Our grandfather sent the elk – some problems for hunter-gatherer predictive modelling

Unser Großvater schickte den Elch - Zur Problematik einer Vorhersagemodellierung von Jäger-Sammler-Kulturen

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Abstract - The paper discusses problems related to the use of predictive modelling as a means of locating/mapping of hunter-gatherer sites. From a management point of view the method is seen in some sectors as a cost-effective alternative to the use of expensive remote sensing and physical survey methods, as well as traditional fieldwork. Where the method is itself being developed to cope with an increasing spatiotemporal resolution of the basis data employed, a couple of central problems are highlighted relating to the underlying assumptions in the approach.

Whereas a stable environment with stable resources is generally assumed, the reality is that natural environments are normally highly dynamic with significant variations on a year to year basis for some species. Furthermore, natural environments – even under constant conditions – develop over time through a series of ecological phases moving in the direction of stable 'climax biotopes', until they burn/break down again. The term for this is 'ecological succession'.

Another important assumption is that hunter-gatherer cultures will behave similarly in similar environmental situations. It is argued that this is far from the case. Hunter-gatherers seem generally to have many different subsistence strategies to choose from and different groups/cultures do not appear to make similar choices in similar situations.

A very basic assumption is that hunter-gatherers are 'passive' users of their environment. This paper argues on the basis of ethnographic and archaeological data, that extensive and systematic resource manipulation must be assumed to have taken place at least back into the Mesolithic and possibly earlier, and this was to such a degree that distinguishing it from what is perceived as Neolithic economy may be problematic.

The conclusion reached here is that predictive modelling of prehistoric hunter-gatherer cultures can be used to distinguish types of typical settlement locations characterised by observable features that are stable over longer periods of time. However, the large number of settlements located relative to naturally fluctuating or artificially created resource concentrations will tend to avoid detection by this method. The main emphasis should therefore be on the spectrum of complementary methods available in management-based survey as well as on research based reconnaissance.

Zusammenfassung - *Das Papier diskutiert Probleme der Nutzung einer Vorhersagemodellierung (prädiktive Modellierung) als Mittel zur Lokalisierung und Kartierung von Jäger-Sammler-Fundstellen. Aus haushaltspolitischer Sicht wird dieses Verfahren in einigen Bereichen als eine kostengünstige Alternative zum Einsatz von teureren Fernerkundungs- und/oder geophysikalischer Untersuchungsmethoden sowie zur traditionellen Feldarbeit angesehen. Das Verfahren selbst wurde entwickelt, um anhand eines erhobenen Datenbestandes eine möglichst weit reichende raumzeitliche Auflösung bei der Auswertung zu erreichen. Dabei sind aber einige zentrale Probleme bei den Grundvoraussetzunge dieses Ansatzes zu berücksichtigen.*

Während dabei im Allgemeinen eine stabile Umgebung mit stabilen Ressourcen vorausgesetzt wird, bildet in der Realität dagegen eine hochdynamische natürliche Umgebung mit erheblichen jährlichen Variationen die Lebensgrundlage für viele Arten. Zudem verändert sich - selbst unter konstanten Bedingungen - die natürliche Umgebung in einer Abfolge ökologischer Phasen über die Zeit hinweg - auch nach zwischenzeitlichen Zusammenbrüchen in einem stets wiederkehrenden Prozess in Richtung eines stabilen 'Klimaxbiotops'. Dieser Prozess wird auch "ökologische Sukzession" genannt.

Eine wichtige Voraussetzung ist weiterhin, dass sich Jäger-Sammler-Kulturen bei gleichen Umweltbedingungen stets gleich verhalten. Dieses ist aber keineswegs immer der Fall. Jäger und Sammler scheinen im Allgemeinen zwischen sehr verschiedenen Subsistenzstrategien wählen zu können, so dass verschiedene Gruppen / Kulturen in ähnlichen Situationen nicht immer vergleichbare Entscheidungen treffen müssen.

Eine weitere wichtige Grundannahme ist, dass Jäger und Sammler "passive" Nutzer ihrer Umwelt sind. Die Auswertung ethnographischer und archäologischer Daten zeigt aber, dass eine umfangreiche und systematische Manipulation natürlicher Ressourcen spätestens in der Mittelsteinzeit, möglicherweise aber bereits sehr viel früher einsetzt. Deshalb muss eine Abgrenzung von dem Konzept einer neolithischen Wirtschaftsweise als problematisch angesehen werden.

Die Schlussfolgerung ist, dass eine prädiktive Modellierung prähistorischer Jäger-Sammler-Kulturen verwendet werden kann, um verschiedene Arten typischer Siedlungsstandorte zu unterscheiden, die durch nachweisbare und über einen längeren Zeitraum stabile Merkmale gekennzeichnet sind. Allerdings wird die relative Lage vieler Siedlungen an natürlich schwankenden oder

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künstlich geschaffenen Ressourcenkonzentrationen tendenziell durch diese Methode jedoch nicht erfasst werden. Deshalb sollte das Hauptgewicht auf ein breites Spektrum komplementärer Methoden gelegt werden, die sowohl in denkmalpflegerischen Voruntersuchungen als auch wissenschaftlichen Projekten enthalten sind.

Keywords - neolithisation, resource manipulation, subsistence strategies, controlled burning, ethnoarchaeology
Neolithisierung, Manipulation der Ressourcen, Subsistenzstrategien, kontrolliertes Abbrennen, Ethnoarchäologie

Introduction

If powerful resource location models can be developed then cultural resource managers could use them as planning tools to guide development and land disturbing activities around predicted archaeologically sensitive regions. This planning potential of predictive models can itself represent significant cost savings for governmental agencies.

(Kvamme 1990: 289)

Predictive modelling appears to be a cost-effective and thereby attractive way of obtaining information about the location of possible prehistoric settlement zones for the purposes of research and cultural heritage management. Due to their attractiveness to cultural heritage managers, archaeology is under pressure to substitute expensive field survey with cheap desk-top methods of this kind which may even result in the mounting of fewer expensive excavations (e.g. Kamermans 2007). As these developments affect the data available for research, and probably also the accepted methodologies for research-based surveys, it is important to clarify the scope and potential of the modelling approach.

In order to address the complexity of long-term prehistoric/environmental developments, predictive models have recently been developed which differentiate between various chronological phases and, accordingly, cultural phases exhibiting different behaviours (Brandt et al. 1992). Despite possible developments in the methodology it seems relevant to question whether such an approach, in its essence, is able to deal with satisfactory precision with the fluid and flexible cultures who based an important part of their economy on hunting and gathering. A central assumption behind this approach is that such cultures adapt spatially to the landscape they operate in (its topography, resource distribution, soil variation, hydrology, etc.) and recent work on the subject accepts the necessity of employing landscape/environmental data of relatively high spatiotemporal resolution (Bettinger 1980; Kamermans 2007). This is consistent with the generally accepted idea in archaeology that hunter-gatherers exploited the 'un-manipulated and relatively stable' resources of their 'pristine' environments, in contrast to Neolithic cultures that, to a major extent, relied on manipulation of their environment and its resources (Madsen 1987; McCormack 1977).

