MODELING MESOLITHIC HUNTER-GATHERER LAND USE AND POST-GLACIAL LANDSCAPE DYNAMICS IN THE CENTRAL NETHERLANDS

By

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ABSTRACT

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Dramatic and widespread environmental changes occurred during the early Post-glacial period in Europe (10,000-6000 ^{14}C B.P.). These changes included climate amelioration, sea-level rise, vegetation succession, and landscape transformation. Mesolithic hunter-gatherers living in the central Netherlands adapted to these dramatic shifts in landscape configuration and character in various ways. The aim of this study is to identify potential Mesolithic land use behaviors based on ethnographic data, and to develop a method of determining which behaviors were most suitable in specific environmental contexts.

To accomplish this goal, a multi-criteria decision-making model is generated using GIS and environmental modeling. The model framework begins with a detailed landscape reconstruction for three separate representative study areas. To this base, floral and faunal components are added, depicting areas more or less suitable as habitat for particular species. The species modeled are those relevant to Mesolithic hunter-gatherer life. The completed model framework, incorporating reconstructed paleo-environments, allows simulations of decision-making choice with regard to hunter-gatherer land use. Each choice is keyed to a number of broad objectives and specific criteria for querying the landscape reconstruction, thereby acting as a heuristic device for testing the interplay and outcomes of different combinations of ethnographically-derived criteria and objectives. The behavioral model identifies areas most

likely to have been used for specific resource provisioning and settlement purposes, and the criteria and objectives that condition such outcomes. The model reveals the degree to which edge areas and/or distances to a variety of biotopes conditions general hunter-gatherer land use and exploitation. Further, as sea-levels rose and large parts of the central river valley became inundated or influenced by the tides, wetland adapted hunter-gatherers would have gained a competitive advantage.

The results of this model compare well with the archaeological record for the Mesolithic in the Netherlands, predicting that a wetland adaptation would be highly viable only in the western portion of the river valley during the latter half of the period. This prediction is indeed borne out by the archaeological evidence. The model also sheds light on some of the potential decision-making processes and cultural adaptations of past hunter-gatherers, in addition to generating practical predictions concerning areas of high potential for future hunter-gatherer research and heritage management.

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Chapter 1

INTRODUCTION

At the end of the last glacial period in Europe (ca. 11,650 cal B.P./10,000 ^{14}C yr B.P.)[1], the environment underwent dramatic changes in composition. The climate ameliorated, melting continental glaciers and releasing huge quantities of water in the oceans. Sea levels steadily increased, inundating low-lying lands, such as the Doggerland plateau and the modern-day Netherlands (see Chapter 4). Small groups of hunter-gatherers inhabited Western and Northern Europe at the time, and considerable organizational constraints on these peoples were undoubtedly imposed by the widespread changes in the landscape (Crombé et al. 2011). Exactly how this interaction occurred, however, is the subject of this study.

During the Upper Paleolithic, nomadic hunter-gatherer groups roamed what were largely tundra plains and boreal forests of Europe, following the movement of gregarious herd animals, such as reindeer and horse. Multi-family residential groups were supported by the predictable nature of their primary subsistence resource. Communal hunts were often undertaken using spears and the bow and arrow. These mobile hunter-gatherer groups made periodic pauses in locations with high resource abundance, constructing semi-permanent shelters from raw materials available in the surrounding environment (Bailey and Spikins 2008; Champion et al. 1984; Jochim 2002; Mithen 2001).

This scenario began to change around 10,000 ^{14}C yr B.P., at the beginning of the Holocene interglacial and Mesolithic cultural period (ca. 10,000–6000 ^{14}C yr B.P.). These

[1] All dates herein are reported as radiocarbon years B.P. unless otherwise stated.

changes appear to have been initiated by shifts in the environment, which became comparatively wetter and warmer, supporting new mixes of plant and animal habitat. First, and foremost, the open tundra plains were replaced by forests and scrublands, which drove the large herds of reindeer and horse to the north and east (Champion et al. 1998:90; Mithen 2001:86). More solitary or small herd species replaced them, such as deer, boar, and aurochs. These new species required different acquisition strategies that in many ways were responsible for catalyzing transitions in social organization (e.g., Welinder 1978; also see evidence of increased plant gathering activities: Constantini 1989; Holden et al. 1995; Galanidou and Perlés 2003; Jacobsen 1981; Larsson 1990; Price 1987; Van Andel and Sutton 1987; and evidence of increased marine food use: Andersen and Johansen 1986; Burton and Price 1990; Richards and Hedges 1999). The multi-family groups split into single, most likely extended family groups for large parts of the year, living in small and ephemeral campsites, and moving between productive resource patches (Jochim 2002; Larsson 1990; Price 1981; Rimantiene 1994; Zvelebil and Zvelebil 1990). This way of life was punctuated by periods of group aggregation to facilitate information exchange, communication, the exchange of exotic goods, and perhaps even the formalization of marriage partners[2] (Clark 1975; Clarke 1968, 1976; Eriksen 2002; Fischer 1982; Gendel 1984; Kozlowski 1973; Newell et al. 1990; Rähle 1978; Rankine 1949; Sulgostowska 2006; Whallon 2011; Wobst 1974). Thus, the settlement and subsistence patterns left on the ground were different during the Mesolithic period than during the Upper Paleolithic.

Throughout the Mesolithic period (ca. 10,000–6000 ^{14}C yr B.P.; the beginning part of the Holocene), the landscape continued to change and so too did the lifeways of hunter-gatherers

[2] Wobst (1974) realized that small hunter-gatherer bands were not large enough to be viable breeding populations and thus, locating potential marriage partners would have required a good deal of networking effort and gathering of information (Whallon 2011:6).

(see Chapter 3). In many parts of Europe, Mesolithic people diversified their subsistence regimes to include plants, small mammals, birds, and aquatic species, in addition to large game. These altered subsistence pursuits precipitated new settlement and mobility strategies, such as more permanent settlements and increased sedentism during particular seasons (e.g., Bicho 1994; Jochim 2002; Larsson 1990; Price 1990). In some locations, year-round sedentism may have occurred, potentially leading to--or at least linked with--the emergence of social stratification and increasingly differentiated status roles (e.g., Larsson 1990; O'Shea and Zvelebil 1984; Price 1990). The hunting and gathering way of life persisted until about 6000 ^{14}C yr B.P., when farming became a major contender in subsistence strategies, with all of its attendant changes in settlement, mobility, socio-political, and ritual-ideological organization. The shift to agriculture has been variously described as a replacement of cultures, an adoption by indigenous cultures, or as an indigenous development (see Chapter 3 for more detail). Whatever the case, hunting and gathering as a lifestyle was phased out in many parts of Europe by 6000 ^{14}C yr B.P. (Dennell 1992; Grönenborn 1999; Jeunesse 1986; Louwe Kooijmans 1990; Milisauskas 2002; Raemaekers 2003; Stafford 1999; Whittle 2001; Zilhao 1998; Zvelebil 1998).

1.1 Problem Development

While the archaeological record has revealed some clues as to how these changes in lifeway occurred, there are still remain many explanatory gaps in current Mesolithic hunter-gatherer theory. This is especially the case in the Netherlands, where various direct changes to the landscape have affected understandings, as well as the indirect effects of modern scholarship. For example, areas that have received the most research are those in the south and north of the country, where many archaeological remains lie close to the modern-day surface and can thus be identified more easily through field-walking surveying techniques as well as chance encounters by farmers, construction workers, and residents.

As discussed by Verhart and Groenendijk (2005), there are four primary factors that obstruct a clearer grasp of the manifestations of Mesolithic life in the Netherlands. First, geologic-geomorphological development in the Netherlands has been erratic, with some areas of the country experiencing substantial sedimentation and other areas experiencing only surficial erosion by wind and water. Further, glacio-isostatic subsidence also impacted the geomorphology of the country to some degree (see Chapter 4), a fact that has directly affected the preservation and accessibility of archaeological remains. In the east and south of the country, Pleistocene deposits lie at, or just below, the present-day surface. Archaeological remains here are easily found, such that most Mesolithic evidence comes from these areas. However, the shallow location of these remains means that preservation is poor and that primarily imperishable evidence is preserved (e.g., flint, carbonized hazelnut shells, charcoal). Conversely, in the north and west of the country, vast amounts of shallow marine, fluvial, and peat deposits buried archaeological remains deep below the present-day surface. Here archaeological remains are well preserved and have yielded such finds as wooden tools and structures, netting, basketry, and zooarchaeological remains.

Thus, the geologic-geomorphologic situation poses an archaeological dilemma: should researchers focus efforts on recovering the easily accessible, though poorly preserved remains in the east and south, or should the focus be on long-term and costly projects that focus on recovering well preserved remains from the west and north? There are important reasons to conduct research in both cases. In the first case, those remains at or near the surface are constantly in danger of being removed by laypeople, construction projects, or other landmodifying practices. To collect and conserve these remains costs little, and requires mainly time and effort; however, their poor preservation may yield only scant information about Mesolithic life. In the second case, spending the time and money to recover well preserved finds buried under many meters of peat and clay may greatly increase understandings not only of the material culture utilized by Mesolithic people, but also their lifeways. However, the resources necessary for such projects are not always readily available. At the root of both research strategies is a need for better predictive spatial models and their resultant graphic displays depicting areas most likely to have hosted Mesolithic activity. One of the main goals of this study is to produce such a predictive model of where and how the landscape was used, as a way to direct future research endeavors.

Understandings of Mesolithic lifeways are hampered by a second factor: the (sub)-recent disturbance of the archaeological record by subsequent human groups (Verhart and Groenendijk 2005:162). Mesolithic peoples apparently did not often dig pits, but rather left most of their remains on the ground surface. Over time, these remains were removed from their primary contexts and dispersed over large areas. They also became highly eroded during this process, as little accretional sedimentation occurred to either preserve them or keep them in place. Thus, many archaeological remains occur in the top 30 cm of the soil profile, which has often been disturbed by more recent activities like plowing, digging, and sod cutting. This is a consideration mainly in the eastern and southern portions of the Netherlands; in the north and west, finds tend to be buried deep enough to avoid such disturbances. Those sites found *in situ* in the east and south of the Netherlands were those that were buried beneath substantial sediments, such as Medieval *plaggen* soils or peats (Figure 1.1; see also Chapter 4).

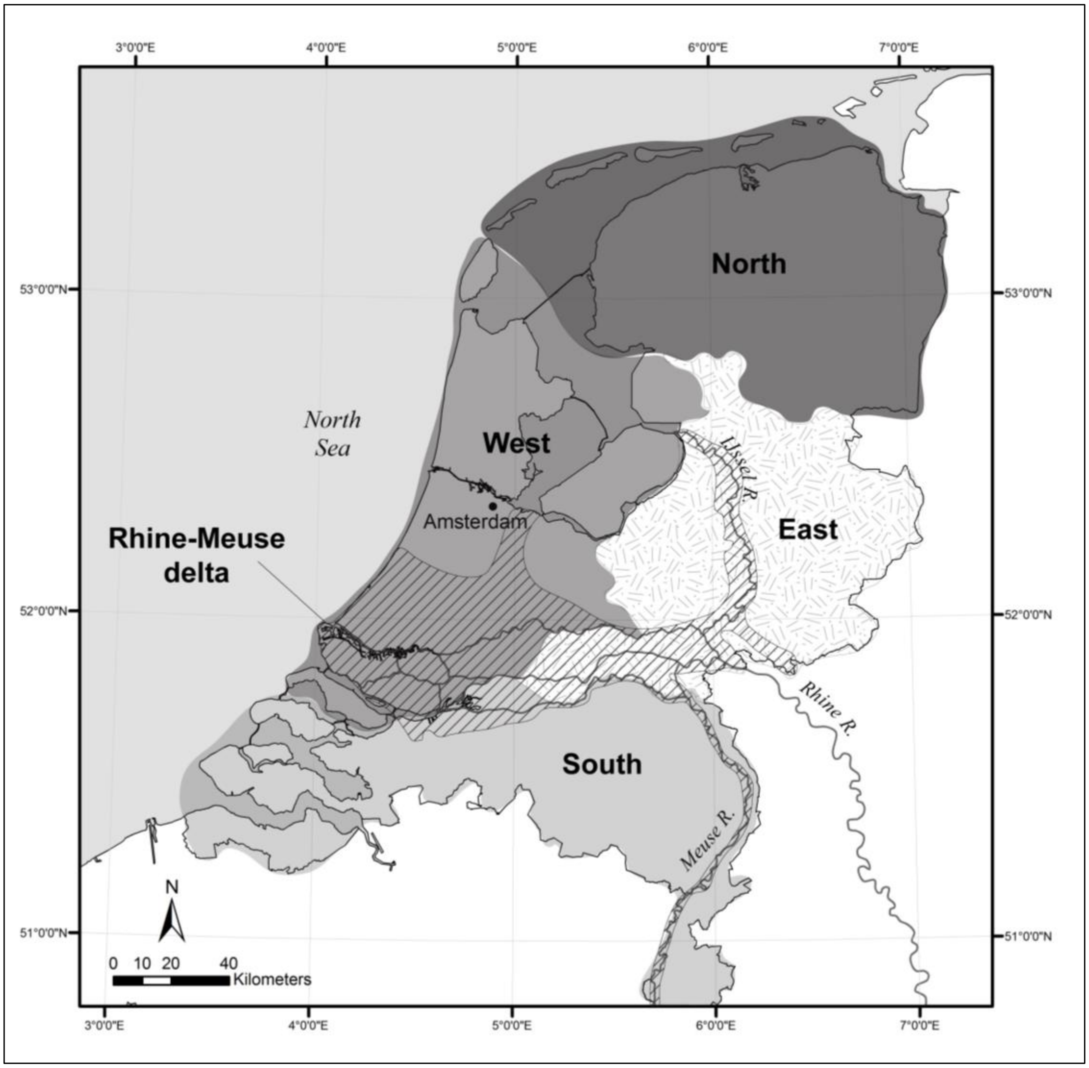

Figure 1.1 Areas of the Netherlands as Referred to in this Text.

A third factor that has affected understandings of the Mesolithic in the Netherlands is differential research focus. Only a few regions of the country have been "thoroughly" studied, generally those in close proximity to a university with active archaeology programs (for a more thorough example, see Crombé et al. 2011 for Sandy Flanders). For example, extensive research was conducted in the area east of Groningen, as part of programmatic studies supported by the Groningen Institute of Archaeology (GIA; formerly referred to as the BAI, or Biological-Archaeological Institute; Groenendijk 1987; Niekus and Groenendijk 1998; Price 1975, 1980).

Similarly, the southern provinces of Limburg and Noord Brabant have been investigated in detail through efforts initiated by L. Verhart and others and the Rijksmuseum van Oudheden in Leiden and the Limburgs Museum in Venlo (Verhart 2003; Verhart 2006; Verhart and Arts 2005; Verhart and Wansleeben 1991; Wansleeben and Verhart 1990). Such research foci have benefitted sub-regional studies of Mesolithic adaptations; however, the Mesolithic manifestation in the intervening areas is only partially known (e.g., in the west and central parts of the country). However, it should also be noted that the so-called "Malta Legislation"–part of the Valletta Treaty of 1992, the goal of which is to protect European archaeological heritage–stipulates that archaeological excavations only be carried out when archaeological heritage is under direct threat (Council of Europe 1992). Thus, even fully-funded and well-equipped scientific researchers must abide by this legislation and focus on sites that are in danger of being destroyed (Weerts pers. comm.).

The fourth factor impeding clearer understandings of Mesolithic life is the archaeological record itself. For reasons yet unknown, Mesolithic people tended to reuse the same sites repeatedly over long periods (Bailey 2007; Crombé et al. 2001; Crombé et al. 2003; Peeters 2007; Smit 2010). This behavioral pattern greatly complicates the job of the archaeologist, as it becomes nearly impossible to discern separate or discrete occupation episodes or individual activities (Verhart and Groenendijk 2005: 163). Thus, archaeologists must instead observe site characteristics from an agglomerative perspective, or what Amkreutz has referred to as the 'time-averaged' lithic spectrum (Amkreutz et al. 2010:657). That is, since most Mesolithic sites are assumed to have been occupied for multiple events, they can be thus be considered as equivalent entities that can be compared as to their varying artifact assemblages. Of course, this analytic approach has many obvious drawbacks, not least of which is the fact that we simply do not know how many times--or for how long--each site was occupied. However, the approach provides a starting point from which questions of site function, seasonality, and settlement patterning can be posed.

1.2 Research Questions

Given the above information, the main thrust of this study is to obtain a better understanding of Mesolithic lifeways in the central belt of the Netherlands from a 'landscape approach', which calls for a "concentration on land use, potentially synergistic relationships among environmental systems, landscape physiology and the spatial aspects of human land use strategies" (Rossignol 1992:4). More specifically, the study focuses on different adaptive land use strategies and how they may have changed over time, whether in concert with environmental changes or not. Hunter-gatherer land use strategies involve three primary systems: economic, socio-political, and ritual. Each of these systems can be unpacked into various subsystems. Following Jochim (1976), the economic system is concerned with questions of resource usage and scheduling (i.e., subsistence organization), settlement location, and demographic arrangements. The socio-political system shares some of these questions, but also addresses exchange and other relationships (e.g., gender and age), as well as the spatiotemporal expression of power and prestige. The ritual system involves sacred knowledge, myth, and cosmology. While this study will cursorily address the social and ritual systems of land use, the main focus will be on the economic system and its constituents.

Thus, the main research questions posed by this study are:

1. What adaptive strategies were used throughout the course of the Mesolithic period by hunter-gatherers in varying environmental contexts?

2. Given that perturbations in the natural environment occurred during the Mesolithic, were hunter-gatherer land use decisions altered in response?
3. What are the archaeological correlates of these adaptive strategies that can be found in the archaeological record?
4. Can land use decisions be predicted based on knowledge of ethnographically-documented hunter-gatherer decision-making?

In addition to these questions, this study also seeks to understand how different habitats were used over time, as current archaeological evidence suggests that wetlands were not fully utilized by hunter-gatherers until the late Mesolithic (e.g., Crombé et al. 2011). It is argued that the western wetlands of the early Holocene Netherlands would have posed as rich and diverse habitats within which to make a living based on hunting and foraging. Contrary to the modern notion of wetlands as marginal, unproductive, and even evil or dangerous landscapes (Nicholas 2001; Peeters 2007), wetlands were likely areas of high resource potential, equivalent to a modern-day grocery store. Wetlands display great biological diversity, due to their ecological position between dry land and the ocean (Peeters 2007:13). Furthermore, hunter-gatherer communities are known to view the world holistically, such that no distinction is made between cultural and natural landscapes. Thus, the Western view that wetlands should be altered to better accommodate the wants and needs of society would not be a consideration for hunter-gatherers, who see themselves and all other parts of the landscape as inextricably entwined and equally important components (Ingold 2000).

Another question relates to the nature of the archaeological record. As noted above, most archaeological remains derive from the east and south of the country, with comparatively less material coming from the west and north. Some concentrations of well preserved remains from the west and north have also been uncovered, such as the sites near Hardinxveld-Giessendam (Louwe Kooijmans 2001a, 2001b), as well as dredged from Europoort near Rotterdam (Louwe Kooijmans 1971; Verhart 1988), the Brown Bank, and the Doggerland Hills (Gaffney et al. 2007). These findings intimate that more remains are lying at the bottom of the ocean or buried beneath meters of sediment, awaiting discovery. Further, these findings suggest that the current archaeological record of the Dutch Mesolithic is biased towards areas where finds are closer to the surface and therefore more easily accessible.

1.3 Project Overview

To address the above questions, this study simulates Mesolithic hunter-gatherer land use behavior based on known decision-making considerations within boreal and temperate forest contexts. This is accomplished in several steps. First, landscape reconstructions are generated based in part on the paleo-geographic overview map of Berendsen and Stouthamer (2001), which was based on 200,000+ radiocarbon and OSL-dated sediment cores taken from the central portion of the Netherlands. Other geologic-geomorphologic databases were also draw upon to develop paleo-landscape maps for three study areas throughout the central river valley of the Netherlands (see Chapter 4, Figure 4.4). These depictions of physiographic features are then paired with information about paleo-groundwater levels to derive probable distributions of vegetative habitats (see Appendix B). Drawing upon faunal habitat preference data from modern and sub-recent species (see Appendix C), inferential spatial displays are produced that portray the suitability of vegetative habitats for individual faunal species. These spatial suitability data are then used as input for the modeling procedure.

The three study areas selected for this study each measure roughly 25x25 km, a size that was chosen because it could easily facilitate manipulation of the available spatial data. The study areas were placed strategically throughout the Rhine-Meuse river basin in the central Netherlands, with two study areas in the Rhine-Meuse alluvial plain and the third in an upstream tributary catchment of the Rhine (see Figure 4.4). These areas were chosen because of their unique abiotic and biotic conditions during the Early and Middle Holocene. Furthermore, each area contained at least two Mesolithic sites against which the heuristic models developed herein could be compared.

A multi-criteria, decision-modeling framework is used here, in which the objectives, criteria, constraints, and decision rules of specific hunter-gatherer adaptive strategies can be detailed (see Chapter 5; Eastman et al. 1995; Krist 2001). Both ethnographic and archaeological case studies are referred to for this information (see Chapter 6). The results of this modeling procedure are maps that depict areas most suitable for specific adaptive alternatives. To test whether an adaptive strategy may have been in use, the location of known archaeological sites is compared with the suitability maps. If an archaeological site co-occurs or is adjacent to an area of high suitability, it is probable that the strategy was a viable alternative for hunter-gatherer subsistence and settlement. If there is no correspondence between an archaeological site and highly suitable areas, it is likely that that particular strategy was not a viable mode of living. The spatial output from this modeling is not intended to reflect reality, but rather is used as a heuristic device that sets up constraints on behavior and explores how these constraints affected the resulting outcome. The purpose of this activity is to discern whether any of the documented adaptive strategies may have been in use in various parts of the Netherlands during the Mesolithic period. Further, when the most viable strategy has been discerned for each area and site, trends can be investigated between the changing landscape and changes in adaptive strategies.

Once the most viable strategy for each site has been determined, the modeled strategy is further tested on the archaeological assemblage of that site. As part of this study, the material remains from seven different site complexes in the central Netherlands were observed. Chapter 7 provides summaries of the functional analyses that have been undertaken on these assemblages (see Chapter 7, section 7.5.1.1 through 7.5.1.7). These site functional analyses are used to further test the applicability of different adaptive strategies during the Mesolithic. Once the most viable strategy is known for each site, knowledge can be extrapolated to predict which other locations in the study area may also contain archaeological remains. This exercise results in a predictive map of potential land use by Mesolithic hunter-gatherers in the Netherlands.

1.4 Hypotheses

Based on knowledge of ethnographic and archaeological data, three adaptive strategies are considered here as possible strategies used by Mesolithic hunter-gatherers. These alternative strategies are not considered as rigid constructs, but rather as flexible modes of living. Further, these strategies in no way encompass the total number of ways in which the hunting and gathering lifestyle may be expressed. However, for the purpose of this study, three unique strategies will be discussed as follows:

1. A large game-focused strategy, in which hunting plays a predominant role in securing daily subsistence needs. Groups practicing this strategy would have had relatively large territories, and used a combination of logistical and residential mobility strategies to maintain their living. Sites are generally small and ephemeral, although periodic group

aggregation may have occurred. Assemblage composition should be relatively the same, as similar activities were undertaken at each location (e.g., butchering, processing, cooking, eating, sleeping, maintaining tools). However, some variability is expected within the assemblages, as hunter-gatherer settlement patterning is quite complex (e.g., Nassaney and Lopinot 1986; Robertson 1987). Further, it has been established that as assemblage size increases, so too does diversity (Kintigh 1984).

2. A generalized, broad-spectrum strategy, in which a diverse array of food and non-food resources were exploited on a daily basis at the local level (that is, whatever was encountered in the daily search). Territories were covered more intensively and thoroughly, meaning that individual moves were shorter, whether residential or logistical. Settlements are small and ephemeral, with some group aggregation. Sites created under this strategy should reveal different procurement activities, as different resources were focused upon at each location. Thus, there is likely an emphasis on logistic extraction camps.
3. A targeted strategy focused on wetland or coastal resource exploitation (e.g., shellfish, fish, aquatic birds and mammals, wetland/coastal plants). Mobility is expected to be relatively low at these sites, as abundant resources would have precluded the need for frequent moves. Logistical moves may have been longer, not only to acquire non-local goods (e.g., tool stone and hard wood for canoes), but also to find new sites as well as exchange and trade information and marriage partners. One or a few main settlements are expected, at which the same mix of domestic activities would have occurred, surrounded by a number of smaller logistical settlements, where targeted acquisition activities took place.

1.5 Dissertation Outline

In the following thesis, a number of related topics are addressed as they pertain to hunter-gatherer land use strategies during the Early to Middle Holocene in the central Netherlands. The development of hunter-gatherer theory is described in Chapter 2, which discusses how that theory relates to human land uses. A broad overview of the Mesolithic way of life in Europe is provided in Chapter 3, and notes some of the variety of cultural adaptations that were developed. This review also highlights some of the different ways in which humans and the environment interacted, and zooms in on the Netherlands to set the scene for developing suitable behavioral models. The development of the external environment of the Early and Middle Holocene in the Netherlands is outlined in Chapter 4, using known geomorphologic, groundwater, and vegetation data to recreate the paleo-landscape. An overview of decision-making theory and predictive modeling is provided in Chapter 5, especially as utilized in the Netherlands. This chapter also details a method for simulating hunter-gatherer land use behaviors, the product of decision-making processes. Three possible adaptive hypotheses for hunter-gatherer behavior are outlined in Chapter 6, in which a set of expectations about these alternatives for spatial land use modeling is developed. The results of the modeling exercises are presented in Chapter 7, which further discusses the outcomes and ramifications of the results. Finally, the outcomes in relation to the larger research questions of this study are summarized in Chapter 8, and a program of study that can be implemented to continue and refine such research in the future is suggested.

Chapter 2

THEORY OF HUNTER-GATHERERS AND LANDSCAPE

2.1 Introduction

The goal of this chapter is to provide background on the development of theory directed at an understanding of hunter-gatherer behavior, as well as to discuss theory pertinent of an understanding of human use of the landscape. The first section of this discussion addresses the development of hunter-gatherer theory from the mid twentieth century, evaluating which analytical theories and approaches are best suited to answer the central questions of this study. The second section focuses on ideas of space, place, and landscape, and how these concepts manifest themselves in the hunter-gatherer experience. These guiding principles will then be used as a framework for the simulation of hunter-gatherer land use behaviors and perceptions in the Post-glacial Netherlands (see Chapters 5 and 6).

2.2 Approaches to Hunter-Gatherers Studies

2.2.1 Definition. The hunting and gathering way of life is said to have been in use by the human species for about 99 percent of our time on Earth; clearly, it is one of the most long lived and successful economies employed by human beings in order to maintain their livelihoods and consequent biological viability (Lee and DeVore 1968:ix). However, achieving consensus about what actually constitutes a hunter-gatherer group is harder to pinpoint. In the first half of the twentieth century, hunter-gatherers were considered as the lowest rung on the ladder of human evolution, primitive societies in which the fundamental attributes of humanity were developed

(Lee and DeVore 1968:ix). Much of the field of modern-day anthropology was built on understanding our origins, both biologically and culturally (Kuper 1988).

The defining characteristics of a hunter-gatherer group may be approached economically, as people who do not rely on domesticated plants or animals; socially, as fundamentally egalitarian people who lived in small groups with flexible membership rules; or territorially and in terms of mobility, as people who move their residences with some frequency (Kelly 1995:2). For the purposes of this study, hunter-gatherers are regarded as peoples who lived in small egalitarian groups, practiced some degree of residential mobility over the course of a year, and obtained some portion of their diet from hunting, fishing, and gathering (Kelly 1995:3). There are clearly some loopholes in this definition; hunter-gatherers may stay in one location for long periods, or they may move every other day. Such mobility strategies may change from season to season and year to year. Hunter-gatherers may obtain a significant part of their diet from exchange or formal trading or from low level horticultural pursuits. The hunting and gathering way of life has manifested itself uniquely over the ages and across the globe.

Further, Myers' (1988) concludes that the only way to adequately define hunter-gatherers is to do so in a reflexive manner, in which foraging[3] groups define themselves as such (Myers 1988). Riches (1982) also demands a reflexive definition, believing that hunter-gatherers should be defined both *eticly* and *emicly* (Riches 1982). In other words, not only must we take into consideration how scholars have and do define hunter-gatherers, but we must also make sure that the cultural components of forager society used by ethnographers are evident and used by the hunter-gatherers themselves. Barnard (1983) has also weighed in on this contentious issue,

[3] The term 'forager' is often considered a subcategory of hunter-gatherer; however, because 'forager' is used interchangeably with 'hunter-gatherer' in the field of European prehistory (e.g., forager-farmer transition), I will use the terms similarly.

concluding that the category ‘hunter-gatherer’ still has some utility, although we must establish two major factors: (1) that we can easily distinguish between non-hunter-gatherers and our study groups, and (2) that this difference in economics represents further differences in cultural components that will lend themselves to comparative analysis (Barnard 1983).

Since the inception of the field of anthropology, scholars have endeavored to understand hunter-gatherer communities, for a variety of reasons and using a number of different approaches and techniques. In this study, a theoretical approach is utilized that considers the pros and cons of a number of approaches, incorporating what is perceived to be the most applicable components of both ecological and social perspectives. Thus, this section will begin with a discussion (in chronological order) of a number of approaches targeting hunter-gatherer land use strategies. The strengths and weaknesses of each approach will be described, and the components of each approach that can be utilized for the purposes of this study are outlined. This review of hunter-gatherer theory will start broadly and zoom in on particular issues and components of band level society.

2.2.2 Evolutionary Development and Culture Area Concepts. Since its inception, anthropology has relied on hunter-gatherer groups to help define what civilized cultures are *not*. Especially within evolutionary and neo-evolutionary approaches, “primitives” or “savages” have acted as the basal end of various developmental trajectories. Unlike their primarily European observers, hunter-gatherers had few possessions and no concept of private property. Their lack of sophisticated technologies and socio-political entities was attributed to an intellectual inability (Kelly 1995:9-10). Scholars who subscribed to the idea that progress and social evolution were inherent characteristics of all human culture (e.g., Service 1962; Steward 1955; White 1959) found it easy to see hunter-gatherers as fossil remains from an earlier, surpassed stage of human evolution. White (1959) saw himself as the intellectual heir of Tylor and Morgan – and was a proponent of unilinear evolution – but regarded cultures as thermodynamic systems. Thus, he believed that the complexity of a culture is directly connected to the amount of energy it can harness. Service (1962) took this idea a step further with his band-tribe-chiefdom hierarchy (the 'patrilocal-band model') by combining it with Morgan and White's framework for cultural development (Service 1962).

This perspective began to change with the influence of anthropological researchers such as Franz Boas and Alfred Kroeber, both of whom tried to shift the focus of hunter-gatherer studies away from evolutionary classifications, and toward holistic cultural studies. The idea of culture areas arose—regions where unique cultural traits could be discerned in particular historical frameworks. While this notion helped scholars to draw connections between cultural manifestations, subsistence regimes, and geographic areas, no real causal links between the environment and culture were ever determined. Kroeber, for instance, could accept that nature and culture were intimately related, but could not reconcile the fact that "in each situation or area different natural factors are likely to be impinging on culture with different intensity" (Kroeber 1939:205).

2.2.3 Cultural Ecology. By the mid twentieth century, the shortcomings of the culture area concept began to be addressed. Instead of trying to understand how culture can come from culture (sensu Boas), Julian Steward took normative descriptions of cultural groups and their surrounding environs and drew functional connections between these unrelated communities. He coined the phrase 'cultural ecology' to encompass this new approach, which focused on the environment, technology, and society of a culture, and their multiple interrelationships (Steward 1955). The main assumption of this approach was that every group has basic behaviors that are related to energy extraction, and these behaviors form the "culture core" of that group. Social organization and ideology is built upon this core, with additional input from diffusion and innovation (Steward 1955:37-41). As Steward saw hunter-gatherers as the simplest (i.e. most basic, least complex) form of society, he consequently believed that these groups operated on little more than the essentialized culture core. Further, Steward intentionally did not develop any specific methodologies for identifying the culture core of a group and argued that methods should be developed in a case-by-case manner. This methodological loophole gave anthropologists free reign in terms of how and what they identified as a target group's culture core (Harris 1968:661), sparking the rise of attendant problems of subjectivity, post-hoc explanations, a lack of common terminology, and an inability for comparisons to be made between studies.

Steward (1955) wrote that a group's social organization was based on their environment and technology, and that multiple courses of social development could result (e.g., "multilinear evolution"). He formalized these hypotheses in regard to hunter-gatherer society with the concept of the 'band', of which Steward (1955) discerned three main types: patrilineal, matrilineal, and composite. Patrilocal bands typically reached a group size of between 50 and 100 members, had political autonomy, local exogamy, patrilineal descent, patrilocal residence, and communal land ownership. This form of band organization is the most common in the ethnographic literature, and thus, Steward assumed it was the earliest to have developed. Matrilocal bands were similar to patrilineal bands, although descent and residence were matrilineal/local. Steward believed that this form of organization was due to one of a number of factors: 1) the wife's family territory was more favorable; 2) there were few men in the wife's family; 3) the wife's family had a lack of women; and 4) the assistance of the wife's mother was desired for child rearing purposes. Steward also noted that this organization could occur on account of diffusion from neighboring areas. Composite bands, by contrast, were described by Steward as the confluence of several independent family groups, making them larger than larger than patri- or matrilineal groups, with few or no rules of residence and endogamous bilateral descent. Steward concluded that such band organization was possible in areas with abundant food resources (e.g., among groups following migratory herds), and implicated factors such as the facilitation of parallel and cross-cousin marriages and the subdivision of land for particular economic purposes. Further, it should be noted that some groups did not fit into any of the above categories, and in these cases, Steward classified these bands as organized at the "family level of integration." Such configurations were thought to occur only in environments with harsh conditions, thereby preventing true band formation.

While cultural ecology did inspire a renewed interest in hunter-gatherer studies, it was fraught with problems. Apart from those listed above, there was the fact that cultural ecology had the tendency to view hunter-gatherers as isolated, ahistorical, and pristine groups. In addition, there were two "fatal flaws", according to Kelly (1995:45-49) that led to the rejection and replacement of the approach. The first was a circular view of adaptation as static, unchanging behaviors, that exist because they are adaptive. This precluded the existence of any non-adaptive behaviors, or evolution and change through time. The second flaw was the focus on group selection as the primary unit of social behavior (Kelly 1995:47). This issue was based on the fundamental assumption that people always do what is best for the group (i.e., they act altruistically), putting their own lives on the line if necessary. This tenet was roundly criticized, especially by biologists, who were currently producing studies that indicated that, in fact, altruistic communities are rarely found in nature.

2.2.4 Generalized Foraging. The inability of previous approaches to adequately explain hunter-gatherer diversity led a number of scholars to convene in 1966 in order to discuss new and fruitful routes forward. The resulting "Man the Hunter" conference sparked a renewed and urgent interest in studying hunter-gatherers for their own sake, especially since it was becoming apparent that hunter-gatherers groups were quickly disappearing (Lee and DeVore 1976). An important topic of the conference was to establish what exactly was meant by the term "hunter-gatherer." To this end, ethnographers, anthropologists, and archaeologists developed a "nomadic style", which included the following requirements for inclusion in the social category of hunter-gatherers: (1) a group must rely primarily on hunting, gathering, or fishing in order to qualify as a hunter-gatherer (passing use of agriculture is acceptable only in the most limited and uncommitted sense); (2) hunting by men is supplemented by 60-80% reliance on plant resources gathered by women; (3) social organization tends to be egalitarian and fluid but not without structure; (4) hunter-gatherers tend to live in small groups between the size of 25 and 50 people; (5) these groups are generally very mobile; and (6) resource rights are not privatized and personal property is kept to a minimum (Lee and DeVore 1976).

The scholars who attended "Man the Hunter" helped to codify the 'nomadic style' through the creation of a new model known as *generalized foraging theory*. This theory held that the majority of the forager diet comes not from meat, as previously thought, but rather from plant food (Isaac 1990). Further emphasis was given to the environment and subsistence pursuits of hunter-gatherer groups. These scholars regarded culture as an adaptive *system*, in which changes in one component would potentially have repercussions in seemingly unrelated aspects of society. For this reason, it was imperative to maintain a balance not only within society, but also between societies and the environment. This theorizing was based on general systems theory, which was popular among economists and biologists at the time. This theory, originally developed by the biologists Ludwig von Bertalanffy in the 1940s, was brought to anthropology to explain cultural change (e.g., Clark 1968; Flannery 1968; Johnson 1978; Rathje 1975; Watson et al. 1971). Systems theory sought the underlying rules that drive behaviors of individual parts, as well as larger and more complex entities. Identifying these rules, as well as charting the interactions of the component parts, was the overall goal of systems theory (see Chapter 5 for further elaboration).

One of the most important and long-lived outcomes of the conference was Sahlins' (1968) proposal of the 'original affluent society" (Sahlins 1968). This concept was formulated with the notion that hunter-gatherers lived in a pure state of being, at harmony with their environment and with each other. This concept applied directly to time and labor, such that hunter-gatherers were thought to only work a few hours per day to procure their livelihoods. Lee found that Ju/'hoansi San only worked 12 to 19 hours per week to secure their subsistence. Sahlins (1968) argued that hunter-gatherers had learned from experience that their environment would provide for them, resulting in a generally held assurance of subsistence. Also, because these groups were largely mobile, they had little reason to concern themselves with personal property. Sahlins (1968) dubbed the hunter-gatherer society a 'Zen' economy, in which hunter-gatherers wanted no more than they already had. Such neo-functional views persisted into the 1960s and 70s and conditioned the way that archaeological, ethnographic, and anthropological work in general was conducted on hunter-gatherers.

Since the time of the Man the Hunter conference, all of the original general foraging characteristics have been questioned in terms of their relevance. The idea that hunter-gatherers had all they needed in terms of subsistence was found to be inaccurate, as many groups often existed in a state of undernourishment (e.g., the Dobe !Kung San; Isaac 1990). Many hunter-gatherer groups deal with drastic seasonal variation in food availability, which greatly effects overall health. Many Ju/'hoansi often complain of hunger and are more susceptible to death by disease because of their general state of undernourishment (Howell 1986:173-174; Isaac 1990). It is argued that prehistoric hunter-gatherers also led lives that were very physically demanding (e.g., Yesner 1994). Some hunter-gatherers do not, or hardly, rely on plant foods, such as Arctic foragers. It has also been shown that while meat only provides 35 percent of the total food weight consumed by an average hunter-gatherer group, that meat makes up more than half of the calories consumed (Hayden 1981). The notion that hunter-gatherers had only to work a few hours per day was found to be inaccurate, as the time involved in processing the food in camp, maintaining sufficient tools, as well as a number of other necessary tasks were not considered. Thus, groups like the Paraguayan Ache were found to spend 70 hours per week securing their subsistence (Hawkes and O'Connell 1981). Violence has been found among so-called 'egalitarian' hunter-gatherers, whether to protect territorial boundaries, to steal food, or to get revenge (Ember 1978). Also, some inter-group inequality has been discerned, mostly between men and women and young and old people (Hayden et al. 1986; Leacock 1978; Woodburn 1980). One of the most visible cases of inequality is food sharing, in which women and men eat different diets, men generally consuming the majority of meat (Speth 1990; Walker and Hewlett 1990).

The impacts of the Man the Hunter Conference were numerous, not least the fact that hunter-gatherer research was a worthwhile pursuit, one made all the more pressing given the steady incorporation of forager groups into modern economic systems. Much of the resulting scholarly work took an ecological perspective, identifying the ways in which humans interacted with their environments. This ecological approach provided the foundation for two major models – the optimal foraging model and the behavioral ecology model.

2.2.5 Optimization Models. Optimizing models have long been popular among researchers attempting to explain non-human and human behavior alike, and arose out of the general cultural ecological framework. The primary aim of such models is to reconstruct foraging decision-making, as it occurs in real time (e.g., Mithen 1989, 1990). The main assumption of such models is that humans want to maximize their net rate of energy gain, which they accomplish by carefully selecting the most efficiently procured and prepared food resources from a range of options (Bettinger 1987). Models of optimal foraging always include a goal (usually optimal foraging efficiency), a type of currency (usually calories, although see for alternatives Belovsky 1978; Foley 1985; Keene 1979; Keene 1981; Sih and Milton 1972; Smith 1978), and dual sets of constraints and options. The benefit of optimizing models is their ability to predict how resources should be used under certain decision-making constraints, thereby providing a heuristic model against which empirical observations can be cast.

Optimization models focuses on three main aspects of human behavior: foraging space, group size, and diet (Keene 1983). The factors that drive these decisions may not be conscious; it seems logical to assume that—given a variety of potential energy sources and all other factors being equal—humans and animals alike will subconsciously rank all resources along a scale of net energy and procurement investment. When conditions are plentiful, the resources taken should fall along the high net energy, low procurement cost end of the scale. However, under conditions of scarcity, more time should be spent searching for resources (increasing procurement cost), and thus, more foods of variable net energy will be acceptable.

Linear Programming. Three important optimal foraging models have been developed to investigate the above assertions: patch-choice, diet-breadth, and linear programming. Linear programming was first developed in the 1970s as a way to model diet in a detailed manner (Keene 1979; Keene 1981; Reidhead 1979, 1980). In this approach, various dietary elements (not just calories) can be modeled simultaneously. Keene (1981) undertook such a study to understand how the diet of pre- and post-contact Netsilingmiut peoples changed. The input data was taken from the ethnographic record and involved measures of how easily accessible certain resources were. Keene's (1981) model did not perfectly predict when the Netsilingmiut procured certain resources; however, the model did reveal that even when sufficient protein and energy was available to a group, they did not necessarily receive adequate amounts of nutrients. A similar study was undertaken by Belovsky (1987), the goal of which was to predict how much meat versus plants constituted the Ju/'hoansi diet. By running different model scenarios (in which different factors were given more or less importance), Belovsky found that the Ju/'hoansi tend to follow an energy-maximization strategy when foraging.

There are, however, drawbacks to using linear programming. First, accurate estimates of values such as tool-manufacturing and resource processing times are critical and can greatly affect the outcome of the model. In short, "the parameters of a linear-programming model have to be very precise in order to be accurate" (Kelly 1995:77). Another downfall of the model is its assumption that resource acquisition requires a constant amount of time and energy when, of course, such a relationship is neither linear nor constant. While neatly describing hunter-gatherer diets, linear programming models do not present a method for testing hypotheses of hunter-gatherer subsistence.

Diet-breadth. This model was adopted from ecology (e.g., MacArthur and Pianka 1966), and has been used by anthropologists to predict whether a forager will use a resource (or resources) in a patch upon encountering that resource (Kelly 1995:78). The primary difference between the diet-breadth and linear programming models is that the former views the parameter of resource acquisition as part search cost and part handling cost. These parameters are generally measured in kcal/hour and can be based on experimental tests (e.g., Simms 1987) or ethnographic data. Under this model, resources tend to be ranked according to their post-encounter return rate, which measures how much energy and time it takes to acquire a resource after coming across said resource. Kelly (1995:81, Table 3-3) reveals that some food groups yield comparatively higher or lower post-encounter return rates (e.g., plants tend to yield lower return rates than meat). Changing food densities will directly affect search costs, as well as the type of technologies used to locate the food (e.g., using new tracking methods). The latter also has a large impact on handling costs and return rates. As Simms (1987) found, removing seeds from plants by hand is much has a higher handling cost and lower return rates than using a paddle to remove the same seeds. Of course, return rates will also differ greatly based on the time of year, especially in locations with high seasonality.

Understanding that resource acquisition involves two separate activities is a critical element of the diet-breadth model. Assuming that hunter-gatherers want to maximize their net return rates, these additional parameters give researchers the ability to approximate the decision-making process (Kelly 1995:83). Some interesting insights have been derived using the diet-breadth model. For example, Hawkes, Hill, and O'Connell (1982) found that among the Ache, a resource will not be taken unless it provides a higher return rate than what is currently being consumed. Conversely, there appears to be a minimum return rate below which the Ache will not take a resource, unless under starvation conditions (Hawkes et al. 1982). Another useful insight derived from this diet-breadth study is that resource usage cannot be predicted from abundance values alone (Kelly 1995:88). Just because a low ranked resource is very abundant does not mean that the Ache will procure that resource. However, when a highly ranked resource suddenly becomes available, it will be taken over the lower ranked ones. The Ju/'hoansi illustrate this point nicely, as they will abandon mongongo nuts (a low-ranked resource) immediately upon finding meat or honey (both higher-ranked resources; Lee 1968:33).

There are various pitfalls to the diet-breadth model. First, Western observers may be biased towards the 'edibility' of certain items and discount their dietary importance. For example, insects often comprise an important part of hunter-gatherer diets in places like Australia and the Great Basin. Grasshopper runs, for example, can pose temporarily as a high-ranking resource (Madsen and Kirkman 1986); however, such a resource may be easily overlooked as it is not traditionally part of the Western diet. Similarly, it may be very difficult to estimate how much net energy can be gotten from a resource used very infrequently and therefore not recorded in field notes or other records. Second, diet-breadth models may give researchers an inaccurate idea of how frequently certain high ranked resources were taken. As mentioned earlier, even though a particular resource is highly abundant does not mean it will be procured. As noted by Kelly (1995), "the diet-breadth model only proposes that all high-ranked items will be taken *when encountered*, but if they are encountered rarely they will make up only a small portion of the diet" (Kelly 1995:88). While the Ache prefer to take collard peccary, it is only infrequently procured due to low encounter rates (Hawkes, Hill, and O'Connell 1982). Third, the model assumes that resources are distributed homogeneously across the landscape, which is often not the case for a study area. Fourth, the model assumes that hunter-gatherer search their territories randomly, which has also been shown to be rarely the case. Hunter-gatherers tend to have an idea of what they are looking for and where to look for it when they undertake a logistical foray. With these considerations in mind, it can be summarized that the diet-breadth model is valid for situations in which hunter-gatherers encounter resources in a fine-grained manner (Kelly 1995:90).

Patch-choice. In the event that circumstances do not conform to the fine-grained encounter, another model must be used instead. This last optimizing model to be discussed here is known as the patch-choice model, which reflects the primary difference between this model and the last. That is, the patch-choice model assumes that resources are distributed heterogeneously or patchily across the landscape, as its name suggests (Charnov 1976:129; Kelly 1995:90). Like the diet-breadth model, the patch-choice model also assumes that hunter-gatherers randomly encounter resources (the drawbacks of which should be duly noted). Further, this model holds that once a patch is left, it will not be returned to until the resources within it have had time to rejuvenate. The main aim of the patch-choice model is to ascertain which resources patches (rather than just resources) will be exploited during a logistical or residential foray (Kelly 1995:91).

Similar to the diet-breadth model, the patch choice model allows for patches to be ranked according to various "currencies", such as the energetic return rate (e.g., kcal/hr or otherwise). Thus, hunter-gatherers should ideally move from a high-ranked patch to another high-ranked patch, the idea being that after the initial arrival of the foragers, the patch slowly starts to decline in energetic returns. But what dictates when the foragers should move their residence? Charnov (1976) and Winterhalder (1987) have written that a point of diminishing returns is eventually reached in the mind of the forager. That is, the benefit of moving to a new patch should outweigh the cost of having to move to that new patch. This is also known as the *marginal value theorem,* which predicts that when the yield of the patch falls below the average for a given environment, then the forager will move to another patch (Charnov 1976:134; Kelly 1995:91). Thus, it is assumed under the patch-choice theory that foragers will exploit the highest return rate patch that they know of.

Multiple resources may be exploited within a single patch. The Ache demonstrate how such resource ranking works. Here, if a higher-return rate item is found within a patch, the current resource extraction practice shifts toward extracting the more valuable resource (Hawkes et al.1982). Such decision-making can be explained if one considers the practice of hunting to be its own patch (Hill et al. 1987). For example, the main goal of the hunting patch is to find a peccary; however, in the event that other resources are found while searching for the prey, then they too will be taken, as they increase the overall return rate of the hunting activity (e.g., patch). However, when a peccary is sighted, all extraneous resource exploitation is curtailed since the peccary now poses the highest return rate resource.

A downfall of theory that emphasizes patch-choice is that it considers traveling between patches as non-productive time, despite the fact that it has been ethnographically documented that trips from patch to patch can serve as useful information and other resource gathering opportunities (e.g., camp moves double as foraging trips among the Malaysian Semang (Rai 1990:59; Schebesta 1929:150). However, Kelly (1995:94) notes that this stipulation may only rarely be true. The Cree, for example, do not practice a patch-to-patch search strategy when they are stalking moose. Rather, they move between potential moose patches looking for moose tracks, and then follow these tracks into patches (Winterhalder 1981). Also critical to note is that Cree patch usage cannot be predicted solely on the density of game in that patch, because other factors play an important role in condition the decision to use a patch. For example, patches that have high game potential but that are densely vegetated will likely *not* be used because of the difficulty in moving through the patch, effectively rendering the patch empty of game. This consideration is important to consider in the context of this study, as it is projected that as the Holocene progressed, parts of the Netherlands became very densely forested. In such patches, even if large game were present, it would have been extremely difficult to access, therefore making other accessible patches more attractive.

In summary, the patch-choice model can be profitably used to predict the patches that should be targeted by foragers, while the diet-breadth model is useful for predicting which resources in that patch should be taken (Kelly 1995:97). These models will be used as a guide in model building for the Dutch Mesolithic context in Chapter 6. It must also be borne in mind that these models are only as strong as their weakest assumptions and input data, and that consideration of nuanced hunting and gathering behaviors must be undertaken.

2.2.6 Behavioral Ecology. Another important model that arose out of Stewardian cultural ecology is the behavioral ecology model. Though both optimal foraging theory and behavioral ecology employ evolutionary theory, the latter does so in an explicit manner. Behavioral ecology can be thought of as a framework for understanding how cultural information is transmitted (Kelly 1995:50). These data are found by investigating the relationships between the distribution and abundance of food resources, and time-allocation decisions between various activities (such as foraging versus other crucial activities). The primary goal of behavioral ecology is to show how human societies are shaped by evolutionary processes, such as natural selection (Cronk 1991:25). Instead of referring to rational choice as the causal factor conditioning human behavior, this model considers more fundamental and testable drivers; however, human choice is still considered to be an important factor in human survival.

One of the major assumptions of behavioral ecology is that people want to maximize reproductive fitness (thereby increasing their contribution to the gene pool) and consequently select behaviors that will help them accomplish this task. As an example, it has been shown that specific time allocation and foraging efficiency strategies can increase an individual's reproductive fitness. Among the Ache, an energy-maximizing strategy is used, which requires long amounts of time hunting in the forest. This behavior is argued to be reproductively successful because Ache men regularly trade meat for sexual favors, and therefore, a successful hunter will have more offspring (Hill and Kaplan 1988; Kaplan and Hill 1985). Among the Efe, a time minimizing strategy is used, which requires high levels of skill on the part of the forager in order to be a reproductively successful strategy. Efe men attract women by having lots of traded goods received from the nearby Lese agriculturalists. So, rather than spending lots of time in the forest, an Efe hunter is better off using his extra time working on trade relations (Bailey 1988, 1991).

Critical to the successful use of behavioral ecology models is the understanding that once culture and cultural evolution is introduced to the equation, the evolutionary process no longer follows a strict biological rubric. While we get our genes from our biological parents, we obtain our culture from many different people. Employing the idea of natural selection allows us to explain variation within human cultures as the product of multiple optimization strategies. For prehistorians and archaeologists, behavioral ecology is particularly useful because it does not assume that pre-contact hunter-gatherers were pristine; rather, this model allows us to understand how hunter-gatherers survive in any environment with any accompanying set of resources, extraction technologies, and preparation methods. Thus, the main benefit of using behavioral ecology is that it provides scholars with a tool to analyze the adaptive behaviors of any group based on the unique array of resources available to it. For the purposes of this study, it is assumed that the choices made by hunter-gatherers regarding land use were reproductively successful. However, due to the nature of the available data, optimizing models based on rational choice and decision theory are used here, rather than considerations of natural selection and reproductive fitness.

2.2.7 Mental Models. The models of hunter-gatherer behavior discussed so far have all considered extrinsic motivations of hunter-gatherer behavior, that is, primarily the acquisition of sufficient food and non-food resources, factors which directly impact basic survival and natural selection. There are, of course, other ways to explore hunter-gatherer behavior, such as from more internal or psychologically-focused perspectives. In this section, models on the role of information, landscape perception, and decision-modeling will be discussed.

Information-based models. While information, or knowledge, is often implicitly considered within hunter-gatherer behavioral models, the recent volume edited by Whallon, Lovis, and Hitchcock (2011) has underscored the importance of this dimension of human behavior which, when studied directly, can yield fruitful insights (Whallon 2011:2). Toward this end, Whallon (2011) has developed a preliminary framework for researching the role of information among band-level societies, or cultural systems. Information is here defined as “knowledge—including how to do things, how to react to various circumstances, how to behave in different social situations, what current resource conditions and availability are (quality, quantity, distribution, etc.)” (Whallon 2011:2).

Within hunter-gatherer groups, three types of information are identified as essential: environmental, social, and technical information. Environmental information is perhaps the most commonly associated by researchers with hunter-gatherers, as their particular lifeway precludes extensive and detailed knowledge of the landscape. In this study, much focus is given to the nature of role of environmental knowledge. Interest in technical knowledge has also received a good degree of research attention, primarily in the line of understanding how such information is transmitted from adults to children or masters to novices, in order undertake various types of necessary activities (e.g., tracking prey, preparing and cooking foodstuffs, manufacturing implements, etc.; Bamforth and Finlay 2008; Ingold 2000:36, 386-387 ; Mesoudi and O'Brien 2008; Ohmagari and Berkes 1997; Roux et al. 1995). Social information involves all of the knowledge necessary to navigate social life—both in everyday contexts within the small group, but also at a larger level, to secure marriage and trade partners, for example. All three types of information are critical to the survival of a group; however, information is not a given. It must be actively acquired, circulated, stored, and mobilized.

Whallon describes the acquisition of information as “the direct obtaining of facts from immediate contact and observation” (2011:3). The most important venue to acquire information among hunter-gatherer groups is through direct personal observation. Furthermore, information acquisition usually requires movement. That is, movement allows the receiver to increase and refresh information, such that receivers tend to have more information about areas frequently moved through than those at further distances. Because information can be acquired while moving, information gathering can also be embedded into other, perhaps more utilitarian activities. Information circulation is the process by which a receiver(s) transmits information to another. This process can happen at a variety of scales, from locally to regionally and beyond. At the local and regional levels, regular information exchange tends to concern more utilitarian needs. Whallon notes, however, that at the interregional level, information "may be used more sporadically [and] will tend to be less detailed and may be more concerned with establishing a few firm social conditions over such large distances and areas (2011:8). Information is circulated through various mechanisms, including symbols, signs, styles, conversation, gossip, gift-giving, discussion, and exchange.

In the event that information is gathered but unneeded, it is advantageous for a person or group to store that information for later retrieval. The simplest storage method is the human memory, which is commonly used by small-scale, band-level societies. Further, information is stored differentially, generally because certain individuals or groups have special 'rights' to knowledge, such as men's versus women's knowledge, or specialists' versus novices' knowledge. Furthermore, this stored knowledge varies in terms of its qualitative and quantitative characteristics. Finally, when needed, information must be mobilized. There are four main ways this can occur. First is the retrieval and usage of information gathered by the original receiver. Second is "when one or more people see and are able to extract and correctly interpret the information that is encoded in a sign, symbol, or style" (Whallon 2011:24). The third type of information mobilization occurs during ceremonies or rituals, in which information is embedded in the belief system of the group. Lastly, information can be mobilized through conversation and planning.

Approaching hunter-gatherer studies from the perspective of information can and is yielding valuable new insights into the behavior of these groups. The role of information in evolutionary and long-term adaptive processes is only beginning to be addressed; however, it is hoped that such endeavors will shine new light on many old and questions of land use, adaptation, and cultural transmission. Before moving on though, it should be noted that information degradation is a critical issue in this line of research, as knowledge that is not properly maintained can be lost entirely. This is yet another aspect of information that warrants further attention, as the loss and retention of knowledge likely holds important implications for hunter-gatherer studies in general.

Perception-based models. Whereas information-based models consider the act of acquiring, circulating, storing, and mobilizing knowledge—certainly all matters having to do directly with the human brain—more explicitly psychological models considering how hunter-gatherers perceive of their landscapes have also been developed (e.g., Ingold 2000; Tilley 2004b; Whitley 2000). These models stem from a larger thrust within the post-modernist philosophical realm to understand how human identity, consciousness, and the body interact with and construct space, place, and landscape, based largely on social theory (Cosgrove 1984; Low and Lawrence-Zuniga 2003; Tuan 1977; Yamin and Metheny 1996). This paradigm of thought will be addressed further in the following section; here, the more targeted application of such scholarship as described in Ingold's (2000) essay titled *Hunting and gathering as ways of perceiving the environment* will be discussed, as it applies specifically to the case of hunter-gatherer communities.

The first key step to Ingold's formulation of how hunter-gatherers perceive their worlds is the acknowledgement of a fundamental difference between Western and indigenous hunter-gatherer approaches to nature and culture: in the former, culture is viewed as separate from nature, although culture is thought to constitute nature (e.g., Sahlins 1976:209); in the latter case, “apprehending the world is not a matter of construction but of engagement, not of building but of dwelling, not of making a view *of* the world but of taking up a view *in* it (Ingold 1996:117, 2000:42). The familiar dichotomy between nature:culture is simply a non-issue among most documented hunter-gatherer societies.

Ingold champions an approach to hunter-gatherer behavior in which human action and intention is grounded in the context of mutually constitutive and ongoing engagement between environment and people (2000:27). In an essay on the subject of hunter-gatherer perceptions of the landscape—and how it is diametrically different from the western view--Ingold investigates the relationship between the Mbuti Pygmies and their forest landscape; between the Cree and the hunted prey; and between Aboriginal Australians and Subarctic Inuit and the landscape. In the first case study among the Mbuti Pygmies, Ingold (2000) notes how the group has an intimate relationship with the forest, in which they play a critical role. To signify this close relationship, the Mbuti refer to the forest as ‘father’ or ‘mother’ (Turnbull 1965:19), as do other tropical band-level societies (e.g., the Nayaka hunter-gatherers of Tamil Nadu; Bird-David 1990:190). Clearly, among these groups, the environment is seen as providing unconditional support to the people. Interestingly, among neighboring horticulturalists, the forest is seen instead as an ancestor that provides only in a reciprocal manner (Bird-David 1990). Hunter-gatherers see no distinctions between parts of their world; it is all one integrated entity (Bird-David 1992:29-30). As such, time spent in the forest is never wasted, as it is considered just as important to know and make social connections with organisms in the forest as it is among one’s fellow group members.

Among the Waswanipi and Wemindji Cree, animals are treated similarly to the forest in the above case. Animals are not taken, but rather present themselves to be taken when they are needed (Feit 1973). Instead of animals posing as separate entities that must be tracked and killed, "they are partners with humans in an encompassing 'cosmic economy of sharing'" (Ingold 2000:48). Animals, and all other 'forces' in nature (such as wind and rain) are included in the category of 'personhood', which among Western thought is confined only to people and restricted to animals and other non-human beings. Thus, the act of hunting is seen not as humans manipulating the external world, but rather as a conversation or dialogue between people and their prey, which is critical to progress of normal social life, in which both people and prey have their particular roles. Further, while animals and other entities in the landscape are often assigned qualities of personhood (Scott 1989:195), hunter-gatherers still maintain an acute understanding of the differences between humans and animals (Ingold 2000:49). Humans, animals, and other forces in nature are all accorded the same type of existence, as an 'organism-person', with an important and unique role to play. Differentiation is made only between the different types of organism-persons. The meaning of life among the Cree is less about reacting and responding to external entities in the environment, and laying meaning on the events in the world, but rather about being in the world and carrying out one's capabilities and purposes (Ingold 2000:51).

The Pintupi of Western Australia perceive of the physical landscape as the metamorphosed remains of activities once carried out by their ancestors in the Dreaming (Myers 1986). The landscape thus represents the congealment of all past activities, rather than as a virgin surface awaiting the imprints of activity (Ingold 2000:53-54). Rather than being continuous, the landscape is constituted by specific places (denoted by physical features), and connected by paths. These places are generally the locations of events or activities, which Basso has noted act to self-reflexively impart wisdom, as they are "symbolic reference points for the moral imagination and its practical bearings on the actualities of lives" (1988:102). As such, landscapes contain the information to furnish an individuals' identity, containing, as they do, peoples' ancestry and life history. Ingold notes that because of these characteristics, "the movement of social life is itself a movement *in* (not *on*) a landscape, and its fixed reference points are physically marked localities or 'sites' (2000:54). Similar approaches to landscape perception are held by the Koyukon of Alaska. The landscape is seen as the sum total of all the activities (i.e., life histories) that have taken place there. Different places contain different types of meaning—be they personal, historical, or spiritual—and are treated accordingly. Hunter-gatherers are *enskilled* in their worlds, meaning that instead of enculturating and constructing the world around them, they have "the skills for direct perceptual *engagement* with its constituents, human and non-human, animate and inanimate" (Ingold 2000:55).

Decision-based models. Yet another way to approach hunter-gatherer behavior is to investigate how hunter-gatherers make decisions about what to eat, where to live, how to interact, socialize, worship. As thinking organisms with specific intentions, goals, and criteria, humans are frequently faced with problems and decisions that must be solved on a daily basis. To this end, a number of scholars have borrowed theories and methods developed in economics, computer sciences, and philosophy in order to unravel some of the complexities involved in decision-making among band-level societies (e.g., Krist 2001; Mithen 1990). This approached is used here; for a more detailed discussion, see Chapter 5.

2.2.8 Using Analogy. The approaches and models discussed above provide useful ways to get at hunter-gatherer behavior and decision-making within the larger ecological and social world.

These approaches function through the practice of drawing analogues, which can come either from the present (ethnoarchaeology) or the past (archaeological ethnography). The former approach involves doing archaeology on ethnographically known groups or social units to gain insight into past behaviors, activities, and depositional sequences. The latter approach advocates that archaeological inquiry be a socially imbedded practice that views the past as a critical component of the present (Hamilakas and Anagnostopoulos 2009). As such, the past can be used to inform understandings of modern groups. In this study, ethnoarchaeological research is used to set up a series of hypotheses about how prehistoric hunter-gatherers may have acted within the landscape. Thus, this approach is described in some detail below.

Ethnoarchaeology could be described as the product of conducting ethnographic research with an archaeologists' eye; that is, observing ethnographic events with the ulterior goal of understanding how the remains of human activity are converted to the archaeological record. Yellen (1976) first noted that ethnographic information could aid archaeology by furnishing analogies and hypotheses to test on the archaeological record, as well as methodologically, by suggesting possible recovery strategies and expectations for preservation in given contexts. Binford's (1978) ethnoarchaeological work among the Nunamiut, while not the first in this regard, was nonetheless critical in developing the subfield, as it provided a set of guidelines for interpreting archaeological patterns based on the implementation of ethnographic facts into archaeological models. In studying the dynamic behaviors of the Nunamiut, and the ordering of remains each behavior left behind, Binford (1978) showed how "signals" of the dynamic past became crystallized in the archaeological record. In recording particular activities, such as butchering an animal, and noting the associated materials, processes, and patterns of discard, Binford (1978) argued that an archaeologist who encountered a similar arrangement of material remains could make some basic assumptions about the activities carried out in the past. In this way, ethnoarchaeology provides archaeologists with an ethnographically documented way of interpreting the archaeological record.

The main approach of ethnoarchaeology is to study the behavior of living groups as a analogy for understanding how people may have lived in the past as well as how and why certain artifacts and patterns were preserved (or not preserved) in the archaeological record. There is a basic assumption here that certain activities and processes change little over time, such as flint knapping hide scrapers (Belkin 2006), brewing chichi beer in Peru (Hayashida 2008), and the formation of ceramic middens (Beck 2006; Sullivan 2008). However, for this assumption to be supported, we must be careful in making linkages between past and present activities, as the relationship between archaeology and ethnography have long been contested. During the 1960s and 1970s, ethnographic analogy was seen in a conservatively positive light. Freeman (1968) advocated the use of ethnographic analogy in archaeological interpretation, but only to a minimal extent. While Freeman argued that ethnographic analogy was the primary way to comprehend prehistoric customs and the processes that maintained or altered a given system, he also warned of the potential pitfalls inherent in applying ethnographic analogy too liberally. To avoid some of these pitfalls, Clark (1968) argued that it is imperative for archaeologists and ethnographers to work together in this endeavor. Binford (1968) doubted that the behavioral contexts of past and present hunter-gatherers were similar enough for direct comparison. For this reason, he argues that the current focus of archaeologists and anthropologists alike – interpreting the past by applying contemporary analogues – ought to be shifted toward explaining cultural variation. This can be done only through the implementation of scientific method, or setting and testing hypotheses of human behavior. To this end, Binford (1977) later incorporated the concept of middle range theory, a method for relating high-level, broad anthropological theories with low-level, confined explanations of assemblages. Originally developed by sociologist Robert K. Merton (Raab and Goodyear 1984), middle range theory was adopted by Binford and applied to the archaeological record. In transforming archaeology into a field that followed the scientific method, Binford bridged the dynamic past (consisting of systemic processes, such as activities and cultural behavior) with the static present (represented by the current archaeological record).

Bettinger (1987) wrote about ethnographic analogy during a transitory period in archaeological theory, that is, during the post-processual/post-modernist critique. He wrote that some models, such as middle range theory, do not explain certain variations in the archaeological or ethnographic record because they do not aptly model hunter-gatherer behavior. In addition, Bettinger (1987) warns that prehistoric remains must often be analyzed for their own sake, without recourse to present conditions, because post-contact hunting and gathering groups may not serve as adequate analogues. Spielmann and Eder (1994) provide the most recent discussions on the use of ethnographic analogy, discussing the many differences between past and present hunter-gatherers. It is concluded that foragers have long been interacting with the modern world system, both consciously (in terms of marriage, trade, and employment), as well as unconsciously (i.e., disease exchange, ideational transfer, gene drift, etc.). Therefore, the wholesale application of data from ethnographically known foragers to the archaeological record must be restrained. Modern hunter-gatherer behavior should only be used to test ideas about the archaeological record and human behavior in general, rather than as a descriptive device.

One of the reasons that caution must be exercised when using ethnographic analogy is related to one of the main drawbacks of ethnographic research: subjectivity, on the part of the researcher, the study subject, or both. As noted by Wobst (1978), there is “tyranny” in the ethnographic record, meaning that there is a fundamental difference between what people *say* they do and what they *actually* do. Also, inherent bias tends to be built into the ethnographic record, as the majority of ethnographers derive and/or were enculturated in the Western/Global school of thought, also known as Relativism. Such biasing of ethnographic accounts can lead to inaccurate hypotheses of human behavior and, subsequently, inaccurate analogies with the archaeological record. However, one of the strengths of ethnoarchaeology is that the actions of people are observed by the researcher, thereby alleviating some of the informant error that can occur. Concomitantly, the ethnographic record often lacks insider, emic insight, although it should be noted that either an emic or etic approach runs the risk of interpretive error.

2.3 Space, Place, Landscape, and Archaeology

The previous section addressed a variety theoretical and methodogical ways in which hunter-gatherer behavior can be studied, and applied to past scenarios. A central question of this research, however, asks specifically how hunter-gatherers use and perceive of the landscape. To approach this question, ideas of space, place, the body and the mind, and landscape must be considered. First, definitions of these terms will be discussed, followed by a brief discussion of how social theory has informed recent understandings of how the human place within the environment, as well as how humans perceive and experience the world. Then, discussion will return to the practical applications of the landscape concept for archaeology. Concrete frameworks for deciphering human land use over time and through space will be described, as well as how landscape and behavioral change affect on another. The chapter will conclude with a description of landscape archaeology, specifically regarding how this subfield can help to answer the questions posed in this study.

2.3.1 Definitions. The terms “space”, “place”, and “landscape” are familiar to everyday language, despite their rather vague meanings. While it is indeed true that these terms are “cultural constructs of modern European society” (Lemaire 1997:6-9), their utility in describing the domain through which daily human existence occurs is indisputable. For this reason, these terms will be maintained here.

Space and place are often defined together, as different ends of the same continuum. Spaces can be vast and continuous or delimited areas, but they are generally more abstract than places, which connote a specific point or position in space. As noted by Tuan (1977), “what begins as undifferentiated space becomes place as we get to know it better and endow it with value” (1977:4-6). Places have both physical features (e.g., rivers, valleys, wildlife, vegetation, soils) and features imposed by humans through their actions, ideas, and experiences (Keys-Matthews 1998). Moreover, one’s sense of place is inextricably linked to all the factors that give places a specific “feel” (i.e., the physical and human characteristics noted above). Whereas places are stable and secure, space is open and perhaps threatening. Space is experienced through movement of the body, while place represents a pause in movement. Movement in space evokes direction and distance, endowing our lived-in spheres with volume.

Landscape can be variously defined. From a traditional cultural geographer’s perspective, landscape refers simply to a segment of the earth’s surface (Cosgrove 1984; Yamin and Metheny 1996). Economically and politically, landscape provides resources to ensure survival but also presents risks and other factors that impact societies The landscape has also social and symbolic qualities, as an “entity that exists by virtue of its being perceived, experienced, and contextualized by people (Knapp and Ashmore 1999:1). Metaphorically, landscape it is “the stage for human action, and thus reflects past activities and encodes the cultural landscape in which people's view of the world are formed" (Yamin and Metheny 1996:xv). These definitions reveal that landscape is 'multivocal' (Rodman 1992), comprised of varying layers of meaning. According to Cosgrove (1984), the term landscape "denotes the external world mediated through subjective human experience … [and] is a social product, the consequence of a collective human transformation of nature" (Cosgrove 1984:13-14). The landscape, as we think of it, is both socially and cultural construction (Ucko 1994:xvii), with different cultures, groups, and individuals experience the landscape uniquely (Rodman 1992:647).

2.3.2 Social Theory: The Body and Experience. The most recent trend in among anthropological studies of the human-landscape relationship has focused on linguistic and phenomenological approaches, both of which "emphasize *landscape* as constituted by humans dwelling within it, a set of potentials instantiated by human choice and action" (Knapp and Ashmore 1999:3). This approach was touched on above (see section on Perception-based models); here, the approach is considered from the perspective of landscape, and how people perceive, experience, and construe their surroundings.

Landscape can be seen as a "process" in which everyday life takes places in the foreground, the background serving as a vast potential field from which to draw one's social existence (Hirsch 1995). Proponents of this approach contend that the landscape is made into a place by the human agent, who subjectively examines their surroundings from their own unique, locally-situated perspective (Bender 1993). In this way, landscape is reflexively considered to shape and be shaped by the human experience. Under the phenomenology rubric, an attempt is made "to reveal the world as it is actually experienced directly by a subject as opposed to how we might theoretically assume it to be [as researchers] (Tilley 2004:1). Subjects are possessed of both a mind (or consciousness) and a body, the two of which cannot be divorced. Thus, our mind-body being interacts with other such mind-body beings in the world. As Tilley writes, “we experience and perceive the world because we live in that world and are intertwined within it … we are part [of the world] and it is part of us: (2004:2). Our physical bodies allow us to inhabit and move about space, imbuing it with meaning and making *places* without minds.

More broadly, the term experience can be seen as the various ways in which we come to know the world and construct our own realities (Tuan 1977:8). Three types of experience may be identified: the sensorimotor or tactile, the visual or perceptual, and the conceptual. The first type of experience involves direct contact with a space or place through the objects within it. This type of experience is direct, sometimes passive, and can be quit intimate. The second type of experience involves knowing about something through active visual contact or otherwise. For example, we may know how to navigate in a city even if we do not know the city intimately. The third type of experience involves the indirect mode of conceptualizing and/or symbolizing something in one’s mind rather than having direct contact with the world (Tuan 1977:9).

Such considerations of the body and experience of one’s landscape—containing, as it is assumed here, all living and inanimate objects—may seem tangential to studies of hunter-gatherer behavior. However, the phenomenological perspective discussed above mirrors to some degree the ways in which indigenous hunter-gatherers conceive of their place within the larger landscape. As noted previously by Ingold (2000), no separation is made between nature and culture, between mind and body, or between human, animal, or otherwise. Furthermore, a large part of the methodology used here (see Chapters 4 and 6) endeavors to recreate how hunter-gatherers perceived and made decisions about using the landscape. Thus, it is critical to understand the interaction between mind and body, between body and landscape, and between mind and landscape.

2.3.3 Practical Applications for Archaeology. Returning from the more cerebral considerations of space, place, and landscape, as conceived of and experienced by human beings, I now turn to the question of how hunter-gatherers use and perceive landscape in a practical sense. First, the utility of the term landscape will be evaluated in the context of archaeological inquiry. Then, a framework for understanding human land use and change in both morphology and behavior over time will be presented.

Form an archaeological point of view, the landscape could be thought of as autobiographical (e.g., Lewis 1979), as it "preserves evidence of everyday landscape use, as well as the intentional and unintentional effects of its use and alteration" (Yamin and Metheny 1996:xvi). Whereas the ethnographic record and historical documents are often biased by the subjective way in which informants and authors recount their stories, the archaeological record is often devoid of such biases, although others may arise (e.g., related to differential preservation and varying taphonomic processes). Consequently, the most reliable way to study the human-landscape relationship is to draw upon multiple lines of evidence from multiple but related fields of inquiry (Wylie 1993).

Archaeology has long been interested in spaces, places, and landscape, especially in the subfield of settlement archaeology. Earlier on, archaeologists were primarily concerned with understanding the more basic aspects of the human-landscape relationship, such as how people impacted the land and how the landscape either constrained or aided them in their goals (e.g., Carniero 1970; Sanders 1977; Steward 1955; Willey 1953). For example, Gordon Willey's

(1953) work on *Prehistoric Settlement Patterns in the Viru Valley, Peru* sought to make linkages between settlement patterns on the ground and the ecological, technological, and social factors that guided and shaped a prehistoric society. Still, at that time, the focus was primarily on the material: the topography, resources, land use strategies, and technology.

Today, most archaeologists realize that environment and culture interact in complex and unique ways. Attention recently has centered on uncovering the role of the individual or agent, who participates in the perpetual act of interpreting and constructing the world around herself or himself (Knapp and Ashmore 1999:7). Furthermore, symbolic construction and expression within the landscape has become an source of much scholarly inquiry, with various scholars attempting in different ways to decipher the meaning of this expression in past contexts, for example Giddens' structuration theory (Giddens 1984), Bourdieu's theory of practice (Bourdieu 1977), feminist theory (Conkey and Gero 1997; Wylie 1992), and phenomenology (Gosden 1994; Tilley 1994, 2004a).

This move in scholarship was also motivated by an expansion of interest away from 'sites,' or places with dense clusters of archaeological material, toward a more comprehensive consideration of the entire archaeological landscape. It has been shown that the remains of human behavior also occur in and between sites, and by ignoring this 'peripheral' data, we are missing out on key components of the land use story. To rectify this shortcoming of traditional archaeological fieldwork, various different approaches have been developed (e.g., siteless archaeology, Dunnell 1992; distributional archaeology, Ebert 1992; off-site archaeology, Foley 1981; and computer simulations of landscape to address artifact and settlement distributions, Thomas 1975). In these approaches, it is assumed that the entire landscape is strewn with a low amount of archaeological 'noise', with 'sites' referring to particularly dense clusters of anthropogenic material. Of the entire area once inhabited by hunter-gatherers, sites represent only a tiny fraction, and thus by considering the entire archaeological landscape, a more holistic picture of land use and perception may be obtained.

Human Land Use. Human land use can be defined as the ways in which humans use the surrounding landscape, whether individually or communally. Human land use is directly related to subsistence and settlement pursuits, but is also influenced by the type of mobility a group practices, as well as their social and ideological frameworks. Furthermore, land use can be seen as occurring within a wider environment, which consists of three general components: the abiotic (non-living physical entities), the biotic (living entities), and the social (interactions between a single species; Halstead and O'Shea 1989:2). However, landscapes are not just the background upon which people conduct their daily lives and interact with these different environmental components. Instead, the landscape "not only shapes but is shaped by human experience… [it] is an entity that exists by virtue of its being perceived, experienced, and contextualized by people" (Knapp and Ashmore 1999:4, 1). Any investigation of human-landscape interactions must consider both entities as equally important contributors. Thus, in addition to studying what the landscape had to offer hunter-gatherers economically, it is also imperative to address the social and ideological potential of the landscape considered from the human perspective.

It must further be noted that the human-landscape relationship is not static or unchanging. In fact, both landscapes and human groups seem to be in a constant state of flux, with varying rates, tempos, and oscillations over time and space. Any study that attempts to understand one or both sides of the equation must account for these temporal and spatial changes, and the particular scales at which these changes occur. On one hand, this study attempts to model the pattern of change within a particular region, the Lower Rhine Basin of the Netherlands; on the other hand, this study incorporates archaeological proxies of change among Mesolithic hunter-gatherer groups. Although human groups and the landscapes they interact with tend to change at vastly different scales, there are ways we can reconcile these differences. One way is to isolate landscape events that occur in humanly recognizable units (e.g., instantaneous or near-instantaneous events in a localized area that are visible or can be experienced by an individual person). Another way is to look at how longer-term, wider-ranging landscape changes affect human groups over time and space (e.g., by looking at changing patterns of land use and mobility). Both approaches are necessary for a well-rounded investigation of human-landscape relationships.

Given that both humans and the landscape are always changing, we may ask how changes on one side of the equation affect the other and vice versa. Thus, I will first discuss how changes in the landscape can affect hunter-gatherers; then I will discuss how changes in hunter-gatherer lifeways can affect the landscape.

Hunter-gatherers and Landscape Change. As mentioned above, changes in the landscape are not always discernable to an individual, and responsive alterations in patterns of land use may occur very slowly over many years, such that the changes are only visible at the generational or multi-generational scale. However, one type of landscape change that is usually recognizable on the individual scale is variability in resources, whether food or non-food. Such variability often elicits a direct or indirect response from a given society (*sensu* Halstead & O'Shea 1989). These responses, or 'buffering mechanisms', help the society to mitigate fluctuation in cultural resources, and can be grouped into four main categories: mobility, diversification, physical storage, and exchange (Halstead & O'Shea 1989:3-4). Briefly, mobility involves simply moving away from the resource scarce area toward a more resource rich area;

diversification entails broadening the subsistence base by either expanding the array of suitable resources and/or expanding the size and variety of the search area; physical storage refers to preserving presently abundant resources for future use; and finally, exchange involves cementing reciprocal, obligatory social relationships that can be fallen back on in times of need.

These buffering mechanisms are chosen based on the particular nature of the temporal and spatial structure of resource variability, along with its relative intensity and predictability. In addition, the unique features of the society in question will also influence what type of alternative coping strategy is utilized. For hunter-gatherers, these features generally include small-sized groups that are widely dispersed, with low levels of technological sophistication and superficial levels of subsistence exploitation (Halstead and O'Shea 1989:4). For the Mesolithic in the Netherlands, there is very little archaeological evidence to suggest that either exchange or physical storage were used as buffering mechanisms (with the exception of restricted exchange of Wommersom quartzite in the south and archaeologically infrequent use of pits for storing hazelnut in the north). Thus, it is assumed that mobility and diversification were the preferred mechanisms for coping with resource variation, although the other two mechanisms cannot and should not be ruled out.

Before proceeding, the issue of spatial and temporal scale must be addressed. Both space and time are continuous phenomena; however, humans experience these entities in discrete units (e.g., events, places). Landscape change (perhaps obviously) does not often occur at the same rate as human life, but ranges from instantaneous events (e.g., lightening strikes, floods, earthquakes) to centurial or millennial events (e.g., tectonic drift, water erosion, sediment deposition). Thus, how can the differences in landscape change and human change be reconciled? Nicholas (1998:720) and Peeters (2007:29) provide two a way of approaching this question, by differentiating between local and regional events within the space dimension, and between short-term and long-term events within the time dimension. These two dimensions can be paired to create a matrix with four space-time dimensions, which reveal different aspects of past ecological, economic, and social systems, as well as facilitate land use and site pattern analysis. These dimensions can be described as follows:

- Local short-term: focuses on events that occur within a delimited time span and space, such as one or a few related activities undertaken at a single site location. Generally involves single sites, which can inform as to site function attributes. May also reveal highly detailed information about seasonally specific behaviors. Occurs at the individual level.
- Local long-term: focuses on events that occur over a longer period in the same area, such as repeated use of a site for various activities, which can lead to palimpsest conditions. Areas with evidence of local, long-term events provide a history of the use of the site or location. Occurs at the individual and group and generational level.
- Regional short-term: focuses on events that occur simultaneously over a large area within a delimited time space (e.g., one month or one year). This dimension yields information about human ecology how larger landscapes are used, similar to the way archaeologists approach regional settlement systems. Occurs at the group level.
- Regional long-term: chronicles the various regional short-term events over a longer period of time, to generate a type of landscape history or 'landscape biography' (Cronon 1983; Hidding et al. 2001). At this level, landscape evolution

and human adaptation to certain circumstances (e.g., economy, environment, demography) can be correlated. Occurs at the group/generational level.

The above framework is useful for structuring studies of hunter-gatherer land use within changing environments.

While landscape change and variability can thus strongly influence hunter-gatherer life, it must be stressed that even nomadic and highly-dispersed groups can have quite an impact on the landscapes they dwell within (archaeological evidence: Berglund 1990; Bos et al. 2005; ethnographic evidence: Lewis and Ferguson 1988; Ostlund et al. 2003; Simmons 1996; Zvelebil and Moore 2006). For example, it is well known that hunter-gatherers and many animal species prefer edge zone habitats between forests and open lands. These edge zones are not always readily available, but can be quickly and efficiently created by felling a handful of trees. Another way hunter-gatherers modify the landscape is by burning (Delcourt et al. 1998; Edwards 1990; Ostlund et al. 2003; Simmons 1996). The use of controlled fires can result in the creation of open, grassy areas that attract many different animal species. Last, hunter-gatherers can both directly or indirectly affect the composition of the resource landscape around them by choosing certain species for exploitation than others. If such cultural preferences operate for a long enough time interval, they can temporarily or permanently affect the composition, distribution, and density of the biotic environment. Although the ethnographic record is not rich in examples of hunter-gatherers altering the abiotic landscape, it remains a possibility that these groups could achieve a palpable effect through digging, tree-felling, and placement of implements such as fish walls (Bouwmeester et al. 2008; Hulst and Verlinde 1976; Jochim 1998).

2.4 Summary and Conclusions

In this chapter, two main themes have been addressed. First, the development of the field of hunter-gatherer studies was discussed, and the strengths and weaknesses of these approaches have been examined. Specific focus was devoted to optimizing theories, which—although they too are fraught with pitfalls and limitations—still provide a useful foundation on which to base the current study. Components of other approaches will also be systematically incorporated where they are appropriate, such as the natural selection component of behavioral ecology, the integral role of information among band-level societies, and the consideration of hunter-gatherer landscape perception. Second, a short account of the difference between the concepts ‘space’, ‘place’, and ‘landscape’ was provided to clarify these otherwise vague terms. A short discussion of current social theory involving the body and experiential perspectives was made, followed by a more detailed exploration of how landscape-focused studies can yield useful and broad-reaching insights about hunter-gatherers groups in the past.

In summary, certain aspects of the theoretical discussion presented above are integral to implementation of the analysis and interpretation of this study. These aspects and where appropriate derivative or associated assumptions include the following:

- Hunter-gatherers tend to behave in optimizing ways, and will position themselves to take advantage of the highest-return rate, easiest or most efficient to procure, or most reliable resources (optimizing models). Periodically, decisions about and strategies for resource use will be guided by non-optimizing parameters, such as changes in the timing and tempo of resource abundance, or sociopolitical or ideological factors. However, the focus of the current modeling is on the patterned and redundant decisions hunter-gatherers make regarding optimal resource extraction.

- Resources are encountered in patches, which can be encountered in a linear, sequential basis (i.e., point-to-point, either residential or logistical strategies) or within a radial network pattern (i.e., complete-radius leapfrog, generally a logistical strategy; Binford 1982:10-11).
- When resource stress or scarcity occurs, hunter-gatherers may respond in the following ways: by expanding the breadth of the resource base (diet-breadth model; Smith 1972), by increasing the intensity of resource extraction, by moving more frequently between resource patches (patch-choice model), by storing temporarily abundant resources, or by visiting family or acquaintances in more resource abundant areas (Hayden 1981; Halstead and O'Shea 1989). General expansion of the exploitation zone, as well as technological innovations resulting in increases in resource procurement outcomes may also be exercised (Smith 1972).
- Settlement types vary according to the type of activities carried out there. Generally, residential sites represent a number of different activities, from tool maintenance and production, to domestic and hunting pursuits, all undertaken within the same area. Logistical sites, i.e. sites directed toward specific resource procurement, can be the location of the extractive activity and/or the temporary residence and processing area for a task group. These sites generally include the remains of gearing up activities (in preparation for the extractive event), and also initial processing activities. Another type of site is the station, consisting of observation posts and hunting stands (Binford and Binford 1966). Caches are the final type of site that may occur, representing stores of raw materials that are buried for future retrieval and use.

- While not conscious, many of the decisions made and strategies used by hunter-gatherers are guided by a feedback loop spurred by the mechanism of natural selection. That is, reproductively successful (and therefore biologically viable) strategies are assumed here to be positively reinforced and reinforcing (as held by behavioral ecology).
- Hunter-gatherers do not conform to a traditional Western cosmology; instead, hunter-gatherers view themselves as an indivisible part of the total environment (perception-based model). They do not differentiate between what is natural and what is culturally constructed. Each organism in the environment therefore has an important role and spirit, which must be negotiated when encountered. Each part of the landscape has unique meaning and also must be treated in a special way to maintain harmonious relationships. As such, certain parts of the landscape were imbued with special significance and were often returned to for the observance of ceremonies, rites, or remembrances.

Each of these key components of hunter-gatherer theory will be variably incorporated into the behavioral models developed here, and then applied to the several research areas.

Chapter 3

LOCATING MESOLITHIC HUNTER-GATHERERS IN TIME AND SPACE

3.1 Introduction

The Mesolithic cultural period in Europe, once referred to as the “Middle Stone Age” by Danish antiquarian Christian Thomsen, spans the interval of time from the end of the Paleolithic to the beginning of the Neolithic way of life (ca. 10,000–6000 ^{14}C yr B.P.). While the Paleolithic-Mesolithic transition (ca. 11,000–10,000 ^{14}C yr B.P.) is marked largely by dramatic changes in the climate and associated shifts in environmental configurations, the Mesolithic-Neolithic transition (ca. 6000 ^{14}C yr B.P.) is highlighted in the archaeological record by the rise of Neolithic cultural traits (e.g., the reliance on animal husbandry and cultivation for subsistence, production of pottery, decreased residential mobility, and increased societal complexity). Some of these traits began to be experimented with already in the Mesolithic, at specific spatio-temporal locations. These transitions were not abrupt, but rather refer to continuous lifeways (e.g., subsistence practices, settlement and mobility schedules, socio-political relations, and ritual-ideological customs) that slowly shifted to take on altered forms, culture being a constantly changing entity.

The goal of this chapter is to provide a broad overview of the Mesolithic way of life in Europe, which manifested itself in many different ways. As the focus of this study is on hunter-gatherer land use and decision-making processes, this discussion is meant to describe the manner in which Mesolithic peoples undertook such choices and activities. The emphasis of this review is the great variability of Mesolithic life, but more importantly, on deciphering the extent to which such unique lifeways were guided by differing environmental and ecological characteristics, and vice versa. Thus, special attention will be given to unique regional expressions of Mesolithic adaptation, over the course of the period. This chapter commences with a short review of the Upper Paleolithic period in Europe, as this period was an important precursor to the adaptations developed in the Mesolithic. Next, chronological and regional trends seen in the Mesolithic archaeological record throughout the continent are discussed. A brief discussion of the transition to the Neolithic is also provided. In the second section of the chapter, a more detailed description of the Upper Paleolithic in the Netherlands is given, addressing the cultural manifestations of both periods bracketing the Mesolithic, as well as the Mesolithic itself. The chapter concludes with a critical look at the behavioral models that have been developed to describe hunter-gatherer behavior in Mesolithic research, as a point of departure for this study, which applies a novel model to the data.

3.2 Setting the Scene: the European Mesolithic

In this section, a broad overview of the cultural expressions that obtained across the European continent from the Upper Paleolithic through the early Neolithic is provided (see Figure 3.1). The goal is to highlight the great variability among Mesolithic adaptations in particular, but also to explore the relationships between hunter-gatherer behavior and the external landscape.

