn about the colonisation process. As noted above, it is possible to break migration down to residential moves. If we take the Nunamiut residential mobility speed as the maximum migration speed, we can make an educated estimate about the pace of the migration and compare this to other data. As illustrated in **Figure 7**, our model foragers travel from Carboniferous flint areas to Finland in six months and from southern to northern Finland (c. 1000 km) in 15 months. On an archaeological time scale, this means that all of eastern Fennoscandia was colonised simultaneously. Currently, the dating evidence does not support this. Carpelan (1999) estimated, on the basis of the known radiocarbon data, that the colonisation frontline speed would have been 0.69 km per calendar year. We retain the original baseline through Pulli and Veretye I to estimate the distances for the new site and radiocarbon data and to update the frontline speed for southern Finland (**Fig. 9**). By fitting a linear trend line through the series of earliest calibrated dates (per area), the frontline speed becomes about 0.62 km per year. This gives 14 kilometres in a generation (20 years). This slow frontline speed suggests that dispersal was a relatively slow process, possibly through the gradual adjustment of home ranges and/or the movement of the younger generation to new areas to form new bands.

It follows from the slow frontline speed that if exotics were related to the earliest phase of dispersal, these were unlikely to be distributed through direct migration from flint areas. In this context, it may not be accidental that the Orimattila Myllykoski site, the earliest currently known site in southern Finland, has not produced exotic lithic materials (Takala 2004:149–150). Clearly, the frontline speed itself tells little about the actual way individuals move. New waves of long-distance migration that have followed, or jumped over the initial frontline, can be a mechanism that explains the slow frontline speed and the exotics as well.

In southern Finland, the dated Early Mesolithic sites that contain flint fall c. 200 years apart (**Fig. 8**). If migration brought the exotics to southern Finland, these data mean that the known Early Mesolithic flint exotics cannot result from a single migration but must be the result of several individual long-distance migrations. Possible further evidence for long-distance migration comes from northern Finland. Rankama and Kankaanpää (2007:57; 2008:896) suggest that the material from Sujala site from northern Finland implies the migration of a group over long distances, i.e., a thousand kilometres in a generation. If Sujala and southern Finnish flint sites are evidence of long-distance migration, it means that new migration waves followed each other and that these gradually went further and further by jumping over the earlier frontline.

Which one of the polarised alternatives approximates the prehistoric reality? Was the colonisation the result of a slow adjustment of the home ranges in the frontline or the result of multiple long-distance migrations? Evolutionary theory offers a reason and argumentation for both views. Habitat selection models, e.g., the Ideal Free Distribution model, predict that the most productive patches should be selected first and the others filled up in diminishing order (Hanski *et al.* 1998). Therefore, these models predict the spatial and temporal structure of the dispersal process. As individuals are free to position themselves in the landscape in relation to resources, the move into a new area should occur when the foraging returns in the old environment have fallen below what can be expected to be found in the new environment (plus costs of the move). From this it is possible to deduce both the close-range movement and the long-distance migration. It is possible to argue that foragers moved to new areas slowly because the general direction of the colonisation was towards the north, i.e., away from the most productive environments. Therefore, it was beneficial to move short distances only. It is also possible to assert that new uninhabited areas that lacked other foragers had higher productivity-to-consumer ratios, and therefore, it was beneficial to migrate from far behind the existing frontline. The new areas would then provide higher returns and benefits than the old one. In the future, this issue can be addressed through systematic modelling to understand the effects of different variables on hunter-gatherer decision-making to move to new areas.

If the exotics in southern Finland and the Sujala technology in northern Finland were to be explained by long-distance migration, then it obviously should have been quite common. This leads to archaeological implications that can be tested to a degree. Given the short discussion on Ideal Free Distribution, the migrations should have led to a systematic and patterned formation of the archaeological record, i.e., the exotic raw materials from different geological formations should be distributed to different areas and show evidence of zonation in the direction of colonisation: for example, Cretaceous flint in Estonia and Latvia (e.g., Pulli, Zvejnieki), Carboniferous flint in southern Finland, Paleozoic flint in Central Finland and so forth. This is a logical deduction from the general logic of the evolutionary argument and of the habitat selection models. This can be tested through future field and analytical work.

Lithic evidence

Theory of raw material procurement, reduction and curation

Understanding lithic reduction is essential to understand the spread of exotic raw materials into southern Finland. Because flintknapping is a reductive process, the available piece of flint becomes smaller and smaller every time it is being worked. Therefore, in general, it can be expected that the farther away from the source areas the foragers move, the smaller their supply of flint becomes, and because of this, the smaller the cores, blanks and tools become. This has been shown to be true in many empirical cases. Munday (1979) demonstrated this in Middle Palaeolithic Negev, Israel (also Marks *et al.* 1991), and Newman (1994) found that flake volume and thickness correlated negatively with distance to raw material sources in the North American Southwest.

To fill up lithic stock, new raw material must be located and procured. If the hunter-gatherers were highly mobile and had large ranges through which they moved frequently, then lithic assemblages should mirror these areas to a degree. For example, during the hypothetical moves between central Russian flint areas and southern Finland, there would have been a need to add to the decreasing tool stone stock. As a consequence, new raw material varieties would have been procured along the way, and the percentage of these would have increased in the supply at the same time as Cretaceous and Carboniferous flint decreased. Ingbar (1994) provides a good simulation study on how proportions of different raw materials in archaeological assemblages vary in relation to different lithic sources used during the annual round. A nearby archaeological example can be found from Late Mesolithic northern Lapland, where hunter-gatherers moved between coastal zone and inland and raw materials were flowing between these areas (see Manninen 2009). In our case, the varieties of Paleozoic flint from Latvia, Estonia, or Russia, must have been present in tool kits when the foragers ended up in Finland. If they started from the Carboniferous or Cretaceous source areas, the other varieties of raw materials should also be much more numerous in the assemblages in Finland, as the last were procured from sources closer to Finland than the first. Furthermore, at the turning point and during the return trip to flint areas, the raw material supply would have been augmented with quartz and other local materials. For example, moving away from southern Finland the amount of quartz at the sites gradually decreases as new local raw materials are encountered and procured along the way. Paleozoic flint procured, for example, from the Pskov's region ends up in Valdai area sites and so forth. The systematic presence of different raw materials in southern Finnish sites is central to testing the hypothesis of high mobility – be it residential, logistic, or migration – between the flint areas, i.e., the Carboniferous and Cretaceous formations, and southern Finland. Therefore, the high mobility hypothesis argues that *flint from sources closer to Finland will be more common here than flint deriving from farther away, all else equal*.