The increasing awareness that prehistoric hunter-gatherers were also capable of significantly manipulating the resources in their environment, and probably did so to a great extent (e.g. Christensen 1997; Hather 1998; Innes et al. 2010; Selsing 2010: 27-24, 271-300), creates an apparent problem relative to the previous, and in this perspective 'naïve', approach to their resource-based spatial behaviour. This paper discusses first the dynamics of natural resources and accordingly hunter-gatherer resource manipulation in an ethnographical/archaeological perspective. On that basis it outlines the consequences for predictive modelling. Ethnoarchaeological data used in the text, that are not covered by references result from the authors own fieldwork record.

Background

'Establishment' Anthropology is 'the purveyor of a myth,' to borrow from Murphy (1971: 153), about hunters and gatherers, agriculturalists and pastoralists. Basically, this anthropological myth holds that there are essential differences between food collectors and food producers in every aspect of culture, from the degree of control each has over the environment to the social structure and psychology of each. These distinctions will be elaborated below. As products of western European cultures and their New World offshoots, anthropologists express as theory a way of viewing the world that seems to derive from the Judaic-Christian tradition underlying their cultures. For this discussion, there are three revealing stories or myths that relate to anthropological interpretations, those of Adam and Eve and their ejection from the Garden of Eden, of Cain and Abel, and of Esau and Jacob.

(McCormack 1977)

Despite the numerous indications that resource manipulation played an important role in recent and prehistoric hunter-gatherer societies, these cultures are still generally seen in archaeology as exploiting the resources of 'pristine', 'un-manipulated' and rather 'stable' environments – in contrast to Neolithic cultures which 'manipulated' their environments (e.g. Madsen 1987; McCormack 1977). During my fieldwork with the Evenk hunter-gatherers in Siberia I began to grasp the fact that these people possessed a dynamic understanding of their environment

comparable to that of modern ecologists (e.g. Odum & Barrett 2005: 224-335). They understood well the many general and local fluctuations that the various populations in their eco-system were subject to and were able to incorporate these oscillations into their highly flexible planning. They were, furthermore, able to manipulate their system's resources to their own advantage to a degree that made them look unpleasantly Neolithic from an archaeologist's point of view. What made it difficult, in some cases, for an outsider to understand what was going on was that, lacking a scientific terminology, they enveloped it in a 'spiritual' one.

In one case we recorded, the Evenk apparently created an artificial local overpopulation of elks (*Alces alces*) – by killing their natural predators in a river zone, resulting in the surplus population from this zone being pushed into the 'hinterland'. This then allowed the group to hunt elk in the hinterland during the winter – their main hunting season – when under normal conditions there would have been no elk and very little other game (e.g. Grøn & Turov 2007). On two of my visits to the hinterland zone they were extremely proud because they had killed an elk just before we arrived (they had been informed in advance over their VHF radio that we were about to arrive). They stated directly that 'normally' there would have been no elks there, but that their 'grandfather' had sent both of them. Their grandfather was the clan's old shaman who, at that time, lived in a village more than 100 km from the camps we visited in the taiga. At a small party in his house in the village I later had the opportunity to ask him if he really had sent the elks. The modest old man smiled and admitted that he had done so. "When one has guests, one must ensure they have plenty of food!" I was beginning to understand that an important part of a shaman's function was to keep track of all temporal-spatial variations and oscillations of the different populations in the environment and, on this basis, to serve as the central 'advisor' in the clan's planning of its economic activities within its territory (Grøn 2011). But it only recently dawned on me that this kind old man was the 'master-mind' behind the successful strategy which had brought elk to a non-elk zone and that, consequently, their very revered old shaman actually was the one who had 'sent them'. He had knowledge which made it possible for him to design strategies for resource manipulation. It was this that the proud hunters tried to communicate to thick-headed old me.

Because of the nature of this observation I checked it with a goup of Karasjok Sami who are reindeer pastoralists but also active elk hunters. They did not find the strategy employed by the Evenk the least strange, but immediately accepted it as 'the only right thing to do'.

My observations in Siberia of smaller and more significant hunter-gatherer resource manipulation – have made me aware that the Evenk possess an ecological knowledge which facilitates significant resource manipulation if this is what they need or desire. Furthermore, the available literature points out that we must accept such a capability as part of the 'hunter-gatherer package'. Consequently, a number of archaeological assumptions and methodological approaches – such as predictive modelling of hunter-gatherers' settlement locations – are in need of re-assessment.

The dynamics of un-manipulated natural resources and their exploitation patterns

The dynamics of natural resources

Whereas the environmental focus of predictive modelling seems generally to be on topography, soil types, hydrology etc., animal populations and the vegetation are normally modelled in very general terms and are conceived as quite stabile. In reality they represent highly dynamic factors that must be assumed to have influenced significantly the use of the landscape by prehistoric hunter-gatherers. We are here dealing with changes which could be of a very short duration and will therefore not be detected by a modelling approach differentiating between a few chronological phases, such as that suggested by Brandt et al. (1992).

Modern ecology describes and attempts to develop precise models for the complex temporal and spatial oscillations of the various animal and plant populations forming the ecosystems. These oscillations reflect different controlling factors for the different populations and can therefore result in highly complicated total resource patterns (e.g. Bjørnstad et al. 1999; Bode & Possingham 2005; Odum & Barrett 2005: 246-255; Vandermeer 2006).

In the Evenk, the subject of my studies, the shaman (who normally strongly emphasises his own function as an 'observer of nature') is able to follow these complex patterns and, on this basis, intuitively predict in detail the local resource configuration within the clan's territory for the coming year. Those of the clan's hunters best suited to the different types of hunting and trapping can then, year after year, be assigned to areas where their skills can be employed optimally (Grøn 2011). In a generally bad elk year, the family of a good elk hunter can be relocated in an area with good opportunities for winter fishing etc.