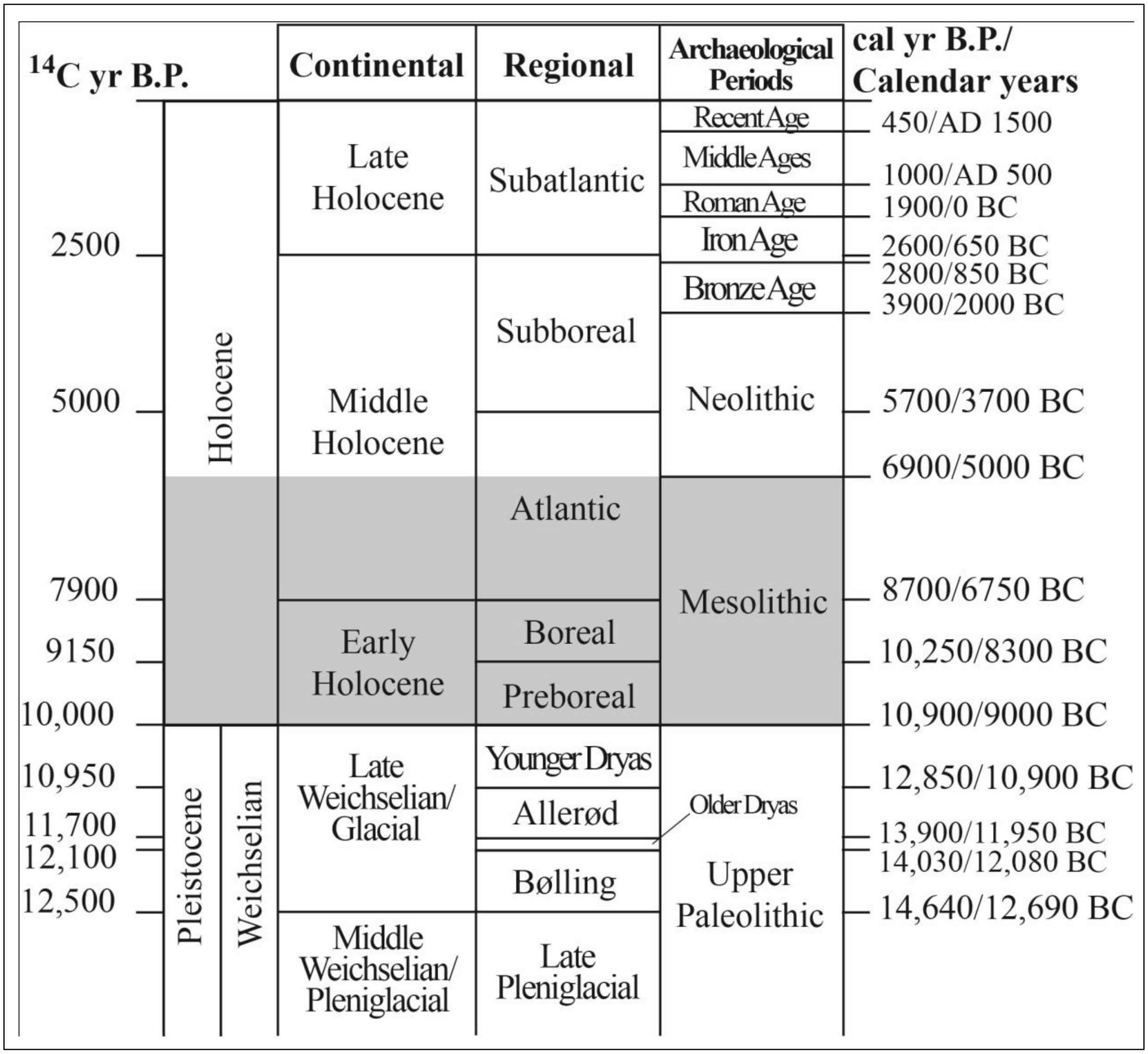

Figure 3.1 Timeline of Continental and Regional Geological Periods, and Archaeological Periods.

3.2.1 The Upper Paleolithic. Prior to Last Glacial Maximum (or "LGM"; c. 20,000–18,000 ^{14}C yr B.P.), Northwest Europe was sparsely and sporadically populated, depending on the extent of continental glaciers. The modern-day Netherlands was located at the ice margins, making the area attractive to few plants, animals, or humans. However, more populous groups of Upper Paleolithic peoples did inhabit parts of Belgium and Southern Germany, at latitudes warm and wet enough to permit widespread human occupation (McPherron 2002; Gamble 1994; Rensink

2005; Jochim 1976, 1998). After the LGM, human presence in the north and south of the Netherlands was relatively continuous, with the exception of a few glacial cold periods. A particularly cold interval, known as the Younger Dryas (c. 11,000-10,000 ^{14}C yr B.P.), drove out the earlier group (known as *Federmesser*, see further discussion below). Around 10,000 ^{14}C yr B.P., a separate group reoccupied the area (known as Ahrensburgian, see below).

The Upper Paleolithic period in Europe was ushered in by the Aurignacian tradition or archaeological “culture”, the first associated exclusively with anatomically modern humans. This culture spread widely throughout Europe and consequently contains much variability (c. 45-30,000 ^{14}C yr B.P.). It also is the first period in which personal objects and ornaments, as well as art, became abundant (Jochim 2002b). During the Aurignacian--and the ensuing Gravettian culture--hunter-gatherer groups continued a lifeway of following large herds of big game (e.g., mammoth, woolly rhinoceros, steppe horse) and producing large blades that could be segmented, modified, and used as spear points. The Gravettian culture (c. 30-20,000 ^{14}C yr B.P.) exhibited somewhat finer blades and greater overall sophistication in the tool industry.

Between this Upper Paleolithic cultural tradition and those following (e.g., the Magdalenian, c. 16/15-11,000 ^{14}C yr B.P.), the LGM occurred (see above). This climatic deterioration affected Europe differentially, and so demographic changes were likewise variable. However, much of northern and eastern Europe was depopulated, evidenced by a lack of archaeological remains in the northern latitudes and the presence of continuous occupations in the southern areas or ‘refugia’ (i.e., the Solutrean tradition of Spain and France and the Epigravettian of Italy, Greece, and the Balkans; Bar-Yosef 2002; Carrión et al. 2003; Straus 1995). By the Magdalenian tradition, the climate was again ameliorating with warmer continental temperatures and the northward retreat of ice masses, and human groups again spread into the northern latitudes of Europe. Simultaneously, significant innovation occurred in tool industries and subsistence strategies, as well as the development of more complex social systems and the elaboration of ritual and artistic activities (Chase 2005; Mithen 1999). For example, the first experiments occurred with items such as the spear thrower, bow and arrow, and microlith, in addition to the first tentative instances of canine domestication (e.g., in Russia; Ovodov 1998; Sablin and Khlopachev 2002; cf. Soffer 1985:201-203). A degree of regional variation also began to manifest itself, leading to various spatial subdivisions of the tradition (i.e., the Hamburgian, Creswellian, *Federmesser*, and Ahrensburgian in the north, and the Azilian, and Asturian in the south, especially Spain; see below for a discussion of the subcultures that inhabited the Netherlands; Gamble 1999; White 1982).

The transition from the Late Paleolithic to the Mesolithic is fuzzy at best (see e.g., Bicho 1994). The most defining characteristic of this passage seems to be the amelioration of the climate, and the subsequent changes rendered on the physical landscape (see Chapter 4). Even these changes were gradual, occurring at time scales largely imperceptible to human beings. However, some changes would have been recognizable, such as the rise of sea level in the western Netherlands in the early Atlantic. In terms of cultural change, the Late Paleolithic to Mesolithic transition appears also to have been gradual and nuanced. Some researchers discern close resemblances between Ahrensburgian and Early Mesolithic tool inventories (Gob 1991:229), while others find similarities between the knapping techniques of *Federmesser* and Early Mesolithic assemblages (De Bie and Vermeersch 1998). Further, Early Mesolithic sites often appear in the same locations as previous *Federmesser* settlements, indicating some continuity in the criteria and objectives informing settlement placement decisions. Clearly, further research concerning this transition is greatly needed, and would further improve understandings of the cultural precedents that became the Mesolithic lifeway. In the next section, the complex of traits that characterize the Mesolithic will be discussed, as well as the variety of ways in which these traits were expressed.

3.2.2 The Mesolithic

3.2.2.1 Introduction. The melting of the last glacial ice sheets, which had covered large tracts of eastern and northern Europe, allowed early Post-glacial hunter-gatherers of the Mesolithic to (re)colonize most of the continent. Hunter-gatherers lived in near equilibrium with the environment (Mithen 2001; although cf. Clark 1989; Innes and Simmons 2000; Mason 2005; Simmons and Innes 1996); this represents the last period in known European history when humans organized in small, primarily egalitarian groups that followed the schedule of seasonally-available resources. Generalizations about the Mesolithic across the European continent include: 1) a focus on three main species (i.e., red deer, roe deer, and wild boar) although in comparison to earlier and later horizons, Mesolithic groups exploited a wider range of food resources; 2) a focus on microblade and microlithic projectile point and other tool production, with the projectiles and cutting implements inserted into wooden, bone, or antler armatures to create composite arrows and knives; 3) a highly mobile and egalitarian lifestyle, in which small family groups subsisted on a primarily hunting-based economy, moving residences frequently, and locating sites near lakes and rivers (Jochim 1998).

3.2.2.2 Chronological Trends. In the following section, archaeological evidence will be presented and discussed that highlights some of the thematic trends that characterize and distinguish the early and late Mesolithic[4]. Examples are drawn from throughout the European continent, in order to indicate some of the variety of cultural adaptations.

3.2.2.3 Early Mesolithic (c. 10,000-8000 ^{14}C yr B.P.). The end of the Younger Dryas cold phase brought about a slow but steady rise in average seasonal temperatures, reaching maximum values by about 5000 ^{14}C yr B.P. As mentioned above, this warming catalyzed melting of the continental glacial ice sheets, simultaneously releasing vast amounts of water into the larger global system. Sea levels rose nearly 100 meters from the global low-stand during the Late, Last Glacial maximum (LGM). Consequently, deltas and coastlines were inundated; low-lying areas with little gradient were affected most severely. Areas such as the Baltic, the northern Adriatic, and Doggerland (today submerged beneath the North Sea Basin) were quickly transgressed by rising sea levels (Gaffney et al. 2007; Trincardi et al. 1996; Velichko 1984; Weninger et al. 1996). The latter area was drowned by about 8000 ^{14}C yr B.P., thereby isolating the British Isles from the rest of Europe. However, recent findings of Neolithic flint axe blades from the Brown Bank area suggest that several high banks may have remained above water into the Neolithic period (Peeters pers. comm.).

After the retreat of the ice sheets, the northern parts of the continent began to rebound isostatically (e.g., Denmark, and southern Sweden and Norway; Johansson 2002; Tanner 1993), while areas adjacent to the ice experienced some subsidence (e.g., the Netherlands, parts of

[4] Making chronological divisions is often a problematic endeavor. In the Netherlands, a typological division between early and late Mesolithic is justifiable and will be used here. However, a technological division between early, middle, and late Mesolithic is equally justifiable (e.g., Verhart 2005:164).

Germany). Around 8500 ^{14}C yr B.P., northeastern Denmark had risen to such an extent that the Baltic was cut off from the North Sea and a strip of land emerged linking Denmark and southern Sweden, creating so-called Ancylus Lake, a freshwater lake (Andrén et al. 2000; Saarse et al. 2007). The Baltic was not returned to a saltwater sea until sea levels had risen sufficiently to cover the land bridge, c. 6000 ^{14}C yr B.P.

During the glacial maximum, many vegetation communities had retreated to more southerly parts of the European continent. The re-colonizing of the previously ice-capped territories occurred in a piecemeal fashion, according to the different requirements of plant species and communities, coupled with the abiotic conditions of the environment. However, the general succession that occurred during the Holocene (and as discussed below) was: 1) the Preboreal, in which pioneering species (e.g., birch and pine) dominated; the landscape was more open than closed; and temperatures increased to the extent that seasons were pronounced (c. 10,000-9000 ^{14}C yr B.P.); 2) the Boreal, during which deciduous species (especially hazel) overtook coniferous species; the environment became increasingly forested; and the climate was drier and warmer (c. 9000-8000 ^{14}C yr B.P.); and 3) the Atlantic, in which a forest mix of oak, elm, and lime grew quite densely, pine was forced into higher and drier territories, and the climate was wetter and the warmest throughout the Post-glacial period (c. 8000-5000 ^{14}C yr B.P.).

Technology and Material Culture. One of the hallmarks of the Mesolithic is the microlith, typically a small blade or segment of a small blade (or less frequently on flakes) that has been retouched and inserted into a composite tool. While microlith production began in the late Paleolithic, manufacture and utilization of these tool inserts flourished during the Mesolithic, when a variety of different non-geometric and geometric forms were created. The larger, single-element weaponry characteristic of the Late Paleolithic was replaced by these new, smaller forms. Most commonly, microliths were produced using the microburin technique, a process that entails notching a blade, snapping the blade at the weakened notch location, and then retouching one or more of the edges (Jochim 2002a:118). A microburin is not, however, a true burin, nor is it intended for use as a tool itself. The final shape of the microlith could range from triangle or crescent to obliquely-blunted or transversal-shaped in the early Mesolithic. Microlith composite tools were most commonly used in hunting activities (e.g., as points and barbs on arrows or harpoons), documented by microwear studies (Crombé et al. 2001). Limited archaeological evidence has also bolstered this argument, such as the recovery of an intact, microlith-tipped arrow shaft from the peat bog site of Loshult in southern Sweden (Clark 1975). However, microliths may also have been used for plant processing purposes (e.g., Findlayson 1990). Other studies have revealed that these small inserts were often highly standardized according to size and shape requirements, implying that gearing up events, or batch production, was practiced in the manufacturing process (Eerkens 1998).

Another tool developed first in the late Paleolithic and further enhanced during the Mesolithic was the backed or steeply-retouched[5] bladelets. These tools were also likely inserted into composite tools, perhaps for use as knives or spear barbs (see ethnographic evidence of Australian Aborigines; Hiscock and Attenbrow 1998; Slack et al. 2004), or as harpoon elements (Larsson 1990). Furthermore, tools such as round, thumbnail-size scrapers, borers or drills, burins, and retouched blades were also important components of the tool kit (Champion 1984:92-93; Mithen 2001:89-97). Chipped-stone flake or blade axes are known from tool kits in northern

[5] In Dutch archaeological parlance.

Europe, and are thought to have served as woodworking or tree-felling tools. Similarly, perforated groundstones have also been recovered from this area (i.e., Geröllkeulen or Spitzhauen; see discussion in the following chapter), and were probably used as weights for digging sticks or a multifunctional tools, such as clubs (suggested by evidence of smashed skulls of small fur-bearing mammals from the sites of Hardinxveld-Giessendam; Louwe Kooijmans 2001a, 2001b). The raw material sources of flint, quartzite, and other stone were often locally available, although sometimes exotic materials were gathered by Mesolithic people during resource forays or other non-utilitarian moves (sensu Whallon 2006).

Wood, antler, and bone were also important raw materials for fashioning tools. In the dense Post-glacial forests of Europe, wood was a very abundant material. Unfortunately, wooden implements require good preservation conditions and thus, most wooden objects have been recovered from peaty or waterlogged sites. The site of Star Carr in England yielded a number of such wooden artifacts, including the handle of an antler mattock and a paddle fragment, as well as postholes and a purported wooden trackway into the wetlands (Clark 1954; Mellars and Dark 1998). However, recently, Coles has reinterpreted the trackway "structure" as a collapsed beaver lodge, as beaver-cut wood was found to be present upon further analysis (Coles 2006; Coles and Orme 1982). The site of Friesack in northeastern Germany revealed an abundance of wooden artifacts (e.g., paddles, digging sticks, bows, arrows, and spears), some of which were ornamented. Netting made of plant fibers, presumably for making fish nets, was also found at Friesack, (Gehlen 2007:18-20; Gramsch 2000) as well as at the site of Zamostje 2 in Russia (Lozovski 1996). While only a few examples of dugout canoes are known from the period (e.g., the Pesse canoe from Drenthe, the Netherlands), the discovery of sites on islands and along lake shores suggests that initial experimenting with water vessels was well underway. In fact, it has been suggested that much of northern Scandinavia was colonized through coastal adaptations (including seafaring; Bjerck 2009).

Antler, most commonly from elk or red deer, was often used as a raw material. The tines and bases of antlers were shaped or perforated to accommodate sharpened-stone inserts, or were sharpened and used for digging roots or other extraction purposes. Furthermore, antler was often shaped into barbed harpoon or spear points. In some rare cases, antler still attached to the cranium have been found and interpreted as possible headdresses for shamanistic activities (see discussion of Bedburg-Kønigshoven and other sites below; Street 1991). Lastly, bone (including teeth) was also an abundant and versatile raw material, used to create a wide array of different tool types, including mattocks, awls, needles, scarpers, and barbed points for either spears or arrows (Mithen 2001:98-101; for regional examples see Bonsall and Smith 1989; Louwe Kooijmans 1971; Zhilin 1998). In Scandinavia, multi-pronged bone leister points have been unearthed, suggesting that fishing was a key subsistence activity in some Mesolithic diets (Larsson 1990).

Settlement. A small body of settlement evidence has endured since the early Mesolithic. Mostly, this evidence derives from northern peat bogs, where preservation was sufficient to conserve delicate organic objects like bark mats and postholes. At sites like Duvensee in Germany, huts were focused around a central hearth, had partially sunken floors, and measured between two and six meters on a side (Bokelman 1991; Louwe Kooijmans 2001a, 2001b; also see below for further discussion). Studies of artifact scatters within huts suggest that two families could be housed in a single dwelling (Grøn et al. 1991). Purported hut impressions--oftentimes surrounded by circular stone patterning--have also been found at dryland sites, such as Mount Sandel in Ireland (Woodman 1981).

Most early Mesolithic sites are quite small in size, suggesting ephemeral usage by highly mobile groups of only five or six people. Early Mesolithic sites with broader and/or deeper artifact scatters (e.g., Svaerdborg I, Denmark; Star Carr, England; Verrebroek Dok, Belgium; see below) were likely created over thousands of years by repeated visits to the same areas. In addition, cave deposits from this period also show deeply stratified deposits representing a number of short, independent visits (e.g., Franchthi Cave, Greece; Roc del Migdia, Spain; L'Abri du Pape, Belgium; (Farrand 2000; Holden et al. 1995; Leotard et al. 1999; McPherron 2002; Perlés 2003; Straus et al. 1999). In comparison to late Upper Paleolithic groups, early Mesolithic hunter-gatherers developed a more stable settlement structure that was confined to a smaller territory and characterized by smaller-sized settlements. However, residential mobility increased, perhaps to exploit as many resources areas in a bounded region as possible (Eriksen 2002). Various lines of evidence suggest that early Mesolithic groups occupied territories between 80 and 100 km in diameter (Jochim 1998): 1) stylistic studies of microlith styles (Gendel 1984; Kozlowski 1973), and 2) distributions of exotic raw materials, burial practices (Sulgostowska 2006), mollusk shells (Eriksen 2002), and personal ornaments (Newell et al. 1990). Moreover, social interaction across territorial boundaries seems to have been rather open, facilitating fluid interaction between micro- and macro-bands in distinct regions (Bang-Anderson 1996; Eriksen 2002; Jochim 1998).

The biased nature of the archaeological record hampers efforts to reconstruct the seasonal settlement rounds of early Mesolithic hunter-gatherers. However, it is generally assumed that the northern European bog sites were used primarily in the warmer months of the year (Larsson 1990). Higher and drier locations, situated further from wet areas of the landscape, are assumed to have been preferred during the colder months. In upland areas, such as southwest

Germany, early Mesolithic groups seem to have moved between high sheltered sites in the winter and low open-air sites in the summers (Jochim 1976). In fact, at this time groups began to colonize mountainous regions, settling at altitudes as high as 2000 meters above sea level in parts the Italian, Swiss, and French Alps (Bintz 1999; Crotti and Pignat 1992; Fedele 1999). Simultaneously, groups were moving further north and west than was permitted during the previous glacial period (Larsson 2000; Woodman 1981). The colonization of new territories meant that hunter-gatherers were adapting to the challenges of new topographic and environmental settings, although proximity to water was still an important prerequisite for site placement. There are only a few documented cases where camps were not close to available water and its associated resource pool (e.g., on plateau edges or hilltops; Kvamme and Jochim 1990).

Subsistence. Early Mesolithic subsistence was focused mainly on hunting large solitary animals like red deer, roe deer, and wild boar. However, at this time hunter-gatherers were diversifying subsistence practices, mostly along habitat boundary intersections. Many new types of foods were incorporated into the diet (e.g., birds and fish), and different procurement systems were experimented with to achieve maximum efficiency in food capture, processing, and consumption. In northern Europe, elk and aurochs were also popular prey species, along with small mammals like beaver, otter, and pine marten. In mountainous areas, chamois and ibex were also common. In southern Europe, rabbits and land snails represented an important component of the diet (Lubell 2004; Telegin 1986). Bird hunting became more popular, along with fishing, undertaken not just along coasts but also inland along rivers and lakes, as evidenced by numerous remains of freshwater species like pike, as well as remnants of fishing tackle (e.g., hooks, harpoon points, leisters, and nets; Louwe Kooijmans 2001a; 2001b). Evidence of marine resource usage is scant due to submergence of many coastal sites. Still, sites from southern Europe suggest that marine resources were often quite important (e.g., Franchthi Cave, Greece; Muge, Portugal; Bicho et al. 2010; Perlés 2003; Rose 1995). These studies have been reinforced by new findings from underwater excavations at the submerged sites of Neustadt in Germany and Tybrind Vig in Denmark (Andersen 1985; Glykou 2010), which have revealed that the coast was also exploited in northern Europe.

The early Mesolithic was also the first period in which plant food appears to have been regularly utilized. In the warmer, southern portion of Europe, a variety of plant foods were available, from tree fruits, berries, and nuts, to tubers, legumes, and seeds. Even in the more seasonal northern areas, hazelnuts were exploited when available (see discussion of Duvensee below), along with berries and tubers. Studies of presumed hazelnut processing hearths have indicated that the nuts were heated over hot coals (Larsson 1990), to be later consumed or stored (e.g., Mithen 2000; Mithen et al. 2001).

Apart from the remains of foodstuffs themselves, stable isotope analysis provides an alternative way to access information on dietary composition. While such studies cannot determine the exact foods eaten, they can indicate what percentage of the diet was composed of terrestrial or marine species. Human remains from an inland Danish site reveal that terrestrial foods were most common (Tauber 1986), while remains from similar contexts in Britain and Sweden have revealed that marine foods constituted some portion of the diet (Burton and Price 1990; Clutton-Brock and Noe-Nygaard 1990; cf. Day 1996; Richards and Hedges 1999; Schulting and Richards 2002). Other analyses have found individuals who appear to have eaten primarily plants (e.g., Leotard et al. 1999; Tarli and Repetto 1985). Nevertheless, this line of research is still developing and thus, results should still be approached with caution (e.g., Day 1996).

The widening array of strategies for procuring a living in the Mesolithic reflects some of the incredible innovations that occurred during the period. However, it also reflects the fact that adaptive alterations were being made in the face of, and in response to, drastic environmental shifts, such as the reforestation of much of the continent, the warming climate, increased precipitation, and rising sea levels. Large herds of game animals migrated east and north, providing the potential for Mesolithic people to shift their subsistence focus to other species, many of which were only available during certain times of year. The diversification of the diet to incorporate whatever resources were seasonally available most likely also affected the division of labor. A survey of the division of labor among ethnographic hunter-gatherers found that the climate and environment a group lives in is closely correlated to which sex procures more food (Ember 1975; Hiatt (Meehan) 1978). For example, men tend to procure more of the diet in colder climates, and vice versa (Kelly 1995; cf. Frink 2009). Thus, Mesolithic women may have played an increasingly important role in food procurement throughout the ameliorating early-middle Holocene period, gathering plants, trapping smaller and more local or sedentary game species, and processing these foodstuffs. Women may also have occasionally and/or opportunistically participated in hunting, as evidenced by some arctic and tropical groups (Estioko-Griffen and Griffin 1981; Landes 1938; Romanoff 1983; Watanabe 1968). The predominant subsistence activity of Mesolithic men was likely hunting, their time spent mainly in tracking solitary large game of the forests across greater distances. Although many plant and small mammal foods would have required more time in terms of procurement and processing (Kelly 1995:81-82), the reliability and abundance of such foodstuffs may have made them the primary stable of the diet during certain seasons, with meat from large mammals contributing on occasion (Bocherens et al. 2007; Holden et al. 1995; Holst 2010; Oud 2009).

Society. Early Mesolithic people lived in small, residentially mobile groups. Within groups, some degree of gendered division of labor probably occurred. Between groups, trade and exchange of raw materials, information, and marriage partners occurred across open boundaries (Zvelebil 1985, 2003, 2008). In the case of north-central Europe, this trade was generally conducted along a north-south axis (Eriksen 2002). While few concrete examples of such inter-regional trade have been documented, the presence of similar artifact styles across large areas suggests that people must have been well connected (e.g., Gendel 1984).

Since few burials or other indicators or ritual life have been recovered from the early Mesolithic, little can be said about cosmology or ideology, although it is probable that Mesolithic people had a rich ritual life. Although most of the human remains from this period are loose finds (e.g., the juvenile tooth from Zutphen-Ooijerhoek; Bos et al. 2005; Groenewoudt et al. 2001), some appear to be unequivocal examples of true burials: Holmegaard V in Denmark, a bog site yielding two burials and grave goods (Larsson 2000:284); Kams on Gotland island in Sweden, with one early Mesolithic burial (c. 8000 ^{14}C yr B.P.; Larsson 1990:284); Uzzo in Sicily, where seven burials were found (Tarli and Repetto 1985); and Margaux in Belgium, a cave in which a stone-capped multiple grave with nine individuals was recovered (c. 9600-9000 ^{14}C yr B.P.; Straus et al. 1999). Concern for treatment of the dead was increasing, possibly in association with other sophisticated rituals and cosmological stories. Simultaneously, interest in producing artistic objects and ornaments appears to have been quite low. In comparison to both the preceding and subsequent periods, the early Mesolithic has yielded very few examples of decorative or symbolic material culture (Larsson 2000). The most common such objects are engraved tools of bone or antler, mostly preserved in the northern bog sites (e.g., in Denmark), and exhibiting mainly geometric forms. At Star Carr, other decorative objects like beads, amber pendants, perforated teeth, and red ochre have also been found (Clark 1954). In southern Germany, different ornaments were fashioned out of shells, fish and canine teeth, and vertebrae (Jochim 1998). In the Netherlands, a ground stone pendant has been recovered from the site of Zutphen-Ooijerhoek (Verneau 1999), as well as ochre-laced sands in pits presumed to represent sitting graves (Verlinde 2005). Although biases of the archaeological record must be considered, early Mesolithic ritual and ideology appear to have been only infrequently expressed as tangible objects or on natural canvases (e.g., rock faces), in contrast to that of the late Paleolithic or late Mesolithic. This could potentially be related to societal reorganization triggered by the many external changes within the wider environment. Concrete evidence of such societal reorganization has been found from later Mesolithic contexts, specifically from cemeteries (see e.g., Albrethsen 1984; Larsson 1984; Lillie 2006; O'Shea and Zvelebil 1984).

3.2.2.4 Late Mesolithic (c. 8000-6000 ^{14}C yr B.P.). By the Atlantic period in Europe (c. 8000 ^{14}C yr B.P.), temperatures had reached modern equivalents, rainfall levels were elevated, and sea levels continued to rise (albeit at an increasingly slower pace than during the Preboreal and Boreal). These conditions in turn led to increasing densification of the mixed-deciduous forests (i.e., oak, lime, and elm) through much of the continent, although the northern and eastern parts were still dominated by coniferous trees and in some cases, open park landscapes. At this time, Britain became fully isolated from the mainland; elsewhere, previous shorelines were inundated, submerged, or subjected to transgression. In low-lying areas, the amount of open land was severely diminished, which undoubtedly led to some population packing. Simultaneously, forests density increased, posing an impediment to hunting visibility and traveling accessibility (Bos et al. 2005; Jochim 1990:185; Spek 2004; Van Beek 2009), and many small lakes filled up with organic matter, decreasing the amount of potable water in the ecosystem. However, the creation of new deltaic and estuarine habitats would have acted as rich resource reservoirs. Vegetative communities were more diverse and more stable than previously, which led to increasing predictability of animal species types, abundances, densities, and available locations.

Technology and Material Culture. Microliths continued to be used frequently among late Mesolithic tool kits, as they had in the early Mesolithic. However, a new variation on the microlith theme arose: the trapezoidal-shaped microlith, or trapeze. Many of these trapezes were made from wide blades (so-called ‘broad’ trapezes). The first instance of their development has been documented at the site of Franchthi Cave (c. 9000 ^{14}C yr B.P.). From there, they appear to have spread along the Mediterranean to France, the Balkans, and central and northern Europe. Not until a millennium later (c. 8000 ^{14}C yr B.P.) were the first trapezes made and used in Scandinavia (Larsson 1978). It seems that this new trapeze technology never reached the British Isles due to flooding of the land bridge (Jochim 2002a:127; Mithen 2001:96); however, large trapezes do occur in the early Mesolithic in England, and get smaller over time, suggesting that an indigenous development of trapezes occurred (Lovis pers. comm.).

The proliferation of trapezes saw a concomitant decrease in the number of other projectile point types. Some researchers believe that the trapeze—mounted with longest and sharpest edge facing out—would have been a more effective hunting weapon that previous forms, as it not only penetrated but also cut into the tissues and organs of prey (e.g., Larsson 1978). Such a tool would have been very beneficial in dense forests, where prey was more likely encountered at close range and tracking a wounded animal for long distances would be exhausting. However, other researchers believe that trapezes may not have been mounted at all, instead being used in plant harvesting and processing (Finlayson and Mithen 1997).

In the north, the tradition of using flake and blade axes for woodworking increased in importance, along with the production of Geröllkeulen (perforated mace heads). A general diversification of other tool types occurred, such as hammerstones and grinding stones--ostensibly for cracking and crushing plant foods--in the western, central, and southern parts of the continent. Further north, a new technique was developed for polishing and pecking quartz and other materials into axes. In Finland specifically, slate was ground into point (Jochim 2002a:128).

The diversity of wooden implements also expanded during this period and again, most of the remains derive from the waterlogged bog sites of the north. At the Russian sites of Vis and Zamostje 2, blunted arrows have been found, perhaps to facilitate skin-preservation of small fur-bearing mammals (Burov 1990; Lozovski 1996). Vis has also yielded wooden fragments of skis and sleds, used to improve transportation during the winter months, have been unearthed. Dugout wooden canoes from this period have been found (e.g., the Netherlands and Denmark), although it is unclear whether this is due to an increase in water transportation and seafaring activities, or to taphonomic issues. At the site of Tybrind Vig in Denmark, one canoe was found that measured 9.5 m long, with the remains of a clay-lined fire pit and a large stone inside (perhaps for ballast; Andersen 1985). In conjunction with ten paddles, the Tybrind Vig canoe suggests that water travel was important as the forests became denser and wetlands spread, and also as part of expanded and more elaborate subsistence strategies targeting new species such as eel (Enghoff 1991; see also discussion of Hardinxveld-Giessendam canoe fragments in Louwe Kooijmans 2001a, 2001b).

Elsewhere, fishing technology advanced by the construction of wooden weirs and traps, innovations that required high maintenance but also returned high yields during fish spawning periods (Andersen 1985). This may also reflect more cooperative or collective procurement strategies, as well as the production of collection facilities that do not require constant tending. Leister prongs, once fashioned out of bone, were more commonly made of wood during the late Mesolithic, along with gorges and hooks. Plant materials like roots and bark were fashioned into baskets, used as net weights, and woven into coarse textiles (Andersen 1985; FitzGerald 2007; Louwe Kooijmans 2001a, 2001b). Mirroring the elaboration and diversification of wooden tools and implements, innovations in the development of bone and antler tools also occurred. Most notably, the slotted bone point or knife (into which microliths were placed and fastened with resin) was developed in Scandinavia and Russia. Bone and antler was also fashioned into novel harpoon and axes shapes.

In some parts of Europe, the late Mesolithic also witnessed the development of early ceramic technology, often construed to be a formal trait of the Neolithic period proper. Evidence for a 'Ceramic Mesolithic' has been found in southern Scandinavia (e.g., the Ertebølle tradition, c. 5600 ^{14}C yr B.P.; Larsson 1990), the Netherlands (i.e., the Swifterbant tradition; Raemaekers and Roever 2010; Roever 1976), Belgium (Amkreutz et al. 2010), and southwest France (e.g., Roucadour Mesolithic-Neolithic pottery; Arnal 1995). It is unclear how hunter-gatherers came to develop ceramic technologies: some feel that the technique was learned from contacts with nearby and contemporaneous farming groups (Raemaekers 1999:182); while others believe that the technique was developed indigenously among hunter-gatherers, following the techniques used in basket weaving (Roever 2004:135-139). While some variation occurs in the production of these ceramic industries, many have pointed-based, wide-mouthed vessels and shallow bowls.

Further, most are constructed with the coiling technique, which is reminiscent of basketry techniques (Raemaekers and Roever 2010:146). Analysis of food residues from the interiors of some of these pots indicates that a variety of food stuffs were cooked, such as meat, plants, nuts, and fish (Boudin et al. 2010; Smits and van der Plicht 2009). The pointed bases would have stabilized them in sand and facilitated their use with hearthstones. It has been further argued that the pointed-based vessels were used for storage, were resistant to breakage, and convenient for transportation in a dugout canoe (Raemaekers and Roever 2010:147).

Settlement. Dwelling structures from the late Mesolithic do not differ greatly from those discussed above for the early Mesolithic. Lining the floors of huts with bark was still a common practice, as seen at the site of Henauhof Nord II in Germany (Kind 1992). In Scandinavia, oval-shaped, stone-cleared living floors have been found on former beaches (Fretheim 2010:62; Larsson 1990). The late Mesolithic site of Remouchamps in Belgium also revealed a circular shape delineated by stones, presumably those that held down the wall material (Gob and Jacques 1985). A (semi-) permanent settlement has also been found in Britain (c. 8800 ^{14}C yr B.P.), along the coast of the North Sea. The site has revealed a circular structure of postholes, hearths, and artifacts, which appears to have been reconstructed in three phases and inhabited for several generations (Waddington et al. 2003). At the time of occupation, the site was likely located further away from the sea than at present; however, the authors conclude that the site would have been an important component of a seasonal round, in which inhabitants traveled from the coast to the inlands.

Despite continuity in hut shape throughout the Mesolithic, the proliferation of different site types in the late Mesolithic is notable. Small sites often seem geared toward specialized and short-term activities. Along the coasts, these sites manifest as targeted activity areas, where specific marine mammals were exploited (e.g., migratory birds, fish, seal). Inland, small sites also imply a focused activity targeting a seasonally-abundant resource. Both the number and type of these small sites rose steadily during the Mesolithic (e.g., Verhart 2000). Conversely, larger sites--especially those from Denmark and Portugal (see below)--are regarded as longer-term dwellings where a variety of activities occurred. Along the coasts, these activities focused on procuring both terrestrial and marine foods, the latter type sometimes resulting in large shell middens. Inland, large sites were likely occupied for a season or two at a time, rather than year-round, with a focus on either winter or summer resources (see discussion of Ringkloster below; Andersen 1994-95; Rasmussen 1994-95).

As may be inferred from the above discussion, late Mesolithic residential mobility appears to have decreased from that of the early Mesolithic. In some places, (near) year-round settlements were occupied (e.g., at the Ertebølle and Smakkerup Huse sites in Denmark) and at Lepenski Vir the Iron Gates area of the Danube; (Andersen 1985; Price and Gebauer 2005; Price et al. 2001; Radovanovic 2000; Rowley-Conwy 1983). These more stable settlements were still the staging locations of frequent yet short and targeted logistical forays made by small groups. The yields of these expeditions were often brought back to the central dwelling place or home base. Here, ‘gearing up’ events often took place, in which a batch of the same tool was manufactured in advance of an expected activity. While diversification of the subsistence economy continued, the means by which these new resources were procured became more specialized, both technologically and in time and space (e.g., specific episodes and places were targeted, such as wetland environments; see e.g. Bocherens et al. 2007; Louwe Kooijmans 2001a, 2001b). The proliferation of travel technologies enhanced the ease and accessibility of over-land and over-water travel. However, as residential mobility decreased, so too did the size of territories, shown again by the distribution of raw materials, artifact styles, and ornamental goods. In some places in northern Europe, a number of small, circumscribed groups have been identified, with territories less than 100 km in diameter (Larsson 1990; Price 1981).

The late Mesolithic also experienced a shift in the distribution of sites across the landscape. Nearly every European country with coastline has yielded evidence of a greater number of sites along the coasts during the Late Mesolithic. In addition, underwater excavations off the coast of Germany have returned a wealth of well-preserved organic materials, some of which are still *in situ* (e.g., the site of Neustadt; Craig et al. 2010:188; Glykou 2010:189; Saul et al. 2010:187). In particular, two Mesolithic settlements have been found off the Bouldnor Cliffs of Britain, revealing complete hazelnuts, a wooden pole with an embedded flint knife, burned flint, and various other worked wood, suggesting woodworking and wood/flint burning was undertaken (Anon. 2006/2007; Williams 2007). Whether the population shift was due to densification of forests or the drying and filling up of inland lakes, the result was that the number of inland sites decreased, while coastal sites increased. The uplands, in particular, were largely abandoned. The few late Mesolithic sites found inland are almost always situated along rivers or lakes (Jochim 1998). On the coasts, late Mesolithic groups preferred somewhat sheltered locations, such as inlets and lagoons, which often also harbored highly productive wetland habitats. At the same time, various islands off the coast of Britain were colonized, evidenced by the presence of shell middens (Mellars 1979). Apart from the demographic shift from inlands to coasts, there was also a more continental shift in which the north European plain and Scandinavia witnessed population growth, whereas central Europe became depopulated. However, this observation may be a fiction of the incomplete archaeological record; if major subsistence and settlement re-organization was occurring, researchers may have yet to discover the preferred locations within the landscape were (e.g., on now-eroded or buried floodbasins or river terraces).

Subsistence. As in the early Mesolithic, hunting was still an important subsistence pursuit in the late Mesolithic, implied by the elaboration of bow and arrow technologies and the continuation of canine domestication. In the ethnographic record, canines are often also used as pack animals, sentries, and a source of emergency food (Fiedel 2005). The same large game species were targeted as preferred food sources, although small mammals, birds, and fish were also taken. Plants were consumed with greater frequency: in the south, wild legumes and fruits were popular, while in the north, water chestnut and lily, along with hazelnut, were still procured. The primary difference in subsistence across the early-late transition was the increasing focus on marine resources, especially shellfish (Bocherens et al. 2007; Mannino and Thomas 2007; Richards and Hedges 1999). Shell middens increase in frequency, along with the remains of deep-sea fish in more southern latitudes (e.g., see discussion of Franchthi Cave below). Marine mammals were also sometimes hunted in the north, such as seals and whales. While these 'fruits of the sea' certainly increased in popularity during the late Mesolithic, freshwater species were still staples: at the site of Ertebølle in Denmark, both marine and freshwater fish remains were found intermixed (Andersen and Johansen 1986).

Both subsistence practices and settlement patterns exhibit some regional variation. One proxy by which to trace differences in subsistence is to study the rate of dental caries in late Mesolithic populations. Caries generally arise when carbohydrates and starches are not adequately rinsed from teeth, causing rot; thus, studies of caries rates provide a proxy measure of the amount of carbohydrates in prehistoric diets. Results have shown that rates of caries are highest in southern Europe and lowest in northern Europe, presumably related to the pace at which cereals and other carbohydrate-supplying foodstuffs were introduced into the Mesolithic diet (Meiklejohn and Zvelebil 1991). In some inland locations, a mainly carnivorous diet is suggested through bone chemical analysis (e.g., at Große Ofnet in Germany; Bocherens 1997). Elsewhere, research has been conducted to understand the importance of terrestrial versus freshwater or marine species in the diet (e.g., in the Iron Gates region, Bonsall et al. 1997; along the Portuguese coast, Lubell and Jackes 1994; and coastal versus inland Denmark, Noe-Nygaard 1988; Tauber 1981). In general, late Mesolithic groups were healthy, with few examples of dietary stress in the skeletal populations (Alexandersen 1993; Meiklejohn and Zvelebil 1991). Average heights were 154 cm for women and 166 cm for men (roughly the same as averages for men and women from the mid-nineteenth century; Blankholm 2008), and life expectancy is assumed to have been similar to that of ethnographically-documented hunter-gatherers, hovering between 30 and 35 years (Angel 1984).

Society. While late Mesolithic groups appear to have been settling down within smaller territories, exchange of exotic goods and raw materials suggests that the range of social contact was expanding during the period. For example, the distribution of Wommersom quartzite--found within a small area in the southern Belgian Ardennes—increases throughout the Mesolithic; by the late Mesolithic, the material was exchanged over an area of 250 km in diameter (Gendel 1984). In southern Europe, Mediterranean shells were transported as far as 600 km north from their source (as far as southern Germany; Rahle 1978). Obsidian was carried some 150 km in Greece, from the islands to the mainland (Buxeda i Garrigós et al. 2005). Of course, final Mesolithic groups also appear to have been trading some key artifacts, practices, and ideas with incoming Neolithic groups (see discussion for the Netherlands below).

In contrast to the early Mesolithic, more artistic and ornamental artifacts have been unearthed from late Mesolithic complexes (Larsson 2000). In some cases, early Mesolithic practices were continued, such as decorating antler and bone axe handles and other shaft-shaped tools. Personal adornment objects, such as beads and pendants, were created from amber, teeth, stone, shell and fossils. A novel innovation of the late Mesolithic was the creation of objects from wood and clay, such as the decorated paddles from Tybrind Vig in Denmark (Andersen 1985), and the Volkerak figurine dredged from the Meuse in the Netherlands (Es and Casparie 1968; see below for more information). An elk/ moose head was carved into one of the wooden skis from Vis in Russia, and geometric motifs were impressed into Ertebølle pottery (Larsson 2000). Another purported artistic innovation is that of stone carving and rock painting: at Lepenski Vir, individual boulders were carved with fish- and face-like effigies, and placed within the trapezoidal houses (Srejovic 1972); in eastern Spain, rock art dating to the late Mesolithic was painted with red ink, depicting animals and humans undertaking activities such as hunting and honey collection (Beltran 1982; Obermaier 1925); in northern Scandinavia, rock carvings first occurred around 5500 ^{14}C yr B.P., and show images of humans hunting large animals with spears and bow and arrows, as well as by boat (Larsson 2000).

The increased ritual and ideological component of late Mesolithic life can also be seen in the proliferation of different ways to treat the dead. Single graves were most common, generally for adult male inhumations, and placed either flexed or lying on their backs. Inclusion of grave goods was not yet a universal practice, as only about half of the known late Mesolithic burials show such evidence. Generally, grave goods consisted of a specific cluster of materials such as animal teeth and bones, sophisticated stone tools, and red ochre. Furthermore, the late Mesolithic period witnessed the first development of cemeteries, where people were interred over a period of time (cf., Meiklejohn et al. 2009). The shell midden sites of Muge, along the Tagus River in Portugal have revealed more than 200 burials (Bicho 1994). The well-known and long-researched sites of Téviec and Hoëdic, off the coast of Brittany, contained 28 and 13 graves, respectively (Pequart and Pequart 1954). Vedbæk-Bogebakken in Denmark yielded 23 burials (Albrethsen and Brinch Petersen 1976). The site of Skatehom in Sweden appears to have three separate cemeteries, containing at least 86 burials (Larsson 1984). At the cemetery of Zvejnieki in Latvia, 60 people were interred (Gerhards et al. 2003), while at the island site of Oleneostrovski Mogilnik in Russia, an estimated 400 people were buried (O'Shea and Zvelebil 1984).

Cemeteries generally occurred in locations where resources were abundant and easy to procure, allowing people to settle into a mainly sedentary life and (ostensibly) develop richer and more diverse ceremonial and ideological customs. They also likely served as markers in the landscape, denoting ancestral land rights and/or primary access to territories. In this way, the landscape was imbued with practical and symbolic meaning through the act of enculturation, as demonstrated by ethnographic groups such as the Siberian Khanty and Kets (Jordan 2003; Zvelebil and Moore 2006). The differential apportioning of grave goods, which simultaneously occurred at these cemeteries, has led some researchers to argue for burgeoning social complexity and the first instance of acquired status opportunities within community organization (Albrethsen and Brinch Petersen 1976; O'Shea and Zvelebil 1984; Pequart and Pequart 1954; Pequart et al. 1937; Price and Gebauer 2005). Furthermore, a few cases of purported violence have been identified: from Skateholm in Sweden, where a microlith was found embedded in a male skeleton (Larsson 1984); from Téviec in Brittany, where another microlith was found in a male skeleton, this time in a vertebrae (Pequart et al. 1937); from Vedbæk-Bogebakken in Denmark, where a bone projectile point was found lodged between the ribs of an individual (Albrethsen and Brinch Petersen 1976); and from the site of Große Ofnet in Germany, where nearly 40 human skulls were removed from their bodies and placed in pits facing west, perhaps part of an intimidation strategy (Frayer 1997; Orschiedt 1998). In the last example, juvenile skulls outnumber adult skulls and female skulls outnumber male skulls, which suggests to many researchers that an act of violence, and perhaps even warfare, was the cause of the massacre. However, the skulls may have been buried over a period of time (Orschiedt 1998), and represent a “skull cult” (Jochim 1998).

3.2.2.5 Regional Considerations. The duration of the Mesolithic differed throughout the European continent, in close relation to the spread of agriculture from the Middle East. While the mechanisms by which a Neolithic lifestyle was adopted by hunter-gatherers has been hotly contested, it is generally assumed that agricultural practices originated in the region of the Fertile Crescent and spread outward. In Europe, this spread was largely on a south to north, and east to west axis. Therefore, the earliest places to undergo the transition to farming were the Balkans and Greece (c. 8000 ^{14}C yr B.P. in Greece, and 7200 ^{14}C yr B.P. in Croatia; Milisauskas 2002:14). The Mesolithic period in these places lasted only about 1500 years, while in northern Europe, the adaptation lasted between 4000 and 5000 years. In the Danube/Iron Gates region of the Danube in Serbia, the Mesolithic lasted about 2300 radiocarbon years (e.g., 10,700-8400 ^{14}C yr B.P.). On the Iberian peninsula, hunter-gatherers remained for a longer time period than in the previously discussed areas (c. 10,000-6000 ^{14}C yr B.P.). On the Central European Plain, Mesolithic lifestyles had time to flourish before the arrival of LBK farming groups around 6500

^{14}C yr B.P. In southern Germany, some 80 Mesolithic sites have been recovered, ranging in age from 10,000-6500 ^{14}C yr B.P. (Jochim 1976). Dates from Mesolithic sites in Northern Germany date from the Preboreal to the Subboreal. In the Baltic region, Mesolithic cemeteries have returned similar dates.

While east/central and western Europe were deglaciated about the same time, agriculture appeared later in the west and was oftentimes preceded by indigenous development of typically 'Neolithic' customs, such as the domestication of dogs and pottery production. Some typical Mesolithic 'traits' never manifest in the British Isles, or were developed independently, after the drowning of the Doggerland Plateau. A few, well known early Mesolithic sites have been found dating to the Preboreal (e.g., Star Carr dates from about 9700-9400 ^{14}C yr B.P.). Later sites yield dates from the Boreal into the Atlantic (e.g., the site of Howick, c. 8800 ^{14}C yr B.P.; Waddington et al. 2003). Ireland was one of the last corners of Europe to be colonized, and consequently, the Mesolithic arrived here late, around 8000 ^{14}C yr B.P. (e.g., the site of Mount Sandel; Woodman 1981). The last region to be deglaciated was Scandinavia (c. 8000 ^{14}C yr B.P.). This area was also the last to adopt agricultural practices (c. 3200 ^{14}C yr B.P.).

3.2.2.6 Human Use and Manipulation of the Landscape. Before proceeding to a discussion of the Neolithic in Europe, it will first be noted that throughout that Mesolithic period, hunter-gatherers developed a number of different land use strategies or adaptations, many of which were specific to particular environments and ecological niches. Here, some of the broad similarities in which hunter-gatherers used the landscape will be reiterated. These similarities will be used as guidelines for formulating models of hunter-gatherer decision-making regarding land use issues. Afterwards, a discussion of the strategies used by Mesolithic people to manipulate the landscape will also be presented. The goal of this section is to highlight the reciprocal manner in which humans and the environment impacted one another.

Land Use Similarities. Various lines of evidence can inform as to the land use strategies utilized by hunter-gatherers in the Early and Middle Holocene in Europe. The material culture is especially revealing. First, stone is one of the ubiquitous raw materials used to make tools and implements; therefore, stone (especially good quality stone) was likely a highly valued commodity. It can thus be assumed that outcrops of tool stone were targeted places within the larger landscape. The flint-rich hills of Limburg (the southern-most province of the Netherlands), the outcrops of Wommersom quartzite in the Belgium, and the prevalence of Helgoland flint in northern Germany are all examples of such targeted, stone-rich areas. In most the Netherlands, very little stone occurs naturally and thus, stone-rich areas to the south and east would likely have been the focus of resource acquisition forays.

The presence of ostensible digging sticks, and the diversification of hammer and grinding stones suggests that over the course of the Mesolithic, plant food procurement and processing became more common activities. Plant foods such as nuts, berries, fruits, leaves, and tubers (or underground storage organs) appear to have gained importance in the subsistence regime (Holden 1995; Craig 2000; Price 2000; Hardy 2007; Carruthers 2000; Kubiak-Martens 2000; Mason & Hather 2000). Thus, areas where these plants occurred would likely have been the focus on subsistence activities. Specifically, plants like *Typha latifolia* (bulrush and cattail) and *Conopodium majus* (pignut or earth chestnut), the former found always near water and the latter found in woods and grasslands, would have been focused upon by Mesolithic hunter-gatherers from time to time (Hardy 2007:5). Similarly, the use of wood for tools, implements, and infrastructure would have made stands of suitable trees the focus of particular resource acquiring activities. For example, flexible wood such as willow and lime would probably have been favored for weaving fish traps and baskets (Blankinship 1905; Hedges 1986; Smith 1933). Conversely, dugout canoes require that tall, old growth wood be felled. The Pesse canoe, one of the earliest of its kind (c. 9100-8500 ^{14}C yr B.P.), was formed out of a 3-meter long, 45-cm wide tree trunk of *Pinus sylvestris* (scots pine; Zeist 1957). Clearly, old-growth forests of pine would have been targeted for canoe-making activities.

The evidence of dugout canoes also points to a proliferation of transportation implements, that would have allowed hunter-gatherers to travel further with less effort, and through previously inaccessible or less accessible landscapes (e.g., over snow and ice, and through water). In addition to canoes, skis and sleds were also developed (Mithen 2001; Burov 1989). Such transportation implements would have made new territories to the north and islands more accessible to humans (e.g., Bjerck 2009). Evidence of nets, weirs, and fish traps suggests that coasts and wetlands were also areas now targeted by hunter-gatherers, perhaps already in the Early Mesolithic, but certainly by the latter part of the period (e.g., Louwe Kooijmans 2001a; 2001b; McQuade and O'Donnell 2007). The Mesolithic ability to adapt to new habitats suggests these people were open to experimenting and expanding into unfamiliar areas, perhaps partly as a way to broaden their subsistence regimes. Last, the possible indigenous development of ceramic technology suggests that areas with clayey soils were the focus of such activities. For example, Swifterbant pottery has been found from the Hardinxveld-Giessendam sites, the Hoge Vaart site, and the Swifterbant sites (Raemaekers 2001a, 2001b; Peeters et al. 2001; Raemaekers

2003-2004). It is perhaps no coincidence that the emergence of ceramic production in the Netherlands took place in locations with abundant clay resources.

Subsistence remains can also emphasize some of the ways hunter-gatherers used the landscape. Large game seems to have been an important component of the diet for much of the Mesolithic (although this could be a taphonomic bias). The pursuing of such animals generally implies targeted use of the landscape, as hunters move between patches searching for signs of prey (Winterhalder 1981). Such targeted behavior is in direct contrast to more thorough coverage, which is more typically associated with broad spectrum, generalized foraging subsistence behavior (Kelly 1995:131). As large game hunting generally falls to men within the ethnographic record (cf., the Agta of the Philippines; Estioko-Griffin and Griffin 1981, 1985), it may be that Mesolithic women tended to use the area closest to the residential camp rather thoroughly, while men tended to use areas farther from camp in a more targeted manner. Later in the Mesolithic, evidence of shell middens sites suggests a focus on wetland and coastal contexts.

Regarding settlement, the small and relative ephemeral nature of most Mesolithic sites suggests the population was low and sparsely distributed. Mithen calculates that the Mesolithic population density hovered somewhere between 0.50 and 0.005 people/km^2 (Mithen 2001:119). As such, use of the landscape must have been quite light, in comparison to later and more densely populated Neolithic communities. Despite the amount of territory available to Mesolithic foragers, many sites appear to have been occupied repeatedly, suggesting that the configuration of these sites' features appealed to hunter-gatherer needs for hundreds of years. As noted by various scholars (Jochim 1976, 1998; Price 1976; Crombé et al. 2003), hunter-gatherers in northwest continental Europe tended to prefer high and dry locations, in close proximity to water and resources, with some shelter from the elements. There is some evidence that lower and wetter environments may have been more likely to be used in warmer months (Jochim 2001), although this was certainly not always the case (e.g., Louwe Kooijmans 2001a, 2001b).

Towards the latter half of the period, larger and more sedentary settlements appear (Louwe Kooijmans 2001a, 2001b; Price 2000; Bicho 2010). These settlements are often found near resource rich locations, such as wetlands and coasts, although it is not clear whether the settlements were placed to feed a larger group, or if the group became larger while living near a rich and abundant resource. Evidence for the exchange of raw material and non-local goods (such as shells and tool stone) indicates that the social interaction between and across regions was rather fluid. At this time, the landscape was apparently not seen as something to be divided and defended, but rather an open realm for maintaining one's livelihood. However, this situation may have changed by the late Mesolithic, when most established residential sites emerged, some with associated cemeteries, which may have functioned to mark the landscape in various ways (e.g., in terms of ownership and/or spiritually). Further, while little in the way of art has been found from Mesolithic contexts, what does exist suggests that the landscape was an integral component of everyday life (Ingold 2000; Jordan 2003). Rock art from Spain and northern Scandinavia depict humans dwelling within their environment, an indivisible component that both relies and is relied upon by the surrounding ecosystem.

Landscape Manipulation. Hunter-gatherers are also believed to have actively manipulated their environments. The strongest evidence of such behavior comes from signs of burning or clearing of wild vegetation in the archaeological record. In Britain, evidence of intentional human modification of the landscape has come from both early and late, as well as upland, lowland, and coastal Mesolithic sites (Mellars 1976; Mellars and Dark 1998; Simmons and Innes 1996; Zvelebil 1994). Areas and sites where evidence of burning or clearing has been found include the North York Moors in the Pennines (Simmons and Innes 1996), Waun-Fignen-Felen in Wales (Barton et al. 1995), Star Carr in Yorkshire (Dark 2000; Mellars and Dark 1998), Uxbridge and Thatcham along the Thames (Smith et al. 1989), in the Severn Estuary (Bell 2000; Bell et al. 2002), and the Inner and Outer Hebrides of Scotland (Edwards and Sugden 2003; Mithen 2000). On the continent, well-documented burning/clearing evidence has been found in the Netherlands at the site of Zutphen-Ooijerhoek (Bos et al. 2005; Groenewoudt et al., 2001), at the Ertebølle site in Denmark (Rasmussen 1995), and at scattered sites across northern Scandinavia (Berglund et al. 1996; Regnell et al. 1995; Welinder 1990).

In many of the above cases, the evidence consists of palynological data coupled with elevated charcoal/carbon densities, which suggests that burning occurred far more frequently than would be expected if the fire started naturally (i.e., by lightning strikes; Innes and Simmons 2000). Mesolithic groups possibly practiced a kind of landscape maintenance similar to that of some native North Americans, for which the ethnohistorical record provides a variety of explanations (Boyd 1999; Clark 1989; Cronon 1983): fire may have been used for 1) driving animals as part of hunting tactics; 2) facilitating human movement and cultivating open grazing areas; 3) promoting collection of certain kinds of food species; 4) encouraging the growth of nuts, berries, and material for basket making (e.g., reeds, sedges, and birch; Bell and Walker 2005). According to Mellars (1976), the carrying capacity of herbivores can be increased 300-700 percent through burning, resulting in mosaic landscapes with a variety of successional vegetation growth, attractive to numerous species.

3.2.3 Neolithic

The ‘forager-farmer’ transition in Europe (also known as the ‘neolithization’ of Mesolithic hunter-gatherers), has received much attention over the years by archaeologists. The defining characteristics of ‘Neolithic” culture are many and vary across the European continent. The most widely occurring characteristics include: new ideologies, new burial practices, more human intervention of the environment, new architectural types, and new technologies (Zvelebil 1998). In general, Neolithic communities in Europe were small (<250 people), without a standard crystallized system of ranked hierarchy or economic/political organization. Individual status could be acquired through personal achievements, gender, or age, as in earlier periods. There were also more overarching social formations including corporate and descent groups such as clans and lineages, and rituals that served broader integrative social, political, and economic functions (Milisauskas 2002).

Perhaps the greatest distinction between Mesolithic and Neolithic societies is that those experiencing ‘neolithization’ shifted their mode of subsistence, which fundamentally changed some of the basic aspects of culture (e.g., seasonal and labor organization, mobility, technology). Although some scholars have argued that agricultural practices alone are sufficient to denote a Neolithic community, others state that the Neolithic way of life was a package of different types of adaptations, of which some--but not all--could be manifest (Pena-Chocarro et al. 2005). This argument helps circumvent the problem of defining Neolithic communities in corners of Europe where agriculture was not practiced until quite late (e.g., the forest zones of eastern Europe and the tundra/taiga areas of Scandinavia; Milisauskas 2002).

The transition to a farming way of life occurred over a three thousand year period in most parts of Europe (c. 8000-5000 ^{14}C yr B.P.; Whittle 2001). In southern locations like Greece and the Danube/Iron Gates region of Serbia and Croatia, this transition was much earlier and quicker (only about 500 years), whereas in Norway the shift took nearly 6000 years. Some scholars perpetuate V. Gordon Childe's idea that a Neolithic 'revolution' swept through Europe, in which farming populations replaced their simple hunting and gathering counterparts (e.g., Zilhao 1998); however, most researchers have embraced a more nuanced interpretation that assumes that a good deal of technological and social exchange occurred between the Mesolithic and Neolithic populations (Stafford 1999).

Studies of material correlates of regional interaction between foragers and farmers have indicated that agriculture spread through a combination of local development and diffusion (Dennell 1992). Zvelebil (1998) wrote that a line of contact and exchange occurred between Mesolithic and Neolithic communities, which he coined the 'agricultural frontier'. Across this frontier, neolithization could occur through a variety of conduits (e.g., mobility, trade, exchange), and phases of interaction and integration (Zvelebil 1998). Applications of Zvelebil's (1998) frontier hypothesis indicate that the frontier between Mesolithic and Neolithic groups could be stationary or mobile (Domanska 2003). In the case of the former, a slow exchange of imports and technological innovation occurred between two relatively stable groups. In the case of the latter, the Mesolithic groups acted as a conduit for information regarding the terrain of the region (e.g., expert knowledge), which proved useful to the expansion of Neolithic groups (Domanska 2003).

Contextual variability (e.g., environmental, economic, and social differences) may have conditioned the processes of neolithization that occurred throughout Europe. For example, in the Iron Gates region of Serbia, farming economies first emerged indigenously among hunter-gatherers (Grönenborn 1999). This lifeway then spread by means of migration. Throughout the early Neolithic, there is evidence of farming settlers interacting with the local hunter-gatherer groups either by incorporating aspects of their foraging economy or by adopting various foraging tools and artifacts. However, as time progressed, climatic and social changes led to a breakdown in these peaceful intercommunity relations and a rearrangement of social elements into more rigid forms (Gronenborn 1999). In the Lower Rhine Basin of the Netherlands, some researchers believe that the transition to agriculture lasted nearly a millennium, from 5300 to 4300 cal BC (Louwe Kooijmans 1998). Others think that the neolithization process was actually much shorter, as suggested by analyses of ceramics (Raemaekers 2003).

3.2.4 Summary

In the above section, a brief introduction to the cultural precursor of the Mesolithic (the Upper and Late Paleolithic) was given, followed by a more detailed discussion of the chronological trends seen throughout the Mesolithic (e.g., in technology and material culture, settlement, subsistence, and society). Regional trends were explored, regarding the initiation of this cultural period and its duration. Land use strategies and manipulation of the landscape were also considered. Last, a short summary of how Mesolithic lifestyles transitioned into the subsequent Neolithic were considered. The goal of this section was to situate the reader in the broader chronological and regional context in which the Dutch Mesolithic tradition emerged. Further, this section was intended to highlight some of the common ways in which past hunter-gatherers utilized their landscapes and made decisions about what to eat, where to live, and when to move, among other things. Such broad-based knowledge will be used later in this study to inform inferences and assumptions of hunter-gatherer land use in the central river valley of the Netherlands.

3.3 Zooming in on the Mesolithic in the Netherlands

Now that a regional perspective has been provided from the Mesolithic tradition in Europe, focus can now be turned to the specific ways in which people lived during this period in the Netherlands. In the following chapter, a review of the archaeological evidence, largely from the south and north of the country, will be presented. The temporal scope will begin with the Late Paleolithic, and end with the arrival of farmer groups in the area (so-called LBK farmers). The evidence that exists for the central Netherlands will be touched on obliquely, as it is reserved in this study for testing behavioral models of hunter-gatherer decision-making (see Chapters 5, 6 and 7).

3.3.1 History of Archaeological Research

In the pioneering years of European prehistoric archaeology (ca. mid-1800s), Dutch research contributed very little to the popular chronological debates of the field at large. In the late nineteenth and early twentieth centuries, research on Paleolithic and Mesolithic sites was carried out primarily by amateur private collectors. Since the focus was on easily accessible and/or visible sites, the archaeological record for the Netherlands was spatially biased toward sites in the north and south of the country. This bias continued until the 1950s and early '60s, when two scholars – amateur archaeologist A. Wouters from the south and professional archaeologist A. Bohmers from the north – began to cooperate on publications and excavations across the Netherlands (e.g., Bohmers and Wouters 1958). Together, they developed a chronology and various artifact typologies for the Paleolithic and Mesolithic periods.

A hiatus in these prehistoric studies occurred from 1964 to 1975, at which time a group of American researchers from the University of Michigan began field work in the Netherlands, in conjunction with the Institute for Archaeology at Groningen University (Deeben and Arts 2005:139). Most notably, the excavation of the famous Mesolithic-Neolithic site of Swifterbant by T. D. Price, R. Whallon, C. Meiklejohn, and others served to stimulate renewed interest in the Paleolithic and Mesolithic periods among Dutch scholars. Prior to this time, most such research had been conducted by amateurs; therefore, this research also served to bring the Paleolithic and Mesolithic periods to the attention of scholars in the field. By the second half of the 1970s, Amsterdam University had initiated prehistoric research in the southeast of the Netherlands. Leiden University was also making strides, although the focus was on the Mesolithic-Neolithic transition and the neolithization process (e.g., Louwe Kooijmans 1974, 1976, 1985, 1993, 1998; Verhart 1990, 2000).

In 1962, an influential publication by H. T. Waterbolk inspired many Dutch archaeologists to widen their efforts from a focus on the site to one at the regional level, as a way to integrate occupations from different time periods and on different landform features (Brongers 2005:41). By the 1970s, the focus of prehistoric studies in Europe shifted toward exploration of settlement systems. In the Netherlands, a number of new, processual-based research projects were begun, such as R. R. Newell's (1980) Bergumermeer excavations and J. D. van der Waals and H.T. Waterbolk's (1976) Swifterbant excavations (with contributions by Price, Whallon, and Meiklejohn; see above). While most of this work concentrated on site-level research (Newell 1980), a few scholars continued the broader perspective of Waterbolk (1962) and developed hunting-territory models (Arts and Deeben 1981). This perspective was heavily influenced by American anthropology, disseminated as it was by Newell, an American-trained archaeologist teaching at the University of Groningen. Since few preserved organic remains had been found at the time, most interpretations were derived from flint scatters and the typologies based on their characteristics (Newell 1973). In the 1980s, a series of Middle and Upper Paleolithic site discoveries in the southern Netherlands (e.g., Maastricht Belvédère, Roebroeks 1984; Sweikhuizen, Arts 1983; and Mesch, Rensink 1986, 2005) prompted further regional studies that focused on prehistoric behavior and the reconstruction of site locations, seasonal occupation cycles, and subsistence patterns. Research at this time was constrained regionally, such that workers at Leiden and Amsterdam Universities were focused on the southern Netherlands, while workers at the University of Groningen were focused on the northern Netherlands. The eastern portion of the country was seemingly left out, only subject to research incidentally. Furthermore, the National Service of Archaeological Investigations (or ROB; now called the Cultural Heritage Agency, or RCE) played only a minor role in Paleolithic and Mesolithic research (Peeters pers. comm.).

These new processual developments, along with the succeeding developments of post-processual or post-modern archaeology in Britain, had little effect on the climate of Dutch archaeology, although they were closely followed by Dutch archaeologists (Van den Broeke et al. 2005: 22). Instead of focusing on methodological and theoretical developments, Dutch archaeology had long emphasized field research and pragmatic interpretations. According to Van den Broeke et al. (2005) "the Dutch approach to the past can be placed in between modest positivism and moderate relativism" (Van den Broeke et al. 2005:23). It is widely held that preconceptions and assumptions of researchers inevitably affect statements made about the past, and that many factors limit clearer understanding. Nevertheless, many Dutch archaeologists take the position that the past can be known–and is *knowable*–through archaeological data.

3.3.2 Review of the Archaeological Record

In the following section, a survey of the archaeological record for the Netherlands will be provided. This survey will begin with a discussion of Late Paleolithic/Late Glacial sites and end with a discussion of early Neolithic sites; however, the focus will be to explain the current configuration of Mesolithic finds throughout the country, and how they relate to finds and sites in neighboring countries.

3.3.2.1 Late Paleolithic. The environment during the Late Glacial period (Weichselian) was characterized by open steppes, which combined both tundra and temperate/boreal species. Temperate grasses served as fodder for the large migratory herd species (reindeer, and horse) that populated the region. During the warmer interstadial periods, stands of trees attracted more sedentary species like roe deer and elk. While this scenario generally applies to most of central and northern Europe at the time, there was also much spatial diversity, especially between high and low ground (steppe versus river valleys).

The first hunter-gatherer groups to continuously occupy the Netherlands did so only by the end of the Late Paleolithic, also known as the Late Glacial or Late Pleistocene (c. 13,000-10,000 ^{14}C yr B.P.; Deeben and Van Gijn 2005:189). During this time, cultural diversity flourished. Magdalenian groups inhabited the south, Hamburgian cultures inhabited the north, Creswellian groups (which some characterize as Magdalenian) inhabited the north (and possibly also the south), and *Federmesser* and Ahrensburgian groups lived throughout the region (Roebroeks and Van Gijn 2005). These cultures are characterized by advanced blade technologies. The Hamburgian tradition (c. 12,500-11,600 ^{14}C yr B.P.)--remains of which have been found in the northern Netherlands--spread over most of the North European Plain. The Creswellian subculture (c. 12,000-11,500 ^{14}C yr B.P.) is documented primarily in Britain where there is currently discussion of it as Magdalenian, although there is some debate about a small Creswellian presence in the Netherlands (Zeijen), perhaps indicating that this group's cultural core lies somewhere on the now-drowned Doggerland plateau (Roebroeks and Van Gijn 2005:79). More crucial is the fact that the Creswellian shares many traits with both the Magdalenian and the more widely spread and later *Federmesser* culture that inhabited continental western Europe. In fact, Arts (1988) has noted that very little, if any, difference occurs between the so-called Creswellian and *Federmesser* assemblages in the southern Netherlands (Arts 1988, see also Barton et al. 2003).

In the following temporal era, the *Federmesser* tradition (c. 11,700-10,400 ^{14}C yr B.P.), has been identified over a large portion of Western Europe; its type site lies in southwestern Germany where characteristic *Feder* knives (in German: *messer*) were found. In the Netherlands, a special subset of this tradition has been identified. This tradition extended over the entire Netherlands, and overlapped in time with another Late Paleolithic group: the Ahrensburgian tradition (c. 10,600-9600 ^{14}C yr B.P.). This group, named for the reindeer hunting camp and type site Ahrensburg-Stellmoor in northern Germany, occupied only the eastern half of the Netherlands. The Early Mesolithic tradition (c. 9600-8200 ^{14}C yr B.P.) is seen by many researchers as a continuation of the Ahrensburgian and *Federmesser* way of life, with only minor adjustments to economy and technology (Deeben and Arts 2005:153; Roebroeks and Van Gijn 2005).

Material culture. The stone technologies of the Late Paleolithic and early Mesolithic are characterized largely by great continuity (Deeben and Arts 2005:145). However, some distinctions can be made, especially among the point types used. *Federmesser* points (including those from groups belonging to the *Federmesser* tradition, such as Gravettian, Creswellian, Cheddarrian, and Azilian) are relatively large and ‘backed’ (retouched at a steep angle), presumably to be used as point inserts for spears. In addition to these composite tools, truncated and backed blades are common, as well as burins and end scrapers (Deeben and Arts 2005:145). The type artifact of the Ahrensburgian tradition is the tanged point, a small point usually exhibiting retouch on more than one edge. Obliquely truncated points (known in the Netherlands as ‘B’-points) and steeply retouched points are also common, although the latter steadily decreased in size (Deeben and Rensink 2005:192). In addition, in the Ahrensburgian tradition, the first microliths arise, a trend that would reach its zenith in the Mesolithic (see below). Other tools often found among Ahrensburgian complexes are burins, scrapers, and truncated blades, along with the occasional unretouched long blade (>12 cm; Stapert 2005:163).

The decrease in the size of projectile points coincided with the development of the microburin technique, in which microblades were notched and fractured into the desired geometric shape. The appearance of microliths suggests that a shift in hunting technology--from a reliance primarily on the spear to the bow-and-arrow, as well as the harpoon--may also have differentiated the *Federmesser* from the Ahrensburgian tradition (Deeben and Rensink 2005: 194). This transition may not have become fully realized until the early Mesolithic, when large points had been completely replaced by microlithic points, suitable only for use as light projectile points and barbs.

The Ahrensburgian site of Gramsbergen, situated along the OverIJssel Vecht River, yielded many microlithic points, about half of which are obliquely truncated (Johansen and Stapert 1999, 2000). Analysis of tool morphology, refits, and the spatial distribution of the assemblage suggests that two flint workers, sitting about one meter apart, produced the scatter in a single event. Based on the morphology of the tools, researchers assume that one knapper was a skilled master, while the other was an apprentice (see Stapert 2005:164 for an artists' impression of the flint working event).

Most flint used for tool manufacture by Late Paleolithic people derived from cobbles found in fluvial deposits and in the boulder clays of the Rhine and Meuse terrace deposits. Some exotic or non-indigenous flint raw material has also been identified, coming from as far as the Belgian Ardennes (c. 230 km), and Helgoland, a small island off the western coast of Jutland, Denmark. In addition to flint tools, Late Paleolithic people made and used a wide variety of other utensils from different raw materials. Grinding stones, arrow straighteners, hammerstones, and retouchers were fashioned out of quartz, quartzite, sandstone, and even granite in the north of the country (Deeben and Arts 2005:146). Lydite was used to make perforated beads and ochre pigment has been found at *Federmesser* and Ahrensburgian sites, in addition to some engraved stone artifacts (see *Federmesser* engraved flint scraper from Budel II; Arts 1988; Wouters 1991; see also engraved *Federmesser* artifacts in Deeben and Rensink 2005:182). Organic materials such as bone and antler were also used, although only a few with reliable dates are known from the Netherlands.

Structures, Sites, and Settlement. Settlement data in the form of features or structural remains from the Late Paleolithic are also very scarce in the Netherlands. The most definitive feature evidence available consists of charcoal concentrations (ostensibly hearths), scatters of burned lithics and ochre, soil discolorations, and isolated pits (Deeben and Arts 2005:147). Since no unambiguous remains of tents, huts, or houses have been recovered, most researchers look to sites in neighboring countries for instruction. For example, at the Duvensee peat bog site in Schleswig-Holstein, Germany, a bark platform has been found that dates to the early Holocene

(Bokelman 1991). Without solid settlement evidence, researchers have focused instead on developing spatial analyses of artifact scatters, as a way to identify locations where specific activities occurred (see Stapert 1992). Paired with refitting experiments, such research projects have yielded useful results in reconstructing the spatial organization of settlements (see Cahen et al. 1979's analysis of the Belgian *Federmesser* site of Meer).

Although most scholarship about Late Paleolithic traditions in the Netherlands derive from lithic scatters (with their numerous shortcomings), such remains have been instructive regarding the type of site location that these groups preferred. These hunter-gatherers settled almost exclusively on coversand ridges and terraces, preferably on smaller tributaries or along valley edges (Deeben and Rensink 2005:192). These ecotones were likely chosen because of the array of habitats and species that could be exploited in a small area. The wider river valleys were probably used for general foraging activities (Deeben and Arts 2005:151). While it was once thought that pingo scars (e.g., glacial kettles) may have been preferential locations for Late Paleolithic and Mesolithic hunter-gatherers (e.g., Stapert 1985:30), it has recently been shown by I. Woltinge of the GIA that no relationship exists between settlement locations and these landform features (Woltinge 2010). Three additional factors seem to have been selected in locating settlements: (1) proximity to water or wet areas; (2) locations on the (south)eastern slope of coversand bodies; and (3) well-drained soils. These site location requirements and preferences are markedly different from locations chosen by similar groups in Germany and Belgium, where deep valleys and more dramatic topography caused Late Paleolithic groups to favor sheltered locations like caves, rock shelters, and incised valleys. It is also quite likely that sites were also positioned along reindeer migration routes, as suggested by Petersen and Johansen (1996), in locations with a good view of the landscape. While much of the Netherlands is characterized by flat terrain, abrupt change in relief do occur (e.g., the ice-pushed ridges in the central and northern Netherlands, the loess area in south Limburg, and the West-Brabant ridge), from which views of the surrounding area could be gotten. Further, in the Late Glacial landscape, which was sparsely vegetated, not much elevational difference is needed to obtain a suitable vantage point (e.g., Stellmoor in Northern Germany; Insulander 1999).

Subsistence. The trend toward focusing on a single species for exploitation was begun already in the Middle Paleolithic (e.g., horse); this trend seems to have intensified by the Upper Paleolithic, when reindeer were the preferred dietary staple (Deeben and Rensink 2005:171; Deeben and Van Gijn 2005:193). This statement is based on environmental, climatic, and archaeological data. At the end of the Pleistocene, the environment was comparatively dry with mostly open vegetation—the preferred habitat of large migratory species such as reindeer and horse. *Federmesser* sites (e.g., Doetinchem, Johansen 2000; and Wierden, Deeben 2006; Rensink 2006) have yielded remains from elk, aurochs, beaver, reindeer, horse, and wild pig. Other sites have yielded charred remains of goose and red deer (e.g., Eersel-Panberg in the southern Netherlands; Deeben et al. 2000/2001:14). At Late Paleolithic sites in Germany (e.g., Meiendorf, Bratlund 1996; Clark 1975; Stellmoor, Krause & Kollau 1943:59) and Belgium (e.g., Maisières-Canal, Jacobi et al. 2010; de Heinzelin 1971, 1973; Haesaerts & de Heinzelin 1979; Hermitage at Huccorgne, Straus et al. 2000), various open-habitat fauna have been recovered, including the remains of chamois, wolf, fox, and snow hare (Deeben and Rensink 2005:193). By contrast, a number of forest-loving species were found at the site of Bedburg-Königshoven, just across the border in Germany, including aurochs, and red and roe deer (Street 1989). Interestingly, the data from Doetinchem and Wierden fit the range seen at Bedburg. Although the evidence is slim, plants were also likely exploited, along with fish and fowl. In general, the species exploited by

Federmesser groups were relatively immobile and uniformly distributed; Ahrensburgian groups focused on the same set of species, although during certain seasons and/or areas, reindeer was the primary focus (Deeben and Arts 2005:154). Clearly, Late Paleolithic groups were not monolithic in their tastes or subsistence preferences.

As reindeer was an integral component of Late Paleolithic diets, it is assumed that hunter-gatherer seasonal rounds probably mirrored some of the movements of these large herds. Reindeer migrate long distances in the spring and fall; in the winter and spring, groups disperse into smaller units. Various seasonal models have been developed based on this biogeographic knowledge, both within and outside the Netherlands, to explain Late Paleolithic annual rounds. Baales (1996) looked at Ahrensburgian faunal remains from sites in Germany and Belgium and concluded that reindeer herds most likely spent the summers in the cooler uplands (e.g., the Ardennes and Swabian Jura), while the winters were spent in the (then dry) North Sea Basin. If this scenario was indeed the case, it is expected that larger group hunting sites, or clusters of smaller sites, should be found along reindeer migration routes. One such site could be that of Geldrop, where reindeer may have been butchered by either *Federmesser* or Ahrensburgian occupants or both, although no hard evidence has yet been recovered (Deeben and Rensink 2005:194). The major flaw with this hypothesis is that determining migration routes is limited by the fact that winter camps may be located beneath the currently submerged North Sea Basin. Until further underwater archaeological research occurs, hypotheses of reindeer-hunter seasonal rounds will remain partially untested.

Among Dutch researchers, Arts and Deeben (1981) developed a similar hypothesis based on finds from the Netherlands, arguing that Ahrensburgian groups aggregated in the spring and fall into large base camps. These camps were the staging areas for group hunts and massive reindeer butchering, meat processing, and consumption. They may well have been positioned along natural migration routes in the landscape, such as the major river valleys of the paleo-Meuse and paleo-Rhine, or along the contemporaneous coastlines (Arts and Deeben 1981; Deeben and Rensink 2005:194; Deeben and Arts 2005:153). In the summer and winter months, when reindeer were dispersed, hunter-gatherers probably lived in groups consisting of one or two nuclear families. During this time, groups were much more likely to exploit a wider array of resources, not just for taste variety but also for nutritional variety. In addition, it has been suggested that the first instance of canine domestication began somewhere during this period, or in the subsequent early Mesolithic; a first example of domestication of animals in general (Stapert 2005). Thus, settlement patterns on the landscape should include both small, short-term extraction sites, as well as large, longer-term aggregation sites.

Society. It is assumed that only a small number of people inhabited the Netherlands at any given time during the Late Paleolithic (c. 500 people) (where does this number come from?) and as such, territory size was quite large while population density was comparatively low. Population during the *Federmesser* tradition is thought to have been somewhat denser than during the Ahrensburgian tradition or the early Mesolithic, as the number of sites decreased over time (see Arts [1989] for population estimates during the Upper Paleolithic and Newell [1973] for estimates from the Mesolithic; Deeben and Van Gijn 2005:192). However, the assumption that site frequency can provide estimates of relative population density is difficult to substantiate. It is equally likely that site frequency may also be related to different mobility systems.

Considering the fact that sites of *Federmesser* age have been found on the western island of Texel, and given the hypotheses discussed above concerning likely migration routes to areas in the now-drowned North Sea Basin, many sites probably lie submerged beneath the sea.

Further, some of the older and larger settlements may be buried beneath colluvium and alluvium in river valleys (a general problem for much of the Late Glacial and Holocene Netherlands), or beneath loess deposits in the Limburg area. Regardless, there seems to have been a balance of high mobility with periods of semi-sedentary aggregation over the course of a given year, based on the timing of gregarious mammal migration. The Ahrensburgian tradition likely represented the territorial boundaries of a macroband or dialect tribe, in which material culture and language were similar enough to allow for easy exchange of information, goods, and marital partners (Deeben and Arts 2005:154). Late Paleolithic groups appear to have been egalitarian in nature, s little evidence has been found to suggest that social differentiation occurred. Some ritual and ideological behavior was undertaken, evidenced by the presence of engraved objects (e.g. two human figures engraved on retouchoirs from Geldrop and Wansum) and the use of ochre. Such finds are extremely scarce in the Netherlands; however, at other famous sites in Europe, both portable and parietal art was executed (e.g., Venus figurines, cave paintings of Lascaux and Altamira, etc.).

Summary. In conclusion, the Late Paleolithic period was one of great changes in the physical environment, and subsequent variation in the type of cultural adaptations. With each glacial and interglacial and interstadial, people modified their lifeways to meet their subsistence, settlement, societal, and ritual needs. While the nature of interaction between these groups is not clearly understood, it is certain that communication and exchange did occur, as styles, technologies, and morphologies were shared across and between regions at varying paces. Large game were relied upon as a staple, but not to the exclusion of other species. Artistic expression flourished during this era, as people felt compelled not only to represent their world two-dimensionally on cave and rock walls, but also three-dimensionally on figurines and carvings. As the last continental glaciers began to melt (c. 10,000 ^{14}C yr B.P.), Late Paleolithic groups again faced an environmental shift and adapted to it fluidly. In fact, the Early Mesolithic in many places appears to be more of a continuation of Late Paleolithic lifeways, adapted to warmer and wetter climes, and associated ecosystem changes.

3.3.2.2 Mesolithic. The environmental changes that were initiated during the Late Glacial period in northern Europe continued along a similar trajectory leading toward complete deglaciation of northern Europe: the ice caps covering Scandinavia and the Alps retreated and temperatures rose steadily. As a result, the much lowered sea levels began to transgress. At the start of the Holocene, the coasts were 65 meters lower than today and the modern, coastal country of the Netherlands was a landlocked, coversand territory (Verhart 2005:157). The coastlines lay nearly 300 km to the southwest. However, only 2000 years later (by 8000 ^{14}C yr B.P.), the sea had risen nearly 40 meters and submerged most of the North Sea Basin, an area of about 180,000 m^2. Such relatively rapid changes in coastal transgression (about 2 cm/yr, or 10 cm per five years) must have been noticeable on an individual human scale in many parts of the low-lying Netherlands. Indeed, given the near level gradient of the land, a single generation could witness the coast moving inland by several kilometers (Verhart 2005:157). This transgression slowed down from 8000-6000 ^{14}C yr B.P., gaining only about 10 additional meters (0.5 cm/yr, or 10 cm in 20 years). Similarly, the climatic amelioration slowed by the Atlantic period, reaching mean annual temperatures somewhat warmer than those of the modern-day in the Netherlands (see Chapter 4 for further discussion).

At a broad temporal and spatial scale, the Holocene could be viewed as a more stable period – the intense climatic and glacial fluctuations of the Late Glacial had certainly abated, leading to more constant vegetation cover and faunal distributions (Deeben and Van Gijn 2005:192). At a finer-grained spatial and chronological scale, it becomes clear that the abiotic landscape could be quite dynamic, with requisite changes in biotic communities. During the Preboreal (10,000-9000 ^{14}C yr B.P.), broad grasslands were interspersed with forests of birch, with coniferous species on the rise. In the Boreal (9000-8000 ^{14}C yr B.P.), the forests expanded and became increasingly dense. Pine dominated the vegetation community, although species like elm, hazel, alder, and oak were also present. In the Atlantic (8000-6000 ^{14}C yr B.P.), increases in forest density continued in the coversand areas, with lime and oak most common. Swamps and peat lands spread across the north and west of the country, where the ground became permanently waterlogged (Van der Woude 1983; Westerhoff 2003; Vos 2005). The area was home to a wide variety of faunal species: aurochs, elk, red and roe deer, wild boar, beaver, migratory and dryland birds, amphibians, reptiles, insects, and fish. While most of these species could be found throughout the period, the re-wetting of soils and forest spread/increased density that occurred toward the early and middle Atlantic Period caused a decline in the number of grazing animals that prefer (semi)open and dry habitats (Verhart and Arts 2005:237). The latter statement is only partially justifiable, however, as grazing animals remains such as horse have been found in wetlands from middle and late Atlantic contexts (e.g., at Ringkloster, Bay-Petersen 1978; Rasmussen 1995; Hoge Vaart, Peeters 2007; and Swifterbant, Peeters 2004).

Material culture. The boundary between Late Paleolithic and Mesolithic periods is largely arbitrary; tool typologies, technologies, and raw material usage constitute the division between Ahrensburgian and Early Mesolithic assemblages (Deeben and Arts 2005:139). Within the Mesolithic proper many researchers differentiate between an early, middle, and late Mesolithic (and even a Final Mesolithic; Crombé et al. 2011; however, early and late subdivisions are common; see Lanting and Van der Plicht 2000:135-136 for a simplified chronology). However, some researchers disagree regarding the accuracy and representativeness of the current typology, which is based heavily on seriation of flint projectile points, tool size, and geometric blade shapes. Among other things, the typology has largely been developed on surface collections, which are often very eroded and difficult to definitively attribute to a single period or horizon. Also, the typology was developed on a narrow range of specific tool types (e.g., projectile points, cores, and flake axes). More reliable chronometric dating of organics stratigraphically associated with stone tools is needed, along with a more integrated and technologically-focused approach that considers all types of stone tools and their byproducts (see Peeters and Niekus 2005:219-222 for further discussion).

Nevertheless, stone tool typology is still instructive, showing that--over time--blades became smaller in size and more regular in production (Deeben and Van Gijn 2005:194). Technological innovations that began in the Late Paleolithic (such as tool diversification and steeply retouching/backing tool edges) carried on into the early Mesolithic. The latter assemblages are more similar in typology and morphology than the former, not only in the Netherlands, but also across northwest Europe (Deeben and Arts 2005:143). The early Mesolithic tool industry also exhibited a strong trend toward microlithization, and the skilled use of notching small microblade blanks to produce geometric projectile points and barbs for composite tool inserts (i.e., the microburin technique; Verhart and Arts 2005:246; Verhart and Groenendijk 2005:165). At this time, steeply retouched or edge-retouched points (also referred to as armatures) were common, such as those with an oblique edge or edges (e.g., in the Netherlands, so-called “A-points”, “B-points”, and triangular shaped points). Other stone tools included scrapers, knives, drills, and true burins (although this tool type decreased throughout the period). Other organic utensils and tools were produced by these stone implements.

Tool production in the middle Mesolithic can only be vaguely distinguished technologically and morphologically through the presence of very small microliths and the production of small and rather irregular blades, made from very small cores. These shifts occur differentially in the flint industries of the north and south of the country. In the south, the middle Mesolithic is represented by points with surface retouch; in the north, C-points are the main guide artifact (Peeters and Niekus 2005:221). Further, north of the OverIJssel Vecht, regular microblades and narrow triangular points appear to be the focus of flint production (Peeters and Niekus 2005:221). South of the Vecht, projectile points are shorter and wider in shape and the blade technology is less regular. Researchers have speculated that these differing tool types (along with some other differences in material culture; see below) could represent separate cultural groups: a Northwest group, which displays morphological similarities to a northern European tradition (e.g., the Danish Maglemose and Kongemose groups); and a Rhine Basin group, possibly the continuation of a western European tradition (e.g., the French Sauveterre and Tardenoisian archaeological groups)[6].

The late Mesolithic is characterized by the rise of the trapeze, or trapezoidal-shaped, point. These points are not to be confused with side blade inserts. These diagnostic points were

[6] The notion of *archaeological cultures*, in which a specific tool tradition is taken to signify a specific and unique cultural group, is not espoused by this study, although it has been used to explain differences in the techo-morphology of tools by other researchers in the field (Crombé 2002; Perdaen et al. 2008). Rather, such named techno-morphology divisions are considered to represent the material culture of hunter-gatherers in a particular place and time.

also produced into the early Neolithic, thus complicating the task of dating a site. In the north, flake axes also were common in the late Mesolithic, while in the south, points with retouched bases and notched blades were produced in large numbers (Verhart and Arts 2005: 251). In general, the flint industry was even more homogenous in morphology than before, as the regional differences seen in the middle Mesolithic disappeared.

A few types of groundstone artifacts have been found in Mesolithic assemblages. In the north, "Geröllkeulen" and "Spitzhauen" refer to oval-shaped stones with hourglass perforations in the centers, thought to be used as weights for digging sticks, drills, or possibly as slinging stones or hammerstones (Verhart and Groenendijk 2005:167). The absence of these unique groundstone artifacts in the south of the country has been used as further evidence for a territorial or cultural split between the north and south of the country during the middle Mesolithic (Peeters and Niekus 2005:225). Purported arrow shaft polishers were recovered from two of the (presumed) graves at Mariënberg and may have been grave goods, as the stones were found with flat edges facing the bottom in both pits (Verlinde 2005:181). Ochre pigment has also been found at a few sites (e.g., Mariënberg), although it appears in secondary contexts, mixed into the sand grains of pit fill (see below for discussion of the significance of this ochre).

Stone raw material sources were available throughout the local environment. In the north, flint nodules could be picked up from the sand, having been deposited as glacial tills. In the south, flint outcropped from terrace deposits was found lying on abandoned river beds (Verhart and Groenendijk 2005:166). Apart from flint, Wommersom quartzite - obtained further south near the Belgian Ardennes – was occasionally used. In some rare cases, Helgoland flint from a small island in the North Sea off Jutland has also been found (Deeben and Arts 2005:145).

Only a very scant number of organic artifacts have been recovered from Mesolithic sites in the Netherlands. This is due to a variety of factors, namely poor preservation due to light sedimentation, highly acidic soil conditions, and limited accessibility to deposits with better preservation potential throughout parts of the country. Many of the existing organic finds have been recovered through dredging operations, and until the invention of AMS-dating, were very difficult to place chronologically (Deeben and Arts 2005:144). For this reason, stone tools and debris have been the focus of archaeological studies; however, as more low-lying clay or peat-capped areas are investigated, many more organic finds may be discovered.

Dryland contexts have yielded only a few organic remains. Charred hazelnut shells--and to a lesser degree, seeds and carbonized bone--are ubiquitous at many inland Mesolithic sites. The Pesse canoe hewn out of oak by Mesolithic hunter-gatherers (dated to the Boreal), was found in the province of Drenthe. An aurochs skull and other skeletal fragments were found in a fossil meander at the site of Jardinga, in association with bones from other fauna and flora (e.g., red deer, beaver, terrapins, fish, and carbonized hazelnut; Prummel and Niekus 2005). At the site of Zutphen Ooijerhoek, some bone and antler implements were found, again in a residual fossil meander (Bos et al. 2005; Groenewoudt et al. 2001). The twin dune sites of Polderweg and De Bruin at Hardinxveld-Giessendam yielded bone, antler, and wood objects, including canoe and paddle fragments, axes and adzes, and the remains of woven fabric, perhaps for fish traps and/or weirs (Louwe Kooijmans 2001a, 2001b, 2005).

Most organic artifacts have been found inadvertently through dredging operations (Verhart and Arts 2005:238). Dredging in the modern-day Meuse River has revealed some bone and antler finds (e.g., at the site of Maaspoort near s'-Hertogenbosch), as well as a wooden figurine dated to the late Mesolithic (i.e., the Volkerak figurine from Willemstad on the Meuse

River). In the area of the IJssel, dredging operations at Spoolde, near Zwolle, yielded hundreds of bone and antler implements, many of which likely derive from the Mesolithic and Neolithic periods (Clason 1983; Peeters 192). The North Sea floor has also yielded bone and antler tools that were likely used as axes, picks, harpoons, spear points, and projectile points (Verhart 2005:157). From the area of Maasvlakte 1 near Rotterdam, a very large harpoon collection has been recovered, numbering over 500 in total (Verhart 1988). Dutch researchers have identified three point classes, which seem to be associated with certain time periods: harpoons and spear points date to the early Mesolithic, while projectile points date to the late Mesolithic (Verhart 2005:158). Across northwest Europe, the placement and spacing of barbs on similar bone and antler points have led to another classification of separate spatio-temporal groups (although see footnote 1). However, at other well-preserved sites across Europe, points, tools, and harpoons have been found and are not temporally discrete.

Overall, the Mesolithic was a time of flourishing technological innovation, most likely to facilitate more intensive subsistence pursuits. The increased variation in tool types and the raw materials employed suggests that early Holocene hunter-gatherers profited from being flexible in their food gathering practices, using whatever materials were available for both planned and spontaneous encounters with prey (Deeben and Van Gijn 2005:195). Such subsistence behaviors likely affected the settlement patterns and mobility of hunter-gatherers, which will be discussed in the next section, followed by further discussion of the evidence bearing on questions of subsistence.