Lithic tools, retouched or not, wear out relatively quickly. Therefore, they need to be sharpened constantly to keep the edges functional. As each sharpening action removes material, the size of the piece gradually diminishes. Consequently, most chipped lithics last for a relatively short time, i.e., minutes, hours, or, at most, days, after which they need to be replaced. For hunter-gatherers who habitually depend on lithic materials, the chipped lithic tool use-life can be expected to be relatively short. Ethnographically, archaeologically and experimentally documented cases support this (Frison 1968; Odell 1980; Shott 1989; Hayden 1979). As documented in ethnographic studies, obsidian hide scrapers, for example, are known to have been sharpened every few dozen or hundred strokes and may have lasted no more than an hour or two (Clark & Kurashina 1981; Gallagher 1977; Håland 1979). In a similar fashion, lithic projectiles do not last long and are literally disposable. In experiments, some projectiles have penetrated as many as 12 animal targets, but they may well break on the first shot (Odell & Cowan 1986; Frison 1989:771). Shott (2002) found the mean number of firings for a projectile to be 3–4.

This has obvious implications for the organisation of lithic technology. As stone tools wear out relatively quickly, they must be maintained and repaired, and new tools must be made constantly. It is evident that the further the hunter-gatherers move from the flint sources, the smaller the primary products they produce must become. Accordingly, to anticipate and compensate for the diminishing raw material stock and blank size, curation of tools is likely to occur. In other words, the use-life of existing tools is increased by re-sharpening the tools over and over again. There is very good reason to suspect that in areas far from good raw material sources, curation is likely to be much more extensive than in areas where flint is readily available. Thus, we should see a marked difference in tool reduction intensity between the flint areas and southern Finland and between material derived from distant and not-so-distant flint sources.

Each technology has its own features and attributes that are best suited for measuring and analysing reduction and curation. In the north-east European Early Mesolithic context, cores were regularly maintained by the removal of core tablets and by platform trimming (e.g., Burov 1999; Rankama & Kankaanpää 2008; Koltsov & Zhilin 1999). This means that core and blade size, especially the length, will depend on the distance to the source area. This will also affect the tools made on blades, which can be predicted to be smaller in Finland than their counterparts closer to the flint source areas. This effect is further strengthened by the increased attempt to lengthen tool use-life by sharpening and reshaping them. The differences in the lithic artefacts can be observed by examining the dimensions and the mass of the flint tools. End scraper length in particular can be expected to strongly depend on the availability of flint. In Early Mesolithic north-eastern Europe, these should be useful measures, together with the other ones cited above, to study reduction and distribution mechanisms.

To summarise, two implications are clear. First, if flint and tool kits were carried along with highly mobile individuals from flint source areas to Finland, flint material, if present this far, should be highly reduced and curated. This means that both primary products and secondary products should be the smaller the longer the distance from the lithic source. Second, on the way towards Finland, there was a need to add to the decreasing tool stone stock that was carried along. As a consequence, new raw material varieties were procured along the way, and the percentage of these increased in the supply at the same time as, for example, the amount of Cretaceous and Carboniferous flint decreased. The varieties of Paleozoic flint, from Latvia and Estonia, for example, should have been present in tool kits when the foragers ended up in Finland. If they started from the Carboniferous or Cretaceous source areas, the other varieties of raw materials should also have been much more numerous in the assemblages in Finland, as they were procured from sources that were closer than the others. At the turning point and during the return trip to flint areas, the raw material supply was filled with quartz and other local materials. Consequently, the archaeological lithic assemblages in and around southern Finland should be systematically structured as discussed above.

	Cretaceous	Carboniferous
Total artefacts	45	270
Blade / retouched blade	2 / 12	30 / 37
Blade / flake	14 / 11	67 / 170

Figure 10. Ristola flint data. Data from Takala 2004:Fig 109.

Evidence for raw material procurement

The Ristola flint assemblage is so far the only relatively large collection of Early Mesolithic flint from one site in Finland for which published data exist. It consists of 315 flint artefacts, though lithics altogether total more than 58,000 artefacts (Takala 2004:Figs. 65, 84, 106). The site is large (several hundred metres long) and includes material and radiocarbon dates from several different periods (Takala 2004). Furthermore, field ploughing has affected site formation by mixing layers at the site (Takala 2004). The problematic history of the Ristola site – the possible presence of flint artefacts from different periods, the high prehistoric use intensity implied by the large lithic collection, and the later ploughing – complicates the use of the site material in studying the spread of exotic raw materials to Finland.

The reported flint material varieties at Ristola derive from two major geological formations, Cretaceous and Carboniferous flint, but no flint from the closer Paleozoic sources present, for example, in Estonia, has been reported (Takala 2004:107–109; Kinnunen *et al.* 1985:50). These determinations are based on the microfossil content of flint. Two blade arrowheads made of a sandstone-resembling raw material of unknown origin (Takala 2004:101) may suggest a spread of raw materials from sources other than the Cretaceous or Carboniferous ones. At the Helvetinhaudanpuro site in eastern Finland, a single flake, which is one of six pieces found at the site, resembles the Paleozoic material from Estonia, and a single piece has also been reported from Kuurmanpohja in south-eastern Finland (Jussila *et al*. 2006:58; 2007:150, 157). In general, the available data from Finland are, therefore, in gross contradiction with the high mobility hypothesis and its implications on raw material procurement discussed above: Paleozoic flint is practically nonexistent, although it should be strongly present.

This either means that no raw material was procured in the area between southern Finland and the Carboniferous or Cretaceous flint belts or that no movement between these areas took place. The latter seems a more likely explanation, given the discussion above concerning mobility, lithic use-lives, and the data we have from Finland, Estonia and Latvia. The fact that local lithic material, mainly quartz, was used heavily in Finland at the Early Mesolithic sites (Jussila *et al.* 2006; 2007; Takala 2004) implies that local materials were considered suitable, accepted, and commonly used in general. Although the Paleozoic flint may have been of lower quality than Carboniferous or Cretaceous material, its properties were clearly much closer to those of these flint varieties than quartz, and therefore, it was better suited for the required tasks and the existing hafts. This predicts that Paleozoic flint should have been on the list of used materials and, therefore, that this material should be present in southern Finland, too. Furthermore, local Paleozoic flint was used at the Early Mesolithic Pulli site in Estonia and at the Zvejnieki II site in Latvia (Jaanits 1990:7; Zagorska 1993:102) at the time colonisation reached southern Finland. It was, thus, generally known and used by Early Mesolithic foragers in the area.