Many resources have highly discrete distributions and are not as evenly distributed in the environment as site-catchment analyses are, in practice, often forced to assume due to lack of precise information (Jarman et al. 1972; Odum & Barrett 2005: 258-260; Roper 1979). Squirrels in Siberia, in areas of rather open forest (taiga), prefer certain types of tall trees which often occur in small detached concentrations in the landscape. Elks prefer rivers and lakes: In summer they dive in search of waterweed, in winter they prefer

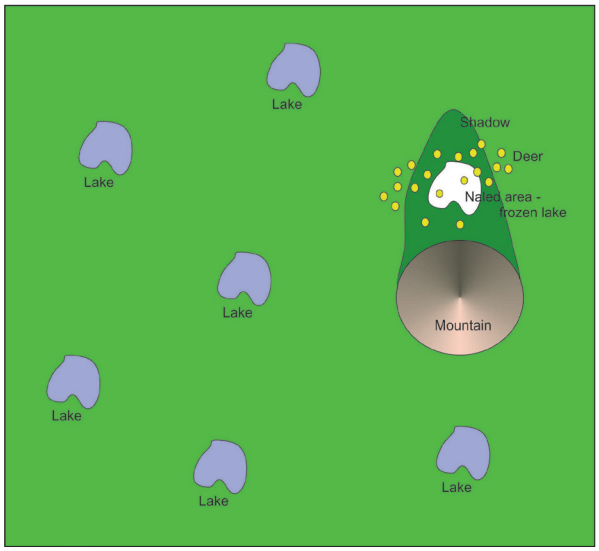

Fig. 1. Illustration of how reindeer (yellow dots) in permafrost landscapes with lakes during the summer will congregate where the shade from mountains maintains naled areas (lakes and rivers frozen to their bed) until August/September and appear in surprisingly small amounts in other areas with good reindeer pastures.

Abb. 1. *Die Grafik zeigt, dass sich Rentiere (gelbe Punkte) in Permafrost-Landschaften mit Seen während des Sommers vor allem in Gebieten versammeln, in denen Flüsse und Seen im Schatten der Berge bis in den August/September eingefroren bleiben (naled areas), während sie in anderen Gebieten mit ebenfalls guten Rentierweiden nur in überraschend geringen Mengen auftreten.*

the willow twigs growing in moist areas in the immediate vicinity of these water bodies. Because reindeer have serious problems with the mosquitoes in summer they will – if such are available – concentrate around the 'naled areas', i.e. lakes and rivers which, despite the summer temperatures of the surrounding landscapes, are frozen to their bed until August/September (Fig. 1). This phenomenon results from a combination of permafrost and shade from nearby mountains. When the reindeer stampede due to mosquito attacks during the day, they escape on to the ice where the cold air immediately kills their small enemies. This means that anyone wanting to hunt reindeer in such a landscape during summer will find them concentrated near the normally relatively rare naled areas, and only to a very limited degree in other areas with good reindeer pastures. In ecological terms, the reindeer exploit the 'ecotones' or the 'edges' between the naled areas and the taiga (forest) (Odum & Barrett 2005: 24-26; Turner et al. 2003).

An important factor for the availability of running water in a landscape – which apparently was important for some Late Palaeolithic hunter-gatherers – is the precise configuration of the permafrost in relation to the air temperature. In some seasons, the layer of melted water running on top of the permafrost can create springs on hill sides that apparently attracted hunter-gatherer settlements (e.g. Taute 1968: 19-21; Woo et al. 2008). Without permafrost, or with permafrost under winter conditions, such locations should have no specific attraction for the hunters who were apparently so focused on access to running water. In a permafrost landscape such as this, the zones where open/running water is accessible will tend to fluctuate with the seasons, following patterns that would be quite complicated to reconstruct.

Some resources with a wide distribution are often only 'extracted' at a few strategic points or zones (the term 'extraction zones' is used here in this respect). Examples include well-known locations where deer come to drink, salt deposits where they come to lick salt, crossing places for migrating reindeer herds etc. From an extraction point of view such populations appear to be very discrete and under normal conditions not worth hunting in the complementary areas they also exploit. In other words the distribution of a species can be very different from the restricted zones where it is extracted/hunted. In Siberia, extraction/hunting zones near rivers are often preferred because they facilitate transport of the prey in boats during the summer or on sledges on the frozen rivers during the winter – the most convenient ways of transporting heavy goods in this environment.

The point is that one should not expect hunter-gatherers to move around according to the random-walk principle, covering all of their resources' catchment areas. They will most likely move along narrow corridors connecting their extraction zones or points and, as far as possible, take into account ease of transportation. Much hunting consists primarily of just waiting at, for instance, the animals' preferred drinking places. The Evenk hunters often have their bark sleeping mats stored there, leaning up against a tree. They know at which times the animals can be expected and will relax in between.

Despite of this apparent rational approach, it should be noted that the Evenk in Siberia often are far from rational in their foraging activities. The distribution of a clan's members in the landscape apart from its resource distribution also reflects the relations between its different subgroups. The distance between the camps of Viktor and Ivan should not be greater than it is possible for one of them to walk to the other in a day or so, have a proper game of cards, and then walk home again. The mutual friendship between some married men and women is also implicitly taken into account, so that they are not placed too far from each other. It is my understanding the Evenk have a considerable margin for economically irrational behaviour.

A natural forest fire during the dry summer period can radically change the resource landscape for a long time and over a very large area, so that a number of extraction zones are lost for a considerable period. In Siberia it can – depending on the type of fire – affect the berry plants growing on the dryer ground, whereas populations of edible plants such as wild chives (*Allium schoenoprasum*) and wild rhubarb (*Rumex hymenosepalus*), growing in and around the

moist river beds, will be much more rarely influenced. An uncontrolled fire over a large area will eliminate the up to 40 cm thick layer of lichen that often forms on the floor of the taiga – so that reindeer will be unable to reside in or pass through the area. The fire will normally kill trees and bushes and kick-start a dense growth of new shots, making it difficult for humans, and animals of any size, to pass through. Natural uncontrolled forest fires will, therefore, have a catastrophic effect on the resources within a large area for a long period of time and will, accordingly, affect the settlement pattern significantly.

Migrating reindeer can change their crossing-places within a particular zone. If a large number of animals are killed at one crossing-point one year, the herd will tend to cross the river at another point not too far away the next. This is probably the reason why the remains of the Evenks' so-called 'tiga sites' (assembly and kill sites at crossing points) can often be observed along 10-20 km of the river banks – a parallel situation to the concentrations of Late Palaeolithic Hamburgian sites such as Meiendorf and Stellmoor (Grøn 2005). The extraction zone for this resource, the place where the reindeer cross the river, will simply move within an interval over time.

Mountain valleys where there is little wind (average winter wind speeds normally below 1 m/s in Central Siberia) will function as cold traps with cold air accumulating at their floors. In these situations the Evenk winter sites will be located high up the mountain sides where the average temperatures are higher (in the northernmost Chita County by as much as 6 °C (Fig. 2) and conditions for game better during winter. In valleys that create a downdraught the valley floor temperatures will, relatively, be much more moderate. Consequently, Evenk winter sites in such situations can be found much lower down, but still up to 5 km from the rivers. Around deep lakes, which serve as climate buffers, the Evenk hunters and the animals are generally attracted by the considerably higher temperatures relative to those of the nearby valley systems (for instance around Lake Nitchatka in northernmost Chita County the winter average is -22 °C in contrast to -32 °C in the surrounding low areas (Kulakov et al. 1997: 16)). As a result, the winter sites associated with this lake are normally located on the banks of the lake/river system in this 'hotspot'.