Settlement. Thousands of Mesolithic sites and find spots have been identified in the Netherlands; however, most of these sites are located at, or near, the present-day ground surface, on coversand ridges and dunes or plowed fields that afford only poor preservation (Verhart and

Arts 2005:235). Due to the problems of preservation in some regions of the Netherlands and difficult access in others, very few traces of Mesolithic settlements have been documented or investigated. In combination with the sparse organic archaeological record, research investigating settlement systems and land use exploitation strategies has necessarily focused on developing site typologies (Newell 1973, 1975; Price 1975, 1978). Newell's (1973) settlement typology recognized four main types of sites: base camps, two kinds of special purpose camps, and aggregation camps; Price's (1975) settlement typology included five site types: extraction camps, small base camps, medium sites, large sites, and very large sites (Peeters and Niekus 2005:223). More recent research has suggested that these classifications are limited in informational value, especially since only a few of the sites on which the typologies were developed were fully excavated. It has also been argued that the large "aggregation camps" and "very large sites" were the result of multiple occupations of the same areas over many hundreds of years (i.e., palimpsest sites; Peeters and Niekus 2005:223; Verhart and Groenendijk 2005:171). It may be that these sites were situated in "persistent places," locations that were returned to repeatedly by hunter-gatherers over hundreds of years. Researchers have attempted to understand the motivation behind this recurrent behavior, and suggest that the particular configuration or landform features may be the cause, perhaps imbuing the locations with cultural or ritual significance (Barton et al. 1995; Littleton and Allen 2007). The application of hunter-gatherer economic models, similar to those developed by Binford (1980) and Jochim (1976), have only tentatively been applied to the Dutch Mesolithic scenario (Price 1975) and with varying results. It is widely held that the lack of organic preservation and settlement traces would greatly skew any type of such analysis of seasonal rounds and settlement systems. Still, approaching the archaeological record with such research frameworks in mind, especially from a regional perspective, can be instructive (Verhart and Arts 2005:240).

As there are no unequivocal examples of Mesolithic houses or tents in the Netherlands (or from most other parts of Europe) much insight into settlement and exploitation strategies has been gleaned from the archaeological records of nearby countries. As mentioned above, the Duvensee site complex in Germany yielded pine bark mats, ostensibly lining hut or tent floors (Bokelman 1991). At the site of Ulkestrop-Lyng in Denmark (dated to the Maglemose period), birch bark floors were found in association with postholes (Andersen et al. 1982).

In the Netherlands, only three sites contain possible traces of settlements with evidence of architecture. The lack of sites may be related to the reoccupation of these sites, as part of the persistent places idea (see above). One of the best known, yet highly contested, examples of a Mesolithic dwelling comes from the site of Bergumermeer S-64B, in the north Netherlands. Here, Newell (1980) and others (e.g., Casparie and Bosch 1995) distinguished six areas with soil discoloration and stone outlines as huts. As only a select portion of the original excavation data has been published (e.g., the spatial distribution of artifacts or the flint inventory), it remains uncertain whether the six areas do in fact represent huts, or whether they were caused by natural processes, such as tree falls or other soil and erosional processes (Peeters and Niekus 2005:213). Another site with potential evidence of living structures is Baarn-'De Drie Eiken' in the central Netherlands. Here, pits associated with diagnostically-Mesolithic flint were found, without any intrusive, younger artifacts. One pit in particular, measuring 5-x-4 meters in diameter, yielded easily recognizable postholes, placed in a circular pattern (Peeters and Niekus 2005:214; Van Haaff et al. 1988). Only a single date was obtained on a fragment of charred bone, yielding an age between 7900 and 7800 ^{14}C yr B.P., which is close to the expected age of 8500-8000 ^{14}C r

B.P. Further, the unmistakable Mesolithic character of the flint tools suggests to most researchers that the pits and postholes were constructed during the Mesolithic. The last, and least contested, example of Mesolithic huts comes from the Hardinxveld-Giessendam sites of Polderweg and De Bruin. Here, oval depressions in the dune sand, with an apparently random scatter of distinct postholes, strongly suggests semi-temporary sunken huts or pit houses (for further discussion, see Louwe Kooijmans 2001a, 2001b).

Despite the scarce traces of Mesolithic living structures in the Netherlands, a number of hearths, pits, and graves have been recovered. At the site of Nieuwe-Pekela 3 (NP-3) in the Groningen peat district, some 500 hearths were found on an elongated coversand ridge (Peeters and Niekus 2005:210). These pits rarely intersect one another, implying that they were recognizable to returning inhabitants long after initial use, or that old spots were recognized while digging new pits, which may have triggered movement to locations away from the pits. Whatever the case, micromorphology studies at the site of Hoge Vaart did not yield any indications of the pits being reused (Peeters 2007). Flints were found nearby these pits, suggesting that both hunting and domestic activities may have occurred, likely at different times, as the site formed over a long period (c. 8500-7800 ^{14}C yr B.P., Boreal). However, there is currently no evidence to suggest that the pits and flint scatters were contemporaneous. Other Mesolithic sites with pits include: Mariënberg (see below); Hoge Vaart-A27, where 100 hearth pits were found on a coversand ridge (7800-6100 ^{14}C yr B.P., early-middle Atlantic; Hogestijn and Peeters 2001); Urk-E4, with 35 hearth pits located on a small river dune near the OverIJssel Vecht (7850-6270 ^{14}C yr B.P., early-middle Atlantic; Peters and Peeters 2001); and Zwolle-

Vrouwenlaan, with 60 hearth pits (8160-6840 ^{14}C yr B.P., early Atlantic; Klomp 2004; Hermsen et al. 2006).

At the site of Mariënberg, on the OverIJssel Vecht, hundreds of round and oval-shaped hearth pits (c. 0.5-1.0 meters in diameter and up to 65 cm deep) were found atop a long coversand ridge (Verlinde 2005). Like the NP-3 pits, these pits exhibited hardly any intrusive activity from younger phases. Two primary types of fill were used: a light fill containing mainly pine wood and dating to the Preboreal and Boreal; and a dark fill containing both oak and pine wood and dating to the Atlantic (Verlinde 2005). Notably, the fills contained hardly any flint or organic remains, nor were there many artifacts found in and around the pits, suggesting the area was not used for dwelling or subsistence purposes. Experimental research into the burning dynamics of the pits found that they would have produced a steady amount of heat for a long period of time, markedly different from the burning dynamics of surface hearths intended to provide people warmth and light. Instead, the Mariënberg pits were probably used in preserving and/or preparing food, in curing of hides (Groenendijk 1987), or for tar production (Peeters pers. comm.). Of the pits, six in particular were unique in sharing internal morphological consistency: all were conical with flat bottoms. In addition, some had ochre-laced sand and ostensible grave goods in their fills. In particular, two matching arrow shaft polishers were found in two of the pits, an occurrence that suggests intentional placement. Verlinde (2005:181) argues that the conical pits were perfect for seated burials in which the dead were placed with knees bent. Similar seated burials have been found from the site of De Bruin (Louwe Kooijmans 2001b), and Padina and Vlasac in the Danube Gorges (Borić and Miracle 2004; Borić 2006; Borić et al. 2008). A number of other graves were also recovered from the Hardinxveld-Giessendam sites. One middle-aged woman was placed in a shallow grave, lying fully-extended on her back. Other various human remains were found, along with a few dog burials (see Louwe Kooijmans 2001a, 2001b).

From the available settlement evidence, some general conclusions about site location may be drawn. As in the Late Paleolithic, all settlements were placed near a source of water, although this may be related to research and taphonomic bias. Camps were usually located on top of low river dunes or coversand ridges with good drainage (Verhart and Groenendijk 2005:173). While early Mesolithic sites are found in more clustered patterns, by the middle and late Mesolithic, settlements became more evenly distributed over the landscape, perhaps as a result of shifts in the abiotic and biotic communities and subsequent changes in the subsistence regime (Deeben and Van Gijn 2005:191). Furthermore, a large chunk of the settlement 'story' may be submerged under the North Sea, or buried deeply below marine and/or fluvial sediments.

Subsistence. The Mesolithic period is distinguished from the Late Paleolithic in that hunting practices shifted from a focus on mobile and gregarious species (e.g., reindeer and horse) to a broader spectrum of resources. As the climate warmed and vegetation biogeography changed, populations of reindeer, horse, and elk migrated further north, following the open steppe/tundra environment. In the boreal and temperate forests that remained during the early Holocene, a diet consisting of a wider array of food resources, available at different times of year, was ostensibly more stable in diversity and abundance of (relatively) evenly distributed and stable species (Deeben and Rensink 2005). Consequently, a shift in hunting strategies, technology, and mobility occurred, from a focus on group hunts/drives and the use of the spear, to more individually based stealth and interception-based hunting tactics that required good tracking skills (e.g., Myers 1989), the use of more sophisticated technologies (e.g., the bow and arrow), and the domestication of the dog. As residential stability increased with a consequent decrease in mobility, they were also able to develop more efficient hunting and gathering strategies, such as the use of untended facilities like fish traps, nets, and weirs, and animal snares (Deeben and Van Gijn 2005:195). Further, if ethnographically-documented hunter-gatherers can be used as a proxy for understanding Mesolithic mobility, then these prehistoric foragers may have had large territories (c. 80-100 km in diameter; Jochim 1998) and moved long distances during the course of a year (Binford 2001; Kelly 1995; Rogers 1962). However, Mesolithic hunter-gatherers were not relegated to marginal environments and, in fact, lived in very biologically rich and diverse habitats. This means that smaller territories could adequately supply sufficient nutrition to a group and that people likely did not travel as far as frequently. However, traveling upwards of 300 km has been documented for the exchange of exotic goods, social relationships, hunting and trapping, and possibly also mates (see Donahue and Lovis 2006; Eriksen 2002; Sulgostowska 2006).

From the scant floral and faunal remains that exist for the Dutch Mesolithic, only a partial construction of subsistence can be formulated. Evidence from specific sites must be extrapolated to larger regions and longer time periods. At the beach of Europoort, and the adjacent submerged sand plain (known as Maasvlakte), many bone and antler tools and fragments with cut marks have been found over the years by amateur archaeologists, or have been dredged up. No worked flint objects have been found among the organic objects, suggesting that the area was used for specialized hunting activities. In particular, hunting seems to have been carried out in a wet area, such as a lake or swamp (Verhart 2005:159). This corroborates the fact that coastal areas are one of the richest biotopes and would have supplied not only a diverse array of resources, but also an abundance of such resources throughout the year (Verhart and Groenendijk 2005:162). At the site of Jardinga in the north Netherlands, a wide variety of faunal data were found in a wet fossil meander, in addition to the remains of four aurochs carcasses (Prummel et al. 1999, 2000). The cut marks on some of the aurochs bones suggests the animals were butchered at the site but that the meat was taken elsewhere for consumption (Peeters and Niekus 2005:217). The site may also have been used for fishing activities during its 300 years of active use.

While evidence for exploitation of large mammals is the most numerous—most likely because large mammal bones tend to preserve well—there is also growing evidence that small mammals, birds, and fish were also important in the diet. For example, at the site of Weelde-Paardsdrank in Belgium, burned fox and deer bones were found in association with Mesolithic remains (Van Neer 1982). Further, species like amphibians, reptiles, insects, and larvae were probably also eaten. As mentioned above, a number of hammerstones (Geröllkeulen or Spitzhauen) have been found in Mesolithic contexts in the northern Netherlands. The purported use of these stones as digging stick weights, if correct, implies that extracting roots and tubers from the ground may have been an important subsistence activity during parts of the year, or during meat-scarce times. Some of these objects also show percussion marks, suggesting they may have been multifunctional tools (Peeters pers. comm.). Moreover, recent developments in the field of stone tool use wear suggest that plant foods and plant working may be underrepresented in the archaeological record (Gendel et al. 1985; Juel Jensen 1986; Gijn et al. 2001a; Gijn et al. 2001b). Foods such as hazelnuts, cherries, and water chestnuts must have played a role in the Mesolithic diet (Verhart and Groenendijk 2005:170), as carbonized remains are often found in hearth pits, but also because they were an easily procurable resource. Tentative evidence from sites like Duvensee in Germany and Ertebølle in Denmark suggests that these temporarily abundant resources may have been stored in pits and bark baskets (Andersen and Johansen 1986; Holst 2010; Deeben and Van Gijn 2005:195; Mithen 2000, 2001). Studies of plant macroremains and pollen analysis have also indicated that plants may have been a staple of the diet (Kubiak-Martens 1999, 2003; Perry 1999) and that Mesolithic hunter-gatherers may have engaged in activities intentionally designed to encourage the growth of particular plants and attract certain fauna, such as burning and clearing (Bos et al. 2005; Groenewoudt et al. 2001; for evidence from the British Isles see for example Simmons 1996; Zvelebil et al. 1992). Although we have no direct evidence for the use of honey in the Netherlands, rock carvings dated to the Mesolithic on the Iberian peninsula suggest that this sweet substance may also have been exploited (Obermaier 1925).

The evidence for site seasonality for the Mesolithic in the Netherlands is scarce, following the poor preservation of organic remains. In fact, even at sites with good preservation (such as the Hardinxveld-Giessendam sites), seasonality can only be guessed at (Louwe Kooijmans 2001a, 2001b). In his settlement typology, Price (1975) attempted to relate different site types to different activities tied to particular times of year. While problematic, this approach stresses the ethnographically-based assumption that particularly in northern latitudes with greater seasonal resource variation that hunter-gatherers tend to exploit different primary species during specific seasons. Although caution is in order when using (semi)modern hunter-gatherers as analogues for prehistoric foragers, it can be assumed that a similar pattern of yearly resource-use scheduling must have occurred for groups to have survived. Based on the faunal data from well-preserved sites like Polderweg and De Bruin, it is clear that waterfowl, fish, and other large mammals were taken in the winter months (Louwe Kooijmans 2001a, 2001b, 2005:184). Plant foods like water chestnuts and hazelnut were probably exploited in the early autumn, when these foodstuffs become ripe. It can therefore be assumed that hazelnut gathering, processing, consumption, and possibly storage, would have occurred during this brief part of the year.

Further, as hazel trees prefer relatively open areas and sunlight, humans may have intentionally cleared over-grown stands of trees to facilitate hazel growth, as well as attract other floral and faunal species into these ‘edge’ zones (Brown 1997; Innes 2003; Simmons 1987; Zvelebil 1996).

Society. The organization and demography of Mesolithic people in the Netherlands is only partially understood, as the above-mentioned biasing factors of preservation have skewed the archaeological record and knowledge of it. Judicious use of analogies to ethnographically-documented hunter-gatherers is one of the main conduits to reconstruct the likely sociopolitical formation of Mesolithic society. The social hierarchy probably consisted of nested and interrelated social groups: the nuclear family (about 3-8 members); the extended family (maximum of 25 members); the microband or band (50 members); the macroband or tribe, the pool from which mates were probably found (200-500 members); and the dialect tribe, which shares the same language and material culture (500-2000 members; Verhart and Groenendijk 2005:167-8; Newell et al. 1990; see also Whallon 2006). Based on the ephemeral traces of Mesolithic occupations and the low number of lithics found scattered throughout the Netherlands, it is unlikely that many macrobands inhabited the country (e.g., the Northwest and Rhine Basin typo-morphological groups discussed above). However, the number likely grew during the middle and late Mesolithic periods, if the increased number of sites and finds reflects population increases rather than preservation and/or other taphonomic factors (Deeben and Van Gijn 2005:192). The prevailing problem here is how to connect the social group hierarchies of the past with site frequencies in the archaeological record, which requires further theory-driven research or a middle-range type (see Binford 2001; Raab and Goodyear 1984).

From the early to late Mesolithic, there appears to have been an ‘exodus from the uplands’ (Waterbolk 1999), following the increase in forest density and decrease in wildlife in the uplands and inlands. It is thought that later Mesolithic groups gravitated toward the biologically richer and more open coastal zones (Peeters and Niekus 2005:225). This description of the current unbalanced nature of the archaeological record could be proven false with further research into low-lying parts of the landscape (see for example the work from inland areas by Arts 1987, 1988; Groenendijk 1987; Verhart 2000). However, there does seem to have been an overall decrease in mobility over the course of the Mesolithic and the subsequent formation of more defined group territories (Verhart and Groenendijk 2005:169). Territorial areas seemed to have been important during the Upper Paleolithic (e.g., during the Hamburgian and Maglemosian periods), but they disappeared in the Late Paleolithic and Early Mesolithic, as noted by the cross-cutting of tool styles during the *Federmesser*, Ahrensburgian, and early Mesolithic periods. Territoriality seems to have re-emerged as an important concept by the middle Mesolithic, when flint industries again become distinctive along geographical boundaries, coinciding roughly with the areas delimited by the Rhine and Meuse (Deeben and Van Gijn 2005:192; Peeters and Niekus 2005:226). However, the population was likely growing during this time and territories must have shrunk in overall size, perhaps forcing an increase in sedentism. An example of increased sedentism is the rise of cemeteries as spatially distinct places in the local landscape (whereas previously, when groups were more mobile, the dead were more likely interred at the particular point in the seasonal round where the death occurred). Also, the exchange of exotic goods also increased (see below).

Although hunter-gatherers do seem to have become more residentially stable over the course of the Mesolithic, it is questionable whether any form of social stratification occurred, as has been documented in Scandinavia (Brinch Petersen 1988; Larsson 1984, 1988, 1995; Rowley-Conwy 1998), the Iron Gates region of Serbia (Borić 2002; Prinz 1987; Radovanovic 2000), and the site of Oleneostrovski Mogilnik in Russia (O'Shea and Zvelebil 1984); for an overview see Clark and Neeley 1987). Only a few examples of grave goods have been found in the Mesolithic, such as the arrow shaft polishers from the (purported) Mariënberg sitting graves. The lack of grave goods or exotic objects suggests that the Mesolithic hunter-gatherers who inhabited the modern-day Netherlands appear to have been primarily egalitarian, with little marking of social differentiation. Some possible interactions with Neolithic groups, if not a function of repetitive reoccupations, are suggested by the presence of a few Bandkeramik adzes and Rössen Breitkeile found in some late Mesolithic collections. Along with the arrow shaft polishers, which are more commonly found among Neolithic burials, this evidence could represent an exchange of customs or that the items were prestige goods (Verlinde 2005:181).

Other unique finds suggestive of prestige goods, ritual activity, and ancestor cults include the Volkerak human-shaped figurine (Es and Casparie 1968), a bullroarer unearthed in Tilburg-Kraaiven (Arts 1987), an engraved stone with a dancing figure from the province of Limburg (Van Ginkel and Verhart 2009:31), and just across the border in Germany, red deer antler masks from Bedburg-Köningshaven (Street 1991). The Mesolithic period was also the first to reveal evidence of burial practices in the Netherlands, for which there is surprising variety. At Mariënberg, a small cemetery was created and the dead were ostensibly interred in a sitting position and covered with ochre, which has one other parallel in the Netherlands (e.g., De Bruin at Hardinxveld-Giessendam; Louwe-Kooijmans 2001b). Other sites with probable burials in the Netherlands include: Dalfsen in OverIJssel, where Boreal-aged, cremated remains of a woman were placed in a pit along with faunal remains (possibly representing cannibalism or other explanations; Verlinde 1974:116); and the sites of Oirschot and Best (also Boreal-aged) in North Brabant, both of which yielded pits with human cremations in association with animal bones

(Arts and Hoogland 1987). Cremation burials occur elsewhere in Europe, although they were not a common way to treat the dead (Brinch Petersen and Meiklejohn 2003; Grünberg 2000).

Some of the mortuary treatment exhibited in late Mesolithic graves mirror practices seen in the early Neolithic, which suggests that preliminary exchange relationships may have been established by this time (Verlinde 1974). Not only is there the evidence of arrow shaft polishers in the purported Mesolithic seated graves of Mariënberg, but there is also ample evidence of the development of a “ceramic Mesolithic”. At the site of Swifterbant in the central Netherlands, pottery appears to have been developed indigenously by Mesolithic groups (De Roever 1976; De Roever 2004; Lanting and Van der Plicht 2000; Price 1981), although other researchers believe the technique may have been learned from incoming LBK farming groups living nearby (Raemaekers 1999:182). It seems probable that ceramic technology arose at different places and times, driven by different mechanisms (see Vanmontfort et al. 2010 volume for a recent discussion). Pottery fragments have also been found at the Hardinxveld-Giessendam sites of Polderweg and De Bruin, of which only the latter extends into the early Neolithic (Louwe Kooijmans 2001a, 2001b). What is certain is that the transition to the “Neolithic” lifeway, which is seen whether correctly or incorrectly as a “package” of behaviors including agriculture, animal husbandry, ceramic production, and decreased mobility, was a long process that occurred in fits and starts at the local level. This may have been related to the geography of the Netherlands, which was mostly low and unsuitable for agricultural practices developed on the loess plateaus of the North European Plain. Mesolithic and Neolithic groups interacted by trading ideas, goods, and practices (e.g., pottery, adzes, projectile points, domesticated animals, grain, and ideas about society and ritual) although again, some of these new ideas and artifacts may have been developed internally or imitated/influenced by Mesolithic hunter-gatherers (Verhart and Arts 2005:245).

3.3.2.3 Neolithic. Contrary to the dramatic environmental and climatic changes that occurred alongside the appearance of Mesolithic hunter-gatherers at the beginning of the early Holocene, the Neolithic cultural period is not associated with any such ecological shift (Van Gijn and Louwe Kooijmans 2005:205). Rather, the onset of the Neolithic is attributed to the spread of *Linear Pottery Culture* (or Linear Bandkeramik [LBK]) farmers into the southern Netherlands by the middle Atlantic. LBK farmers were the first farmers encountered by the hunter-gatherers of northern and western Europe (Milisauskas 2002). These early Neolithic people preferred the fertile loess areas and river valley margins of the Netherlands (De Grooth and Van de Velde 2005:219). They were still reliant on stone technology but also practiced the novel subsistence strategies of crop cultivation and animal husbandry, as evidenced by floral and faunal domesticates from the Near East (i.e., emmer and einkorn wheat, goats and sheep; Grönenborn 1999; Louwe Kooijmans 1998; Raemaekers 2003).

LBK groups persisted for a few hundred years in the Netherlands and surrounding areas; however, there is a hiatus between these first farming communities (documented by the presence of cultigens) and more stable and developed farmers (i.e., the Großgartach and Rössen culture). Unlike places in southeastern and Mediterranean Europe, hunter-gatherers in the north and west were not simply replaced or absorbed into the farming way of life immediately; instead, these groups held on to their traditional way of life for 500 years or more (see Zvelebil 1998, 2006 for notions of such resistance). The La Hoguette culture, which inhabited northern France, the Netherlands, Luxembourg, and southwest Germany, is one such exception to the replacement rule, although this culture is still only poorly understood (De Grooth and Van de Velde 2005:235). These people appear to have independently domesticated animals and experimented with pottery (Jeunesse 1986). At this time, the temperature was perhaps ~2ºC higher than today, a factor that greatly affected the productivity and success of crops and subsequently, early farming endeavors (Van Gijn and Louwe Kooijmans 2005:206). However, this was neither the sole nor most important factor that ultimately led to the adoption of agricultural lifeways by all cultures in Europe.

In the following Subboreal stage (5000-3000 ^{14}C yr B.P.), marine transgression processes were re-initiated and the western portion of the Netherlands experienced massive sedimentation events. The delta transitioned from a tidal area sheltered from the open ocean, to an area of extensive peat and salt marsh growth. These changes temporarily increased the diversity and richness of the ecosystem by creating at least three distinct ecological zones: (1) sedges and reeds along the open water; (2) stands of alder in the backwaters and brackish areas; (3) mixed forests on the dune tops (Louwe Kooijmans 1993). Raised bogs also emerge during this time. Although these areas were unsuitable for habitation purposes, they were quite usable in terms of resource procurement as well as for other social customs (e.g., ritual and ideological practices). Raised bogs played an important role in Neolithic and perhaps also Mesolithic perceptions of the landscape – the presence of many ritual deposits and burials in the peat, and the construction of wooden trackways (e.g., that of Star Carr; Clark 1975) attests to this statement[7]. Further, in the loëss zones lime forests covered the uplands and mixed deciduous

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[7] Coles (2006) claims that the wood of the 'trackway' was gnawed by beavers, and suggests instead that the feature represents a beaver lodge or dam. Further, a re-examination of the site by Conneller & Schadla-Hall (2003) suggests that the site may have been an important base camp

forests populated the valleys. This variety of habitats attracted many different game species, except in the very dense loess regions and raised bogs. Hunting, gathering, and fishing lifestyles persisted until quite late in this period, despite the fact that early farmers were in the region and that the hunter-gatherers had locally developed knowledge of cultivation and domestication processes.

3.4 Summary and Conclusions

The first aim of this chapter was to situate the reader, not only temporally, to understand the progression of cultural adaptations that occurred on the European continent, but also spatially, to understand how the area known today as the Netherlands interacted with the larger continent. In the first section, the scene was set by describing the preceding cultural period, the Upper Paleolithic. Then, specific facets of Early and Late Mesolithic life were presented for different parts of Europe, including technology and material culture, settlement, subsistence, and society. Regional considerations were discussed, as well as the human use and manipulation of the landscape. The proceeding Neolithic period was also addressed and highlights the interaction of Mesolithic and Neolithic culture and adaptations during this transitional period.

In the second section, the early prehistory of the Netherlands was zoomed in on. A brief overview of the history of archaeological research in that country was provided, followed by a review of the archaeological record that began with the cultural group directly preceding Mesolithic hunter-gatherers (i.e., Late Paleolithic groups) and ending with the cultural group directly proceeding them (i.e., Neolithic groups). Again, similarities and differences in material culture, settlement, subsistence, and society were addressed for each period.

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within a lowland context, anchoring a number of smaller and short-term sites in the great Vale of Pickering, and playing a special role as a barbed point manufacturing/deposition location.

The second aim of this chapter was to provide an overview of the variety of manifestations of hunter-gatherer lifeways during the Mesolithic period in Europe. As the current study is concerned with how hunter-gatherers make decisions about land use, this chapter was meant to highlight some of the many ways in which such decisions were carried out. While a variety of cultural elements were addressed, the goal was to underscore how humans and the landscape interacted; that is, how people influenced their environment and vice versa. Emphasis was placed on the ways such interactions occurred in time and space. This chapter provides concrete archaeological evidence for Mesolithic lifeways; based on this evidence, a model will be constructed in the following chapters that tests which factors within these lifeways may have driven decision-making strategies in regards to land use. The output of these models will be compared with the archaeological data discussed here in Chapter 7.

Chapter 4

REGIONAL LANDSCAPE EVOLUTION AND TAPHONOMY

4.1 Introduction

The archaeological record of the Mesolithic from the Netherlands contains gaps that are greatly in need of attention. One way to potentially improve understandings of human land use strategies during this period is, in the absence of new data, to harness the existing data in new and different ways (e.g., Krist 2001; Peeters 2007; Whitley 2000). A primary goal of this research is to do just that: to link existing spatial and archaeological data in a novel manner that facilitates testing of hypotheses concerning human behavior in the Early Holocene. This chapter explains the landscape evolution and taphonomic sequence of three study areas within the regional landscape of the central Netherlands. The chapter also describes the vegetative development of the region, and touches on some of the mapping and modeling methods used here.

The goal of this chapter is to provide readers an understanding of how the external landscape of the early-middle Holocene Netherlands arose, and the factors and constraints that helped to shape the Mesolithic landscape. Unique geomorphologic, groundwater, and vegetation processes occurred in each of the three study areas, all of which are related to one another through a shared river system (the Rhine). This is an important characteristic, as hunter-gatherers are known to delimit their territories along natural boundaries such as watersheds and river catchments (e.g., Evans et al. 2010; Lovis and Donahue 2011). Thus, the study areas provide a useful case study by which to test hypotheses regarding human land use strategies over time, and how these strategies might correspond to perturbations in the natural environment or to cultural changes in conceptualizations of the landscape.

4.2 Background and Study Area Selection

The Netherlands is situated in the northwest corner of continental Europe, between latitudes 50º-54ºN and longitudes of 03º-08ºE, roughly that of Edmonton, Alberta in Canada. However, the climate of the Netherlands is quite mild due to southwest-trending winds. The country is located in the Lower Rhine embayment, which is itself part of the southern portion of the North Sea Basin (Busschers et al. 2007:3217). The country is also part of the North European Plain, a low-lying area (between 0 and 200 m in elevation) bounded by the North and Baltic Seas, and a chain of hilly areas and low mountains to the south (also known as the Rhenish Massif). Today, nearly a quarter of the country lies below sea level and is kept dry by a series of levees, dikes, and a coastal barrier overlain by ridges, swales and dunes (Beets and Van Der Spek 2000:4). The Netherlands has an extensive coastline; however, during the Late Glacial and Early Holocene, the coastline lay much further to the west, only reaching its current extent after 8000 ^{14}C yr B.P. (Figures 4.1, 4.2). Prior to that time, inhabitants of the Netherlands may well have had territories extending far out into the Doggerland Plateau, today drowned by the North Sea. Two main rivers run through the Netherlands: the Rhine and Meuse. A number of fault zones (part of the Rhine Rift System, RRS) and grabens occur in the southeastern portion of the country, linked to the Rhenish Massif in Belgium and Germany.

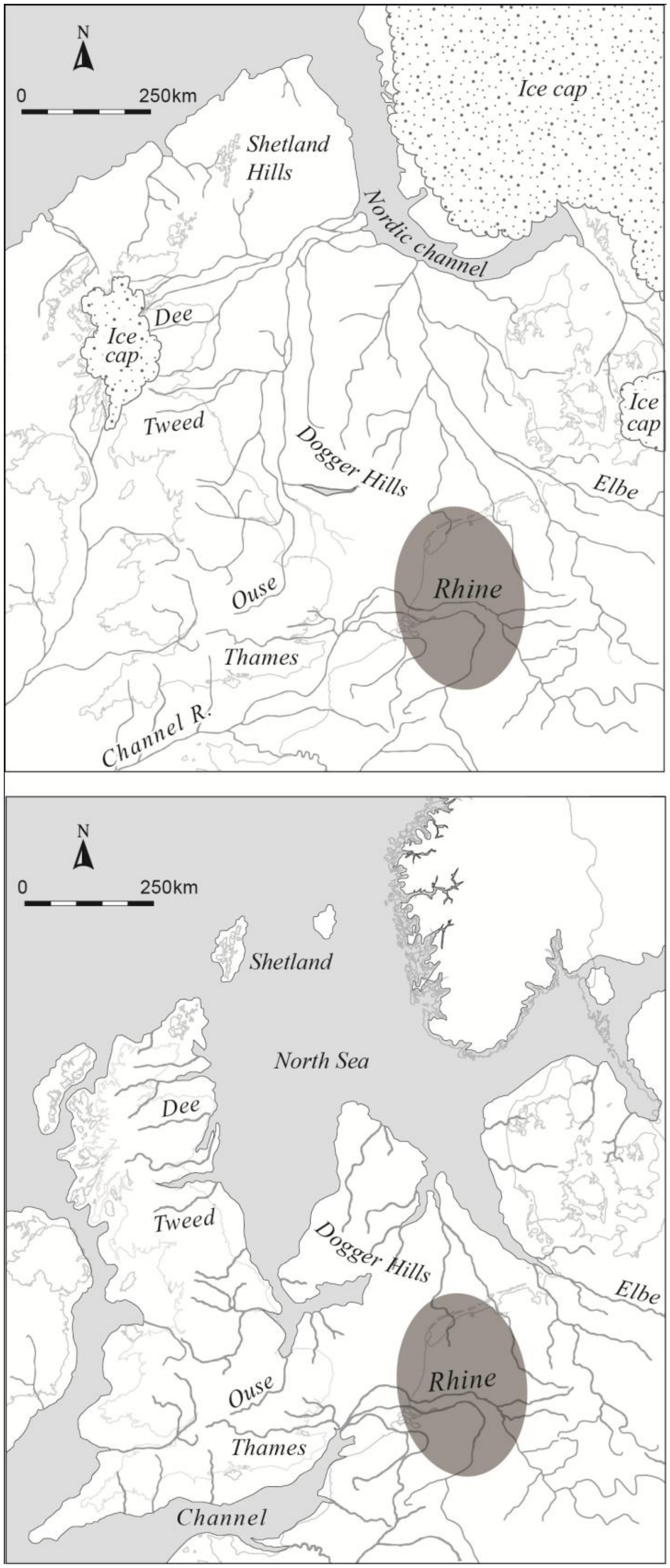


Figure 4.1 Late Glacial (top) and Early Holocene (bottom) Coastline and Doggerland (redrawn from Coles 1998). Position of the Netherlands indicated by shaded circle.

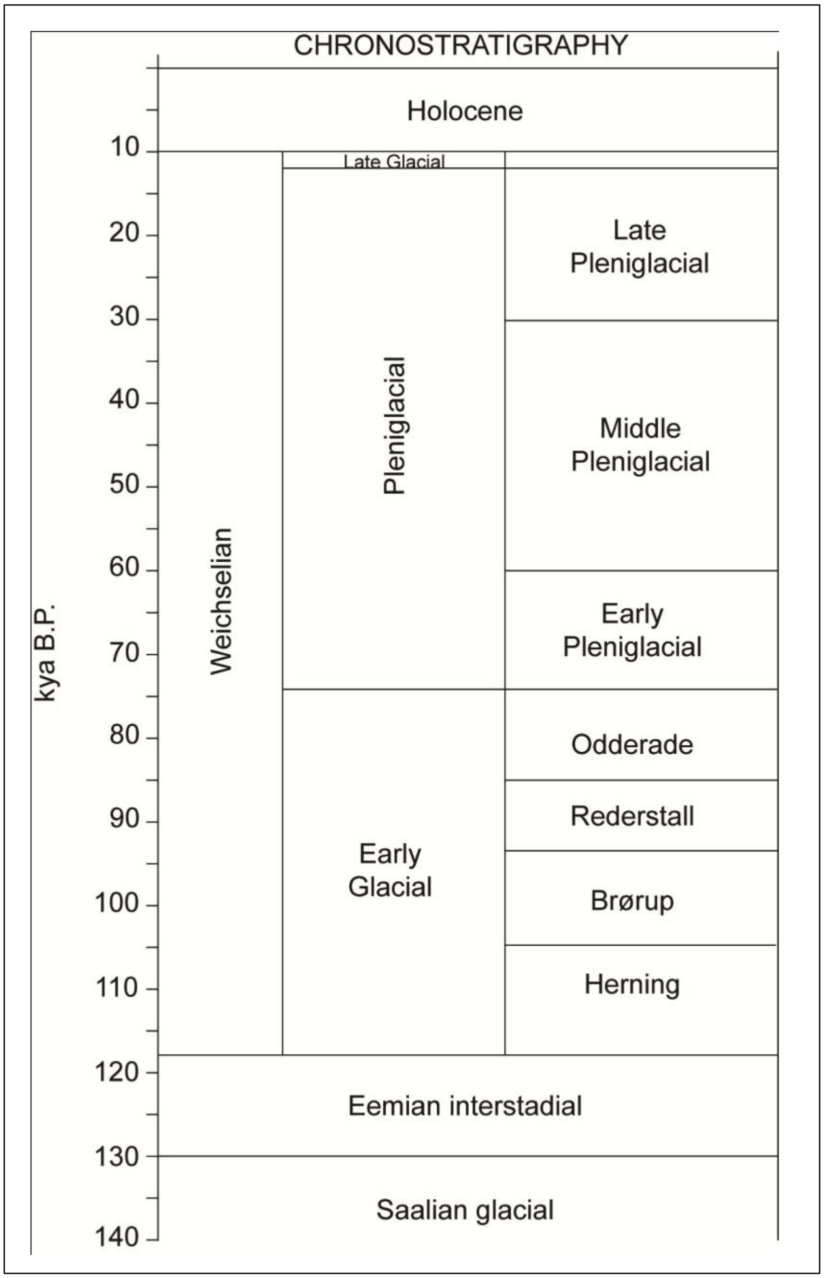


Figure 4.2 Glacial and Post-glacial Chronological Timeline (Adapted from Busschers et al. 2007:3220).

The central Netherlands is composed of a large wedge of sediment that has been building up since the early Holocene (c. 8000 ^{14}C yr B.P.; see Figure 4.6). This area, along with most of the modern-day Netherlands, is part of an active depocenter of the North Sea Basin, which has been active for millions of years. This wedge of sediment extends from the coast of the modern-day

Netherlands eastward, roughly to the German border, and measures from about 1 m thick near the Dutch-German border to over 20 m at the North Sea coastline. Post-glacial sea level rise and subsequent river gradient adjustments governed this differential sedimentation (low in the east, high in the west).

Two major rivers flow through the central Netherlands: the Rhine and Meuse. The former river begins in the Swiss Alps and flows northward and westward, encompassing a catchment size of 185,000 km^2 and with a modern mean discharge of 2350 m^3/s (Erkens and Cohen 2009); the latter river begins in northeastern France and flows northwest through a catchment area of 36,000 km^2 and with a mean discharge of 230 m^3/s. The Rhine-Meuse delta is not a typical delta. Instead of being formed by submarine sedimentation in front of the river mouth/tidal area, the Rhine-Meuse delta was formed by subaerial processes consisting of fluvial sedimentation and peat formation behind the tidal area (Beets and Van der Spek 2000; Figure 4.3).

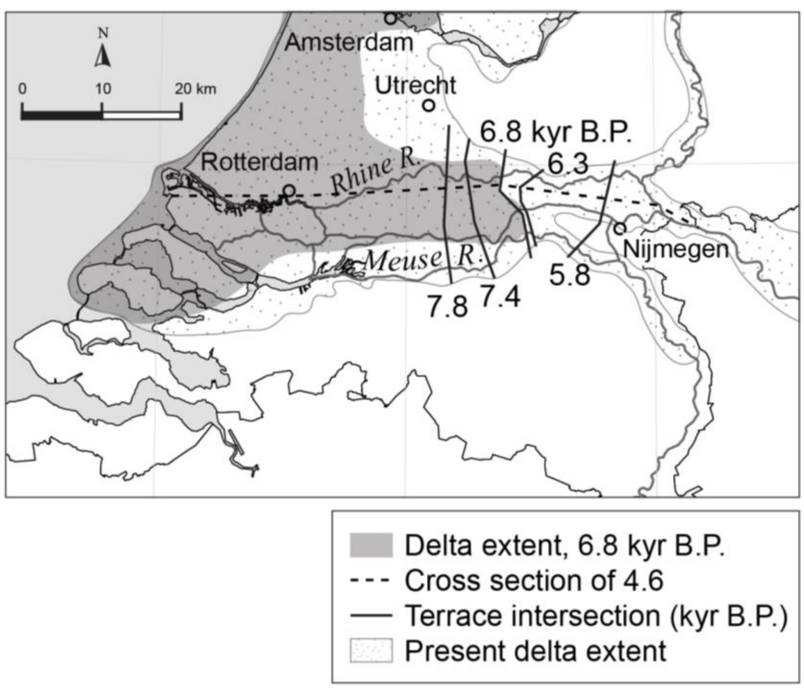


Figure 4.3 Location of Paleo- and Present-Day Rhine-Meuse Delta, Depicting Terrace Intersections (after Cohen 2003:24).

Three study areas were selected for this study, two of which lie within the Rhine-Meuse alluvial plain in the central portion of the Netherlands (Figure 4.4). The third area encompasses a part of a smaller tributary catchment in the paleo-Berkel valley, a small tributary of the Rhine. The areas were chosen because their Early to Middle Holocene abiotic conditions are representative of much larger areas: the Polderweg area (NL-RD SW corner: 107500/425500, NE corner: 132500/450500) changed from a relatively stable alluvial plain with meandering channels into a deltaic environment; the Deest area (SW corner: 165000/420000, NE corner: 190000/445000) was an alluvial plain with meandering channels flanked by higher Pleistocene grounds; and the Ooijerhoek area (SW corner: 197000/455000, NE corner: 222000/480000) was situated in a smaller, stable tributary environment with Pleistocene sediments. These different scenarios are useful case studies by which to explore the effects of hydrology and landform change on vegetation, fauna, and the land use strategies of hunter-gatherers over the course of the Early and Middle Holocene.

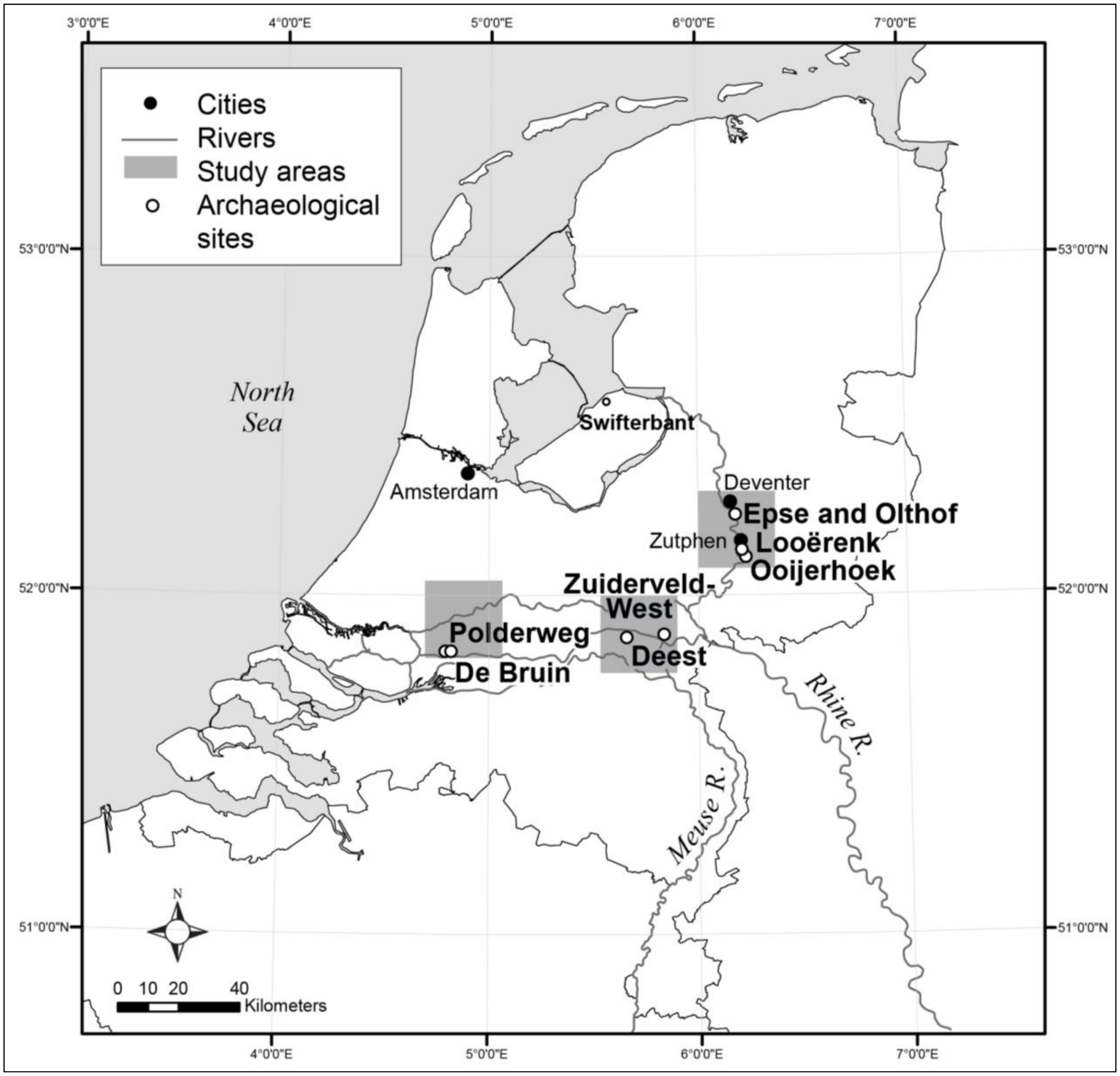


Figure 4.4 The Study Areas, Situated in the Netherlands. White Dots Represent Mesolithic Archaeological Sites Considered in this Research.

The study area size was set at ~25x25 km, a scale at which hydrological and geologic-geomorphologic trends can be explored on a sub-regional scale; when all three areas are considered together, they can reveal much about the broader geological setting within the region of the central Netherlands. In the Polderweg and Deest areas, the Rhine and Meuse rivers and small side channels were present, flanked to the north and south by ice-pushed ridges (i.e., glacial moraines) and Pleistocene river terraces covered by cover sand in the Weichselian. In the

Ooijerhoek area, small tributaries of the Rhine and IJssel systems drained the surrounding ice-pushed ridges and cover sand terraces. In the Polderweg and Deest areas, the rivers flowed roughly east to west. In the Ooijerhoek area, the Berkel tributary flowed north to south while the Schipbeek tributary flowed south to north, with a shallow watershed in between (see Figure 4.12 below). Today, all of the Netherlands is highly canalized, cultivated, and populated; however, thousands of core data, detailed soil maps, and a nation/wide digital terrain model (AHN) have yielded sufficient data to reconstruct the substratum with high levels of accuracy.

In the following paragraphs, the geological setting and lithostratigraphy of the region will be discussed for the Pleistocene and Holocene periods. Climate and general vegetation development of the Younger Dryas through Middle Holocene will then be presented. The paleo-geographic development of the individual research areas will be outlined, followed by the vegetation development. The methodology for all map generation and modeling is provided in Appendix A.

4.3 Geological Setting and Lithostratigraphy

4.3.1 Pleistocene. To understand the configuration of Holocene sedimentation and landform morphology, Pleistocene geology must be considered to differing extents. For the Polderweg area, pertinent geological history includes the Weichselian Pleniglacial onward. For the Deest and Ooijerhoek areas, the Saalian glaciation onward must be considered (see Figure 4.5 for the chrono- and lithostratigraphy of the Holocene Rhine-Meuse delta).

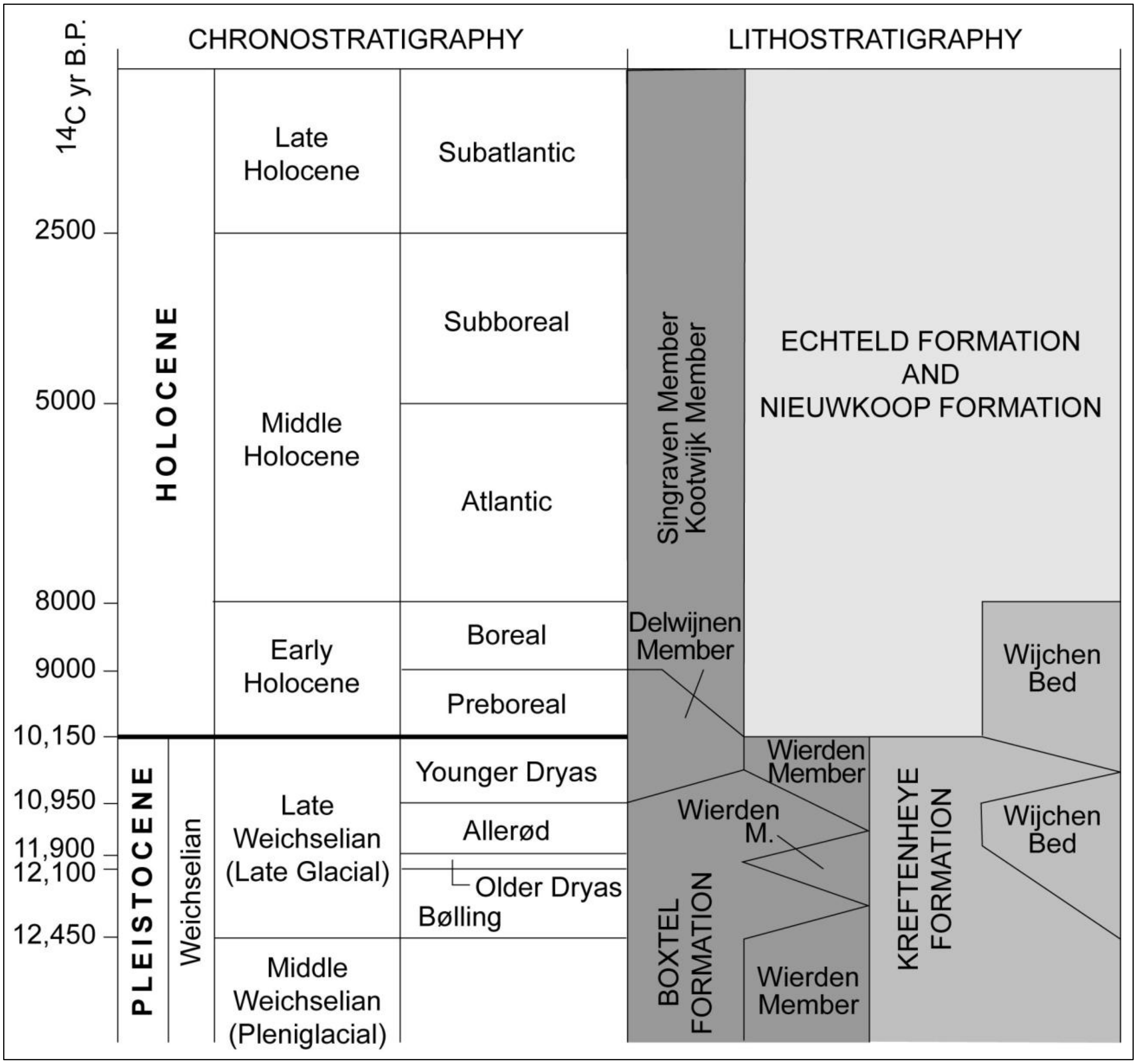


Figure 4.5 Chronostratigraphy and Lithostratigraphy of Holocene Rhine-Meuse delta (adapted from Gouw and Erkens 2007:24). ***Note:*** **the Boxtel Formation comprises mainly local eolian and small brook deposits; the Nieuwkoop Formation comprises large peat beds; the Kreftenheye Formation comprises fluvial deposits from the Rhine and Meuse Rivers.**

From the Late Glacial Maximum or LGM, c. 30 to 18 ^{14}C yr B.P., the Rhine and Meuse Rivers formed a wide alluvial plain. They were characterized by braided channels, and deposited sand and gravel (i.e., the Kreftenheye Formation; Gouw and Erkens 2007; Westerhoff et al. 2003). During the Bølling and Allerød interstadials, meandering rivers incised their channels in the Low

Terrace (In this study, the younger and lower surface is referred to as 'low terrace plain', and the older, higher surface is called 'terrace plain'). Much of the Polderweg area was covered by a massive, silty clay loam layer known as the Wijchen Bed[8] (Kreftenheye Formation; Tornqvist et al. 1994; Westerhoff et al. 2003). The deposition of this member was due to incised meandering channels periodically overflowing their banks due to spring snowmelt waters, which caused aggradation of floodplain clay (Autin 2008; Berendsen et al. 1995; Bazelmans et al. 2011).

In the following Younger Dryas stadial (11,000-10,000 ^{14}C yr B.P.), the thalwegs of the Rhine and Meuse incised channels were widened to the extent of the Younger Dryas braidplain, continuing the processes of braiding and aggrading from the previous period. In the Polderweg area, the Younger Dryas braidplain and the Low Terrace are difficult to distinguish; however, in the Deest area, the latter terrace is located above the former braidplain (Weerts pers. comm.). In some locations (especially to the northeast of the incised channel belts), Younger Dryas-aged eolian dunes lie atop the Wijchen Bed, mainly on the Pleniglacial braided terrace (Berendsen et al. 1995; Gouw and Erkens 2007:24). These dunes (Delwijnen Member, Boxtel Formation) were created during low discharge phases, when sand was easily blown up and out of the river beds (Pons and Bennema 1958). Some of the dunes were as much as 15 m in height (Hijma et al. 2009:28).Thus, two braid plain surfaces existed in the Rhine/Meuse alluvial plain (Gouw and Erkens 2007:24). The north and south of the Rhine-Meuse paleo-valley in the west is bordered by older Rhine/Meuse river terraces covered with thin windblown sand from the Weichselian Pleniglacial age. To the east, the paleo-valley is bordered in the east by Pleistocene-aged eolian sand deposits (i.e., 'coversand' sheets of the Wierden Member, Boxtel Formation; Westerhoff et

[8] Workers at Utrecht University also refer to the Wijchen Bed as a Member. While the unit was introduced as a Member in 1994 (Tornqvist, Weerts & Berendsen 1994), it was adopted by the Geological Survey as a Bed in 2000 (Weerts et al. 2000) and 2003 (Westerhoff et al. 2003).

al. 2003) covering older Rhine-Meuse terraces and ice-pushed ridges of Saalian age (160,000 years ago), predominantly consisting of older Rhine and Meuse deposits (Gouw and Erkens 2007:24). The Younger Dryas braided terrace was covered in the Early Holocene by increased Wijchen Bed overbank deposits, caused by meandering channel belts that were deeply scouring their beds (Berendsen et al. 1995; Hijma et al. 2009; Pons 1957).

The Pleistocene setting in the Deest area bears many similarities to that of the Polderweg area, although there were some notable differences. The Deest area was flanked to the north and southeast by Saalian-aged ice-pushed ridges (Cohen et al. 2002). These ridges were formed by glacial reworking of fluvial sediments of Early and Middle Quaternary age (Cohen et al. 2002:22). During full glaciation, both the Rhine and Meuse were forced into westward-flowing channels; after glaciation, the Rhine re-entered the IJssel glacial basin and partly filled it up before avulsing into a more southerly course by the Middle Weichselian (Van de Meene & Zagwijn 1978). Inland ice sheets did not reach the Netherlands during the Weichselian glaciation.

Adjacent to these ice-pushed ridges are Saalian age fluvio-glacial sandur deposits (Schaarsbergen Member, Drente Formation), which overlie earlier Pleistocene deposits (Westerhoff et al. 2003). The sandur deposits trend east to west. The lower parts are overlain by sandy Boxtel Formation deposits from the Weichselian, including Younger Dryas-aged eolian sand sheets or coversands (Wierden Member; Westerhoff et al. 2003). Further, two fault zones are situated between the Polderweg and Deest areas: the Peel Boundary and Tegelen fault zones, which have been active since at least the Early Neogene and continue to be so today (Cohen et al. 2002:19; Westerhoff et al., 2003). It has been shown that the activity of these fault zones had some influence on the infilling of the Rhine-Meuse alluvial plain (Cohen et al., 2002).

During the Late Pleniglacial (c. 32,000-13,000 ^{14}C yr B.P.), the Rhine flowed in a braided pattern, which contracted in width during the Bølling and Allerød glacial periods (Cohen 2003:108, 123). This contraction was made possible by the formation of new meandering and incising channel belts. In the Late Glacial, the Rhine and Meuse cut into the older Weichselian terraces in a meandering pattern. These channel belts were narrow (about 1-2 km in width; Cohen 2003:123). However, during the Younger Dryas (c. 11,000-10,000 ^{14}C yr B.P.), the Meuse resumed a braided pattern, which incised part of the Pleniglacial plain and is thought to be related to climatic deterioration (Vandenberghe 1995; Berendsen et al. 1995). The Rhine underwent a massive flood caused by the eruption of the Laacher See volcano and subsequent damming and breaching of large amounts of flood waters (Litt et al. 2003). This too led to a braided pattern.

As noted above, the IJssel basin was a 100 m deep glacially-scoured basin that was formed at the end of the Saalian glacial (Busschers et al. 2007). The valley was in-filled soon thereafter by glaciolacustrine and fluvial deposits. Until the Weichselian Middle Pleniglacial (c. 40,000 ^{14}C yr B.P.), the valley served as the main depocenter of Rhine sediments (Van de Meene and Zagwijn 1978). It was flanked on the west by the Saalian-aged Veluwe ice pushed ridge, and the Sallands ice-pushed ridges to the east. The Rhine left the area because of the formation of alluvial fans at the base of the Veluwe and Salland ice-pushed ridges during the cold Weichselian Pleniglacial (Stiboka 1979: Figure 2.2). Along with the alluvial deposits by the Berkel system, these fans raised the gradient of the land to a level at which it became easier for the Rhine to flow southeast instead of north (Busschers et al. 2007; Cohen et al. 2009).

In the Late Pleniglacial and into the Late Glacial period (c. 30,000-10,000 ^{14}C yr B.P.), only evidence of small, local rivers and streams is present (Busschers et al. 2007) from this area. In the north of the Ooijerhoek area, small stream valleys drained the Salland ice-pushed ridges (Cohen et al. 2009; Spek 1996). As in earlier periods, permafrost inhibited surface water infiltration, creating deep drainage channels (i.e., snow meltwater valleys) on the slopes of the ice-pushed ridges and terraces (Stiboka, 1979: Figure 2.2). Coarse-grained alluvial fan deposits were subsequently created on both sides of the former Rhine floodplain (Busschers et al. 2007). During the Younger Dryas, most of the former floodplain appears to have been covered by fine-grained, eolian coversand sheets (Koster 2005; Van den Berg et al. 2000). These dunes were parabolic in shape in the area west of Zutphen (Van Beek 2009) and elongated in the area north of Deventer (Spek 1996). A wide and shallow coversand ridge, probably also deposited during the Younger Dryas, divided the separate stream catchments. In the Ooijerhoek area, the groundwater level was low, with the dunes reaching to several meters in height (Stiboka 1979). The sand for this ridge was likely blown out of drainage channels. At the transition from the Late Glacial to the Early Holocene, locally some overbank deposits of the Wijchen Bed are present (Busschers et al. 2007). This is indicative for Rhine snowmelt floodwaters reaching the area.

4.3.2 Holocene

The late glacial-early Holocene transition was climatically abrupt, although the response in sedimentology and vegetation was more gradual. The first primary geomorphological change that took place in the Rhine-Meuse alluvial plain was the formation of the fluvio-deltaic wedge (or, 'coastal prism;' Gouw and Erkens 2007:23) in the western portion of the current delta, c. 8200 ^{14}C yr B.P. caused by the fast sea level rise (NITG-TNO 1998). The relative sea level rise

(SLR) during the Early and Middle Holocene was between 8-10 mm/year, dropping down to near zero in the Late Holocene (Hijma and Cohen In press; Jelgersma 1961; Van de Plassche 1982). In the alluvial plain, the wedge consists of shallow marine deposits in the western part and fluvial deposits and peat in the central and eastern part. Outside the alluvial plain, only marine deposits and peat formed. The wedge was protected in the west by an initially open and later closed barrier coastline, behind which Holocene sediment could accumulate (Erkens 2009:120). In fact, aggradation of this coastal prism was caused by rising eustatic sea level rise (until about 4000 ^{14}C yr B.P.; Gouw and Erkens 2007: 52), which had been occurring at a global scale since the end of the LGM (Fairbanks 1989), and subsequent groundwater rise. The aggradation-incision boundary of the prism migrated upstream (eastward) over the course of the Holocene. Downstream from the aggradation line a succession of stacked deposits formed (i.e., the fluvio-deltaic wedge; Gouw and Erkens 2007:25). Consequently, the wedge thickens in the downstream (western) extent, up to 20 m in depth at the debouching point into the North Sea. Shallow marine deposits are also present in the westernmost part of the fluvio-deltaic wedge, reaching as far east as Rotterdam (see Figure 4.6).

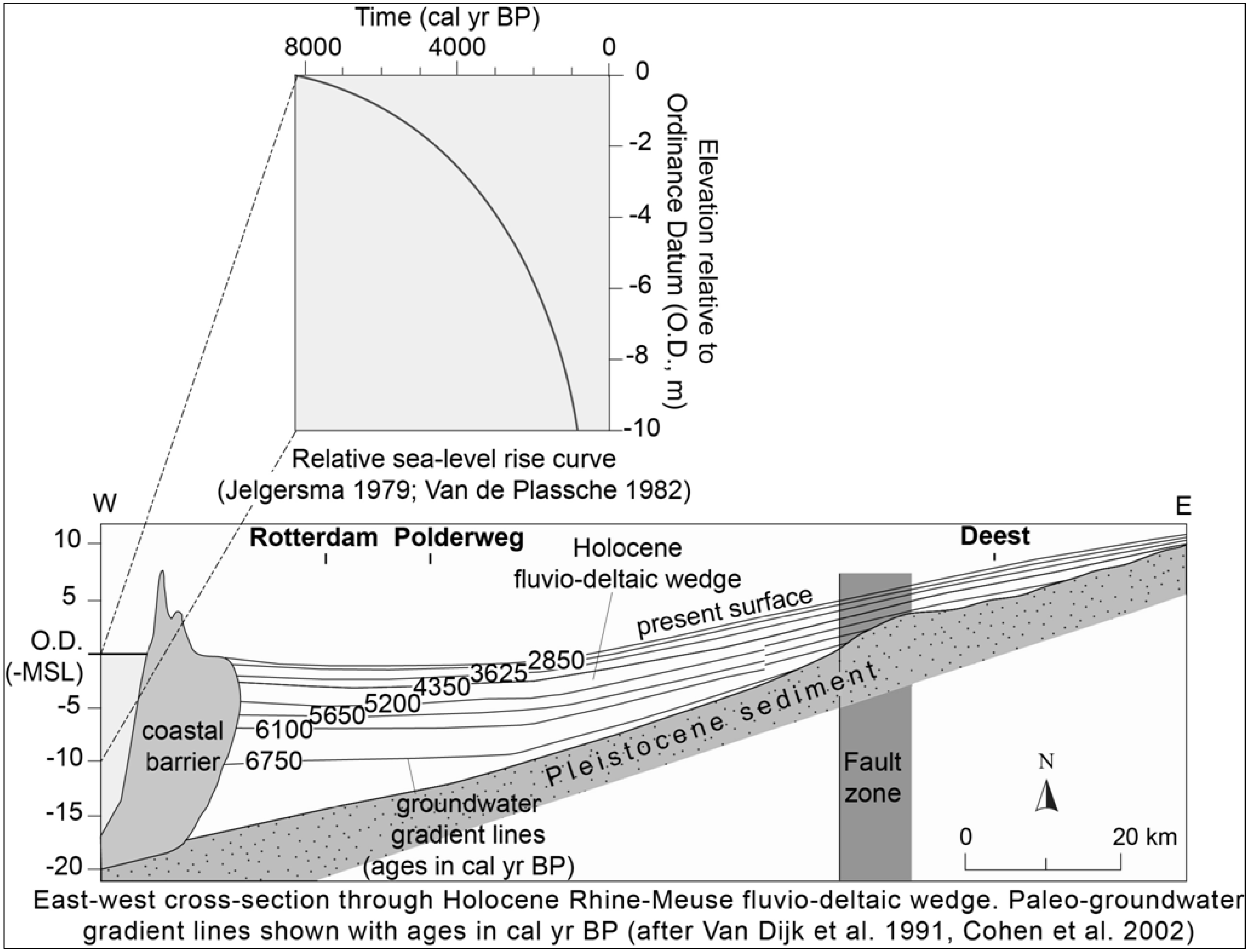


Figure 4.6 a. Relative Sea Level Rise; b. Cross-Section Through the Fluvio-Deltaic Wedge of the Rhine-Meuse Delta During the Holocene (redrawn from Gouw and Erkens 2007:26).

East of Rotterdam, the fluvio-deltaic wedge is characterized by different types of clastic fluvial deposits (of the Echteld Formation) and organic deposits (of the Nieuwkoop Formation; see Table 4.1). The deposits represent different morphological features and processes that occurred at different times throughout the Holocene. The upstream extent of the wedge (or the updip limit) occurred where the groundwater and Pleistocene substrate intersected (see Figure 4.5b; Gouw and Erkens 2007:26). This updip limit transgressed the Polderweg area of the current study around 8500 ^{14}C yr B.P. (middle Boreal), and the Deest area around 5000 ^{14}C yr B.P. (transition between Atlantic and Subboreal). Downstream of the updip limit, sedimentation and / or peat formation takes place.

Table 4.1 Fluvial and Non-Fluvial deposits and Paleo-Environments of the Rhine-Meuse Paleo-Valley (adapted from Westerhoff et al. 2003; Weerts 1996:32).

Formation	Lithogenetic unit	Description
Echteld	Meandering to anastomosing channel-belt deposits	Fine to coarse sand, can be mixed with gravel
	Natural levee deposits	Silty and sandy clay
	Crevasse-splay deposits	Very fine to coarse sand, silty and sandy clay, and clay
	Channel-fill deposits	Clays (can be silty), slightly to strongly humic
	Floodbasin deposits	Clays (can be silty), slightly to strongly humic; can be intercalated with peat and gyttja
Nieuwkoop	Organic deposits	Peat and gyttja. In the Rhine-Meuse delta intercalcated with floodbasin clays and clastic lake fills such as clay, sandy/silty clay and sand
Kreftenheye	Braided channel belt deposits (outside the area of scope also other deposits)	Sand, moderately fine to extremely coarse, gravelly and local clay layers

Table 4.1 (cont'd)

Wijchen Bed	Overbank deposits in floodplain setting, with some pedogenesis	Silty clay loam, stiff
Boxtel	Eolian, niveo-eolian and small scale fluvial deposits	Sand, extremely fine to very coarse, clay and loam, local peat
Singraven Member	Small scale fluvial deposits by meandering brooks	Sand, very fine to coarse, loam and peaty channel fills.
Wierden Member	Coversand dunes and sheets	Sand, extremely fine to moderately coarse
Delwijnen Member	Younger Dryas eolian dunes	Sand, fine to very coarse

Glacio-isostatic subsidence also had a small role in the overall relative sea-level rise, contributing between 25-30 m to total sea-level rise (Weerts pers. comm.). However, this rise varied regionally along the Dutch coast, and thus glacio-isostatic subsidence is not considered to have driven large-scale regional changes in landscape evolution. This was especially the case in the early Holocene, when eustatic sea-level rise was the driving force (e.g. Steffen 2006; cf. Peltier 2004). Isostatic subsidence appears to have increased regionally in a northeastern direction, from Belgium, to Zeeland, to Holland, and northwest Germany (Vink et al. 2007). Relative sea-level rise was also partially affected by structural tectonic movement (Cohen 2003); in the delta east of the Peel Boundary Fault, sea-level rise was somewhat delayed due to the rising of the area, as compared to the delta west of this fault.

At the Pleistocene-Holocene transition in the Polderweg area, the Rhine flowed in two major channel belts while the Meuse flowed in one (Hijma et al. 2009:53). These channel belts are characterized by gradual bed-lowering processes and simultaneous Late Glacial deposit re-workings (Hijma et al. 2009). In the Deest area, the Rhine and Meuse channels continued to incise their channels, reworking older Younger Drays channel belts (Cohen 2003:109). By the Early Holocene, the Rhine and Meuse resumed a meandering pattern (Berendsen and Stouthamer 2001; Shala 2001). Most Early Holocene channel deposits occur within previously formed

Younger Dryas/Weichselian belts, although the channel belts were narrower than their Weichselian predecessors (Cohen 2003:123, 110). Wijchen Bed overbank deposits are present throughout the Early Holocene paleo-valley, representing a deposition environment in which the groundwater level was lower than the ground surface level (i.e., *floodplain* setting), with the exception of periodic flooding (Autin 2008). Other overbank deposits also occurred in the Holocene, although these are distinct from the Wijchen Bed because the latter had time for some soil development to occur prior to being capped by fluvio-deltaic sediments. In addition, the non-Wijchen, Middle Holocene overbank deposits were laid down in a setting with groundwater at, or above, the ground surface (i.e., *floodbasin* deposits; Cohen 2003). While the channel fills of the Early Holocene belts are narrow, new evidence suggests that the channel belts may have been much wider, with numerous meanders (Cohen 2003:110, 123-129). Many of these meanders were cut off during the period and in-filled with sediment.

During the Middle Holocene, the delta apex reached the Deest area, meaning that the rivers shifted from incising to aggrading of their channels. The event was probably completed around 5000 ^{14}C yr B.P. (transition between Atlantic and Subboreal), meaning that at the end of the Mesolithic, the Deest area was still undergoing this shift (this is reinforced by the description of paleo-geographic development below). With this transition to an aggrading delta system, peat-filled floodbasins formed in the lowest areas. In the higher areas, such as the Pleniglacial terraces, aggradation occurred later, with a lag time difference of at least 1800 ^{14}C years (Gouw and Erkens 2007:32). The Rhine, which had been following the more northerly course of previous channels, began to avulse to a more southerly course; however, this process would not be complete until the Late Holocene (Cohen 2003:128). The Meuse became diverted to a more southerly course by the beginning of the Middle Holocene.

In the Ooijerhoek area, local Holocene streams continued to drain the inherited Weichselian landscape. The Berkel river entered the valley from the east, turned south near Zutphen, and joined the Rhine near Arnhem (Cohen et al. 2009). The forerunner of the Schipbeek system drained the area north of Deventer. Vegetation took hold in the Ooijerhoek area, severely curtailing the amount of sand that could be transported and deposited by eolian action. While further permafrost melting did occur in the Preboreal, temporarily elevating the groundwater level at this time, many of the Late Glacial stream valleys dried up, yielding a landscape of dry east-west depressions (Pierik 2010:14). Pingo scars/remnants dotted the Ooijerhoek area and in the Early Holocene, were filled with seepage water from the adjacent uplands, finally leading them to fill in completely with peat.

4.4 Climate and General Vegetation Development

4.4.1 Climate. During the Middle Weichselian (Pleniglacial), the climate was for the most part extremely cold and dry, with the exception of a few slightly warmer interstadials (e.g., the Moershoofd, Hengelo, and Denekamp interstadials; Van Gijssel and van der Valk 2005:55). Permafrost was widespread, rivers were mostly braided in style, and sea level was low. Mean July temperatures were around 3-4^{o}C (Van Gijssel and van der Valk 2005). During the short interstadials (only a few thousand years in duration), warmer conditions occurred, although mean July temperatures only rose to about 7^{o}C in the Moershoofd interstadial and 9^{o}C in the Hengelo and Denekamp interstadials.

The Late Weichselian/Glacial (c. 13,000-10,000 ^{14}C yr B.P.) was marked by dramatic climatic oscillations. At the start of the period, a comparatively warmer interstadial occurred (the

Bølling; c. 13,000-12,000 ^{14}C yr B.P.), with mean July temperatures of about 14°C. The Older Dryas period briefly interrupted the Bølling and Allerød interstadials, a short cold spell in which mean July temperatures dipped below 10°C. It was also quite dry, while the following Allerød interstadial (c. 11,800-11,000 ^{14}C yr B.P.) was comparatively wetter (Bohncke 1991:96). However, during this transition, temperatures hovered around an average winter temperature of -17°C and a summer temperature of 14°C. This steady temperature lasted nearly a millennium, until the beginning of the Younger Dryas (c. 11,000-10,000 ^{14}C yr B.P.), and is evidenced by organic deposits, as well as the development of podzolic soils. In particular, the development of charcoal-rich Usselo soils occurred, which is thought to be synonymous with forest fires ignited by volcanic eruptions that occurred around the Laacher See in Germany (c. 11,000 ^{14}C yr B.P.; Bosinski 1992:52).

This climatic plateau began to deteriorate at the end of the Allerød interstadial (c. 11,000 ^{14}C yr B.P.; Bohncke 1991). During the following Younger Dryas stadial, mean temperatures dropped to -20°C in winter and 11°C in summer. By 10,500 ^{14}C yr B.P., the temperature increased and it became slightly dryer. These changes have been traced by the expansion and retraction of successive plant species, which can be read in pollen sequences. For instance, pine forests contracted during the first half of the Younger Dryas and expanded again during the second half (Bohncke 1991:104). In phases of scarce vegetation, winds blew sand up and out of river channels and deposited it in sheets or dune formations (Koster 1992:91).

The transition to the Holocene was marked by a steady warming trend in temperatures, c. 10,250 and 10,000 ^{14}C yr B.P. Mean winter temperatures reached 0°C by the beginning of the

Boreal (c. 9000 ^{14}C yr B.P.), and summer temperatures peaked at 17°C. These warmer climes facilitated the rapid spread of successive vegetative communities (see below), and contributed to glacial melting and sea-level rise. These factors greatly affected the physical landscape, perhaps most notably by opening up the English Channel and subsequent connection between the southern and northern North Sea around 8300 ^{14}C yr B.P. (Zagwijn 1986: Figure 26). However, though billions of gallons of water had been unlocked from ice sheets, the climate remained relatively dry and continental until the beginning of the Atlantic (Bohncke 1991:98), when mean temperatures and precipitation approached modern conditions. This was probably also due to the formation of the North Sea, which did not exist prior to this time. The Netherlands was from this point onward situated close to the coast – causing the climate to become more oceanic than before.

4.4.2 Vegetative Successions. Pollen and plant macrofossil studies indicate that the Lower Rhine Basin (including the modern-day countries of the Netherlands and parts of Belgium and Germany) transformed from an area covered primarily by cold-adjusted plant species at the end of the Pleistocene, to an area with covered by various types of thermophilic species (Van Gijssel and van der Valk 2005:61). Specifically, Early Holocene soils have revealed that heliophilous shrubs (e.g., Scotch pine and hazel) dominated. Further, a northerly migration of different types of vegetation zones after the end of the Pleniglacial occurred (Van Gijssel and van der Valk 2005:51). Within these vegetation zones, smaller microregional plant communities existed, as evidenced by paleo-botanical research in various locations (e.g., the southern Netherlands; Leeuwaarden 1982). These inter- and intra-regional differences were largely driven by temperature, precipitation, landscape variation, entailing unique soil, lithology, groundwater, and drainage conditions (e.g., between coversand uplands and riverine lowlands). Below, general trends of biozone shifts, as well as growing requirements, will be discussed.

During the Weichselian Pleniglacial period, the species composition of local flora was affected by the low temperatures (including full permafrost soil conditions), long snow covers, high winds, widespread erosion, and lack of developed soils (Van Gijssel and van der Valk 2005:53). During the coldest phases, polar deserts characterized the region, while in the warmer phases the physical environment was tundra (e.g., scrub or steppe tundra consisting of dwarf birch), in which only low and hardy vegetation could grow. All of this changed, however, with the onset of the Bølling interstadial. At that time, birch trees and sage and wormwood shrubs increased in number, such that birch forests and temperate park landscapes with scattered trees (e.g., *Betula nana* and *Pinus sylvestris*) expanded over the area (Van Gijssel and van der Valk 2005:55, 62). During the Older Dryas, open park landscapes remained, although they became subarctic in nature rather than temperate. The birch forests re-emerged during the Allerød, and *Pinus* also increased in number. At the very end of the Late Glacial, during the Younger Dryas, a subarctic park landscape with scattered permafrost returned for a period around 1400 to 1500 years.

During the Preboreal (c. 10,000-9000 ^{14}C yr B.P.), areas with well-drained soils were covered in increasingly closed, mixed woodland dominated by birch and pine. Poplar was also dominant, with hazel, oak, and black currant (present in lesser numbers, according to the pollen data (Bos et al. 2005:36-38). Hop vines grew in the forests. Grasses, which had been very common during the preceding period, suddenly dropped in number, and were replaced by shrubs and herbs on the forest floors and open uplands (Berendsen and Zagwijn 1984). Shrub willow stands and reed-swamps abounded along the damp soils of river and lake edges, the latter consisting of species such as meadow rue, meadowsweet, nettle, and sedge. In the fens and shallow water habitats, floating aquatic plants like pondweed and water lily grew. In addition, aquatic species (such as algae) and other submerged taxa were also present in lakes and wetlands (Bos et al. 2005).

In the Boreal period (c. 9000-8000 ^{14}C yr B.P.), pine continued to dominate the dryland forests, while birch decreased in frequency in the pollen record (Bos et al. 2005:36-38). Hazel surged in number, becoming very widespread. However, this lasted only a short time and the species returned to its previous levels of abundance by the end of the period. Oak was on the rise, along with trees such as lime and elm. Overall, the forests were becoming increasingly dense and ferns dominated the undergrowth (Bos et al. 2005; Bos and Urz 2003). Alder expanded in the wet soils along river and lake margins, partially replacing shrub willow. Marsh herbs, grasses, and sedges also grew in these wetland-dryland transition zones. Eutrophic peats began to form in the waterlogged soils of the western Netherlands. Semi-aquatic and aquatic species remained the same (Bos et al. 2005).

By the Atlantic period (c. 8000-5000 ^{14}C yr B.P.), pine numbers dropped considerably, hazel numbers fluctuated but remained low overall, and birch became very sparse (Bos et al. 2005:36-38). Oak dominated the dry uplands, with lime, elm, and ash comprising a small fraction of the tree community. During this time, dryland groundcover spread to its maximum extent, consisting mainly of ivy, mistletoe, and holly. Nettles flourished on the wet-dry margin of river dunes. Alder dominated the wet marsh woodlands, often growing on top of peat and forcing out willow. In places, openings must have occurred in the dense alder marshes--perhaps due to periodic tree fall—permitting sun-loving groundcover to grow (e.g., loosestrife, mint, hops, and bittersweet; Bakels and van Beurden 2001; Bos et al. 2005; cf. Vera 1997, as discussed below in section 4.6.4). Sedges and reeds grew abundantly in shallow wet soils, and marsh fern occupied the transition area between the peat bogs and alder marsh. Other semi-aquatic, floating-leaf species inhabited this zone (such as cattail/bulrush, arrow-grass, and water plantain), their roots growing in submerged, anaerobic conditions (Gucker 2008). Floating aquatic species like water lily, pond lily, and pondweed grew in slow-flowing open water, along with algae.

4.5 Paleo-Geographic Development of the Research Areas

The paleo-geography of the three study areas was modeled here. This landscape modeling was based in part on previously developed reconstruction maps for the Netherlands (Figures 4.7, 4.8, 4.9). As will be discussed in further detail below, the Early Holocene was relatively stable, becoming more dynamic into the Middle Holocene.

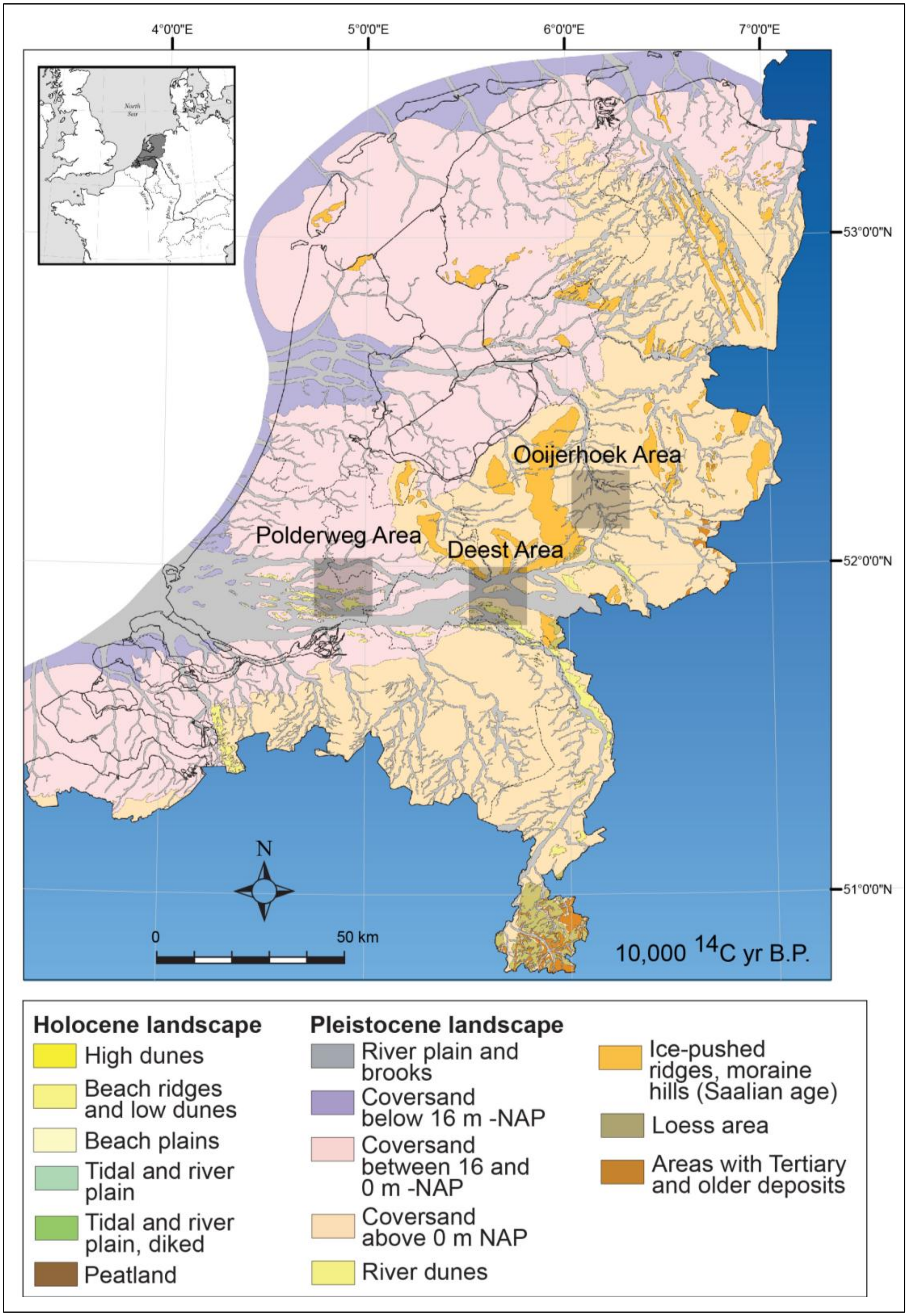


Figure 4.7 Paleo-Landscape of the Netherlands c. 10,000 ^{14}C yr B.P. (adapted from Vos et al. 2011:39). Study areas shaded in gray boxes. For interpretation of the references to color in this and all other figures, the reader is referred to the electronic version of this dissertation.

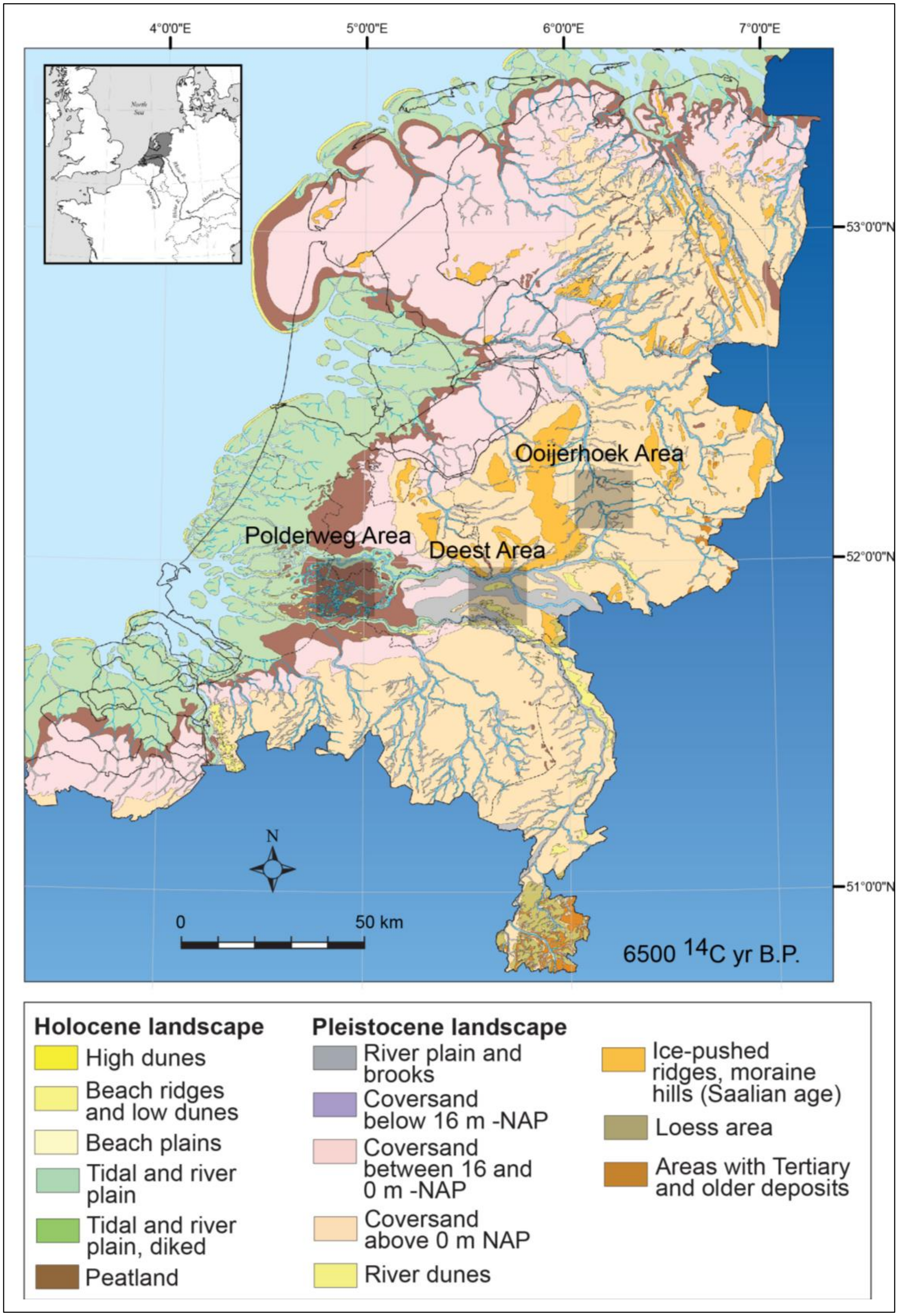


Figure 4.8 Paleo-Landscape of the Netherlands c. 6500 ^{14}C yr B.P. (adapted from Vos et al. 2011:39).

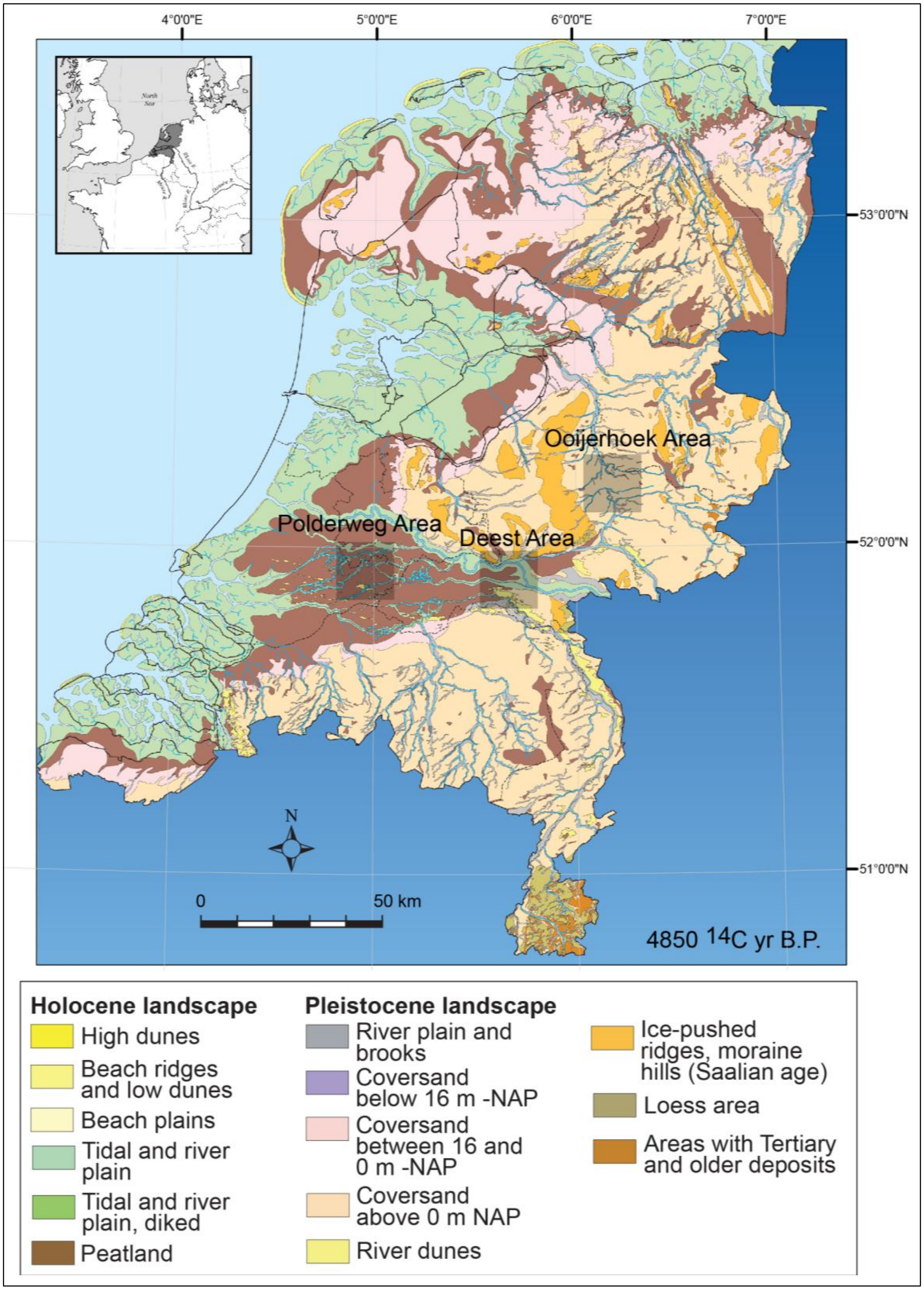


Figure 4.9 Paleo-Landscape of the Netherlands c. 4850 ^{14}C yr B.P. (adapted from Vos et al. 2011:39). Study areas shaded in gray boxes.