The absence of Paleozoic flint in Finland implies that flint did not end up in Ristola with immigrants from Estonia, as suggested by Edgren (1984) and Takala (2004), nor is it likely that that the immigrants came from any area where Paleozoic flint material was readily available. That the flint material found at Ristola was not brought from the south, i.e., Estonia, is further supported by the data on the ratios of Carboniferous and Cretaceous materials found at the site and what is known from other sites in neighbouring countries. For example, in Estonia, at the Early Mesolithic Pulli site, Cretaceous flint is well-represented and forms approximately two-thirds of the material, whereas Carboniferous material is scarce (Jaanits 1990:7; Jussila *et al.* 2007:157; Zhilin 2003:691). This is in contradiction to the ratios found at Ristola, where Carboniferous flint predominates (**Fig. 10**), and it contradicts the earlier arguments (Edgren 1984; Takala 2004) that immigrants to Ristola came from the south.

The nearly complete absence of Paleozoic flint reported thus far from sites in Finland does not support high residential or logistical mobility between the Cretaceous and Carboniferous flint areas and southern Finland either. Furthermore, in the Carboniferous areas of the Upper Volga region in Central Russia, the sites contain little if any Cretaceous flint (Zhilin 2003). The same applies to quartz in sedimentary rock areas. For example, at the Pulli site in Estonia, the proportion of quartz is very small: only 0.7% (Jussila *et al*. 2007:159). To us, this implies that the home ranges were not large enough to cover, for example, both the Cretaceous and Carboniferous belts. This also provides an archaeological estimate of Early Mesolithic home ranges in north-eastern Europe that is in line with the above discussion concerning the predicted home ranges. It seems that Early Mesolithic home ranges in general were not large enough to reach southern Finland from Lithuania, central Russia, the area south of Lake Onega, or even from the Paleozoic zone. However, not all of the data agree with this. The common presence of Cretaceous flint at Pulli is best explained through personal procurement and, therefore, through high mobility. It is unlikely that exchange or trade could explain the presence of this flint at Pulli. Relying mainly on trade to achieve the major part of the lithic materials that are needed and used everyday would not be a good strategy for mobile hunter-gatherers. Cretaceous flint at Pulli suggests that some home ranges extended 300 to 400 kilometres north from the Cretaceous flint sources. The size of these areas may have been somewhere around 60,000 to 80,000 square kilometres (300–400 x 200 km) in size.

To keep things simple, we have not discussed core efficiency and core use-lives here but simply assumed them to be constant. In reality, core efficiency affects core use-lives and, therefore, affects the formation and nature of archaeological lithic assemblages. Elsewhere we suggest that the conical core reduction strategy was preferred by mobile hunter-gatherers in the area and that this affected assemblage formation (Hertell & Tallavaara, *this volume*). To make large conical cores on the small Paleozoic material may not have been a viable option, and large nodule size may have been preferred. Furthermore, mobile hunter-gatherers elsewhere preferred high-quality lithic materials (Amick 2002; Hofman 1991). In the present context, this might denote the preference for good-quality and large-nodule-size Carboniferous or Cretaceous flint over the Paleozoic material. This complicates model building and suggests that the flint material ratios found in southern Finland need not be linearly related to raw material proximity. Nevertheless, travelling hundreds of kilometres from the Carboniferous or Cretaceous formations means that the original cores would have been heavily reduced by the time hunter-gatherers were in the Paleozoic zone. Thus, there was a need to fill up the lithic stock carried along, and this affected lithic assemblage formation and raw material proportions, as Pulli demonstrates. The current non-existence or low proportion of Paleozoic lithic materials from southern Finland is contrary to the expectations of high mobility.

Evidence for reduction and curation

The issue of southern Finnish exotics can also be approached through the study of reduction and curation. If the proposed route for flint through Estonia were correct, then the minimum distances from both source areas, i.e., the Carboniferous and Cretaceous formations, to Ristola would be around 600 km. This suggests that the reduction intensity, on average, should be similar for the two flint varieties. Our analyses, however, suggest that this is not the case.

The Ristola material shows that the reduction intensity of the flint varieties at the site is related to the linear distance to the flint source. This is supported, first, by a simplistic proxy, i.e., the absolute amount of flint. The amount of Carboniferous flint that originates from sources that are closer to Ristola than the Cretaceous sources is higher in the assemblage (**Fig. 10**). The same results are also seen in the relative ratios of blades to tools, blades to flakes and for tool sizes. These mirror core sizes and curation, and therefore, distance to the sources. For Cretaceous flint, the blade/retouched blade ratio (specified tools excluded) is 2/12, whereas for Carboniferous flint, the ratio is 30/37 (Takala 2004:Fig. 109). Clearly, a relatively larger amount of blades/fragments of Cretaceous flint are retouched and, therefore, are more curated than ones of Carboniferous flint. The same also applies to the blade and flake ratios. For Cretaceous flint the blade/flake ratio (specified tools excluded) is 14/11, whereas for Carboniferous flint it is 67/170.

Data on tool size further suggest that Cretaceous flint came to Ristola along a longer path than did Carbon-