Even though the resource-manipulation perspective is ignored in this section, and although some types of hunter-gatherer settlements can be expected to be

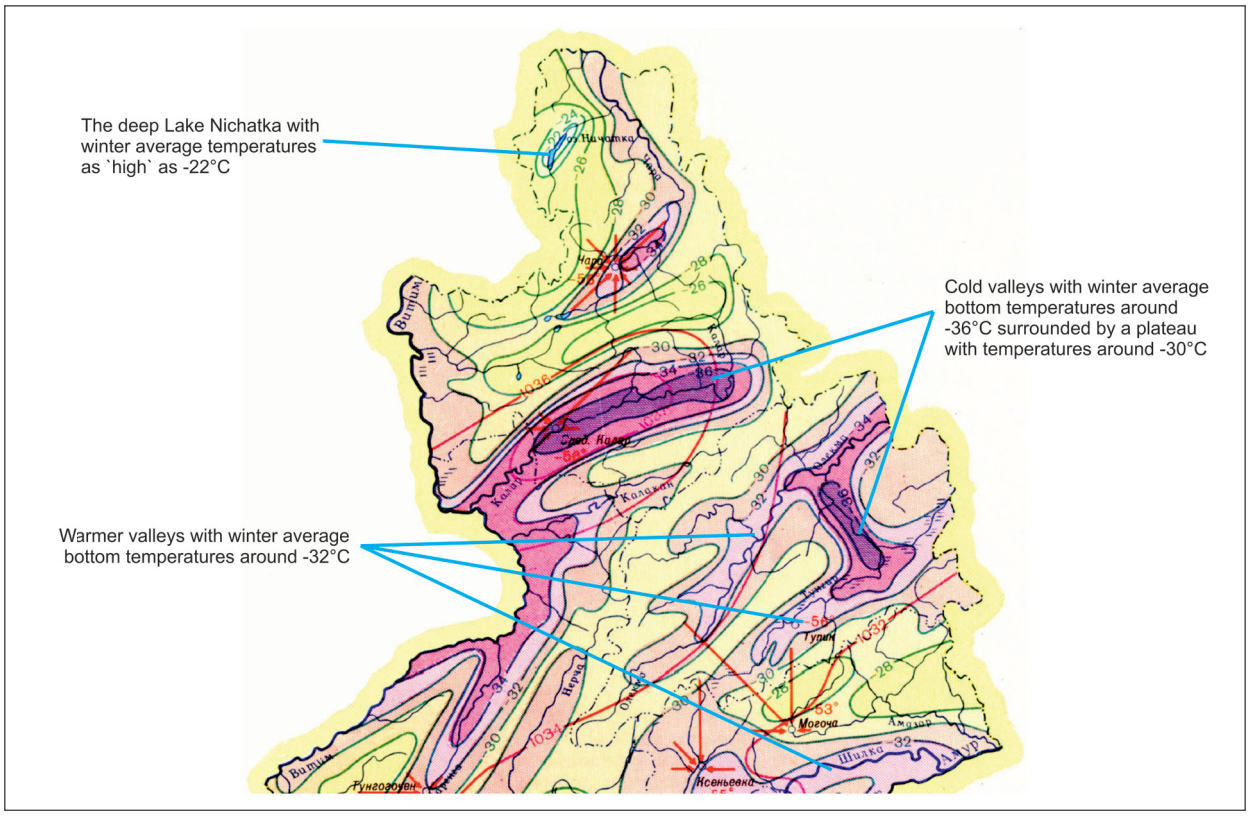

Fig. 2. Variations in average winter temperature in the northernmost part of Chita County, Siberia according to Kulakov et al. 1997: 16. This area has mountains of up to 2-3 000 m in height. In winter the deep Lake Nitchatka and its valley system attracts so much game, due to its relatively mild climate, that the Evenk hunter-gatherers living here are more or less sedentary.

Abb. 2. *Variation der durchschnittlichen Wintertemperatur im nördlichsten Teil des Chita Distrikts, Sibirien (nach Kulakov et al. 1997: 16). Die Berge in diesem Bereich haben eine Höhe von bis zu 2-3 000 m. Im Winter zieht der tiefe Nitchatka See und sein Tal-System aufgrund des relativ mildes Klimas so viel Wild an, dass die hier lebenden Evenken auch als Jäger und Sammler hier mehr oder weniger sesshaft sind.*