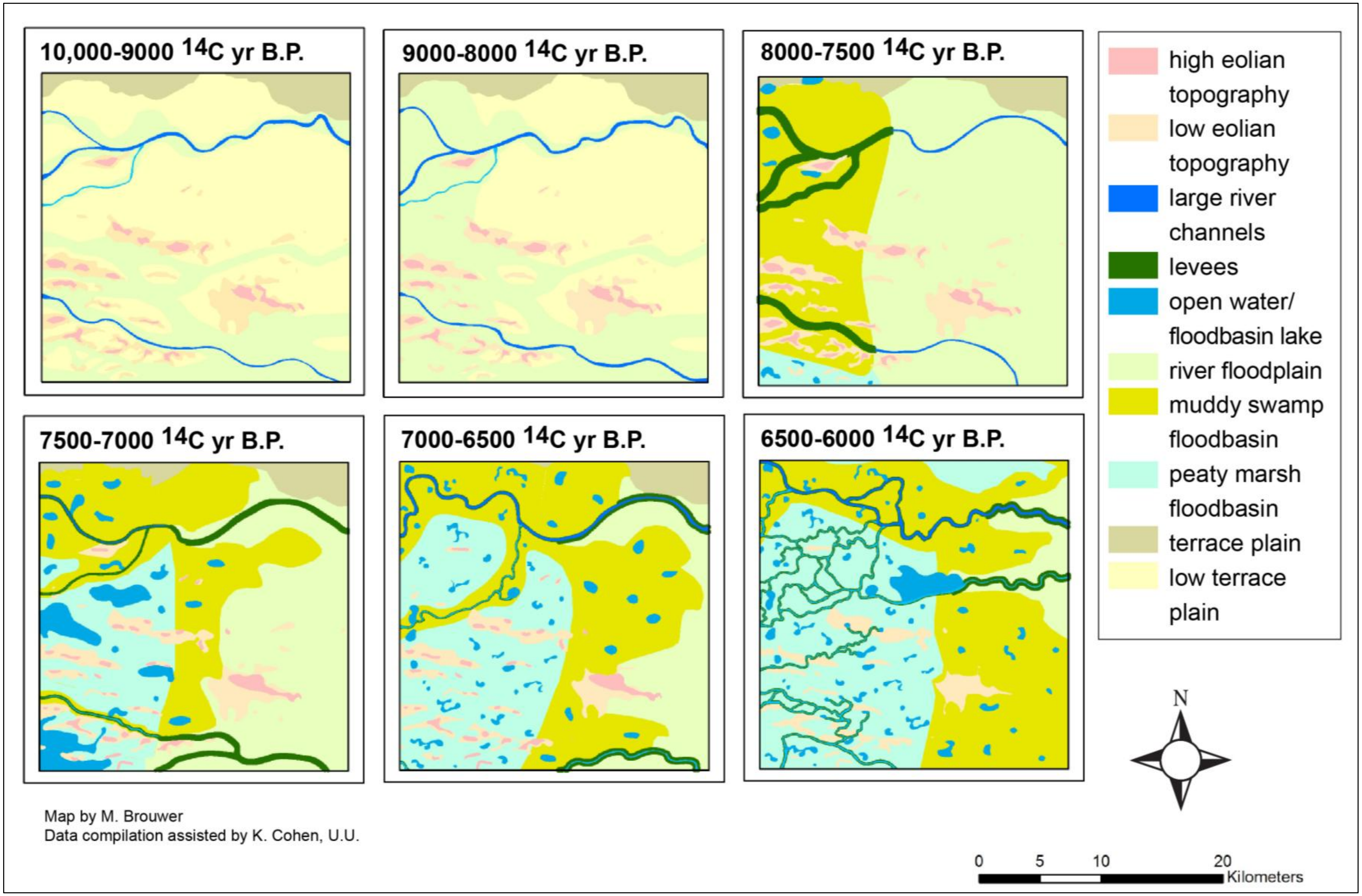
4.5.1 Polderweg. From the Younger Dryas through the Preboreal (11,000-9000 ^{14}C yr B.P.), the Rhine-Meuse paleo-valley remained relatively stable in the Polderweg area: the Meuse was incising its narrow meandering channel, while the Rhine was incising a slightly wider channel, branching into three distributaries in the west (Figure 4.10; Hijma et al. 2009:51-53). The low terrace plain had already been incised into the Pleniglacial terrace plane, and eolian dune formation was taking place.

During the first half of the Boreal period (9000-8500 ^{14}C yr B.P.), the rivers continued to meander and incise their channels. However, the effects of sea and groundwater level rise, and the eastward-migrating fluvio-deltaic wedge, were beginning to take hold: in the western portion of the Polderweg area, the river floodplain was accumulating onto the low terrace plain. By the middle Boreal (8500 ^{14}C yr B.P.), the area was transgressed by the updip limit of the fluvio-deltaic wedge. At this time, rivers began aggrading, or building up the floors of their channels. It is likely that some of the dune fields were created or added to during the late Boreal (Hijma et al. 2009:52).

By the early Atlantic (8000-7000 ^{14}C yr B.P.), the Polderweg area was fully engulfed within the fluvio-deltaic wedge. Peat formation, which had begun at the start of the period and acts as a marker of the onset of Holocene aggradation, became quite widespread and most of the Polderweg area was now periodically flooded (Bos et al. In press:95; Hijma and Cohen In press:53), although tidal influences remained at bay. In areas close to channels, the peats would have been subject to further fluvial (and clastic) sedimentation (Bos et al. In press: 97; Hijma et al. 2009:41). Away from the channels (e.g., in the river floodplain), the peats often graded into gyttja, suggesting that the formation of peat was slower than that of groundwater rise (Hijma et al. 2009). Simultaneously, organic facies also formed on the flanks of topographically higher features, such as eolian dunes (Bos et al. In press:95). Gyttja deposits occurred more frequently in the Meuse catchment, while reed peat formed in the Rhine catchment. Some lakes were present in the area during the first half of the period 8000-7500 ^{14}C yr B.P.), as well as broad levees along the downstream western portion of the river channels. During the second half of the period (7500-7000 ^{14}C yr B.P.), more numerous and larger lakes occurred, and thin levees spread along the entire extent of the river channels. Simultaneously, the Meuse began to avulse into a smaller, southern channel belt.

By the middle Atlantic (7000-6000 ^{14}C yr B.P.), more small lakes formed in the ever-expanding area of peaty marsh floodbasin. The Meuse completed its avulsion to a more southerly course. By the latter half of the period, an anastomosing system had developed, which consisted of multiple, straight or moderately meandering and interconnected channels, each lying within its own narrow floodplain (Makaske 1998). This shift in river pattern was the result of groundwater levels rising so quickly that the volume of added accommodation space slightly exceeded the total volume of river sediment. All river sediment was dumped into aggrading river channels and into the alluvial plain behind the back-barriers of the coast (Beets and Van der Spek 2000:12). Because accommodation space was larger than the rivers' capacity to deposit sediment, peat formation occurred and even shallow fresh water lakes existed. This was the case for much of the area. In fact, the Polderweg area was chosen specifically because it is located in the most distal portion of the delta to maintain freshwater conditions during the Early-Middle Holocene. Large tracts of peat beds formed and even began to encroach on the eolian dune fields and the northern terrace.

Figure 4.10 shows landform reconstruction maps for the Polderweg area; similar map surfaces were produced for the Deest and Ooijerhoek areas as well. For each region, landform units were chosen that are assumed to have been relevant to Mesolithic hunter-gatherers as discrete environmental zones. These zones would have been recognizable to prehistoric inhabitants primarily because of the differing groundwater regimes, flora, and fauna of each area. The extents of the landform units were estimated from borehole data and existing geomorphologic-geologic maps. Appendix A provides a detailed explanation of the reconstructive mapping procedures undertaken.



Figures 4.10 Paleo-Geographic Development of the Polderweg Area.

4.5.2 Deest. During the Younger Dryas period (11,000-10,000 ^{14}C yr B.P.), the Deest area was traversed by a number of channel belts (Figure 4.11). The Meuse had a few small tributaries that drained the elevated areas of snowmelt water and of water released by melting permafrost. A small brook valley system flowed through the southeast of the Deest area, draining the higher Pleniglacial terrace. Another series of brooks drained the northern ice-pushed ridges of meltwater, flowing into the larger and more northerly channel of the Rhine. A narrower tributary joined the main Rhine branch from the south, although this river also branched off in the central portion of the Deest area, to drain the Pleniglacial terrace that ran east-west across. This Pleniglacial-Allerød terrace separated the Rhine alluvial plain in the north from the Meuse valley in the south. It was on this surface that widespread eolian dunes formed.

In the Preboreal (10,000-9000 ^{14}C yr B.P.), the Rhine contracted in width and formed a single, meandering channel. Small brook valleys continued to drain parts of the uplands that, along with the low terrace, were quite wet during this period on account of melting permafrost (Weerts, pers. comm.). The Rhine began to shift its main channel to the south, and large new meanders formed in the northwest. A large brook valley drained the ice-pushed ridges in the northeast, while the channel in the central part of the Deest area was abandoned.

In the Boreal (9000-8000 ^{14}C yr B.P.), only a single brook valley remained in the Gelderse Valley, draining the high Veluwe terrace to the north of the area. The Rhine continued to rework the underlying Weichselian terrace in a meandering pattern. This situation did not change much in the early Atlantic (8000-7000 ^{14}C yr B.P.; Figure 4.10). However, major changes occurred in the Deest area during the subsequent middle Atlantic (7000-6000 ^{14}C yr

B.P.). Most notably, nearly half of the area was transgressed by the updip limit of the fluvio-deltaic wedge. Seasonally-wet floodplains accumulated onto the Pleniglacial and Late Glacial terraces; muddy swamps formed in the far west, where the groundwater level had exceeded that of the ground surface. The Rhine formed a new distributary to the south, and the Meuse avulsed into a more southerly course.

Figure 4.11 depicts the evolution of landform units for the Deest Area. See Appendix A for a full discussion of the mapping procedure.

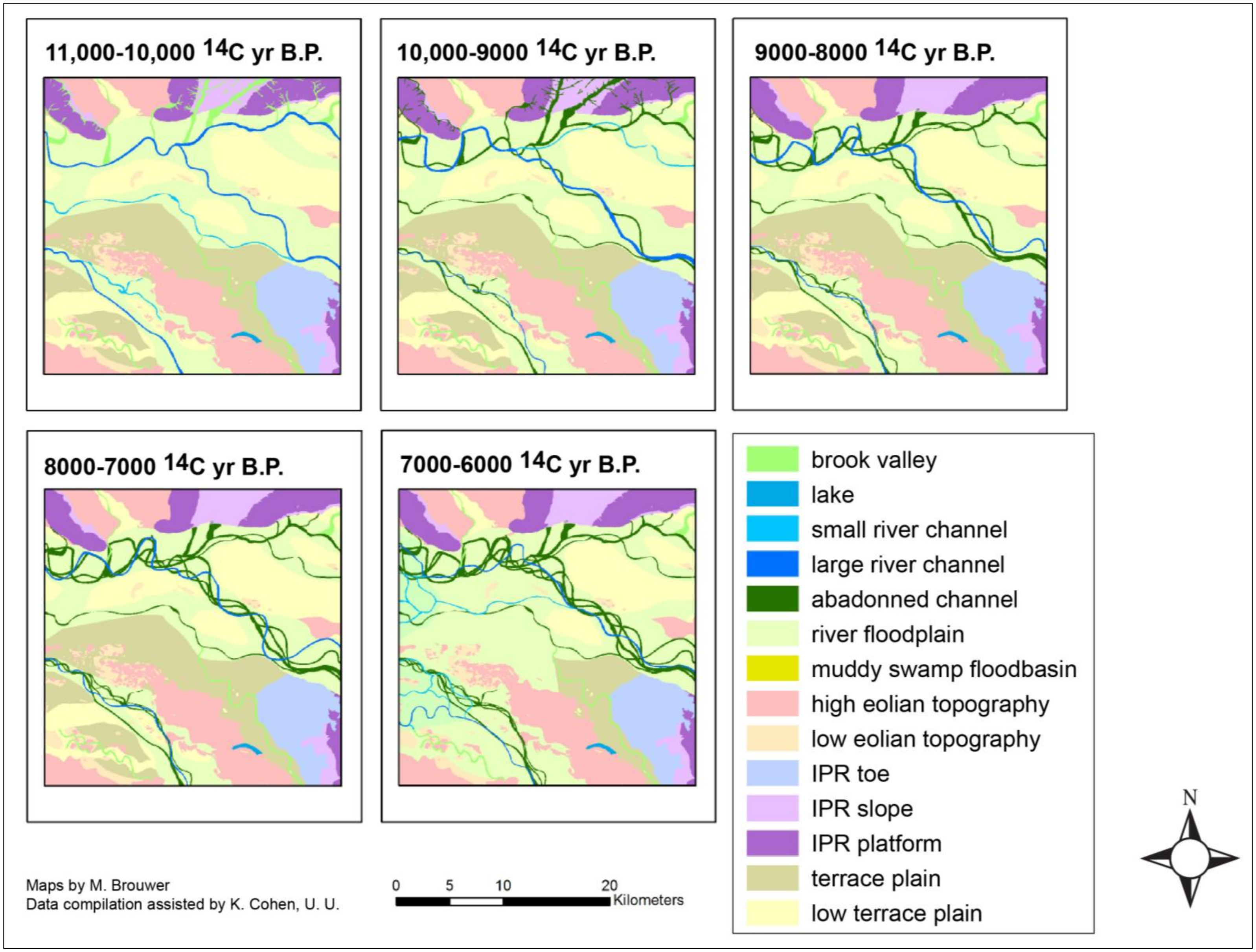


Figure 4.11 Paleo-Geographic Development of the Deest Area.

4.5.3 Ooijerhoek. The Ooijerhoek region was quite stable in a sedimentological sense from the Late Glacial to the Middle Holocene (Figure 4.12). The primary changes would have been those related to fluctuating groundwater levels and vegetation successions. In the last part of the Younger Dryas, the landscape was quite dry, and probably only herbs and grasses grew in the area. As mentioned above, the Preboreal was somewhat wetter due to permafrost melt. Groundwater levels are thought to have dropped in the Boreal, and then rose again slightly in the Atlantic (e.g., Pierik 2010). The effects of groundwater on vegetation are assumed to have been constant, such that at any given time, wetland and dryland vegetation mixes can be mapped based on the then dominant species based on the current general palynological knowledge (see section 4.6 below).

Figure 4.12 depicts the evolution of landform units for the Ooijerhoek Area. See Appendix A for a full discussion of the mapping procedure.

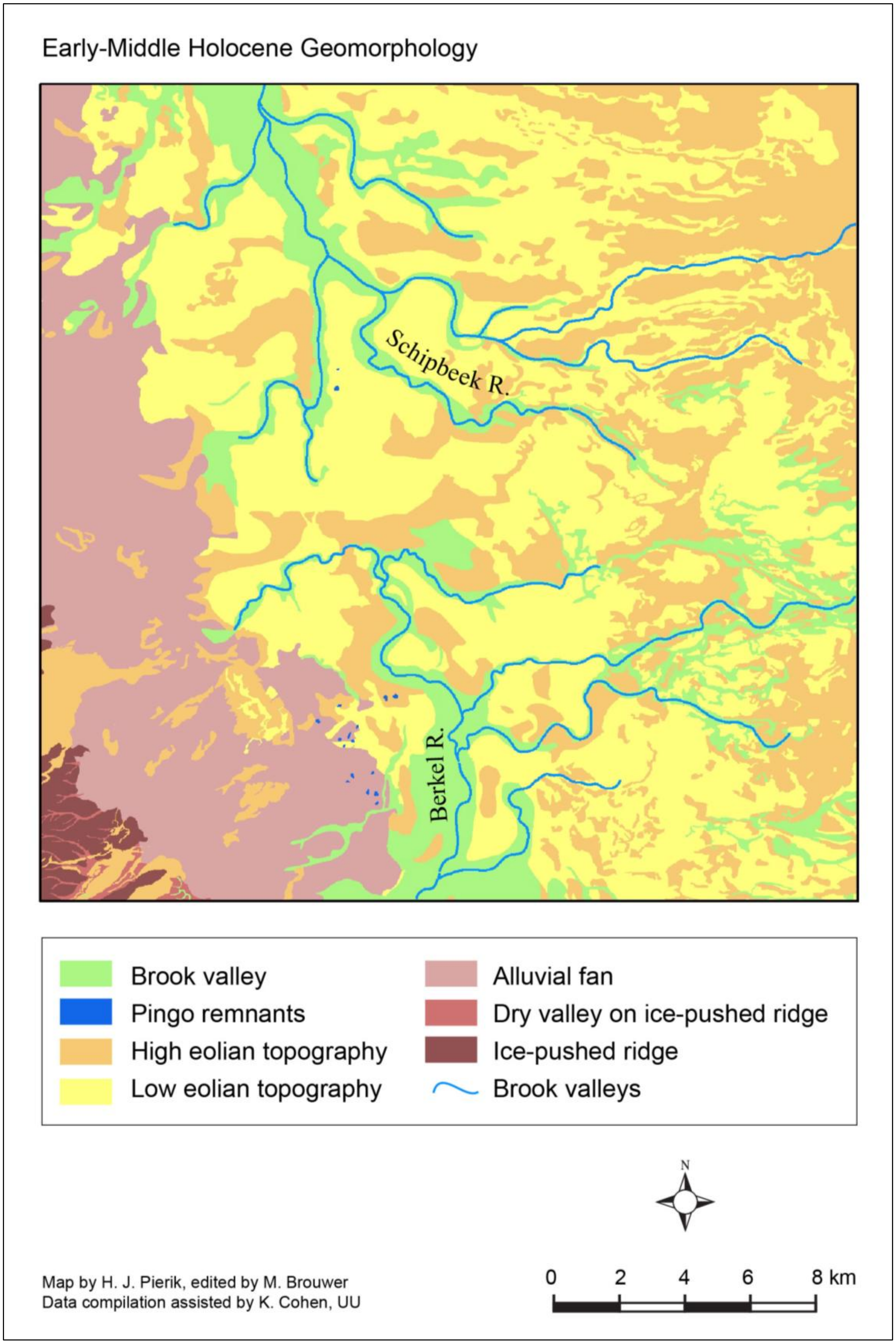


Figure 4.12 Paleo-Geography of the Ooijerhoek Area.

4.6 Vegetational Development of the Research Areas

A critical step in understanding human-landscape relationships in the past is to develop solid reconstructions of floral communities, as vegetation affects the distribution and composition of faunal communities (and subsequently, human activities and land use choices). Vegetation in any environment is dependent on climate (ambient temperature, precipitation levels), soil conditions (coarseness, moisture), and competition (from other plants). In the absence of exact climate measures and paleo-soil types, pollen and macrobotanical data can be used to estimate vegetative communities from the Early to Middle Holocene. For the purposes of this study, pollen diagrams and macrobotanicals remains from the three study areas were scrutinized to ascertain the dominant tree, shrub, groundcover, semi-aquatic, and aquatic species. In addition, charred ecofacts and preserved organic artifacts were also considered, to the extent that these objects could be identified as to the original plant species. The survey was not exhaustive; rather, the aim was to identify species that would have been important to humans and the fauna targeted by humans (see Appendix B for a description of those species). Thus, floral species that affected the human resource base both indirectly and directly were considered (e.g., the species are edible or influenced faunal distribution). Six vegetation zones (or, vegetative categories) were developed to represent areas with similar growing requirements and plant community composition. These zones were spatially assigned based on the location of geomorphic units as well as groundwater levels. These zones are assumed to have been discernable to Mesolithic hunter-gatherers as distinct environmental units. For further discussion of the modeling procedure, see Appendix A:345-350. Below, the results of the model developed here are described.

4.6.1 Polderweg. At the onset of the Holocene (10,000-9000 ^{14}C yr B.P.), the predominant vegetation zone in the Polderweg area was semi-open park landscape alternating between dry forests of birch and pine, and open grasslands (Bos et al. 2005; Figure 4.13). On the Pleniglacial terrace to the north, pine and pine stands abounded. The lower areas were inhabited by wet forests of willow, birch, and poplar, along with open grasslands and shrubbery. A comparatively lower depression occurred in the middle of the area, where a small lake and wetlands probably existed. At the edges of the river channels, narrow stands of reed and sedge grew. In the Boreal and into the early Early Atlantic periods (9000-7500 ^{14}C yr B.P.), the scenario did not change much, other than that the forests on the terraces shifted to a mix of hazel and pine, and the woods became denser, finally also colonizing the dune fields (Bos et al. 2005:40; Cohen pers. comm.; Hijma 2009:184-186).

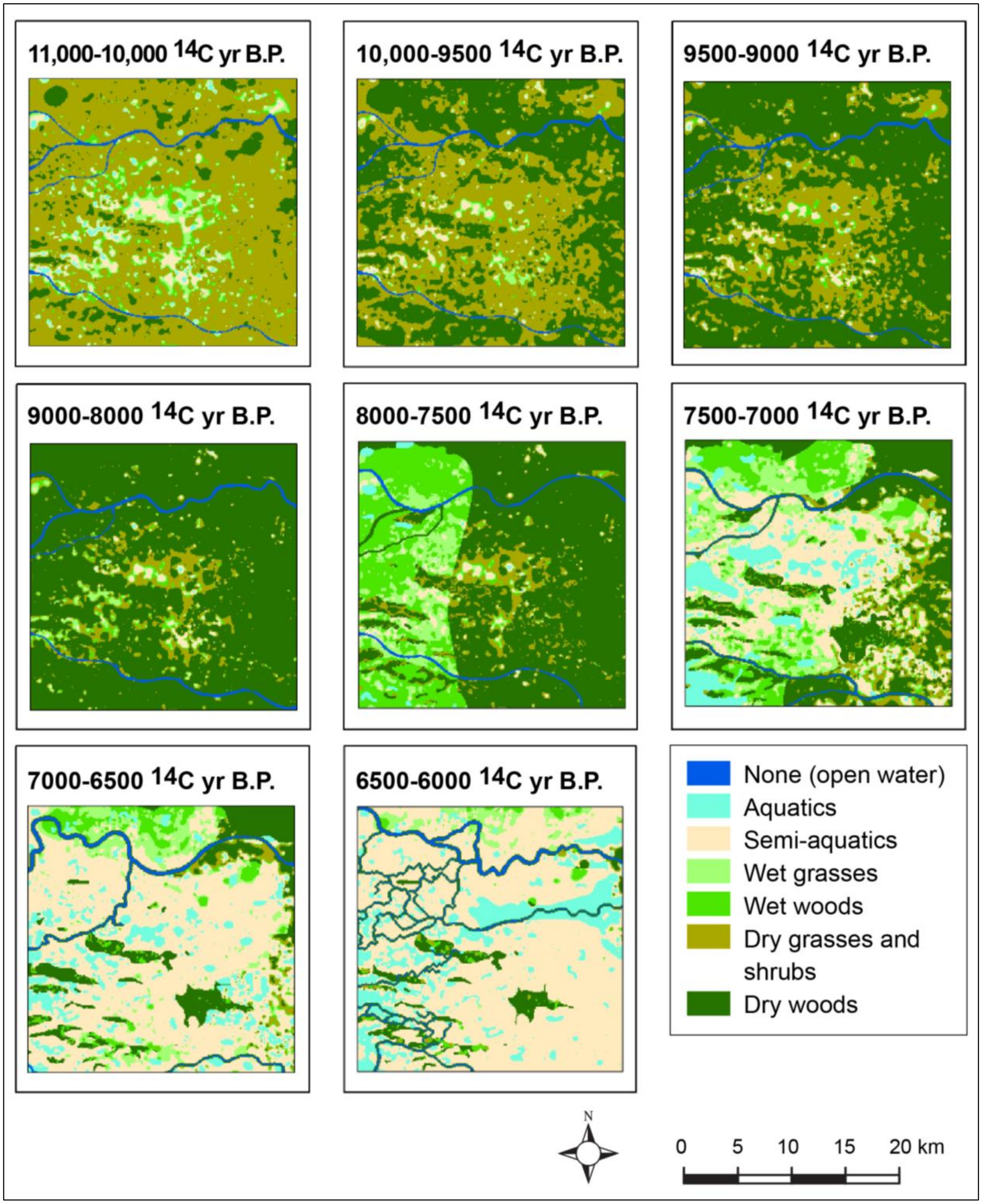


Figure 4.13 Vegetation Development of the Polderweg Area.

During the late Early Atlantic (7500-7000 ^{14}C yr B.P.), the low terrace was replaced by a river floodplain, indicating that open water, aquatic vegetation, and reed and sedge beds became widespread (Cohen pers. comm.; Hijma 2009:184-186). The dune tops and northern Pleniglacial terrace were home to increasingly dense stands of dry forest consisting of lime, oak, elm, and hazel (Van Der Woude 1983:82). Along the flanks of the dunes, wet forests of elm and hazel flourished. In the western portion of the area, muddy swamp and peaty marsh habitats expanded: the former consisted of alder swamp forests (i.e., alder carrs) alternating with stands of emergent species like reed and sedge; the latter consisted of large fields of sedge and reed, aquatics, and open water. Shallow floodbasin lakes formed in these large reed fields (Bos et al. 2005; Bos 2010; Hijma 2009). Various semi-aquatic and aquatic species grew in the water. Levees formed alongside river channels, and here a mix of elm and hazel grew, with alder and sun-loving undergrowth on the wetter edges (Van der Woude 1983:79). In the early and late Middle Atlantic, muddy swamp and peaty marsh areas continued to expand eastward, and many smaller river segments also developed. This caused an increase in the number of levee formations that, along with the slowly drowning dunes, provided the main (seasonally) dry places in the wetland landscape (this is confirmed by geologic and palynologic research conducted by Van Der Woude 1983).

Figure 4.13 depicts the vegetation development for the Polderweg Area from the Younger Dryas through the middle Atlantic period. Similar to the procedure for landform unit reconstruction, vegetation zones were chosen that are assumed to have been relevant and recognizable to Mesolithic hunter-gatherers. In addition, these vegetation zones were also selected for their pertinence in modeling faunal habitats. The extents of the vegetation zones were based on the underlying groundwater levels and landform types; the composition of the vegetation zones was based on data from mostly unpublished pollen diagrams and macrobotanical remains (cf. Bos et al. 2005), knowledge of the vegetation succession in the region, and information about the ecology and ethology of modern and historical plant populations. Appendix A provides a detailed explanation of the reconstructive mapping procedures undertaken.

4.6.2 Deest. At the very end of the Pleistocene, the Deest area was an open landscape of dry grasses and herbs, with a number of small rivers and streams draining the uplands (Figure 4.14; Cohen pers. comm.). A few brook valleys were also active at this time, in which wet herbs and grasses would have grown, along with a few stands of cold-tolerant trees. This scenario changed rapidly with early Holocene warming: in the Preboreal (c. 10,000-9000 ^{14}C yr B.P.), many channels drained the permafrost melt (Weerts pers. comm.). In the brook valleys and low terrace areas willow, birch, and poplar grew densely (Bos et al. 2005). Some sedge fields may have formed in the very wet depressions of the low terrace, which were probably wet all year round. The rest of the landscape was covered with open forests of pine and birch, along with grasses and shrubs. In the northwestern portion of the Deest area, a very wet depression occurred with sufficiently deep waters to allow the growth of aquatic species among the sedge and reed fields (Cohen pers. comm.).

By the Boreal period (c. 9000-8000 ^{14}C yr B.P.), the landscape again became drier and more densely forested (Bos et al. 2005:40). Only two primary channels were active; a few brook valleys were still seasonally active and some wet forests grew there, as well as in some of low terrace depressions (Cohen pers. comm.). The northwestern low area was taken over by sedge and reed and wet willow forest. Elsewhere, dry forests of hazel and pine became widespread. All forests grew in density during this period. With the onset of the Atlantic (c. 8000-7000 ^{14}C yr B.P.), the scenario changed very little. Finally, in the middle Atlantic (c. 7000-6000 ^{14}C yr B.P.), the Deest area became much wetter, due to both climatic and sea-level rise factors. The updip limit of the Rhine-Meuse delta entered the area in the western half (Cohen 2003:106-134). This resulted in the spread of permanently wet muddy swamps, likely inhabited by sedge and reed fields. The tops of levees would have supported grasses, shrubs, and alder stands. Aquatic vegetation grew in the deeper stagnant waters. A number of new branching channels formed in the western extent of the area. The low terrace and floodplain depressions were populated with ever-denser alder forests and sedge fields. In the uplands, very dense broadleaf forests continued to grow, consisting mainly of lime, oak, elm, and hazel.

Figure 4.14 depicts vegetation development for the Deest Area. See Appendix A for a full discussion of the modeling procedure.

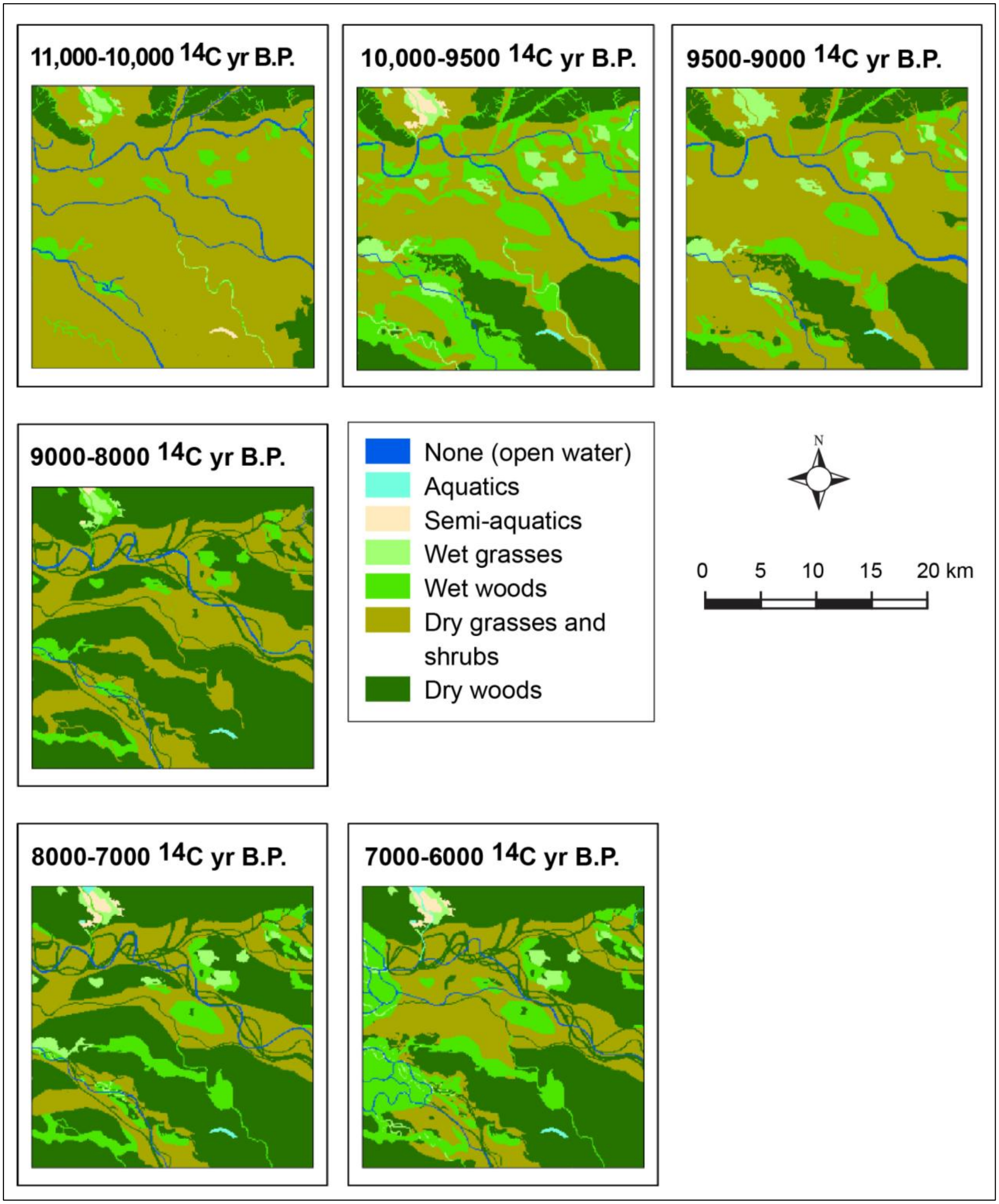


Figure 4.14 Vegetation Development of the Deest Area.

4.6.3 Ooijerhoek. The vegetative development of the Ooijerhoek area was primarily influenced by changes in the groundwater regime and climate. In the Younger Dryas, the area was very dry, with herbs and grasses dominating the uplands (Bos et al. 2005:40; Figure 4.15). A few wet spots occurred and there, wet herbs, grasses, and a few hardy trees grew. The Ooijerhoek area was drained only by two small rivers. The onset of the Holocene brought about a short lived period of a much wetter the environment, as permafrost melted and precipitation levels increased (Weerts pers. comm.). After the permafrost had disappeared, the area became much drier because the precipitation surplus could easily infiltrate into the sandy subsoil. Open forests of pine and birch spread over the Ooijerhoek area, alternating with grasslands. In the lower and wetter locals, some sedge and reed fields developed, interspersed with willow, birch, and poplar. The river and stream systems expanded to drain the hinterlands (Cohen et al. 2009).

The Boreal period saw a slight drying trend, which began already in the late Preboreal and affected mainly wet forests in the north and southeast corners of the Ooijerhoek area (Bos et al. 2005:40). These wet forests still consisted of willow, birch, and poplar, although the dry forests were dominated by hazel and pine. Both wet and dry forests were becoming increasingly dense and closed during this time. By the Atlantic, wet forests had regained the same territory as was seen in the Preboreal. The wet forests consisted of alder, while the dry upland forests were a mix of lime, oak, elm, and hazel; all forests had become very dense and closed. The main open areas would have been along the rivers and streams, and in the lower and wetter niches where water-loving sedges, reeds, grasses, and small shrubs grew.

Figure 4.15 depicts vegetation development for the Ooijerhoek Area. See Appendix A for a full discussion of the modeling procedure.

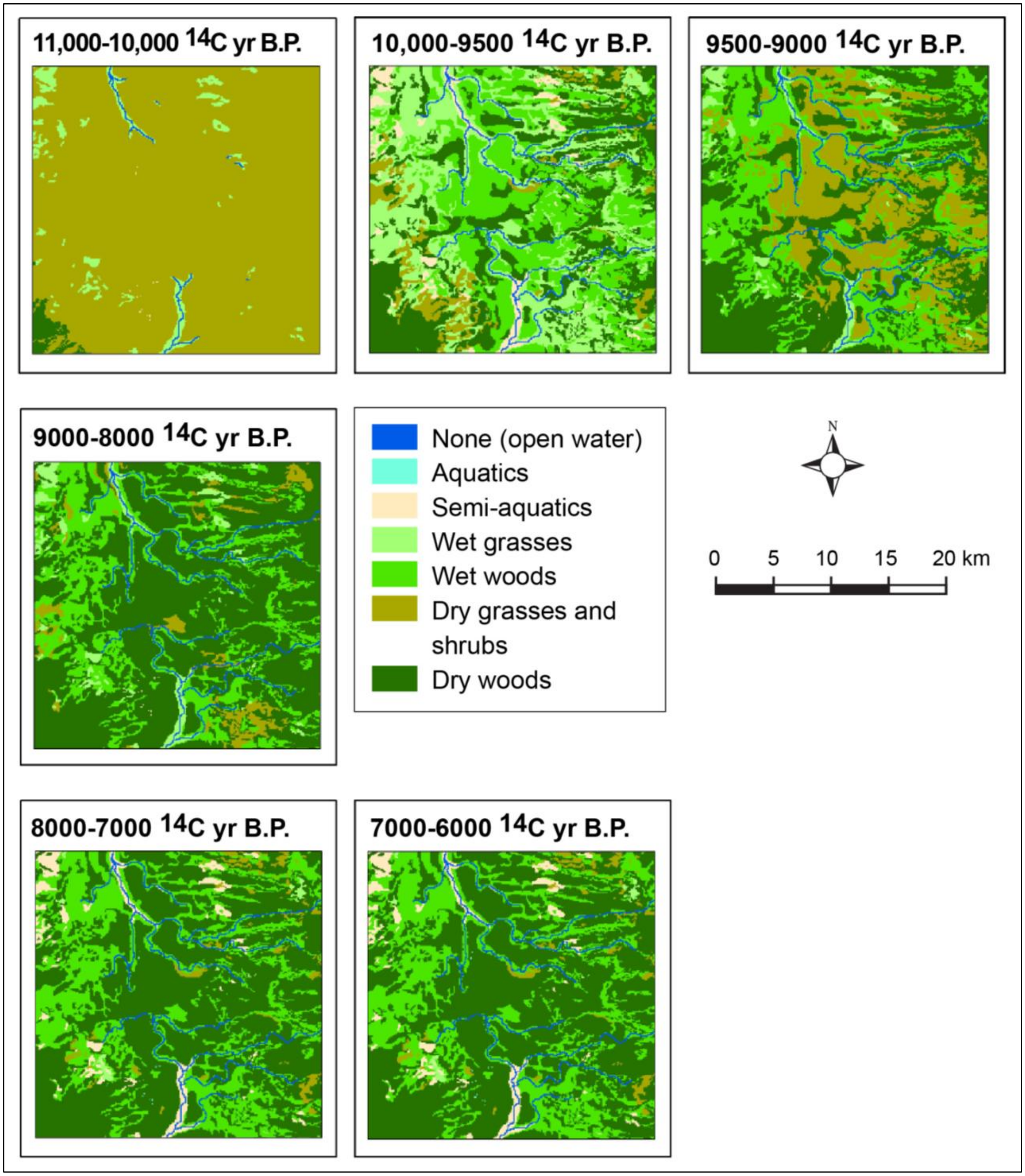


Figure 4.15 Vegetation Development of the Ooijerhoek Area.

4.6.4 Additional Vegetation Considerations. Before continuing, it should be noted that while most scholars agree that the Late Glacial period was exceedingly dry and open, competing hypotheses have been forwarded to explain the apparent change in relative wetness and openness of the ecosystem during the early and middle Holocene. Some researchers feel that vegetation has a much larger impact on evaporation rates than climate (Spek 2004; Zagwijn 1986). An open landscape of heath or scrub grassland loses through plant transpiration and soil evaporation far less water per year than a closed deciduous or coniferous forest (e.g., 300-500 mm/yr versus 400-700 mm/yr; Spek 2004) and thus, forested areas should have lower groundwater levels. Also, trees consume much more water than herbaceous plants. Since coniferous trees were most prominent during the Preboreal and Boreal periods, it is suggested that water levels were lowest during these periods. The increase in wet vegetation (such as alder, marsh herbs and wetland grasses) in Atlantic-age pollen diagrams seems to support this argument (Bos et al. 2005). Further, there is a near absence of dryland grasses in Atlantic diagrams, while peat formation began in the westernmost part of the country (Bos et al. 2009:29).

Other researchers feel that the situation may have been reversed: small streams and rivers were often blocked by newly-formed coversand dunes and ridges, making the Preboreal and Boreal periods wetter than the Atlantic period (Neefjes and Willemse 2009). Further, it was at this time the gulf stream probably shifted north causing increases in yearly precipitation rates (Van Gijssel and van der Valk 2005). While precipitation rates remained high into the Atlantic period, the purported densification of forests could have led to lower groundwater levels than in the previous periods (Neefjes and Willemse 2009; Peeters 2007).

For the purpose of this model, the view forwarded by Spek (2004) is used, primarily because his study is based on evapotranspiration and water consumption rates of species known to be very similar to those living in the Post-glacial Netherlands. The hypothesis of Neefjes and Willemse (2009) does not take vegetation into account, and is based primarily on the presence of coversand dunes and ridges that were ostensibly damming streams and rivers. However, these physiographic features were formed during the Late Glacial period, a time when rising temperatures would have led to melting permafrost, which would have contributed to the overall volume of water draining the area. It is likely that this water would have found some outlet around these purported ‘dams’ prior to the onset of the Holocene. Notwithstanding, if the hypothesis of Neefjes and Willemse (2009) is correct, then different hydrological modeling would result in slightly different vegetation distributions, with the Preboreal and Boreal being somewhat wetter overall than the Atlantic. Such exploratory modeling has been carried out for the Ooijerhoek area by Pierik (2010:29-31). The primary difference lies in a slightly drier Preboreal and Boreal, and a slightly wetter Atlantic following Spek’s (2004) hypothesis.

Regarding the overall openness of the environment, some researchers argue that vegetation was more open during the Atlantic, perhaps due to large game grazing pressures that created open, park landscapes (Vera 1997). The argument holds that faunal populations had exploded in the region, leading to over-exploitation of trees such that saplings were not able to grow into mature trees, and a general decrease in forests overall. However, the general consensus among scholars remains that Atlantic forests were quite dense and deciduous in composition (Bos et al. 2005; Spek 2004; Van Beek 2009). It is less certain where forest density occurred, whether at the canopy or lower down in the undergrowth. Roebroeks and Van Gijn (2005) suspect that the forest canopy was very dense, leading to dark forests where only shade-tolerant undergrowth species could flourish. Such a scenario would be unfavorable to the growth of sun-loving edible plants and associated wildlife, and could have deterred a number of human uses of the forest. The hypothesis entailing dense Atlantic forests is followed in this study; however, if Vera’s (1997) hypothesis is true, then vegetation distributions would have to be modified such that the extent of large herbivores, in addition to groundwater levels, is used as one of the main determinants of vegetation. In this case, faunal distributions would have to be created prior to or in conjunction with vegetation distributions.

For the purposes of this study, it was assumed that groundwater levels in the Deest and IJssel areas increased over time, with a slight drying trend during the Boreal, when dense coniferous forests had a palpable impact on the groundwater. In the Atlantic, the spread of dense deciduous forests would draw less on the ambient groundwater and thus, water levels probably rose slightly. This is confirmed by the fact that peat formation began at this time in some of the upland sandy areas (Vos 2010; Zagwijn 1986). Also, the increasingly continental climate during the Atlantic led to greater precipitation levels (see above). In the Polderweg, by contrast, sea-level rise and its impact on local groundwater has been modeled with sufficient accuracy to establish that the Atlantic period was definitely wetter than the Boreal or Preboreal periods (Hijma 2009; Hijma and Cohen 2011). It is important to note that the groundwater regime in the upstream areas (Deest and Ooijerhoek) were affected primarily by vegetation and precipitation, while the regime in the downstream area (Polderweg) was mainly impacted by rising base-levels, causing a drowning of the landscape.

Also worth consideration is the fact that research on the relative openness of the landscape is still poorly understood for all of the Netherlands. Counts of arboreal pollen versus non-arboreal pollen can be instructive in this case, although there are a few serious drawbacks to this method, primarily that some trees (such as pine) can be strongly over-represented due to very mobile pollen (Brinkkemper, pers. comm.). Thus, a pollen record with very high pine pollen counts could indicate that the area was once inhabited by a closed stand of pines, or it could indicate that a small stand of pines simply dropped a lot of pollen in the tested area. Along these lines, another issue complicating research on vegetative openness concerns pollen coring methodology. Generally, cores are taken from wet (and thus, well-preserved) areas such as lakes and buried wetlands and river channels. There is thus a bias toward wetland species, as they would have grown in the near vicinity. It is much harder to estimate what the dry upland context would have been, as pollen does not preserve well in dry locales. Given these drawbacks, the best way to estimate the relative openness of the landscape at any given time is to look at the full pollen and macrobotanical spectrum for ratios of wet- versus dry-adapted species.

4.7 Faunal Distributions in the Research Areas

4.7.1 Introduction. The general distribution of vegetation zones for the Polderweg, Deest, and Ooijerhoek areas has been established. These distributions are intended to show a pattern of vegetation succession and changes in overall ecosystem wetness and openness. The distribution of fauna during the early-mid Holocene was highly contingent upon the habitat types present at the time. An ecosystem or habitat is characterized by the interaction between plants, soils, and climate. To begin the modeling process, then, plant community distributions were approximated. These floral zones included a range of species, which shifted in abundance related to changes in climate and groundwater levels (see Appendix B). Faunal distributions are modeled next, although expectations about the behavior and habitat preferences of faunal species must first be generated. Appendix C details habitat requirements of faunal species that were important to Mesolithic life, along with their preferred habitats.

4.7.2 Background. Many species quickly re-colonized the previously inhospitable areas of northern and western Europe shortly after the Younger Dryas period, as evidenced by the discovery of a wide range of fossilized terrestrial, aquatic, and marine species at Mesolithic archaeological sites. Table 4.2 gives a general idea as to the breadth of available species in the Mesolithic landscape. Of these, a few key species will be selected for further modeling, because they have been found in large numbers at Mesolithic occupations throughout Europe and are therefore believed to have been resources frequently targeted by hunter-gatherers, anchoring day-to-day subsistence pursuits. The other species, while no less important for diet breadth and variety reasons, will not be individually modeled but will be considered within larger agglomerative categories (e.g., large mammals, small mammals, terrestrial birds, aquatic birds, fish, and other).

Table 4.2. Common Fossilized Species from Mesolithic Occupations (Lauwerier et al. 2005; Peeters 2007:177-181).

Scientific name	Common name	Scientific name	Common name
Terrestrial wild		**Aquatic birds**	
Alces alces	Moose/elk	*Anas platyrhyncos*	Mallard
Cervus elaphus	Red deer	*Anas penelope*	Eurasian wigeon
Capreolus capreolus	Roe deer	*Anas crecca*	Teal
Bos primigenius	Aurochs	*Anas* spec.	Duck
Bos spec.	Cattle	*Anser anser*	Grey goose
Sus scrofa	Wild boar	*Fulica atra*	Eurasian coot
Sus spec.	Pig/boar	*Phalacrocorax carbo*	Great cormorant
Equus spec.	Horse	*Mergus merganser*	Merganser
Ursus arctos	Brown bear	*Cygnus cygnus*	Whooping swan
Felis silvestris	Wild cat	*Cygnus olor*	Mute swan
Vulpes vulpes	Fox	*Grus grus*	Common crane
Meles meles	Eurasian badger	*Pelecanus crispus*	Dalmatian pelican
Martes spec.	Marten	*Botaurus stellaris*	Great bittern
Mustela putorius	European pole cat	*Larus argentatus*	Herring gull
Mustelidae spec.	Weasel	*Gavia stellata*	Red-throat diver
Sciurus vulgaris	Red squirrel	*Ardea* spec.	Heron
Talpa europaea	European mole	**Terrestrial birds**	
Microtus oeconomus	European vole	*Gallinula chloropus*	Moor hen
Apodemus sylvaticus	Wood mouse	*Scolopax rusticola*	Woodcock
Arvicola terrestris	Water vole	*Bubo bubo*	Owl
Aquatic wild		*Dendrocopos major*	Woodpecker
Castor fiber	European beaver	*Emberiza schoeniclus*	Bunting
Lutra lutra	European otter	*Charadrius* spec.	Plover
Marine wild		**Freshwater fish**	
Phoca vitulina	Common seal	*Cyprinidae*	Carp
Halichoerus grypus	Grey seal	*Abramis brama*	Bream carp
Domesticated		*Tinca tinca*	Tench
Bos Taurus	Cattle	*Perca fluviatilis*	European perch
Sus domesticus	Pig	*Esox lucius*	Northern pike
Ovis aries/Capra hircus	Sheep/goat	*Acerina cernua*	Ruffe
Canis familiaris	Dog	*Siluris glanis*	Wels catfish
Prey birds		*Rutilus rutilus*	Roach
Corvus corone	Carrion crow	*Alosa fallax*	Shad
Accipiter gentilis	Hawk	*Leuciscus cephalus*	Chub
Buteo buteo	Buzzard	**Anadromous fish**	
Haliaetus albicilla	White-tailed eagle	*Acipenser sturio*	Sturgeon
Song birds		*Salmo salar*	Atlantic salmon
Passeriform	Passerine	*Anguilla anguilla*	European eel
Turdus spec.	Thrush	*Coregonus lavaretus*	Whitefish
Garrulous glandarius	Eurasian jay		

While the current study will assign fauna distributions based on floral extents (which are themselves based on abiotic data such as geographic-geologic, hydrologic, and lithologic information), it is important to note that fossilized faunal remains can themselves be used as biotope indicators. In most cases, the remains of animals that were deposited in certain locations lived in the near vicinity, with the exception of animals hunted elsewhere and their remains transported to the site. For this reason, a distinction will be made between animals that prefer terrestrial or aquatic habitats, because in understanding the ecological and ethological[9] characteristics of a particular species, further biotope information may be gleaned (Wijngaarden-Bakker et al. 2001:181). For example, knowledge of the birds, fish, and insects that lived in a wetland habitat can yield useful information about the type of riparian vegetation present, as well as the depth and flow velocity of the water.

The most common food species pursued as prey in the Mesolithic were red deer (*Cervus elaphus*), roe deer (*Caprelous capreolus*), wild boar (*Sus scrofa*), and beaver (*Castor fiber*). While some archaeological contexts have also yielded remains of brown bear, moose, elk, and horse, it is not likely that these species played a more role in hunter-gatherer subsistence during the early-mid Holocene in the Netherlands, on account of the ameliorating temperatures and (in the case of horse), the disappearance of open steppes. Also, remains from marine species like seal, and early domesticates like dog, have been recovered from Mesolithic sites. Seal would only have been available near the coasts and dog, although often eaten as an emergency food, were not a significant source of nutrition in the Mesolithic hunter-gatherer diet. The fossilized species most often encountered are those that thrive in transition habitats or ‘edge’ zone biotopes between forest and grassland or marsh.

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[9] The field of *ethology* is concerned with animal behavior.

For the purposes of this study, a number of species were selected for modeling. Those chosen species were all assumed to be supply important food and non-food resource needs, as suggested by zooarchaeological evidence from the archaeological and ethnographic records. Agglomerative categories were made for species that were regularly caught but not a major source of nutritional or raw material needs unless considered *en masse* (i.e., small terrestrial mammals, aquatic and terrestrial birds, freshwater and anadromous fish), and that also share similar habitat preferences (e.g., small woodland mammals, terrestrial birds, freshwater fish, etc.). For a detailed discussion of the assumptions, materials, and methods used in producing the faunal distribution maps, see Appendix A:350-354. In the following sections (4.7.3, 4.7.4, 4.7.5), the results of the faunal modeling are described.

4.7.3 Polderweg. The faunal distribution in the Polderweg area changed dramatically over the course of the Mesolithic period (see Appendix D: Figures D.1-D.8). In the Preboreal and Boreal periods, the area was highly suitable for large game (including red deer, roe deer, aurochs, and wild boar), small terrestrial mammals, and terrestrial birds. A major shift in faunal suitability began in the early Atlantic, as the area was transformed into a wetland by the middle Atlantic (c. 7000 ^{14}C yr B.P.). During this shift, the environment became increasingly more suitable for species such as aquatic birds, freshwater fish, and anadromous fish. Simultaneously, the environment became sharply less attractive to large game and other terrestrial mammals and birds. The environment was relatively unsuitable for beaver during the entire period, except for the early Atlantic, when rising water levels led to the creation of expanses of wetland. However, by the middle Atlantic, the environment had likely become too wet to facilitate high beaver potential.

4.7.4 Deest. Unlike the trends seen in the Polderweg area, the faunal suitabilities within the Deest area remained largely consistent throughout the period (see Appendix D: Figures D.9-D.16). The environment was highly suitable for large game, small mammals, and terrestrial birds, with the exception of slightly less suitable patches during the early Preboreal and late Middle Atlantic. Wild boar and terrestrial birds, it should be noted, were highly attracted to this area, especially given that they are most capable of surviving within very dense forests. Beaver would have been moderately attracted to the area, again with the exception of the Younger Dryas and Boreal phases, which were comparatively drier in nature. Aquatic birds and freshwater fish also would have been moderately attracted to the area, and would likely have been found around wet areas. During the Preboreal and late Middle Atlantic, the landscape was somewhat more compatible with their habitat requirements. Last, anadromous fish were relatively unlikely to have inhabited the area, remaining only in the main channel and stream belts.

4.7.5 Ooijerhoek. Suitable areas for faunal habitat in the Ooijerhoek mirrored trends seen in the Deest area (see Appendix D: Figures D.17-D.24). The suitability for most species remained relatively unchanged, with the exception of conditions in the Younger Dryas. The environment was highly or moderately suitable to large game, small terrestrial mammals, and terrestrial birds. The period of the least suitability was the early Preboreal, a wetter period. Wild board yielded similar values, although the early Preboreal was even less suitable to this species. Overall, the environment was not very suitable to aquatic species or beaver. The latter species would have been best suited to the wet conditions of the early Preboreal, and only returned medium and low values for the rest of the period. The same trend was discerned for aquatic birds, freshwater fish, and anadromous fish. Anadromous fish, in particular, were highly unsuited to the landscape and the chances of finding would have been poor.

4.8 Summary and Conclusions

The overall goal of this chapter was to provide a clear and succinct description of the environmental setting, or “total landscape” that Mesolithic hunter-gatherers dwelled within, and to illuminate some of the factors and constraints that shaped the Early Holocene landscape. The selection and justification of the study areas was addressed, as well as the pertinence of these areas for testing human land use strategies in space and time. A detailed discussion of the evolution of landform types, groundwater level rise, vegetation development, and faunal distribution sets the scene for further modeling of human land use strategies.

Chapter 5

SIMULATING HUNTER-GATHERER BEHAVIOR THROUGH A PREDICTIVE DECISION-BASED MODEL

5.1. Introduction

There are two primary goals of this study. The first goal is to provide a method to reconstruct or simulate hunter-gatherer land use behaviors, the product of decisions made about resource usage, settlement, mobility, and beliefs. Decision-making is assumed here to be the main driver of hunter-gatherer behaviors. External environmental changes (e.g., resource distributions or vegetation successions) are also considered to be important factors, although in this study they are assumed to have provided certain boundary conditions and contexts in which decisions were made. The second goal of this study is to use the decision-based approach to ask questions about the motivations of hunter-gatherer behavior, specifically concerning the ways that hunter-gatherers adapted to the dynamic Post-glacial landscape. To meet this end, a decision-based model is developed that simulates hunter-gatherer behavior (based on Krist 2001; Whitley 2000). With this model, hypotheses concerning Mesolithic land use (e.g., resource use and settlement practices) in the Post-glacial Netherlands can be tested, along with hypotheses about mobility and perception. Three main hypotheses or alternatives are developed and individual simulations run for each scenario (see Chapter 6).

This approach is undertaken in a deductive fashion, in that many different factors are considered and deductively combined to return output (although see section 5.2.2 below for a critique of deductive approaches, many of which inadvertently pair aspects of inductive approaches and involve staged feedback or toggling between induction and deduction). The approach is therefore also predictive in nature, as it suggests a number of suitable areas for particular activities that must be further "ground-truthed" on the existing archaeological data. It is assumed here that the co-occurrence or adjacency of an archaeological site and an area rated as highly suitable for a particular adaptive strategy signifies that that strategy was a viable mode of living. The "fit" between a model and the archaeological record does not provide definitive proof that the strategy was used, but suggests the strategy would have been a successful choice for hunter-gatherers. The absence of fit implies that the strategy was not a viable way to make a living in the specific area. The strength of this approach is its flexibility. Input expectations, goals, and criteria can be easily changed to facilitate exploitation of different hypotheses. The end goal of the model is to identify which adaptive strategies were in use at certain times and locations in the study areas. As this model is concerned with decision-making and predictive modeling, discussions of each topic will first be presented, followed by details about the model itself, including the approach, underlying assumptions, materials, and the procedure. The chapter will conclude by addressing how the model will be implemented.

5.2. Theory and Background

5.2.1 Decision Making Theory. Decision theory attempts to model rational behavior by "comparing the expected utility of different courses of action in terms of the probabilities and utilities assigned to the different possible outcomes" (Bermudez 2009:2). In other words, decision theory attempts to understand the process by which a decision is made, from the initial realization of a problem or choice, to the consideration of alternatives, and the final selection of the course of action to take. Human decisions tend to be made in non-random ways, meaning that most of our choices are goal-directed (Hansson 1994). However, humans also make decisions that are driven by randomly occurring events, a counterpoint which must be kept in mind when modeling rational decision-making processes. Decision-making is not a continuous process, but rather entails periods of active decision-making, followed by periods when the decision is implemented and the results are returned. Expected utility refers to the widely used theory of probability-weighted utility, in which “each alternative is assigned a weighted average of its utility value under different states of nature and the probabilities of these states are used as weights” (Hansson 1994:29). The utility of a particular option thus describes how much benefit or profit will be secured in choosing that option. Section 3 below describes how expected utility is incorporated into the current modeling exercise.

It is assumed that humans make conscious decisions about how to allot their time and energy, taking into consideration all of the possible alternatives, which may be mutually exclusive or competing (Jochim 1976:4). These decisions often depend on the nature of the activity to be undertaken: they may be planned out to satisfy certain goals or target specific resources, or they may be prospective or opportunistic (or expedient) in nature, as in the case of forays made to gather information about potential resource abundances, or when chancing upon the immediate availability of some resource or circumstance. However, it will be assumed here that hunter-gatherers make rational decisions about economic and settlement pursuits, which are generally organized well in advance. The use of the adjective ‘rational’ begs explanation: it refers to the economic theory of rational choice (or optimal choice theory), in which the agent (human or animal) tends to make a decision that will maximize overall utility, with utility defined as the fitness of an activity or decision with a specific purpose or worth in mind (cf. Ingold 2000 for a critique of the economic approach to hunter-gatherer behavior). The primary strength of rational choice theory is that in simple situations, common sense and rationality generally correspond. For example, if a person was offered $1 or $10, they will choose to take the higher sum as it will return greater utility (Herrnstein 1990:357). A rational decision-maker is thus an agent who considers all possible actions and their consequences, ranks these actions based on how well they will satisfy the original need, and then chooses the action that is most effective (i.e., the most preferred consequence; Rapoport 1960:107-108). However, rational choice theory comes with a caveat: it can only poorly account for actual behavior, as other motivations, circumstances, and information can--and often do--condition a choice. Still, as a normative theory, rational choice theory is a useful way to describe decision behaviors and will be used in this study.

Decision Theory can be broken down further into four constituent parts: 1) the state of knowledge under which a decision is made; 2) the criteria for the decision; 3) the form of the solution, and; 4) the procedures involved in the decision (Jochim 1976:5). When humans make decisions, the state of their knowledge will have an effect on the alternatives and outcomes of the decision (Hansson 1994:24-28). There are often various factors that the decision-maker cannot control or does not know about. If a decision-maker knows about these extraneous factors, then they are acting under certainty, based on background information acquired previously. If a decision-maker does not know about these factors, then they are acting under non-certainty. The state of knowledge of the decision maker can thus be broken down as follows:

- Certainty: when “each action is known to lead to a specific outcome” (Luce and Raiffa 1957:13); deterministic knowledge.

- Risk: when "each action leads to one of a set of possible specific outcomes, each outcome occurring with a known probability" (Luce and Raiffa 1957:13); complete probabilistic knowledge.
- Uncertainty: when "either action or both has as its consequence a set of possible specific outcomes, but where the probability of these outcomes are completely unknown or are not even meaningful" (Luce and Raiffa 1957:13); partial probabilistic knowledge (Hansson 1994:28).

These categories are neither exhaustive nor mutually exclusive and depend largely on the type of information one has, whether complete or perfect (the former refers to having all the "knowable" knowledge of a given situation; the latter refers to all the information available, both knowable and not knowable; see further discussion in Chapter 6). In fact, the state of knowledge of many decisions tends to fall between the categories of uncertainty and risk. Some scholars also use the category of "ignorance" to refer to decisions made with absolutely no probabilistic knowledge of a decision's outcome (Hansson 1994:28). Jochim (1976) notes that "among hunter-gatherers, the state of "partial uncertainty" would seem to operate, since the exact probabilities of the consequences of various economic choices are not known, but at best are estimated from previous experiences and new scouting information" (Jochim 1976:5). In this study, then, it is assumed that the decision-making process takes place under conditions of partial uncertainty.

Understanding and reconstructing the criteria used in any decision-making process that occurred in the past is an extremely difficult task. While many of the external, survival related criteria can be assumed based on known requirements for human survival, other internal, non-survival related criteria may be impossible to identify. To this end, the ethnographic record can be instructive, providing cross-cultural ideas of possible motivations, stimuli, and incentives. In regards to the basic survival and external criteria facing hunter-gatherers, the guidelines of game theory can be a useful starting point. Any decision made by an individual forager essentially represents the game (or rather, gamble; Jochim 1976:5) between one person and nature (Luce and Raiffa 1957). Within this framework, criteria may be considered in various ways. For example, a particular criterion may be chosen because it returns the highest average yield (e.g., the LaPlace criterion). As advocated by Jochim (1976), the Simon satisficer criterion is the most applicable for describing the decision-making process of hunter-gatherers operating under partial uncertainty. This criterion "seeks, not to maximize, but to satisfy some predetermined aspiration level; this is descriptive, attempting to explain how people do act, rather than normative, or attempting to determine how they should act" (Jochim 1976:6).

Any decision-making strategy will contain choices between mixed and pure strategies as solutions. While a pure strategy involves selection and implementation of only one strategy, a mixed strategy combines components of the various alternative strategies (Jochim 1976:7). Most real life decisions are mixed strategies, as people tend to undertake multiple activities at a time, or exploit multiple locations at a time. The ethnographic record, for example, shows a consistent 'multi-tasking' among hunter-gatherer bands, task groups, families, and individuals in order to satisfy their goals and objectives. One such goal, which appears to be particularly prevalent, is to maximize efficiency by minimizing the amount of effort expended in obtaining food, raw materials, information, social contacts, etc. (Jochim 1976:7). In fact, Jochim (1976) goes so far as to say that "considerations of effort limitation underlie all economic choices" (Jochim 1976:7; cf. Hawkes and O'Connell 1981; Yesner 1994 for a critique of the least-effort perspective).

Lastly, the procedure involved in decision-making generally runs as follows: identify the objectives of the group; determine the priority of these objectives; establish which resources could satisfy the objectives as well as which constraints could hamper goal achievement; apply a decision rule; make an evaluation of the best course of action; make the decision. Jochim (1976) likens this process to systems theory, in which entities like computer programs and sociocultural systems are depicted as a large system with a number of overarching goals that are met by various parts of the system working together to achieve these goals under specific rules that describe how to use available resources given particular environmental constraints (Bertalanffy 1969; Laszlo 1972a, b). Jochim (1976) uses this analogy to argue for the use of a human ecological model, in which humans are but one part of the overall system, working with and within the present resources and constraints, to survive. This background theory helps to establish the framework upon which the decision-making procedures of hunter-gatherers can be developed (see section 3 below).

5.2.2 Background on Predictive Modeling. Archaeological predictive modeling has been defined as “a technique used to predict, at a minimum, the location of archaeological sites or materials in a region, based either on the observed pattern in a sample or on assumptions about human behavior” (Kohler and Parker 1986:400). While this technique has its roots in the ecologically-based work of Julian Steward (1937, 1943, 1955), it was not until the late 1970s that use of the technique in academic contexts began to gain momentum in the US. In fact, predictive modeling could be seen as a special type of location-allocation analysis, in which ‘suitable’ locations are allocated to human activities (and their material correlates). Location analysis provides the suitability criteria, by identifying a set of behavioral rules from observations about how people behave today or behaved in the past (Van Leusen et al. 2005:27). Predictive modeling has two primary applications: 1) it allows for better preparation, preservation, and management of spatial planning projects in its ability to predict the location of unknown sites; and 2) it provides a way to test anthropological theories of human land use and thereby provide further insight into the human-landscape relationship (Van Leusen and Kamermans 2005:7). In general, these two applications tend to fall into the cultural resource management (CRM[10]) sphere (application 1), and the academic sphere (application 2; see below for further discussion). Apart from this baseline aim of predictive modeling, it could also be used to "predict the probable type and quality of [archaeological] remains, their current state of conservation and likely rate of deterioration, and from these deduce their cultural and scientific interest" (Van Leusen et al. 2005:25).

The goal of archaeological predictive models is to represent as accurately as possible phenomena and processes that occurred in the past. Necessarily, these representations are overly simplified, on account of the modeler's distance from the actual event. Further, a predictive model is only as strong as the input data used to construct it, so care must be given to the choice of model, the input data, and the modeling theory. While models can be both explanatory and correlative (Van Leusen et al. 2005:30), this study attempts to combine the aims of both approaches. Thus, in attempting to understand the drivers of land use and settlement behavior among past populations (in an explanatory sense), the model developed here also strives to improve conservation and preservation of archaeological heritage by determining the probability that archaeological remains will be present in a given area (in a correlative sense). Toward this end, the current predictive modeling entails a number of assumptions.

[10] CRM refers to cultural resources management, which can be either governmental bodies (e.g., part of the National Park or Forest Service) or private entities. Referred to as archaeological heritage management in the Netherlands (AHM).

The first is that human land use behavior tends to be patterned in various ways (e.g., in terms of subsistence, settlement, and mobility practices) and at various scales, both spatial and temporal. Another important assumption is that the existing archaeological data (used here in the deductive sense, as a post-hoc test of the quality of the predictive model) are representative of the total archaeological record for the study areas. This assumption is always tenuous at best; however, without further building of models (with attendant assumptions), scholarship will not proceed and archaeological remains will continue to be threatened by the ever-present thrust of human development. Thus, making such an assumption is considered justifiable in this context, although it will remain a caveat for the output of the model.

The last assumption involves the fact that statistical analyses are frequently used to "determine whether the characteristics of a particular set of locations (namely, those where archaeological sites of interest were found) is sufficiently 'unusual' to imply something of interest to the archaeologist" (Van Leusen et al. 2005:32). The assumption of *normality*—that archaeological variables plotted in a histogram will conform to a normal distribution, Gaussian curve—generally does not hold for archaeological data. Thus, non-parametric statistics are preferred for such non-normal data distributions. It should also be kept in mind that the statistics used for spatial and non-spatial applications differ based on their assumptions and approaches. Thus, different statistical tools must be used for geographic and non-geographic data (Van Leusen et al. 2005:33). Techniques such as auto-correlation must be incorporated if one wants to understand the association between adjacent locations. In this study, statistical analyses were not undertaken because of the small sample size and non-representative nature of the archaeological record. Furthermore, the modeling here does not result in numerical output and at best, would only have facilitated rank-ordering testing.

The first non-CRM, truly academically based predictive model developed to study European Late and Post-glacial hunter-gatherer behavior was undertaken by M. Jochim in 1976. In this influential work, hunter-gatherer land use strategies were by assessed by correlating ecological variables and site locations. Quantitative measures of resource characteristics (e.g., caloric and nutrient yields, search and processing times) and assumed universal objectives of ethnographically known hunter-gatherers were used as input material. This study was followed upon by other researchers (Keene 1981; Kohler and Parker 1986; Mithen 1990; Price 1978; Reidhead 1979, 1980), the majority of which also attempted to model behaviors in the past by estimating productivity and other settlement-related values through complex mathematical equations. The main drawback of using such quantitative approaches is the fact that most of these values are estimations of past ecosystem characteristics for which modern analogues and other proxies serve as the basis, although it is not always clear that these dimensions accurately represent conditions in the past.

An alternative to the quantitative approach is one which models general relationships between factors (Egan 1993; Krist 2001). While such models can potentially become unrealistically simple, this drawback can be circumvented by gathering detailed information about resources and other external criteria as a way to produce rankings that represent resource or factor relationships (e.g., Egan 1993). Whitley (2000) developed a similar model, albeit from the assumed perspective of the individual decision maker. In this approach, knowledge of historic and modern-day hunter-gatherers is used to generate a series of statements describing the suitability of parts of the landscape for different goals. The main components of this approach are perceived costs and benefits of using certain parts of the landscape for particular activities.

A number of dichotomous classifications can be made regarding the various practical applications and theoretical aims of predictive modeling, including inductive vs. deductive, ecological determinism vs. social/cognitive models, and possibilistic vs. probabilistic (Van Leusen et al. 2005:25, 30-37; Whitley 2005:123). The inductive approach refers to the process of amassing large and complex data sets--that may contain both archaeological records as well as geographic, geologic, pedologic, palynologic, and other types of environmental data—and then querying these large data sets to elucidate those properties most commonly associated with archaeological sites (i.e., a directed search for inherent patterns). Other areas with these specific mixes of properties are then assumed to be possible locations of as yet unrecorded archaeological sites. This inductive approach makes observations of the current archaeological and environmental data and extracts rules from these observations, rather than from existing theory of human behavior (Van Leusen et al. 2005:29). Many such inductive approaches tend also to be correlative, assuming that available archaeological material are representative, on a broad scale, of the total archaeological record (that is, both what has been discovered and what remains to be discovered (Van Leusen et al. 2005:32). While this approach is useful for deriving broad estimations of areas of archaeological potential, the results are generally simple. Further, because the inductive approach lacks solid theoretical footing, it fails "to take into account the cultural and environmental mechanisms that produced the statistical correlations that were found" (Van Leusen et al. 2005:29; Van Leusen 1993, 1995, 1996; Wansleeben and Verhart 1992, 1997).

The deductive approach to predictive modeling, by contrast, takes current understandings of human behavior in the past and generates models based on this knowledge. The environmental variables associated with these behaviors are used to predict site distribution and other land use activities (such as resource acquisition). The existing archaeological record is then used to test the validity of the prediction. While this approach has not yet been formalized, most recent predictive models undertaken in the US and Europe have taken this approach and rejected the inductive approach (e.g., Krist 2001; cf. Kvamme 2006). The strict distinction between inductive and deductive predictive models must, however, be treated with caution, as the terminology was originally meant to describe how much weight ought to be given a layer in a model, rather than the entire model (see Kvamme pers. comm. in Van Leusen et al. 2005:29). Thus, there is some confusion about what exactly constitutes an inductive versus deductive model, as a researcher may claim that their approach is deductive because they did not consider the location of existing sites when preparing the model, although they knew some general characteristics about the types of soils and physiographic forms favored by groups in the past. In other words, there seems to be an intrinsic inductive component in any 'deductive' model, as they are always built on previously gained knowledge (Peeters pers. comm.). Van Leusen et al. (2005) describe the benefits of using a 'hybrid' approach, in which "inductive statistics are only used to obtain a first impression of site location characteristics, and general knowledge about the locational behavior of human societies in the past is then added to the model" (Van Leusen et al. 2005:30). This hybrid approach will be utilized in this study.

Following this debate is that concerning the perceived dichotomy between approaches that are ecologically deterministic, and those that are post-modern (i.e., focused on social and cognitive motivations of land use). There is a general assumption that models taking primarily an ecological stance are devoid of theory, while more humanistic approaches are so theory laden that they become impossibly complex to test. The primary practical differences boil down to a contrasting use of so-called cognitive variables, with ecological determinism giving less emphasis to such factors and post-modernism giving more. However, both approaches are essentially deterministic when applied to modeling, although not overbearingly so, such that both approaches assume their respective motivators of choice *guide* human behavior rather than determine it in a strict manner. This study attempts to use a composite version of these approaches, one that allows for the consideration of both ecological and cognitive/social variables when it comes to human behavior and decision-making, similar to the approach of cognitive processualism, espoused by Renfrew and Zubrow (1994).

The last dichotomy of predictive modeling to be described here is that between possibilistic and probabilistic studies. A possibilistic model depicts the *suitability* of particular locations for human activities in the past (Van Leusen et al. 2005:30). For a given point in time, it is impossible that all suitable locations were used concurrently. Thus, as noted by Ebert (2000), the success of such a model can not ever achieve more than about 70% accuracy (Ebert 2000:133). The model developed here is a possibilistic approach. Conversely, a probabilistic predictive model indicates the *likelihood* that a particular activity was undertaken at a specific location. Van Leusen et al. (2005) argue that "whilst possibilism seems the more appropriate approach in cultural resource management […] probabilism would appear to be more appropriate in a research context – not only because probabilistic models are more informative, but also because they can be tested and refined in a straightforward manner" (Van Leusen et al. 2005:31). The difference between the two models could also be conceptualized as a difference in the scale of the research, possibilistic studies focusing more broadly and probabilistic studies focusing more narrowly on predicting location usage in the past. Given the nature of the data available for this study and the modeling theory chosen, a possibilistic approach is the most appropriate. It is believed that the current possibilistic predictive model of hunter-gatherer land use for the study areas, while not as informative or accurate as a probabilistic model, is better than no model at all.

Further, the model provides a necessary stepping stone for future research by providing a testable set of hypotheses about hunter-gatherer land use behavior. In addition, many behaviors do not result in tangible sites, and thus cannot be tested in a probabilistic manner.

In the Netherlands, predictive modeling is just one of a set of tools used by heritage management institutions to establish the archaeological potential for areas of current land use planning (Van Leusen et al. 2005:35). This modeling was first introduced to Dutch archaeology through K. Kvamme (who taught courses at Leiden University; Brandt et al. 1992) and was therefore largely influenced by the American tradition (Ankum and Groenewoudt 1990; Brandt et al. 1992). In the beginning, inductive approaches were the norm, in which multivariate statistics were used to assess areas of potential land use (Ankum & Groenewoudt 1990); however, with the development of Geographic Information Systems (GIS), the process of modeling areas of archaeological potential became largely computerized, especially since large bodies of data could now be efficiently analyzed and stored. The technique is used widely today for archaeological heritage management endeavors, having been initiated in the 1990s by RAAP Archaeological Consultancy, as well as at the Cultural Heritage Agency of the Netherlands (RCE). The aim of these early efforts was to produce a national predictive model (the Indicative Map of Archaeological Values of the Netherlands [IKAW]; Deeben and Hallewas 2005; Deeben et al. 1997; Deeben et al. 2002). These initiatives were started at both agencies by the same researcher, R. Brandt. Within the research sphere, other Dutch academics have also made an impact on the development of predictive modeling theory and method at the international level (e.g., Van Leusen 1995, 1996; Verhagen et al. 2000).

Geographic Information Systems (GIS) is a key tool employed in predictive modeling, as it is both efficient and flexible. In North America, GIS is used pragmatically, as a tool for testing and applying analytical methods to large datasets in the context of heritage management, thereby providing an effective yet relatively cheap way to protect and control cultural resources (Westcott and Brandon 2000). In Britain and continental Europe, GIS is used more idealistically, in which scholars endeavor to understand past behaviors prior to attempting to predict the spatial extent of this behavior in the archaeological record (Van Leusen et al. 2005:27). Many archaeological applications of GIS have successfully predicted new site locations and other features, and also have considered the spatial component of human land use choices (Dalla Bona 2000; Peeters 2005; Whitley 2005). Further work is needed, however, to explain what factors and criteria motivated the decisions of prehistoric hunter-gatherers. Predictive modeling via GIS can be used as a tool for answering archaeological and even anthropological questions; GIS will be used in this capacity in the current study, in order to develop a deductive predictive model with foundations in anthropology and decision theory. An advantage of formal modeling is that it forces researchers to explicitly state assumptions about the relationships between introduced variables. Further, formal modeling permits the researchers to adjust control factors as a way to test multiple scenarios, and the importance of different criteria. Oftentimes, straightforward archaeological approaches yield only impressionistic results in which assumptions are implicit at best. As such, predictive modeling provides a real analytical tool with transparent assumptions, adjustable factors, and testable outcomes.

5.3. The Behavioral Model

5.3.1 Introduction. The model developed here is rooted in decision theory and is predictive and deductive in its approach. The goal is to simulate hunter-gatherer decision-making given a set of general objectives, criteria, and decision rules associated with the particular strategy utilized by that group. In the following pages, the approach and assumptions of this model will be discussed, along with a detailed description of the procedure.

5.3.2 Approach. The approach used in this study combines modeling procedures developed independently by two researchers. The first procedure was developed by Krist (2001), with the aim of identifying the most suitable strategies of resource use and settlement placement used by Late Pleistocene Paleo-Indian groups of the Great Lakes region. While a number of such sites have been recorded for this region and time period, there is little consensus among scholars about what subsistence and settlement patterns were in use. To answer such questions, Krist (2001) constructed a paleo-environmental model for the Great Lakes region during the Late Pleistocene and a corresponding anthropological framework. Three separate alternate hypotheses of resource use and settlement placement were identified in the existing literature. A cognitive decision-making approach was applied to each hypothesis; given the particular goals, criteria, and constraints of hunter-gatherers, multi-criteria evaluations (MCE) of areas most suitable for particular subsistence and settlement activities were undertaken. The result of this procedure was a series of cartographic surfaces depicting landscape suitability. These maps were then compared statistically with the existing archaeological record of the area to establish goodness of fit.

The strengths of this approach lie in its flexibility, as new decision-making criteria and objectives can be added when necessary. Further, the approach can accommodate both general and specific data through the use of procedures of standardizing and weighting factors that condition hunter-gatherer decision-making. This standardizing process is implemented through the construction of pairwise comparison matrices (see Krist 2001:143, 147-150), which are robust enough to incorporate both quantitative measures of factors and general relationships between factors. This approach thus incorporates both types of data available in the archaeological record, and is ostensibly flexible enough to permit addition of other types of data in the future.

The second procedure was developed by Whitley (2000), with the aim of identifying from a cognitive (or deductive) perspective the process of decision-making, specifically regarding site selection and individual motivation (Whitley 2000:1). By investigating the components of site selection, the actual behavior of site placement can be clarified. A model is developed in which attractors are identified (items that provide some benefit to the individual or community), the specific costs and benefits of site placement are simulated from empirical data, and are then harnessed into a cost-benefit landscape that integrates the attractors (i.e., a cognitive landscape). The main drawbacks of such a model include informational paucity/overload (in which either too little or too much information is included and therefore impedes reasonable modeling); neutral decision (in which the preference between alternatives is not known, or cannot be assumed); and that some decisions are inherently unpredictable, reflecting the fact that human behavior is often impulsive in the short term, although long-term generalizations can be identified.

The general approach followed here was applied to archaeological contexts through GIS applications by Krist (2001:145-162), who in turn adapted the methodology from IDRISI software developers, specifically Eastman (1999; 1995). Whitley's (2000) considerations of perceived costs and benefits of landscapes are incorporated into the multi-criteria evaluation. The method is designed to produce output maps depicting the spatial outcome of hunter-gatherer decision-making processes. The model was implemented through raster GIS analysis, using ESRI ArcGIS™ software and PCRaster Environmental modeling software.

To begin, a set of problems or decisions must be identified for a hunter-gatherer group. The current study is concerned with the following questions:

- Which resources were exploited? Where were they exploited, and when?
- Where did people place themselves on the landscape, and how did they arrange themselves?
- How did people perceive of the landscape?
- How did these uses and perceptions change over time?

Various hypotheses may be constructed to describe the possible alternatives developed either consciously or subconsciously to answer these questions. In this study, three hypotheses or alternatives are developed in conjunction with known facts about hunter-gatherer behavior from the ethnographic and archaeological record (see following chapter). These alternatives are used to generate a unique set of objectives, criteria, and decision rules to approximate decision-making processes in the past. Each alternative hypothesis therefore contains three main components or modules, in which information concerning either hypothesized or observed data on the environment and hunter-gatherer behavior is inputted (Krist 2001:145). In the first module, objectives are identified and ranked in order of importance according to what is known from the ethnographic record. In the second module, the adaptive strategy of the group is established. In the third module, criteria were identified that affected the attractiveness of each alternative, and are ranked in importance. Both objectives and criteria are combined with weighted linear combinations. The final evaluation is made using another weighted linear multi-criterion process, which is discussed in further detail below.

5.3.3 Assumptions. A number of assumptions underpin this research. Most importantly, it is assumed that hunter-gatherers want to fulfill a set of goals and will make decisions accordingly (see Chapter 1 for examples). To facilitate the modeling process, it is also assumed that hunter-gatherer decision-making is guided by a set number of goals regarding resource use, settlement and mobility, and perception (e.g., Egan 1993; Jochim 1976). Further, it is assumed that hunter-gatherers make rational decisions in the process of satisfying their set of goals, such that these goals shape the adaptive strategy of a group. It should be noted that the approach used here is additive in nature, such that any criteria values may be combined. This is not to be confused with the hierarchical decision framework utilized by rational choice theory (e.g., Kohler and Parker 1986).

5.3.4 Model Components. The main components of this simulative model are the objectives, criteria, and decision rule (Figure 5.1). Each will be addressed in detail below, followed by a discussion of how the model is implemented.

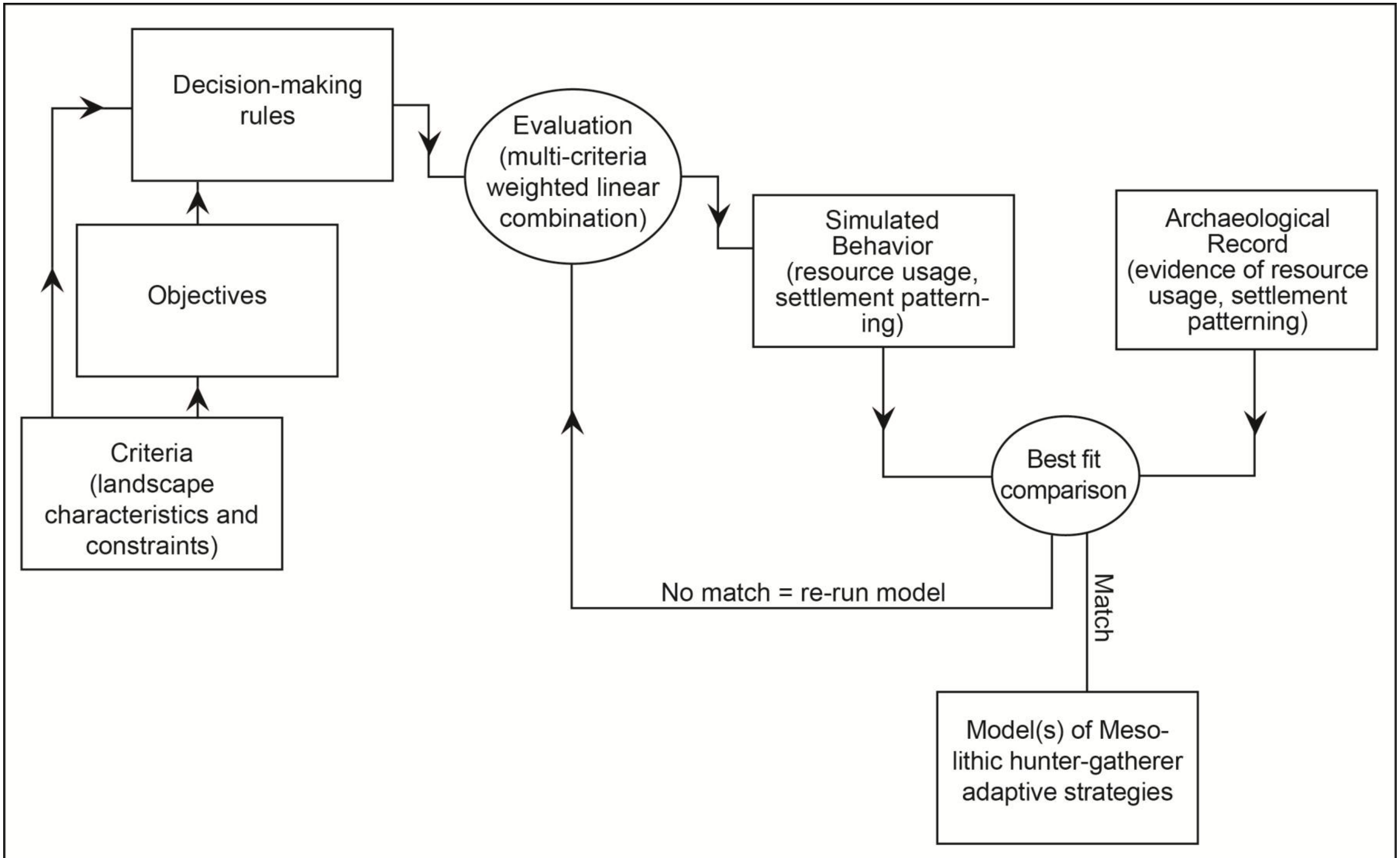

Figure 5.1. Flowchart of Decision-Making Model.

5.3.4.1 Objectives. Objectives are essentially the overall aims of the hunter-gatherer community in question (whether archaeological or ethnographic is irrelevant). As such, they inform what components of the real world must be considered in the decision-making process. Objectives often vary between individuals and groups, depending largely on the motives and perspectives of the decision-making body. That said, some universal goals that condition the choices of hunter-gatherers have been formulated by Jochim (1976, 1998) and Keene (1981). When an objective is met through successful decision-making, it is often reinforced through further redundant and patterned choices (Egan 1993; Jochim 1998). These choices may be consciously or subconsciously reinforced. While the generalized objectives do not hold in every scenario, they do provide an informative starting point from which further hypotheses about hunter-gatherer behavior can be built.

5.3.4.2 Criteria. Criteria entail both the factors and constraints that affect the degree to which an alternative adaptive strategy satisfies the objectives and decision rule. Factors are essentially the "attractors" or benefits within the landscape (Krist 2001:140; Whitley 2000:3-4). Constraints are "limitors" or costs that limit the total array of alternatives. For example, a constraint on hunter-gatherer traveling would entail an imposed maximum daily travel distance of 20 km, which effectively restricts the hunter-gatherer from accessing more diverse or rich resource patches outside of that area.

5.3.4.3 Decision Rule. The decision rule can be thought of as the operative framework in which the decision must be made, which is informed by the original objectives. Using a foraging strategy (versus a collecting strategy; Binford 1980) is an example of a decision rule utilized by hunter-gatherers (see discussion below). An example of a decision rule is Binford's (1980) collector strategy, in opposition to the foraging strategy. In either strategy, the decision-making process views the criteria of food resources uniquely. For example, collectors move resources to settlements (or people) through logistical forays and typically place settlements near non-food resources that are important to survival (e.g., water; Kelly 1995). Conversely, foragers move their settlements (people) to be in close proximity to food resources, which includes water. Thus, when simulating collector behaviors, the main decision-making criteria involve proximity to important non-food resources and placement of sites in areas that permit easy movement to resource-rich areas at a distance. This assumption is based on the knowledge that logistical strategies are designed to resolve conflicts when multiple resources are available at the same time or in the same place (Robertson 1987:21). In the case of foragers, the primary decision-making criterion is the access to food resources, since this strategy entails moving people between food resource patches. Further, to incorporate a more emic perspective of the motivations that guided hunter-gatherer decision-making, perception statements can be formulated (see below for discussion).

5.3.5 Procedure. The process of modeling decision-making begins with establishment of the goals and objectives of the modeled hunter-gatherer group under the designated hypothesis or alternative (see Chapter 6). These objectives are ranked in order of importance, using a nine-point continuous scale (following Krist 2001:147-148 and Eastman 1999; see Figure 5.2).

		Less important				More important		
1/9	1/7	1/5	1/3	1	3	5	7	9
Extremely	--	Strongly	--	Equally	--	Moderately	--	Very strongly

Figure 5.2. Nine Point Rating Scale (adapted from Krist 2001:148 and Eastman 1999).

The relative importance values are then placed in a pairwise comparison matrix, which produces weights for each objective based on its importance in relation to other objectives and thus, on hunter-gatherer decision-making. All pairings of objectives must be compared in this matrix (Table 5.1). Pairwise comparison matrices are a useful way to schematize the relative importance among variables (Eastman 1999). Further, these matrices can be used to derive weights for objectives and criteria. A further benefit is that pairwise matrices can accommodate multiple criteria and/or objectives.

Table 5.1. Pairwise Comparison Matrix for Settlement Placement Objective (adapted from Krist 2001:149).

	Proximity to resources	Proximity to water	Shelter
Proximity to resources	1	3	3
Proximity to water	1/3	1	1/5
Shelter	1/3	5	1

In the example here, proximity to water is moderately more important to site placement than the proximity to resources, and thus scores a “3”. Conversely, proximity to resources is moderately less important to site placement and receives a score of “1/3”. Proximity to water is strongly more important to site placement than shelter, and thus receives a score of “5”. Proximity to resources is also moderately more important to site placement than shelter and receives a “3”.

Once the relative importance values are entered into a pairwise comparison matrix, a principal eigenvector value must be calculated[11]. Then, each column is summed (the column marginal total), and each cell of the table is divided by the column marginal total, and the resulting value is recorded per cell. Next, values are averaged across the rows. These final

[11] In linear or matrix algebra, an eigenvector represents a vector that is scaled up by a transformation. The magnitude of the transformation is referred to as the eigenvalue. A principal eigenvector value refers to the largest eigenvalue in a dataset. Notably, this type of transformation is non-directional, and simply represents the increasing or decreasing magnitude of the original vector. For this reason, the value is appropriate for computing value weights.

averaged values should sum to 1. These values represent best-fit weights for the initial criteria or objectives. For Table 5.1 above, the column marginal totals are obtained (Table 5.2), then each cell is divided by this total, and the rows are averaged (Table 5.3).

Table 5.2. Column Marginal Totals.

	Proximity to resources	Proximity to water	Shelter
Proximity to resources	1	3	3
Proximity to water	1/3	1	1/5
Shelter	1/3	5	1
Column marginal total	1.67	9	4.2

Table 5.3 Principal Eigenvector Values.

	Proximity to resources	Proximity to water	Shelter	PEV*
Proximity to resources	0.60	0.33	0.71	0.35
Proximity to water	0.20	0.11	0.05	0.12
Shelter	0.20	0.55	0.24	0.33
Column marginal total	1.67	9	4.2	

* PEV: Principal eigenvector value.

Prior to making a choice between alternatives, a decision rule must also be applied. Akin to an adaptive strategy, the rule is generally formulated from a hypothesis regarding how a hunter-gatherer group flourished. From this hypothesis, a number of expectations about hunter-gatherer decision-making and behavior can be generated. This information is incorporated into the model through the model developer rather than numerically. It is used to inform the relative rankings of the objectives and criteria and also plays a part in the evaluation process. Returning to the example discussed above, a collector strategy (*read* decision rule) entails different objectives and criteria than does a forager strategy. The expectations derived from decision rules act as guidelines for identifying pertinent objectives and criteria, as well as in making the final evaluation.

To add the perspective of indigenous perceptions of, and significance surrounding, the context under consideration, these expectations can be re-formulated into a grammar of site use and placement, as suggested by Whitley (2000:55):

Observable characteristic of/by/to **constraint** is/are **effect** for **regional/local goal**

Some examples of statements formulated in this grammar are:

"Steep faces of **geological features** are **costly** for **comfortable habitation**, and

Proximity to **mountain sheep** is **beneficial** for **subsistence"** (Whitley 2000:55).

Where characteristics are attractors within the landscape, constraints limit the characteristic. Qualification represents the nature of the expectation (e.g., beneficial or costly), and the goal is one of the previously appointed objectives. While formulated in reverse from the modeling procedure, these expectation statements help to hone the entire modeling process. For each adaptive hypothesis, a series of such statements can be generated and referred to during the evaluation phase (see Chapter 6).

Criteria are established based partly on the objectives and decision rule of the hunter-gatherer group. Each objective can have a number of criteria, although the more criteria included, the more complex the model and modeling procedure becomes. Criteria are flexible components of the model and can be easily changed to test various hypotheses. Criteria take the form of known information about the external world (i.e., landscape), but can also be incorporated as perceptions of the landscape and its suitability for different purposes. An example of a criterion is distribution of vegetation types. Multiple criteria can be accommodated by this model. Thus, when considering where to place a settlement, the criteria of forest cover, groundwater levels, and view may all be considered.

An important area of consideration is the accuracy of the criteria, which is approximate at best even with complete available knowledge. Further, assumptions must be made about how and why hunter-gatherers used particular ecosystems in the past. Unlike more targeted mathematical models that require detailed quantitative information (e.g., Keene 1981; Jochim 1976), the model used here can accommodate both specific and general information. As noted by Krist (2001:153), suitability models that reflect plant or animal availability along a continuum from low-medium-high is sufficient. In the end, the model is only as accurate as the least accurate data.