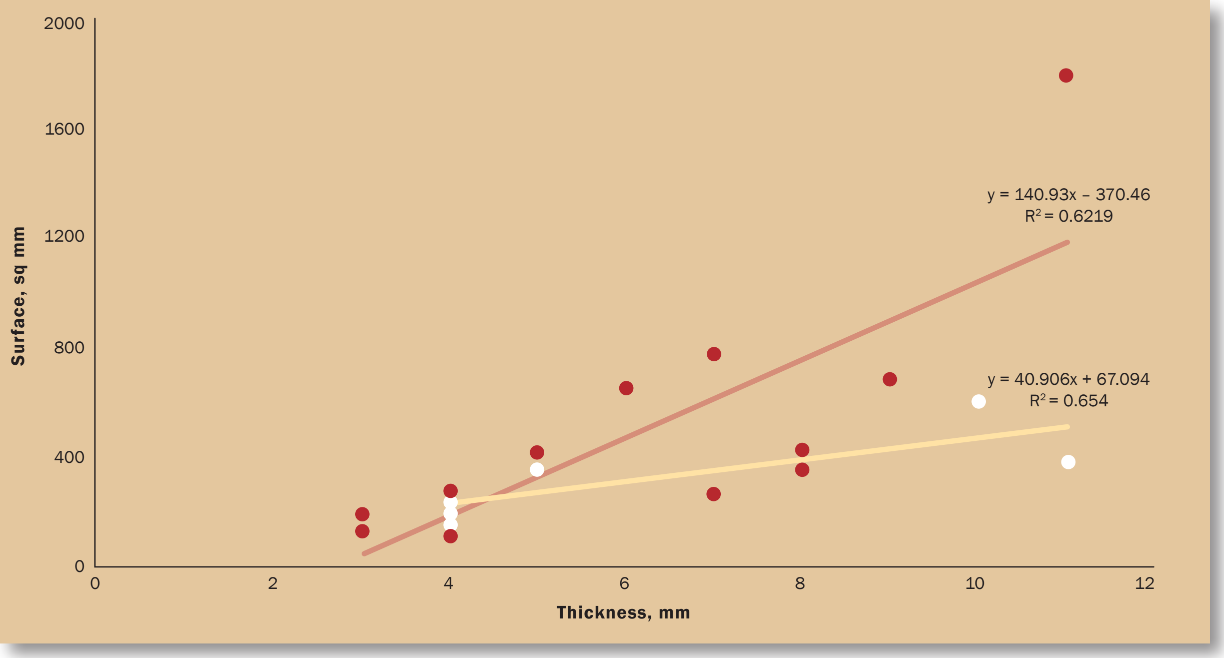

Figure 11. Reduction analyses of Ristola flint scrapers. Red =Carboniferous (n=14), white =Cretaceous (n=6). Data from Takala 2004: Figs. 130, 138.

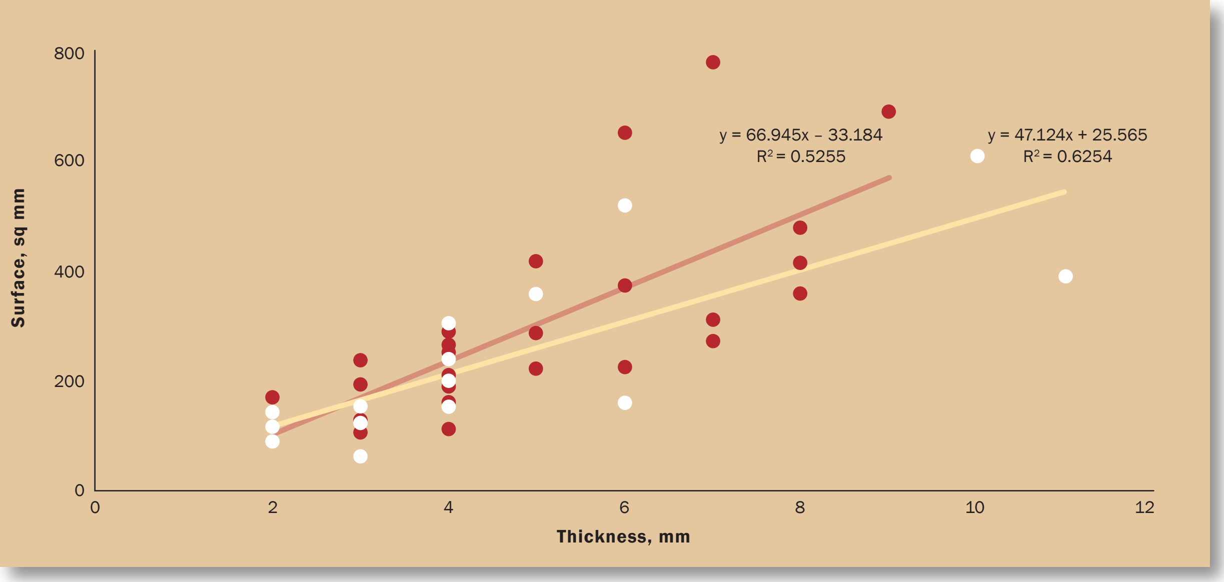

Figure 12. Reduction analyses of all tools (arrowheads and inserts excluded) from Ristola. Red =Carboniferous (n=28), white =Cretaceous (n=15). One large Carboniferous outlier excluded. Data from Takala 2004:Figs. 126, 130, 132, 136, 138.

iferous flint. The measure of reduction and/or curation is dependent, as expected, on the raw material variant and its relative distance to the geological formation. For all tools, the surface-area (length x width)-to-thickness ratio is higher for Carboniferous than for Cretaceous tools. The same applies if the scrapers are examined separately (**Figs. 11, 12**). All of the above figures suggest that Cretaceous flint had a longer distance to travel to Ristola than did Carboniferous flint. This is the result of the natural raw material distribution in relation to the site and implies that the routes along which the flint material was brought to Ristola were different and variable. To summarise, there are currently no data to support the argument that both Carboniferous and Cretaceous flint came to Ristola from the south, i.e., through Estonia.

Little comparative data suitable for studying lithic reduction and curation exist in the monographic treatments of the north-west Russian Mesolithic (e.g., Koltsov & Zhilin 1999; Oshibkina 1983; 2006; Sorokin 2006). Oshibkina has made comparative data on blades and scraper size in Veretye I available (Oshibkina 1997). At Veretye I, the blade-to-retouched-blade ratio is clearly higher than the ratios at Ristola (**Fig. 13**). Not surprisingly, the general availability of flint around Veretye I resulted in less intensive use and curation of blades compared to Ristola.

Metric values of scrapers are given for Veretye I type 1 scrapers, i.e., round scrapers (Oshibkina 1997:61). It is reasonable to suggest that the retouched round scraper form developed, at least in part, under an intensive reduction regime (e.g., Dibble 1995). This means that type 1 scrapers are likely to be more heavily reduced and, therefore, smaller than other scraper types. Nevertheless, it is a proper proxy for scraper and tool size in Veretye I.

In comparison to Ristola, the Veretye I scrapers are clearly larger. Approximately 73 percent of the Veretye scrapers are larger than 25 mm in maximum size, whereas at Ristola, most scrapers and other tools are smaller than 25 mm in size (**Fig. 13**). This implies that the overall reduction intensity was higher at Ristola. This difference is emphasised when considering the argument above that Veretye type 1 scrapers are more intensively reduced than other scrapers. The comparison between Ristola and Veretye I suggests that the artefacts of exotic raw material found in Ristola are heavily reduced and curated. This fits the high mobility model but need not contradict exchange.

Blades		
	Veretye I	**Ristola (specific tools excluded)**
Not retouched	1183	32
Retouched	129	49
Ratio	9.2	0.7
Scrapers		
	Veretye I (type 1)	**Ristola (all scrapers)**
20–25 mm	150	15
25–35	290	4
35–60	119	1

Figure 13. Comparison of Veretye I and Ristola blades and scrapers. Data from Takala 2004; Oshibkina 1997.