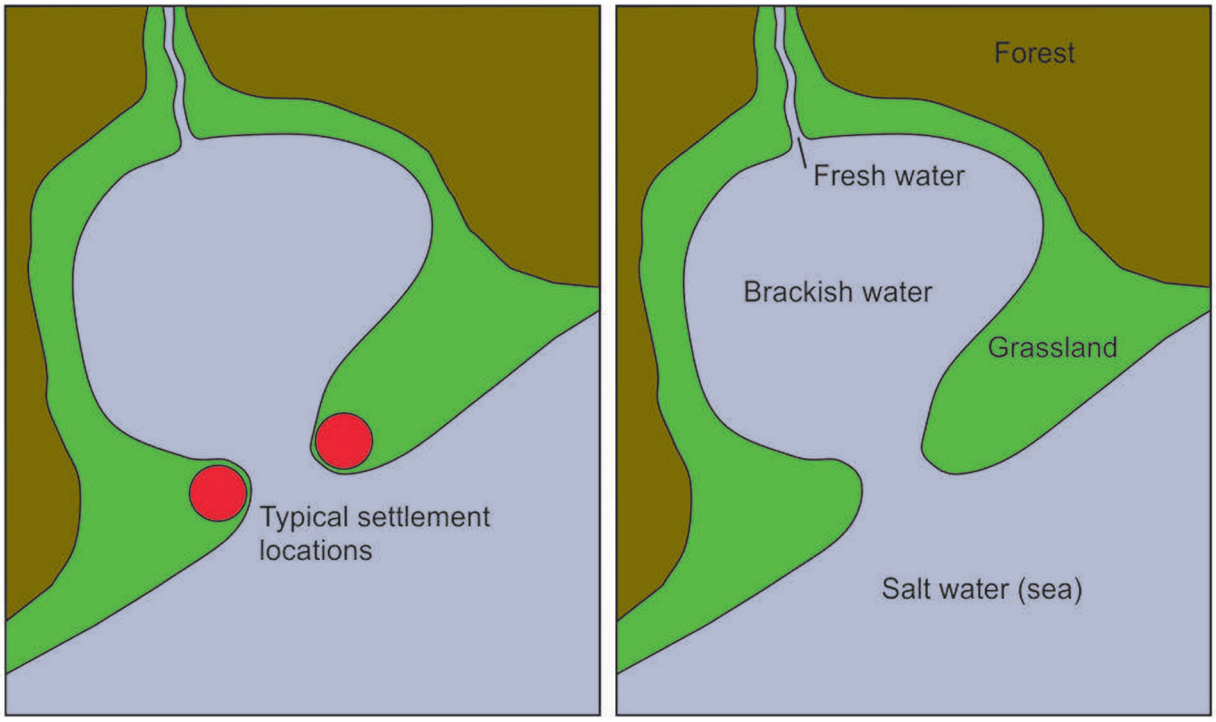

Fig. 3. A typical Late Mesolithic strategy for locating settlements (large red dots) with immediate access to a large variety of biotopes centres on the mouths of brackish inlets (e.g. Fischer 1997). Such settlements can be said to be located in relation to the intersecting 'edges' between several environmental communities: sea, brackish inlet, freshwater, open grassland, forest, etc. The distinctive factor in this case is, however, the significant and controlling topography/bathymetry The major problem is to distinguish site types that are not influenced by such controlling topographical features.

Abb. 3. *Eine typische Strategie zum Auffinden spätmesolithischen Siedlungen (große rote Punkte) mit direktem Zugang zu einer großen Vielfalt von Biotopen an den Mündungen von Brackgewässern wie Haffseen, Bodden oder Lagunen (z.B. Fischer 1997). Solche Siedlungen befinden sich häufig nahe dem Schnittpunkt verschiedener ökologischer Lebensgemeinschaften: Meer, Brackwasser, Süßwasser, offenes Grasland, Wald, etc. Der markante Faktor in diesem Fall ist jedoch eindeutig die Topographie / Bathymetrie, die eine Kontrolle der verschiedenen Biotope ermöglicht. Das Hauptproblem ist die Identifizierung von Siedlungsplatztypen, die nicht primär durch solche topographischen Merkmale zur Kontrolle einer Region beeinflusst werden..*

located relative to the more well-defined and stable boundaries or 'edges' between different environmental communities (Turner et al. 2003), it is obvious that several other factors, such as fluctuating resource populations in the environment and variable extraction zones, should be expected to play a central role with respect to the precise location of a large proportion of the sites. One should also be aware that the location of edges will tend to fluctuate over time, under the influence of varying climate and landscape fires (its 'fire-history'). In addition to these factors, environments will – even under constant conditions – tend to develop through a series of ecological phases over time to a level where they become stable ecosystems, 'climax biotopes', until, once more, they burn down. The term for this development is 'ecological succession' (Odum & Barrett 2005: 336-373).

It should be apparent from the few examples given above that, even if one ignores human environmental manipulation, it is very difficult to reconstruct a resource scenario at a particular time in prehistory in such detail that it can provide a solid basis for the reconstruction of the precise settlement locations at that time. The exceptions to this will typically be the few landscape situations where it is obvious where people would settle regardless of the configuration of the vegetation and the faunal resources (e.g. Fig. 3). In other words, apart from relatively clear-cut – mainly topographically determined – situations, predictive modelling of hunter-gatherer sites cannot be regarded as a reliable method for the general identification of potential settlement areas, even if we ignore the disturbing effects of resource manipulation.

Differing cultural patterns of adaptation to natural resources

In addition to variability and dynamics in the configuration of the natural resources, variations in cultural concepts also lead to variation the ways in which different cultures perceive their resource landscapes and extraction zones. The totem birds I am familiar with in Siberia are mostly economically unimportant species (raven, loon, swan.), so the fact that a clan is not permitted to kill its own totem bird does not present a resource problem. Drinking water is, on the other hand, an important resource. In contrast to the Mistassini Cree, whose cultural rules prohibit the drinking of melted ice and snow (Adrian

Tanner, personal communication), the Evenk prefer to drink water derived from melted snow in winter. They state directly that they prefer its taste to that of river- or lake-water but are adamant that it must be boiled. This is the reason that these two hunter-gatherer cultures, which inhabit quite similar environments (Shirokogoroff 1929: 13-26; Tanner 1979: 1), have significantly different ways of locating their winter hunting sites. Those of the Mistassini are on the banks of rivers and lakes, where it is possible to make holes in the ice to obtain unfrozen water. The winter hunting sites of the Evenk are located up to 5 km from the nearest water body, because their extraction zone for drinking water is the whole landscape, apart from its rivers and lakes.

Settlements are sometimes located near important extraction zones because this is convenient. In other situations, however, they can be found at an appropriate distance to avoid disturbing these zones (e.g. the drinking places and salt sources of prey animals). The fact that the Evenk generally seem to locate their winter hunting sites several kilometres from water bodies may reflect a wish to avoid disturbing the elk territories that are often densely concentrated along the river banks and lake shores, as well as a strategy – shared with the local game - to avoid the low temperatures of the valley floors (e.g. Fig. 2). The Evenk culture may therefore, over time, have developed cultural features which allow them to enjoy melted snow as a substitute for un-frozen drinking water. According to Adrian Tanner, the elks in the Mistassini Territory have a greater tendency to congregate primarily in the moist hinterlands of the rivers. This may be due to the more plain-like character of the landscape across large parts of the Mistassini Territory with no significant 'valley effects' on the temperature and with wider river systems (including meanders and lakes). This may explain to some degree why the Mistassini have their winter settlements located directly on the river banks (Tanner personal communication). Elk represent an important winter resource for both groups.

Apart from differences in the distance from hunter-gatherer winter settlements to the nearest water bodies, there seem to be significant general differences in the patterns of resource exploitation employed within a specific area. In her thorough study 'Economic Change in the Palaeoeskimo Prehistory of the Foxe Basin' one of Murray's central conclusions about the cultures in this 'harsh' area is that:

'… it is clear that there was a wide range of economic options for Arctic peoples, despite a perception that this might not have been the case. While it is true that the number of different animal resources in the Arctic may have been limited, the ways in which humans chose to exploit available resources were highly variable. Economies varied temporally, geographically and culturally.