For each objective, one or more criteria are selected and ranked based on their importance in the decision-making process. Constraints are also identified for the objectives. They are not ranked, but act to temper the benefits of the criteria. An example of a constraint would be areas inaccessible due to territorial boundaries or insufficient watercraft technology. Another common constraint used among modelers of hunter-gatherer behavior is a maximum daily walking ratio (e.g., 12 km or 20 km depending on the group).

In the event that a single criterion can satisfy an objective, there is no need to construct a comparison matrix. Because no comparison between criteria takes place, all that is necessary is for the criterion to be ranked on a percentage scale (from 0-100%), based on the degree to which the criterion satisfies the objective. Thus, the original values of the criteria (represented as low, medium, or high) are modified such that they reflect which areas better satisfy a particular objective. In effect, this step acts to adjust the overall value to account for how well the criterion satisfies the objective. For example, if the objective is to minimize risk, then the distribution of wild boar would receive a low percent rank (40%) because the animals are solitary and relatively unpredictable in territorial behavior. Within the original suitability raster--where each cell has a value based on whether the habitat has a low, medium, or high chance of wild boar—each cell is then multiplied by 0.40 to obtain the adjusted raster with attendant satisfying values. Risk minimization can also be incorporated into the model at this step (e.g., by assigning low percentage scores to areas that pose potential risk). Risk can also be incorporated as an objective (see discussion in Krist 2001:160-161).

In scenarios where multiple criteria are considered as components of a single objective, weights must also be adjusted according to a standardized scale. This allows further comparisons between criteria, which may have been generated with different values. Following Krist (2001:155), the following linear scaling transformation is utilized:

$$x_i = (R_i - R_{min}) / (R_{max} - R_{min}) * \textit{standardized range}$$

Where x_i = adjusted score of criteria i
R = raw suitability score

This scaling standardizes values between minimum and maximum parameters.

To evaluate the model according to the specific objectives, criteria values and weights must be combined. A multi-criterion, weighted linear combination is used here (see Krist 2001:157), in which the criteria weights are multiplied by each criteria value, the products of which are summed (Eastman 1999). The equation is as follows:

$$S = \sum w_i x_i * (\prod c_j)$$

Where S = suitability
w_i = weight of criteria i
x_i = adjusted score of criteria i
$\prod$ = product
C_j = adjusted score of constraint j

The equation set off by parentheses is only used in the event that a location has a constraint.

The weighted linear combination will yield a value for each individual cell that ranges from 0 to100, a number chosen for ease in visually inspecting the resulting surfaces. The higher values indicate areas that are more suitable for meeting the preset objective; lower values indicate areas less suitable to achieve the objective. For models with multiple objectives, another weighted linear combination must be calculated. For input, a pairwise comparison matrix must again be made, this time ranking the objectives in terms of importance. The resulting weights and adjusted values are again combined in the equation listed above. The result is a suitability map surface showing the probability that certain behaviors were undertaken in certain locations—the basic unit of analysis in this case being of a 100x100 m grid cell, taken to represent a location or zone--as part of an overall objective set and adaptive strategy of the hunter-gatherer group. This final suitability map can also reveal the extent to which individual criteria or objectives influenced decision-making. This information can be gleaned by examining the suitability values for each objective, as well as the adjusted criteria scores that can identify which individual criteria most impacted final suitability. These values can also be used to estimate resource productivity in a particular location, and further extrapolate the number of potential inhabitants that could be supported.

5.4. Summary and Implementation

The simulative model discussed above provides a flexible and efficient way to reconstruct the probable outcomes of hunter-gatherer decision-making. These decisions are assumed to have been made based on a number of goals and societal requirements. It bears repeating that the general objectives assumed here to be representative of the goals of prehistoric hunter-gatherers are but a starting point (see discussion of Jochim’s cultural universals in Chapter 1), to be tested and refined as better data and modeling procedures are developed. This assumption is based on the knowledge that over the long-term, individual and group decision-making that satisfies the needs of individuals or society tend to become patterned and redundant (Egan 1993).

The behavioral model developed here provides a tool for revealing some of the motivations, guidelines, and constraints of hunter-gatherer decision-making. The tangible outcomes of the model—map surfaces depicting the suitability of areas for specific behaviors—will be compared with the archaeological data in Chapter 7 to determine which strategies were most suitable at certain times and places. In the following chapter, three alternative land use strategies will be described for Mesolithic hunter-gatherers in the Post-glacial Netherlands, detailing the specific objectives, criteria, and decision rules for each. This modeling will be undertaken with the ESRI ArcGIS™ suite of programs and PCRaster Environmental Software.

Chapter 6

MESOLITHIC ADAPTIVE ALTERNATIVES

6.1 Introduction

While much is known about the subsistence and settlement pursuits of Mesolithic hunter-gatherers, the information supporting current theories is fragmentary for much of Europe. This is due in part to differential preservation across micro- and macro-regions, which has directly affected the quality and quantity of botanical and zooarchaeological remains, as well as structures and features in the archaeological record. Most open air and dryland sites are poorly preserved and yield mainly scattered assemblages of (often poorly preserved) stone tools and stone raw material, along with charcoal and charred botanical remains. Wet and submerged sites have thus provided most of the data on aspects of Mesolithic life apart from the more durable stone component. Consequently, an information lacuna still persists regarding the specifics of what people ate, how they obtained their food and other goods, and how they positioned themselves on the landscape throughout and over the years. Furthermore, it is well established that large-scale changes occurred in the environment of the Netherlands throughout the period, yet there is still little understanding of how people coped with these changes.

This study aims to address these questions by generating possible hypotheses of hunter-gatherer behavior; developing a set of expectations about these hypotheses; breaking the hypotheses down into the decision-making components; simulating the suitability of different parts of the landscape for various land use behaviors; and finally, comparing the outcomes of the simulated alternatives with the existing archaeological data. In the absence of better archaeological data, the use of a behavioral model founded on detailed environmental, ecological, and ethnographic data should help to clarify which adaptive strategies were practiced by Mesolithic hunter-gatherers at certain time intervals within the study areas. Only one other behavioral model has been developed for the Netherlands, in the area of Flevoland (Peeters 2007); for the rest of the European Mesolithic context, no other behavioral models have yet been developed. The hypotheses outlined in this chapter will be evaluated based on the requisite objectives and criteria, resulting in relative rankings of each hypothesis for a given habitat. While this model is based mainly on environmental factors, it also allows for exploration of the individual and inter-group motives and perceptions of landscape that drove hunter-gatherer decision-making, since the criteria and objectives can be modified as needed to better fit the archaeological data (see Figure 5.1). Furthermore, the environmental factors are considered to be guiding criteria and limitations to decision-making, rather than direct influences of hunter-gatherer behavior.

6.2 Background

Various scholars have weighed in on the issue of hunter-gatherer land use and the considerations that underpin decisions about which adaptive strategy to follow. It has been postulated that the most critical decisions facing hunter-gatherers are a) the selection of resources, b) the composition of the diet, c) the location of settlements, and d) the size of settlements (Keene 1981:4). These general decisions were identified as the basic biological requirements of a group, which may or may not be consciously identified (e.g., nutritional criteria). A number of other, more specific, factors have also been established. For example, Nicholas (1998) has identified four main variables that affect hunter-gatherer land use strategies. These variables are: resource type, resource diversity, resource productivity, and resource reliability (Nicholas 1998:722). Resource type refers to the kind of flora and fauna in a habitat, which may have been used for a variety of purposes by Mesolithic hunter-gatherers, such as food, raw material, and medicine (e.g., Erichsen-Brown 1979; Wheat 1967). Resource diversity represents the number of different species present, the breadth of which depends greatly on the size and type of ecosystem. For example, swamps are attractive to a smaller number of species than are marshes; edge zones between grasslands and forests are attractive to a larger number of species than is dense woodland. Further, the size of a biotic zone may also affect resource diversity: small wetlands tend to be more biologically homogeneous than larger wetlands (Nicholas 1998:722).

Resource productivity is also germane to land use strategies and decisions, and is represented by the total biomass/hectare/year[12]. Such estimates are difficult to make for past ecosystems, although general categories may be used to determine which biotic zones were more productive than others. It is also important to consider that high resource productivity and human usage are not linearly related; highly productive areas may be infrequently used or ignored. However, for the purpose of this study, it will be assumed that the majority of the time, if an area is biologically productive it will probably be targeted by hunter-gatherer groups (Nicholas 1998:722). Lastly, resource reliability refers to the stability and predictability of resource type and productivity at a given time and place. This variable may fluctuate over the course of the year. Also taken into consideration in this equation is risk and hazard, which affects the reliability of procuring certain resources.

In the following section, three hypotheses of subsistence and settlement location will be discussed. These adaptive alternatives are not meant as static or unchangeable strategies; rather,

[12] It should be noted, however, that many paleo-environmental records do not yield such fine-grained data, either spatially or temporally.

they are intended as heuristic devices and are presented as unique adaptive approaches to the same linked problems of what to eat, where to live, when to move, and where to move. These alternatives are not mutually exclusive and are intended to describe only a few specific manifestations from within the enormous gamut of ways in which hunter-gatherers may have interacted with the environment. It is assumed that during certain time intervals and in certain locations, all three alternatives may have been in practice; at other periods and places, perhaps none of them were in use. The express goal of this modeling exercise—the constituents of which are set up in this chapter—is to obtain a better understanding of the interplay (and perhaps utility) of these adaptive strategies, by comparing their spatial cartographic results with the archaeological record.

6.3 Alternative Adaptive Strategies

The available evidence for Mesolithic hunter-gatherers suggests a number of lifeways were developed to meet subsistence and settlement goals. From a broad perspective of the European Mesolithic, however, three main lifeways can be observed, which can be summarized as follows:

1. Focused hunting of large game within forests and grasslands and along edge zones. Territories were large, and both residential and logistical mobility was high. Over the course of the Early and Middle Holocene, residential mobility decreased in frequency and distance, while logistical mobility increased in these dimensions. Logistical forays, in particular, became longer. Sites were generally ephemeral and small to medium in size, as occupation length was short (a few days to a week or so). Some differentiation of artifact assemblages is expected, as different activities occurred at residential camps and logistical extraction camps. Further, some larger and longer-term residential camps are

also expected to have formed during abundant periods of these high-return rate resources (e.g., during the rut).

2. General foraging of a diverse array of food resources within different vegetation zones. Residential mobility was comparatively higher in frequency, as people covered their territories more thoroughly. However, moves were probably shorter, as groups moved from patch to patch searching for resources. Logistical forays were shorter overall, as residential mobility was the main way to move people to food. Settlements were mostly small, ephemeral, and similar in composition, as many of the same activities were undertaken at each new site.
3. Targeted exploitation of wetland and aquatic resources (e.g., shellfish, fish, and migratory/water birds). Residential mobility was low, as the resources were either readily available at the site or were brought back through logistical forays into neighboring zones. Long-distance mobility to find new sites and resources, as well as interact in trade and information exchange, was probably high as people were otherwise relatively confined to small areas. Settlement types would have been more diversified, depending on the duration of use of the wetland site and the number of other sites used throughout the year for other extraction purposes.

6.3.1 Alternative Strategy One: Large Game Focus

6.3.1.1 Background. Supported by a predominance of large game remains in the existing zooarchaeological record, and well-developed hunting gear (i.e., bow and arrows, geometric and microlithic technology), the first adaptive alternative commonly followed at various places and times was that of targeting large game hunting (Champion et al. 1984; Jochim 2002; Kelly 1995;

Mithen 2001:86). As gregarious game had largely vacated Western Europe by the Holocene, the focus of this hunting was on more solitary species like red deer, roe deer, wild boar, and aurochs. Such species tend to live in small groups (less than ten) throughout most of the year, requiring hunters to invest time tracking their prey or targeting edge zones and watering locations where small groups of these game would gather. Although the amount of energy required to locate and kill the animal was significant, the pay off was a rich energy package that could feed a family group for at least a week or two and which had storage potential. Further, some of these species congregate during the fall breeding season, and hunter-gatherers often exploited these agglomerations.

As in known from the ethnographic record, hunter-gatherers living in this way tend to organize themselves in an egalitarian manner. Men spent most of their time stalking, tracking, and killing prey, as well as gathering information about future areas of resource potential, while women occupied themselves with food and raw material processing, equipment repair, and child rearing (Kelly 1995:96). Certainly some plant gathering and small mammal hunting also occurred; however, under this alternative, it is assumed that large game hunting was relatively low risk and due to the high yields of such species, was an easy way to ensure the survival of small hunter-gatherer groups (Spiess 1979). Ethnographic accounts reveal that meat is highly preferred to any other source of energy, ostensibly because of its high-quality protein and nutrient density, components that ensure normal metabolic functioning (Kelly 1995:104-105). The fat content of meat also makes this resource taste good to hunter-gatherers (Speth 1990; Speth and Spielmann 1983). Furthermore, meat may be sought after by males even when there are more easily accessible and less risky alternatives simply because hunting and acquiring meat allows men to ‘show-off’, which in turn can lead to more sexual partners and greater overall reproductive fitness (see for example the case of the Ache; Hawkes 1990, 1991, 1992, 1993)

Following an adaptive strategy focused on large game has implications for settlement and mobility. Hunter-gatherers would have been largely dependent on the movement and distribution of game species that, like all species, are in a constant state of flux (Kelly and Todd 1988). Thus, these small groups had to be relatively flexible regarding their settlements and ability to move frequently. Hunter-gatherers focused on large game hunting can practice both high residential and logistical mobility; the two are not mutually exclusive, and in fact form the ends of a continuum (Kelly 1995:132). Further, these groups were likely to have larger territories than hunter-gatherers subsisting mainly via gathering (Kelly 1995:130). Among the Ona of Tierra del Fuego, groups follow the movement of the guanaco, settling for a few days at a time after each kill. When the food source is used up, the group moves on again, in pursuit of another kill (Gusinde 1934:276). Groups focused on large game tend to search their territories less thoroughly than gatherers and probably undertook long logistical forays in search of prey (Kelly 1995:131). However, in cooler environments where prey is patchily or sparsely distributed, hunter-gatherers will move residential camps more frequently to cut down on the potential for lost energy during long logistical forays (Kelly 1995:124). Thus, it should be expected that in the early Holocene when the climate was cooler, greater residential mobility would have occurred in groups following large game. Later in the Middle Holocene, hunters could undertake longer logistical forays and thus, it is assumed that residential mobility would have decreased in relation to its prior very high rate. Further, higher return rate packages can be more successfully procured away from camp than lower return rate resources. Thus, residential movement was likely never as high as logistical mobility. Overall, it is expected that groups focused on large game searched their territories in redundant and patterned ways, although this searching was not thorough (Kelly 1995:131).

Ethnographic data suggests that logistic settlements were occupied for short-durations (a few days to a few weeks) and were relatively small and simple, with few structures. Some larger residential camps are expected, along with a number of smaller logistical camps. For example, boreal forest Montagnais hunter-gatherers moved about once per week during the winter (Leacock 1954); other boreal and temperate forest groups have also been documented to move in a similar fashion (e.g, Ona/Selk'nam [Gusinde 1934]; Dogrib [Helm 1972]; Tasmanians [Hiatt 1967, 1968; Blackhouse in Roth 1890]; Mistassini Cree [Rogers 1972]). In general, where primary production of plant food is low, the number of residential movements should increase over the course of a year (Kelly 1995:125). This was undoubtedly the case during the Early Holocene in the Netherlands. In such instances, all material goods have to be portable and stone tools were likely curated, meaning that they were multi-purpose and carefully maintained, rather than being expedient and disposable. This strategy also allowed for redundant use of the same habitat, given that a previously used area had been “replenished” by game moving back in. Thus, food availability, especially for high-ranked resources, was a main driver of settlement and mobility choices.

6.3.1.2 Expectations. Use of this strategy was probably preferred by small groups of hunter-gatherers moving back into the region after the Late Glacial. In the early Holocene, the climate was still cool and the environment was relatively homogeneous with a balance of open grasslands and forests; the suitability of the landscape for large game at that time was optimal, and it is probable that the populations of these species would have been highest then. Thus, as large game was abundant and available year round, and hunter-gatherer population density was still low, this strategy was probably an easy decision (Kelly and Todd 1988). Further, the ethnographic sample has shown that in such homogeneous resource landscapes, foraging efficiency is obtained by group dispersion to areas of abundant resources (Kelly 1995:120). Frequent and longer-distance residential moves were probably common (cf. the cases of the Netsilingmiut and Baffinland Inuit; Damas 1969a, b, 1972) and logistical mobility would also have been high. No new technologies were required; bow and arrows and stone projectile point production had simply to be refined for the circumstances from Late Paleolithic forms. Most of the sites in the eastern Netherlands with early Mesolithic components (e.g., Ooijerhoek, Looërenk, and Epse-Olthof) could be explained as residential camps of a group following a large game-focused strategy, as mainly projectile points, scrapers, and associated-debris have been found along with various domestic tools and few structural remains other than surface hearths. The lack of organic data does, however, leave open the possibility that different activities were undertaken at the sites, or that different adaptive strategies were followed.

During the Boreal and Atlantic periods, the environment became more heterogeneous, with dense forests in the eastern part of the Rhine river valley and open marsh and swamp in the west (Bos et al. 2005; Spek 2004; Van Beek 2009). At the same time, the climate had reached modern-day averages. The available area of preferred edge zone decreased, and large game populations likely declined. At this time, the amount of energy required to find and procure large game may have increased. If so, there may have been a concomitant need for new technologies to deal with the changing external circumstances. For example, the rise of the trapeze is seen by some as the development of a more efficient hunting tool, which could be deployed in close-range scenarios (i.e., within a dense forest) and were more effective at bringing down the stalked animal (Larsson 1978). The frequency and distance of residential moves may have decreased somewhat during this time, but logistical mobility would have been undertaken more frequently and over longer distances. It is known that in areas with patchily distributed resources, hunter-gatherers can maximize the efficiency of their foraging by aggregating in central locations and using logistical forays to obtain resources (Kelly 1995:120). These mobility changes likely occurred along with the development of watercraft technology, as canoes facilitated longer logistical forays into the dense forests and wet marshy areas. At the same time, competition among hunter-gatherer groups was likely increasing, as population packing occurred. The latter was caused not only by demographic increases, but also by rising sea levels, which slowly reclaimed previously dry territory.

6.3.2 Alternative Strategy Two: General Foraging

6.3.2.1 Background. The second adaptive alternative that was followed by Mesolithic hunter-gatherers was a generalized foraging strategy that utilized a broad spectrum of a diverse array of food resources within different vegetation zones. Little evidence exists for such a diversified subsistence regime, perhaps because many plant and small mammal remains do not preserve well in the archaeological record, and also because the implements associated with the capturing of these resources are generally perishable implements like nets, snares, traps, and weirs. The lack of such technological evidence from the eastern part of the central Netherlands does not prove, however, that such an adaptive strategy did not occur, but rather that the archaeological record is fragmentary and therefore biased toward stone tools.

As omnivores, humans (with few exceptions) acquire a wide array of nutrients and food types to maintain their health. A broad-spectrum economy would satisfy these needs, provided that sufficient resources could be found. As discussed above, it is likely that despite the availability of other resources in the environment, meat from large game was still the preferred food resource. Other foods were probably still seen as secondary or starvation resources. Therefore, it is likely that men spent a good deal of time stalking game under this adaptive strategy, while women took on a more pivotal role in subsistence by gathering predictable and abundant low-return rate, low-risk resources (Kelly 1995:98-99). Women's activities tend to be more spatially constrained than men's work, although they can still produce high yield results, focusing on gathering and trapping various local resource patches (Egan 1993). Thus, the residential settlements of hunter-gatherers following a generalized foraging pattern are expected to be small and ephemeral. There is a further drawback to the broad spectrum approach: that one must have information about many different types of species, not only when and where they are available, but also how they are to be extracted and processed prior to consumption. Conversely, with large game, the killing and butchering process is more or less the same from animal to animal. Hunter-gatherers utilizing a generalized or broad-spectrum foraging strategy would have had to be innovative and resourceful to cope with resource risk, as they encountered a variety of more predictable resources. Further, these strategies often have the advantage of being more flexible, such that low yields can be compensated for by targeting other, more abundant resources.

This type of strategy would have had implications for mobility and settlement pursuits as well. Residential mobility would have been more frequent and the distances between camps shorter, since gathering economies are based on lower-return rate resources (e.g., plants, fish, insects, small mammals and birds), which are not worthwhile procuring at long foraging distances (Kelly 1995:131). Therefore, resource patches were more thoroughly searched through these residential moves, and logistical forays (when undertaken) would also have been shorter. Areas with homogeneous resource distributions tend to be best exploited through group dispersion to areas of resource abundance, while heterogeneous resource areas (with resources competitive in time and/or space) are best exploited through aggregation and logistical forays (Kelly 1995:117). Thus, Early Holocene hunter-gatherers may have found generalized foraging to be a successful subsistence strategy, while in the Middle Holocene other strategies may have been developed. Ethnographic samples suggest that moving camp can also provide ample time to undertake other activities, such as foraging and information gathering (Kelly 1995:123). For example, the Micmac only remained at a campsite as long as there were sufficient resources (LeClerq 1910:100). Following the law of diminishing returns, most hunter-gatherer groups will leave a site as soon as the energy required to obtain lower-return resources at further distances from camp are greater than the effort of moving to a new patch (Kelly 1995:136).

6.3.2.2 Expectations. In the early Holocene of the Netherlands, the landscape was homogeneous at the regional level, but heterogeneous at the local level with birch and pine forests mixed with open grasslands. At this time, resources were distributed rather evenly throughout the region, especially since many plant and animal species prefer edge zones between forest and meadow. It is probable that hunter-gatherers following a generalized foraging strategy during this time would have practiced high residential mobility, moving from patch to abundant patch. Logistical forays may have been made at irregular intervals to obtain exotic raw materials, such as tool stone, and other tasks were probably embedded in these forays (e.g., information and marriage partner exchange). The use of new technologies would have benefitted such foraging groups, such as mass-capturing devices (e.g., fish traps and weirs, birding nets), traps, and snares. Unfortunately, very little evidence exists for such new technology, apart from the well-preserved late Mesolithic sites of Polderweg and De Bruin. However, these sites suggest that generalized foraging in the wetlands may have developed into a new strategy: one that focused on wetland exploitation for much of the year (see strategy three below). It is possible that the wetland strategy was simply an alteration in patch selection made to the broad-spectrum economy. The archaeological record is unclear on this point: as most coastal Mesolithic sites are currently submerged, it may be that research on dryland sites is only representative of inland activities. Currently, workers do not know concretely whether the exploitation of wetlands and coastal areas was largely a late Mesolithic phenomenon, or whether these areas were also used earlier.

By the Boreal and Atlantic periods, the landscape became more heterogeneous at the regional scale, with dense forests in the eastern portion of the country and vast wetlands in the west. The wetlands themselves were also probably somewhat heterogeneous with stands of alder and willow outcropping on river dunes among sedge and reed fields, with many channels draining the area. Such an area would attract many different species, especially shallow water fish and migratory birds. If sufficient dryland could be found, such a heterogeneous and rich habitat would provide excellent conditions for hunter-gatherers with a broad-spectrum economy. The dense forests, however, would have posed a different problem: that of finding the resources. Large game dislike dense forests as exclusive habitat and would have been both highly dispersed and difficult to locate. According to the diet-breadth theory, when highly-ranked resources, such as meat, become scarce, the breadth of the diet should increase through the successive inclusion of lower ranked resources (Kelly 1995:84). Thus, it is quite probable that with the increasingly dense forests of the Middle Holocene, hunter-gatherers were faced with a choice: to take a wider variety of resources (e.g., small game, terrestrial fowl, and river fish) and develop new technologies (e.g., the trapeze, net, and snare), or to move toward the more productive wetlands, which constituted an easier and more predictable source of subsistence.

6.3.3 Alternative Strategy Three: Wetland Focus

6.3.3.1 Background. Another adaptive strategy that has been demonstrated at various wetland and coastal sites in Europe is a focus specifically on shellfish, fish, and migratory birds. Sites at Norsminde in Denmark, the Polderweg and De Bruin sites in the Netherlands, Téviec and Hoëdic, and the Muge shell midden are all examples of what could be termed wetland-based subsistence strategy. In both wetland and coastal areas, dependence on aquatic resources tends to be high (cf., Hoge Vaart; Peeters 2001, 2004, 2007). At these sites, residential mobility was probably low, as resources could be obtained at or near the site (e.g., fish weirs set up next to a settlement to facilitate easy transportation and maintenance; Yesner 1980). At the site of Mount Sandel, an early Mesolithic site (ca. 9000-8500 ^{14}C yr B.P.), feature evidence has been found which suggests fish-drying racks may have been in use. Further faunal evidence of eel, mackerel, shellfish, and seal imply that aquatic and marine resources may have been a periodic component of the Mesolithic diet. Among the Cree, the search time associated with aquatic resources is much less than that of large game, although aquatics are not as predictable as plants. However, the development of better tools and watercraft suggests the diet became more specialized toward aquatics, such that earlier resource choices were partially or completely ignored (Winterhalder 1981b).

Longer-distance logistical forays were likely made into the drylands or neighboring zones to obtain other necessary resources (e.g., wood, meat, and tool stone). In general, as primary biomass[13] increases, causing game to become more elusive and dispersed, a group's dependence of aquatics should also increase (Kelly 1995:125). This seems to be the case for the late Mesolithic in the Netherlands, where the increasingly dense forests impeded the easy acquisition of large game, making aquatic resources an increasingly viable resource for hunter-gatherers (e.g., Bos et al. 2005; Spek 2004; Van Beek 2009; Roebroeks and Van Gijn 2005; Waterbolk 1989; cf. Vera 1997). As with the general foraging hypothesis, women likely played a greater role in resource procurement, as men did not stop hunting large game altogether. Some storage of aquatic resources may have occurred, amassed and processed when the resource was abundant; however, we have very little evidence for such storage in the Mesolithic period.

Given that one or a few specific resources were readily available all year, the residential camp could become large, housing at least a band (i.e., 25 people) and possibly more during group aggregation periods. Ethnographic data from northern fishing communities (e.g., Klamath, Ainu, Makah, and Southern Kwakiutl) suggest that winter settlements are often located on the coasts, near river mouths, while spring/summer gathering camps are placed nearby, either inland or along the coast (Kelly 1995:129). Settlement was thus diversified between the residential site—where a variety of domestic, social, and ritual activities were undertaken--and logistical sites, where specific activities took place. Long-distance logistical mobility to find new sites and interact in trade and information exchange was probably infrequent yet important to the viability of the group, as people were otherwise relatively confined to small areas. Many ethnographic samples suggest that these logistical forays were quite long, although the use of boats biases any comparison with similar terrestrial forays (Kelly 1995:132).

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[13] Kelly describes primary biomass as "the total amount of standing plant matter in an environment … [which is] inversely correlated with the effective abundance of edible plant food."

Such grouping of a larger number of people for parts of the year may have led to the need for a simple stratification of the society, such that particular individuals achieved positions of short-term or activity-specific influence, related to their prowess in particular pursuits or ability to organize the group. This strategy would have largely been stable and predictable, given that the seasonal behavior and availability of species, as well as favored locations, were known. At the same time, many of these stable and predictable resources may have required large amounts of energy to extract and process, and were not as nutritionally rich as a single large game kill.

6.3.3.2 Expectations. In the Early Holocene of the Netherlands, the coast and wetland margins lay far to the southwest of the modern-day coast, along the Doggerland plateau (see Late Glacial and Early Holocene Coastline and Doggerland map in Chapter 4). However, as sea-levels rose and the coasts were pushed eastward, vast tracts of wetland formed behind coastal barriers (Beets and Van der Spek 2000). These wetlands would have formed only in the westernmost study area of Polderweg, between 8000 and 7500 ^{14}C yr B.P. (Hijma 2009; Bos 2010). It is quite possible that wetland and coastally adapted hunter-gatherers living beyond the current coastline of the Netherlands, on the now submerged Doggerland Plateau, were already using aquatic and marine-based lifeways in the early part of the Mesolithic. This lifeway may have been brought to the modern territory of the Netherlands by way of three different factors in the later Mesolithic: 1) sea-level transgression; 2) population packing; and 3) increasing densification of the eastern, forested areas. All three of these factors may have driven this adaptation; similarly, none of these factors may have been responsible.

Given that hunter-gatherers utilizing this strategy would have focused on aquatic resources, it is expected that the archaeological record would contain a surplus of remains from fishing, shell fishing, and birding activities. Fishing activities are most often discerned from the presence of fish scales and bones, along with fishing nets, weirs, barbed harpoons, hooks, and traps. Shell fishing involved similar accoutrements, although the most obvious evidence is the shell midden left behind. Most Mesolithic shell middens date to the late Mesolithic (Atlantic period), when hunter-gatherers had had sufficient time to spread out throughout the region and become acquainted with the territory and its resources[14]. Also, by the Atlantic period, sea-level rise had slowed substantially, allowing for the placement of more stable and long-term settlements, as well as for the crystallization of knowledge about predictable resource acquisition locations. Most wetland sites also derive from the late Mesolithic, although a few (e.g., the Duvensee site complex; 8200 ^{14}C yr B.P.; Holst 2010) have returned some early Mesolithic dates. Birding, too, is expected to yield similar implements and zooarchaeological remains in the archaeological record.

The wetland adaptation also entails lowered residential mobility, with a greater number of people living within the residential camp. The increased density of people at each site, coupled with longer site occupations, implies that more structural remains should be found to house the community, in addition to greater quantities of food remains and other refuse. Further, the artifact assemblages and features from such sites is expected to be large and diverse, as a number of activities were undertaken over an extended period of time. Furthermore, a number of satellite locations ought to be found within a day or two’s walk from the central residential site. At these logistical camps, the remains of specific activities are expected, such as faunal remains reflecting exploitation of a beaver lodge, the spearing of spawning anadromous fish, or the netting of a flock of migratory birds. Lastly, under this adaptive strategy, it is expected that some

[14] Note that no shell middens have yet been found in the Netherlands.

long-distance mobility occurred, for food and non-food resource acquisition, information gathering and exchange, and even negotiating of marital partners. Such mobility refers to trips made out of the yearly territory of a hunter-gatherer band, and often refers to trips made into the territories of neighboring groups. Material correlates of such interaction would include the presence of exotic materials (e.g., tool stone and ochre), and the sharing of ideas (e.g., technological and decorative styles, the Neolithic customs of animal husbandry and cultivation of plants). As was discussed in Chapter 3, some examples of such exchange do occur from the wetland sites of Polderweg and De Bruin, including the presence of Wommersom quartzite from the Belgian Ardennes, new technological input in the form of LBK points (which are bifacially worked), and the introduction of new subsistence strategies. (*NB:* it is still debated to what extent these new ideas and items were adopted from incoming Neolithic cultures, or were indigenously developed). It should further be noted that many of these examples of long-distance contact may also have been the product of intermittent visits to river dunes by later Neolithic peoples.

6.4 Mesolithic Hunter-Gatherer Resource Usage

To survive, hunter-gatherers developed strategies that satisfied both food and non-food requirements. Each of the adaptive alternatives discussed above entail strategies for obtaining sufficient food and non-food resources, as well as sufficient shelter and socio-political needs (e.g., organization of the population, interaction with other groups, ideological considerations). In this section, resource acquisition behaviors are developed for each adaptive alternative; the resulting spatial raster maps depict areas most suitable to for such behaviors. In the following section, settlement location and patterning is modeled for each adaptive strategy.

Within the decision-making model, it is assumed that hunter-gatherers wishing to achieve a set of objectives would have considered a variety of alternatives and made a number of choices (or decisions). It is nearly impossible to know what the objectives of prehistoric hunter-gatherers may have been; however, some researchers have already identified a set of objectives that appear to be cross-culturally important in guiding hunter-gatherers decision-making (Jochim 1976, 1998; Keene 1981). Objectives guiding resource selection and utilization are:

1. Attain the minimum amount of (non)food resources;
2. Limit energy and time expenditure (maximize efficiency);
3. Minimize risk;
4. Attain a variety of foods and tastes;
5. Attain prestige or items imparting prestige;
6. Attain (or maintain) a basic division of labor;
7. Facilitate population aggregation when necessary;

While many hunter-gatherers worldwide appear to make resource acquisition choices based on these objectives, the weight each objective is given can vary drastically between specific ecosystems and hunter-gatherer cultures (Jochim 1998). Further, each objective affects decision-making uniquely. Not all of the above objectives are always considered when an individual or group is contemplating a resource-related decision, and some objectives are decidedly less important than others. For example, the attainment of a variety of taste and nutrient content in foods, as well as prestige acquisition and division of labor, tend to be of secondary importance to the other objectives, which arguably impact basic survival more directly. In cases where simply obtaining sufficient sustenance is a difficult chore, these 'secondary' goals may be altogether ignored. Depending on the adaptive strategy followed, the importance of the above objectives differs; in most cases, only a handful of objectives will be considered as highly significant and these objectives alone will be modeled.

6.4.1 Model Large Game

The suitability of the large-game hypothesis for attaining the above resource-related goals is modeled here (Model Large Game). As hunter-gatherers targeting large game can utilize either residential or logistical mobility (Kelly 1995:132), both strategies will be considered. It is assumed that both of these strategies may have been used at the same time, or in alternating intervals. Also, to streamline the modeling process, it is assumed here that large game had relatively the same territories, habitat requirements, and resource preferences all year long, despite temperature fluctuations and vegetation growth cycles. Although some of the resources included in this modeling were more seasonal in their distributions (e.g., anadromous fish and migratory water fowl), these resources would not have been given primacy in this adaptive strategy. Therefore, these seasonally available resources are given very low weights, causing them to have very little effect on the overall suitability surfaces and thereby justifying the omission of seasonal modeling. In the following paragraphs, the objectives of this adaptive hypothesis will be discussed in detail. For a discussion of the other components of decision-making (i.e., decision-making rules, criteria, and evaluation), the reader is referred to Appendix E.

6.4.1.1 Objectives. The large game hypothesis holds that Mesolithic hunter-gatherers focused primarily on hunting large-bodied mammals such as red deer, roe deer, wild boar, and aurochs (Jochim 1976, 1998). This strategy required people to practice high mobility, pursuing animals wherever they went, with little consideration given to energy minimization (Kelly and Todd 1988). Group size was relatively small, probably no more than a nuclear or extended family in size (i.e., 5-10 individuals). Larger group aggregation occurred periodically, sometimes around high-density resource patches (such as rutting areas). During times of band fusion, food, non-food resources, information, and companionship was shared among the 25-50 members (Birdsell 1968; Lovis et al. 2011).

The most important objective of hunter-gatherers following this lifeway was likely the attainment of sufficient food and non-food resources, as well as the types of resources that would best satisfy this requirement. As large packages of usable food and non-food resources, large game would have easily satisfied this requirement. Further, hunter-gatherers using this strategy likely targeted edge zones, where plenty of raw materials could also be derived, such as grasses for bedding, insulation, and kindling, as well as wood for fire, tools, and structural needs. As for obtaining a variety of tastes and sufficient nutrient content, it is assumed that large game alone--perhaps with minimal infusions of plants and other smaller package mammals--could provide these requirements. For instance, different parts of the animal contain various nutritional properties, such as the internal organs, cartilage, stomach contents, and unhardened antlers (Spiess 1979). Water will also be considered as an important 'food' resource, as it is necessary for human survival. However, this factor will be considered more directly in the criteria section below.

Another important factor that likely guided the decision-making of hunter-gatherers was risk minimization. Certainly, there is some risk directly involved in hunting large game, especially wild boar, which is known to be confrontational to humans. Aurochs, too, with their large horns and heavy body weight, may also have been considered dangerous. Further, bringing an aurochs down may have required close-range tactics using spears and other more sturdy weapons--microlith-tipped arrows were probably not as effective. These specific considerations aside (it will be assumed that hunters were well versed in the most successful tactics for bringing down animals without incurring personal bodily harm), there is also the risk of not finding sufficient food. The best way to eliminate this risk is to target resources that were both abundant, reliable, and predictable in their distributions. During the Preboreal and into the Boreal, the environment was quite favorable to large game species; thus, the subsistence strategy posing the least risk would probably have been to target this bracket of mammals. Deer, boar, and aurochs populations were likely elevated and widespread during this time, constituting a stable resource base. Further, as the landscape was very heterogeneous with plenty of edge zone habitat, it is assumed that the presence of these species was quite reliable and predictable to Mesolithic hunter-gatherers.

Regarding efficiency, it is unlikely that energy and time maximization were important factors for hunter-gatherers following this lifeway, as much time and energy were expended in following, tracking, killing, and processing of large game mammals. Rather, prior to mobilizing a resource extraction activity, hunter-gatherers utilizing this strategy probably considered the chances of encountering a resource and the potential yield that could be obtained.

Attaining prestige through hunting high status or dangerous animals is certainly a consideration that may have motivated some hunter-gatherer resource acquisition. Generally, this is reserved for animals that are unpredictable in their distributions, and very large or dangerous. Prestige hunting probably focused on mammals like aurochs and wild boar, and possibly also elk (cf. Speth 2010) and brown bear. However, the latter species only occurred in very small numbers at this time. The fact that most zooarchaeological remains come from red deer, which was both a reliable and predictable resources, suggests that prestige hunting was not common. It probably happened occasionally, as suggested by findings of bear, fox, and other predatory species (such as eagles). Prestige hunting would not, therefore, have been a primary objective guiding decision-making.

The objective of maintaining some outside contact with other hunter-gatherer groups was probably only of secondary importance in guiding choices of resource usage. In the Preboreal and Boreal periods, the hunter-gatherer population was likely quite low, implying that the number of possible outside contacts were few (although cf. Whallon 2011). However, they must have occurred as the population remained biologically viable ostensibly through the exchange of marriage partners. Evidence exists for information transmission and raw goods exchange in the central Netherlands, such as Wommersom quartzite from Belgium[15], particular burial styles (e.g., seated burials), the presence of two distinct projectile point industries, and the differential distribution of deep hearth pits tentatively identified as smoking pits (Andersen et al. 1990; Eriksen 2002; Gendel 1984; Groenendijk 1987; Kozlowski 1973; Louwe Kooijmans 2001a, b; Sulgostowska 2006; Verhart 2000; Verhart and Groenendijk 2005). This evidence suggests that open, permeable boundaries existed between band territories, as goods and information appear to have easily traveled between regions. The main question remaining, then, is how to identify these territories, and how to discern whether the boundaries changed over time. Unfortunately, the extent of interactions between regions and groups in the Netherlands and beyond is not well understood and thus, this objective will be assumed to have been of secondary importance. Further, the lack of storage pits or other storage practices (e.g., evidence for elevated huts,

[15] It should be noted, however, that the designation of Wommersom quartzite as “exotic” may be the product of biased archaeological speculation (Peeters pers. comm.), especially given the fact that very little evidence has been discovered to support the idea of this raw material having a special role (e.g., for ritual tools or inclusion in burials).

baskets, etc.) implies that groups must have relied on one another in times of resource shortage, as a kind of ‘safety net’ against starvation (see Halstead and O'Shea 1989 for a discussion of food sharing as a stress buffering mechanism; O'Shea and Halstead 1989). Further, kin networks, maintained by long distance marriages and exchange relationships, provide an indirect source of resource buffering, as kin can be relied upon during times of hardship.

Mesolithic hunter-gatherers may have periodically aggregated around resource-rich areas, mostly along coastlines (e.g., in Portugal and Denmark), but also inland along rivers (e.g., the Polderweg/De Bruin dune complex in the central Netherlands and the Danube Gates). Typically, group aggregation for hunting purposes tends to focus on intercepting migratory herds at key locales in the landscape (e.g., caribou in northern hemispheres). However, since the majority of large mammals exploited during the Mesolithic were solitary or small-group dwellers, it is assumed that group aggregation would have been formed to target large mammals during breeding seasons (roe deer living in open areas will cluster into groups of 40-90 individuals during the winter; Sempéré et al. 1996) or to gather other seasonally abundant resources (e.g., shellfish, fish, or migratory birds). These aggregations would have served a variety of socio-political needs as well. At these sites, exotic and raw materials may have been exchanged, along with information and marriage partners. Some of this information may have guided future decision-making, although it is impossible to recreate or estimate the extent of such knowledge transmission on adaptive choices. Furthermore, evidence of such grouping is scant and derives mainly in the late Mesolithic. There is an equally plausible possibility, supported by radiocarbon evidence, that many of these sites were used repeatedly over long periods rather than being the location of a large group gathering. Despite this evidence, it is assumed that population aggregation was periodically an important objective guiding residential resource acquisition, most notably because this strategy located people in a central location from which a variety of resources could be gathered simultaneously (see, for example, Archaic evidence from the Saginaw Valley; Robinson 1987). For logistical contexts, population aggregation is not considered to have been an important objective, as people must already be somewhat gathered in order to undertake targeted logistical forays.

Attainment of a basic division of labor, either by sex or age, may have affected hunter-gatherer resource use choices. It is assumed here that hunter-gatherers focusing mainly on large-game had a built-in division of labor, as men generally participate in the tracking, stalking, and killing of the animals, while women, children, and the elderly generally help in processing and preparation of the animals, along with other domestic chores. For this reason, maintaining age and sex differentiation is not considered here as a main objective of resource acquisition.

To conclude, it is assumed that hunter-gatherers put much consideration into resource acquisition costs (Kelly 1995:73), including the energy, time, and risk involved in obtaining sufficient resources, and the potential benefits of group aggregation. However, energy and time minimization concerns have already been shown to be only a secondary factor guiding decision-making (see argument above). Thus, the primary objectives guiding hunter-gatherer resource acquisition choices under Model Large Game were:

- Minimization of risk
- Attainment of the minimum amount of food and non-food resources
- Aggregation of the population

Residential and logistical resource use was thus most prominently affected by the hunter-gatherer desire to target low risk and reliable resources. Large game would have easily satisfied this desire, as their behaviors were likely known and thus predictable, and they supplied high energy and nutrient-rich food packets. For both residential and logistical resource use strategies, the objectives were ranked accordingly (Appendix F: Tables F.1-F.2). The attainment of resources is considered to be equally important as risk minimization at both residential and logistical sites. Aggregation of the population is considered to be strongly less important than resource attainment, and moderately less important than risk minimization, despite the fact that aggregation may be important to processing or distributing food surpluses.

For the decision-making rules, criteria, and evaluation of Model Large Game (see Appendix E). Figure 6.1 below depicts in a visual manner the flowchart of the model.

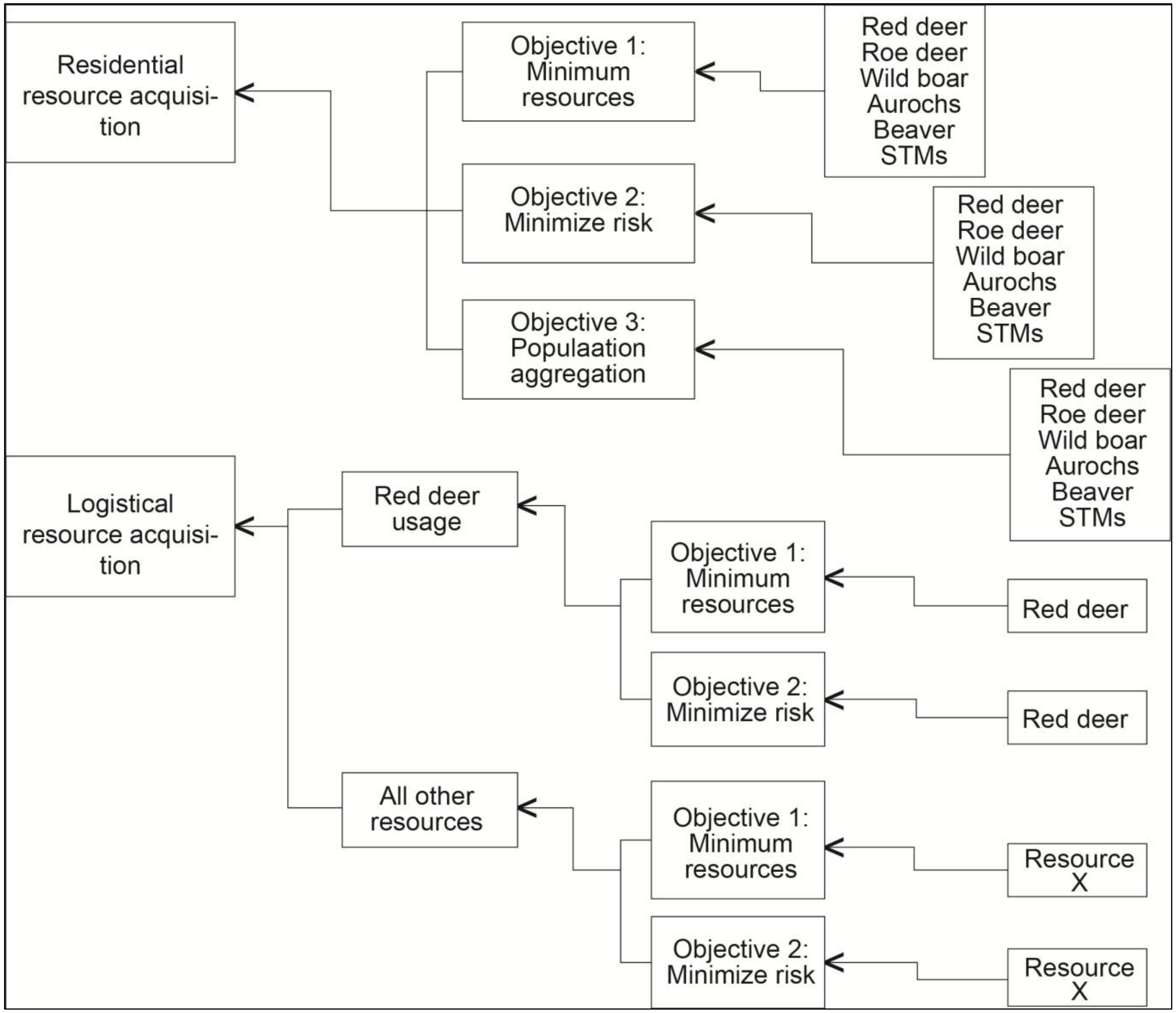

Figure 6.1 Flowchart of Residential and Logistical Resource Acquisition for Model Large Game.

6.4.2 Model General Foraging

Under this hypothesis, Mesolithic hunter-gatherers exploited a wide range of species throughout their territories (Jochim 1998; Manning and Thomas 2009; Christenson 1980; Clark 1987; Edwards 1989; Neeley and Clark 1993; cf. Miracle 1995,1996, 1997; Morales et al. 1998). It is assumed under this model that hunter-gatherers focused on whatever resources were seasonally available, similar to a pattern of resource exploitation followed by various boreal and temperate forest ethnographic groups (e.g., Montagnais [Leacock 1954, 1969]; Mistassini Cree [Rogers 1962, 1972]; Ainu [Watanabe 1968, 1972]; Mistassini Cree [Winterhalder 1981a]). As many of these food and non-food resources were plant species, growing seasons must at least be cursorily addressed. During the Early and Middle Holocene, seasons would have been relatively pronounced. However, by the Atlantic period, winter temperatures approached summer temperatures, making this warm/cold distinction less pronounced. Despite the seasonal fluctuations in resource abundance that certainly occurred, a more holistic picture will be sought in this modeling exercise, in which the overall contribution of certain species to the diet is generated. In this way, one may get an approximate idea of what resources were taken during particular seasons (e.g., with the warm growing season or cool dormant season), simply by applying some knowledge of when particular species are available or at their heaviest body weight. Furthermore, it is assumed that logistical mobility was quite low for hunter-gatherers practicing a generalized foraging strategy, and that resources were acquired by thoroughly covering a group's territory via residential mobility. Thus, logistical mobility will be given a low weight in this stage of the modeling exercise.

6.4.2.1 Objectives. The general foraging model implies that Mesolithic hunter-gatherers considered more than just basic survival needs, as was the case in Model Large Game where attaining the minimum amount of food resources was scored as the most important objective. Not only would hunter-gatherers using the generalized foraging strategy have sought out a wider range of food resources, they also would likely have had a broader array of resource acquisition goals. For example, hunter-gatherers in this model are able to work in a concern for the variety and taste of their food, factors which have been shown in numerous ethnographic examples to be very important to foragers (Jochim 1976). While plants may make up the staple of a band's diet, meat is almost universally preferred and valued highly (Dwyer 1985). In some arctic and subarctic communities, where meat is the principle subsistence resource, different tastes are obtained by consuming various parts of the animal, such as the internal organs, marrow, and even the remains of vegetal-based stomach contents (Spiess 1979). Even among hunter-gatherers with narrow resource bases, provision was made to ensure that the subsistence base remained interesting to the human palate.

Following this discussion and notwithstanding the likely greater reliance on plants and other low-return-rate resources, the attainment of prestige, often through successful or prodigious hunting, was also likely a concern guiding hunter-gatherer decision-making in this adaptive strategy (e.g., Hill and Kintigh 2009; McGuire and Hildebrandt 2005; Riches 1984:237-238; Sharp 1977:383; Thomas 1969:196-197). As has been documented among various ethnographic groups, men can 'show-off' through successful hunting, thereby (according to some) improving their reproductive fitness, so it makes sense for them to continue to pursue hunting even under a generalized foraging strategy (Gragson 1993; Hawkes 1990, 1991, 1992; Hawkes et al. 1991). While men continued to hunt periodically, women took on the burden of gathering most of the food and non-food resources for the group, recognizing the fact that gathering supplies fewer resources in northern latitudes than southern latitudes. Most of the resources targeted by gathering forays had lower return rates, yet in general, these resources are more predictable and less risky to procure. Thus, a basic division of labor would have (perhaps unconsciously) developed itself according to the prescribed roles of men and women regarding food gathering. Population aggregation also would have occurred at various intervals, generally around seasonally abundant resources. By uniting as a larger band with men, women, children, and the elderly to undertake various tasks associated with procurement (see Egan 1993 for a model), temporarily abundant resources could be efficiently taken. In addition to food gathering reasons, population aggregation was also a good time to share environmental, technical, and social information (see Whallon 2011:3)

While all of the above objectives were certainly important in guiding hunter-gatherer resource acquisition choices, basic survival elements were still most crucial. Attaining the minimum amount of food and non-food resources remained the most important consideration of any group following a generalized foraging strategy. Risk minimization was also critical, as resources can and often do vary in their predictability, spatial extent, frequency, and intensity (Kelly 1995:101), all of which pose risk to the survival of hunter-gatherer groups. Hunter-gatherers can mitigate periods of resource stress by broadening their resource base, intensifying the exploitation of the same resources, or expanding the procurement area to include more resources (Hayden 1981a, b). Further, intensification may have involved the use of more patches, or the lowering of resource-return thresholds such that moves between patches were undertaken more frequently. The objective of limiting energy expenditures and time expenditures were probably also important, despite the fact that many gathered resources tend to require a good deal of time and energy to procure. This energy and time expenditure would likely have been balanced by the fact that these resources were low-risk and provided predictable and stable resources. Hunting of large and small game was still a component of the subsistence regime, not only because of the taste and prestige components, but also because game is highly efficient to procure (i.e., similar tracking knowledge, tools, and processing procedures can be used on any animal; Winterhalder 1981; Jochim 1998). These less predictable yet energy minimizing resources would have balanced those resources that were more predictable yet energy and time consuming.

For the above reasons, the primary objectives guiding hunter-gatherer residential and logistical resource acquisition under the general foraging model are:

- Minimum amount of resources (food and non-food)
- Limit energy and time expenditure
- Minimize risk

In addition to these objectives, which are critical for individual and group survival and are thus ranked as "1" for equally important, four other objectives were also included for residential resource use:

- Taste
- Variety
- Prestige
- Population aggregation

These secondary objectives were ranked as "1/3", or somewhat less important, in relation to the three primary objectives. Division of labor was not considered in this modeling, as it was assumed that this objective would have been built into the strategy (i.e., men still hunting, but also fishing and helping out during periods of particular resource abundance; women undertaking the rest of the gathering and trapping activities; Egan 1993). For logistical mobility, dietary variety and population aggregation were not considered, because the express purposes of small task group logistical forays is to obtain specific resources ostensibly to broaden the subsistence base (Binford 1980). Tables F.9 and F.10 in Appendix F present the pairwise comparison matrices for both residential and logistical mobility.

6.4.3 Model Wetland Focus

This adaptive hypothesis assumes that hunter-gatherers found wetlands to be rich and abundant locations for the extraction of aquatic resources. Not only would these resources have been periodically plentiful, they also would have been relatively predictable to foragers (e.g., migratory birds stop in the Netherlands in the spring and fall; anadromous and freshwater fish spawn in the late spring and early summer months; see Appendix C). When these aggregating resources had dispersed, many other species would still be available, albeit in low quantities. Assuming that some preservation and storage of these periodically profuse resources occurred, hunter-gatherers could remain in wetlands and along coastlines for long periods. Consequently, larger and longer-term residential settlements developed, from which small task groups could spread out over the surrounding landscape to gather other resources, bringing them back to the base camp for sharing. Some long-distance trade and exchange occurred, presumably to maintain necessary social connections as well as to obtain resources not available in the wetlands or along coasts (e.g., tool stone, old growth tree trunks for dugout canoes, ochre for ritual purposes).

While such settlements were probably used on a seasonal basis, this modeling will focus on generating maps depicting areas most likely to have been used for residential and logistical resource acquisition. As is known from Pacific Northwest coastal groups in the Americas, bands focused on aquatic resources spend the winters along the coasts and move inland during the summers to extract other abundant and available resources (Kelly 1995:129-130). These ethnographic cases tend to exhibit or engage in only short distance moves, purportedly related to the high population densities that developed over thousands of years. In the Early and Middle Holocene of the Netherlands, however, it is unlikely that population densities reached anything near that of recent Northwest coast fishing societies. Therefore, it is expected that longer distance moves were undertaken, possibly during the winter months.

6.4.3.1 Objectives. As seen previously in Model Large Game and Model General Foraging, obtaining a minimum amount of both food and non-food resources remained a very important and constant objective for hunter-gatherer groups. Perhaps obviously, a group that could not successfully provide for its members would not survive. While a wide variety of prolific resources were available in the wetlands of the prehistoric Netherlands, certain important resources would have been scarce, or at least not as abundant as in the drylands to the east. These resources include large and small game animals, as well as wood (especially long and straight old growth wood) and tool stone. As will be seen below in the criteria section, these non-food resources needs most likely had an important impact, particularly on logistical resource areas.

Within the wetland context, the majority of resources yielded low-return rates. Therefore, it was imperative that hunter-gatherers maximize efficiency in procuring such resources, which would increase the overall return rate. Archaeological evidence from various sites throughout Europe suggest that maximizing efficiency was quite important, as new technologies were developed to extract abundant resources in the least amount of time, and with the lowest energy expenditure as possible. Such technologies included fish weirs and traps, and nets for both birding and fishing. More sedentary shellfish, such as clams and mussels, were gathered in large reed baskets. A larger group of people, perhaps somewhere between a minimal and maximal band (c. 25-50 members) would also streamline the process. Large site complexes like those of Téviec, Hoëdic, and Muge, suggest that population aggregation did occur and may have been a strategy to increase the efficiency of aquatic resource extraction (Bicho et al. 2010; Pequart and Pequart 1954; Pequart et al. 1937). In addition, population aggregation would also have served a number of other social, informational, and ritual purposes. Thus, maximizing efficiency is scored as equally as important as obtaining the minimum amount of resources and population aggregation is scored as moderately less important.

Minimization of risk is yet another consistent objective for hunter-gatherer groups, regardless of the adaptive strategy in use. In the context of the wetland focus hypothesis, risk minimization was certainly a concern, as aquatic resources tend to be rather predictable and stable; that is, they tend to be low-risk resources. Thus, any group practicing this strategy was probably quite intent on keeping risk to a minimum. Residential camps located in resource rich areas allowed for frequent logistical forays into the hinterlands, which would have supplied even more food and non-food resources. The development of efficient technologies and social mechanisms like group aggregation would have increased the overall yield of aquatic resources, thereby decreasing subsistence risk. Further, population fusion at certain times of year would have reinforced the social bonds between families and kin groups, providing yet another buffering strategy against potential risk. Thus, minimizing risk is considered to be a very important objective under this strategy, and is scored equally as important as obtaining a minimum amount of resources.

Obtaining a varied diet may also have been a consideration to hunter-gatherers targeting wetlands, as the main staple was likely to have been aquatic resources and birds. To this basic diet was added other foods such as plants, small mammals, and large game, the latter obtained primarily through logistical forays. However, it is assumed here that the wetlands would have provided a rich array of resources within a short distance from the residential site, and therefore dietary variety is scored as strongly less important. Taste seems to have been another important objective in the wetland strategy, as a variety of high fat content species would have been available in these locations, especially in the wetlands. As was discussed for Model General Foraging, taste can be estimated by looking at the fat content and sweetness of particular foods. Sweetness was probably obtained through extraction of plants (e.g., berries and fruit). Water and migratory birds tend to have high fat contents (e.g., ducks and geese), and thus were probably preferred by hunter-gatherers over other terrestrial birds, such as the moorhen or woodcock. Fish species vary in fat content, but in general freshwater fish like perch and pike tend to be lower in fat than ocean fish like shad and salmon. Therefore, it is probable that when anadromous fish like salmon were spawning, they constituted a highly desirable resource on account of their fattiness. Conversely, shellfish are generally low in fat content, so along coastlines, taste may have been strongly less important than the objectives of minimizing risk and attaining sufficient subsistence resources. For this reason, taste was scored as strongly less important, meaning that it was still a driver brining people to the wetlands, most notably during periods of migratory/water bird and anadromous fish abundance.

Regarding the objective of prestige, large game was still likely considered a prestigious resource, and would have been stalked for this reason and for its high efficiency rates and fat content. The lack of prestige resources in the wetlands suggests that this objective was very strongly less important driving use of these areas for resource acquisition. Table F.24 in Appendix F gives the general objective rankings for residential resource use under Model Wetlands. For logistical resource acquisition, the objectives of dietary variety and population are again left out, as was done for Model Large Game and Model General Foraging (Appendix F: Table F.25).

For the above reasons, the primary objectives guiding hunter-gatherer residential and logistical resource acquisition under the general foraging model are:

- Minimum amount of resources (food and non-food)
- Limit energy and time expenditure
- Minimize risk

In addition to these objectives, which are critical for individual and group survival and are thus ranked as "1" for equally important, four other objectives were also included for residential resource use:

- Taste
- Variety
- Prestige
- Population aggregation

These secondary objectives were scored accordingly, as discussed above. All objective weights will be used below, when multi-criteria evaluations are run in order to determine which areas of the landscape were most likely to have been used for residential and logistical resource extraction.

6.5 Mesolithic Hunter-Gatherer Settlement Placement and Patterning

Cross-culturally, a number of objectives are consistently found to guide hunter-gatherer decision-making in regards to settlement placement and patterning (Jochim 1976:50; Krist 2001:204). These are:

1. Attain proximity to resources;
2. Attain protection and shelter from the elements;
3. Attain a position with a good view to intercept animals and other humans;
4. Attain a location with sufficient ground dryness.

The landscape of the Netherlands during the Early to Middle Holocene changed dramatically, from mixed forest and open grasslands to polarized distributions of dense forests and swamps/marshes at the regional level. All three of the adaptive alternatives presented in this chapter operate under the assumption that in the early Holocene, the landscape was relatively homogeneous—the same general mix of flora and fauna could be found throughout the central river valley. However, by the Boreal and Atlantic periods, variegated regions developed: the vast wetlands of the west and the dense forests of the east. These differing environmental constraints would have led to differing subsistence and settlement strategies by hunter-gatherers, most notably high residential and logistical mobility (large game model); high residential mobility and low logistical mobility (general foraging model); and low residential mobility and high logistical mobility (wetland model). These strategies are not assumed to have been mutually exclusive; however, the timing and duration of these strategies are unknown, as well as ideas about the interplay and overall fluidity with which hunter-gatherers employed these 'poles' of the subsistence and settlement spectrum.

Each adaptive strategy would have had varying requirements for settlement placement. In this model, only external characteristics are considered. Further, each strategy puts primacy on differing factors: for Model Large Game and Model General Foraging, settlement placement was decided primarily based on the location of food resources (e.g., the position of large game, plants, etc.). For Model Wetlands Focus, settlement placement was also decided primarily based on the location of both food and non-food resources, although the latter differ to some extent (e.g., location of firewood, bedding and shelter material, and tool stone). Factors that would have been considered for all models include the relative dryness of the ground, the view afforded by any one position, and the availability of shelter.

For the reasons discussed here, only two settlement models are developed, one that places primacy on the location of food resources (the Forager Model), and one that places primacy on the location of non-food resources (the Collector Model). The Forager Model is used to approximate areas most likely to have been used for residential and logistical sites by hunter-gatherers focused on any of the three hypothesized strategies. Resource use suitability surfaces from Model Large Game, Model General Foraging, and Model Wetlands are used as partial input for calculating suitable settlement areas. The Collector Model is used to approximate areas most likely to have been used for residential and logistical sites by hunter-gatherers. Resource use suitability surfaces developed in the previous section were used as partial input. These models are not intended to be representative of the wide array of different settlement strategies used by hunter-gatherers, but are rather intended to provide a baseline from which further research and modeling can depart.

ESRI ArcGIS™ and PCRaster were used to produce the settlement maps for each hypothesis. See Appendix A for sample scripts and further detail regarding map generation.

6.5.1 The Foraging Model. Briefly, foragers tend to move people to resources, effectively mapping themselves onto available food (and sometimes non-food) resources (Binford 1980). Small residential and logistical sites are not differentiated here, as it is often very difficult, if not impossible, to distinguish between the two. The large residential sites are assumed to have been the location of periodic population aggregation around temporarily abundant resources, during which time, some logistical mobility may have occurred. Small logistical and residential sites are assumed to have been the related to a more logistical resource use, in which people map onto the available resources and make a temporary settlement occupied either by the specific task group (as in the case of a logistical party), or by a small family group (the case for groups practicing high residential mobility). The resulting output maps do not, unfortunately, depict the relationship between residential or logistical sites, whether older, younger, or contemporary. Further, areas suitable for both residential and logistical mobility may overlap spatially.

6.5.1.1 Objectives. It is assumed here that the spatial arrangement of resources was a critical factor driving the placement of settlements under the foraging model (Jochim 1976). The abundance and availability of resources also directly affected how long a group remained in a patch, as well as the type of settlement (be it a short-term residential or logistical site, or a longer-term residential site). Thus, the objective of attaining proximity to resources was given a high rating in terms of its impact on settlement location (Appendix F: Tables F.38-F.39). As discussed in the section on Mesolithic resource acquisition, two primary areas of resource use can be modeled for hunter-gatherers: residential and logistical use areas. Areas used under residential resource use generally contain the remains of residential sites and tend to be large in size. These sites often contain the remains of domestic activities, such as hearths for warmth and cooking, tool manufacturing areas, outlines of shelters, and food debris. A certain amount of trash is expected, as people generally stayed at these sites for a week or longer. Conversely, areas used for logistical resource use only contain small sites, which often yield the material remains of one specific activity. However, some remains of domestic activities may also be found, as hunter-gatherers had to keep warm, maintain tool sets, and eat during such events. Further, a logistical strategy requires the presence of a residential base in the vicinity, so it is expected that strictly logistical extraction camps, small field camps, and larger residential camps would have been used (e.g., as was probably the case for foragers following the General Foraging Model). The non-food resources of wood and tool stone will not be considered here, as it is assumed that wood was plentiful during the Early and Middle Mesolithic, and tool stone acquisition would have been embedded in other resource forays.

Shelter and protection from the elements was also an important consideration for hunter-gatherers focusing on large game, particularly during the winter months. It is not an efficient practice for highly mobile foragers to transport the generally heavy and cumbersome components of substantial structures. Further, hunter-gatherers following the movement of large game had to be perpetually ready to pick up and move their residences, severely limiting the amount of time and effort that could be spent in constructing shelters. In the ethnographic sample, mobile hunter-gatherers tend to rely on temporary and portable tents (e.g., the Netsilik [Balicki 1970]; Montagnais-Naskapi [Leacock 1969]; Cree [Rogers 1972, 1973; Winterhalder 1981]). The archaeological record of Mesolithic Europe has yielded little in the way of structural evidence (and much of this is circumspect), with the exception of a few postmolds, surface hearths, stone-cleared areas, sunken and/or bark-lined floors, and pits (Bokelman 1991; Casparie and Bosch

1995; Fretheim 2010; Gob and Jacques 1985; Kind 1992; Larsson 1990; Louwe Kooijmans 2001a, 2001b; Newell 1980; Radovanovic 2000; Waddington et al. 2003; Woodman 1981).

In the absence of more durable structures, hunter-gatherers may have relied on a number of other ways to protect themselves from the elements, including wearing warm clothing, seeking warmth beneath trees with dense foliage, and/or finding naturally protective areas in the surrounding topography. In particular, wearing multiple layers of clothing made from the skins of animals already adapted to the environment, would have been provided a good deal of protection and was a successful way to cope with exposure to cold temperatures (Gilligan 2008; also see adaptations of the Netsilik, Balicki 1970). Some tree species provide ample protection from wind and precipitation, on account of their dense foliage. Coniferous evergreens (i.e., pine varieties in the Early and Middle Holocene in the Netherlands) tend to provide the most protection to humans and animals alike, especially given that these trees do not loose their leaves in the cold months. Deciduous trees like oak and elm provide ample protection from sun exposure. Further, trees that tend to grow in dense clusters (e.g., alder) would also have provided some measure of protection; however, since alder is assumed to have grown mainly in perennially wet areas, this species was not considered here to be a good source of protection and shelter.

Another way hunter-gatherers could find respite from the elements was to locate sheltered spots in the natural landscape. While the central Netherlands is generally very flat topographically, features such as river dunes, ridges and terraces, coastal beach barriers, small valleys, and ice-pushed ridge formations may have served such a purpose. The eolian-formed river dunes, in particular, consistently formed on the eastern side of rivers and streams, implying that the winds during the Holocene were north-northwesterly in direction. Thus, hunter-gatherers may have sought shelter on the eastern and southern sides of these dunes during the cold and windy winter months. During the Early and Middle Holocene, the Netherlands was already affected by an oceanic or maritime climate, meaning that precipitation levels were generally constant over the course of the year. Thus, it is assumed that protection from at least precipitation was required all year long. For this reason, the objective of obtaining protection and shelter was considered equally as important as proximity to resources in regards to residential settlement placement (Appendix F: Table F.38). For logistical site placement, the objective of protection was ranked as strongly less important, as these sites were used shortly for specific resource extraction, rather than for residential purposes (Appendix F: Table F.38).

The objective of obtaining a position with a view of animals and other people would have largely been a moot issue for hunter-gatherers in the Netherlands, as the gradient of the landscape is very low. However, the edges of river dunes and ice-pushed ridges would have served just such a purpose. In the Early Holocene, these areas would have looked out over a grassy landscape dotted with stands of trees. Both prey and other human groups would have been visible at some distance, although the height of the feature directly affected how far a person could see. By the Middle Holocene, dense forests would have prevented much visibility in the eastern portion of the country, while the river dunes would have remained an important sighting location for hunter-gatherers living in the wetlands. Also, settlements positioned along edge zones between forests and grasslands would have served as beneficial locations for observing many different types of food resources. Among hunter-gatherers following a foraging settlement strategy and high mobility, this objective was not likely a major concern as members of the family or task group were focused on exploiting an already identified resource. Thus, this objective was ranked as strongly less important for residential locations and was not considered with logistical locations.

The objective of placing a settlement on dry ground was also important to hunter-gatherers, especially those living in perennially wet environments (e.g., the west-central Netherlands during the Middle Holocene; Jochim 1976). In the Netherlands, most sites are located on elevated features (such as river dunes, ridges, and terraces), which tend to consist of well-drained, sandy soils. This correlation underscores the importance of ground dryness, at least to residential site location. Some exceptions exist, such as the Jardinga site, where a couple of aurochs were killed and butchered along the banks of fossil meander, and Ooijerhoek Site M, where other targeted extraction activities ostensibly took place on a residual channel. This evidence suggests that ground dryness was much less of a consideration for foragers targeting specific resources, which makes sense given that foragers probably retreated to dry ground once the extraction event was over. Thus, this objective is considered moderately less important score for residential sites, and very strongly less important score for logistical sites (Appendix F: Tables F.38-F.39).

6.5.1.2 Decision-Making Rule. It is assumed that hunter-gatherers using a largely foraging settlement strategy would choose settlement locations based mainly on the objective of resource proximity. These groups traveled the majority of the time in small groups (the nuclear/extended family), but also periodically aggregated into larger bands of about 25 members. Small and large family groups move according to different schedules (Kelly 1995:141); however, to facilitate the modeling process, these differences will be explored only in the aspect of group aggregation. Thus, most sites settled by hunter-gatherers using this strategy would be small and contain components of both residential sites (i.e., domestic activities such as tool maintenance and food processing), as well as logistical sites (i.e., targeted tool types and the remains of specific food/non-food resources). Various sites in the eastern portion of the Netherlands contain both of these elements, and have been variously described as residential camps and resource extraction camps (Ooijerhoek, Groenewoudt et al. 2001; Epse-Noord, Verneau-Peeters 2001; Looërenk, Verneau-Peeters 2002; Verneau-Peeters 2007). This is not to deny that such sites could have been logistical sites that were repeatedly visited over the course of the Mesolithic and even into the Neolithic. However, sites such as the Olthof-Noord/Epse complex certainly had occupations in which a number of activities occurred, including hide, wood, and bone working (scrapers, burins, and awls), along with cores in various stages of utilization, and projectile points in different phases of production. Very little material would have been transported from settlement to settlement, so it is probable that these hunter-gatherers obtained protection from the elements via warm and layered clothing, and topographic features. Further, view was not a large concern, other than targeting edge zones, while the dryness of the ground was an important objective. A site placement grammar can be developed that would have guided the placement of foraging sites:

- Proximity to food and non-food resources is beneficial for settlement
- Presence of sheltering landforms (e.g., river dunes and terraces) is beneficial for settlement
- Presence of sheltering tree species (e.g., pine and oak) is beneficial for settlement
- Absence of dry ground is costly for settlement
- Absence of open areas is costly for population aggregation

These statements were used to guide the evaluation of criteria regarding how well they satisfied the overall objectives.

6.5.1.3 Criteria. Settlement placement is affected by a number of criteria, including the location of suitable resource patches; the presence of certain landform features (such as river dunes and ice-pushed ridges); the distribution of protective tree species; the spatial extent of edge zones; and the degree of wetness of the ground. Proximity to water was added to this modeling exercise as a constraint, as all hunter-gatherers and animal species are in some ways tethered to locations with suitable sources of water (Kelly 1995:126-127). The following discussion applies to criteria for both residential and logistical settlement placement. Any differences in the weight of these factors will be applied later (see Evaluation).

The placement of settlements is generally closely related to the location of rich and abundant resource patches (Jochim 1976). The degree of patch suitability (for either residential or logistical resource use) should have a direct impact on its ability to 'pull', or influence, the placement of settlements. Therefore, all residential and logistical resource use suitability maps for Model Large Game and General Foraging (produced in section 4 above) were used as input criteria for the objective of proximity to resources, which is assumed to be very important to hunter-gatherers using a foraging settlement strategy. These suitability maps depict areas, or resource patches, most likely to have been used by hunter-gatherers under these different strategies for both residential and logistical resource use. The layers depicting either residential or logistical resource use (i.e., areas in close proximity to resources) were employed directly as a measure of areas mostly likely to have been used for residential and logistical site placement. No additional comparison matrices were thus necessary.

For the objective of protection and shelter from the elements, other criteria were drawn upon. Physiographic landform features are assumed to have been an important source of shelter, although not as important as clothing[16]. Features like river dunes and ice-pushed ridges would have been the most protective, especially on the eastern flanks, as the prevailing winds in the Early and Middle Holocene were likely from a north-northwest direction. River dunes and ice-pushed ridges could be found in all study areas, although they became partially drowned in the Polderweg Area by the Middle Holocene. For these reasons, these particular landscape features were scored as the most important, with all other landform features scored as extremely less important. Also, the distribution of some tree species would have been an important criterion in terms of satisfying the need for protection from the elements. Pine, in particular, would have been useful for sheltering purposes and was thus scored as moderately less important than landform features. To a lesser extent, an oak-mix forest would also have provided some protection and shelter, if even just during the summer months. The distributions of this tree mix was scored as very strongly less important (Appendix F: Table F.40).

For the objective of obtaining a view, landform features were again used as a criterion. It was assumed that river dunes and ice-pushed ridges were the most likely features to provide a view from a settlement. Thus, this criterion was scored as the most important (Appendix F: Table F.41). Because edge zones can also provide views of animals, the distribution of such zones was also considered a criterion relating to this objective. Surfaces depicting the intersection of forested and grassland zones were used as input. This criterion was scored as strongly less important than landform features.

[16] Clothing would be scored as the highest-ranking criteria, if this adaptation could be modeled spatially. However, virtually no remains of clothing have yet been recovered from the Mesolithic archaeological record.

For the final objective of obtaining sufficiently dry areas for settlement, only one criterion was considered: the vertical extent of the groundwater table. Such approximates were made in Chapter 4, during the reconstruction of the paleo-hydrology regimes for each study area. It was assumed that locations at least 100 cm above the groundwater table (or classed as ‘dry’ or ‘extremely dry’) would remain sufficiently dry during the whole year, with the exception of large-scale flooding events, which may have only occurred once every generation. This category was scored as the most important regarding the objective of obtaining dry ground (Appendix F: Table F.42). Land that was between 25 and 100 cm above groundwater level (or ‘seasonally wet’) was scored strongly less important, and land that was less than 25 cm above groundwater level (any variation of ‘wet’) was scored as extremely less important.

The last item included in the evaluation of the Forager Model is the constraint of proximity to water. This constraint would have affected choices concerning both residential and logistical settlement placement. Throughout most of the Early and Middle Holocene, many different sources of water would have been available in the study areas, including rivers, streams, intermittent streams, ponds, lakes, wetlands, and marshes. The portability of this water is the main constraint, as very little evidence exists from the archaeological record of the Mesolithic to indicate the use of vessels or other containers (e.g., bags made of animal stomachs, gourds, etc.). However, the areas targeted in this research were all within a day’s walking distance (around 25 kilometers, the length/width of each study area) from plentiful water sources, such as rivers, lakes, streams, or ponds. Further, in the winter, snowfall could also be used to maintain proper hydration. Therefore, it will be assumed in this modeling exercise that water was plentiful and easily accessible to all hunter-gatherers living within the study areas.

It was assumed that forager groups targeting either large game or a wide array of resources would have formed both residential and logistical settlements, as periodic group aggregation likely occurred. The same matrices were used, however, different resource use suitability maps were used as partial input (see Figure 6.2).

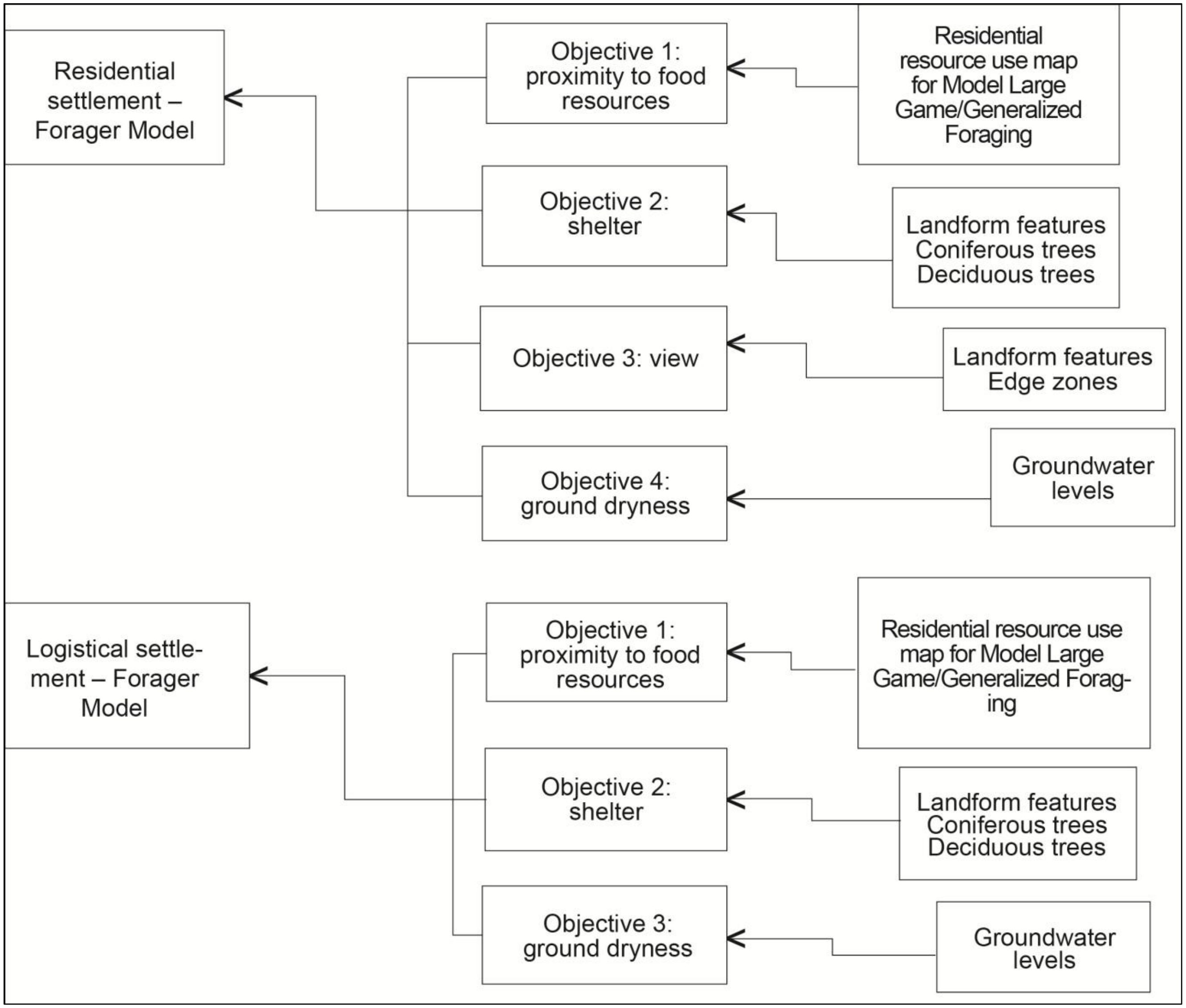

Figure 6.2 Forager Model Flowchart.

6.5.1.4 Evaluation. The criteria weights produced in Tables F.40-F.42 (Appendix F) were applied to the requisite surfaces, resulting in suitability maps. These surfaces were then combined with the resource suitability maps generated in the Resource Acquisition Model (see section 6.4, Model Large Game and Model General Foraging) through a multi-criteria evaluation (Figure 6.2). The final suitability maps depict areas most likely to have been used residentially and logistically by 1) hunter-gatherers focused on large game; and 2) hunter-gatherers using a generalized foraging strategy.

6.5.2 The Collector Model

Under this model, is it assumed that hunter-gatherers preferred to move goods to people, or central to locations, through the use of task-oriented (usually extraction and "field processing") logistical forays (Binford 1980). These central locations were usually residential camps placed in areas of diverse and abundant food and non-food resource potential. For this reason, emphasis is put on settlement locations with a wide range of resources in close proximity, as well as high suitability in other dimensions necessary for human survival (e.g., protection from the elements, ground dryness, proximity to water, etc.). For this model, only the adaptive strategy of targeting wetlands was considered (see discussion above), as this strategy entails the centralized placement of large residential sites, from which small logistical forays can be mounted.

6.5.2.1 Objectives. The objectives for this model are very similar to those discussed above for the Forager Model; however, the objectives have been weighted differently. Within the wetland context, the most important objective would have been to secure a place with sufficient dry ground (Appendix F: Tables 43-44). Especially within wetlands, this was a critical component, as various diseases and bodily maladies can occur if the skin is not allowed to thoroughly dry out. Proximity to food and non-food resources would also have been important, although wetlands are assumed to have been very rich and abundant in food resources during much of the year. Other resources would also have been accessible via frequent logistical forays into the hinterlands, including food and non-food types. The most important non-food resources were probably firewood and implements and tool stone. While most tool stone forays must have occurred during longer-distances trips, wood could be obtained from higher inland areas with relatively little energy (perhaps a day or two's walk). Peat would also have been abundant in wetland areas, which when cut and dried, provides ample burning material. Further, it should be noted that watercraft were likely utilized by hunter-gatherers living in wetlands and along coastlines, which would have streamlined forays inland for such goods, making possible transportation of larger and heavier quantities of raw materials. For this reason, proximity to resources is ranked as equally as important as the objective of finding dry ground.

The objective of obtaining protection from the elements was probably also a constant consideration of hunter-gatherers. As discussed above, it is likely that clothing, topographic features, and trees were used to allay some of these risks to survival. However, in wetlands, topographic features were not as pronounced, many of the river dunes having been partially covered by peat formation. Some stands of trees were still present on these river dune tops and along levees, and may have provided some degree of shelter from wind, sun, and rain. However, it is also possible that with the help of watercraft and a larger population, more permanent shelters could have been built. The objective of shelter is therefore scored as strongly less important than ground dryness (Appendix F: Table F.43).

Lastly, the objective of a view shed to hunter-gatherers wishing to place a residential settlement was probably of some concern. However, this objective becomes marginalized when one considers that the only places with dry ground in a wetland (e.g., river dunes and levees) are also those that are slightly elevated and thus afforded some view. Of course, there may have been some cases in which hunter-gatherers settled on the edges of wetlands, along terraces or ice-pushed ridges, and in these cases, view may have played a more important role in the settlement placement decision-making. Certainly, groups living for large parts of the year in one place can benefit from being able to see what resources are available where, or if neighboring groups have entered their territory. However, it is assumed that group members could gather much of this knowledge while on a logistical foray. For this reason, the objective of obtaining a place with a view will be scored as strongly less important.

For the placement of logistical settlements, the same objectives and rankings are used as in the Foraging Model (Appendix F: Table F.44). That is, proximity to resources would have been the most important objective, following by availability of shelter and ground dryness. View is not considered as an objective.

6.5.2.2 Decision-Making Rule. It is assumed that hunter-gatherers using a collector strategy would have placed settlements in areas with abundant food and non-food resources. Within such an environment, the site need not have been placed precisely in a rich food patch, but close to several such patches. These patches could then be exploited through frequent logistical forays. Sometimes, longer-distance forays also took place (e.g., Lovis et al. 2005), to obtain harder to find raw materials and resources (e.g., straight wood for canoes, tool stone, large game). The residential sites would have been occupied for a few months or more, and a rotation between two or three such camps throughout the course of year was probable. It is also possible that this strategy was countered with more of a foraging strategy at other times during the year, when groups split up into smaller units to alleviate some of the social and resource stress that may have occurred during the long occupation. Logistical sites would have been small, the location of targeted extraction events. As such, the territories of such groups would have been thoroughly searched. Longer distances may have been moved to undertake trade and exchange with other bands, facilitated by watercraft. Further, more permanent shelter and storage structures could be constructed under this strategy, as people were less residentially mobile, and due to the periodic glut of certain resources, had time to divert to the building of such structures. Statements to guide the evaluation are:

- Proximity of non-food (e.g., water) and food resources is beneficial for residential settlement
- Proximity of food resources is beneficial for logistical forays
- Absence of wood and stone sources is costly for settlement and technology
- Presence of dryland is beneficial for residential settlement
- Presence of open water is beneficial for water transportation and subsistence

6.5.2.3 Criteria. Most of the criteria considered in the Collector Model are similar, in not the same, as those discussed above in the Forager Model, recognizing that these are end points on a continuum that emphasizes degree and not necessarily the kind of criteria involved in decisions and strategy. For this reason, these objectives will be mentioned briefly (please see section 6.5.1 Forager Model for more detailed descriptions).

Under the Collector Model, locating a settlement in close proximity to both food and non-food resources was also very important, although it is suggested here that finding a dry location was the foremost goal of hunter-gatherers within wetland contexts, which were generally rich in resources all year long (Appendix F: Table F.43). To evaluate this objective, the previously generated residential and logistical resource acquisition maps for Model Wetlands were utilized (see above for development of surfaces). These cartographic maps depict areas within the landscape most likely to have been exploited by hunter-gatherers for either residential resource extraction or logistical resource extraction. Only a single non-food resource was considered in this modeling—the distribution of tool stone—as this commodity would have been important and difficult to find. While wood may also have been an important non-food resource, it is assumed here that sufficient amounts could be gathered within a day or two's walk from the central residential camp, well within the purview of a logistical foray. It is assumed that other non-food resources like ochre may have been undertaken during long-distance trips to conduct trade and exchange of other goods, information, and people. The maps used in this step are readymade and thus, no further comparison matrices were necessary.

To satisfy the objective of shelter, the same criteria were used as in the Forager Model. That is, the type of physiographic feature was considered, river dunes, terraces, and ridges being ranked the highest. All other features were considered extremely less important (Appendix F: Table F.45). The location of pine and certain deciduous trees (i.e., oak mixes) were also considered and ranked accordingly.

To obtain a good view, the criteria of landform features and the distribution of edge zones was again considered (Appendix F: Table F.46). The location of river dunes, ridges, and terraces was again scored as the most important criterion in terms of satisfying the view shed objective.

All other landforms were scored as extremely less important, as they would have provided no view. The location of edge zones was scored as strongly less important, since these areas would not have provided a view into the distance, but would have increased the visibility of incoming animal species and perhaps even human groups.

Lastly, to satisfy the most important criteria of finding a dry spot to settle, the elevation of land above groundwater was used. Raster maps produced in ArcGIS were queried in PCRaster for this evaluation. As in the Forager Model, areas of land that lie more than 100 cm above groundwater level were scored as most important (Appendix F: Table F.47). Those areas lying between 100 and 26 cm above were scored as strongly less important, and areas lying below 25 cm above groundwater were scored as extremely less important.

The matrices described briefly here were applied to considerations of both residential and logistical settlement areas. The main exception was that the objective of obtaining a view was not considered to drive decision-making in locating logistical settlements.

6.5.2.4 Evaluation. The criteria weights produced in Tables F.45-F.47 (Appendix F) were applied to the requisite surfaces, resulting in suitability maps. These surfaces were then combined with the resource suitability maps generated in the Resource Acquisition Model (see section 6.4.3, Model Wetlands) through a multi-criteria evaluation (Figure 6.3). The final suitability maps depict areas most likely to have been used residentially and logistically by hunter-gatherers employing one of the three hypothesized subsistence strategies.

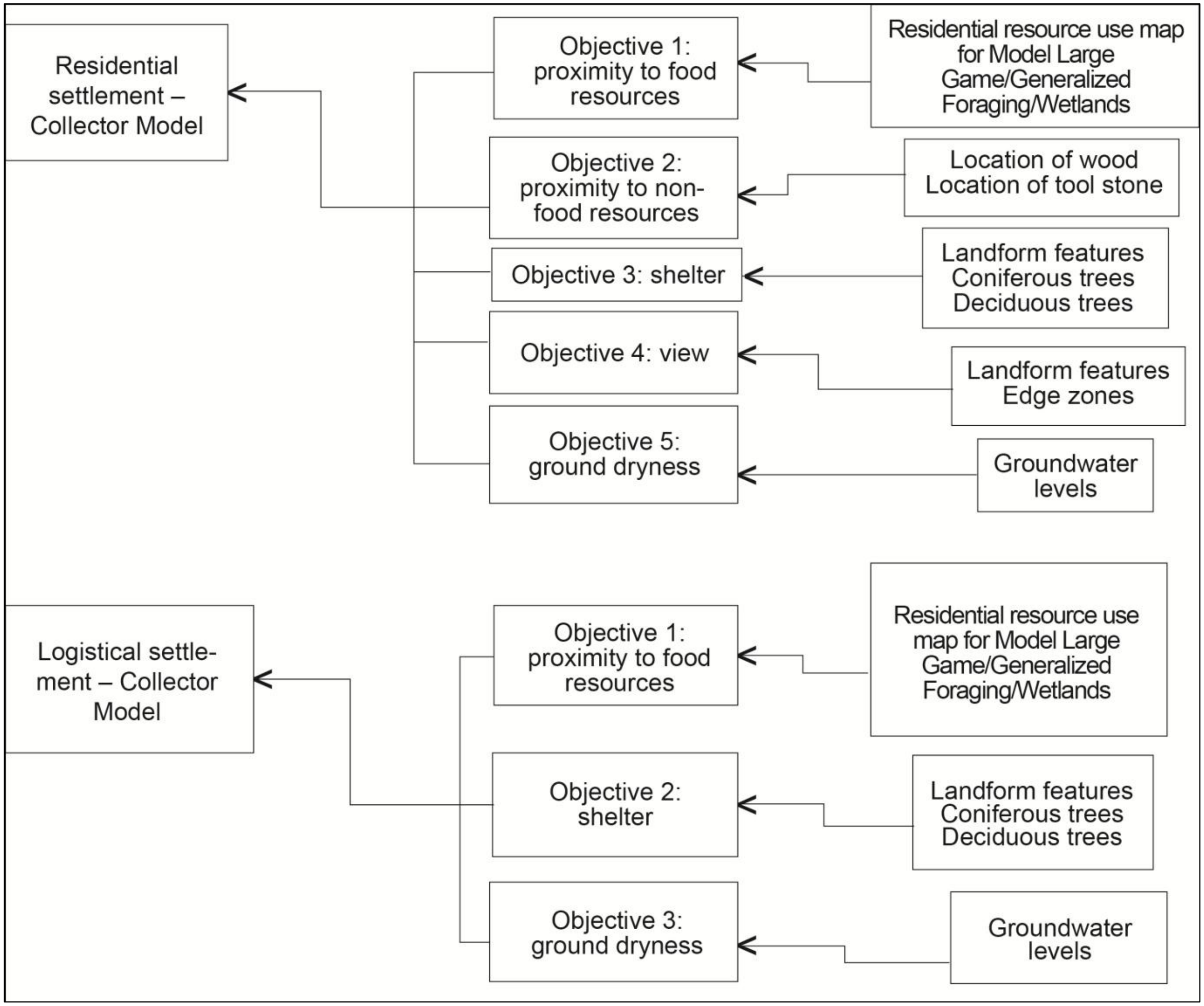

Figure 6.3 Collector Model Flowchart.