We suspect that not all flint was equally distributed. A pattern that sheds light on the distribution is found at Central Russian Butovo Culture sites, i.e., on and around the Carboniferous formation. Single regular blades, inserts and especially symmetric arrowheads of Cretaceous flint are found at Belivo 4a, Kurevaniha 5, Pekunovo, Prislon 1, Sukontsevo 3 and Zaborovje 2 (Zhilin 2003:690). This hints at a mechanism for the distribution of arrowheads and, especially, arrowheads of Cretaceous flint in north-eastern Europe. Zhilin (2003:692) has suggested that the exotics at Butovo sites were either exchanged or part of the tool kits that were carried along while hunter-gatherers moved around in the area but favours the latter option. We suspect that if this was the case, the Butovo Culture assemblages should also show evidence of heavily curated tools of Cretaceous flint, especially scrapers and other multifunctional tools, rather than only regular blades, inserts and arrowheads of high symmetry. It seems to us that the presence of Cretaceous arrowheads at Ristola and at Butovo Culture sites is better explained by the selective exchange of specific artefacts, e.g., hafted arrowheads and inserts, and symmetric blades for their production. The pattern seems to indicate that special artefacts were flowing from Cretaceous areas to the north and north-east. It suffices to say here that there must be a reason for the emerging distribution pattern of exotics. The high quality of Cretaceous flint is undoubtedly an important factor to be considered to understand the reason for exchange. However, given the fact that many of the artefacts were projectile points with short use-life and the fact that the flint was exchanged to areas where high-quality flint was readily available, the physical quality of the flint itself may be of relatively little importance. We suggest that it is not unreasonable to argue for social causes of exchange. Whatever the case, the above and other similar unexpected patterns can be utilised to refine our understanding of the flint distribution mechanisms and the exact way transfers took place when more data become available from other sites in the future.

Evidence for the raw material variability and intrasite spatial distribution at Ristola

At Ristola, the spatial distribution of flint is a further key to understand the site and its assemblage formation. Schulz (1996) observed that the flint material was distributed over a long stretch of the Ristola site. Judging by the data on find distributions (Takala 2004), exotic finds are spread over an area that covers 50–100 x 50 metres. This fits well with the reported raw material diversity, which is very large given the small size of the flint assemblage. Of the two major exotic raw material groups present at Ristola, Carboniferous and Cretaceous flint, the flake category alone (181 pieces) can be further separated into at least 17 different minor raw material varieties (Takala 2004:113, Fig. 106). This means that the material represents at least 17 different cores and, therefore, at least 17 individual knapping sequences. On average, this makes a very small amount of debitage per raw material variety (315/17). Other published Mesolithic flint collections in Finland parallel the Ristola case. In Helvetinhaudanpuro, all six pieces of flint seem to be made of different materials (Jussila *et al.* 2007). At the Syväys 1 site in eastern Finland, the flint material of eight blades, for which a general Mesolithic date can be suggested, is diverse, and all of the blades are made of different raw materials (Hertell & Manninen 2006:42). We suggest that the available data on Mesolithic flint at these sites suggest gradual accumulation.

For example, in the Ristola case, we suggest that the flint was not discarded at the site during one occupational episode. Rather, it seems that the site was used repeatedly, e.g., once a year as a part of an annual round, or over a number of decades, and this gradually resulted in the deposited flint assemblage. This explains the diversity of the lithic raw materials and their wide distribution and low density at the site. Together with what has been discussed earlier, this means that local groups that lived in southern Finland occasionally received small amounts of flint, possibly not every year or even every decade but over a few decades or a few hundred years. They used this material within the local settlement system. Some of the material was left at Ristola, and other pieces were left at other sites, residential or logistic; it is this slow process of accumulation that explains the assemblage characteristics. In a strict sense of the word, the Ristola flint material, therefore, is not an assemblage but a slowly accumulated collection of items separated by long periods of time.

These hypotheses can be tested by nodule analysis (Larson & Kornfeld 1997; Tallavaara 2005), systematic refitting and analyses of intrasite spatial patterning at the Ristola and at the other Early Mesolithic sites. These methods should allow us to have good control on the formation of the sites and the site assemblages. On a larger scale, we need published and quantified data on raw material surveys from different geological areas to understand the natural lithic raw material distribution, availability, patchiness, predictability of locations, nodule size and quality, and so forth. It is acknowledged that major differences exist between different areas and that these differences have affected the organisation of the lithic technologies in the area (e.g., Koltsov & Zhilin 1999; Kriiska *et al. this volume*). We also need tests on the mechanical properties of different varieties of flint, e.g., from a flintknapper's perspective, and further geochemical sourcing of archaeological collections (e.g., Matiskainen *et al.* 1989; Galibin & Timofeev 1993). These data should allow for systematic modelling to understand lithic preferences, reduction strategies, and the whole organisation of lithic technologies. We recognise that these are integral to the study of the spread of exotics and the whole colonisation process in north-eastern Europe.

Summary of lithic evidence

Based on the above discussion on the Ristola lithic assemblage, it seems reasonable to conclude that the material was unlikely to have come to the site with individuals who personally procured it from the source areas. The material gives little support to the argument that immigrants from the south brought the material with them. Migration can explain the Carboniferous part of the flint assemblage, but this would mean that the source areas should be found east of Finland, where Paleozoic flint is not available, or possibly south-east, where it was possible to traverse the Paleozoic zone quickly without procuring local Paleozoic flint. However, high mobility, either through migration or some other form, is a poor explanation for the presence of all of the Ristola exotic material as explained above in detail. Instead, we suggest that the exchange of lithic materials and tools between several parties and different regions is a more elegant explanation for the Ristola material.

Exchange explains why lithic material at Ristola is highly variable, originates from two distant geological formations, and represents several individual nodules and, therefore, multiple cores and knapping episodes. In addition, exchange explains why the Ristola flint material composition differs from that of the Central Russian and Estonian sites. Furthermore, exchange explains the observed ratios of reduction and curation in the lithic data, although high mobility is not counter-indicated by these. Cretaceous flint came from longer distances and from a different direction than Carboniferous flint. However, the exchange network *per se* does not explain why the presence of exotics seems to be related to the colonisation phase. We now turn to discuss a mechanism of Early Mesolithic exotic distribution and its diachronic patterning.