(Murray 1996: 123)

Hunter-gatherer resource manipulation in ethnography and in the NW European Mesolithic

Ethnography

In the 1970s, Henry T. Lewis began his important systematic ethno-ecological studies of the many different ways in which American Indian hunter-gatherers used controlled burning of the landscape. These studies were based on interviews with Indian informants who could remember the use of these traditional techniques, together with historical sources and the analysis of environments subjected to controlled burning (Lewis 1973, 1977, 1978; Lewis & Ferguson 1988). Increasingly detailed pollen studies of burnt Late Mesolithic horizons in British peat bogs have been carried out since the 1960s by Ian G. Simmons and several other researchers in order to demonstrate that at least some of these were not of natural origin (Innes et al. 2010; Innes & Simmons 2000; Simmons 1975; 1996). The focus on systematic 'Pre-Neolithic' resource manipulation has also slowly but consistently sharpened in archaeology in recent years (Grøn 1998; Göransson 1994; Hather 1998; Jennbert 1992; Law 1998; Mason 2000; Selsing 2010: 27-24, 271-300).

Ethnographically, there is increasing evidence that burning strategies, employed for a number of different resource-management purposes, were part of the traditional hunting-gathering package as a technological facility which could be applied where relevant by cultures relying partly or fully on such a hunter-gatherer economy. Although the most detailed information on this theme has been collected in North America, data are appearing today which strongly indicate a similar situation across the rest of the world (e.g. Bird et al. 2005; Brandisauskas 2007; von Fürer-Haimendorf 1943: 13, 63; Hitchcock 1995; Laris 2002; Lewis 1982; Lewis & Ferguson 1988; Mason 2000; Pyne 1994, 1996).

Whereas un-manipulated landscapes, under normal conditions, consist of 'large-scale fire mosaics', i.e. dense brush and forest vegetation representing various age and successional stages following large, high-temperature, natural dry-seasonal fires, interspersed with recently burned open areas, the main aims of the hunter-gatherer landscape management revealed by ethnography are: **1)** To create and maintain grassy plains and open forests with a grassy floor. This is achieved by burning the grass on an annual basis – after the seeds of grasses and herbs have been harvested – to prevent colonisation by scrub and also to boost next year's harvest of grass and herb seeds. And: **2)** To create and maintain controlled small-scale fire mosaics by systematic burning of patches of open grass in dense shrub and forest ('spot-burning'), thereby significantly increasing both *edge length* (between different environmental communities) and, accordingly, productivity. The

anthropogenic fires are set in seasons (not too dry) and/or in selected areas where they can be controlled and serve a series of specific purposes (Bird et al. 2005; Lewis 1973).

In addition to increasing the productivity of the landscape, controlled burning reduces the danger of uncontrollable wild fires started by lightning, as it reduces the accumulation of dry and dead organic matter in the landscape. This fact is well known to the indigenous informants who were interviewed (e.g. Bird 2005; Lewis 1977) – and has recently been 're-discovered' and applied to modern wildfire prevention strategies (e.g. Bleken et al. 1997; Govender et al. 2006).

Parts of open grasslands, such as the American prairies and the Australian and African savannas, depend on anthropogenic fire management if they are not to become overgrown by scrub. The production of toxins by the latter inhibits the germination and growth of the grasses and herbs which form the existence base for a rich wildlife. Where controlled burning has ceased, the grasslands can be seen today to have become overgrown (Barry 2005; Bird et al. 2005; Laris 2002; Lewis 1973; 1977; Loud 1918: 230-231; Pyne 2001: 57-64; Sheuyange et al. 2005).

An interesting example is provided by the unmanaged parts of the coastal North Californian redwood and pine forest where natural fires are rare because the lightning strikes are drawn by mountains in the hinterland (Stephens & Fry 2005). Loud (1918) cites a report by the first overland party which in 1849 travelled from the Sacramento Valley to the coastal region of the Wyot Indians in Humboldt County. This was a journey through a forest choked with deadfalls, through which it was possible to make no more than two miles headway a day. They were starving because they saw no game – the animals also had problems finding their way through the forest. Later the same party observed a totally different forest landscape when they reached the areas managed by the Indians via a system of small open 'prairies' hosting abundant game. These prairies had been created in the forest and were kept open by systematic burning and were interconnected by proper trails to facilitate the passage of both humans and animals (Loud 1918: 228-231).

Controlled burning must be adapted to different environments (its use can be irrelevant in some environments), leading to strategies and seasonal timings varying significantly from place to place. Important factors in the control of fires are: **1)** The time they are set – in some areas and for some purposes for instance in early spring, just after the snow has disappeared, **2)** the type of landscape they are set in – for example moist ground, uphill, downhill, etc., **3)** the weather when they are set (e.g. Ferguson 1979; Lewis 1977; Lewis & Ferguson 1988).

To facilitate easy collection on clean ground of tree crops such as acorns in California (American Indians) and the flowers and leaves of the mohua tree (*Bassia latifolia*) in India, (Chenchu), hunter-gatherers are known to have burnt off the grass below these trees every year before harvest (von Fürer-Haimendorf 1943: 63; Lewis 1973: 69). It seems that these burnings – at least initially – also served to maintain open grasslands within the privately owned 'oak orchards' of the Californian Indians, as well as improving the acorn harvest by removing competing vegetation. They also killed diseases and pests which otherwise might attack the oaks (Lewis 1973: 69; True 1957). One should bear in mind that oaks with their crowns fully exposed to sunlight yield higher than trees with their crowns partially or totally shaded (Johnson 1994). The creation of open grasslands with free-standing oaks may therefore represent areas managed to yield an optimal acorn production – just as has been suggested for elm trees in 'pre-Neolithic' Scandinavia, in order to optimise the production of elm fruits (Grøn 1998). It should be noted that acorns have most probably been afforded too little attention as a food resource in the Late Mesolithic of NW Europe, including Southern Scandinavia (Mason 2000, 2004).

Mesolithic

Another interesting area is 'coppicing' and pruning. It is an established fact that the American Indians manipulated hazel and redbud (*Cercis occidentalis*) on a large scale by burning and, in some cases, also by coppicing or pruning. After two to three years this results in regenerated areas with dense 'bushes' of straight shoots around 1-2 cm in diameter, which are well suited to basket weaving (Anderson 2000; Lewis 1973: 51-65). The large number of straight hazel stakes and rods (other species also appear) recovered from Late Mesolithic sites in NW Europe (e.g. Fischer 2007; Larsson 1983: 66-72; McQuade & O'Donnell 2007) are difficult to interpret as anything other than the result of a similar manipulation strategy. A reasonable proportion of these, about 2.5 cm in diameter, appear to have been produced on a large scale for the 'panels' of fishing weirs. According to Christensen (1997), the construction of a 200 m long weir required several thousands of straight stakes. It would have been quite a problem to procure these in an unmanaged forest where the relevant species would generally grow as trees. Christensen carried out a detailed analysis of the Mesolithic rods from the Halsskov fishing weirs, dated to around 5 000 calBC. In their first year, they had increased in length from about 1 m to almost 2 m; 76 % of them had a lower diameter between 20 and 40 mm. This strongly indicates that they all grew in the light of 'unnatural' openings in the forest (Christensen 1997; Pedersen 1997).