6.6 Conclusion

In this chapter, three possible adaptive alternatives utilized by Mesolithic hunter-gatherers were described in detail. To simulate decision-making processes revolving around choices of resource use acquisition and settlement location, each adaptive 'model' was broken down and reformulated within the multi-criteria, decision-making model described in Chapter 5. The resulting maps produced in this exercise depict areas that were most likely to have been used by Mesolithic hunter-gatherers for the residential or logistical resource use and settlement, based on the assumed objectives of these groups, as well as associated environmental characteristics. For each adaptive alternative, a set of simulations was run for each study area and time period. To test the 'fit' of these alternatives, the spatial maps were compared with Mesolithic site distributions from the central Netherlands. The results of these comparisons will be addressed in the following chapter.

Chapter 7

RESULTS

7.1 Introduction

The aim of this research was to investigate decision-making at the group level, the specific case studying involving hunter-gatherers in the central river valley of the Netherlands, 10,000-6000 ^{14}C yr B.P., and approached by means of simulation modeling. Within this aim, the focus was to identify what kinds of decision-making factors were the most important to such groups. The study revealed that resource targeting (that is, where to devote subsistence effort) was an important decision for hunter-gatherers. Further, two related dimensions of resource targeting decision-making were examined:

1. Relative flexibility of mobility in time and space, and
2. Affect of decisions on the relative use of areas and resources in time and space.

Instead of trying to reflect reality, the model developed here is intended as a heuristic device, which allows the researcher to set up constraints on behavior across a range of variables, alter their primacy, and then analyze how these constraints affect the spatial outcome. This research also has an important practical component, in that what is learned about decision-making can be turned into predictions concerning Mesolithic hunter-gatherer land use strategies. Such predictions are useful for planning and heritage management (see section 7.5).

7.2 Modeling Tools

A number of modeling variables, or ‘building blocks’ were incorporated into the model developed for this analysis. These variables fall into three distinct categories: landscape, vegetation, and fauna (see Figure 7.1 below). The following discussion describes how these variables are related to one another in the modeling framework, and how each were modeled in separate ‘modules.’ Consideration is also given to the influence of certain variables on others.

Modeling was performed using PC Raster. PCRaster is an environmental modeling software in which spatio-temporal models can be developed and deployed (PCRaster 2011). The models are scripted for individual projects using a number of basic and analytical functions available through the program, many of which involve different types of map algebra transformations. The program is used primarily for simulation and prediction in the fields of geography, hydrology, ecology, etc., but its uses and benefits can be applied widely beyond these fields.

The software works on a spatially organized scalar cell-based platform, similar to ASCII. Each cell contains a value pertaining to the information held in that map, such that an individual cell in an elevation map will contain an elevation measurement in the scale specified by the researcher. All the maps are assigned a geographic extent, which stipulates the coordinates of the map according to a specified Earth projection. In addition, the map must contain a value scale, which stipulates the type of data contained in the map (e.g., Boolean, nominal, ordinal, or scalar). The value scale will determine what type of map operations can be undertaken in the program. Operations and functions can be carried out on individual cells or on cells within a specified spatial “neighborhood”.

One of the main benefits of using PCRaster generally, and in its application to this analysis, is its capacity for running dynamic models that allow for scripts to run various map operations over a defined number of iterations or time steps. New map attributes that are computed in individual iterations can be strung into the model over time. The software also has two useful program plug-ins: Aguila and MapEdit. Aguila allows the user to view maps and animations, while MapEdit enables freehand editing of any map on a cell-by-cell basis.

In this study, PCRaster was used in conjunction with ESRI ArcGIS. For each study area, landscape reconstruction maps, paleo-groundwater maps, Digital Elevation Models (DEMs), etc. (see Appendix A for a full list) created in ArcGIS were exported to PCRaster, where they were stacked. Vegetation surfaces were generated from a script module that queried different landform, groundwater, and elevation characteristics. For example, reed-sedge vegetation was assumed to occur in river valleys, floodplains, and floodbasins with a groundwater level between -101 and -50 cm (again, see Appendix A for more detail). Similarly, faunal suitability maps were generated from stacked vegetation and landform maps. In addition, edge zone maps were created by intersecting forested and open areas.

7.3 Description of Modeling Variables

7.3.1 Landscape. Landscape variables were derived from input spatial data including reconstructed landform (geomorphologic-geologic) maps, Digital Elevation Models, Depth to Sand map, a groundwater rise model, and soil maps (see Appendix A for further description of these spatial data). These spatial data were combined into intermediate output maps for all study areas and time intervals. The output maps took two forms: composite paleo-geomorphologic maps and composite paleo-hydrology maps. The maps produced in this module were used as boundary conditions for each time interval. They were derived in a deterministic manner, based on the most up-to-date bore hole and ^{14}C data available, courtesy of the Faculty of Geosciences at Utrecht University.

7.3.2 Vegetation. Vegetation variables were derived directly from some of the landscape variables discussed above. Vegetation development was assumed to be related to five main factors: groundwater level, lithology, soil, climate, and succession. These factors were considered in different degrees, according to data availability. The variables of groundwater level and lithology (via the proxy of landform type; see Appendix A for more detail) were drawn upon most directly.

Six vegetation zones were selected to represent the different types of habitats present during the Early to Middle Holocene. The composition of species within each vegetation zone was determined based on known growth requirements and community tendencies (see Appendix B). Output maps for each study area and time interval were created by querying the landscape data for specific landform type and groundwater level characteristics. Thus, the quality of these maps is directly related to the quality of the composite paleo-landscape maps developed in the first module. The vegetation output maps depict the spatiotemporal distributions of assumed vegetation zones.

7.3.3 Fauna. Faunal suitability distributions were calculated based on four main criteria: availability of food, water, cover, and space. In this study, food availability and cover were focused upon due to modeling and data constraints. A number of species were selected for modeling, although some composite groups were also created to facilitate the use of those species that may not have made up a large part of the Mesolithic diet. However, the goal of this modeling was not to estimate how many of a particular species lived in a given habitat during a set time, but rather to predict areas that would have been more suitable to a given species than others.

Vegetation zone data from module two, along with some landform data (in the case of edge zones) and knowledge of habitat requirements and community composition was used to model faunal suitability. Thus, the faunal suitability maps are primarily dependent on the quality of the vegetation maps, which are themselves dependent on the initial landform data for overall quality. Output maps were created by assigning relative suitability values for specific vegetation zones for given faunal species. The resulting product consisted of spatiotemporal distributions of assumed areas of higher or lower habitat suitability.

All three modules (landscape, vegetation zones, and faunal suitability distributions) were used as intermediate input for the modeling of behavioral adaptions. For more information on this module, please see Chapter 6.

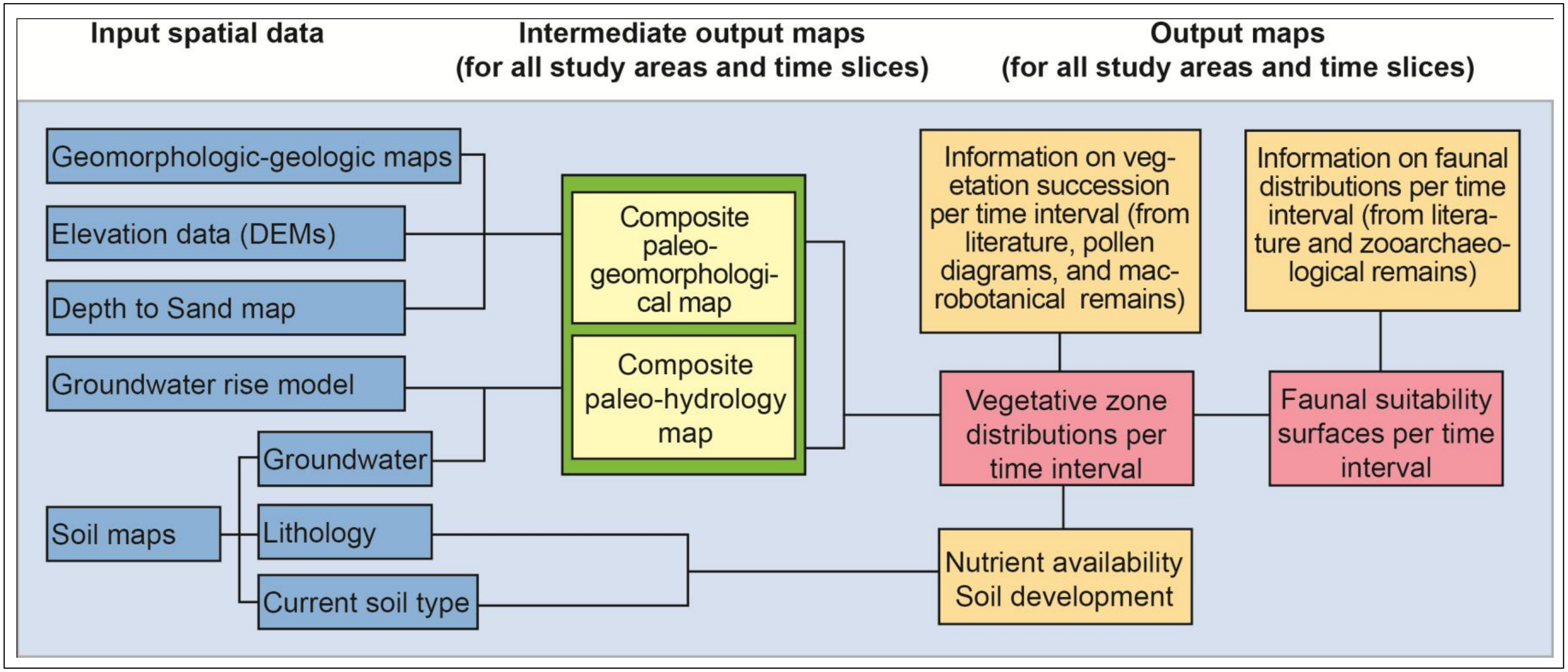

Figure 7.1 Modeling Components and Procedure (redrawn from Pierik 2010:22).

7.4 Caveats of the Data

Before continuing on to discuss the results of the modeling undertaken in this study, some important limitations of the data must be discussed. As can be seen from Figure 7.1, the modeling is in many ways deterministic. The output maps are based primarily on the distribution of geologic-geomorphological features and groundwater levels. These output maps are thus only as good as the input spatial data. Uncertainties are introduced to the data when vegetation zones are assigned to various combinations of physical and groundwater features in the paleo-landscape. The faunal distribution maps were similarly constructed from the vegetation zone maps, and thus, any biases or uncertainties that occurred in the latter became compounded in the former. With each successive step in the landscape modeling, the modeled environmental context becomes more speculative. Steps were taken to alleviate some of this uncertainty (such as consulting the pollen record, and looking at macrobotanical and zooarchaeological remains); however, the biases of the modeling process cannot be entirely removed and are therefore recognized and accepted. Further, one could argue that future incarnations of the model should take measures to alleviate some of the inherent determinism, but again, such a step would require further field work and data collection. Thus, it was felt that given the scope of this study, accepting the biases and uncertainties inherent in the data was the only route to take.

It should also be noted that the amount of bias in the data is not the same in all three study areas, due to varying amounts and qualities of input data. The most well-supported area is probably the Polderweg area, where much coring and reconstruction of the subsurface has been undertaken (e.g., Berendsen and Stouthamer 2001; Bos 2010; Cohen 2003; Hijma 2009; Weerts 1996; Stouthamer 2001). The Ooijerhoek and Deest areas have not received as much research attention, although some coring projects have been carried out (e.g., Cohen et al. 2010).

Furthermore, many archaeological excavations have taken place in the Ooijerhoek area, along with palynological studies that have attempted to reconstruct local habitats (e.g., Bos et al. 2005). Reconstructions of these areas could be greatly improved with more pollen- and plant-based reconstructions of the Post-glacial landscape. Perhaps the least well-understood area is that of Deest, where the subsurface has undergone much river reworking by the Rhine and Meuse. Currently, the data for this area are rather coarse, so more refined reconstructions could be achieved with more fine-grained coring campaigns. Further, it may be that more coring work will yield only little additional information about the evolution of the landscape during the early and middle Holocene. To summarize, the output maps developed here are least able to explain the situation in the Deest area and best able to explain the Polderweg area. That said, what is presented below about all three areas is only a speculative ‘best guess’ about the development of the physical and biotic landscape in the early Post-glacial.

7.5 Results

This study was driven by a question-based approach to understanding hunter-gatherer decision-making in regards to subsistence-settlement pursuits. Given that dramatic changes were occurring in the external environment at a broad scale (see Chapter 4), the following questions were posed:

1. What strategies are predicted by the model to be most suitable at the known sites, and how do they compare with the archaeological record?
2. Does environmental and ecological change over time affect the relative suitability of habitats for different hunter-gatherer strategies at the local level?
3. To what degree do different resource foci affect the suitability of an area?

4. How much flexibility did hunter-gatherers have in terms of organizing subsistence-settlement strategies?
5. To what degree do different decision-making objectives and criteria alter spatial output?
6. How do sub-regions relate to one another? Do they function across space as integrated resource zones, or are they discrete? Is there change over time in this aspect?

In the following sections, each of the above questions will be discussed in detail and results will be presented to support the inferences.

7.5.1 Question 1. The first question posed in this study asks what strategies are predicted by the model to have been most suitable at the known archaeological sites, and how these outputs compare with the archaeological record. It is important to recall that the model outputs discussed are for heuristic purposes, and are not intended to represent reality. However, these outputs can still be compared with the archaeological record in order to determine the subsistence-settlement strategies most likely to have been carried out at a particular site and time. The comparison of the model outputs and archaeological record can also help to inform predictions about what types of subsistence-settlement strategies were used for places and time periods that currently lack archaeological data (see section 7.5).

7.5.1.1 De Bruin. The dune site of De Bruin, in the downstream Polderweg area, was occupied from about 6700-5400 ^{14}C yr B.P.[17], from the middle to late Atlantic. This period spanned the end of the Mesolithic[18] and into the early Neolithic, when animals were first domesticated. Thus, the site provides a crucible for studying the transition to a Neolithic way of life, or neolithization (see e.g., Louwe Kooijmans 2001a, 2001b; Raemaekers 1999). Inhabitants of the site depended on a large variety of animals, from large game, to fowl and fish. Beaver and otter were targeted for their furs and a diverse array of vegetation was collected, including nuts, fruit, and tubers. The presence of many flint cores and complete stone tool kits (along with antler implements) suggests that the site was used at one time as a base camp. The production of wooden implements, including dugout canoes, strengthens this argument. Excavators believe that the site was used initially as a cold-season base camp, and was later used primarily in the warmer months as a logistical extraction camp.

The model developed in this study predicts that a collector strategy was used at the site to gather large game, non-preferential resources, and wetland resources (Appendix G: Figure G.1; Table 7.1). Further, the model indicates that the site was viable for residential settlement from 7000-6000 ^{14}C yr B.P., after which logistical strategies may have become more successful, although to a lesser degree. These findings correlate well with what is known from the archaeological record.

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[17] All dates are reported as uncalibrated radiocarbon (^{14}C) dates.

[18] One of the notable characteristics of the De Bruin and Polderweg sites is the discovery of a non-agrarian, but ceramic-producing Mesolithic.

Table 7.1 Viable Subsistence-Settlement Models at De Bruin.

Site	Time period (^{14}C yr B.P.)	Model	Suitability
De Bruin	7000-6000	Collector Model, large game focus, residential settlement	Medium
	7000-6000	Collector model, general foraging focus, residential settlement	Medium
	7000-6000	Collector model, wetland focus, residential settlement	Medium

7.5.1.2 Polderweg. Similar to De Bruin, the Polderweg site was also a dune top site that was inhabited from c. 6800-5800 ^{14}C yr B.P. A diverse array of resources were hunted and gathered there, from wetland resources to large game, although fish was the staple resource. The site appears to have been used most frequently during late winter, but also in the fall. Unlike De Bruin, Polderweg yielded no evidence of neolithization. Some depressions in the dune sand, and associated postholes, may represent sunken hut structures. Along with this evidence, the presence of human and dog burials suggest that Polderweg served as a semi-permanent base camp for complete families. Further, a broad spectrum of activities were been identified through a variety of tools and implements (Louwe Kooijmans 2001a).

The model developed here predicts that hunter-gatherers using the Polderweg site would have had more flexibility in terms of the strategies they chose to use (Appendix G: Figure G.2; Table 7.2). These people probably collected most of their resources, bringing them back to a central base camp, although some foraging may also have occurred. Furthermore, the analysis here predicts that collecting large game and non-preferential species by placing a residential settlement in close proximity to those resources was highly viable, while wetland resources could be more successfully gained by logistical forays. These predictions correspond closely with the archaeological remains and interpretations of the Polderweg site.

Table 7.2 Viable Subsistence-Settlement Models at Polderweg.

Site	Time period (^{14}C yr B.P.)	Model	Suitability
Polderweg	6500-6000	Wetlands, logistical resource use	Medium
	7000-6000	Foraging model, wetland focus, logistical settlement	Medium
	7000-6000	Collector model, large game focus, residential settlement	Medium
	7000-6000	Collector model, general foraging, residential settlement	Medium
	7000-6000	Collector model, wetland focus, logistical and residential settlement	Medium (logistical higher, residential lower)

7.5.1.3 Deest. The archaeological investigation area referred to as “Deest” in this report refers to a number of small archaeological scatters that have been uncovered over a series of excavations (e.g., Boer and Baetsen 2001; Van Beek and Hamburg 2005; Krist and Veldhuis 2003). The area lies atop a ridge surrounded by lower areas and a river channel, which is known to be a favored location of Mesolithic hunter-gatherers (see Epse-Olthof below; Peeters 2007). One of these scatters in particular has yielded both Mesolithic remains and a matching radiocarbon date (6187±50 ^{14}C yr B.P.). The remains consisted of charcoal, burned clay, and burned and unburned bone, as well as some flint. Location 8, in particular, appears to represent a site occupied briefly and perhaps frequently for specific hunting activities. It is also possible that Location 8 was used by early Neolithic farmers who were supplementing their domesticated diet via hunting, although it is equally likely that late Mesolithic hunter-gatherers used the site. Furthermore, the overall paucity of archaeological remains from the Deest area may be related to the fact that sites were very small and deeply buried below the modern-day surface.

The model developed here predicts that the site of Deest was relatively unsuitable for either foraging or collecting strategies (Table 7.3). Large game was likely targeted via residential resource use (see higher, yet still unsuitable, values in Table 7.3), and non-preferential resources could be obtained with either residential or logistical extraction. Wetland resources appear to have been taken more sporadically, generally via logistical resource use. These scant results for the site of Deest are likely related to the coarseness of the data for this area. Further, in the general Deest area, river reworking and low sedimentation has left little in the way of archaeological or geologic-geomorphologic remains. Conversely, it may be that future excavations that penetrate to deeper depths will reveal new finds. Whatever the case, Mesolithic people *did* live in this area, yet the model developed here does not suggest the area was highly viable for the hypothesized strategies, so perhaps other strategies were used or perhaps the modeling input data needs to be reconsidered.

Table 7.3 Suitability of Subsistence-Settlement Strategies for the Site of Deest.

Model	Time Period (^{14}C yr B.P.)	Resource Use/Settlement Type	Suitability Score	Rank
Model Large Game	7000-6000	Residential	19.84	Unsuitable
		Logistical	4.26	Unsuitable
Model General Foraging	7000-6000	Residential	19	Unsuitable
		Logistical	21	Low
Model Wetlands	7000-6000	Residential	7.8	Unsuitable
		Logistical	14	Unsuitable
Forager Model, large game focus	7000-6000	Residential	1.8	Unsuitable
		Logistical	0.2	Unsuitable
Forager Model, general foraging focus	7000-6000	Residential	1.7	Unsuitable
		Logistical	3	Unsuitable
Forager Model, wetland focus	7000-6000	Residential	0.2	Unsuitable
		Logistical	4.1	Unsuitable

Table 7.3 (cont'd).

Collector Model, large game focus	7000-6000	Residential	1.4	Unsuitable
		Logistical	0.2	Unsuitable
Collector Model, general foraging focus	7000-6000	Residential	1.3	Unsuitable
		Logistical	0.2	Unsuitable
Collector Model, wetland focus	7000-6000	Residential	0.4	Unsuitable
		Logistical	4.1	Unsuitable

7.5.1.4 Zuiderveld-West. The site of Zuiderveld-West is located within the basin of the Waal River on a natural levee. The site lies in a relatively depressed and wet area of the Rhine basin, so excavations could not proceed further than 1.5 m below ground surface, making it possible that prehistoric finds still remain buried below that depth. In total, 73 lithics were recovered from various chronological periods. A few of those dates hover around the late Mesolithic (c. 6500-6000 ^{14}C yr B.P.). Some 18 artifacts were found in a single horizon and were thought to be Mesolithic in age based on their technological characteristics, consisting mainly of flakes and blades (Broeke 2002; Haarhuis 1995, 1996). It is possible that these scant remains represent a highly transitory extractive camp, where expedient tools were discarded. It is equally possible that the remains were disturbed from their initial deposit location through river action, or that they represent the remains of a poorly preserved site. Either way, it is nearly impossible to make any solid conclusions about Mesolithic hunter-gatherer use of this area.

Similar to the case for the site of Deest, the model developed here predicts that no strategies were particularly successful at the site of Zuiderveld-West (Table 7.4). Large game, non-preferential resources, and wetland resources could be obtained within the overall area, but within a 200 m area around these sites the suitability of these resources was not high. This evidence strongly indicates that these "sites" may simply be the result of secondary depositional processes, caused by river disturbance. It is perhaps more likely that hunter-gatherers would have used the upland margins as residential locations, from which to stage forays into the river valley or forested hinterland. Furthermore, it is possible that some Mesolithic sites existed on dune outcrops and levees adjacent to contemporary river meanders, but that these areas have since been obliterated through river actions.

Table 7.4 Suitability of Subsistence-Settlement Strategies for the Site of Zuiderveld-West.

Model	Time Period (^{14}C yr B.P.)	Resource Use/Settlement Type	Suitability Score	Rank
Model Large Game	7000-6000	Residential	22.3	Unsuitable
		Logistical	5.5	Unsuitable
Model General Foraging	7000-6000	Residential	26.7	Unsuitable
		Logistical	21.8	Low
Model Wetlands	7000-6000	Residential	7.9	Unsuitable
		Logistical	15.1	Unsuitable
Forager Model, large game focus	7000-6000	Residential	2.4	Unsuitable
		Logistical	0.4	Unsuitable
Forager Model, general foraging focus	7000-6000	Residential	3.3	Unsuitable
		Logistical	3.5	Unsuitable
Forager Model, wetland focus	7000-6000	Residential	0.7	Unsuitable
		Logistical	2.7	Unsuitable
Collector Model, large game focus	7000-6000	Residential	3.4	Unsuitable
		Logistical	0.4	Unsuitable
Collector Model, general foraging focus	7000-6000	Residential	3.8	Unsuitable
		Logistical	0.4	Unsuitable
Collector Model, wetland focus	7000-6000	Residential	1.7	Unsuitable
		Logistical	2.7	Unsuitable

7.5.1.5 Epse-Olthof. The site complex of Epse-Olthof lies atop a series of river dunes that run southeast-northwest adjacent to the Dorther Creek. Multiple excavations have been conducted on this parcel. A small concentration of Mesolithic flint remains were recovered (216EN), consisting of hunting and domestic tools and dating from c. 9500-7800 ^{14}C yr B.P. At this location, it appears that a narrow range of activities were undertaken, namely hide scraping and hunting tool production, suggestive of a temporary hunting camp, from which further extraction activities were mounted (Verneau 2001). Other scatters of Mesolithic material were recovered to the north of 216EN during the 270ON excavation. A number of hearth pits were recovered and of the 21 sampled hearths, all returned early-middle Mesolithic dates. Unfortunately, no features other than these hearth pits were found to indicate the type or duration of the occupations. The limited range of tools suggests that the area was used at least once as a base camp, and the presence of many hunting tools indicates that the ridge was also used as a gearing up or logistical camp for procuring resources. It is also possible that some fishing and birding occurred at the site, although preservation has not allowed for the recovery of such sensitive ecofacts and artifacts (e.g., bird bones, fish scales, fish weirs, etc.). However, it is certain that Mesolithic people were collecting hazelnuts and burning their shells, most likely for consumption, as attested to by a large number of charred hazelnut fragments. It may be concluded that the Epse-Olthof area was used perhaps a few times during the early Mesolithic as a residential camp, or more frequently as a hunting/extraction camp. The main focus of activity at these times seems to have been the production of hunting tools and other basic tools for the primary processing of animal products (e.g., scrapers and sharp flakes and knives). By the middle-late Mesolithic, the site was not forgotten, but activity appears to have shifted to other parts of the Netherlands.

The model used here predicts that the Epse-Olthof site was most viable for the collecting of large game and non-preferential resources (Appendix G: Figures G.3, G.4, G.5; Table 7.5). It appears that hunter-gatherers had some flexibility as well, such that foraging of large game and non-preferential resources was also a potentially successful strategy to offset collecting. Both residential and logistical settlements tend to be useful for extraction of these resources, although from 9500-9000 ^{14}C yr B.P. residential settlement was more suitable, while from 8000-7000 ^{14}C yr B.P. logistical settlement was more suitable. During the Boreal, the model predicts that collecting non-preferential resources using logistical settlement would have been highly successful. Some collecting of wetland resources was also a successful strategy, but only during the wetter Preboreal period. These model predictions closely mirror what is known about activities and land use strategies utilized at the site of Epse-Olthof. Although the archaeological record is unclear about individual activity events due to extensive overlapping of archaeological deposits and low sedimentation, it is possible that a variety of subsistence-settlement strategies may have been used over the 2500 years during which the site was occupied.

Table 7.5 Viable Subsistence-Settlement Models at Epse-Olthof.

Site	Time period (^{14}C yr B.P.)	Model	Suitability
Epse-Olthof	9000-7000	Large game, residential or logistical resource use	Medium
	9000-7000	General foraging, residential or logistical resource use	Medium
	9000-7000	Foraging model, large game focus, residential or logistical settlement	Medium
	9000-7000	Forager model, general foraging focus, residential or logistical settlement	Medium
	9500-8000	Collector model, large game, residential settlement	Medium
	9000-7000	Collector model, large game focus, logistical settlement	Medium
	9500-8000	Collector model, general foraging focus, residential settlement	Medium
	9000-8000	Collector model, general foraging, logistical settlement	High
	8000-7000	Collector model, general foraging, logistical settlement	Medium
	9500-9000	Collector model, wetland focus, residential settlement	Medium

7.5.1.6 Ooijerhoek. Located in a transitional zone between a stream valley and a river dune, the Ooijerhoek site complex originally sat on an island that looked out over a wetland environment. The stream joined with another, just south of the sites, and became part of a southward-flowing drainage system. Most of the sites occur on the top of the dune, while one site was found in the depression of the fossil meander itself (e.g., Verneau 1999; Verneau and Peeters 2000/2001; Groenewoudt et al. 2001; Bos et al. 2005). It appears that the sites on top of the dune were hunting camps in which hunting tools were prepared and maintained and some primary processing of resources occurred. In the channel, it appears that some of this material was tossed, perhaps as part of a 'clean-up' effort. Further, there is some evidence to suggest that active burning of the reeds and sedges occurred along the margins of the stream valley, perhaps to attract sun-loving food species like deer. The site has yielded dates between 9200 and 7100 ^{14}C yr B.P.

The model developed here suggests that a collector strategy was almost always the most viable strategy, and could be used to obtain large game, non-preferential resources, or wetland resources (Appendix G: Figures G.6, G.7, G.8; Table 7.6). In fact, wetland resources appear to have been a successful strategy for the entire period, which accords well with what is known about the location of the Ooijerhoek sites next to a small relict river meander. The model also predicts that the site would have been most viably exploited through residential settlement. Most likely, these residential camps were short-term locations where hunter-gatherers could access a number of different resources in the near vicinity. Also interesting is that the model does not predict large game to be particularly useful until the early Atlantic, a time when forests were increasingly dense and hard to penetrate. This finding contradicts Bos et al. (2005), who posit that human presence in the Ooijerhoek area declined with increasing forest density (Bos et al.

2005:40). Dense vegetation tends to make animal tracking more difficult, which would certainly hamper the ability of hunter-gatherers to make a viable living in the area; however, the evidence of fire-clearing around the waters' edge may explain an alternative strategy used to attract herbivores to the location.

Table 7.6 Viable Subsistence-Settlement Models at Ooijerhoek.

Site	Time period (^{14}C yr B.P.)	Model	Suitability
Ooijerhoek	8000-7000	Collector model, large game focus, residential settlement	Medium
	9000-7000	Collector model, general foraging focus, residential settlement	Medium
	9500-7000	Collector model, wetland focus, residential settlement	Medium

7.5.1.7 Looërenk. The Looërenk site complex consists of two primary artifact assemblages, one (WP167; c. 8900-8000 ^{14}C yr B.P.) lying along the edge of a stagnant fen, the other (WP82; c. 8900 ^{14}C yr B.P.) lying on a coversand ridge along the western edge of the excavation. A pit was also found yielding a radiocarbon date of 7230±50 ^{14}C yr B.P. WP167 displayed only a limited range of tools, suggesting the site was the product of one or a few focused extraction activities. Given the location of WP167, it is possible that this specialized, non-domestic activity area was related to birding or fishing. Nearby, in the fen depression, a cluster of about 400 cylindrical pits was discovered, with an average diameter of 25 cm and depth of 10-20 cm. The lack of stratigraphy in the pits suggests they were dug in a short period, perhaps one or two events. These pits have tentatively been explained root extraction pits, although no clear archaeological correlates are known from the Netherlands. The rhizomes of edible plants such as arrowhead may have been the target of such digging (Fermin, in Bouwmeester 2008). A piece of oak bark from within one of the pits yielded a radiocarbon age of 7230±50 ^{14}C yr B.P., suggesting the pits were dug in the late Mesolithic. Also noteworthy is the discrepancy between a high number of backed blades and a very low number of blade cores, which suggests that the blades were produced elsewhere and cached at WP167. Alternatively, the blades may have been produced on the spot, but the unexpended cores removed to a different location.. WP82 also yielded a narrow tool spectrum, and the remains of two possible surface hearths with scattered charcoal debris. Though small, this cluster does appear to represent a small-scale, ephemeral event that focused on creating expedient tools for immediate usage. Unlike the assemblage from WP167, no specific resources seem to have been targeted at WP82; rather, some all-purpose, generalized tools were produced, most likely for a wide-range of activities.

The model developed here suggests that both foraging and collecting of large game and non-preferential resources were highly suitable strategies (Appendix G: Figures G.9, G.10; Table 7.7). Further, hunter-gatherers would have had high flexibility between strategies, except for collecting wet resources, which would have been more viable if following a collector/residential settlement strategy. This appears to correlate well with the location of WP167 along a stagnant fen, from which various wetland resources could be exploited, including plants. Large game and non-preferential species could easily be exploited from the edges of the fen, perhaps in an opportunistic manner, as suggested by the presence of expedient tools. The purported cache of backed blades may have been intended for birds or other specific resources.

Table 7.7 Viable Subsistence-Settlement Models at Looërenk.

Site	Time period (^{14}C yr B.P.)	Model	Suitability
Looërenk	9000-7000	Large game focus, residential or logistical resource use	High
	9000-7000	General foraging focus, residential or logistical resource use	High
	9000-7000	Foraging model, large game focus, residential or logistical settlement	High

Table 7.7 (cont'd).

9000-7000	Foraging model, general foraging focus, residential or logistical settlement	High
9000-7000	Collector model, large game, residential or logistical settlement	High
9000-7000	Collector model, general foraging focus, residential or logistical focus	High
8000-7000	Collector model, general foraging focus, residential settlement	Medium
9000-7000	Collector model, wetland focus, residential settlement	Medium

To conclude, the model developed here compares well with the archaeological data. At the end of the Mesolithic period, the downstream area was best exploited through collecting strategies, while the upstream locations could be viably exploited through either collecting or foraging strategies through most of the period. The close correlation of the model and the data will allow further predictions to be made about potential land use choices of hunter-gatherers in section 7.5.

7.5.2 Question 2. The second question posed above asks whether the suitability of different habitats for particular hunter-gatherer subsistence-settlement strategies were affected by change over time in the external landscape. This question can be answered by inspecting the spatial outputs of the modeling exercise in Chapter 6, as well as by calculating the proportion of suitable locations within each location. It may be said that changes in the environment do seem to affect the suitability of habitats for hunter-gatherer strategies. For example, from 8000-6000 ^{14}C yr B.P. in the Polderweg area, environmental reconstructions show that the landscape became increasingly waterlogged and was dominated by semi-aquatics and aquatic vegetation (see Chapter 4, Figure 4.10). The main dry areas were river dune tops and levees, and consequently, the most viable strategy for hunter-gatherers in this 10 km^2 area became a wetland-focused strategy (Appendix G: Figure G.11, G.12; see section 7.5 and associated figures for discussion of how the area may have been used prior to the Atlantic).

In the Polderweg area, focusing on wetland resources became much more successful over time, in keeping with the transformations known to have been occurring in the environment (Appendix G: Figure G.11; see also Figures G.42, G.43). Figure G.11 in Appendix G shows that a residential resource extraction strategy was less suitable for the collection of wetland resources than a logistical resource extraction strategy, at least from 7000-6500 ^{14}C yr B.P. However, from 6500-6000 ^{14}C yr B.P., both a residential and logistical strategy focused on wetland resources would be quite successful. Neither strategy was acceptable for obtaining large game or non-preferential resources.

When subsistence-settlement strategies are considered, further evidence of change over time in the suitability of different strategies can be seen for the Polderweg area (Appendix G: Figure G.12). From 7000-6000 ^{14}C yr B.P., the viability of residential strategies decreases dramatically for collecting all resources types (Appendix G: Figure G.12, left side), while the viability of logistical strategies increases for obtaining wetland resources, whether by collecting or foraging (Appendix G: Figure G.12, right side). This Figure also shows that logistical mobility was the preferred manner for obtaining wetland resources. Last, there is some suggestion that from 7000-6500 ^{14}C yr B.P., large game and non-preferential resources were more viably obtained through residential collecting.

In the Ooijerhoek area, the landscape first became drier (9000-8000 ^{14}C yr B.P.), and then wetter (8000-7000 ^{14}C r B.P.; see Chapter 4, Figure 4.13). Large tracts of open dry grassland and wet woods became drier and more densely vegetated in the Boreal, followed by continued forest density but wetter soils in the Atlantic. Here, large game and non-preferential resources were the most viable means of subsistence (Appendix G: Figure G.13; see also Figures G.44-G.45), with a slight increase in viability from the Preboreal to the Boreal (9500-8000 ^{14}C yr B.P.). It is interesting to note that, unlike the Polderweg area, very little difference occurs in the suitability of residential or logistical resource extraction; either appears to be equally successful (Appendix G: Figure G.13; this point is addressed further in the following sections).

Figure G.14 in Appendix G also indicates that both residential and logistical strategies were, for the most part, highly viable for obtaining large game and non-preferential resources. Both strategies increased in viability from the Preboreal to the Boreal (9500-8000 ^{14}C yr B.P.). Early on, collecting with a residential strategy was quite successful; by the Atlantic period (8000-7000 ^{14}C yr B.P.), either residential or logistical movement could be easily used for collecting or foraging of resources other than wetland species. This trend speaks to the relative flexibility of hunter-gatherers in this area as the Mesolithic period progressed, and may be related to the fact that the environment became more densely forested, hunter-gatherers had to be more flexible in order to take advantage of the available resources (see section 7.5.4 for further discussion). It is also interesting to note that a residential strategy focused on collecting wetlands could also have been an acceptable subsistence-settlement strategy, although logistical extraction of such resources would have been poor.

The evidence presented above seems to suggest that environmental and ecological change did affect the suitability of habitats for different hunter-gatherer strategies at the local level, such that certain strategies would have become all but obsolete in particular environments, while other environments could support many different strategy variations (see section 7.5.3 for more discussion). However, factors other than environmental change also conditioned the way that hunter-gatherers used their landscape (see section 7.5.5). Moreover, until a thorough sensitivity test of the model is carried out, it may be impossible to provide a full answer to this question, as changing the values of the input variables may well cause variations in the model results. Thus, the results presented above are presented as preliminary, upon which further analysis will surely reveal more detailed and nuanced findings. In the following section, the location of resource foci will be considered in regards to use of the landscape.

7.5.3 Question 3. The third question posed above asks to what degree different resource foci affect the suitability of an area. To answer this question, faunal probability maps were investigated both at the local and sub-regional levels (Table 7.8). From 7000-6500 ^{14}C yr B.P. at De Bruin, beaver, terrestrial birds, and wild boar were the most suitable food resources available, followed by red deer, roe deer, aurochs, plants, and small mammals. From 6500-6000 ^{14}C yr B.P. at De Bruin, only terrestrial birds are highly suitable, although beaver and wild boar have medium suitability. These findings correspond to some degree with what is known from the archaeological record, although fish and waterfowl are also known to have made up a large component of the diet. These wetland resources are not highly suitable in the immediate (i.e., 200 m radius) area around the site; however, when the overall suitability of those resources are investigated for the entire Polderweg area, it can be seen that some of those resources could be readily found within the environment (e.g., plants and aquatic birds; Table 7.9). This is a puzzling result, given that the archaeological evidence demonstrates that a large component of the diet in the Polderweg area did consist of fish. It may be that wetland resources were gathered via longer logistical forays targeting areas at a distance from the base camp (perhaps even beyond the scope of the study area). Further, it may be that the proximity of large game and non-preferential resources was more important to the placement of a wetland base camp than the location of the wetland resources themselves, ostensibly since the latter were widely available throughout the sub-region, while the non-wetland species were clustered in specific resource foci (Appendix G: Figure G.15). The crux of the problem here is that a good understanding of how hunter-gatherers use the landscape concurrently at different spatial (and temporal) scales is lacking. Unfortunately, such two-dimensional models of human behavior can only hint at the complexity that likely lies beneath such decision-making, a problem that must be continued in further research (see section 8.4).

Table 7.8 Effects of Individual Species on Hunter-Gatherer Decision-Making at De Bruin (200 m radius around site).

Site	Time period (^{14}C yr B.P.)	Species	Suitability
De Bruin	7000-6500	Anadromous fish	Unsuitable
		Aquatic birds	Low
		Beaver	High
		Freshwater fish	Unsuitable
		Plants	Low
		Red deer, roe deer, aurochs	Medium
		Small mammals	Medium
		Terrestrial birds	High
		Wild boar	High
De Bruin	6500-6000	Anadromous fish	Unsuitable
		Aquatic birds	Low
		Beaver	Medium
		Freshwater fish	Unsuitable
		Plants	Medium
		Red deer, roe deer, aurochs	Low
		Small mammals	Low
		Terrestrial birds	High
		Wild boar	Medium

Table 7.9 Effects of Individual Species on Hunter-Gatherer Decision-Making, Polderweg Area (entire study area).

Time period (^{14}C yr B.P.)	Species	Suitability
7000-6500	Anadromous fish	Unsuitable
	Aquatic birds	Medium
	Beaver	Unsuitable
	Freshwater fish	Unsuitable
	Plants	High
	Red deer, roe deer, aurochs	Low
	Small mammals	Unsuitable
	Terrestrial birds	Unsuitable
	Wild boar	Unsuitable
6500-6000	Anadromous fish	Unsuitable
	Aquatic birds	High
	Beaver	Unsuitable
	Freshwater fish	Unsuitable
	Plants	High
	Red deer, roe deer, aurochs	Unsuitable
	Small mammals	Unsuitable
	Terrestrial birds	Unsuitable
	Wild boar	Unsuitable

At the site of Polderweg, the model predicts that plants, and aquatic and terrestrial birds were the most viable resource to extract from 7000-6500 ^{14}C yr B.P. (Table 7.10), while from 6500-6000 ^{14}C yr B.P., plants, aquatic birds, red deer, roe deer, aurochs, terrestrial birds, and wild boar were successful resources. Here, there appears to be a mix of terrestrial and wetland resources in close proximity of the site. Birds, in particular, may have been a reason to return to the site year after year. Again, the archaeological evidence only partially corroborates these model predictions, suggesting instead that fish also made up a large portion of the diet. This may simply be due to the fact that only a 200 m buffer around the site was analyzed for faunal suitability, or because the total area of potential fish habitat is proportionately smaller than the total suitable area for other species.

Table 7.10 Effects of Individual Species on Hunter-Gatherer Decision-Making at Polderweg (200 m radius around site).

Site	Time period (^{14}C yr B.P.)	Species	Suitability
Polderweg	7000-6500	Anadromous fish	Unsuitable
		Aquatic birds	Medium
		Beaver	Low
		Freshwater fish	Unsuitable
		Plants	High
		Red deer, roe deer, aurochs	Low
		Small mammals	Low
		Terrestrial birds	Medium
		Wild boar	Low
Polderweg	6500-6000	Anadromous fish	Unsuitable
		Aquatic birds	Medium
		Beaver	Low
		Freshwater fish	Low
		Plants	High
		Red deer, roe deer, aurochs	Medium
		Small mammals	Low
		Terrestrial birds	Medium
		Wild boar	Medium

Interestingly, as was seen in Figures G.1 and G.2 of Appendix G, there is little correlation between the suitability of a resource category and the probability of the strategy practiced (e.g., high and high). This suggests that the proximity to resource foci was not the only objective conditioning the decision-making process. As will be further discussed in section 7.5.5, objectives such as ground dryness were also important. What does seem clear is that in wetland contexts, residential base camps tend to be placed in areas with the maximum amount of resource diversity. This assertion is supported by the finding that such model outputs (i.e., for collector strategies focused on large game, general foraging, and wetland resources) were also medium to highly patchy in their resource distribution, making these heterogeneous environments particularly suitable to aggregative settlements with logistical forays (see section 7.5.4 for more discussion).

At the site of Deest, terrestrial birds and wild boar were highly suitable from 7000-6000 ^{14}C yr B.P., as well as beaver, red deer, roe deer, aurochs, small mammals, plants, and terrestrial birds (Table 7.11). At the site of Zuiderveld-West, small terrestrial mammals, plants, and terrestrial birds were highly suitable, as well as large game. These findings correspond to what is known about the landscape at that time: it was becoming increasingly forested and remained dry until the middle Atlantic. These results are also instructive regarding the possible activities that may have been undertaken at these sites, since the archaeological evidence is very slim (see Tables 7.3 and 7.4 above). Clearly, terrestrial mammals, with the exception of some beaver at Deest, were the most viable resources. Further, as mentioned above, the location the Deest and Zuiderveld-West sites in the river plain suggests that they may have been used to obtain wetland resources, although this assertion cannot be backed up by any data currently.

Table 7.11 Effects of Individual Species on Hunter-Gatherer Decision-Making at Deest and Zuiderveld-West (200 m radius around site).

Site	Time period (^{14}C yr B.P.)	Species	Suitability
Deest	7000-6000	Anadromous fish	Unsuitable
		Aquatic birds	Unsuitable
		Beaver	Medium
		Freshwater fish	Unsuitable
		Plants	Medium
		Red deer, roe deer, aurochs	Medium
		Small mammals	Medium
		Terrestrial birds	High
		Wild boar	High
Zuiderveld-West	7000-6000	Anadromous fish	Unsuitable
		Aquatic birds	Unsuitable
		Beaver	Unsuitable
		Freshwater fish	Unsuitable
		Plants	High
		Red deer, roe deer, aurochs	Medium
		Small mammals	High
		Terrestrial birds	High
		Wild boar	Medium

When the suitability of the landscape from 7000-6000 ^{14}C yr B.P. in the Deest area is investigated, it can be seen that obtaining terrestrial species was the only successful strategy available to hunter-gatherers (Table 7.12). Thus, it may be assumed that the area was most frequently utilized for the extraction of large game, small mammals, plants, and terrestrial birds. The model developed in this study suggests resources could have been exploited using either a collecting or foraging pattern. However, since the overall patchiness of the landscape was low (see section 7.5.4), it is expected that hunter-gatherers would have benefitted by using a foraging strategy in their generally homogeneous environment. The only exceptions would have been for non-wetland and wetland resources, for which a collector strategy may have been more useful (see section 7.5.4 for more discussion).

Table 7.12 Effects of Individual Species on Hunter-Gatherer Decision-Making, Deest Area (entire study area).

Time period (^{14}C yr B.P.)	Species	Suitability
7000-6000	Anadromous fish	Unsuitable
	Aquatic birds	Unsuitable
	Beaver	Unsuitable
	Freshwater fish	Unsuitable
	Plants	High
	Red deer, roe deer, aurochs	High
	Small mammals	High
	Terrestrial birds	High
	Wild boar	High

At the Epse-Olthof site, terrestrial birds, wild boar, small mammals, red deer, roe deer, aurochs, and plants were highly viable food resources (Table 7.13). From the Preboreal to the Boreal, the suitability of the landscape for the above species increased, perhaps due to the densification of forests; at the same time, however, the suitability of the landscape for plant species decreased. Wetland resources were highly unsuitable, except for beaver, which must have been occasionally available. These predictions compare well with what is known from the archaeological record, namely that residential base camps as well as for logistical extraction camps focused on obtaining large game were inhabited. As the results indicate, it is also quite likely that other terrestrial species were also taken, such as small mammals, terrestrial birds, and plants. Even beaver may have been exploited on occasion, for its fur, meat, or both. Furthermore, there is a high correlation between resource suitability and subsistence-settlement strategy suitability (see Appendix G: Figures G.3-G.5). This suggests that in the Ooijerhoek area, resource foci were more directly related to the suitability of an area for a particular strategy than, for example, in the downstream area. Unfortunately, these results do not allow any conclusions to be made about the number of resources present in the area, or how easily they could be found. Thus, it must be assumed that the increasingly dense forest made it somewhat more difficult to track prey, although there may have been plenty of prey available.

Table 7.13 Effects of Individual Species on Hunter-Gatherer Decision-Making at Epse-Olthof (200 m radius around site).

Site	Time period (^{14}C yr B.P.)	Species	Suitability
Epse-Olthof	10,000-9000	Anadromous fish	Unsuitable
		Aquatic birds	Unsuitable
		Beaver	Low
		Freshwater fish	Unsuitable
		Plants	High
		Red deer, roe deer, aurochs	Medium
		Small mammals	Medium
		Terrestrial birds	High
		Wild boar	High
	9000-8000	Anadromous fish	Unsuitable
		Aquatic birds	Unsuitable
		Beaver	Low
		Freshwater fish	Unsuitable
		Plants	Medium
		Red deer, roe deer, aurochs	High
		Small mammals	High
		Terrestrial birds	High
		Wild boar	High

Table 7.13 (cont'd).

8000-7000	Anadromous fish	Unsuitable
	Aquatic birds	Unsuitable
	Beaver	Low
	Freshwater fish	Unsuitable
	Plants	Medium
	Red deer, roe deer, aurochs	High
	Small mammals	High
	Terrestrial birds	High
	Wild boar	High

At the site of Ooijerhoek, the model predicts that something very different was occurring (Table 7.14). While the area is only of low suitability to wetland species and plants, it is also of low suitability to large game and small mammals, quite unlike what was seen in the Epse-Olthof area. At best, the landscape provided only medium suitability to terrestrial birds and wild boar. These findings do seem to correlate with the archaeological data, which suggest that the site was used to collect large game as well as nearby wetland resources. In fact, the low suitability of the landscape for many species provides a possible motivation for hunter-gatherers to actively burn the surrounding vegetation as a way to attract more species to the area. Only a weak correlation appears to exist between resource foci and strategy suitability: while collecting wetland resources is predicted to be a highly successful strategy, the landscape is only of low suitability to such resources throughout the period (see Appendix G: Figures G.6-G.8). This implies that objectives other than obtaining a minimum amount of resources were instrumental in driving the decision-making process behind the location of the Ooijerhoek site. Perhaps other factors, such as minimizing risk, or obtaining dietary variety through proximity to a wide range of resources, were more important.

Table 7.14 Effects of Individual Species on Hunter-Gatherer Decision-Making at Ooijerhoek (200 m radius around site).

Site	Time period (^{14}C yr B.P.)	Species	Suitability
Ooijerhoek	10,000-9000	Anadromous fish	Low
		Aquatic birds	Low
		Beaver	Low
		Freshwater fish	Low
		Plants	Low
		Red deer, roe deer, aurochs	Low
		Small mammals	Low
		Terrestrial birds	Medium
		Wild boar	Medium
	9000-8000	Anadromous fish	Low
		Aquatic birds	Low
		Beaver	Low
		Freshwater fish	Low
		Plants	Low
		Red deer, roe deer, aurochs	Low
		Small mammals	Low
		Terrestrial birds	Medium
		Wild boar	Medium
	8000-7000	Anadromous fish	Low
		Aquatic birds	Low
		Beaver	Low
		Freshwater fish	Low
		Plants	Low
		Red deer, roe deer, aurochs	Low
		Small mammals	Low
		Terrestrial birds	Medium
		Wild boar	Medium

At the site of Looërenk, all wetland resources are highly unsuited to the landscape, while all terrestrial resources are well suited (Table 7.15). This scenario is closer to what was modeled for the Epse-Olthof site above, and compares very closely with the archaeological evidence. Clearly, the site was used for obtaining large game and other terrestrial resources. There seems to be a direct correlation between resource foci and the suitability of strategies to procure them (see Appendix G: Figures G.9-G.11). This finding does not hold for wetland resources, though, where other objectives and perhaps environmental factors may have been more important motivators. In other words, while wetland resources were not highly viable in this area, they may still have been taken opportunistically.

Table 7.15 Effects of Individual Species on Hunter-Gatherer Decision-Making at Looërenk (200 m radius around site).

Site	Time period (^{14}C yr B.P.)	Species	Suitability
Looërenk	9000-8000	Anadromous fish	Unsuitable
		Aquatic birds	Unsuitable
		Beaver	Unsuitable
		Freshwater fish	Unsuitable
		Plants	Medium
		Red deer, roe deer, aurochs	High
		Small mammals	High
		Terrestrial birds	High
		Wild boar	High
	8000-7000	Anadromous fish	Unsuitable
		Aquatic birds	Unsuitable
		Beaver	Unsuitable
		Freshwater fish	Unsuitable
		Plants	Medium
		Red deer, roe deer, aurochs	High
		Small mammals	High
		Terrestrial birds	High
		Wild boar	High

When the entire Ooijerhoek area is investigated regarding resource suitability, it can be seen that wetland species are for the most part highly unsuitable and therefore, not highly successful resources to exploit (Table 7.16). Large game (excluding wild boar) and plants, are only moderately useful resources, perhaps on account of the increasingly dense forest cover and disappearance of edge zones. Small mammals, terrestrial birds, and wild boar were best suited to the landscape, and were likely the most important resources to people living in this area during the Mesolithic.

Table 7.16 Effects of Individual Species on Hunter-Gatherer Decision-Making, Ooijerhoek Area (entire study area).

Time period (^{14}C yr B.P.)	Species	Suitability
10,000-9000	Anadromous fish	Unsuitable
	Aquatic birds	Unsuitable
	Beaver	Low
	Freshwater fish	Unsuitable
	Plants	Medium
	Red deer, roe deer, aurochs	Medium
	Small mammals	High
	Terrestrial birds	High
	Wild boar	High
9000-8000	Anadromous fish	Unsuitable
	Aquatic birds	Unsuitable
	Beaver	Low
	Freshwater fish	Unsuitable
	Plants	Medium
	Red deer, roe deer, aurochs	Medium
	Small mammals	High
	Terrestrial birds	High
	Wild boar	High
8000-7000	Anadromous fish	Unsuitable
	Aquatic birds	Unsuitable
	Beaver	Low
	Freshwater fish	Low
	Plants	Medium
	Red deer, roe deer, aurochs	Medium
	Small mammals	High
	Terrestrial birds	High
	Wild boar	High

To conclude, resource foci appear to differ in their affect on strategy suitability. In wetland contexts, the location of more clustered terrestrial resources seem to contribute more weight in the decision-making process of locating a site, whereas widely dispersed wetland resources are less important. However, in dryland forest contexts, there is generally a more direct correlation between resource foci and strategy suitability, such that areas highly suitable for large game tend to be used for obtaining this resource. Even in these dryland scenarios, wetland resources continue to have a weak correlation with strategy suitability, although they often appear to have been at least a moderately viable strategy. This suggests that these resources would have been collected opportunistically but had little bearing on the decision of where to place a settlement.

7.5.4 Question 4. The fourth question regards the degree of flexibility hunter-gatherers had in organizing mobility and settlement. The model predicts that hunter-gatherers focused on large game and non-preferential resources had a good degree of flexibility regarding whether they practiced residential or logistical strategies (Appendix G: Figures G.16-G.17), as shown by the near identical nature of the output maps for residential and logistical resource use. The only place and time when large game and non-preferential resources were more successfully acquired through residential resource use was during the Preboreal in the Ooijerhoek area (see Appendix G: Figure G.17).

Hunter-gatherers focused on wetland resources tended to be more restricted in their decisions regarding settlement and subsistence (Table 7.17). In the Polderweg area, logistical resource use was more successful throughout the Mesolithic, while in the Deest and Ooijerhoek Areas, logistical resource use only became a more useful strategy in the Atlantic period. In other words, from 10,000-8000 ^{14}C yr B.P. in both the Deest and Ooijerhoek areas, either strategy could be used with high flexibility.

Table 7.17 Subsistence-Settlement Flexibility Among Hunter-Gatherers Focused on Wetland Resources.

Area	Time period (^{14}C yr B.P.)	Flexibility
Polderweg	10,000-9000	Skewed toward logistical
	9000-8000	Skewed toward logistical
	8000-7000	Skewed toward logistical
	7000-6000	Skewed toward logistical
Deest	10,000-9000	Either strategy
	9000-8000	Either strategy
	8000-7000	Skewed toward logistical
	7000-6000	Skewed toward logistical

Table 7.17 (cont'd).

Ooijerhoek	10,000-9000	Either strategy
	9000-8000	Either strategy
	8000-7000	Skewed toward logistical
	7000-6000	Skewed toward logistical

Note: Both medium and high suitability values were considered.

When foraging and collecting models are investigated, further insights are revealed. For example, in the Polderweg area, a foraging strategy focused on large game could be accommodated by residential or logistical settlements, whereas a forager strategy focused on non-wetland resources was somewhat less flexible (Appendix G: Figure G.18), with residential settlements constituting a more viable option. Further, logistical extraction of wetland resources was highly successful (Appendix G: Figure G.19). These results suggest that the type of resource focused upon, and the type of subsistence-settlement strategy used, directly affected how easily a group could switch back and forth between residential or logistical mobility. Most importantly, it is shown that within a wetland context, a collecting strategy focused on wetland resources is more successfully exploited through logistical mobility, and that hunter-gatherers would have had less flexibility in their mobility choices.

Another interesting and related question asks which strategy--foraging or collecting--is more flexible. The following table demonstrates with select data that a foraging strategy is inherently more flexible than a collector model (Table 7.18). This accords with what is known from the archaeological record, in that a semi-permanent residential camp, from which logistical forays are mounted, are much harder to pick up and move than logistical camps or more ephemeral short term residential camps.

Table 7.18 Association Between Flexibility of Mobility and Settlement-Subsistence Strategies.

Model	Area	Time period (^{14}C yr B.P.)	Flexibility
Foraging, large game focus	Polderweg	7000-6000	Either strategy
		6500-6000	Either
	Deest	7000-6000	Skewed logistical
	Ooijerhoek	9500-9000	Either
		9000-8000	Either
		8000-7000	Either
Foraging, general foraging focus	Polderweg	7000-6000	Skewed logistical
		6500-6000	Skewed logistical
	Deest	7000-6000	Either
	Ooijerhoek	9500-9000	Either
		9000-8000	Either
		8000-7000	Either
Foraging, wetland focus	Polderweg	7000-6000	Skewed residential
		6500-6000	either
	Deest	7000-6000	Skewed logistical
	Ooijerhoek	9500-9000	Either
		9000-8000	Either
		8000-7000	Either
Collecting, large game focus	Polderweg	7000-6000	Skewed residential
		6500-6000	Skewed residential
	Deest	7000-6000	Skewed logistical
	Ooijerhoek	9500-9000	Skewed residential
		9000-8000	Either
		8000-7000	Skewed logistical
Collecting, general foraging focus	Polderweg	7000-6000	Skewed residential
		6500-6000	Skewed residential
	Deest	7000-6000	Skewed logistical
	Ooijerhoek	9500-9000	Skewed residential
		9000-8000	Either
		8000-7000	Skewed logistical
Collecting, wetland focus	Polderweg	7000-6000	Skewed logistical
		6500-6000	Skewed logistical
	Deest	7000-6000	Skewed residential
	Ooijerhoek	9500-9000	Skewed residential
		9000-8000	Skewed residential
		8000-7000	Skewed residential

Yet another interesting question, also related to question three, is how the flexibility of an area is related to the patchiness[19] of that area, and what implications that might hold for suitable strategies. The patchiness of the modeled vegetation maps was determined by taking the minimum and maximum number of continuous cell groups in the three study areas and setting these values as brackets within which higher and lower patchiness attributions could be made. As can be seen in Table 7.19, the model predicts that the Polderweg area was much patchier overall than the other two areas, returning many more continuous groups of cells (e.g., 2266 out of 10,000 cells total) than the other areas (e.g., 577 out of 10,000 cells). These patchiness levels changed over time, ostensibly as the landscape and vegetation shifted. If it is assumed that patchy or heterogeneous areas are best exploited through aggregation and logistical forays (Kelly 1995:117), then it is expected that collector strategies would be most common in the Polderweg area, while homogeneous areas would be expected to have been best exploited via foraging strategies. This is not to say that strategies could not overlap, and indeed, switching between strategies appears to have been possible and perhaps common at least in the Ooijerhoek and Deest areas. However, in general, it is expected that the more common strategies practiced by hunter-gatherers in the latter areas were based on frequent residential movement of people to resources, rather than resources to people.

To answer the question posed at the beginning of this paragraph, areas of low flexibility (e.g., the Polderweg area) are also areas with high patchiness. Conversely, areas of high flexibility (e.g., the Ooijerhoek area) are associated with low patchiness (Appendix G: Figure G.20). This suggests that highly patchy areas, and therefore areas with lots of edge zone, would

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[19] Patchiness measures were obtained with the clumping function of PCRaster, which calculates the number of continuous cells with the same value within a predefined area. It should be noted here that the patchiness of the output maps in this study are only as strong as the coarsest data (e.g., data from the Deest area in this case).

be better exploited through a collecting strategy that utilized logistical forays from a home base. In areas of lower patchiness, it can be argued that maintaining a good degree of subsistence-settlement flexibility was the most successful way to deal with resources as they were encountered.

Table 7.19 Relative Patchiness of Study Areas.

Area	Time period (^{14}C yr B.P.)	Patchiness
Polderweg	11,000-10,000	High
	10,000-9000	Medium
	9000-8000	Medium
	8000-7500	Low
	7500-7000	High
	7000-6500	Medium
	6500-6000	Low
Deest	11,000-10,000	Low
	10,000-9000	Low
	9000-8000	Low
	8000-7000	Low
	7000-6000	Low
Ooijerhoek	11,000-10,000	Low
	10,000-9000	Medium
	9000-8000	Low
	8000-7000	Low
	7000-6000	Low

In conclusion, hunter-gatherers in the downstream wetlands had less flexibility than in the upstream grasslands and forests. It seems that a strategy in which wetland resources play an integral part are less malleable: a collecting strategy is by far the best way to exploit these resources. Foraging strategies, by contrast, appear to be inherently more flexible in nature, perhaps related to the associated ease of moving shorter-term and smaller camps. Investigating the patchiness of landscapes also adds to the argument: highly patchy areas tend to be more restrictive regarding the types of strategies that can be viably practiced.

7.5.5 Question 5. The fifth question asks to what degree different decision-making objectives and criteria altered spatial output. To answer this question, various model runs were undertaken in the analysis of this study, which showed notable results concerning the effects of decision-making criteria and objectives. First, it was found that including additional non-food criteria in one model and not others greatly skewed the output maps. For example, in the initial model runs, tool stone and wood were included in the wetland model. These resources were found to give undo weight to high and dry areas (where these resources are assumed to have been found; Appendix G: Figures G.21-G.22). This output was disconcerting because it was expected that a wetland-focused model should yield the most suitable values in and around low and wet areas. At the same time, if these non-food resources had been included in the large game and general foraging models, they would have increased the pull or weight of high and dry areas. To keep the output even, no non-food resources were considered in this modeling; it was assumed that sufficient non-food resources could be found while undertaking food resource forays.

A second run of the wetland model was undertaken, this time excluding non-food resources but including some non-wetland resources like large game, terrestrial birds, and small terrestrial mammals (these species have been found in the zooarchaeological collections of wetland sites such as Polderweg and Deest). Analysis revealed that inclusion of these non-wetland species, even when ranked at a very low weight, still affected the output maps, such that high and dry areas were still projected to be most viable for a logistical wetland strategy in the Ooijerhoek area (Appendix G: Figure G.23). It was further perplexing that areas adjacent to stream and river valleys were being ranked as unsuitable, when they should have been given rankings of high or medium.

In the final wetland model run, only wetland species were included (e.g., fish, aquatic birds, and beaver), similar to the way large game had been modeled. The outputs of this new model compared much more favorably with the archaeological data (Appendix G: Figures G.24-G.25).

It should be noted that the general foraging model was the only one that considered both terrestrial and wetland species. However, as will be discussed below, the terrestrial species acted to skew the general foraging outputs toward high and dry areas, as these resources tend to rank higher in terms of objectives than do wetland resources (e.g., the ability to satisfy minimum resource needs, population aggregation, prestige, etc.). Thus, while other resources were likely encountered and perhaps exploited by hunter-gatherers in an opportunistic (i.e., unplanned) manner, the model suggests that a narrow versus broad spectrum resource focus would have affected how hunter-gatherers perceived of the usefulness of their environs. And even when a broad spectrum of resources were targeted, large game and the great seasonal abundance of certain species such as fish and migratory birds tended to skew the usefulness of the landscape accordingly.

These findings have further implications for question three (above), which asks about the affect of certain resource foci on area suitabilities. It can be argued here that certain species posed as more important criteria in decision-making than others. These more important species consisted of red deer, roe deer, aurochs, and wild boar (the large game category), as well as species that are periodically very abundant and easy to procure (e.g., fish and migratory birds). This is not to say that other species were not useful, but rather that the distribution and availability of large game and seasonally abundant resources had a greater affect on the perceived usefulness of a landscape than did other resources. This was undoubtedly due in some part to the ability of these select resources to satisfy many of the basic objectives of hunter-gatherer groups.

Analysis was also undertaken to test the degree to which different objective weights affected the output maps. This was primarily conducted for the wetland models, which after two reruns, were still yielding results in which high and dry areas were depicted as most suitable under foraging and collecting strategies (see Appendix G: Figures G.26-G.27). Even when only wetland resources were used as input for the evaluation of objectives, high and dry areas still came back as the most suitable areas for wetland resources extraction. This finding indicated that perhaps objectives, rather than criteria, were causing the illogical results. This hypothesis could further signify that the objectives considered in the decision-making process were more important than the selection of certain resources.

For the large game and general foraging models, objectives such as ground dryness, shelter, and view had all been given relatively equal weights, it was found that for a strategy focused on wetlands, the objectives had to be modified. First, the objective of prestige was removed from the evaluation of the wetland model, as large game had been removed from the criteria list, and due to the fact that very little ethnographic evidence exists to support the contention that fishing or birding are high prestige-yielding activities. This omission resulted in wetland maps that correlated somewhat better with the archaeological data from the central river valley of the Netherlands.

Next, the objectives for the forager and collector models were shifted to better reflect what hunter-gatherers may have been considering in their decision-making processes. A model run was conducted in which proximity to resources and ground dryness were the most important objectives for residential settlement, and shelter and view were strongly less, and very strongly less important than the latter, respectively. For logistical settlement/resource extraction, shelter and view were dropped out altogether, as these objectives were deemed unimportant to groups targeting specific resources for a short period of time. Thus, proximity to resources was considered the most important objective, while ground dryness was very strongly less important, but still a necessary consideration to some degree (and notwithstanding that some collecting of resources may have been undertaken from dugout canoes). The resulting foraging and collecting maps produced much more logical results for the Deest and Ooijerhoek areas, placing the focus on wetland areas and their margins for wetland resources exploitation (Appendix G: Figures G.26-G.31).

These findings indicate that for the Deest area, foraging for wetland resources was not a successful strategy, although collecting wetland resources was somewhat more viable. In the Ooijerhoek area, foraging for wetland resources was not a highly useful strategy, although collecting such resources was useful if residential settlements were located in the drier parts of the landscape.

In the Polderweg area, the new model placed emphasis not on the dry dune tops and levees, but on the surrounding wetlands. Based on the archaeological evidence from the sites of Polderweg and De Bruin, it is likely that hunter-gatherers located their residential camps in high and dry areas that were surrounded by wetlands, which were highly suitable areas for logistical resource extraction (Appendix G: Figures G.32-G.33). Further, the model predicts that either a collector or forager strategy would be equally viable for the entire area. However, at the local level, site such as Polderweg and De Bruin would have been better suited to collector strategies.

What seems clear is that proximity to resources and other objectives are playing a tug of war: under a wetland strategy, the ‘core’ objectives of having a view, staying dry and obtaining natural shelter must be compromised. Thus, it may be that new technologies arose as a way to combat these compromises in human survival objectives. It is around at this time (the Atlantic) that evidence suggesting a florescence of water- and wetland-related technology occur (e.g., water craft, fish weirs and traps, and semi-subterranean shelters; see e.g., Louwe Kooijmans 2001a, 2001b), although it should be noted that this evidence could be biased by differential survival and discovery (Peeters pers. comm.).

Thus, while it is certainly true that some “universal” or common objectives are considered in the decision-making processes of hunter-gatherer groups (see Chapter 6, section 6.4 for a recap), these objectives are relaxed or tightened based on the context of the environment and the available criteria. The objective weights that seem quite important to hunter-gatherers following large game or other terrestrial food resources are not necessarily the same for hunter-gatherers focused on wetland resources. This finding is perhaps a bit obvious, but speaks to the fact that hunter-gatherer groups are and were extremely unique in their decision-making, which is related not only to cultural differences, but is also in some respects tied to the particular environment inhabited by the group. At the same time, understanding that certain challenging ecosystems, such as wetlands, pose certain risks and benefits to hunter-gatherer groups, it can be argued that a relaxing of basic objectives, and the development of new technologies, may reflect the decision-making process change that led many such groups to embrace ecological settings that were previously less desirable than dry uplands.

The above section provides a basic sensitivity test of the model developed here. It should be noted that, when compared with the archaeological evidence from the Polderweg area, wetland resources may be underestimated in the model. The values of wetland resources may be set at too low a level, which consequently affects the modeling output maps. Given this uncertainty, the results described here should not be regarded as “true”, but rather only as accurate as the model and model input. Furthermore, until a thorough sensitivity test of the model is conducted, this question can only be partially answered. Performing such a test is one of the first steps that will be conducted in future research (see section 8.4).

7.5.6 Question 6. The last question to be posed in this research asks how sub-regions relate to one another, whether they function across space as integrated resource zones, or if they are discrete entities. The model suggests that the sub-regions are related to one another in a linked, but delayed relationship. Hunting was only moderately suitable in the three areas during the Preboreal, suggesting this period was characterized by a transition environment that was more amenable to a combination of hunting and gathering activities. It could also be that during this time, a strategy focused on migratory herd animals remained more successful (this suggestion could be easily tested by running another version of the model configured for this type of settlement-subsistence strategy). By the Boreal (9000-8000 ^{14}C yr B.P.) hunting and gathering diverse resources is very suitable in all areas (Appendix G: Figures G.34-G.35). However, the suitability of this strategy appears to migrate upstream over time, such that by the Atlantic period (8000-7000 ^{14}C yr B.P.), hunting is no longer viable in the downstream location, replaced by a focus on wetland resources (Appendix G: Figures G.36-G.37).

These trends in successful settlement-subsistence strategies essentially follow the eastward movement of the deltaic apex (note how the suitability of wetland resources in Appendix G: Figures G.38-G.41 gradually increase). Before the apex surpassed an area, hunting large game and other non-preferential resources appears to be the most viable strategy while post-apex, areas become more useful for collecting wetland and other resources. This is perhaps an obvious conclusion but is nevertheless useful as it can help to predict where and what sort of resources were most likely to have been targeted by hunter-gatherers at certain places in time. This argument is bolstered by the fact that wetland and coastal material culture has been found with early dates at the modern-day coast of the Netherlands – the first place to have experienced sea-level transgression. These remains, including bone and antler harpoon tips, implicate collector strategies focused on aquatic and marine resources. Many bone and antler adzes were also recovered from the site of Spoolde, although the majority of these artifacts date to the late Atlantic/early Neolithic periods, a time when the paleo-Schipbeek was experiencing gradual inundation and the encroachment of peat, both of which are suggestive of a wetting of the landscape. It should also be noted that these points have never been characterized as harpoon points but were more likely thought to have served as arrow tips and adzes.

To conclude, the sub-regions studied here were seamless resource zones that hunter-gatherers could easily move between using the similar strategies from the Preboreal to the Boreal. The results of this study indicate that suffienct resources were available in all three locations during the Early Holocene, suggesting that the area was highly suitable for hunting and gathering activities. Thus, Mesolithic groups probably inhabited the entire area and it is expected that evidence of their activity will be found in future excavations. By the Atlantic, the downstream area began a transformation into a wetland environment. Such an environment would have appeared to hunter-gatherers used to focusing on terrestrial resources as distinct, in that it required new strategies and innovations for exploitation. This transformation occurred over about a 500-1000 year window; it is likely that the need for new technologies and customs was very gradual, but at the same time, the window of environemntal change was short enough to suggest that the rise of cultural adaptations to the new landscape would probably have been recorded in the mythology of local groups.

7.6 Predictions

The model developed here is intended as a heuristic device and is not intended to represent reality. However, the model outputs can still be fruitfully used to determine the most suitable subsistence-settlement strategies for given areas, the results of which compared well with the archaeological record. This close matching allows for solid predictions to be made for time periods when no such archaeological evidence existed. In this endeavor, information was drawn from resource distributions, knowledge of the landscape, and hunter-gatherer land use strategies in order to predict areas most suitable for use.

As already discussed in section 7.2.4, hunting large game and gathering other resources was the most viable strategy in the Preboreal and Boreal in the downstream area (Appendix G: Figures G.42-G.43). This trend continued into the Atlantic for the Deest and Ooijerhoek areas (Appendix G: Figures G.44-G.47; Note that the output maps for non-preferential foraging are the same as those for large game extraction). It is assumed that many of these resources could be gained through a combination of residential and logistical mobility, and in fact, it can be seen that either strategy was quite successful. Therefore, it is predicted that areas along edge zones—between open and closed vegetation and along the margins of water bodies—could have been the most desirable locations in the landscape. If this is correct, sites are predicted to be found in such locations.

In the Polderweg area, such locations would include edge zones between dry woods and grasses, along levees, on the tops of the river dune, and in stream valleys and river margins. For much of the Mesolithic, this could mean that a majority of the area was highly suitable.

However, by the Atlantic period, the foraging of these resources would have been confined to the remaining dune tops and levees. In the Netherlands, the probability of finding stone age archaeology when coring or digging river dunes is very high (Peeters pers. comm.). Thus, any work that intrudes into known dunes is conducted with caution, as the likelihood of encountering the remains of human activity associated with dwelling and the taking of large game and other non-preferential resources is quite high. Furthermore, logistical camps are expected to be scattered throughout most of the area, on dunes and levees, but also in the wetlands themselves. While some of these more ephemeral remains may never be recovered, it is expected that the material remains of extraction activities in the wetlands would be preserved very well.

It is also interesting to note that in the Ooijerhoek area, hunting and gathering seems to be most suitable, although the known sites are situated adjacent to both woodlands and rivers and streams (Appendix G: Figures G.44-G.45). This suggests that hunter-gatherers could switch back and forth between a residential or logistical strategy, depending on what resources were most abundant and accessible. Collecting wetland resources appears to have been a viable strategy during the Preboreal, suggesting that the early Mesolithic sites in this area could have viably focused on a mixed wetland-terrestrial resource spectrum. This trend diminishes in the Boreal, but by the Atlantic, the wetlands again became a successful option if logistical strategies were utilized. It certainly appears that the area was suitable for resource extraction into the Atlantic; in other words, the densification of the forests was not so extreme so as to curtail human movement and use of the landscape. The forests may have become denser and harder to navigate on foot, but dugout canoes or river and stream margins could still have permitted hunter-gatherers to access the area. Thus, future excavations targeting river dunes or other areas adjacent to paleostream and river channels should exert caution, as archaeological remains as likely to be recovered.

The Deest area remains somewhat of a mystery, as sites were found in “unsuitable” locations (Appendix G: Figures G.46-G.47). This could be due to the coarseness of the data in this area (the coarsest of all three areas), but may also indicate that this area was a transition zone between the upstream tributaries and the downstream area. Hunting and gathering were likely most viable, while a wetland focus was never extremely successful, expect near the two large rivers that coursed through the area, as well as the lake which persisted throughout the Mesolithic period. Further, the exact courses of the rivers are not known due to the extreme reworking of the subsoil in this area, so it may be that the known sites did lie adjacent to a water body during occupation.

7.7 Summary and Conclusion

In summary, each question posed above will be briefly revisited. Regarding question one, the model developed in this study compares well with the archaeological record. It predicts that hunter-gatherers choose to use downstream sites with collecting strategies and focused on a variety of resources, from wetland species to large game. While the currently known sites are only representative of residential base camps, it is certain that many small logistical/extractive camps exist in the areas surrounding dunes and levees. In the upstream area, foraging and collecting were both successful strategies. Logistical settlement became more useful by the Atlantic (perhaps a way to cope with the increasing density of the forests). The site of Ooijerhoek seems to have been rather unique: located adjacent to a river meander, a base camp may have been placed to collect various species. Residents may have burned the surrounding vegetation in an attempt to attract more species to the water's edge. Further, at the site of Looërenk, plant collection was at one time a focus of activities. This could point to hunter-gatherers supplementing a largely meat-based diet with plants, or it could indicate that meat (in the form of large game) was becoming harder to find and other resources and extraction techniques were necessary.

Predictions about the use of the Deest area are quite tentative. Based on the available evidence (which is coarse), the model suggests that the area was most viable for large game hunting and gathering of terrestrial species. Some sporadic collection of wetland resources may have occurred as well, especially along the margins of oxbow ponds and truncated river meanders. Seasonal flooding of the Rhine and Meuse undoubtedly also provided ample access to wetland resources. For these reasons, it is posited here that the Deest and Zuiderveld-West sites (definitely not highly suitable to hunting) may have been logistical/extraction sites focused on wetland resources. Despite the lack of evidence to support this conjecture, the location of the sites in the river valley, away from the forest margins, suggests the sites may have been located near water at the time of occupation. It should also be noted that it is entirely possible that the sites did lie near water, as the extent of river channels used in this study were only best guess approximations.

In regards to question two—is there a correlation between environmental change and the suitability of the environment for different subsistence-settlement strategies—the answer can be succinctly put: yes, changes in the environment did appear to affect the suitability of areas for different hunter-gatherer strategies. It was shown that the rise of groundwater in the Polderweg area correlated with the increased viability of strategies focused on wetland resources. Such changes in the environment and ecology also appears to have affected the suitability of different settlement strategies, such that a reliance on logistical mobility became key (see Appendix G: Figure G.12). In the Ooijerhoek area, environmental change was less dramatic (forests became denser and ground water levels ebbed somewhat). This relative stasis in the environment is mirrored in the continued viability of either residential or logistical, foraging or collecting strategies. It appears that a flexible strategy was the most successful way to exploit this relatively homogeneous landscape.

Question three asked about the affect of resource foci on the suitability of strategies. The model indicated that in wetland contests, proximity to large game and other resources was more important to the placement of base camps than the location of wetland resources themselves, for which there was a general preference to gather wetland resources remotely using logistical forays. Thus, resources that are clustered (such as large game would have been in a wetland environment) appear to contribute more "weight" to the settlement placement decision than do more evenly dispersed resources. In the upstream area, a high correlation was found between resource foci and strategy suitability; that is, the location of resource foci was more directly related to the suitability of an area for particular subsistence settlement strategies than in the downstream area. At the site of Ooijerhoek, an upstream site, resource foci and strategy suitability were weakly correlated, which could perhaps indicate why an attempt was made to attract more species to the site through the burning of vegetation. At this site and others where the correlation between resource foci and strategy suitability was weak (e.g., De Bruin and Polderweg), it is probable that objectives other than obtaining a minimum amount of resources were more important in site placement decision-making. In general, it may be stated that a stronger correlation exists between resource foci and strategy suitability when terrestrial resources are targeted, whereas a weaker correlation exists when wetland resources are targeted.

The degree of flexibility of hunter-gatherer strategies was the subject of question four. In answer, strategies focused on large game and non-preferential resources tended to be relatively flexible, while wetland focused strategies were more restricted toward collector strategies and logistical mobility. Further, the type of resource focused upon and the strategy utilized appears to have directly affected how easily a group could switch back and forth between residential and logistical mobility. A foraging strategy was found to be inherently more flexible than a collector strategy, perhaps because it is easier to move an ephemeral, short-term residential camp than a central base camp at the center of a logistical mobility network. The relative patchiness of areas was also investigated. An inverse relationship was found to exist between the patchiness of an area and the degree of organizational flexibility allowed hunter-gatherers. Thus, areas of low flexibility (e.g., the Polderweg area) were highly patchy and heterogeneous, indicating that edge zones were best exploited via collector strategies. Conversely, area of high flexibility (e.g., the Deest and Ooijerhoek areas) were very homogeneous with low patchiness, indicating that it being flexible in organization was beneficial in an environment where resources were encountered on a more ad hoc basis.

Question five focused on how the decision-making objectives and criteria affected the model outputs. It was found that terrestrial species (a criteria) acted to skew all models toward high and dry areas of the landscape, ostensibly because these resources tend to rank higher regarding satisfying minimum resource needs, population aggregation, and prestige. Whether hunter-gatherers pursued a narrow or broad resource spectrum was found to affect how hunter-gatherers perceived of the landscape, such that even when a broad spectrum was exploited, large game and seasonally abundant species (such as migratory birds and fish) could skew the usefulness of the landscape substantially. This led to the tentative conclusion that certain species were more important criteria in the decision-making process than others. Thus, species like large game and seasonally abundant fish and birds had a greater affect on the perceived usefulness of the environment than other species, most likely due to the ability of these resources to amply satisfy more objectives than others. Further, it was found that the objectives guiding settlement placement differ somewhat given the environment; that is, the objectives of wetland and dryland settlement models are different. The 'core' objectives that tend to be followed for dryland models are relaxed in wetland scenarios. New technologies and customs may have mitigated this relaxation and made living in a wet environment more bearable.

Last, question six aimed to identify the relationship between the three study areas within the central river valley of the Netherlands. It was found that these sub-regions were linked in a delayed relationship. While hunting was important early in the period when the whole valley was still dry, areas highly suitable to hunting began to migrate upstream as sea-level transgression began to inundate parts of the downstream area. By the Atlantic period, the downstream becomes more useful for wetland-focused, collector strategies. This relationship follows the eastward movement of the deltaic apex, and has important implications for predicting what sort of resources and settlement strategies were utilized at particular times. Further, it seems abundantly clear that the discrepancy between early Mesolithic data from the east of the river valley and late Mesolithic data from the west is simply a function of differential access and research. It is expected that further research in the downstream area of the Netherlands will uncover well-preserved evidence of early Mesolithic encampments with a hunting focus.

To conclude, it may be stated that the central river valley of the Netherlands was a dynamic area during the Mesolithic as a whole, although parts of the landscape did not change all that much, to the extent that hunter-gatherers may not have detected any changes at the local level or individually. However, these changes would have been recognized at the regional level and at a generational scale. Decision-making concerning what to eat and where to live was integral to daily life, and the configuration of the landscape affected these decisions to some degree. However, other factors also played a key role in group decision making, such as obtaining a minimum amount of resources while minimizing risk and maximizing efficiency, acquiring taste, variety, and prestige, as well as the location of dry ground, and the acquisition of sufficient shelter and view. The targeting of resources was particularly important and was focused on in this study as a way to understand the functions of known archaeological sites, as well as to predict the uses of locations lacking in archaeological data. Lastly, while the model developed in this study was successful in answering some of the questions posed at the beginning of this chapter, other questions have only been partially answered. Until a thorough sensitivity test of the model is conducted, the answers provided here for questions two and five should be regarded as preliminary findings to be followed up in future research (see section 8.4).

Chapter 8

DISCUSSION AND CONCLUSIONS

Over the course of the early to middle Holocene (ca. 10,000-6000 ^{14}C yr B.P.), changes occurred in the landscape of the central river valley of the Netherlands. In the east of the Rhine-Meuse river valley, these changes consisted primarily of superficial alterations to the vegetation, in terms of both succession and density. In the west of the river valley, the changes involved more intensive geomorphologic, geologic, and hydrologic transformations, in addition to some vegetation succession. Both the archaeological data and the heuristic model developed here suggest that these environmental changes had some impact on human decision-making and land use behavior. While various factors impede clearer understandings of Mesolithic lifeways in the Netherlands, this study presents a method for targeting some of these questions from a different perspective – one that takes its departure from known geologic-geomorphologic and ethnographic data, in order to simulate the ways hunter-gatherers may have behaved in the past. In this chapter, the original research questions will first be addressed and answered to the extent that this study allows, followed by a consideration of the broader implications of this study for Mesolithic studies in the Netherlands and beyond. Last, future research directions will be discussed.

8.1 Addressing the Research Questions

The broad research questions posed in Chapter 1 of this study ask:

1. What adaptive strategies were used throughout the course of the Mesolithic period by hunter-gatherers in varying environmental contexts?
2. Given that perturbations in the natural environment occurred during the Mesolithic, were hunter-gatherer land use decision altered in response?
3. What are the archaeological correlates of these adaptive strategies that can be found in the archaeological record?
4. Can land use decision be predicted based on knowledge of ethnographically-documented hunter-gatherer decision-making?

To varying degrees this study has helped to shed light on all of these questions, although further research will be necessary for more robust answers to be developed.

8.1.1 Question 1. Regarding the first question, a range of adaptive strategies was likely used by hunter-gatherers. To streamline the modeling process here, six subsistence-settlement strategies were considered: foraging strategies focused variously on large game, general foraging (in which all species considered here were included), and wetland resources; and collecting strategies, also focused variously on large game, general foraging, and wetland resources. While these strategies provided useful ends of a foraging-collecting spectrum (see Binford 1980), they are in no way necessarily representative of the myriad combinations of settlement-subsistence strategies practiced by hunter-gatherers. They are, however, instructive when the goal is to establish what strategies were most suitable in certain environments.

It was found that the adaptive strategies used by hunter-gatherers was partially influenced by the location of the deltaic apex, such that areas lying above this apex tended to be used for the extraction of terrestrial resources (although some opportunistic use of wetland species cannot be denied), generally accompanied by a foraging strategy or moving people to resources (see Chapter 7). Areas lying below the deltaic apex tended to be used for procuring wetland resources (again with the caveat that hunting large game and other terrestrial species was still an important component), usually accommodated with a collector strategy of moving resources to a central base camp (see Chapter 7). Thus, while very little early Mesolithic evidence has been found in the western portion of the central river valley, the model developed here suggests that the area would have been well suited to both foraging and collecting of large game as well as other general foraging resources. It is argued that further research in the western portion of the country will yield evidence from these earlier settlements. It appears that past research in this area has either not penetrated the subsoil deeply enough, or has not targeted areas likely to have been used by hunter-gatherers at that time. While we know that the high and dry dune tops were favored oases for late Mesolithic groups (and may also have been for early Mesolithic groups), it is probable that other locations in the downstream sub-region were also used, prior to becoming wetland.

In the eastern portion of the central river valley (e.g., the Ooijerhoek area), the model predicts that hunter-gatherers could effectively implement either foraging or collector strategies, and switch between the two with relative ease. The main factor that appears to have affected the use of the area was the vegetation, which became quite dense in the Boreal and Atlantic periods (c. 9000-6000 ^{14}C yr B.P.). This increasing density of the forests would have made the landscape harder for hunter-gatherers to penetrate, not to mention stalk and kill prey. It is likely that river and stream valleys became the main conduits into and out of the sub-region. As the archaeological record suggests, placing residential camps along these water bodies would have been beneficial for intercepting prey on its way to drink. Further, as suggested by evidence for burning of brush from the site of Ooijerhoek, hunter-gatherers may have encouraged the spread of edge zone along the rivers and streams to further attract prey.

Similarly, in the intervening sub-region--where the Rhine and Meuse are at their closest proximity (in the Deest area)—foraging and collecting large game and other terrestrial species would have been the most viable strategy for survival. Further, the location of two ephemeral sites in the river valley itself suggests that wetland resource extraction may have been an important component of the overall subsistence base. While the data from this region is the coarsest of that considered in this study, it is proposed here that residential camps were placed on the edges of dryland features such as terraces, ridges, dunes, and levees. From these central locations, logistical forays could be mounted to obtain wetland resources in the river valley, or terrestrial species in the hinterland.

In summary then, it is possible that a range of adaptive strategies were practiced by hunter-gatherers during the Mesolithic, with strict foraging at one end of the spectrum and collecting at the other. Most likely, even in the downstream area, there was a continual shift between the settlement-subsistence strategies and the resources focused upon. For some areas and times, this may have been a seasonal shift; for others the shift may have occurred from day to day. Further excavation and research on Mesolithic land use in this area is needed to fill in the gaps of the archaeological record as well as understandings about the timing, flexibility, and character of specific subsistence-settlement strategies.

8.1.2 Question 2. The second question posed in the Introduction asks if hunter-gatherer decisions had to be altered in response to environmental and ecological perturbations. Clearly, hunter-gatherer decisions and behavior did have to be altered to some degree, as discussed above in relation to the changes in physical environment. Furthermore, it was shown in Chapter 7 that the criteria and objectives that guide hunter-gatherer decision-making are changed for particular external circumstances. For example, while obtaining shelter, a good view, and dry ground are important objectives for hunter-gatherers who wish to position a residential camp, these objectives must be relaxed in a wetland context, where the abundance and easy extraction of resources skews the objectives such that shelter and view are no longer key objectives. Also, it was seen that certain resources, regardless of their suitability for a given environment, always seem to 'pull' decisions in their favor. These resources are those that satisfy many objectives well, such as large game and seasonally abundant wetland species like migratory birds and fish. Conversely, other resources that were highly suitable for a given area (e.g., small mammals and terrestrial birds) had little pull on the overall decision models, ostensibly because of their relative inability to satisfy the basic needs of hunter-gatherers. In sum, it can be said that large game and seasonally abundant and easily accessible resources were perceived by hunter-gatherers to be more important in regards to settlement positioning and resource provisioning than other species. As has been noted in various ethnographies, these 'other' species are often considered by hunter-gatherers to be secondary or starvation foods, only relied upon when other choicer resources are not available or accessible (e.g., Honigmann 1949:104; Savishinsky 1974:25).

In summary, then, hunter-gatherer decisions were altered, although this may not have been conscious on an individual level. The most rapid environmental changes occurred in the downstream area, from 8000-7000 ^{14}C yr B.P., when the entire Polderweg area became overtaken by the deltaic apex, and dry woods and grasslands were replaced with wetlands. This change would have been noticeable across many successive generations, and may have been recorded in the cosmology and mythology of groups living there. However, it is likely that any alterations in decision-making would have happened very gradually over the course of hundreds of years until some relative threshold was attained that "tipped" the system directionally. Similarly, any cultural adaptations necessary to adapt to new ecological environments, such as wetlands, would have had ample time to develop. Thus, it is likely that the archaeological remains of a wetland adaptation that can be seen from the Polderweg and De Bruin sites was the product of many generations of hunter-gatherers experimenting with the best ways to exploit this environment. This long time frame perspective makes it abundantly clear that dugout canoes, fish traps and weirs, nets, semi-subterranean dwellings, and pottery could easily have been developed indigenously, perhaps with (but not necessarily requiring) some technological exchange with neighboring groups.

8.1.3 Question 3. The third question asks about the archaeological correlates related to differing adaptive strategies. Some very specific characteristics of material culture can be used to discern different subsistence-settlement strategies. For example, evidence such as water craft, fishing and birding tackle, and semi-permanent residences is highly indicative of a wetland focused collecting strategy, as was seen at the sites of Polderweg and De Bruin. To indicate foraging strategies focused on large game or general foraging, archaeological remains are expected to be ephemeral in nature, and represent only select segments of the tool kit, in addition to a few domestic tools. For example, at the site of Looërenk WP82, primarily hunting related tools have been found (e.g., sharp flakes and blades), and appear to have been fashioned in a rather expedient manner, that is, to satisfy the needs of an immediate extraction event. The remains of targeted hunting events may also have a different signature, such as a cache of specific tools or tool components intended for a particular extraction activity. An example of such a signature in the archaeological record is the cache of backed blades that was found at the site of Looërenk WP167, where over one hundred of these tool components were recovered, potentially for birding or other extraction activities. Larger foraging or collecting sites focused on large game are expected to contain more remains of domestic activities, along with some extraction tools, such as was found at the site of Epse-Olthof and Ooijerhoek.

What is clear from the archaeological data especially from the eastern portion of the central Netherlands is that hunter-gatherers reused particular areas time and again. Sediment was slow to accumulate in this region, and thus the remains from each occupation have become intertwined in a palimpsest of material that is nearly impossible to extract into individual occupation events. In such a scenario, it is difficult to say definitively what types of subsistence-settlement strategies were undertaken. Instead, the assemblage must be considered as a whole. It is therefore possible that the wide range of tool types and quality from sites such as Ooijerhoek and Epse-Olthof represent the remains of both short-term foraging and logistical camps, as well as a few longer-term residential camps[20]. By the same token, it is equally likely that the remains were accumulated through years of logistical or short-term residential use. However, the presence of many pits at the Epse-Olthof site suggest either a large residential site or repeated use of the site within a short window of time, such that the location of earlier pits could be avoided when digging new ones. In sum, some archaeological correlates can clearly point to specific land use behaviors by hunter-gatherers, while other remains are more elusive and will require further excavation to improve understandings.

[20] It should, however, be recalled that assemblage diversity increases with assemblage size and thus, both sites may have been the product of numerous short-term and small-scale re-occupations.

The last question posed above questions whether land use decisions of past hunter-gatherers can be predicted from knowledge derived from ethnographically-documented hunter-gatherers. As the model developed here has shown, it is possible to model hunter-gatherer decision-making in the past based on information gleaned from modern or sub-recent hunter-gatherer groups. Such an exercise allows the researcher to explore the nature of the decision-making process, including how important certain criteria and objectives were in relation to land use and perception of the environment, as well as highlighting which configuration of objectives are perceived as important to consider in the context of different environments. The graphic results of the modeling undertaken here compares well with the archaeological data and it is therefore argued that predictive output maps for time periods without known archaeological remains can be used to inform future heritage management efforts (see further discussion below).