From high mobility to gift exchange – case "breeding population"

From an evolutionary ecological perspective, fertility and mating are essential for theory building, and the number of surviving and reproducing offspring is commonly used as a measure of fitness. Fitness or evolutionary success is known to be density-dependent (the Allee effect in ecology, Stephens *et al.* 1999). During dispersal, population density was probably very low, and this has implications for archaeology. A small population density is a threat to both survival and reproduction. A small number of individuals means that although individuals of opposite sex are available, many of them may be too young or too old or already have spouses. Another result of the slow growth rates that characterise populations with small numbers of individuals is that in the beginning, many individuals are closely related, e.g., they are genetically separated only by a few generations, if any. This can lead to problems especially if cultural mating taboos are in operation. Therefore, a small number of individuals denotes a high risk that no spouse can be found at all, and the possibility to reproduce is severely threatened. To overcome these situations, mates need to be sought over wide areas, and energy needs to be invested to attract and secure a mate.

MacDonald and Hewlett (1999) studied population density and mating distance and found that these are inversely correlated (y = -8,5659Ln(x) + 27,362, r=0.92, n=11): the higher the density, the shorter the mean distance between mates. The minimum estimates for North American Late Pleistocene and European Upper Palaeolithic population densities are of the magnitude 0.3–0.07 individuals per one hundred square kilometres (Bocquet-Appel *et al.* 2005:Table 5; MacDonald 1998:Table 3). It is reasonable to assume that the Early Mesolithic population densities in the present case were not smaller than this. If we use the model of population density and mean mating distance, we can estimate Early Mesolithic mean mating distances. Assuming that population densities were of the magnitude 0.01, the model gives rather modest mating distances that are below 100 km.[4] MacDonald and Hewlett's (1999:Fig. 6) data also show that the maximum mating distance can be four times the mean distance, as it is for the Agta. This suggests that maximum mating distances could have been considerable, possibly 200–300 km, in Early Mesolithic northern Europe, too.

For a hypothetical Nunamiut equivalent group residing in southern Finland, e.g., in and around Ristola, this suggests that the mean mating distance extends to Estonia and the Leningrad region. Most mates would have come from a person's own and neighbouring groups. This is also what Rogers (1969), for example, found for the Cree-Ojibwa in the Canadian East Arctic, where most incoming spouses came from neighbouring groups. Some, however, would have found spouses from much farther away; in our case, for example, from the Pskov region or East Karelia.

From an evolutionary perspective, it is good to search for mates over long distances, not just in order to locate one, but because mating distance increases fertility. Labouriau and Amorim (2008), for example, found that human fertility increases with marital distance and reduction in inbreeding. It is likely that in the Early Mesolithic, reduction in inbreeding and, thus, an increase in fertility was best achieved when mates were received from long distances. Increasing distance, however, will also increase the cost of searching and attracting mates or simply maintaining contacts with a possible mate pool. Therefore, it is reasonable to expect that there should be a point after which increasing distance will no longer increase fertility as fast as the costs will rise. For example, the data from contemporary Denmark (Labouriau & Amorim 2008:Fig. 1, 2) show that growth in fertility decreases markedly when mating distance exceeds 20 km. At the same time, the size of the area, and related costs, will increase exponentially. It can be expected that

[4] In the original model, increasing population density leads to a situation in which mating distance becomes negative. This suggests that the model does not give proper estimates for high population densities. Low-population-density distances, however, also give somewhat unrealistic values. See Riede 2009:Fig. 2.4 for an application of the data.

in archaeological cases, this threshold should be visible if gifts are exchanged between the groups.

As females are typically the limiting factor in reproduction, the female choice of mates can be considered to be important in this context. Furthermore, the sex ratios in Early Mesolithic contexts may have enhanced the role of females as the limiting factor, when measured by the sheer number of individuals of opposite sexes. Hewlett (1991) found that with increasing male contribution to the diet, the juvenile sex ratio was increasingly biased in favour of males, probably due to different investment on children. It is not unlikely that this was the situation in the Early Mesolithic, too. Sex ratios from the Mesolithic Olenij Ostrov cemetery in Russia support this (adult male/female ratio 1.34) (Jacobs 1995:376; see also O'Shea & Zvelebil 1984:25). If the juvenile sex ratio is not stabilised during maturation, by the time reproductive age is reached the excess of males will create a competition for females. From an evolutionary perspective, an uneven sex ratio is an unstable situation, to which males needed to respond. Low population density combined with biased sex ratios can be expected to lead to very high investment in searching, attracting and contacting potential mates. This may result in archaeological manifestations.

MacDonald (1998), for example, has suggested that Folsom hunters travelled long distances to find mates and maintain social networks, and this explains the presence of exotic stone at some sites in North America. Assuming similar personal lithic procurement and transportation in the present case should lead to a situation in which raw materials mirror, to some degree, the mate search area. As most mates are typically found within a close range and the percentage of marriages decreases with distance, explaining southern Finnish Carboniferous and Cretaceous exotics by mate search mobility is equally as problematic as the other mobility options discussed above. If this mechanism were to explain the presence of exotics in southern Finland, Paleozoic flint from, for example, Estonia should be markedly present in southern Finland, as this is the area were most spouses would have been acquired.

In the following, we build a simple and general model on this basis to explain the appearance and the disappearance of exotic materials in Early Mesolithic southern Finland. This should be understood as an alternative model that currently explains better the existing archaeological record of exotics than the mobility models discussed above. In the following formulation, we define a breeding population as a group of individuals that has the opportunity to mate with each other.

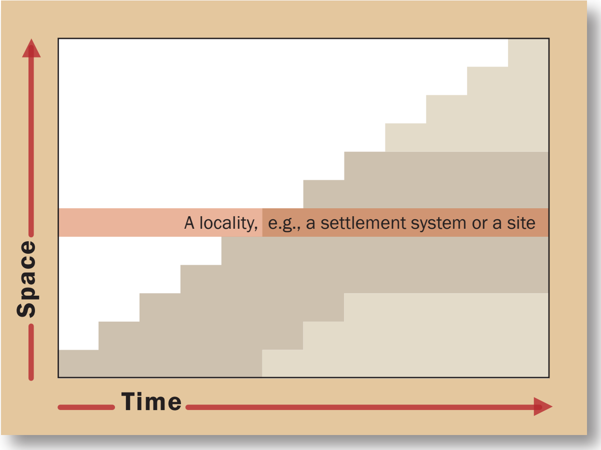

Figure 14. A time-space model of changes in the breeding population cover deriving from proceeding colonisation, seen from the perspective of a locality. White = uninhabited, light grey = populated areas, grey = breeding population.