Another advantage of hazel burning/coppicing is that the resulting straight shoots produce a reasonable crop of hazelnuts already in their third year. These are

much easier to harvest than those growing on larger trees scattered throughout a mixed forest. Of the Mesolithic stakes analysed by Christensen, 54 % were between six and eight years of age. This would leave a period of hazelnut production of about four to five years, resulting an annual yield of order of – including shells – several tons per ha (Snare 2008). This is of considerable interest because, judging from the archaeological record, hazelnuts were clearly a very important food resource in the Mesolithic of NW Europe. At some of sites with good preservation they appear to have been processed almost in an industrial manner. In addition to the generally large amounts of hazelnut shells in the archaeological layers associated with the Maglemosian Holmegaard I and II sites (covering a long phase during the central part of the Maglemose culture) Broholm (1924) observed several heaps of hazelnut shells measuring about 30 cm in thickness and 5 m in diameter. In the light of our present knowledge, including Becker's later find at the same location (Holmegaard IV) of a substantial Maglemosian bark floor covered by a compact 5 cm thick layer of hazelnut shells, and examples at Duvensee in Germany of Maglemosian dwelling floors with concentrations of hazelnut shells, such heaps must be interpreted as the remains of dwellings filled with hazelnut shells and at times with regular hazelnut roasting places preserved on the floors (Becker 1945; Bokelmann 1981; Brinch Petersen 1973; Schwantes 1939: 97). The importance of hazelnuts appears to have been just as great during the Late Mesolithic (Kubiak-Martens 1999; Larsson 1983: 76; Mason 2004).

The exceptionally well preserved dwellings at Sarnate in Latvia, dating from the period 4 400-3 600 calBC, represent an economy (either 'Mesolithic hazelnut farming' or 'Neolithic hunter-gathering') with large-scale hazelnut procurement as an important element. Layers of hazelnut shells – one up to 40 cm in thickness – were found inside, and related to, the c. 13 dwellings. A total of 23 wooden nut-cracking mallets were found associated with these dwellings. The people at Sarnate had, furthermore, access to straight stakes and rods in larger numbers (Bērziņš 2008: 42-43, 105-106, 299, 304, 311, 320, 326, 346, 407-413; Timofeev & Zaitseva 1998; Vankina 1970: 29-33, 55-56, tables XI, XII, XX). Regardless of whether the Sarnate people were 'Neolithic' and grew cereals, a significant part of their economy comprised large-scale exploitation of hazelnuts as seen in the earlier Mesolithic.

Whereas investigations based on palynology/charcoal particles/fungal spores indicate strongly that some of the recorded fires were anthropogenic in origin, the weak point in their testimony is vertical resolution; under normal conditions this is insufficient to allow detailed distinction of such short-term events (Innes et al. 2004). However, we may have a 'smoking gun' from the Early Mesolithic in the shape John Hather's detailed analysis of a burning at the classical Star Carr site, dated to 8 800-8 200 calBC (Dark 1998). Hather's analysis of identifiable macroscopic charred plant remains found in three monolith samples taken from the peat outside the site reflects, with a high probability, the *in situ* burning in spring (most likely March or April) of the reed zone by the lake shore affecting the overhanging aspen branches. Acording to Hather 'There is no evidence for either domestic wood burning derived from adjacent occupation, or an aeolian deposit of small fragments of wood charcoal derived from local burning of woodland' (Hather 1998).

It is crucial in this case that the juvenile stage of the charred remains of the burnt reeds (*Phragmites australis*) points to spring as the season of the event. The burning of a lake shore reed zone in March-April is consistent with the controlled burning of a 'corridor' along the bank in Lewis and Ferguson's terminology, at a time of the year when the fire is easy to control (Lewis & Ferguson 1988), and at this time of the year is highly unlikely to be the result of a fire ignited by lightning. This case is probably as close as one can get to a 'smoking gun' in archaeology. It underpins the importance of the many palynlogical indications of patch-burning as a generally applied Mesolithic resource manipulation strategy.

Another 'smoking gun' is apparently seen in the unnaturally large number of straight stakes and rods which Mesolithic cultures had access to for their fishing weirs, and probably also a number of land-based structures. Anyone familiar with natural forests will react strongly to the suggestion that these numbers of straight rods and stakes would be available there. Combined with the perspective of producing easily accessible concentrations of storable hazelnuts, it certainly appears as if one has to accept significant environmental manipulation as an integrated part of the 'Mesolithic' repertoire.

A large number of manipulation techniques known from social anthropology (e.g. Anderson 2000, 2005; Lewis 1973, 1977; Lewis & Ferguson 1988; Minnis & Elisens 2000; Rhoades 2005) are not discussed here because they have so far not been reliably distinguished in the prehistoric archaeological record or do not seem to be of great strategic importance with respect to the statements made in this paper. One must bear in mind the fact that the direct manipulation of the vegetation is often an indirect manipulation of hunting resources. The creation of mosaics comprising open grassland areas of restricted size in dense forest can significantly increase the amount of game. According to our social anthropological data it also seems natural for hunter-gatherers to collect and plant seeds (e.g. Bean & Lawton 1973; Lewis 1973). This paper does not address the question of whether resource-manipulating hunter-gatherer cultures should be regarded as 'proto-agriculturalists' or 'agriculturalists'. Its sole aim is to discuss the consequences of natural

variation, ecological succession and human manipulation on Mesolithic resource patterns and, accordingly, to discuss the possibilities for the development of a reliable and reasonably precise methodology for predictive modelling of prehistoric hunter-gatherer settlement patterns.

Human resource manipulation back in time

It now seems likely that significant and systematic human resource manipulation as demonstrated above, extends further back in time than the generally accepted introduction of a Neolithic economy and culture. But the important question then is 'how far back in time does it actually go?' At the moment there are no solid data on which to address this problem, merely a few vague indications. One of these comes from the analysis of the content of particular charcoal in the atmosphere, based on two deep sea cores from the Atlantic, sampled off the coasts of France and Spain (Daniau et al. 2010). A generally declining trend, with some small-scale variation, can be observed for the last 70-25 000 years for the French core, whereas its Spanish counterpart shows a significant increase between 70 000 and 50 000 years ago, with values rising to about 200 % of the oldest ones recorded, followed by a slight general decline – also with some small-scale variation - until 20 000 years ago. The general decrease between 50 000 and 20 000 years ago, observed in both cores, could be consistent with Australian observations that anthropogenically controlled fires produce less charcoal than the uncontrolled natural fires which they partially replace (Daniau et al. 2010). This is a logical consequence of natural uncontrolled landscape fires burning more 'dead' biomass such as fallen tree trunks etc., than controlled patch fires which consume much more 'live' biomass (grasses, herbs, shoots from bushes and trees, etc.) and the latter tend, as a consequence to suppress the development of large amounts of dead biomass. This is why controlled patch-burning has recently regained its importance as wild-fire prevention measure in land management (Bleken et al. 1997; Govender et al. 2006). The trend revealed by Dainau et al.'s analysis of these cores is important because the data must be assumed to have been only minimally affected by changes in the northern vegetation brought about by the last glaciation.