8.2 Non-Economic Drivers of Land Use and 'Livelihood'

Given the spatial data available, this study has taken a strong economic approach to questions of hunter-gatherer land use, settlement, and subsistence. This underlying theme of the dissertation was also partly a result of the model building process, which demanded that a basic environmental framework was first constructed, followed by the incorporation of basic human survival requirements (e.g., proximity to resources and water, shelter, ground dryness, etc.). However, it is in no way the author's intention to assert that these survival requirements are the only factors the drive hunter-gatherer decision-making. Certainly, a number of other sociocultural, political, and/or ritual factors may have been at play, and these are described in the following paragraphs. Furthermore, it is hoped that in future research the present model can be “fleshed out” to include a more diverse array of factors that may have conditioned the decision-making process (see section 8.4 below).

When confronted with a decision, human agents must choose between a number of choices. This study has been largely concerned with decisions involved in land use and ‘livelihood’ (i.e., subsistence and settlement), exploring the affects that environmental change and different land use choices have on spatial output maps. Essentially, the dimensions of livelihood and land use can be seen as the outward manifestations of social processes that condition or produce choices. These choices are, in turn, a groups’ way of interacting and coping with their environment, but they are not restricted to survival requirements alone. According to McCusker and Carr (2006), settlement and subsistence refers not just to what is consumed or where people live; these dimensions of human life are also largely motivated by 1) the need to construct a nested social order at the local, sub-regional, and regional level; and 2) to circulate (political) power among individuals and groups. Land use reflects the way a group orders their world in regard to access and power, “where the appropriate crops, labor, land area and intensity for a given context are not only agricultural/biophysical facts, but important forms of knowledge that rest upon and produce relations of power in local contexts” (McCusker and Carr 2006:791). Clearly, access to resources, knowledge, and the power involved in having these rights will condition the choices that are made by a group.

Land use and livelihood choices can be driven by the need to maintain a social ordering of society, such that relationships between individuals, generations, and groups can be observed. These relationships may define the division of labor between men and women or between the young and old; simultaneously, observing larger-scale relationships is also an important consideration in the land use/livelihood decision-making process. For example, relationships within and between kin groups, bands, and tribes could easily affect what land is used when, what type of subsistence is practiced where, and what types of sharing and exchange is carried out. Issues of territoriality, land tenure, and ownership can also have an important impact on what land use choices are made, informed by power relationships. Kelly (1995) notes that while the sharing of goods and access to land is observed by many hunter-gatherer communities worldwide, it is the product of a decision-making process that weighs the costs and benefits of such a choice, while considering both future expectations and past experiences (Kelly 1995:202).

Again, the location and transference of (political) power is also assumed to greatly affect decisions regarding land use and livelihood. It is likely that Mesolithic hunter-gatherer were egalitarian in their organization of power, such that no one individual had more influence on a group decision than any other. It must be allowed, however, that some acquired-status positions may have arisen in Mesolithic communities, in which the opinions of particularly adept hunters, fishers, fire lighters, shelter builders, etc., would have carried more weight than other members of the group when considering where to hunt, fish, or place a temporary camp or settlement. Similarly, the special ritual or spiritual knowledge held by shamans was most likely another important conditioner of how to use a habitat or where to place a new settlement. Shamans or spiritual leaders would also have possessed a degree of decision-making power based on their secret, limited-access knowledge.

In sum, a number of non-economic factors were certainly important driving factors that shaped decisions of land use and livelihood. These factors ranged from the need to organize and maintain a social structure (both at the local and regional levels) and to uphold power relationships (which among hunter-gatherers were mostly based on access to resources and knowledge).

8.3 Broader implications

The model developed in this research has shed new light on the questions posed above, mainly regarding the use of different adaptive strategies over time, the interactions between humans and the environment, and some of the intricacies of the decision-making process regarding settlement placement and resource provisioning. This is the first model of its kind developed for the central river valley of the Netherlands, and it should be noted that apart from Peeters' (2007) model for the Flevoland area, no similar Mesolithic-focused models have been generated anywhere in Europe. Thus, despite the fact that the model constructed here needs some additional refinement, and a sensitivity test run in order to understand the breadth and subtleties that lie therein, it is believed that this approach to answering questions about hunter-gatherer behavior in the past is an important step forward in Mesolithic archaeology, and perhaps beyond in both a spatial and temporal context. Pairing geospatial and other environmental data with ethnographically-documented behavioral strategies is a novel approach to unpacking questions of land use and land use change over time, as well as perceptions of the landscape, and the processes involved in decision-making that have, in many cases, been otherwise lost over the millennia. It is advocated here that such environmental and behavioral modeling should become an important component of any field-based research program, as unexpected insights can be gained and future research trajectories identified.

These findings hold for the central river basin of the Netherlands, specifically the sub-regions focused upon in this study. But what are the broader implications of these results for the Mesolithic in the Netherlands? Currently, most data on the Mesolithic period derives from the north and south of the country, in part due to research focus and accessibility. The 'canon' of knowledge about the Dutch Mesolithic is built largely on data from a few key areas (e.g., the Flevoland polders, the downstream Alblasserwaard polder, the Groningen peat district sites, the OverIJssel Vecht area, and the Venray region). Most of the sites found in these areas occur on high and dry topographical features such as dune tops, terraces, and ridges, despite the fact that other lower and wetter parts of the landscape were surely utilized by hunter-gatherers. The strength of the model developed here is its ability to locate where these other, non-high and dry locations may have been for further research, which will likely contribute to fuller understandings of how the total landscape, including wetlands, was exploited.

Another strength of the model developed in this research is its ability to accommodate both stratified *in situ* archaeological data, as well as scattered finds. While the latter are not very informative about the specific use of a site, they can still be used comparatively to test the accuracy of the model in predicting areas of high or low suitability. Such sites can also provide information simply from their lack of good preservation and characteristic content. In the case of Deest and Zuiderveld-West, only small collections of lithic artifacts were recovered, both of which may have been the result of secondary depositional processes. However, in the context of the decision-model, these finds become informative as they occur in areas with low suitability for hunting or gathering general resources. Thus, it is proposed here that the sites may have been ephemeral logistical camps placed in the wet river valleys to extract wetland resources, with the larger residential camps placed further up on dunes and terraces. Further research conducted on the remaining terraces and ridges will help to support or reject this hypothesis. Regardless, the model developed here has generated new hypotheses for future testing. Prior to the results of the modeling, very little could be said of hunter-gatherer land use in this area, apart from general speculation.

As discussed in Chapter 7, the model makes some predictions about how the central river valley of the Netherlands was used over time. It is argued therein that the position of the deltaic apex appears to be related to the type of subsistence-settlement strategies utilized. But how was the region used as a whole? Were multiple bands and networks living within the confines of the modern-day country? To answer the first question, the model can only say that the downstream area would have been viable for hunting and gathering in the early Holocene, with the inclusion of wetland resources by the middle Holocene. This downstream area may have been used in certain seasons (although these probably shifted over time; see Louwe Kooijmans 2001a, 2001b), alternating with other occupations further to the west along the contemporaneous coastline, to the eastern portion of the river valley, or to the forested terraces to the north and south (see Figures 8.1 and 8.2 for possible locations). Unfortunately, the model cannot yet make any definitive statements about the nature of seasonal use of the region, or the degree of mobility practiced. However, it does suggest that over time, hunter-gatherers had to adapt to the new external characteristics of the ever-encroaching tidal wetlands to the west, which they appear to have done. Only a larger and better preserved archaeological record, and more in-depth analyses of existing artifacts (e.g., chemical sourcing of stone tools) will help to shed light on these questions and provide further information about the connections or boundaries between areas and the seasonality of site usage.

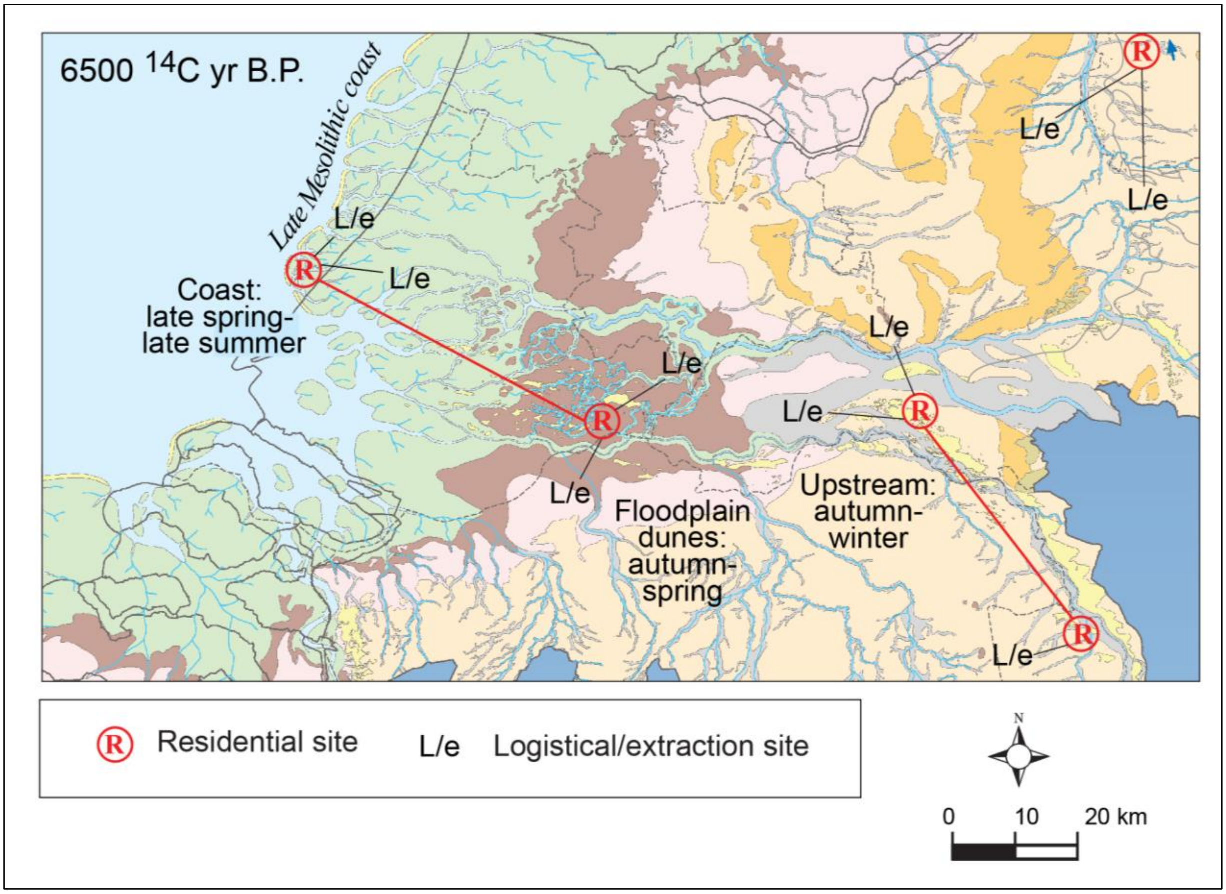

Figure 8.1 Possible Band Territories with Seasonality Included – Small-Scale Mobility (adapted from Vos et al. 2011).

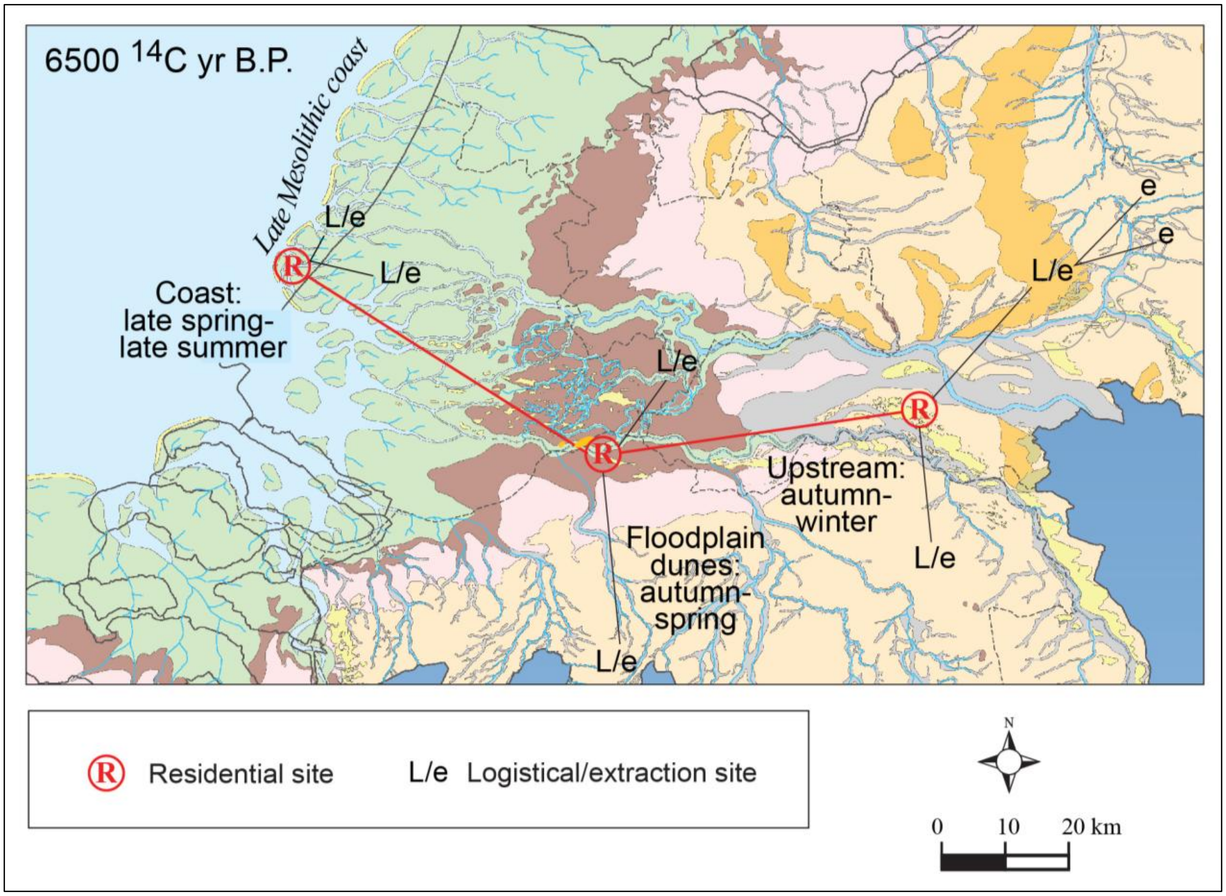

Figure 8.2 Possible Band Territories with Seasonality Included – Large-Scale Mobility (adapted from Vos et al. 2011).

It is also interesting to consider how many hunter-gatherers may have inhabited the modern-day Netherlands at any given time. While the model developed here does not incorporate estimations of the amount of calories available in the landscape, such an endeavor would be possible to pursue with future research. Suffice it to say, the landscape of the central river valley appears to have been quite viable for hunter-gatherer groups during the course of the Mesolithic, although less so during the Preboreal than other periods (see Chapter 7). Furthermore, by the Atlantic in the eastern part of the country, forests are assumed to have become very dense, impeding both movement through these areas as well as the easy extraction of forest resources. Nevertheless, hunter-gatherers seem to have developed strategies to counteract these forces, by focusing more opportunistically on wetland resources, and by burning brush around rivers and streams in an effort to attract more game.

Given the small number of Mesolithic sites known from the Netherlands, it is possible that the population density of the area was similarly low, perhaps consisting of ten or so bands linked into larger networks by alliances or other formalized relationships (Whallon et al. 2011). However, this statement must be written with an important qualification: not only are there many more sites and remains to be found, much evidence of Mesolithic people has no doubt been lost to the ravages of time. Thus, this estimate of population size is a *minimum* estimate only. Further, some archaeological evidence indicates that two such larger networks existed in the late Mesolithic of the Netherlands (Figure 8.3). This figure shows the division of the country into two main networks: a Rhine Basin Group, which has common links with the western Tardenoisian tradition in Belgium and France; and a Northwest group, which appears to be a continuation of Maglemose and Kongemose traditions of Scandinavia). This demarcation was drawn from stylistic differences in lithic tools (Verhart and Groenendijk 2005). The right portion of the figure shows the location of deep hearth pits, which may be yet another outward representation of this boundary between Rhine Basin and Northwest groups. The sub-regions considered in this study would have fallen into the Rhine Basin Group, although if deep hearths are taken as an indicator of territorial boundaries, then it could be that the sites in the Ooijerhoek area were inhabited by a different group of people than the Polderweg or Deest area sites. Thus far, comparison of lithic styles has not been definitive in terms of supporting linkages with the north or west, primarily because of the time lag between eastern assemblages and western assemblages. The discovery of early Mesolithic tool kits from the west of the country, or better preserved and more complete late Mesolithic tools kits from the east, could thus prove insightful regarding this question of territoriality.

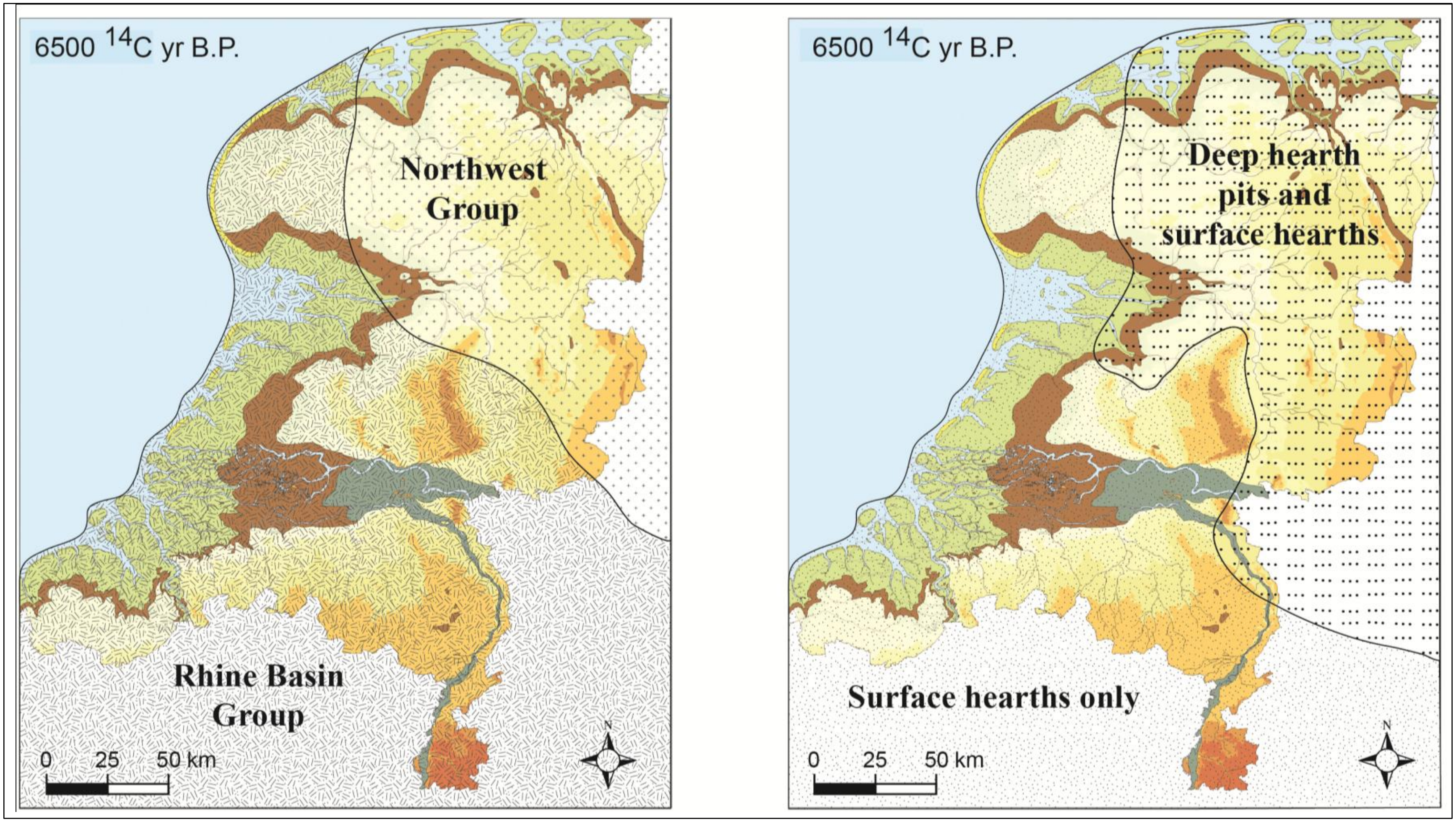

Figure 8.3 Extent of Possible Mesolithic Group Boundaries across the Netherlands.

8.4 Future Research

The model developed in this research was intended to be a heuristic device for learning about hunter-gatherer land use strategies and perceptions of the landscape in the context of decision-making. It is the first of its kind to be applied to this area, preceded by a similar model developed by Peeters (2007) for Flevoland. As noted above, no similar models of hunter-gatherer behavior have been developed for the Mesolithic anywhere in Europe. Though this model has many strengths (see section 8.2 above), it also has much room for improvement and growth. First, the model (as with any model) is only as strong as its weakest data. However, improving the quality and quantity of the data is unlikely to be a possibility–currently, the Netherlands has one of the most detailed databases of subsurface geology and geomorphology in the world. If the model is applied to any other region, it is unlikely that the environmental data will be nearly as populous or accurate. There are also uncertainties and biases that crop up in such modeling, which is inherently deterministic in various ways. To get around some of these biases and uncertainties, a thorough sensitivity model must first be undertaken to expose which factors the model favors and which factors are downplayed. Conducting such a sensitivity model will be the first step taken in future research; afterwards, when the uncertainties and idiosyncrasies of the modeling process are identified, steps can be taken to diminish or remove them. At the same time, it should be realized that modeling of past environments and of past human decision-making will always entail a certain degree of uncertainty, which must simply be accepted.

Notwithstanding the limitations of the model, additional research questions may be posed, and new modules added on. For example, more detailed information about resource availability by season, as well as caloric yields, could be harnessed in order to generate estimations of the total carrying capacity of the environment. Such a project could reveal invaluable information about the population density of the central Netherlands. In addition, as discussed in section 8.2 above, the range of factors influencing hunter-gatherer decision-making should be expanded to include non-subsistence drivers (e.g., sociocultural, political, and ritual/spiritual factors).

The model could also be improved by testing its predictions against the archaeological record; however, in the absence of further data, other sources of information must be sought. One such potential source are the 200,000+ borings that have been taken in the central river valley of the Netherlands by the Physical Geography Department of Utrecht University, along with the Dutch Geological Services (TNO). Some of these borings have yielded archaeological remains and thus, a fruitful future study may involve further comparison between the location of these finds with the suitable areas as predicted by the model. The results of such a study could not only be used to improve the accuracy of the model, but also be used to indicate which adaptive strategies were utilized in specific places and times. Furthermore, the bore hole data in conjunction with the predictive model could highlight areas for future excavation.

The model developed here reveals much about paleo-environments in the Post-glacial, as well as the possible decisions and actions undertaken by Mesolithic hunter-gatherers. Nevertheless, as was seen in Chapter 7, there still remain many questions to be answered. One way to answer such questions is to focus on gathering increasingly detailed data. We run a risk, however, in forever questing for more and more data, which many in the archaeological modeling community currently assume is the best way to improve a model (Doran 2008). In the long run, it is not more data that is required, but rather smarter and more targeted models. Only with "validation, sensitivity analysis and parameter space exploration, and the critical task of choosing an appropriate level of abstraction (or granularity; Doran 2008:3)" can better models be developed. Perhaps one of the most challenging issues facing the current model is how to link different spatiotemporal scales in order to extract new and useful information. Determining how to make a smarter model, which can shed light on issues of spatial and temporal change, is an critical trajectory of future research for the author.

Broader implications could be gleaned for the entire Netherlands if the model was applied to the entire country. While this is not yet possible on account of a lack of sufficient geomorphologic, geologic, and hydrologic data, it may soon be, as a detailed atlas of the paleo-landscape has been developed jointly by the Cultural Heritage Agency, the Geological Services, and the firm Deltares (Bazelmans et al. 2011). Such an endeavor would require great computing power, but has the potential to reveal intriguing linkages between seemingly separate archaeological regions and the configuration of the landscape over time. The main drawback of such a large-scale model would be the potential loss of specificity on the local level; however, the benefits of having a region-wide predictive model of subsistence-settlement strategies would no doubt be highly instructive for Mesolithic scholars, helping to answer some of the questions posed above, concerning for example, the linkages between uplands and lowlands, coasts and inlands, the type of mobility practiced in moving between these areas, the seasons such areas were occupied, and estimated population densities. Surely, such a model would generate many new questions worthy of multiple future research projects.

Lastly, the model developed here could be expanded into a full-blown agent based model (ABM). ABM has the advantage of being able to model individual or group decision-making at the local level, or group decision-making at the sub-regional or regional level. Further, this type of modeling allows for the creation of individual agents who are placed on a landscape and given a number of decision-making rules that they must follow when tasked to complete an action.

That action could be to find subsistence, or place a settlement. Such interactive modeling allows the researcher to quickly and easily identify the decision-making components that are important in different ecological contexts, as well as explore how hunter-gatherers perceive of various criteria. This type of modeling is also iterative, such that an agent can be programmed to ‘learn’ from past decision-making that was not successful. Thus, a closer approximation of the adaptive process that led to the development of a wetland lifestyle could be obtained, perhaps also shedding light on the mobility and settlement constraints that accompanied such a strategy.

8.5 Conclusion

In conclusion, the model developed here has shed light on hunter-gatherer land use strategies and perceptions of the landscape in the central river valley of the Netherlands. While most of the area was suitable for hunting large game and collecting other species during the entire Mesolithic period, the western portion of the study area became inundated by the Atlantic (c. 8000 ^{14}C yr B.P.). Hunter-gatherers coped with these changes in the external environment by developing new adaptive strategies, technologies, and lifeways focused on extracting wetland resources. However, the old strategies were not forgotten and were still widely practiced in the other inland study areas. While environmental factors were by no means the only factors shaping Mesolithic life, the position of the deltaic apex did have a perceptible influence, one that affected the adaptive strategies practiced as well as the decision-making processes that underpinned these strategies.

This study was built upon detailed landscape reconstructions, replete with probable vegetation areas and faunal habitat extents. From this base, a multi-criteria based decision model was developed using ethnographically-documented knowledge of hunter-gatherer decision-making components and processes. The results of this model were spatial-temporal maps that depict areas most likely to have been used by hunter-gatherers for resource extraction activities and settlement placement. The strength of this model is its ability to incorporate data of various types and quality. It has facilitated exploration of the differential components and processes of decision-making at the group level and found that these processes and components are not universal but change given hunter-gatherer perceptions of their current environment. Furthermore, the model has produced graphic displays depicting areas most likely to have hosted Mesolithic occupations and therefore supplies a needed predictive model for use in future heritage management.

APPENDICES

Appendix A

LANDFORM RECONSTRUCTION AND FLORAL AND FAUNAL MODELING METHODS

A.1 Introduction

To reconstruct maps of the paleo-landscape and generate floral and faunal distributions, a number of existing digital, spatial data sources were used, along with archaeological data and related literature. These included data on groundwater levels, vegetation succession, climate, lithology, soils, and floral and faunal habitat requirements. First, landform reconstruction will be discussed, followed by the modeling procedures used to produce vegetative and faunal distributions.

A.2 Landform Reconstruction

A.2.1 Approach and Assumptions. The overall goal of landform reconstruction was to produce accurate depictions of the Late Glacial through Middle Holocene surficial geomorphology, which would act as an armature on which vegetation zones could be draped. To achieve this aim, a number of factors were considered that impact vegetative growth to some degree, including landform features, lithology, soils, groundwater levels, climate, and vegetative succession. Mapping landform features required knowledge of the underlying lithology and soils of the area. As there is only a limited paleo-soil record for the Netherlands, general information concerning the prerequisites for soil formation were considered. To this was added information regarding fluctuating groundwater levels due in part to climate-induced sea level raise and increased precipitation levels. Knowledge of climate change and the basic vegetative successions that transpired in the Post-glacial period was also a crucial component. All of this information was layered together in a GIS framework, from which specific maps could be drawn (e.g., landform features or groundwater levels at a specific time and place).

The approach taken in this study assumes that in many locations, buried paleo-landscape features remain intact under more recent deposits. Where more recent disturbances have occurred, the extent of subsurface features were estimated from known characteristics of certain lithological units (e.g., the Wijchen member always occurs adjacent to river channels as it represents overbank sedimentation) and links were sought with existing features. In this manner, landform features that were present at the surface at given time intervals could be mapped. Groundwater levels were approximated in two different manners. For the Polderweg area, an interpolation curve developed by researchers at Utrecht University was used. This curve is based on the age and depth at which peat began to form, indicating when and where the sea transgressed certain areas. In the Deest and Ooijerhoek areas, a 1960s soil map of the Netherlands was used that contains groundwater classes for different soil units. In the absence of more detailed paleo-groundwater data, this map provided the closest estimates of groundwater levels during the Early Holocene. There are also important drawbacks to using this data, which are discussed in further detail below.

A.3 Materials

Reconstructing the paleo-landscape of the study areas involved integrating number of key data sources into a GIS (Table A.1). The Geotop DEM, Geomorphologic-geologic maps, the Geomorphological map of the Netherlands, and the Sand-Depth map were used to construct the evolving morphology of the Post-glacial period. All of these data sources were constructed previously by coring the subsurface, drawing cross-sections by linking the stacked stratigraphies of the cores, and then projecting these cross-sections laterally between north-south trending sections. Various dating methods were used to date features in the subsurface, such as OSL and radiocarbon dating. As noted, the formation of basal peat was used to indicate sea water transgressions.

The groundwater rise model and the Soil Map of the Netherlands were used to glean information concerning groundwater levels in the past. The digital elevation map was used as a reference to understand which areas of the landscape have been significantly reworked since the Early-Middle Holocene, and in which areas the paleo-landscapes are preserved beneath buried deposits. Written literature describing geologic, geomorphologic, hydrologic, and pedologic processes within the study areas were also consulted and utilized to a great extent (e.g., Berendsen and Stouthamer 2001; Busschers et al. 2007; Cohen 2003; Erkens and Cohen 2009; Gouw and Erkens 2007; Hijma et al. 2009; Spek 2004; Weerts et al. 2004; Westerhoff et al. 2003).

Table A.1 Data Sources Utilized for Landscape Reconstruction.

Data source	Description	Area(s) Used	Reference
Geotop DEM	Fine-grained (e.g., x-y-z = 100 x 100 x 0.5 m cell size) representation of upper 30 m of Dutch subsurface	Polderweg	(Stafleu and Schokker 2010)
Groundwater rise model	Based on radiocarbon dates of >300 basal peat samples, interpolated geostatistically into 3D output	Polderweg	(Cohen 2003; Cohen 2005)
Geomorphologic-geologic maps	Depict time-series channel belts for the Rhine and Meuse Rivers, and end of Pleistocene valley configuration	Polderweg	(Berendsen and Stouthamer 2001; Hijma 2009)
Geomorphological map of Netherlands	Detailed map of current geomorphology of the Netherlands	Deest and Ooijerhoek	(Koomen and Maas 2004; Maas and Makaske 2007),
Sand-Depth map (Zand in Banen)	Depicts depth to Pleistocene sand for east-central Netherlands, and intervening geomorphology	Deest and Ooijerhoek	(Cohen et al. 2009)
Soil map of the Netherlands	Shows soil units and groundwater levels of the modern day; also a version from 1960	Deest and Ooijerhoek	(Steur and Heijink 1991)
Digital Elevation Model of the Netherlands (AHN)	Shows elevations of the modern-day Netherlands	Deest and Ooijerhoek	(AGI 2005)

A.4 Methods

The same general procedure was followed for each study area, with some minor differences according to data allowances. Briefly, databases representing elevation, groundwater, geomorphology-geology, and soils were used as input ‘building blocks’ in Module 1 (Figure A.1). By combining these datasets, geomorphologic and hydrologic maps were produced for thousand-year time intervals (and in some cases, 500-year intervals; for examples, see Chapter 4). Further refinement and selection of hydrologic maps were made for the Deest and Ooijerhoek areas based on divergent views in the related literature, and expert knowledge about nutrient availability and soil development. The geomorphologic and preferred hydrologic maps were then used as the basis for developing vegetation distributions (see Chapter 4 for resulting map surfaces).

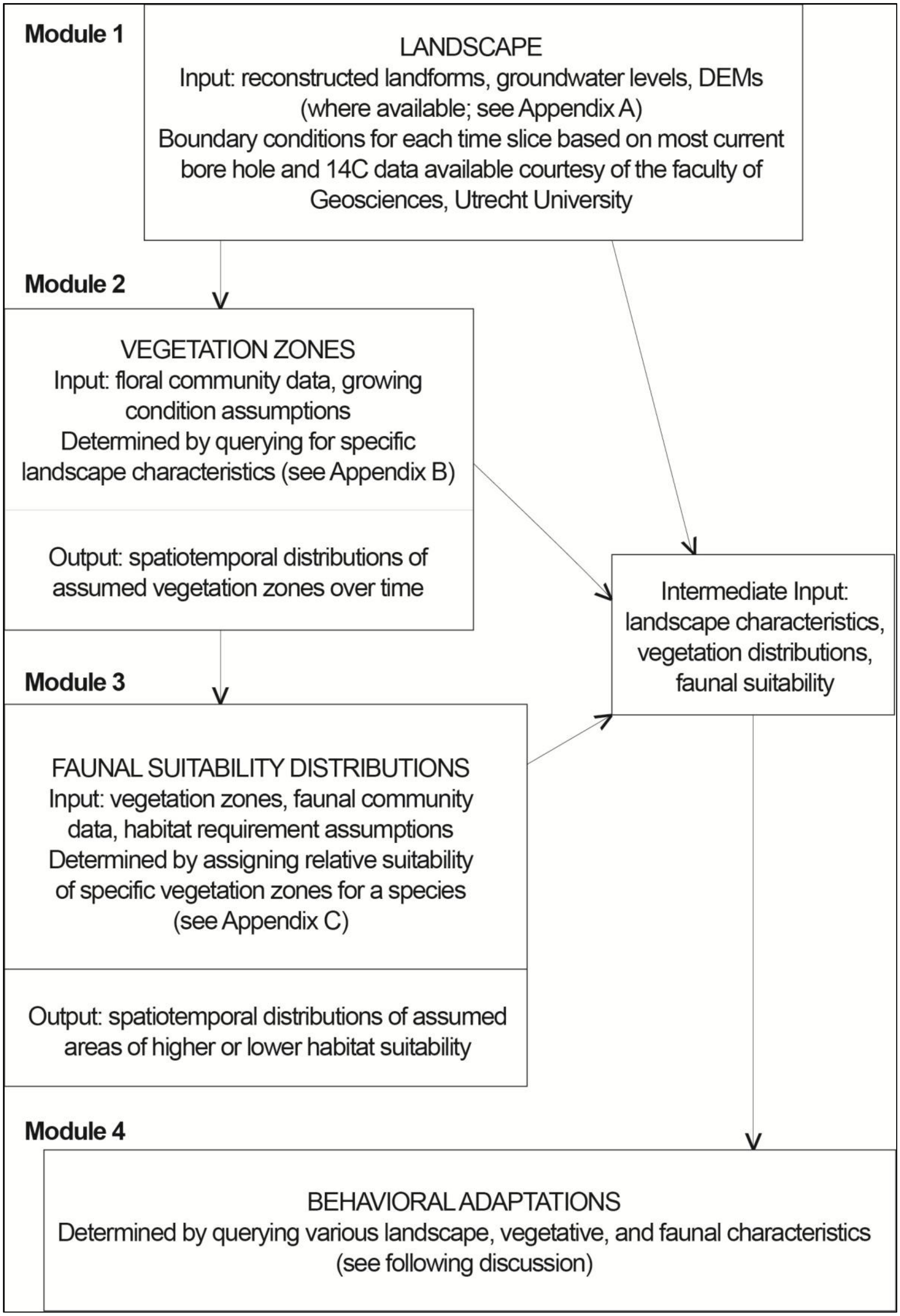

Figure A.1 Modeling 'Building Blocks.'

A.4.1 Constructing Paleo-Geomorphologic Maps

A.4.1.1 Polderweg. The basic procedure for Polderweg began by importing existing data sources containing dated information on buried landform features (e.g., the geologic-geomorphologic maps of Berendsen and Stouthamer 2001; Hijma 2009). A number of unique landforms types were selected for reconstruction, not only because they were present during the intervals of interest, but also because they are assumed to have represented parts of the landscape that were recognizable to Mesolithic hunter-gatherers (Table A.2). The "recognizability" of these landform features may have been due to differing elevations, groundwater levels, vegetative communities inhabiting the features, all of which would have affected the suitability of these areas for various hunter-gatherer activities. The only landform types that may not have been individually distinguishable were the river floodplain and the low terrace plain. However, it was deemed necessary to keep these landform features separate, as river floodplains were susceptible to seasonal flooding and were first incising and then aggrading the low terrace plain.

Next, modifications and additions were made (primarily to river channels and wet floodplain habitats) as suggested by various literature sources (e.g., Hijma 2009). Based on knowledge of groundwater level rise, certain features were shown to diminish in size and height over time, such as the eolian river dunes in the center of the study area. The extent and number of floodplain lakes was estimated by identifying the amount of subaqueous deposits during a given time interval from a cross-section of the area. All time interval maps were then checked for completeness and accuracy by K. Cohen (Utrecht University) and H. Weerts (the Cultural Heritage Agency of the Netherlands), and were then converted to raster format and imported to PCRaster (see Chapter 4, Figure 4.10).

Table A.2 Landform Categories Used in Paleo-Landscape Mapping.

Landform category	Code number	Derivation
Brook valley	11	Brook/stream
Brook channel	12	Brook/stream
River floodplain	20	River
Small river channel	21	River
Large river channel	22	River
Abandoning river channel	23	River
Abandoned river channel/levee/alluvial ridge	24	River
Active crevasse splay	25	River
Muddy swamp floodplain	30	River
Peaty marsh/fen floodplain	31	River
Open water/floodplain lake	32	River
High eolian topography (e.g., dunes)	40	Pleistocene eolian
Low eolian topography (e.g., dunes)	41	Pleistocene eolian
Ice-pushed ridge toe	50	Pleistocene ice-pushed ridge
Ice-pushed ridge slope	51	Pleistocene ice-pushed ridge
Ice-pushed ridge platform	52	Pleistocene ice-pushed ridge
Terrace plain	60	Pleniglacial river
Low terrace plain (Terrace 'X')	61	Pleniglacial river

A.4.1.2 Deest and Ooijerhoek. For the Deest and Ooijerhoek areas, the reconstruction procedure began by identifying where paleo-landforms still remain intact at the surface, where they remain buried beneath more recent deposits (e.g., post-6000 ^{14}C yr B.P.), and where they have been totally erased through river dynamics and human intervention. Thus, geomorphologic maps containing important components of the buried paleo-landscape were queried (e.g., the Geomorphologic map of the Netherlands and Sand-Depth map). Paleo-landforms that have changed little since the beginning of the Pleistocene include high eolian terraces, all ice-pushed formations, and to some extent the terrace plain. In other places, more recent deposits were identified (e.g., those from modern river channels, urban areas, Medieval dunes, and plaggen soils; Figure A.2 and A.3). These deposits were then removed to reveal the underlying landforms present in the Early and Middle Holocene. These underlying landforms are known from coring campaigns associated with mapping the subsurface (e.g., the Zand in Banen project, Cohen et al. 2009; the Geomorphologic map of the Netherlands, Koomen and Maas 2004; Maas and Makaske 2007; and the Soil map of the Netherlands, Stiboka 1979; Steur and Heijink 1991). In the event that no underlying landforms were present, estimations of previous landform features were made based on knowledge of the behavior of existing landforms, and projected landform distribution. Five time-series maps were made for the Deest area (see Chapter 4, Figure 4.11). However, only one geomorphology map was made for the Ooijerhoek area, as it is assumed that the landforms did not change significantly during the period (see Chapter 4, Figure 4.12).

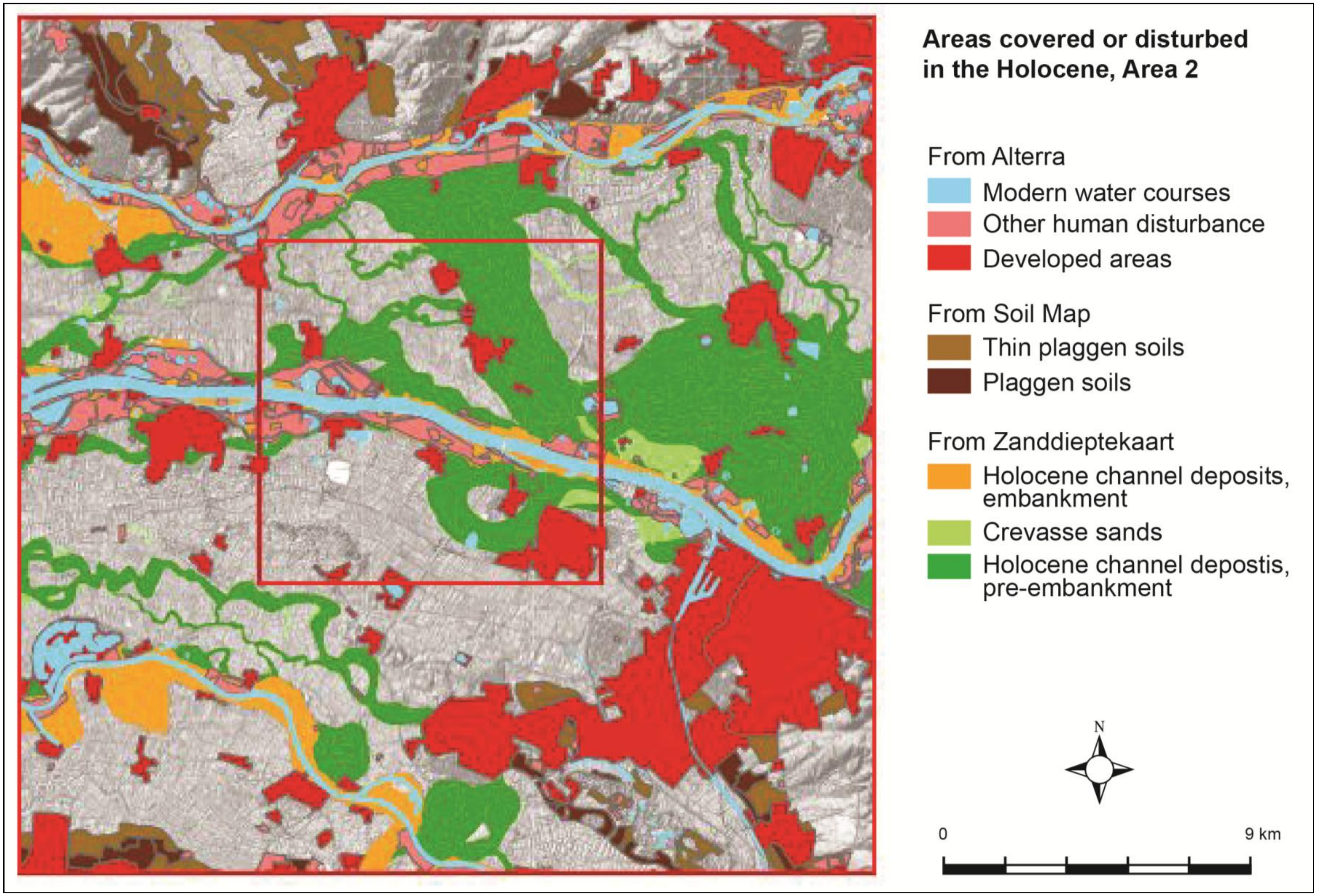

Figure A.2 Areas Disturbed Since the Middle Holocene in the Deest Area.

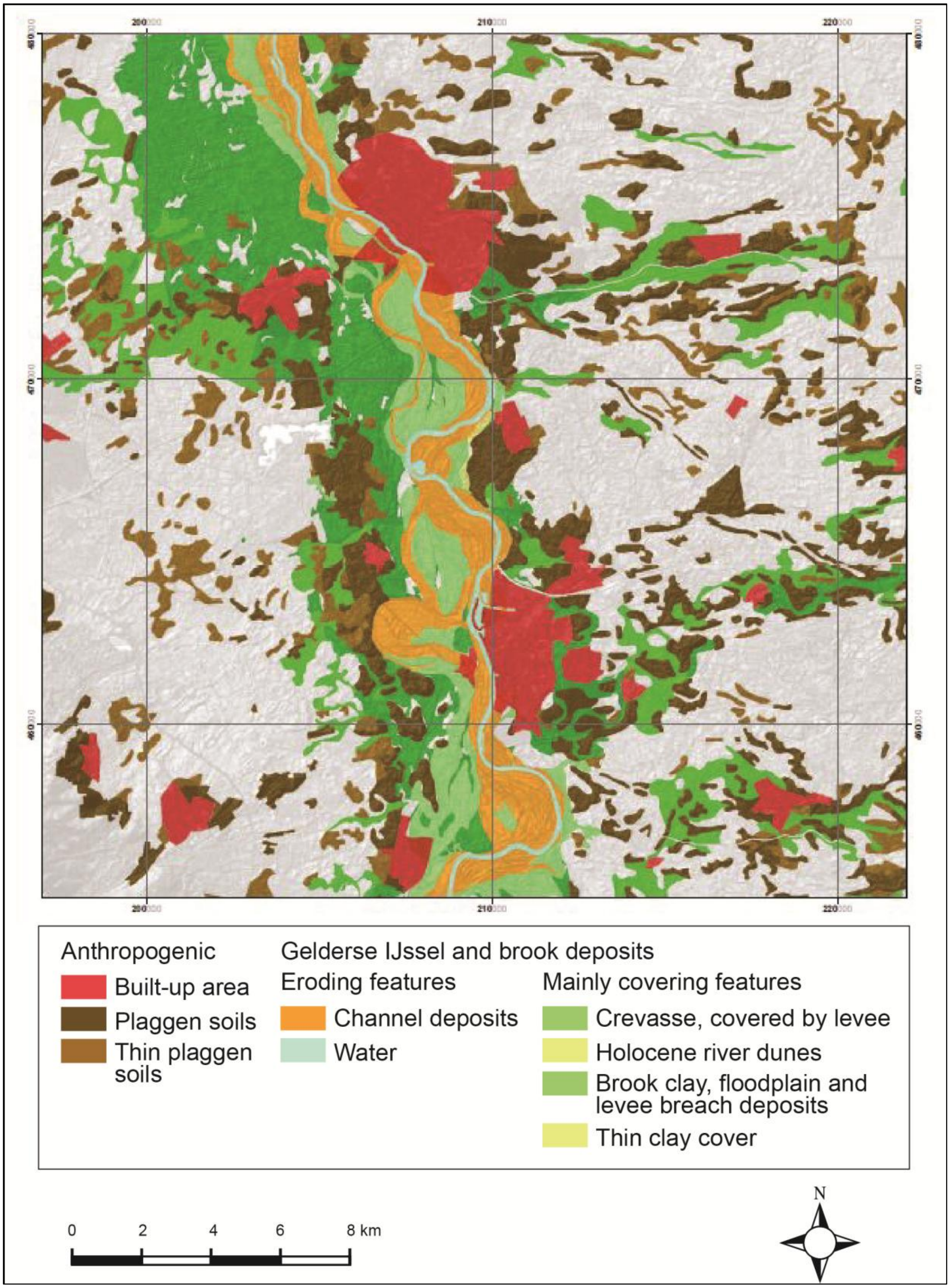

Figure A.3 Areas Disturbed Since the Middle Holocene in the Ooijerhoek Area (adapted from Pierik 2010:21).

A.4.2 Constructing Paleo-Groundwater Level Maps

A.4.2.1 Polderweg. The basic procedure for reconstructing the groundwater levels of the Polderweg area began with a digital elevation model of the top of the Pleistocene surface (e.g., Geotop DEM). This surface was assumed to represent the basic elevation and morphology of the ground surface throughout the period, as only small amounts of sedimentation occurred during the period. It was assumed that the primary changes in geomorphology were more closely related to inundation of previously dry landforms and initiation of peat growth.

The next step was to add interpolated groundwater levels for the time intervals. Within the study area, a number of indexed depth-to-groundwater points occur (Figure A.4). The groundwater elevation for each point was established per time interval, and then an interpolated surface was produced (Figure A.5).

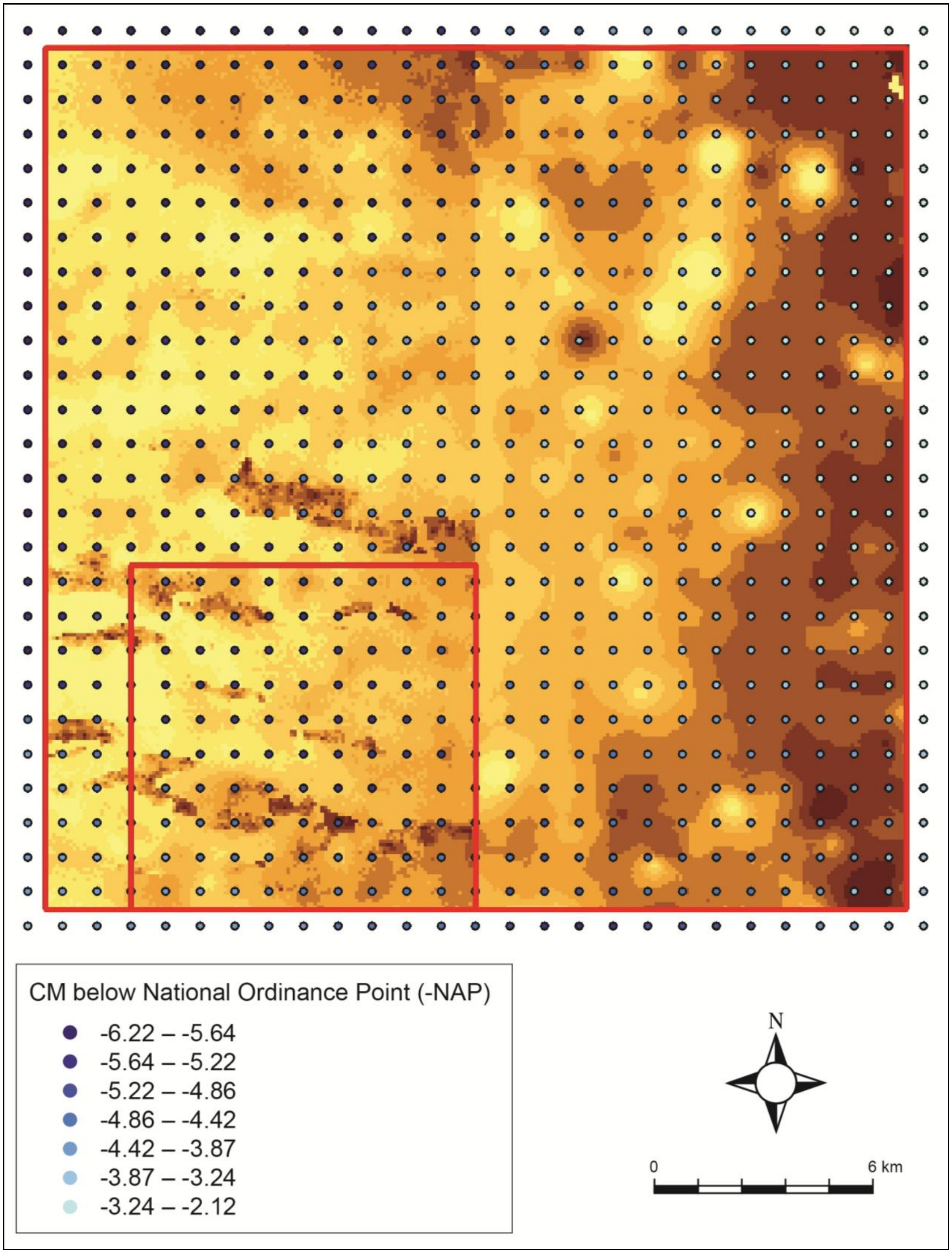

Figure A.4 Groundwater Interpolation Points in the Polderweg Area.

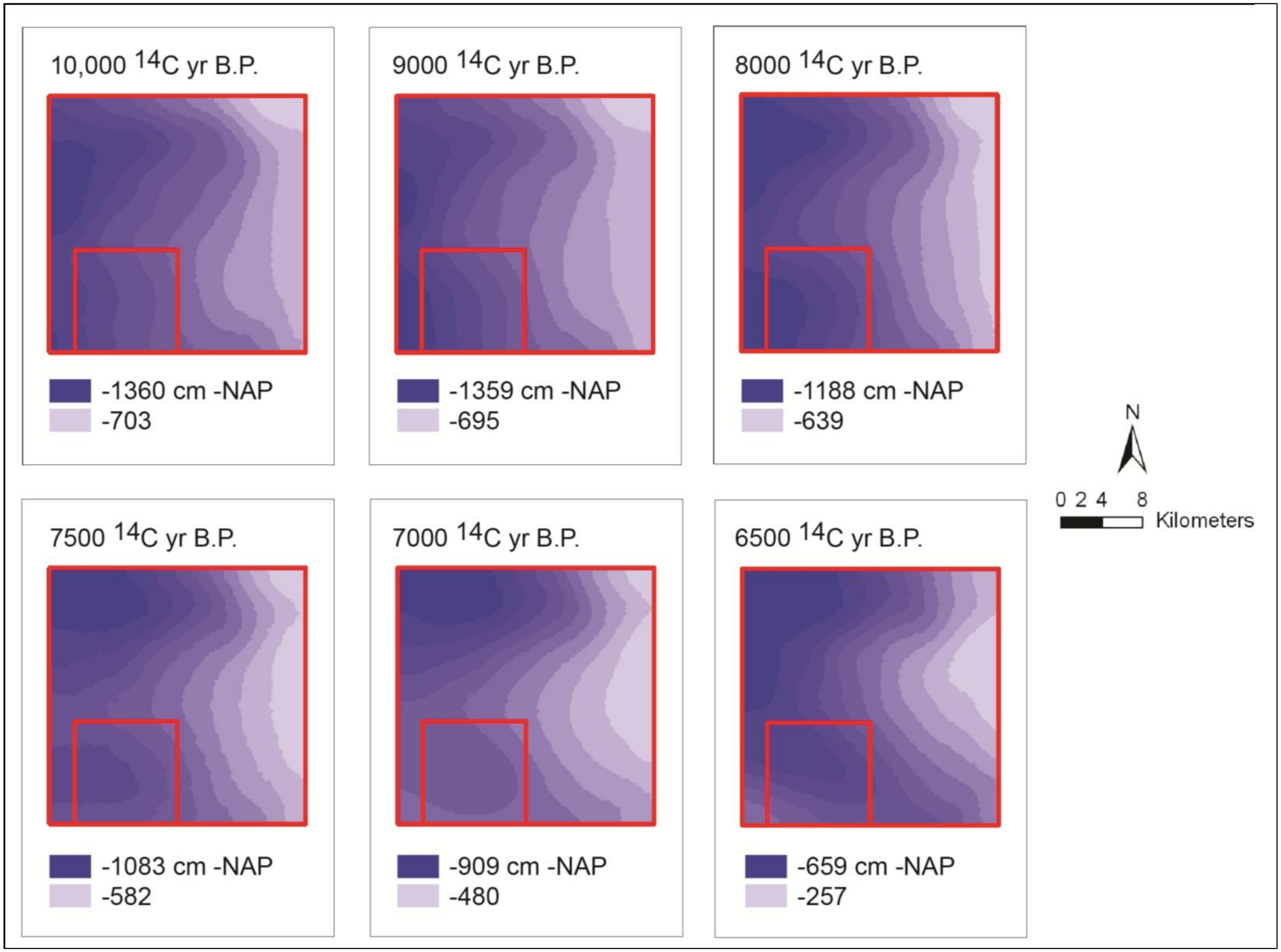

Figure A.5 Interpolated Groundwater Level Ranges (in cm)shown as Smooth Surfaces for the Polderweg Area.

To obtain an overall idea of the extent of wet/dry locations, the DEM and groundwater interpolations were merged for each time interval. The result is a series of maps depicting areas above and below water at given times (Figure A.6).

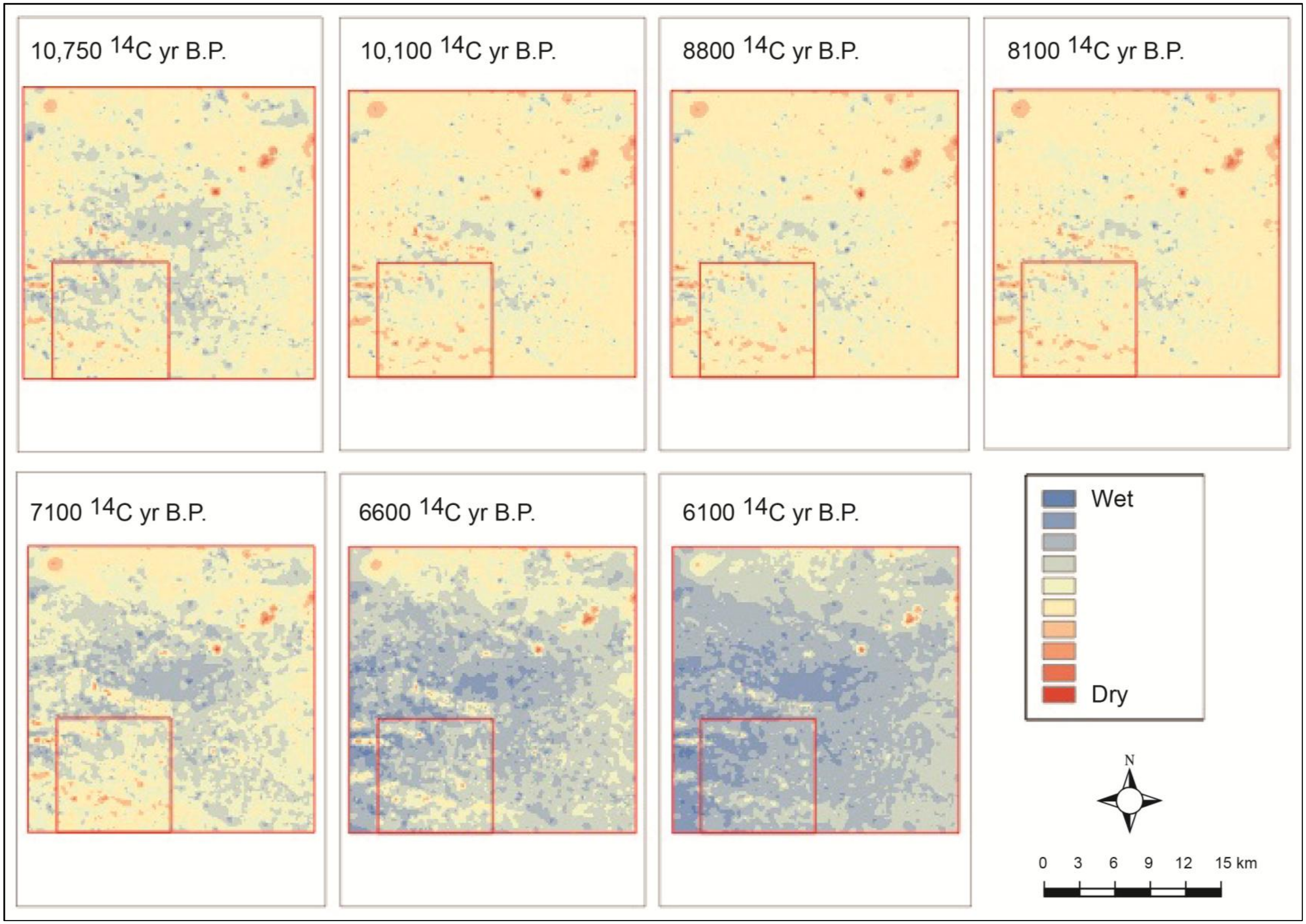

Figure A.6 Overall Wet/Dry Areas in the Polderweg Area.

A.4.2.2 Deest and Ooijerhoek. Establishing groundwater levels for the Deest and Ooijerhoek areas was not straightforward, as no groundwater level curve has been established for these locations. Instead, a new method was developed by H. J. Pierik (Pierik 2010) for the purposes of this study, and is described here.

For areas that have remained unchanged since the Middle Holocene, groundwater levels were taken directly from the Soil Map of the Netherlands. This map contains groundwater classes from ‘very wet’ (I) to ‘very dry’ (VII; Table A.3). In the absence of more accurate groundwater data, the assumption was made that the groundwater classes of the Soil Map (made in the 1960s) reflect those of the Early and Middle Holocene. Although this may seem like an unfounded assumption, no better groundwater data exists and furthermore, most large-scale landscape development occurred after the 1960s in the Netherlands. However, it should be noted that post-Mesolithic forest clearances and canalization into the historic period likely led to increased groundwater levels and thus the true Early and Middle Holocene groundwater levels were probably somewhat lower than the Soil Map depicts (as forests evaporate more water than open areas). Clearly, more research on groundwater levels and regime change in the interior of the Netherlands is greatly needed to improve the accuracy of this modeling exercise.

Table A.3 Groundwater Levels from the Dutch Soil Map (Stiboka 1979; De Bakker & Schelling 1989).

Groundwater class	Mean highest level* (in cm below surface)	Mean lowest level (in cm below surface)	Relative wetness
I	<-20	<-50	Very wet
II	<-40	-50-(-80)	Very wet
III	<-40	-80-(-120)	Wet
IV	>-40	-80-(-120)	Less wet
V	<-40	>-120	Seasonal alteration
VI	-40-80	>-120	Dry
VII	>-80	>-120	More dry

*Mean highest level represents winter groundwater levels; mean lowest level represents summer levels.

For areas that have been re-worked since the Middle Holocene, the process was more complicated. The geomorphology map was laid over the AHN map of the Netherlands. The latter was used to inform groundwater levels attributions in the former, such that low areas received a high level (e.g., 2/very wet) and high areas received a low level (e.g., 7/very dry). Areas of intermediate elevation were assigned the seasonal alteration class (e.g., 5). It was assumed that the river valleys in the center of both areas were relatively dry, at least until the Middle Atlantic.

The resulting surfaces represent groundwater levels as they are assumed to have been configured during the Mesolithic period (see Figure A.7 for the Deest area and Figure A.8 for the Ooijerhoek area). Depending on climate and tree cover during any given time interval, the actual outcropping groundwater levels would have differed. For example, during the very dry Younger Dryas phase, outcropping groundwater was very low, such that only areas with a groundwater class of I and II are represented. During the wet Preboreal, outcropping groundwater levels were higher and thus, areas with classes I-IV are represented. Further, within the literature there are two competing camps arguing for either a wetter or drier Atlantic period (see discussion of this in Chapter 4). Both versions were mapped, although for reasons elaborated in Chapter 4, the wet Atlantic scenario was used as the preferred scenario for further modeling.

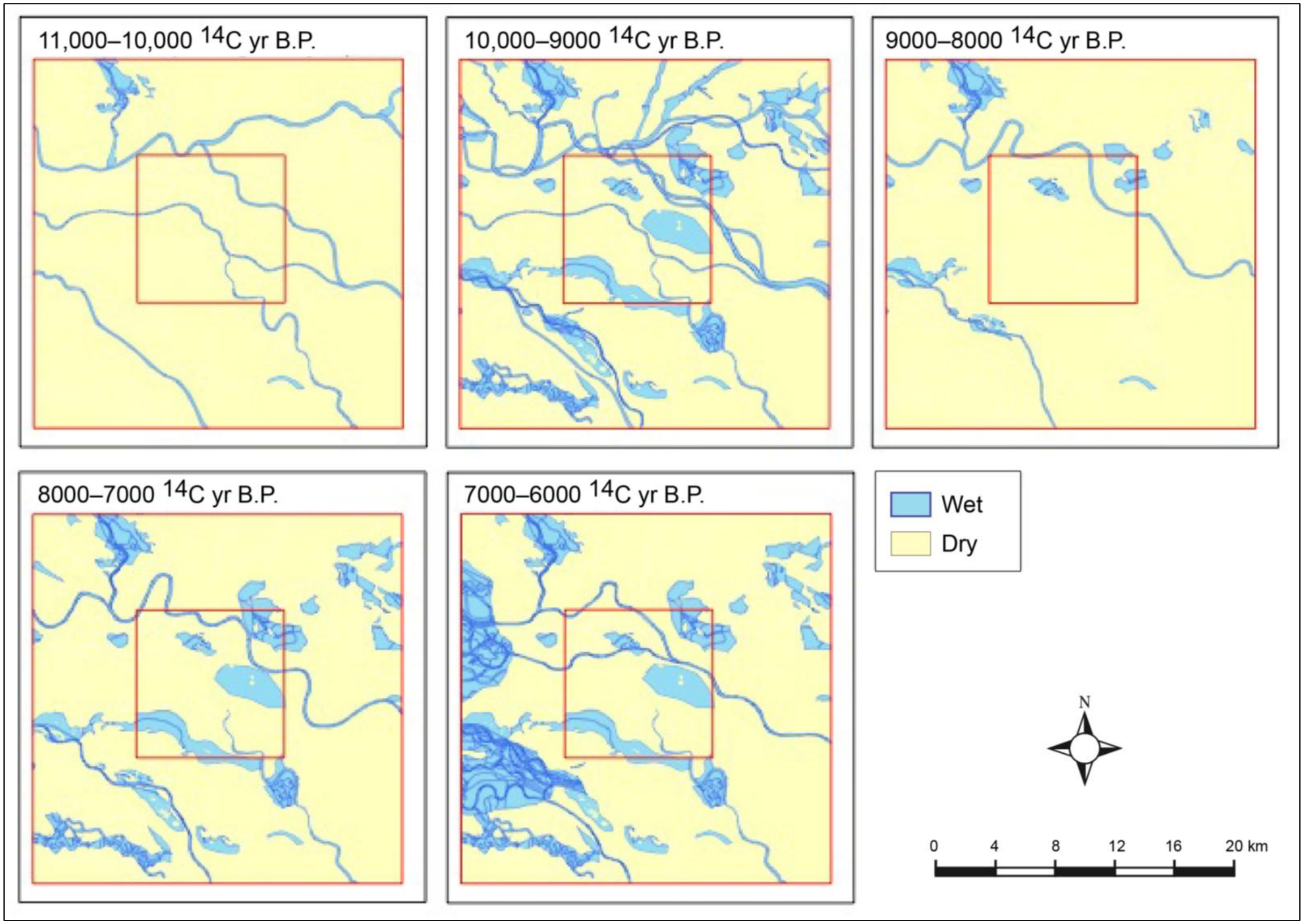

Figure A.7 Outcropping Groundwater for the Deest Area – Wet Atlantic Scenario Depicted. Younger Dryas wet classes: I, II; Preboreal wet classes: I, II, III, IV; Boreal wet classes: I, II, III, IV; Early Atlantic wet classes: I, II, III, IV; Middle Atlantic wet classes: I, II, III, IV.

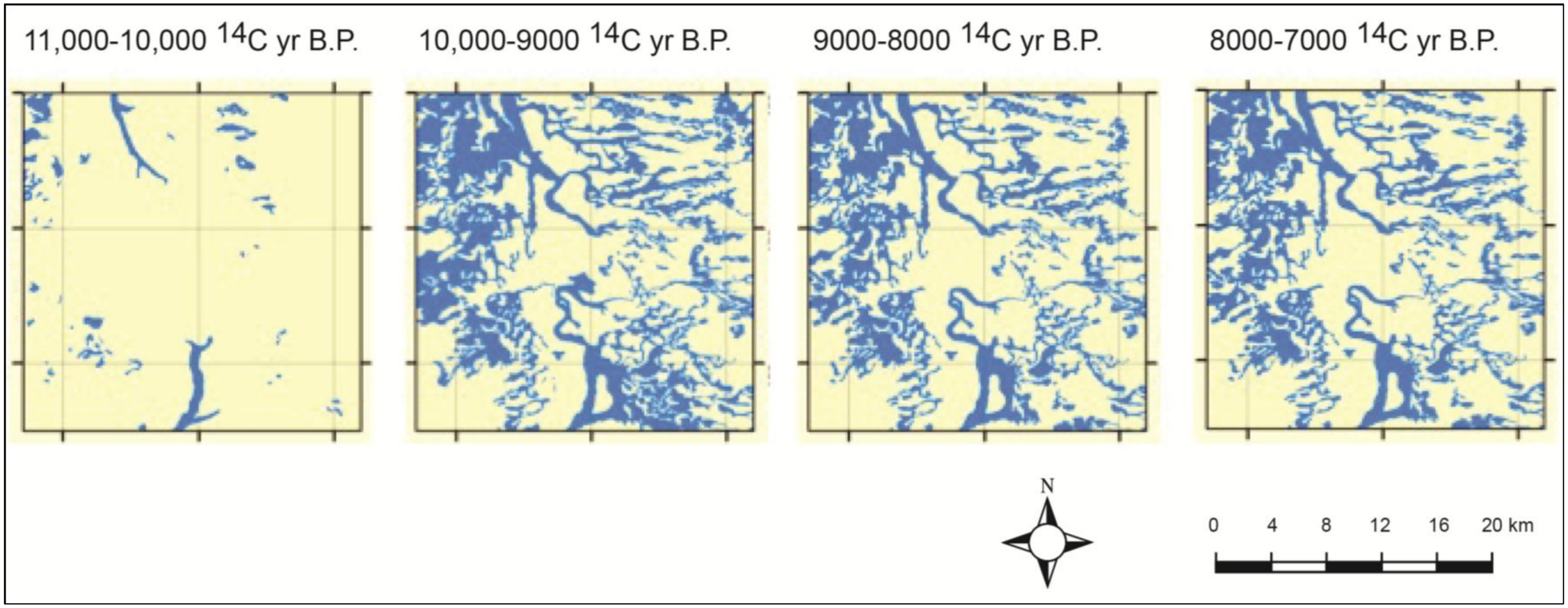

Figure A.8 Outcropping Groundwater for the Ooijerhoek Area. Younger Dryas wet classes: I, II; Preboreal wet classes: I, II, III, IV; Boreal wet classes: I, II, III; Early Atlantic wet classes: I, II, III; Middle Atlantic wet classes: I, II, III (map by H. J. Pierik; modified by M. Brouwer).

A.4.3 Modeling Vegetation Distributions

Vegetation development is related to five main factors: groundwater level, lithology, soil, climate, and vegetative succession. Each factor was taken into consideration for the modeling of vegetation distributions, some more directly than others due to the availability of spatial data. In particular, groundwater level and lithology (via the proxy of landform type) were given priority, followed by climate and succession, and finally soils. Pollen diagrams from the three study areas were also used to 'flesh out' the dominant species present in the vegetation mix during given time periods (see Figure A.9).

A.4.3.1 Approach and Assumptions. Lithology was assumed to be linked directly to landform type (see Table A.4), such that clays and peats occur in brook and river valleys, fine-medium sand comprise eolian dunes, and coarse-sands make up ice-pushed ridge formations. Soils were also important factors influencing vegetation (and vice versa); however the lack of a paleo-soil record for the central Netherlands made this driver nearly impossible to integrate. It was assumed that in the early Holocene, soil formation began as soon as vegetation became widespread and precipitation levels increased. At first, soils would have been undeveloped, but probably became more mature throughout the period. Podzol formation did not begin until around 6000 ^{14}C yr B.P. Regarding the degree of forest openness, it was assumed that by the Boreal period in all areas forests had become relatively closed (see evidence cited in Bos et al. 2005). Groundwater levels were assumed to increase over time, except for the Boreal period, which appears to have been somewhat drier.

Table A.4 Assumed Associations Between Lithology and Landform Types (adapted from Hijma 2009:111).

Lithology	Characteristics	Associated landform types
Coversand areas	Fine, well-sorted, non-calcareous sands	High eolian topography and Pleniglacial high terrace
Inland eolian dunes	Medium-coarse, well-sorted sands	Eolian dunes
Abandoned floodplains	Variable although mostly thin, calcareous fluvial loams	Low Pleniglacial terrace
Active channel systems	Very fine to coarse and calcareous sand	Active river/stream channel
Fluvial overbank deposits	Nearest to channels: silty clay loam, sandy loam; further from channels: silty or humic clay	Nearest: alluvial ridges and levees; further: brook and river floodplains
Wetlands, marshes, and lakes	Peat and gyttja	Muddy swamp floodbasin, peaty marsh/fen floodbasin, floodbasin lakes

Six unique vegetation zones were chosen to represent the array of different habitats that would have been discernable to Mesolithic hunter-gatherers (Table A.5). The species composition of each vegetation zone was selected based on the known growth requirements described in Appendix B, as well as from published (Bos et al. 2001) and unpublished pollen diagrams acquired through TNO (Dutch Geological Services), courtesy of Marjolein Bouwman and Frans Bunnick. It is assumed that each of the vegetation zones would have had represented distinct resource patches within the greater environment and therefore, set some preliminary boundary conditions for how and when each zone was utilized for extractive purposes (e.g., sedge wetlands were probably used mainly for extracting food and non-food resources, primarily in the winter months; Louwe Kooijmans 2001a:476). Further, the openness and wetness of the zones differ and would have impacted the ease with which hunter-gatherers could move through the territory, as well as the suitability each area held for different settlement purposes.

A.4.3.2 Materials. Vegetation information was gleaned from a number of sources focusing on modern-day species requirements and growing tendencies. Data from archaeological contexts was also incorporated, such as distribution, diversity, and seasonality information taken from pollen and macrobotanical studies (see Figure A.9), as well as proxy sources, such as the presence of red deer and wild boar in a marshy habitat, which suggests that some edge zones between dry forests and wet/dry grasslands occurred.

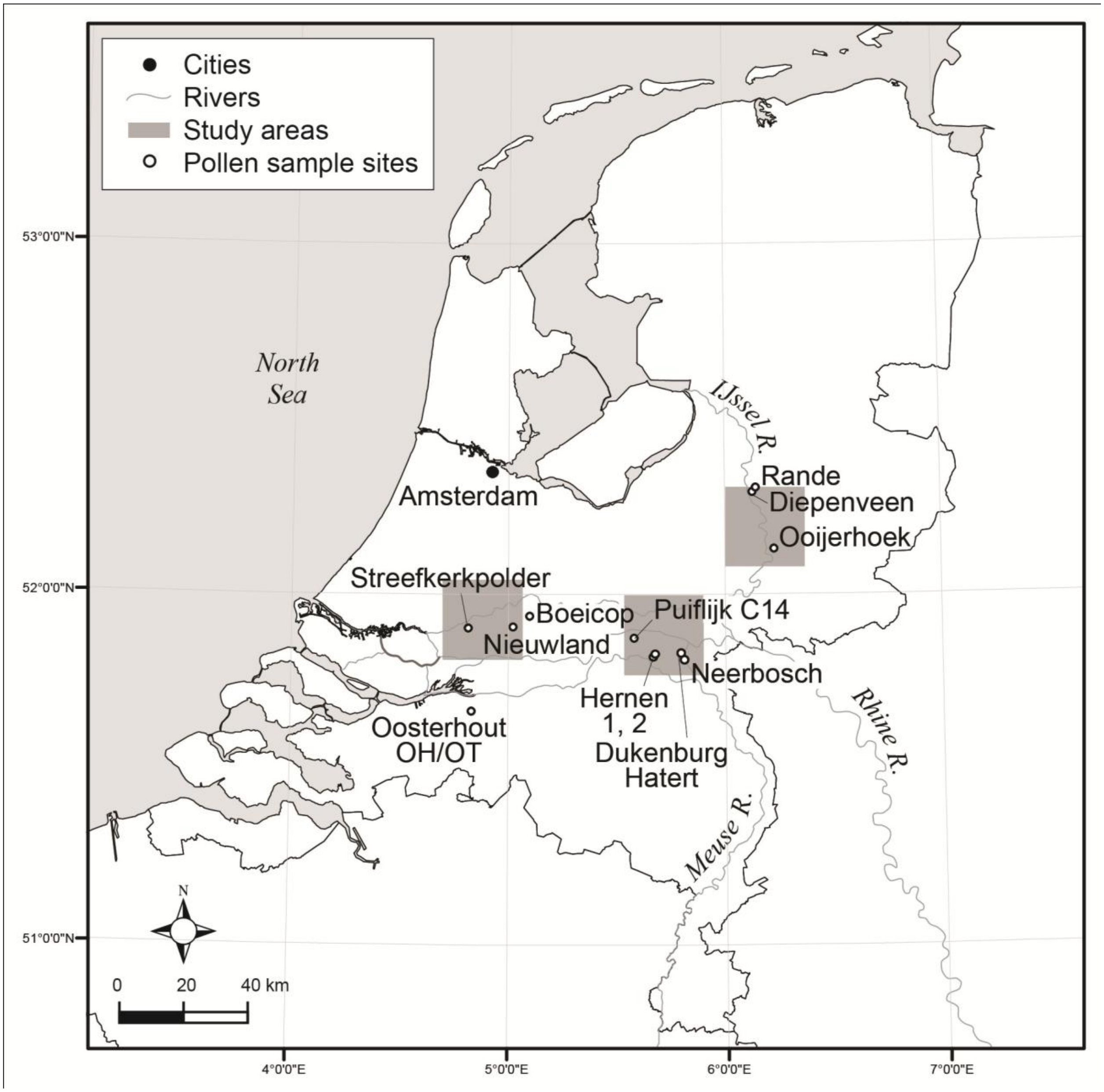

Figure A.9 Locations of Pollen Sample Sites Referenced by this Study.

A.4.3.3 Methods

A.4.3.3.1 Polderweg. The vegetation development of Polderweg was modeled somewhat differently from the Deest and Ooijerhoek areas. Because fine-resolution groundwater level data was available, more nuanced inquiries could be made based on the depth above or below groundwater at any given time (see Table A.5 for the general breakdown of vegetation types in relation to groundwater level; it should be noted that these values are approximations and were modified in different time intervals to reflect varying distributions of wet/dry and open/closed habitats). Landform type and groundwater level rasters for each time interval were imported into PCRaster. Within that program, *if-then* statements were written to assign vegetation categories based on the intersection of landform types (e.g., lithology) and groundwater level requirements (see Table A.6). The composition of these categories changed during each time interval due to successional processes driven by climate change (see Chapter 4). Small and large river channels and brooks were not included as they were assumed to always be very wet, with no vegetation (other than some reeds and sedge at the edges). Further, it should be noted that for the Polderweg area, "wet" refers to groundwater depths less than zero (zero = the transition between wet and dry ground; positive values are dry, negative values are wet) and "dry" refers to areas above groundwater.

Table A.5 Vegetation Category by Groundwater Level.

Relation to groundwater (gw)	Vegetation category
<-100 cm	Aquatic plants
-101< and <-50 cm	Sedge and reed beds
-50< and <-25 cm	Wet grasses and shrubs
-25< and <10 cm	Wet forest (marsh woodland)
10< and <50 cm	Dry grasses and shrubs
<100 cm	Dry forest

Table A.6 Vegetation Category by Landform type/lithology for All Study Areas.

Period	Landform type (based on lithology)	Relative wetness/dryness	Vegetation category
11,000-9000 ^{14}C yr B.P. (Younger Dryas and Preboreal)	High eolian topography, terrace plains	Dry	Open dry forest (pine, birch), grasses and shrubs
	River floodplain, low eolian terrace, terrace plains	Dry	Open dry forest (pine, birch), grasses, herbs, shrubs
		Wet	Open wet forest (willow, birch, poplar), grasses
9000-8000 ^{14}C yr B.P. (Boreal)	High eolian topography, terrace plains	Dry	Closed dry forest (hazel, pine)
	River floodplain, low eolian terrace, terrace plains	Dry	Closed dry forest (hazel, pine)
		Wet	Closed wet forest (willow, birch, poplar)
8000-6000 ^{14}C yr B.P. (Atlantic)	High eolian topography, terrace plains, river floodplain	Dry	Closed dry forest (lime, oak, elm, hazel)
		Wet	Closed wet forest (alder)
	Levees, abandoned channels	Wet/dry	Semi-open wet forest (alder), grasses and shrubs
	Floodplain lakes	Wet	(depending on depth) reed and sedge

Table A.6 (cont'd).

	Muddy swamp floodbasin	Wet	Wet forest (alder), reeds and sedge
	Peaty marsh floodbasin	Wet	Grasses, reeds, sedge

A sample *if-then* statement script ran as follows:

#11to10k B.P. (Younger Dryas)

```
open water = if ((lf11k == 21 or (lf11k == 22)), veg_1);
aquatics = if ((gw11k < -100), veg_2);
semi-aquatics (reed and sedge) = if ((gw11k > -101 and (gw11k < -50)), veg_3);
wet grasses = if ((gw11k > -51 and (gw11k < -25)), veg_4);
wet woods (willow) = if ((gw11k > -26 and (gw11k < -5)), veg_5);
dry grasses and shrubs = if ((gw11k > -6 and (gw11k < 200)), veg_6);
dry grasses and shrubs = if ((gw11k > 199), veg_7);
dry woods (birch, pine) = if ((lf11k == 21 or (lf11k == 22)), veg_1);
```

Where "gw" = depth of groundwater and "lf" = landform type between 11-10 k B.P. The resulting vegetative distributions are depicted in Chapter 4.

A.4.3.3.2 Deest and Ooijerhoek. For these areas, only coarse-grained groundwater levels were known. Thus, vegetation categories were assigned based on which groundwater classes were wet or dry during each time interval (see Table A.6 above). For the Deest and Ooijerhoek areas, relative wetness/dryness was assigned as follows:

Table A.7 Wet Versus Dry Groundwater Classes for Deest and Ooijerhoek Areas.

Period	Wet groundwater classes	Dry groundwater classes
11,000-10,000 ^{14}C yr B.P. (Younger Dryas)	I, II	III,IV, V, VI, VII
10,000-9000 ^{14}C yr B.P. (Preboreal)	I, II, III, IV	V, VI, VII
9000-8000 ^{14}C yr B.P. (Boreal)	I, II, III	IV, V, VI, VII
8000-7000 ^{14}C yr B.P. (Atlantic)	I, II, III, IV	V, VI, VII

Some differentiation between strictly 'wet' and strictly 'dry' vegetation was attempted. For example, during the wet Preboreal, areas with a groundwater class of two (quite wet during that period) were labeled aquatic vegetation. Areas with a groundwater class of three (moderately wet) were labeled reed and sedge and areas with a groundwater class of four (less wet) were labeled wet forest. In this way, some variation was introduced into both the 'wet' vegetative scenario and the 'dry' vegetative scenario. It should be noted that for the Deest and Ooijerhoek areas, vegetation was calculated for the Younger Dryas period as well (c. 11,000-10,000 ^{14}C yr B.P.), based on the palynological evidence that suggests these locales were inhabited primarily by dry herbs and grasses characteristic of a tundra environment. At this time, only select areas (e.g., brook valleys and pingo remnants) were wet enough to support wet herbs and grasses.

Similar to Polderweg methodology, landform type and groundwater level rasters were imported from ArcGIS into PCRaster, where if-then statements were run that queried both surfaces for the desired characteristics of each vegetative category (see Tables A.6 and A.7). It was again assumed that active channels would be free of vegetation except for along the edges. The resulting categories (mutually exclusive in space) were then resampled into a single composite map depicting vegetation distribution for each time interval. Below is a sample of the *if-then* script:

#11to10k B.P. (Younger Dryas)

Open water = if ((lf11k == 21 or (lf11k == 22 or (lf11k == 12))), veg_1);
Aquatics = if ((lf11k == 32), veg_2);
Semi-aquatics (sedge and reed) = if ((gw11k == 1), veg_3);
Wet grasses and herbs = if ((gw11k == 2), veg_4);
Wet woods (willow) = if ((gw11k == 3), veg_5);
Wet woods (willow) = if ((lf11k == 11), veg_5);
Dry grasses and shrubs = if ((gw11k == 4 or (gw11k == 5 or (gw11k == 6))), veg_6);
Dry woods (birch, pine) = if ((gw11k == 7 and (lf11k == 51 or (lf11k == 52))), veg_7);
Dry grasses and shrubs = if ((gw11k == 7 and (lf11k == 40 or (lf11k == 50 or (lf11k == 60 or (lf11k == 20 or (lf11k == 41)))))), veg_6);

Where "gw" = groundwater class (either wet or dry given the time interval) and "lf" = landform type at time interval 11,000-10,000 ^{14}C yr B.P. The distributions are depicted in Chapter 4.

A.4.4 Modeling Faunal Distributions. With the completion of vegetation models for the study areas during the Late Glacial through Middle Atlantic, faunal distributions can next be targeted. Faunal communities have four important habitat requirements that involve sufficient amounts of food, water, cover (shelter), and space (territory). In this study, faunal distribution is modeled based on the suitability of vegetation zones for each species or species category. Suitability maps are prepared for each species or species category based on two main habitat requirements: food availability and cover. Food availability (or 'food') refers to the likelihood that a vegetation zone provided a species sufficient subsistence resources. Cover refers to both the availability of shelter from the elements, as well as shelter from predators. At the same time, cover was considered within the context of the species' ecological and ethological preferences, such that medium or high suitability values were only given if the animal was likely to inhabit a given vegetation zone. For example, while a dry forest would provide good cover to an otter, the otter is very unlikely to live in a dry forest because this zone does not satisfy the food or water requirements. Regarding the other main habitat requirements, drinking water is assumed to have been readily available and easily accessible in most dryland contexts. Space or territory size was also not considered at this stage of the modeling.

A variety of species likely inhabited the Late- and Post-glacial Netherlands (see Table 4.2 in Chapter 4 for a range of archaeological known species); however, for this modeling exercise, a select number of species were considered (see below). These included red and roe deer, wild boar, beaver, aurochs, small woodland mammals, otter, aquatic and terrestrial birds, and freshwater and anadromous fish. The combination of some species into agglomerative categories was based on the fact that while many of these species were hunted, trapped, or netted frequently, they did not make up a large component of the diet singularly. Thus, composite groups were formed, and suitability values were assigned by averaging the food and coverage suitability for all species within the category, and then rounding to the closest suitability value. The small terrestrial mammal group consisted of badger, hare, martin, weasel, and squirrel. The aquatic bird group consisted of cormorant, blue heron, water rail, coots, swam, divers, wigeon, and sea-eagles. The terrestrial bird group consisted of woodcock, buzzard, sparrowhawk, woodpecker, thrush, and eagle-owl. The freshwater fish category consisted of pike and cyprinids (e.g., carp-like fish), and perch. The anadromous fish category consisted of sea sturgeon, eel, Atlantic salmon, and brown trout. See Appendix C for further discussion of ecological and ethological characteristics of species.

In this section, materials, expectations, and assumptions will first be addressed, followed by a discussion of the methods used and the resulting faunal distribution surfaces.

A.4.4.1 Materials. Information regarding faunal habitat requirements and preferences was gathered from associated literature sources, which are detailed in Appendix C. Further, data from Mesolithic archaeological assemblages within the Netherlands were also consulted.

A.4.4.2 Approach and Assumptions. Faunal composition can be estimated for each vegetation zone based on knowledge of habitat suitability for individual species and agglomerated categories. It is assumed that the behaviors and habitat preferences of modern-day and historically documented species adequately represents that of prehistoric populations. The suitability of each zone was based on expert knowledge from the associated literature (see Appendix C for discussions of species' habitat requirements and preferences). A simple four-point scale was used in the initial transformation: completely unsuitable (0), low suitability (1), medium suitability (2), and high suitability (3). Suitability values were estimated for both the cover and food potential of an area by species (Table A.8); score values were checked by Dr. R. C. G. M. Lauwerier of the Cultural Heritage of the Netherlands prior to modeling.

Table A.8 Suitability of Vegetation Zones for Species/Agglomerates.

Species/Agglomerate	Vegetation zone						
	None (open water)	Aquatics	Semi-aquatics	Wet grasses	Wet woods	Dry grasses and shrubs	Dry woods
Red deer							
Food	0	0	1	2	1	2	2
Coverage	0	0	1	1	3	1	3
Roe deer							
Food	0	0	1	2	1	2	2
Coverage	0	0	1	1	3	1	3
Wild boar							
Food	0	0	1	1	2	2	1
Coverage	0	0	1	1	3	1	3
Beaver							
Food	2	2	2	2	3	1	1*
Coverage	2	2	2	2	3	1	1
Aurochs							
Food	0	0	1	2	1	2	2
Coverage	0	0	1	1	3	1	3
Small terrestrial mammals							
Food	0	0	1	2	2	3	3
Coverage	0	0	1	1	3	2	3
Aquatic birds							
Food	3	3	3	2	2	1	1
Coverage	2	2	3	2	2	1	1
Terrestrial birds							
Food	0	0	2	2	3	3	3
Coverage	0	0	2	1	3	2	3
Freshwater fish							
Food	3	3	2	1	1	0	0
Coverage	3	3	2	1	1	0	0
Anadromous fish							
Food	2	1	0	0	0	0	0
Coverage	3	1	0	0	0	0	0

*It should be noted that for beaver, dry woods are highly suitable if they are in close proximity to water (e.g., within 10 m).

For animals that prefer edge zones, medium suitability was assigned to both the open grassland and closed forest. So, for example, red deer prefer an open park landscape or the transition zone between forest and open areas. Thus, a score of "2" was marked for both the dry grasses and shrubs and the dry forest, since the preferred habitat is at the boundary of the two ecosystems. Additionally, while some ecosystems may provide superior coverage to an animal, they are scored according to how likely the species is to inhabit that zone. For example, while an aquatic bird can obtain good coverage in a dry forest, they are unlikely to inhabit such a dry zone due to lack of food. Further, while competition between similar-sized species is often an important factor affecting faunal distribution, the available data is insufficient to model this factor in detail. Nevertheless, it will be assumed that red deer out-competed roe deer, wild boar, and aurochs for edge zones, as red deer is the most commonly found zooarchaeological remain.

A.4.4.3 Methods. Based on the above assumptions and approach, faunal distribution maps were produced for the animal species/agglomerative categories listed in Table A.8. The first step was to generate a pairwise comparison matrix for food and cover, which were assumed to be the main determinants of species distribution (Table A.9). In this table, food was assumed to have been moderately more important in determining species distribution than cover, which was scored as moderately less important. The principle eigenvector values (PEV) were computed. These values were multiplied by the raw score for each cell in a given species' food and cover surfaces for time *t*.

Table A.9 Pairwise Comparison Matrix for Food and Cover.