Initial model building – breeding population characteristics

Let us assume, for the sake of simplicity, that population density and the size of a breeding population are constant. Let us further assume that a breeding population is a closed system that will form between interacting individuals and, therefore, those who live next to each other. Given these assumptions, from the perspective of the frontline pioneers, the spatial location of the breeding population will shift in concert with the proceeding colonisation (**Fig. 14**). The individuals of the pioneer frontline are always on the outer zone of the breeding population, and they must maintain contacts with groups behind the frontline. This is not the case for the individuals in the backlines. This is best illustrated by thinking of the location, e.g., the site, the river valley, the home range, etc., in which an individual lives. As colonisation proceeds, the location will first be on the frontline, but later, as the front line proceeds beyond the location, it becomes surrounded by a resident population. Therefore, the geographic position of the potential breeding population for individuals living in the location will change over the course of time.

The same result as above is achieved even if population density is not constant but is allowed to vary (**Fig. 15**).

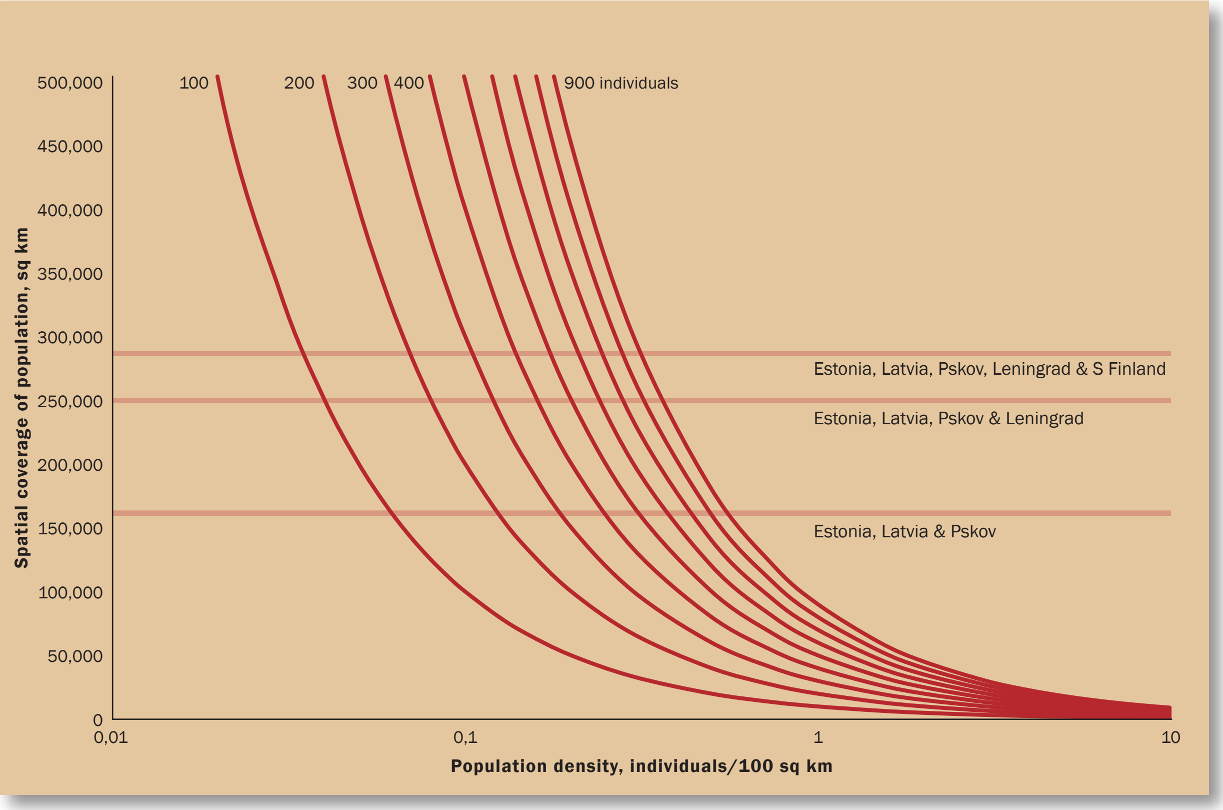

Figure 15. Relationships between population density, breeding population size, and its spatial extent.

It is likely that during dispersal population density is lowest at the pioneer frontline. As population density grows after the colonisation of an area, the spatial extent of a breeding population will diminish. Although fluctuations in population density are likely to have occurred, in the long-term, prehistoric populations must have grown to survive. This means that the spatial extent of a breeding population of a constant size will diminish in time. In reality, there is no need for the breeding population to be of a constant size, nor a closed unit, as real life examples inform us that this is not the case. Nevertheless, it can be argued that the simple model captures the essence of reality accurately enough and, therefore, does what models do: it helps us to understand how the world functions.

Incorporating variation in the model – risk and foraging returns

When we explore only the availability of spouses, there is no mutual interest between the frontline pioneers and the backline groups in mating. The former do have the need to maintain contact with the latter to secure mating opportunities, but the opposite is not true. From the backliner's perspective, potential spouses are available in all directions. If this mechanism alone were operating in the population, the archaeological signature would be different from a situation where further factors were added to the model. To build a more realistic model, we explore other factors that affect the selection of a spouse than the general availability of potential mates. One thing can be considered essential for the model presented here: the potential gain would have been higher after moving into a new area than it would have been if the group had stayed in the old area.

Moving into a new environment can be highly risky if no prior knowledge about the environment and the resources, animal behaviour, water sources, etc., exists. In this context, we define risk to be *uncertainty of future foraging returns* and further define *uncertainty* as variance. Higher risk must always come with higher potential benefits; otherwise, no one would ever venture to move into a new area. In the present case, the risk involved in migration was not very high. This is due to the structure of the Late Preboreal environment in north-eastern Europe.

The local environment is and was patchy. It repeats itself over and over again on the landscape. When pioneers arrived in a new area, specific information, e.g., on animal paths, nests, etc., was not available, but the general structure of the environment remained much the same. The kinds of patches where, e.g., European elk or beaver, water fowl, etc., were likely to be found were well known, as they remained the same from area to area. Furthermore, as the frontline proceeded slowly, i.e., around 14 km in a generation as discussed above, on average, new areas came to be inhabited relatively slowly. The colonisation of north-eastern Europe, thus, was slow enough for the environment to remain sufficiently similar from one generation to the next for all of the culturally learned behaviours to be applied in full suit in each new area. As long as the general concepts of how to cope in the environment are mastered, the specifics of localities can be learned quite quickly. This is familiar to those who fish, pick berries, gather mushrooms, etc.