A study of the charcoal concentration in sediments from all parts of the world dated to the last 21 000 years reveals a dip during the last glacial maximum (Power et al. 2008). The authors suggest that this is possibly due to reduced vegetation volume in the glaciated area, followed by an increasing amount up to 10 000 years BP and thereafter a continued slight decrease. Because this study covers areas where the vegetation was clearly influenced by the last glaciation, the data from the time of the glacial maximum are somewhat problematic. However, those relating to the last 10 000 years must be of some value. Where an increase would be expected after the glaciation, the data actually indicate a slight relative decline. The charcoal data thereby give an indication of an ongoing general decrease in the amount of particular charcoal in the atmosphere over the last 50 000 years.

A DNA study of four African ethnic groups, uninfluenced by the bottleneck phenomena which seem to have affected non-African populations, indicate that both the Biaka and San (hunter-gatherers) and the Mandenka and Yoruba (today farmers) increased their growth rates around 59, 29, 25 and 36 thousand years ago, respectively (Cox et al. 2009). Accordingly, the general – very rough – trend over the last 50 000 years appears to be a decrease in the amount of charcoal particles emitted into the atmosphere, despite a generally increasing human population (Cox et al. 2009). This could – as one possible explanation – reflect an increase in anthropogenic burning – resource manipulation.

Environmental resource variation and consequences for predictive modelling of hunter-gatherers

Steward's cultural ecology placed strong reliance on the explanatory power of environment, but not to the extent that the relationship between culture and environment was strictly determined. Rather, their interaction was mediated by technology and labor. In effect, the environment is a given, immutable condition to which labor must conform, and that conformity is to a large extent dictated by technology. In turn, the organization of labor required conformity from social and political organization.

(Bettinger 1980/Steward 1938: 260-261)

Already in his 1980 paper on hunter-gatherer predictive modelling, Bettinger is clearly aware of weaknesses in Steward's approach whereby the environment is regarded as a 'given', and attempts to control the problem of variability in hunter-gatherer behavioural patterns by focusing on 'techno-environmental' explanations where possible:

However we choose to reconcile the relationship between the various views of cultural ecology, there is almost no debate that a comprehensive approach to almost any aspect of hunter-gatherer culture must be firmly grounded in a detailed assessment of the technological-environmental context [. . .]. Furthermore the presumption is equally strong that techno-environmental explanation is inherently superior to other kinds of explanation (e.g., historical). In practice, this has meant that to account for a behavior pattern or a behavioral difference between two groups on other than technological or environmental grounds requires that the possible effects of man-land relationships be first considered and convincingly dismissed[. . .].

(Bettinger 1980)

Despite his concerns with respect to hunter-gatherer behavioural variability, Bettinger and other predictive modellers have not been able to develop methods which cope well with natural short-term resource oscillations and changes, or the types of cultural resource manipulation outlined in the above sections. Apart from the costs involved in the collection of the necessary data and in sufficiently detailed spatiotemporal reconstructions of such prehistoric environmental dynamics, which would cause most administrators to lose interest, a major problem is that, with the dating methods available today, it is not possible to date with adequate precision resource fluctuations of a few years' duration. One central problem is, therefore, not the development of new advanced methods of modelling, but the collection of basic environmental data of an adequate spatial and temporal resolution.

Another central problem is that even given access to an ideal set of environmental data, we must accept that different cultures may act differently in similar resource situations. Attention has been drawn above to differences in the distance from hunter-gatherer winter settlements to the nearest water bodies as well as the significant variation in the general economic strategies adopted in one specific area (Murray 1996).

Consequently, the conclusions reached with respect to predictive modelling are: **1)** It seems realistically possible, via predictive modelling of prehistoric hunter-gatherer cultures, to distinguish some types of potential settlement locations characterised by observable features that are stable over longer periods of time. However settlements located relative to naturally fluctuating or artificially created resource concentrations will tend to avoid detection by this method. **2)** The quality of the modelling applied will depend directly on the resolution and quality of the data fed into it. The interesting question here is at what level of quality the approach will lose its attractive cost-effectiveness. **3)** The resource situations in prehistory could have been exploited in accordance with many different strategies. As a consequence even ideal environmental data are no guarantee that it will be possible to reconstruct one specific settlement pattern used to exploit them.

Predictive modelling of the settlement patterns of prehistoric hunter-gatherer cultures must, be seen as one technique which in conjunction with various types of direct detection (remote sensing), in conjunction with traditional fieldwork, can provide a useful survey methodology. Predictive modelling may well be suited to mapping of some of the more 'topographically stereotypic' hunter-gatherer sites, but not those reflecting environmental or cultural dynamics. The discussion section of this paper clearly demonstrates that, if the aim is to obtain a representative picture of the sites within a given area, predictive modelling should generally be regarded as being of minor importance for survey work, relative to the spectrum of methods available for direct detection.

With regard to submerged Stone Age landscapes one would expect the coastal zone, with its extremely high biomass production, to be an important determining factor in the location of settlements (Odum & Barrett 2005: 95-96; Grøn 1998). However, it is important to keep in mind the fact that many of the sites found on the seabed were related to inland fresh-water or brackish water systems when they were inhabited. With regard to underwater archaeology, where precise location sites and finds is especially important due to the costs involved predictive modelling seems even less useful than on land.

Indications that systematic hunter-gatherer resource manipulation played a more important role than hitherto assumed represent an important factor in the discussion leading to such a negative attitude to predictive modelling. It is obvious that significant and systematic hunter-gatherer resource manipulation, including burning of the landscape and the collection and planting of seeds, will tend to undermine an operable economic definition of the Mesolithic-Neolithic transition, i.e. regarding it as a discontinuous progressive step as perceived by Childe (Brothwell 2009). The development of domesticated species does not necessarily signify the existence of 'Neolithic' societies. In addition to a re-assessment of 'hunter-gatherer' predictive modelling, the whole concept of the Neolithic apparently requires reappraisal. Does the domestication of local resources qualify cultures as 'Neolithic' - or does this require the introduction of foreign species? Even in the latter case, we will have to find out how to deal with a type of hunting and gathering involving resource manipulation which apparently extends far back in time – the fingerprint of modern man?

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