Incorporating variation in the model – sexual selection

It follows from the above discussion that one option for the backliners was to actively seek to benefit from the higher return rates in the newly inhabited areas. One solution was to marry frontliners. Evolutionary theory suggests that an individual should select a spouse who maximises his/her fitness. Those mates who are better able to contribute to the support of offspring, e.g., provision food to offspring to secure their survival and growth, should be selected over others. It would have been possible for the backline females to benefit from the higher foraging returns of the males in the frontline. By selecting a male who could produce higher-than-average energetic returns from foraging, it should have been possible for a female to optimise her evolutionary fitness. For males, other options were available, e.g., the possibility to migrate to a new home range, where higher-than-average potential returns could be expected with subsequent results. For example, Kaplan and Hill (1985, also Hill & Hurtado 1996) found that more efficient Ache hunters had more surviving offspring, and Bailey (1991) showed that efficient Efe hunters are also wealthier than others and that this is positively correlated with their marital status.

Furthermore, other forms of selection may operate at the same time. As the frontline pioneers are likely to be closely related as cousins, aunts, uncles, etc., to some of the backliners, kin selection can further help to refine an evolutionary explanation for the contact network in north-eastern Europe. Members of close kin can, among other things, seek a suitable partner for their frontline relatives and help in mating over large land areas. Gradually, over the course of generations, the effect of kin selection should lessen due to the genetic separation of the groups, and, accordingly, the contact network should gradually shrink and cease to function. In other words, this leads to the same results as those of the simple model discussed above (**Fig. 14**).

Summarising breeding population model expectations for archaeology

We assume that a breeding population, i.e., social network, was formed between individuals and groups that could benefit from being part of the network, as explained above. The system of exchange was embedded in these social relations, and the social relations functioned to help mate search and acquisition. Therefore, the exotic lithics and other perishable materials were the by-products of these relations, and the material goods, ideas, etc. flowed through the network from one group to next. However, gift-giving itself may have also played a more active role, especially in the Early Mesolithic when cohesion between individuals was beneficial in mate acquisition. When population density is very low, the potential mate pool covers enormous areas. For example, a group of 500 persons covers 500,000 square kilometres at a density of 0.1 ind/100 sq km. This approximates the size of all of modern-day Finland and Russian East Karelia put together (**Figs. 2, 15**). Travelling over such large areas frequently to, for example, have large seasonal aggregations is costly. Through gift-giving, it was possible to create obligations, enhance reciprocity, and build alliances to increase cohesion between individuals and families (Mauss 1990; Sahlins 1972).

In the earliest phase, when the population density was low and home ranges were large, the chain of groups between southern Finland and Cretaceous and Carboniferous formations was relatively short. Consequently, exotics spreading from these source areas reached southern Finland through only a few hands. From the perspective of the foragers living in southern Finland, proceeding colonisation gradually made it possible to acquire spouses from all directions. Increasing population density and decreasing home ranges increased the amount of links in the chain between southern Finland and Cretaceous and Carboniferous formations. Therefore, the probability of exotics spreading to southern Finland decreased with time.

From an archaeological perspective, the area where exotics end up on archaeological sites will change over the course of time. With time, the distance the exotics travel from their sources decreases as the population grows or as colonisation proceeds and the breeding population position changes. Therefore, the early sites of a specific archaeological research area are expected to contain material derived from farther away than are later sites. In other words, sites closer to the specific source of a given raw material received exotics over a longer period of time than sites that were situated farther away.

At archaeological sites, exotic materials are expected to be highly variable, as they originate from different sources and areas. In addition to exotic lithics, we expect refuse faunas to contain relatively high amounts of high-return-rate species in the early phases of colonisation. This is best studied location by location or by comparing contemporaneous backline and front-line locations.

Furthermore, we want to stress that the breeding population is not meant to be a general explanation. Instead, it is a situation-specific tool especially suitable for understanding the archaeological record in a low-population-density demographic situation. If it was a standard explanation, for example, in Finland (with a standard breeding population size), we should expect to see highly variable breeding population areas during the Stone Age. If, as many have suggested, archaeological materials, e.g., Stone Age pottery styles, were only related to ethnic groups that formed breeding populations, then we should expect to see the smallest spatial extensions of pottery styles during the mid-Holocene population peak (Siiriäinen 1981b; Tallavaara *et al.* 2010). The situation is clearly not so as quite the opposite is true. However, we argue that the low-population-density models are reasonably well grounded for exploring the colonisation situation in archaeology in general. On a very general level, therefore, our model agrees with Zhilin's (2003) distributive mechanism.

Final conclusion

We have discussed different variables of mobility within the context of the north-east European Mesolithic in an effort to understand how exotic lithic materials arrived in southern Finland and why they subsequently disappeared from the archaeological record. To summarise, it can be said that both theoretical arguments and the available archaeological data imply that Early Mesolithic flint was not distributed to southern Finland through population mobility. It is reasonable to say that few, if any, prehistoric foragers used the whole region covering southern Finland, Lithuania, and Central Russia during their annual cycle and that the emerging archaeological pattern of exotics in southern Finland is not the result of residential mobility inside a home range. In a similar fashion, logistical mobility seems an unlikely cause for the spread of exotics to southern Finland. Long-distance migration can be a mechanism that explains part of the exotics, but this must have originated from areas where Carboniferous flint was locally available and where Paleozoic flint was not encountered; this means areas south-east or east of Lake Ladoga. Currently, there is no evidence of migration from the south, i.e., Estonia, to southern Finland in the exotic lithic record.

In the case of the Ristola site, however, migration cannot explain all of the exotics, unless we assume that more than one migration from different regions reached the same site. Instead, we suggest that gift exchange explains the archaeological record better. The system of exchange was embedded in the social relations between individuals who formed breeding populations. The proceeding colonisation and population growth explain why the exchange network diminished in its spatial extent and why flint is mainly found on the earliest sites.

In the future, we will need both theoretical and practical work to understand the exotic distribution mechanism as part of the human dispersal process in northern Europe. We do not argue that the past hunter-gatherer land-use systems were analogous to that which is ethnographically documented but maintain that these data offer a way to understand hunter-gatherer life in Mesolithic northern Europe. We also suggest that there should be an attempt to build systematic theories of how the exotic spread and colonisation of northern Europe took place, instead of inconstantly adopting ideas to produce a mixed set of arguments. In this paper, we have discussed the issue from the evolutionary ecological perspective. We believe that the study of dispersal has huge potential and is one branch of archaeology where data from Finland and their careful analysis can significantly contribute to hunter-gatherer anthropology world-wide.

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