	Food	Cover	PEV
Food	1	3	0.75
Cover	1/3	1	0.25

Next, each species was standardized to a common scale of 0-10, using the following equation:

$$x_i = (R_i - R_{min}) / (R_{max} - R_{min}) * standardized\ range$$

Where x_i = adjusted score of criteria *i*
R = raw suitability score

These standardized food and cover surfaces were combined with the PEV weights using the suitability equation (Eastman 1999):

$$S = \sum w_i x_i * (\prod c_j)$$

Where *S* = suitability
w_i = weight of criteria *i*
x_i = adjusted score of criteria *i*
$\prod$ = product
C_j = adjusted score of constraint *j*

The resulting cartographic surfaces generated represent areas within the landscape most suitable for specific faunal species and agglomerative groups. In other words, highly suitable areas represent low risk decisions for hunter-gatherers, as it is fairly likely that a prey species would have inhabited the territory. Conversely, areas of low suitability would have posed higher risks to hunter-gatherer resource acquisition pursuits.

A sample of the script for red deer suitability in the Polderweg area during the Younger Dryas is:

```
#Red deer habitat suitability from 11to10k (Younger Dryas)
#FOOD & COVER

binding
VC11k = VegCat11to10k.map; #VC11k: vegetation categories, 11to10ka B.P.
#veg_1; open water
#veg_2:aquatics
#veg_3:semi-aquatics (reed and sedge)
#veg_4:wet grasses
#veg_5:wet woods (willow)
#veg_6:dry grasses and shrubs
#veg_7:dry woods (birch, pine)

#FS = faunal suitability
#RD = red deer
#f=food, c=coverage
suit_0 = nominal (0);
suit_1 = nominal (1);
suit_2 = nominal (2);
suit_3 = nominal (3);


initial
f1.map = if ((VC11k == 1), suit_0);
f2.map = if ((VC11k == 2), suit_0);
f3.map = if ((VC11k == 3), suit_1);
f4.map = if ((VC11k == 4), suit_2);
f5.map = if ((VC11k == 5), suit_1);
f6.map = if ((VC11k == 6), suit_2);
f7.map = if ((VC11k == 7), suit_2);
c1.map = if ((VC11k == 1), suit_0);
c2.map = if ((VC11k == 2), suit_0);
c3.map = if ((VC11k == 3), suit_1);
c4.map = if ((VC11k == 4), suit_1);
c5.map = if ((VC11k == 5), suit_3);
c6.map = if ((VC11k == 6), suit_1);
c7.map = if ((VC11k == 7), suit_3);

resample –clone Area1clone.map f1.map f2.map f3.map f4.map f5.map f6.map f7.map
RDF_11to10k.map

resample –clone Area1clone.map c1.map c2.map c3.map c4.map c5.map c6.map
c7.map RDC_11to10k.map
```

pcrcalc RDF_11to10ksca.map = scalar (RDF_11to10k.map)

pcrcalc RDC_11to10ksca.map = scalar (RDC_11to10k.map)

pcrcalc RDFStd_11to10k.map = (RDF_11to10ksca.map / 2) * 10

pcrcalc RDCStd_11to10k.map = (RDC_11to10ksca.map / 3) * 10

pcrcalc RDFWeigh_11to10k.map = (RDF_11to10ksca.map * 0.75)
pcrcalc RDCWeigh_11to10k.map = (RDC_11to10ksca.map * 0.25)

pcrcalc RDSuit_11to10k.map = (RDFStd_11to10k.map * RDFWeigh_11to10k.map) + (RDCStd_11to10k.map * RDCWeigh_11to10k.map)

Lastly, each map surface was exported to ArcGIS to be prepared for graphic display. In Appendix D, faunal suitability maps are displayed graphically, depicting the suitability of the Polderweg, Deest, and Ooijerhoek areas for all of the above-listed species/categories.

Appendix B

FLORAL COMMUNITIES AND GROWING CONDITIONS DURING THE EARLY TO MIDDLE HOLOCENE

This section describes the habitat requirements, and faunal and human uses of an array of different plant species, which are categorized based on the general location within the habitat that is occupied: over-story, understory, groundcover, (semi-) aquatic and floating aquatics, and submerged aquatics.

B.1 Over-Story Trees
B.1.1 Birch (Betula). Birch is a genus that prefers full sun or light shade, and moist, yet well-drained acidic to neutral soils. It can tolerate some drought as well (Gates and Johnson 1996). Sandy or silty-loams and clays can support birch growth. The tree propagates relatively fast and provided sufficient space, it can grow between 50-70 ft high (30 m) and 30 ft wide (9 m). The species is prevalent in temperate and boreal zones of the northern hemisphere, its preferred habitats including damp woods, lakeshores and stream banks, and peatlands (eFloras 2011). Birch provides little nutritional value to humans, though the bark can be used for containers and baskets, and the wood itself is highly valued for lumber. Deer often consume birch leaves in the fall, rabbits browse on young saplings and shoots, and beaver will eat birch bark, and birds and rodents eat birch seeds (Martin et al. 1951; USDA 2011[21]). The sap of birch trees is consumed by squirrels and grouse eat the buds and flowers. In addition, birch provides a welcome place for birds and small mammals to take shelter.

B.1.2 Pine (Pinus). Much like birch, pine (especially Scotch/Scots pine) is an early colonizer with a rapid growth rate (USDA 2011), being highly adaptable and hardy due to its efficient reseeding capabilities (Aas and Riedmiller 1994). Pine does not tolerate shade (Skilling 1990) and prefers moist, well-drained soils that are coarse-medium textured (Gates and Johnson 1996; Kudish 1992; USDA 2011). However, pines will tolerate acidic soils ranging from sandy to clayey and even peaty soils (Skilling 1990), as well as some drought (USDA 2011). Pines can grow between 50-100 ft (15-30 m; Moran et al. 1981; Skilling 1990), its dense foliage serving as a windbreak for humans and animals alike (USDA 2011). For example, owls often nest and/or roost in pine branches. The seeds and buds of pine are eaten by song and game birds, rabbit, squirrels, and even black bear in the summer and fall (Sullivan 1993; USDA 2011). The bark is edible for beaver, rabbit, and mice. Deer will also browse on pine, although it is not a preferred source of food (Sullivan 1993).

B.1.3 Poplar (Populus). Poplar trees are a rapid-growing, sun-loving species with dense foliage in the summer months (USDA 2011). They can mature to a height of 100 ft (30 m), and are adapted to coarse, medium, and fine soils. While poplar prefers medium soil moisture, they can

[21] In lieu of a more informative European alternative, the USDA Plant Database is used here. This database does include descriptions of many European species; in cases where it does not, information at the level of genera was sought to represent species from both continents.

withstand some drought conditions (ibid 2011). Poplar is moderately palatable to browsing animals and has a variety of panacea-like properties that are known from the ethnohistorical record (Herrick 1977; Reagan 1928:231).

B.1.4 Oak (Quercus). Oak trees grow somewhat slower than birch or pine, although they are by no means slow growers with an annual rate of one foot of height per year (Gates and Johnson 1996). These trees also prefer full sun although they will tolerate some shade. Oaks require nutrient-rich soils that are moist and well-drained (USDA 2011). In the absence of these conditions, growth will be retarded. Oak trees grow between 50-80 ft high (15-25 m) and nearly as broad, provided they have the space to spread out. Acorns are produced by oaks in September and October in the northern hemisphere, although crops often occur irregularly (i.e., every 1-10 years, depending on the species or sub-species; Aas and Riedmiller 1994; eFloras 2011). These high protein packages are eaten (and in some cases stored) by small rodents, birds, and large browsing mammals. Deer will eat most parts of the oak in times of food shortage, along with small mammals and water birds. The leaf buds and other segments provide high food value to terrestrial birds all year round, as well as good cover (Martin et al. 1951; Yarrow and Yarrow 1999). The broad spread of an oak tree makes it an important shade provider for all animals. For human consumption, acorns require intensive and time consuming preparation to remove tannins (eFloras 2011).

B.1.5 Elm (Ulmus). The elm tree grows in temperate regions in the northern hemisphere. It grows rapidly and has dense summer foliage (USDA 2011). Elm will grow in coarse-fine textured soils but is intolerant to shade. This species grows equally well in wetlands and dry uplands and can reach heights of 114 ft (35 m; ibid 2011). Elm wood is good for fuel and lumber. It has only low palatability for large browsing animals, small mammals, and water and terrestrial birds, although many of the latter species use the tree for cover/shelter (Martin et al. 1951; Yarrow and Yarrow 1999).

B.1.6 Lime (Tilia). Lime (otherwise known as linden or basswood in North America) is generally a hardy species, with high drought, heat, and fire tolerance (USDA 2011). They are moderate-rate growers, preferring full or partial sun and moist, well-drained soils. Lime can grow between 45-100 ft (13-30 m) and produce dense summer foliage (ibid 2011). Wet soils are not ideal for lime, although they will grow in a variety of soil pH and textures, from acidic to alkaline and clayey to sandy, and coast to medium in texture. Bees are particularly attracted to the flowers and nectar of lime trees, and the wood itself is fine-grained. A close relative to European lime (*T. europaea*) is the American basswood (*T. americana*), which has an extremely wide array of uses, from cough medicine and gastrointestinal aids (Hamel and Chiltoskey 1975), to cordage, tools, containers, and decorations (Smith 1933).

B.2 Understory Trees and Shrubs

B.2.1 Hazel (Corylus). Hazel is a type of small tree or large shrub, growing between 15-25 ft (5-8 m) in height and 10-12 ft (3-4 m) in width (Aas and Riedmiller 1994; eFloras 2011). It is relatively hardy and with a moderate growth rate. Hazel can tolerate dry conditions, although moist and well-drained soils are preferred, with medium to fine textures (USDA 2011). Very heavy marshy soils or clays are difficult for this genus, which can be found growing in thickets or in dry open woods (ibid 2011). Full sun conditions produce moderate foliage in the summer months (ibid 2011). Hazel stands are used for shelter and food by many species (e.g., game, song, and water birds, small and large mammals), although reliance is low overall (Martin et al. 1951). Even bats are known to roost in hazel diurnally. Similar to oak, hazels produce nuts in September and October, after 4-5 years of maturation. Modern hybridized varieties produce around seven pounds of nuts/bush/year (Aas and Riedmiller 1994). Prehistoric varieties are estimated to have produced between 900-3000 nuts per tree or roughly 1-4 kg usable nut meat (c. 2-9 lbs; Holst 2010; Howes 1948; McComb 2005). The ethnohistorical record of North America reveals that *C. americana* (a variety very similar to the European *C. avellana*) was used to treat many different ailments, such as laceration treatment, hemorrhages, diarrhea, hives, and hay fever (Moerman 1986).

B.2.2 Willow (Salix). The willow tree requires full sun or partial shade, and grows well rapidly in wetland conditions (i.e., 67-99 percent wetland growth; Gates and Johnson 1996; USDA 2011). The need for wet soil overrides shortages in soil nutrition; coarse-fine textured soils are acceptable (USDA 2011). Willows can reach heights of 30-70 ft (9-20 m), although the shrub variety most commonly found in pollen diagrams of the early and middle Holocene is shorter. This tree has moderate foliage cover in the summer and provides shelter for many birds and small mammal, as well as low levels of food for beaver, rabbit, deer, and birds (Martin et al. 1951). Willow also is a source of salicin, which acts as an antidiarrheal, and dermatological and throat aid (Hamel and Chiltoskey 1975).

B.2.3 Alder (Alnus). The alder genus is another flexible species: they produce their own supply of nitrogen, can thrive in poor soils (Gates and Johnson 1996), and survive moderate drought conditions (USDA 2011). Alders are fast-growing, early colonizers, adapted to coarse, medium, and fine soils (ibid 2011). Although they require full sun, alders grow in moist-wet soils, places where other trees would rot (eFloras 2011). The USDA states that alder grows in wetlands 67-99 percent of the time (i.e., 'facultative wetland;' USDA 2011), in addition to moist floodplains and stream banks (eFloras 2011). The alder genus can come in large shrub or small tree varieties, generally reaching heights of 10-45 ft (20m), with moderate-partial foliage (USDA 2011). The fruit (catkins) and leaves of alder are eaten by moths and butterflies, attracting a variety of birds in the summer and fall. Humans can consume catkins as well, which are high in protein and often serve as a good survival food. The bark of alder contains anti-inflammatory agents long known and used among ethnographically-document North American hunter-gatherers (Speck et al. 1942).

B.2.4 Holly (Ilex). Holly comes in both deciduous and evergreen varieties, and can grow to shrub or understory tree height. Full sun to half shade is preferred by holly, which flourish in acidic soils (pH from 5.0-6.0) that are moist, fertile, and coarse-medium textured (Gates and Johnson 1996; USDA 2011). Holly is a slow-growing plant, which is not conducive to exposed, windy, or dry soils (ibid 2011). The maximum growing height of holly trees is from 20-40 ft (6-12 m). The berries of holly are somewhat toxic to humans, although they are an important food source to birds, deer, and squirrels, as they ripen at a time of year when other food sources are scarce (e.g., mid-winter to early spring; Coladoanto 1991; USDA 2011). Holly also provides important shelter for birds and other mammals, as it retains its dense foliage all year round (USDA 2011).

B.2.5 Juniper (Juniperus communis). Juniper exists as either a small tree or shrub and is coniferous. They can grow to heights of 10 m, although this happens infrequently (Aas and Riedmiller 1994). The species will grow in a variety of biotopes, from heaths and poor grasslands to open pine woodlands, as well as diverse soils (ibid 1994). Juniper produces a round, berry-like cone from September-October; these ‘berries’ are palatable to browsing game animals, small mammals, and terrestrial birds (Martin et al. 1951). They have also been long used by humans for medicinal applications (Hart 1981; Herrick 1977; Kari 1985; Smith 1929; Smith 1933) and (more recently) to make gin alcohol. Juniper bushes and trees provide important cover for terrestrial birds, and to a lesser extent, small and large mammals.

B.2.6 Dogwood (Cornus sanguinea)

Dogwood is a deciduous shrub that flowers in the spring (May through June; Aas and Riedmiller 1994). The species prefers deciduous woodlands, along with scrub and woodland edges, sometimes within river valleys (ibid 1994). Dry to moist soils are favorable for the growth of dogwood. Fruits are produced in the fall, and are fed on by water and terrestrial birds, as well as large and small mammals (Gee et al. 1994; Martin et al. 1951).

B.2.7 European Cranberrybush (Viburnum opulus)

The European cranberrybush, of Guelder rose, is a small tree or shrub, which is distinct from the genus *Vaccinium*, the genus grown for commercial cranberry production today. The European cranberrybush blooms in the late spring and produces fruit in the summer and fall (USDA 2011). It is a facultative wetland species (ibid 2011), preferring to grow in sedge meadows and shrub carr (ibid 2011). The species is of limited palatability to browsing mammals, although birds and small mammals eat the berries (Martin et al. 1951). Further, the berries are eaten raw or cooked by various hunter-gatherer groups in North American (e.g., the Iroquios and Ojibwa; Parker 1910; Reagan 1928).

B.3 Groundcover species

Groundcover species commonly found on dry soil conditions include ivy (*Hedera*), mistletoe (*Viscum*), nettle (*Urtica*), grasses (*Poaceae*), and ferns. Ivy is a ground-creeping/climbing woody vine that is fire resistant will grow in nearly any location provided adequate sun and water (USDA 2011). It can grow up to 80 ft (24 m) high, with a horizontal spread of 3-50 ft (1-15 m; Kemper 2011). Ivy produces seeds in the late winter to mid-spring, which birds (such as thrushes and woodpigeons) feed on, along with the nectar (Kemper 2011). Moths and larvae feed on the leaves, further attracting birds and other species.

Mistletoe is a shrub-like, aerial, and semi-parasitic (Geils et al. 2002). As such, mistletoe grows in the branches of other trees, and derives most of its water and mineral nutrient from the host, although it can provide itself organic nutrients through photosynthesis (Kuijt 1969). Common hosts of mistletoe include woody plants and conifers (Geils et al. 2002). Like holly, mistletoe is poisonous to humans, but the seeds are palatable for birds and many animals will eat the young shoots and leaves. Also, mistletoe is sometimes used for nesting and roosting, and has long-standing ritual, mythical, and spiritual roles in various cultures worldwide (Frazer 1930). It can also be used for medicinal purposes, as a dye, and for fodder (Geils et al. 2002).

The nettle is a type of forb[22] that grows in moist soils with high phosphate and nitrogen content, oftentimes areas that have recently been used by mammals and humans (eFloras 2011). These seed-bearing, yet rhizomic plants can grow up to 3.3-6.6 ft (1-2 m) in height in the summers, but die down completely in the winter (Carey 1995). Nettles grow in upland and wetland contexts (they are a facultative wetland species, growing 67-99 percent of the time in wetlands), in habitats adjacent to marshes and meadows, along streak banks, and in woodland clearings (Carey 1995; USDA 2011). Nettles are tolerant of shade and have a tendency to establish dense colonies to the exclusion of other plants(Carey 1995). The food quality of nettles for wildlife is low, but they do provide important cover for small mammals (ibid 1995). Although most types of nettles can deliver stinging histamines that irritate skin, the leaves are very nutritious and can be eaten after soaking or cooking. They can also be used for herbal teas and soup, and are widely regarded for their medicinal qualities. Northwest coast Native Americans are documented to have used nettle fibers for rope, twine, and fishing nets (Turner and Bell 1973).

Grasses and ferns can grow in both wet and dry soils. The grass family (*Poaceae*) is composed of thousands of individual species and hundreds of families. Given this vast amount of variation, grasses flourish in many habitats and ecosystems, from open areas with well-drained soils (e.g., grasslands, prairies, savannah), to closed forests, cool steppes and tundra, and even wetlands (Chapman and Peat 1992). Grass stems are typically hollow with nodes (eFloras 2011). Grasses comprise forage for grazing and browsing animals and birds, as well as many modern-day food staple cereals. As mentioned, some grass varieties thrive in wet soils (e.g., marshes, and fens; see below), where they provide shelter and food for birds, amphibians, and aquatic species. Human uses of grasses include consumption, bedding, and kindling.

Ferns are another plant division (*Pteridophyta*) with many hundreds of species that can survive in a variety of contexts, and are especially good at flourishing in marginal habitats (Moran 2004). While it is common to think of ferns preferring shady moist forests, many thrive in open fields and open water, and in acidic wetlands (e.g., swamps and bogs). The largest group of ferns (*Leptosporangia*) contains about 9000 species (AFS 2011). A precursor to many modern plant species, ferns originated about 300 million years ago, when they dominated vegetation of the Carboniferous period (c. 354-290 mya). Ferns have a complex morphology and life cycle development, and propagate through the distribution of spores (Moran 2004). Ferns can be ingested by humans (e.g., the fiddlehead variety), and mice and birds each fern spores.

B.4 (Semi-) aquatics and floating-aquatics

Many different kinds of plants grow in (semi-)aquatic environments, some only floating their leaves and flowers above water (so-called floating aquatics, such as water-lily). Apart from grasses and ferns, common (semi-)aquatic and floating-aquatic species include sedges (family *Cyperaceae*), reeds (family *Phragmites*), cattail (genus *Typha*), water plantain (genus *Alisma*), arrowhead (genus *Sagittaria*), and water-lily (genus *Nymphaea*).

Sedges resemble grasses and rushes although they are structurally distinct: they are triangular instead of circular in cross-section (eFloras 2011). Nearly all sedge varieties grow in moist to wet habitats of marshes and wetlands, as well as arctic tundra and mountainous environments (ibid 2011). They can also occur as understory in temperate deciduous forests (ibid

[22] A *forb* is a flowering herb that is not part of the grass order, e.g., sunflower and milkweed.

2011). Sedges reproduce vigorously via rhizome networks underground (Tomocik 1996). The long stems of sedges (c. 2-8 feet) can be used for weaving mats and baskets, or for bedding and padding purposes (eFloras 2011). Some common genera from the sedge family are true sedges (*Carex*), as well as water chestnut (*Eleocharis*) and bulrush (*Scirpus).* Various sedges are edible to humans (e.g., the shoots and root balls). It is therefore plausible that Mesolithic hunter-gatherers used this plant, especially since it has been found that fossilized Carex fruits from the Late Glacial and Holocene in Europe closely parallel modern species in morphology and growing requirements (Jankovska and Rybnicek 1988). Some sedges can grow more than 20 feet in height and have an important role as food and coverage sources for water fowl, terrestrial birds, and small and large mammals (Catling et al. 1994; Martin et al. 1951; Yarrow and Yarrow 1999).

The common reed (or rush) is a widely-occurring round, hollow-stemmed, and flowering grass that grows almost exclusively in the wet soils of floodplains, estuaries, saturated depressions, and emergent wetlands (they are facultative to obligatory wetland species; Cowardin et al. 1979; Gucker 2008; USDA 2011). Reeds grow rapidly and can reach heights of 13-20 ft (4-6 m). They will propagate and flourish in all types of soil textures and are highly tolerant of both anaerobic conditions and fire (USDA 2011). Reeds can also tolerate seasonal drying, and frequent and prolonged floods (Gucker 2008). Reeds often grow in large, monotypic stands known as reed beds, in which dead reed litter builds up over time (Gucker 2008). Certain tree and shrub species may colonize the litter beds over time (eFloras 2011). Reeds can exist in semi-aquatic or aquatic habitats, and can grow to heights of 10 feet or more (Tomocik 1996). Reeds and reed beds are attractive to a variety of wildlife, from song birds to game and water birds (e.g., heron and spoonbills), and from small rodents (e.g., mice and voles) to aquatic species like beaver and otter, as well as fishes, mollusks, crustaceans, and aquatic insects (Decker et al. 1987; Holm et al. 1977). Reeds provide both food, in the form of the flowers, fruit, and stems, as well as cover, nesting areas, and shade (Gucker 2008). Reed has historically been used by Native Americans for a variety of purposes: some groups ate reed rhizomes and seeds, which provided a reliable, year-round source of nutrition (Duke 1992; Elias and Dykeman 1982); others used reed for roofs, baskets, fuel, insulation, and tools and implements (e.g., arrows, pipes, flutes; Zigmond 1981).

Cattail can grow between 4-9 feet, producing its characteristic cylindrical flower in late summer (Tomocik 1996). The species prefers full sun but will endure shade; soil requirements are few as the plant will grow in nearly any slightly brackish and/or emergent wetlands (eFloras 2011). Cattails will grow in up to 1.5 m of water. One plant can produce thousands of seeds, which germinate and later grow into monolithic stands via rhizome propagation (ibid 2011). The fluff of the flower was historically used by Native Americans to dress burns, for padding purposes, and as insulation and tinder (ibid 2011). The leaves can be used for matting, basketry, and roofing material, and parts of the plant (including the seeds) are edible to humans (Grace and Harrison 1986; Morton 1975). Cattail stands provide high food value to small mammals, and good coverage for water fowl and song birds (Martin et al. 1951).

Water plantain grows in moist soils (it is an obligate wetland species), with full or partial sun. Its roots and rhizomes are usually submersed in fine soils, while the leaves are floating (eFloras 2011; USDA 2011). The foliage of this plant resembles that of plantain, with round, veined, or grass-like leaves (Tomocik 1996:108). The plant is only partially palatable to humans but has some useful medicinal properties (e.g., as a gastrointestinal aid; Leighton 1985).

Arrowhead, as its name suggests, has arrow-shaped leaves, which grow on 1-4 feet stems (Tomocik 1996:153). The plant will grow in full or partial sun and prefers still water – it is also an obligate wetland species (USDA 2011). The rhizomic tubers of the arrowhead are edible for humans (Fletcher and La Flesche 1911; Smith 1933) and can also be used as a pediatric drug and dermatological aid (Hamel and Chiltoskey 1975; Herrick 1977). Small mammals and water birds have minor use of the plant for food (Martin et al. 1951).

Water-lilies grow in relatively still ponds, lakes, marshes, and sluggish rivers and streams that measure between 2 and 5 feet deep (eFloras 2011; Tomocik 1996:30). Like many of those species just discussed, water-lilies are rhizomic: a main root spreads out horizontally, from which new shoots can begin (Tomocik 1996). The leaves and flowers mostly float above the water, while stems and roots are submerged (the plant is an obligate wetland species; eFloras 2011; USDA 2011). Flowers occur from mid spring through early fall (ibid 2011). Many terrestrial and aquatic animals eat water-lilies roots, leaves, and flowers, such as squirrel, turtles, duck, muskrat, birds, and fish (Martin et al. 1951). Some Native American groups have been observed to eat the roots and tubers of water lily, after boiling or stewing (e.g., the Lakota and Kiowa; Rogers 1980:52; Vestal and Evans Schultes 1939:27).

B.5 Submerged aquatics

Submerged aquatic species are those that live almost completely below water, such as water milfoil (genus *Myriophyllum*), hornwort (genus *Ceratophyllum*), and pondweed (genus *Potamogeton*). Most of these plants are soil-rooted, though they may be free-floating. They are crucial to the health of any aquatic habitat, as the oxygenate and filter the water (Tomocik 1996:164). These functions are necessary for fish respiration and subsistence, as these plants also provide shelter and spawning areas for other organisms. Food and nutrients are absorbed through their foliage. Some submerged species also send their small flowers to the surface; below water, most have coarse leaves (Tomocik 1996:164). All species of submerged aquatics are characterized as obligate wetland species (USDA 2011).

Water milfoil is one such oxygenator/filter, with long red stems and feathery leaves (Tomocik 1996:165). Spawning fish, in particular, are drawn to this species. It was used as a drug by the Menominee of Wisconsin (Smith 1923:37), as well as for food by the Upper Tanana of Alaska (Kari 1985).

Hornwort is a floating, submerged aquatic plant. It is composed of long lengths of bristly leaves, and is also preferred by spawning fish (Tomocik 1996). Most hornwort varieties flower in the spring and summer, in freshwater ponds and lakes, and in marshes and swamps (eFloras 2011). Hornwort is often found in beaver ponds as well (ibid 2011).

Pondweed (*Potamogeton*) resembles freshwater seaweed (Tomocik 1996:165), with curly-edged leaves. Some versions of this species have larger flowers and leaves that float above the waters' surface. They will grow in nearly any soil type (ibid:162). They provide important food and habitat to aquatic animals and (to a lesser extent) terrestrial species (Haynes 1975; Martin et al. 1951; Yarrow and Yarrow 1999). Lastly, it bears mentioning that algae, bacteria, and ascospores also contribute to the richness of an aquatic habitat.

B.6 Summary

The above survey provided information about key species and groups of species that constituted the early and mid Holocene vegetative landscape in the central Netherlands. These species likely played an important role in the distribution of fauna and therefore, also in the distribution and land use strategies of prehistoric hunter-gatherers. Six unique biotic zones (also referred to as vegetation zones) were constructed out of the above species, and are described in detail in the Appendix A. In the following section, key faunal species and their habitat requirements will be similarly described.

Appendix C

FAUNAL COMMUNITIES AND HABITAT REQUIREMENTS DURING THE EARLY TO MIDDLE HOLOCENE

This appendix details the ecological and ethological characteristics of terrestrial and aquatic species known to have been exploited during the Mesolithic. The information is based on modern and historical knowledge and it is assumed in this study that the behaviors and habitats of prehistoric species were not significantly different from current populations.

C.1 Large mammals
C.1.1 Red deer (Cervus elaphus). Red deer is the most widely-recognized deer species today, and also has the largest distribution worldwide (Ludt et al. 2004). There is, in general, some question about the number of species and subspecies within this taxon (Ludt et al. 2004). However, the western subspecies inhabits the European continent, are thought to have migrated to Europe from Asia, and are the most likely correlate Mesolithic red deer (Geist 1998:204). During the Pleistocene, cold and warm-adapted subspecies arose, although only the warm-adapted species seems to have persisted until the present (Geist 1998). About 60,000 years ago, the western red deer developed into two distinct groups, differentiated by antler morphology: the Scottish/Norwegian versions in the north and the German version in the south (Geist 1998:305). The cranial features of the Norwegian version appear to be closest to the early Post-glacial fossil specimen found on continental Europe (Althen 1965).

Red deer typically have large, furry tails, and the males have a bushy throat mane that grows with age and good nutrition (Geist 1998). During the summer, the coats of red deer turn a dark reddish color. The males have highly branching antlers, although the individual tines themselves are short in comparison to more eastern forms (ibid 1998). Various researchers believe that modern-day deer are much smaller in body size than early Post-glacial deer, or even medieval deer (Althen 1965; Geist 1998). A sample of stags killed in East Prussia in 1617 weighed between 250 and 366 kg (Frevert 1957), meaning that Post-glacial deer were even larger. Jochim (1976) takes these considerations into account and uses an estimated measure of 330 kg/stag and 180 kg/doe (Jochim 1976:100).

Modern populations of red deer prefer to live among forested and half-open biotopes in which open grasslands and heaths alternate with mixed forests (Litjens 1992a:205). However, they are also known to inhabit deltas, mountains, and riparian thickets (Geist 1998:208) and are not fussy about altitude. In rich delta and wetland areas, they tend to grow larger than in more sparsely vegetated uplands. The main components of the red deer diet are foliage, forbs, and browse[23] (Geist 1998:207), and can also include berries, mushrooms, nuts, and bark. The guts of red deer are less efficient than domesticated species like sheep, meaning that their overall food intake is high in relation to their body weight (Geist 1998). Red deer have important winter foraging prerequisites: they need ample accessibility to grasses and water, which can only obtained if snow levels remain below 30-40 cm (Lange et al. 1994).

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[23] According to the Merriam-Webster 2010 dictionary, *browse* refers to the “tender shoots, twigs, and leaves of trees and shrubs used by animals for food.”

Red deer group size varies depending on the time of year, the sexes remaining in separate groups except during the rutting season in the fall (Jochim 1976:105). Altitude appears to effect group size, with larger groups forming at higher elevations and smaller groups at lower elevations (ibid 1976). In the low Netherlands, normal group size is around five or fewer individuals (Lowe 1966). Both male and female groups are largest in the winter. In the spring, both groups tend to disperse, the males to gain bulk prior to rutting and the females to calve (Jochim 1976:108). Fall and winter mobility is thus low, while summer mobility can be quite high (ibid 1976:109). Females are heaviest after the rut and prior to calving; males are heaviest just before the rut. In combination with the knowledge of highest antler yields in fall and winter, it can be argued that red deer utilization is highest in January, February, and March (Jochim 1976:110).

Red deer is a highly mobile large mammal, oftentimes traveling many kilometers in a day to find feeding patches or mates. However, the species needs sufficient open area for grazing, and it is therefore likely that the population decreased somewhat over the course of the early-mid Holocene, as forests became denser and shadier, and open areas more infrequent. The range of actual red deer densities reported in the literature by Jochim (1976:102) is between 0.8-16.1 deer/km^2. Jochim (1976) estimates that red deer densities for the Boreal and Atlantic were at the lower end of this range, around 4.0 deer per square km. For the Preboreal period, red deer numbers were probably somewhat higher, about 8.0 deer/km^2. Further, Jochim (1976:105) notes that the nonfood potential of red deer is high, as they supply large hides for structural and clothing material, and antler for tools, implements, and perhaps ritual objects. Based on the above information, red deer is thus assumed to be infrequently found in semi-aquatic contexts.

C.1.2 Roe deer (Capreolus capreolus). The roe deer is the most common wild ungulate in Europe today and is present everywhere except for some of the smaller islands (e.g., Ireland, Corsica, Sardinia; Sempéré et al. 1996; Stubbe 1999). Roe deer are smaller in size than red deer, with long necks and no manes. The tails are short, as are the antlers, which only occur on males and are shed annually in the fall (Sempéré et al. 1996:1). The small size of the antlers probably precluded their use as an important nonfood resource, although the hides of roe deer would have been useful (Jochim 1976:105). In summer, roe deer coats have a reddish-brown coloration, while in the winter, they take on a gray or dark-brown color (Sempéré et al. 1996). Average body mass of modern roe deer females is between 22.6-30.0 kg, while males average between 23.7-32.0 kg (ibid 1996:2). Jochim (1976:100) notes that during the early-middle Holocene, roe deer were larger in body size, estimating an average weight of 34 kg/deer (sexual dimorphism in the species is small). With their slender build and narrow hooves, roe deer can easily travel across soft surfaces, such as mud, silt, or sand (Sempéré et al. 1996). Roe deer appear to have migrated from Asia in the late Pliocene to middle Holocene, and are closer morphologically and genetically to moose (*Alces alces*) and reindeer (*Rangifer tarandus*) (Groves and Grubb 1987; Kurten 1986).

The species is often found inhabiting a diverse array of biotopes, although their preference is for the edge zone between open grassy areas and park woodland with underbrush (Stubbe 1999; e.g., deciduous, mixed, or confierous; Van Haaften and Pelzers 1992:212). In the event of habitat competition from other large mammals or humans, roe deer will take to living in the forest full-time, although their numbers will decrease and they will maintain a preference for younger trees and shorter varieties; low shrubs and tall grass are the ideal vegetation for roe deer (Sempéré et al. 1996:2). When food in scarce, the deer will also move into treeless areas with higher food density, taking shelter in ditches and other depressions in the landscape (Van Haaften and Pelzers 1992). Thus, the increasingly dense forests of the Mesolithic would have been unfavorable to roe deer, although the increasing number of deciduous tree species, especially oak and hazel, would have benefited the species (Jochim 1976:102).

The roe deer has a smaller and less complex digestive system than other ruminants, which means that they forage selectively on more energy-rich and soft, easily digestible foods, such as leaves, shoots, buds and twigs of young trees, as well as herbaceous vegetation (Sempéré et al. 1996; Van Haaften and Pelzers 1992). Unlike red deer, roe deer prefer shrubby browse to grasses and therefore deciduous forests with undergrowth to coniferous forests (Jochim 1976). When foraging material is low in the winter, roe deer curtail their movement and will eat a wider range of foods (Sempéré et al. 1996:3). In the fall, when fat stores are building, roe deer favor calorie-rich foods such as fruit and seeds (ibid 1996). The main natural predator of the roe deer is the wolf (*Canis lupis*) and lynx (*Lynx lynx*), while fox (*Vulpes vulpes*) and other small mammals pose a major threat to fawns and weakened adults (e.g., wild cat, marten, badger, boar; ibid 1996). It is possible that roe deer had the highest predation rates of the large mammals considered in this study due to their size and temperament. In addition, roe deer do not compete well with red deer and wild boar for food and cover, which led Jochim (1976:103) to assume that roe deer had lower densities than wild boar or red deer during the Mesolithic, about 12 animals/km^2.

The spatial structure of roe deer varies on the season, and the availability and distribution cover and food (Sempéré et al. 1996). In the winter, roe deer group together in family units (i.e., males, females, and juveniles together). Depending on the biotope, these groups could range in number from 10-15 individuals in forests to 40-90 individuals in open areas (ibid 1996). In the summer, roe deer disperse living alone or with a small family group (ibid 1996). Unlike red deer, roe deer are sedentary and maintain roughly the same territory throughout their life time (Stubbe 1990), except for young males who must find their own territory upon reaching adulthood. Group size is also more regular throughout the year, with males and females mingling (Prior 1968). Jochim (1976:106) estimates that 2.5 individuals make up an average group. Territory size can vary greatly based on the overall population density of roe deer in the area and the quality of the habitat (Sempéré et al. 1996:4). Males have been documented to have territories between two and 200 ha, while winter ranges can grow to 300-500 ha (ibid 1996).

The timing of the roe deer reproductive cycle is quite distinct from other European ungulates: rutting takes place in the summer, followed by a period of delayed embryonic development, such that the fawns are still birthed in the early-late spring of the following year (Sempéré et al. 1996:3). Usually two, but sometimes three, fawns are born at a time, and reach 60-70% maturation within 3-4 months (Stubbe 1990). Regardless of the differences in seasonal activities, Jochim (1976:111) estimates that peak roe deer utilization occurred from January through March.

C.1.3 Wild boar (Sus scrofa). Wild boar are a wide-ranging species, partly due to human agency in recent times (Oliver and Leus 2008). However, they have been extinct in the British Isles and Scandinavia since the 17th century (Spitz 1999). Wild boar are known to inhabit a variety of wet and dry biotopes, from tropical to temperate forests, and grasslands to semi-deserts (Oliver and Leus 2008). They are not picky about elevation (Litjens 1992b:195), although they will not venture further than the deciduous tree line. The wild boar prefers edge zones between fields/grasslands and deciduous forests with easily accessible water and sufficient tree cover

(Litjens 1992b; Oliver and Leus 2008; Spitz 1999). Dry soils, coniferous forests, and open grasslands are less desirable. However, of all the large mammals discussed here, wild boars seem most tolerant of closed forests (Jochim 1976:103). Based on this knowledge, it can be suggested that the Preboreal and Boreal periods were less favorable for wild boar than the Atlantic, as the former periods were dryer overall, and dominated by non-fruit bearing trees (e.g., birch, willow) or pine. The Atlantic landscape was wetter, with a denser and more preferable forest mix, suggesting that wild boar numbers increased during this period.

The wild boar is technically omnivorous, although in some cases, 90 percent of the diet has been shown to consist of nuts (especially acorns, hazelnuts, and beech nuts), roots, tubers, seeds, fruit, worms, soils, and even fish and crustaceans (Jochim 1976; Oliver and Leus 2008; Spitz 1986). They have also been documented to prey on large vertebrate species, such as roe deer fawns (see discussion above; Jochim 1976:102). Wild boar are gregarious and depending on the location and season, can form herds (or, 'sounders') of up to 20 individuals, with an average group size around 13.5 individuals (Jochim 1976; Oliver and Leus 2008). The primary social unit consists of a female and the most recent litter, although members of a previous litter can often hang around. Males, although generally solitary, will also join the female group in the rutting season (i.e., in late fall; Jochim 1976:106). Litters of around 4-7 piglets occur in the spring (Briedermann 1990). Wild boar are also mobile, although to a lesser extent than red deer (Jochim 1976). The season of greatest mobility is the early fall, when boar travel to areas with high concentrations of ripening nuts (ibid 1976:110).

Similar to the red and roe deer, wild boar today are considered to be smaller in body size than its prehistoric counterparts. Jochim (1976) notes that average male boar body mass can range from 150-350 kg in eastern and central Europe, with females at 150 kg, and a general average of weight among all age groups at 135 kg (ibid 1976:100). The tusks of male boars may have been useful raw materials for tools (ibid 1976:105). Regarding the relative density of wild boar, Jochim (1976) averages values from two German examples to arrive at an estimate of 12 boar/km^2 (Jochim 1976:104). The primary natural predators of wild boar are humans, wolf, and lynx; fox and brown bear can also prey upon boar (Jochim 1976:103) and eagle-owls can take piglets (Wijngaarden-Bakker 2001). Competition for nuts and other vegetative material occurs between the boar and red/roe deer, with the boar often the more successful species (Jochim 1976). Based on the above data, Jochim (1976) estimates that wild boar would have been exploited most frequently by Mesolithic hunter-gatherers in November and December (Jochim 1976:112). At the Hardinxveld-Giessendam site of Polderweg, wild boar was frequently hunted; oftentimes, entire carcasses slaughtered on the dune (Wijngaarden-Bakker 2001).

C.1.4 Beaver (Castor fiber). Beavers are characterized by Jochim (1976) as small mammals; however, they are the largest rodents native to the European continent (Coles 2006), with adults weighing between 20-25 kg, nearly the same weight as a roe deer. Further, evidence suggests that modern day and prehistoric species were relatively the same size (Clark 1954). For this reason, beaver will be grouped with large mammals in this study.

Beavers have very thick, waterproof hair, making the pelts extremely useful to humans. The large incisors can also be repurposed as cutting tools, such as knives or chisels (Jochim 1976:105). Adult beavers pair for life and live in family units with 2-3 kits and 2-3 'teenagers' – last years' kits (Coles 2006). After their second year, the teenagers are chased away by their parents to find new territory for themselves, undoubtedly one of the reasons beavers are early colonizing species (ibid 2006). Beavers are very territorial, defending areas of 400-500 m alongside streams, rivers, or lakes. Jochim (1976) uses projected beaver densities from Ontario to estimate that Mesolithic beaver densities for southwest Germany were about 0.65 beaver/km^2 (Jochim 1976:104). This area is roughly about 2-3 percent water today, similar to that of Areas 2 and 3 of this study. Jochim's (1976) estimate is thus used for these cases. However, Area 1 of this study reveals 10 percent surface water in the Boreal and Atlantic periods, and so the estimated beaver density for this area is doubled to 1 beaver/km^2.

The natural predators of beaver are wolf, lynx, humans, and even some predator birds will take young beaver. Beavers themselves have a strictly vegetarian diet, comprised of dryland and aquatic vegetation, such as the bark, twigs, and leaves of species like willow, poplar, aspen, and fruit trees (Coles 2006). To accommodate such woody foodstuffs, beaver have developed a complex digestive system. Further, they tend to leave characteristic patterns of strewn woody material after a feeding episode (i.e., de-barked twigs at the water's edge known as a beaver feeding station).

Beavers typically inhabit the banks and levees adjacent to water bodies within forest biotopes, preferably deciduous or mixed, but pine is also tolerated (Nolet 1992:230). Beavers require at least 50 cm of running water to build their dams, while the lodges can be built in still or running water (ibid 1992). Beavers also burrow into stream banks, the entrances of which are usually underwater (along with lodges). The most common form of beaver locomotion is swimming; nearly all activity is undertaken nocturnally, underwater and underground (Coles 2006).

Beavers will only build dams on smaller streams (i.e., not on large steams or rivers, which artificially raises the water level in the distal pond, and also helps to obscure the entrance to the burrow or lodge. Dams can be built in carrs or heathlands, using alder, willow, or even shrub branches, although beavers will use any available material (Coles 2006). A substantial dam can be built within two years by an adult pair and their offspring. These dams do not pose a significant impediment to fish, which can usually pass through side channels or over the dam. Trees caught in the holding ponds will either drown, or flourish from the added nutrients in the water (ibid 2006). The holding ponds often act as nutrient traps that can attract new semi-aquatic species, such as reeds.

When a dam is removed, a very sediment and nutrient rich, open area often replaces the holding pond. These areas can attract edge zone fauna and increase the overall biomass and diversity of a habitat, and have even been shown to be good plots for horticultural purposes (Coles 2006). As such, some researchers note that beavers and humans have a semi-symbiotic relationship, in that beavers create patches in the landscape that are quite useful and beneficial to humans; in other words, humans have a positive attraction to beaver-modified areas (ibid 2006). It has even been postulated that Star Carr may have originally been an abandoned beaver lodge location, with gnaw marks on some of the wooden platform planks and beaver bones in the archaeological assemblage. At the Hardinxveld-Giessendam site of Polderweg, beavers remains were the most numerous faunal type, and appear to have been hunted year round, belying their many useful qualities regardless of the season. Cutmarks, burn marks, and differential distribution of skeletal elements suggest that Mesolithic hunter-gatherers both ate beaver and used their fur (Wijngaarden-Bakker 2001). Further, beaver bones and teeth are useful raw material for tools and decoration (ibid 2001). Regardless, Jochim (1976) estimates that the months of highest beaver utilization were December through April, as is the case for the Round Lake Ojibwa (Jochim 1976:38).

C.1.5 Aurochs (Bos primigenius). While aurochs may not have been a regular component of the Mesolithic diet, it does appear to have been hunted opportunistically, and would have provisioned a group or band for at least a few weeks. A single aurochs kill would also have provided a large amount of raw material. Further, archaeological sites with evidence of aurochs kills and butchery reveal a tendency for taking more than one aurochs at a time, sometimes in addition to other large game (Gustavs 1987; Prummel et al. 2002; Street 1991). For this reason, the aurochs will be modeled independently.

Aurochs is the indigenous and now extinct ancestor of modern-day, domesticated cattle (e.g., Bos taurus; Van Vuure 2002). The link between ancestral and current cattle types has been documented in both genetic and archaeological studies (Edwards et al. 2010). The last aurochs died in Poland in 1627; aurochs have not inhabited the Netherlands since about the 4th century AD (Lauwerier 1988). The aurochs is thought to have originated in India and was domesticated independently there, as well as in the Near East (Van Vuure 2002). It was not well-adapted to glacial conditions and thus its numbers and distribution were contingent on the climate (Von Koenigswald 1999). No aurochs remains have been found in northern Scandinavia or Ireland, suggesting in part that aurochs preferred mixed temperate forests over boreal forests (Gromova 1931). The absence of aurochs from Ireland can perhaps only be explained by the fact that the island was completely isolated by sea water during the Pleistocene or Holocene, and aurochs do not swim.

Fossilized aurochs have divergent measurements, but it can be generalized that the height of the withers was approximately the same as the trunk length (Matolcsi 1970), roughly between 160-180 cm for the bulls and about 150 cm for the cows (Van Vuure 2002:4). Sexual dimorphism was apparent, the bulls having larger bodies and horns overall. Also, males tended to be black or brown in coloring, while the females and juveniles were reddish-brown (ibid 2002:4). In comparison to modern-day cattle, the aurochs had longer legs. The horns look similar to those of full grown adult bulls, light in color with dark tips (ibid 2002:4).

Little is known about the habitat preferences of aurochs, as very few remains of aurochs have been found in Europe. One such site where aurochs fossils have been found is that of Jardinga in the Tjonger valley of the northern Netherlands (Prummel et al. 2002). It appears that this narrow valley was highly attractive to grazing aurochs and red deer alike, most likely because of the open grasslands created by seasonal flooding. The uplands, by contrast, were heavily forested and thus avoided by large herbivores (ibid 2002). It is also possible that hunter-gatherers knew of the large herbivore preference for lowland open areas and targeted them opportunistically, when they encountered in such locales (Bridault 1994; Jochim 1976:97). Indeed, the fact that most aurochs kill and butchering sites are located in areas close to streams or rivers supports this contention, such as the site of Bedburg-Königshoven, where the remains of 11 aurochs were found in a silted-up channel of the Erft River (Street 1991).

Further evidence from paleo-pollen and insect analyses, as well as historical accounts, suggests that aurochs populations were constantly searching for open grasslands and sedge marshes within the dense forests of the early and middle Holocene (Van Vuure 2002), competing with other specialized grazers like the wild horse and European bison. Their diet consisted mainly of grasses and graminoids (ibid 2002:7), and occasionally, aurochs in Poland were reported to have eaten acorns in the fall and tree branches in the winter (Schneeberger in Gesner 1602). If light forests with undergrowth and grasslands were favored by aurochs, then the highest populations must have occurred during the Preboreal in the Netherlands, prior to the development of the denser Boreal and Atlantic forests. Indeed, the sites of Schlaatz (Potsdam, Germany), Star Carr (Yorkshire, Britain), and Bedburg-Königshoven (Rhineland, Germany) all date to the early Mesolithic/Preboreal (Legge and Rowley-Conwy 1988; Prummel et al. 2002; Street 1991). It is therefore curious that the activities at Jardinga took place in the late Mesolithic (e.g., 6570-6130 ^{14}C yr B.P.), when forests were denser. Perhaps the Tjonger valley provided the remaining aurochs population an open area for grazing and drinking during rutting or winter. Aurochs aggregate in late summer-early fall for rutting season and remain relatively immobile during the winter months, suggesting that this time of year would have been the most likely time for aurochs exploitation (Jochim 1976:98).

Historical accounts of 16th century gamekeepers in Poland are also instructive about seasonal behavior: populations of aurochs kept by various Polish kings in the Jaktorów forests gathered in large groups in the winter to feed on hay (Schneeberger in Gesner 1602). In the late spring and early summer, new calves were born, and during the summer months, the cows and calves separated from the bulls. The mating season was in late summer and early fall. At this time, the bulls would mix back into the cow and calf group to mate. Generally, much fighting occurred between bulls. The primary natural predator of aurochs was wolf (Van Vuure 2002). Whether this seasonal behavior was characteristic of Mesolithic aurochs cannot be determined; however, this is the best information available on past populations of the species.

C.2 Small mammals

Small mammals will be discussed as a group, as it is likely that no single species regularly contributed more to the diet than others. Together, however, this category of mainly terrestrial mammals was likely an important component of the diet, especially during times of the year when large mammals, fish, and migratory birds were dispersed, or when plants were not growing.

The small mammal category therefore entails the following species: badger (*Meles meles*), hare (*Lepus eruopaeus*), martin (*Martes* spec.), weasel (*Mustela* spec.), and squirrel (*Sciurus vulgaris*). Smaller species such as moles, voles, mice, or shrews will not be included, as these species did not likely comprise a large part of the hunter-gatherer diet. However, their presence in the landscape will be assumed. Otter (*Lutra lutra*) is the only small mammal that will be considered separately, as it has very different habitat requirements than the rest of the small mammals. A single small predatory species will be considered--the fox (*Vulpes vulpes*)--since wolf, lynx, and brown bear bones have not been recovered from Mesolithic occupations in the Netherlands.

Badgers prefer hilly areas, and the transition zones between uplands and lowlands (Wiertz and Vink 1992:172). Their territories are generally long and narrow, within sinuous valleys of creeks and rivers. Burrows are found at the edges of forests, on river dunes, and in bushes or shrubs (ibid 1992). Badgers are omnivorous and their favorite repast the earthworm (*Lumbricus terrestris*), although much of their diet also consists of other worms, snails, amphibians, insects, small mammals such as mice, and fruit (ibid 1992). The European hare, although originally a species adapted to steppe biotopes, lives widely throughout Europe and prefers open and half-open spaces (Jenster and Leeuwenberg 1992:322). They are relative home-bodies, oftentimes moving no more than 5 km from birthplaces throughout their lives (Broekhuizen and Maaskamp 1982; Schneider 1978). The size of the hare population in a given habitat various from year to year based on the weather, which is thought to effect the amount of available food and the potential for parasites to grow (Jenster and Leeuwenberg 1992).

Martens live in half open terrain, from level areas (i.e., peats) to mountains (Broekhuizen and Müskens 1992; Burton 1979). They are mostly nocturnal animals and are opportunistic omnivores that eat whatever is easiest to procure. Their diet is composed of rabbits, small rodents (e.g., squirrels, voles, shrews, mice), birds, eggs, insects, berries and other fruit (Müskens and Broekhuizen 1992:166). The pine marten, as its name suggests, lives primarily in trees, with a marked preference for old oaks and beech (Gautschi 1983). As tree dwellers, pine martens are good jumpers. Females make their nests in trees, which provide ample cover, shelter, and food (Broekhuizen and Müskens 1992:156; Müskens and Broekhuizen 1992:165). Apart from deciduous trees, the pine marten also finds spruce and fir forests acceptable (Reuver and Van der Zee 1984). The stone marten lives more frequently in open areas and in the vicinity of human settlements, especially in the winter, when they can take shelter there (Broekhuizen and Müskens 1992:156). They are better at climbing than jumping (ibid 1992). These small mammals were probably caught with snares and traps set along primary marten routes (Wijngaarden-Bakker 2001).

Weasels (and the subspecies *Mustela putorius or* pole cats) are very long-bodied mammals, which enables them to slink into and prey upon smaller mammal species (Pelzers 1992:142). Weasels display high sexual dimorphism: the males are generally 20 percent larger than the females (Brugge 1977). The species live in a wide variety of biotopes, from meadows and fields, to forests and reclaimed dunes (Pelzers 1992:142). Pole cats prefer to be near water, either in the bank growth of a stream or river, but also in dry and human occupied areas. If weasels inhabit open areas, there must be sufficient cover present (e.g., hedgerows, brush/shrub, woodpiles, hollow trees, and forest edges; Jenster 1992:147; King 1991). Weasels eat a diet comprised mainly of small mammals, such as voles, mice, and shrews, along with birds, insects, reptiles, amphibians; they almost never eat plant material and could therefore be considered predominantly carnivorous (Pelzers 1992:142; Jenster 1992:147). On occasion, hunters may have taken pole cats for their fur (Wijngaarden-Bakker 2001).

Squirrels are forest animals although they adapt well to half open spaces like tree-lined savannas and parks (Bijlsma 1992:222). In the Netherlands, squirrels live mainly in conifer forests (especially in dense stands of pine), as well as in mixed forests with old growth (ibid 1992). The diet of squirrels is comprised mainly of seeds, especially those from pine trees. In the spring, buds, leafs, and even bird eggs may also be eaten, along with nuts, mushrooms, and bark during the rest of the year (ibid 1992).

Otter are freshwater aquatic mammals that inhabit a variety of biotopes, from sea coasts, to lakes, rivers, and streams, although their preferred habitat is riparian zone[24] (Veen and Broekhuizen 1992:178). For otter to flourish, the water must not be too shallow (e.g., more than 50 cm in depth), be stocked with ample fish, and have sufficient bank cover (Veen 1984). In the Netherlands, there are thus four main otter-friendly biotopes: 1) low-lying peat areas that are drained by ditches, ponds, and lakes; 2) marine clay areas drained by creeks, canals, and interlaced with thick overgrown banks; 3) large rivers and old distributaries; and 4) small river and stream systems and their associated lakes and canals (Veen and Broekhuizen 1992:178). Otter diets are mainly opportunistic, with fish as the main staple. However, aquatic species like crayfish and crab, as well as amphibians, birds, and small mammals may also be taken (Mason and Macdonald 1986). In the winter, pike, roach, and perch are focused on. The territory size of

[24] According to the Merriam-Webster dictionary, a *riparian* zone is an area “located on the bank of a natural watercourse (as a river) or sometimes of a lake or a tidewater.”

an adult otter varies based on food and cover availability, and male territories tend to be larger than female territories (Veen and Broekhuizen 1992:179). Territories that stretch along coasts can range up to 40 km in length (Mason and Macdonald 1986), although in the northern Netherlands, home-ranges average between 9-15 km^2 (Veen 1980). Otters are also known to migrate to find new territories, sometimes as much as 60 km in a three month period (Jenkins 1980). Otter were frequently taken at the Hardinxveld-Giessendam sites, where they were likely caught in snares and traps (Wijngaarden-Bakker 2001). To preserve the completeness of the pelt, the animals were usually clubbed on the back of the head rather than shot or stabbed. Otters display routine behavior and after some observation, their movements can be predicted by hunters (ibid 2001).

The red fox is the world's most widespread carnivore (Voigt 1987). It is a small canine with a tail nearly as long as its body and head length (Lariviere and Pasitschniak-Arts 1996:2). The mean adult mass for modern-populations is 6.3 kg for males and 5.5 kg for females (Voigt 1987). The best time of year for pelt harvesting is the winter (Lariviere and Pasitschniak-Arts 1996). The red fox is highly mobile, moving distances of >10 km daily (Voigt 1987), though most activity is nocturnal. Red fox can adapt to a variety of biotopes, due to their highly unspecialized food choices (Mulder 1992:126). The species has been known to eat everything from rodents, birds, reptiles, amphibians, beetles, earthworms, fruits, mushrooms, rabbits and hares, as well as young ungulates, such as roe deer fawn (ibid 1992). As such, the fox can live easily in natural or urban environments, in tundra or semi-arid desserts, although their preference is for half-open, heterogeneous landscapes with alternating meadows and woods (Lariviere and Pasitschniak-Arts 1996:4). The suitability of habitat is also strongly affected by the availability of prey (Phillips and Catling 1991). Cover, in the form of brush and willow shrubs, is an important requirement, as is sufficiently friable sandy soils that allow burrowing and den creation prior to the birthing of a litter (Lariviere and Pasitschniak-Arts 1996; Sheldon 1950).

This concludes the discussion of small mammals, including otter and red fox, which were present during the early and middle Holocene in the Netherlands. It is general believed that modern body sizes roughly correlate to those of prehistory. Jochim (1976) estimates a small mammal density of c. 103 mammals/km^2, weighing on average about 3.6 kg/individual (Jochim 1976:105). This category of species would have provided Mesolithic hunter-gatherers food and raw materials, especially in the form of pelts. Seasonally, it seems that small mammals were used year round, especially during months when larger or more abundant resources were absent (e.g., February, June-July, and December; Jochim 1976:114).

C.3 Birds

Birds did not likely constitute a very large part of the overall Mesolithic diet; however, at certain times of year, it is probable that congregations of migrating birds would have served as an abundant and predictable resource. In Table 4.2, various categories of birds have been assembled, including terrestrial birds, aquatic birds, prey birds, and song birds. It is most likely that terrestrial and aquatic birds were most commonly targeted for food and raw material purposes (e.g., feathers, talons, and hollow bones for instruments). Song birds and prey birds are generally considered not worth the effort for nutritional purposes, although such species can be taken for personal adornment, or as ritual, prestige, and exchange items (Hayden 1998; Trubitt 2000; Wijngaarden-Bakker et al. 2001:222).

Jochim (1976) estimates that only about 2 percent of the Mesolithic diet in southwestern Germany comprised birds (Jochim 1976:107). This estimate is probably an accurate estimate for all three areas considered in the present study, regardless of the fact that Area 1 was likely more attractive to migratory aquatic birds (more wetland available for refueling), and Areas 2 and 3 were more attractive to terrestrial birds (more wooded and shrub nesting areas and food resources). These assertions are partly backed by zooarchaeological evidence from the Hardinxveld-Giessendam sites, where unique distributions of primarily aquatic birds have been found. At Polderweg, 90 percent of all bird species were all water and marsh fowl, with high proportions of wild duck (*Anatidae*), swan, and goosander (i.e., merganser; Wijngaarden-Bakker et al. 2001:225). At De Bruin, 96 percent of all birds were water/wetland birds, comprised mostly of ducks, swans, and geese (Oversteegen et al. 2001). Unfortunately, only a few bird bones were found at the more inland site of Zutphen-Ooijerhoek, and the preservation of these bones were sufficiently poor so as to preclude any classification other than 'indeterminate bird species' (Bos et al. 2005; Groenewoudt et al. 2001).

As mentioned, the most common avifauna species found in wetland contexts of the early-middle Holocene Netherlands were duck, swan, and geese. In addition, red-throated diver, cormorant, heron, reed bunting, little grebe, rail, and plover were also common (Wijngaarden-Bakker et al. 2001:220). All of these species prefer habitats with abundant open and oxygen-rich water, suitable for the growth of reeds, and interlaced with well-vegetated levees, banks, and dunes (ibid 2001). Terrestrial species likely consisted of woodcock, buzzard, sparrowhawk, great spotted woodpecker, thrush, eagle-owl, and sea-eagle. Most of these species prefer forested areas, although they are not picky if the forest is dryland or marsh forest. Also, in the case of buzzard and the sea-eagle, nearby open areas are preferable for hunting purposes (Cramp 1977-1988).

Many of the species that utilized the downstream wetlands of the Rhine and Meuse rivers in the early Holocene were migratory to some extent. Birds that annually breed in the Netherlands in the spring and summer, and fly south for the winter months, include cormorant, blue heron, buzzard, water rail, moorhen, sparrowhawk, coots and buntings (Wijngaarden-Bakker et al. 2001:221). There is also a group of birds that gather in the Netherlands during the winter and breed further north in the summers. These species include the Bewick's and Whooper swan, red-throated divers, bean goose, wigeon, goosander, sea-eagle, and the common golden eye (ibid 2001:221). The quantity of ducks in the Netherlands does not fluctuate much throughout the year, although the spatial distribution does: in the winter, many duck species gather in the delta area, redistributing themselves throughout the country again in the spring (SOVON 1987). It is also quite likely that cranes, wood pigeon, and crows (family *Corvidae*) were commonly encountered bird species in the Mesolithic period. Cranes prefer wetland habitats, crow like tall stands of trees to establish breeding colonies, and wood pigeon favors undergrowth in dry woodlands (Wijngaarden-Bakker et al. 2001:220).

Most birds were probably caught with traps or nets, or hunted with a bow and arrow (ibid 2001). Some species may have been easier to attract than others, such as buzzard and sea-eagles, which may have scavenged around the refuse pits associated with human dwellings. Ducks and goosanders may have been drawn to locations where Mesolithic people were exploiting schools of fish by net-fishing (ibid 2001). Thus, it is possible that bird collection was oftentimes a by-product of other more active food-gathering activities.

C.4 Fish

As with birds, fish were considered in two main ecological categories: freshwater and anadromous. The latter category refers to fish that can tolerate both fresh and salt water, swimming upstream to spawn in their ancestral body of water. The spectrum of fish species would have differed somewhat between the delta and inland environments of study areas 1, and 2-3, respectively. To get an idea of what this spectrum may have looked like, the zooarchaeological data for the Hardinxveld-Giessendam and Zutphen-Ooijerhoek sites will be discussed.

The most common fish families found at the Hardinxveld-Giessendam sites were primarily freshwater varieties: pike (*Esocidae*) and cyprinid (*Cyprinidae*). The cyprinid family (also known as 'carp-like') consists of a variety of species and subspecies, including common and silver bream, chub, ide, roach, rudd, and tench (ibid 2001b). Most cyprinids spawn in the spring, favoring shallow waters with plenty of vegetation (Nijssen and de Groot 1987). They move between open, (semi-) moving water during the warmer months and hibernate in deep lakes in colder months (Beerenhout 2001a:254). Pike and perch (*Percidae*) are the natural predators of the cyprinids and other fish, and prefer clear water. They also spawn in the late winter and early spring (Kottelat and Freyhof 2007). It is possible that the fishing practices at these dunes was focused during some periods on exploiting pike during their yearly spawn (Beerenhout 2001a:265).

Both of these fish families live in bream zone conditions, which typically occurs in deltas and lowland areas with sluggish or stagnant water (Beerenhout 2001a, b). In the fall and spring (especially), the rivers in this type of environment overflow their banks and a large area of land is temporarily submerged (Beerenhout 2001b:310). The zone typically consists of different niches, based on the water depth, expanse, soil type and flow (Beerenhout 2001a:263). For example, the ambient water temperature is affected by the depth and expanse of the water and deep water generally has less vegetation than shallow (ibid 2001a). Ponds with a small expanse of shallow, oxygen-poor water and rich floral growth for cover and food are favored by tench, rudd, and young pike; lakes with more open yet still water are preferred for roach and pike, and the adjacent riparian zone is good for rudd, tench, eel, catfish; creeks vary in water flow and velocity, attracting similar species as lakes in slow-flowing extents, and perch, roach and chub in the faster-moving segments; and rivers attracts oxygen-loving species such as ide, chub, and (seasonally), salmon, trout, sturgeon, and whitefish (Beerenhout 2001a:263). Further, oxbows provide very good areas for young fish and are sometimes referred to as nurseries (ibid 2001b).

In the downstream delta area, anadromous fish were also exploited, including sea sturgeon, eel, Atlantic salmon and brown trout. In the case of sturgeon (*Acipenser sturio*), the young spend the first 2-3 years in freshwater streams and rivers, afterwards migrating downstream to the ocean. They return to the same stream in the summer to spawn (Beerenhout 2001a:262). Salmon also spawns in the spring.

Very high numbers of fish remains were recovered from the Polderweg and De Bruin dune sites (57,886 and 14,622 fragments, respectively; Beerenhout 2001a:243, 2001b:299), indicating that fishing was a primary activity undertaken in these locations, especially at Polderweg. In addition, many (charred) fish bones were recovered from colluvium adjacent to the dunes, likely occupational refuse dumps. The remains must have been deposited in these areas by humans, as fish remains do not usually become embedded in sloped contexts (Beerenhout 2001a:263). Mesolithic hunter-gatherers must have been acutely aware of the spawning behavior and timing of certain fish (e.g., pike, and salmon and sturgeon to a lesser extent), as mostly adult specimen were found (ibid 2001b:264). Such fish would have provided a reliable and predictable source of food, mostly in the late winter and spring months. Fish were most likely taken for food provisioning purposes, as they yield relatively few non-food products, other than for personal adornment and jewelry (Jochim 1976:105).

Various fishing strategies and technologies were used to catch the spawning pike, cyprinids, and other species. As the former was likely amassing in large, lethargic groups, they were probably easy to procure with baskets, fishing spears, or even with bare hands (Beerenhout 2001a:266). As pike begin their spawn in late winter, some ice fishing may also have taken place (ibid 2001b:267). Cyprinids may have been caught with fish weirs and nets. Eel are best caught with traps placed on the river or lake bed and catfish were trapped or impaled at twilight (ibid 2001b). It is not likely that fish hooks were frequently used, as most spawning fish do not feed (and therefore bite) frequently. Other potential strategies involve the use of dogs (to swim into and retrieve fish from the water), and boats and paddles (to facilitate fishing mobility and transportation; Beerenhout 2001a:267; Van Brandt 1984).

In southwestern Germany, the average adult fish weight roughly 1.0 kg (Jochim 1976:112), peaking just before the spawning season. In combination with the knowledge that spawning fish form large, relatively immobile groups, it is possible that hunter-gatherers who exploited spawning populations would have reaped a large amount of fish meat in a relatively short period. For this reason, it is assumed that some type of meat preservation took place, perhaps in the form of drying or smoking (Beerenhout 2001a:268). This assertion is based on the fact that pike is a non-oily fish, making it suitable for drying, and since spring months generally have low levels of humidity and insects (ibid 2001b:268).

The inland site of Zutphen-Ooijerhoek was situated in a much different ecosystem than the Hardinxveld-Giessendam sites, along a cut-off residual channel of a small upstream tributary of the Rhine (Bos et al. 2005; Groenewoudt et al. 2001). Only two species of fish were identified: pike (*Esox lusius*) and roach (*Rutilus rutilus*), suggesting that a bream zone was present here as well, even in the upland and upstream extent of Rhine, in the early Mesolithic (in contrast to the downstream area in the late Mesolithic, as represented by the Hardinxveld-Giessendam sites). Based on the findings of freshwater mollusk (*Unio*), and various arthropods suggests that other freshwater bream species were present, such as rudd, carp, bream, tench, catfish, perch, and eel (Bos et al. 2005:35). The population of fish in this upstream area was probably much smaller than the downstream population, as the river itself was reduced in size and flow and since the fish densities tend to decrease in areas closer to the headwaters (Jochim 1976:104).

C.5 Other

Only one additional species will be considered in the ‘other’ category: terrapins, commonly known as the European pond turtles (*Emys orbicularis*). While it is possible that other types of reptiles, amphibians, insects, and larvae may have occasionally supplemented the Mesolithic hunter-gatherer diet, these sources of calories could never have been major contributors.

European terrapins are terrestrial reptiles that inhabit semi-aquatic freshwater environments. Their preferred habitat includes brooks, streams, and rivers, to ponds and lakes (Baillie and Groombridge 1996). Terrapins are small turtles, weighing around 0.5 kg with their shells; shells tend to comprise about 30 percent of the overall body mass of a turtle (Miller and Birchard 2005:160). As such, terrapins would only yield about 0.35 kg of useable meat. Modern-day turtle meat yields about 95 calories/0.11 kg, in comparison to 102 calories in wild venison meat, 104 calories in wild boar meat, and 140 calories in wild duck meat (Anonymous 2011). Thus, a terrapin would probably serve as a good snack for hunter-gatherers at around 300 calories/terrapin; however, the amount of effort required to extract the meat from the shell hardly seems sufficient justified if food is the main target. Rather, it is more likely that terrapin were hunted or trapped for their shells (top: carapace, bottom: plastron). At the site of Polderweg, terrapin shells were found with cut and burn marks (Wijngaarden-Bakker et al. 2001:229); others were highly fragmented. Turtle shell can be used as containers or vessels (Frazier 1980:332), the leather used for clothing or structural material (ibid 1980), made into everyday implements (e.g., spatulas) or decorative artifacts such as hair combs (Hooper 1943:95). Turtle also features prominently in the cosmology and mythology of many ethnographic and archaeological cultures, such as the Huron and Iroquois in north America (Fenton 1962), the Tamils from Sri Lanka and southern India, the Onge and Selug from the Andaman islands, Burma, and Thailand, and the Maya of Mesoamerica (Frazier 1980; Taube 1988).

APPENDIX D

FAUNAL SUITABILITY MAPS

D.1 Polderweg Area

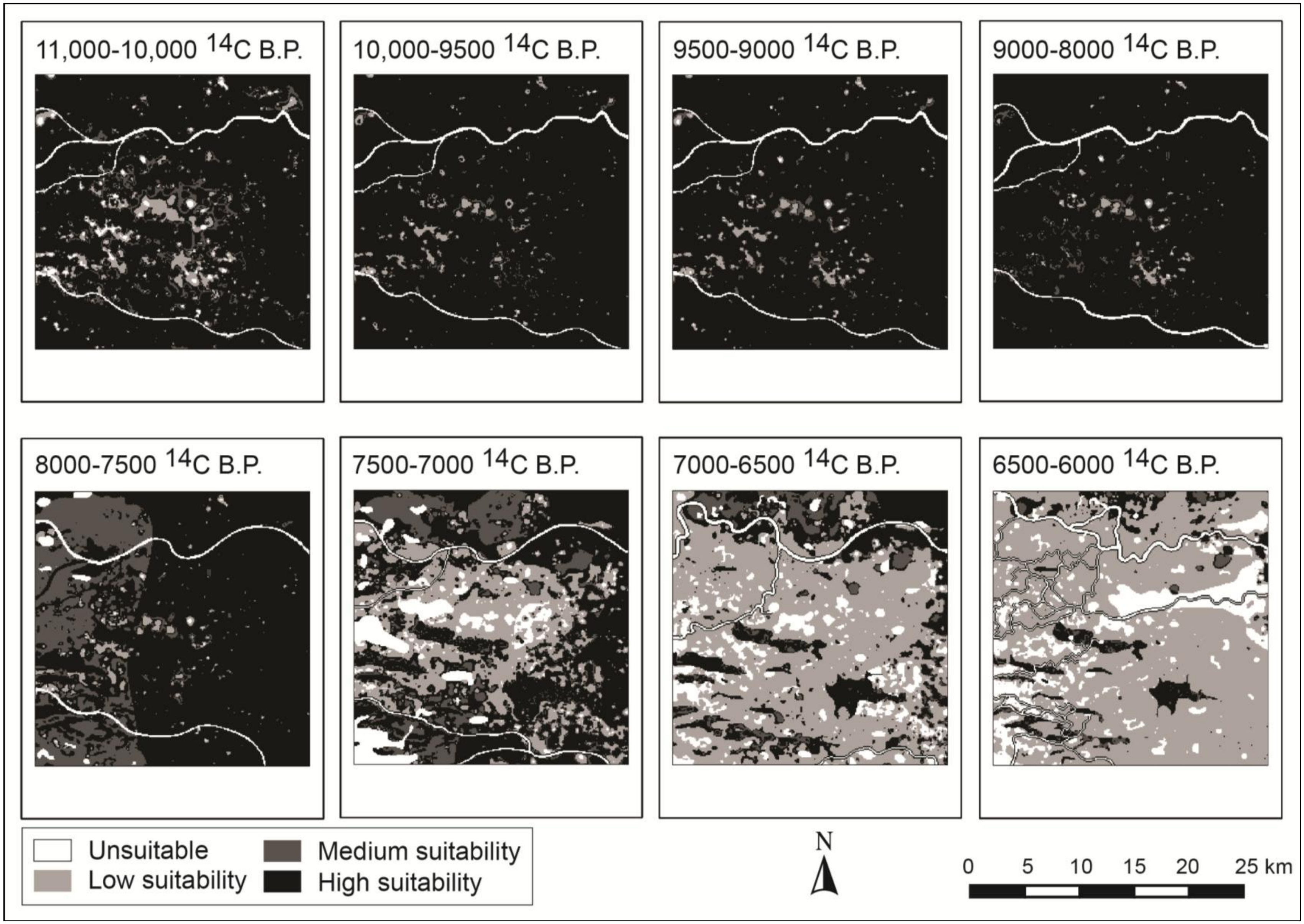

Figure D.1 Suitability Distribution for Large Game Species in the Polderweg Area (i.e., red deer, roe deer, and aurochs).

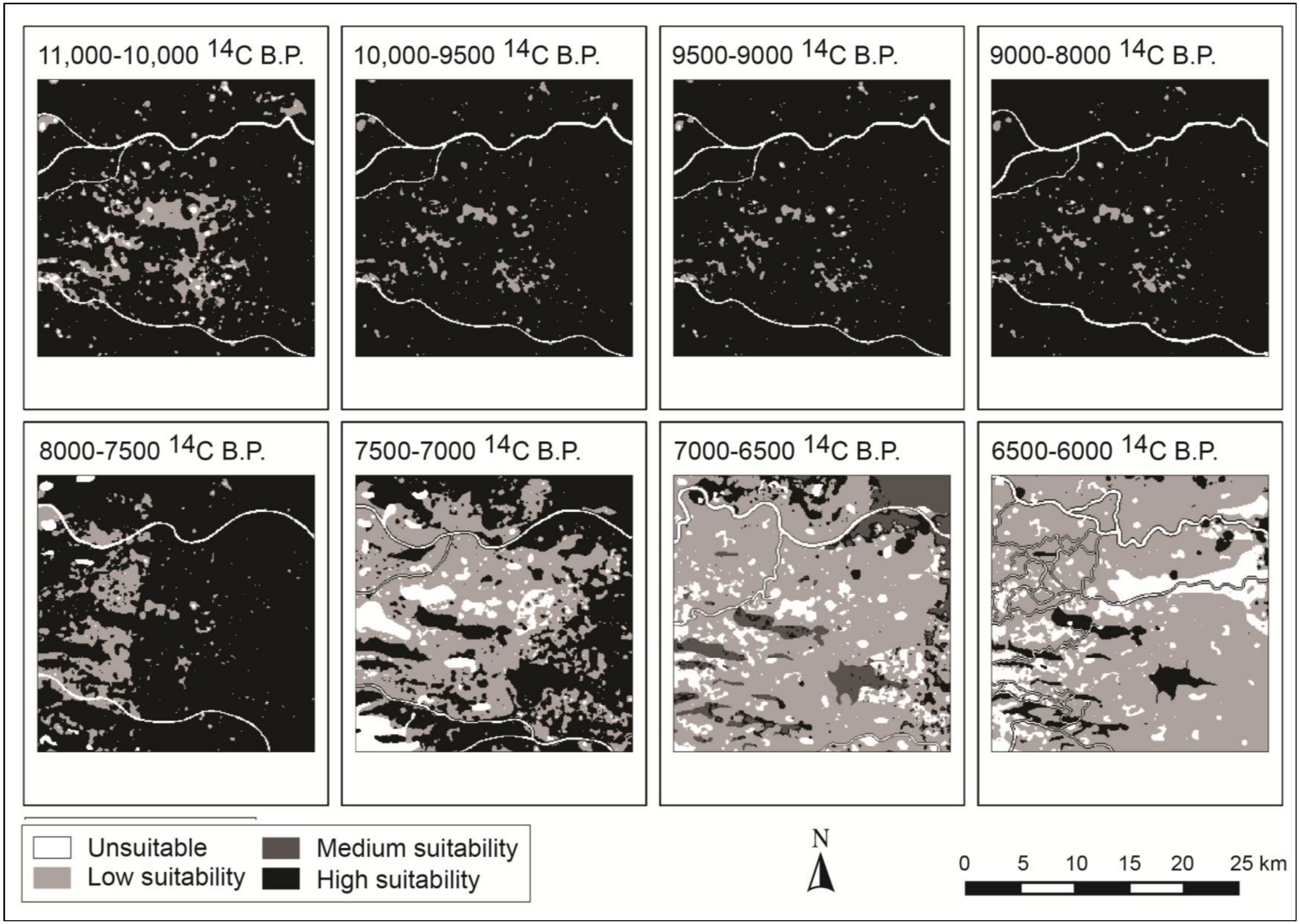

Figure D.2 Suitability Distribution for Wild Boar in the Polderweg Area.

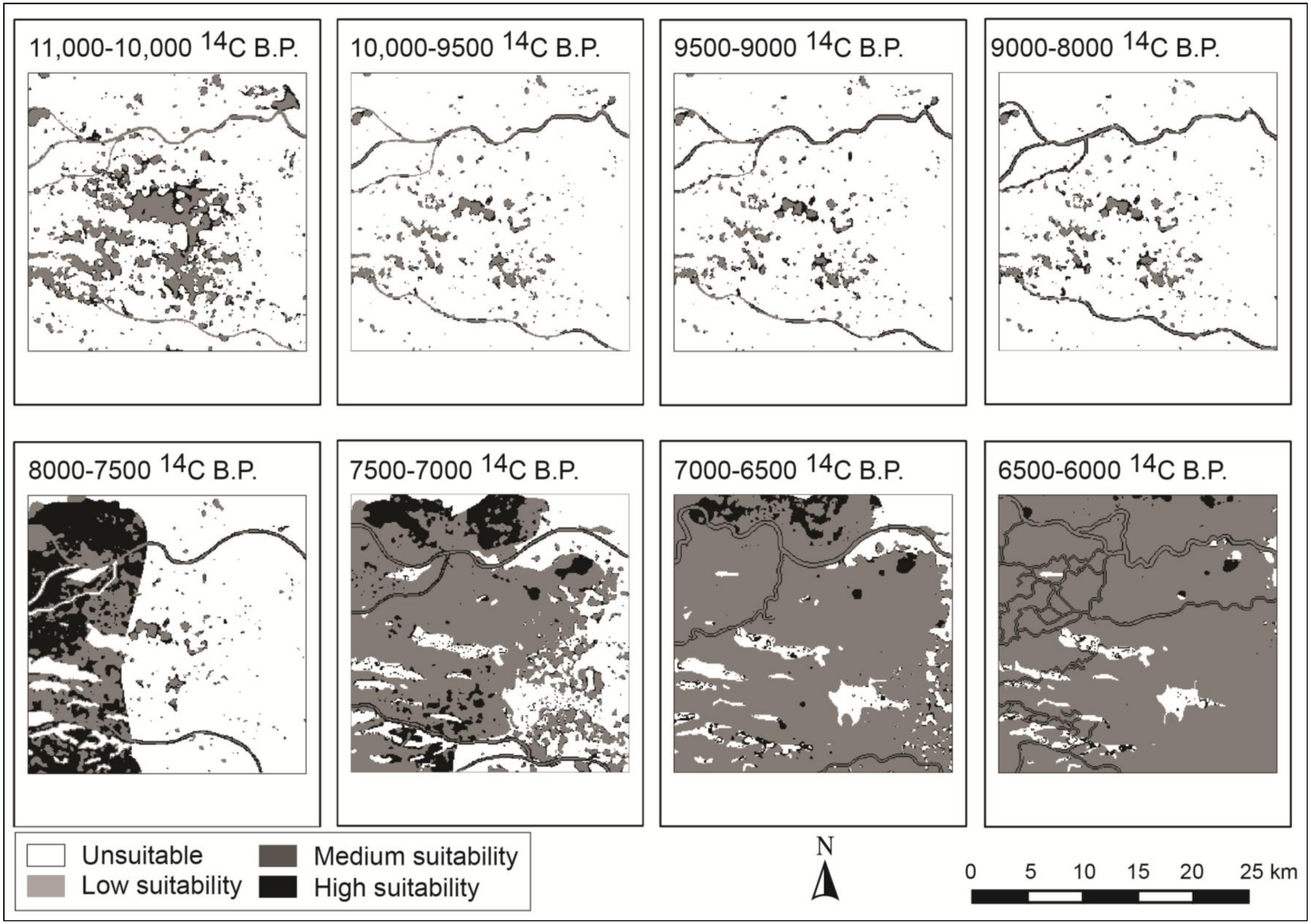

Figure D.3 Suitability Distribution for Beaver in the Polderweg Area.

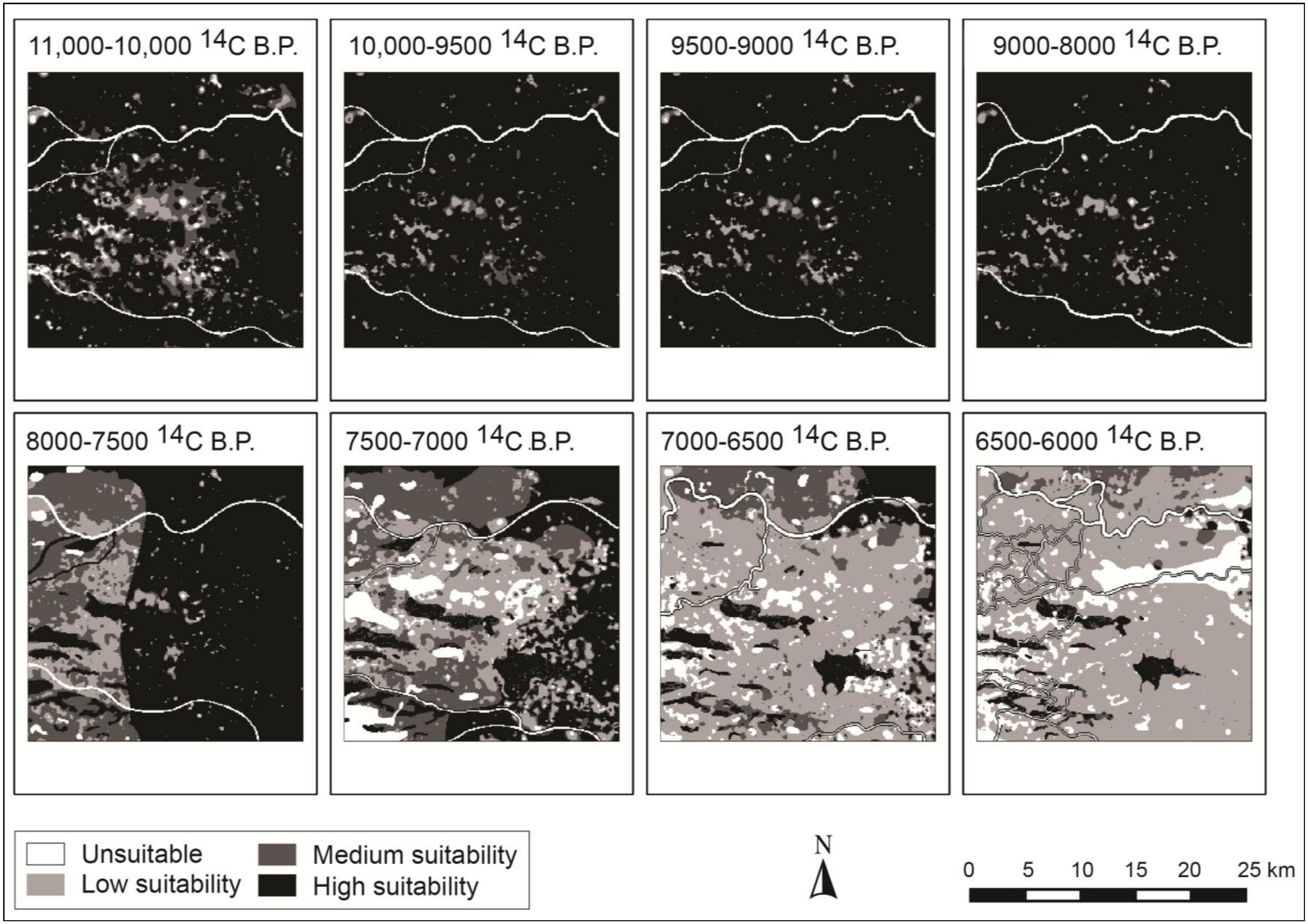

Figure D.4 Suitability Distribution for Small Terrestrial Mammals in the Polderweg Area.

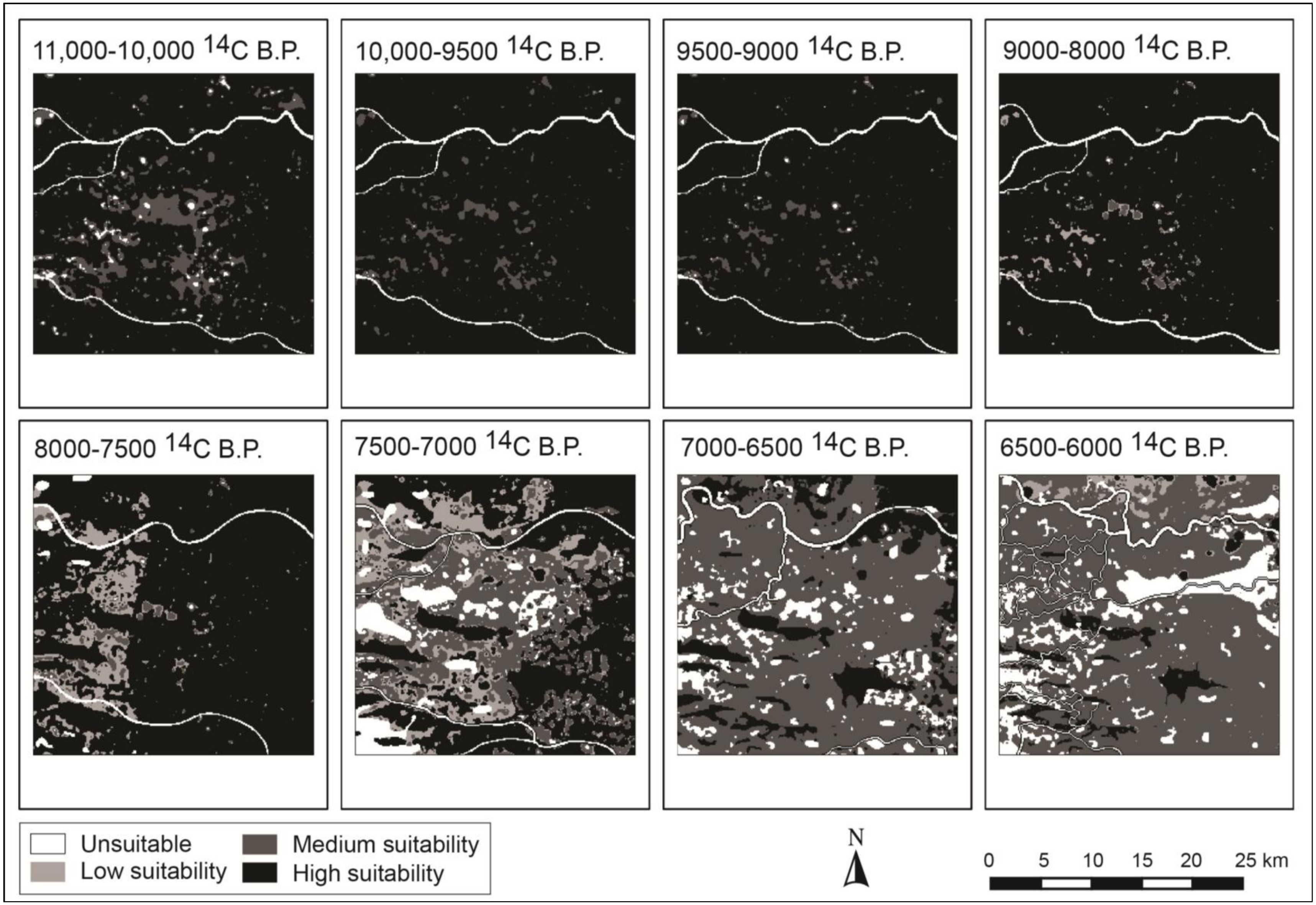

Figure D.5 Suitability Distribution for Terrestrial Birds in the Polderweg Area.

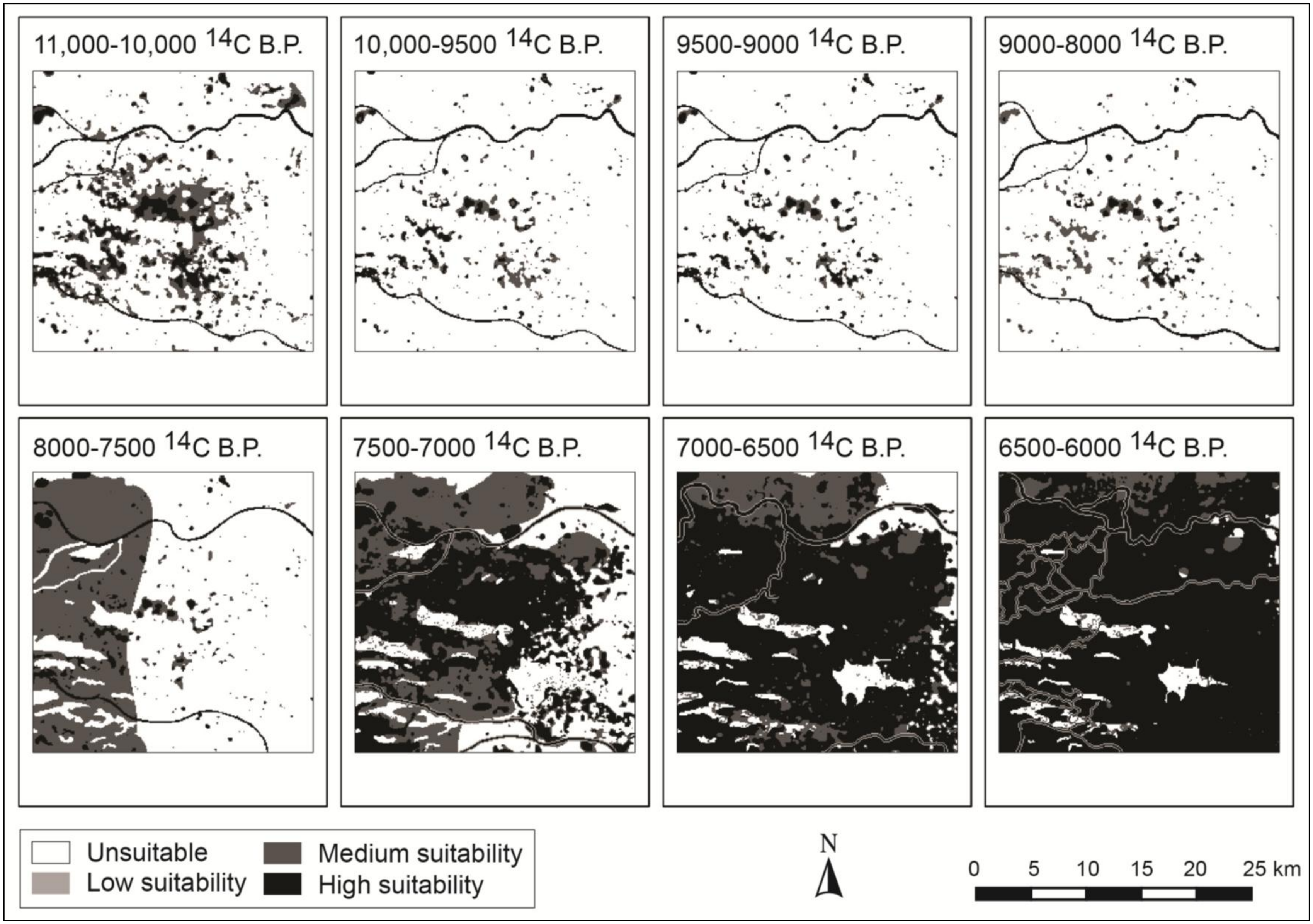

Figure D.6 Suitability Distribution for Aquatic Birds in the Polderweg Area.

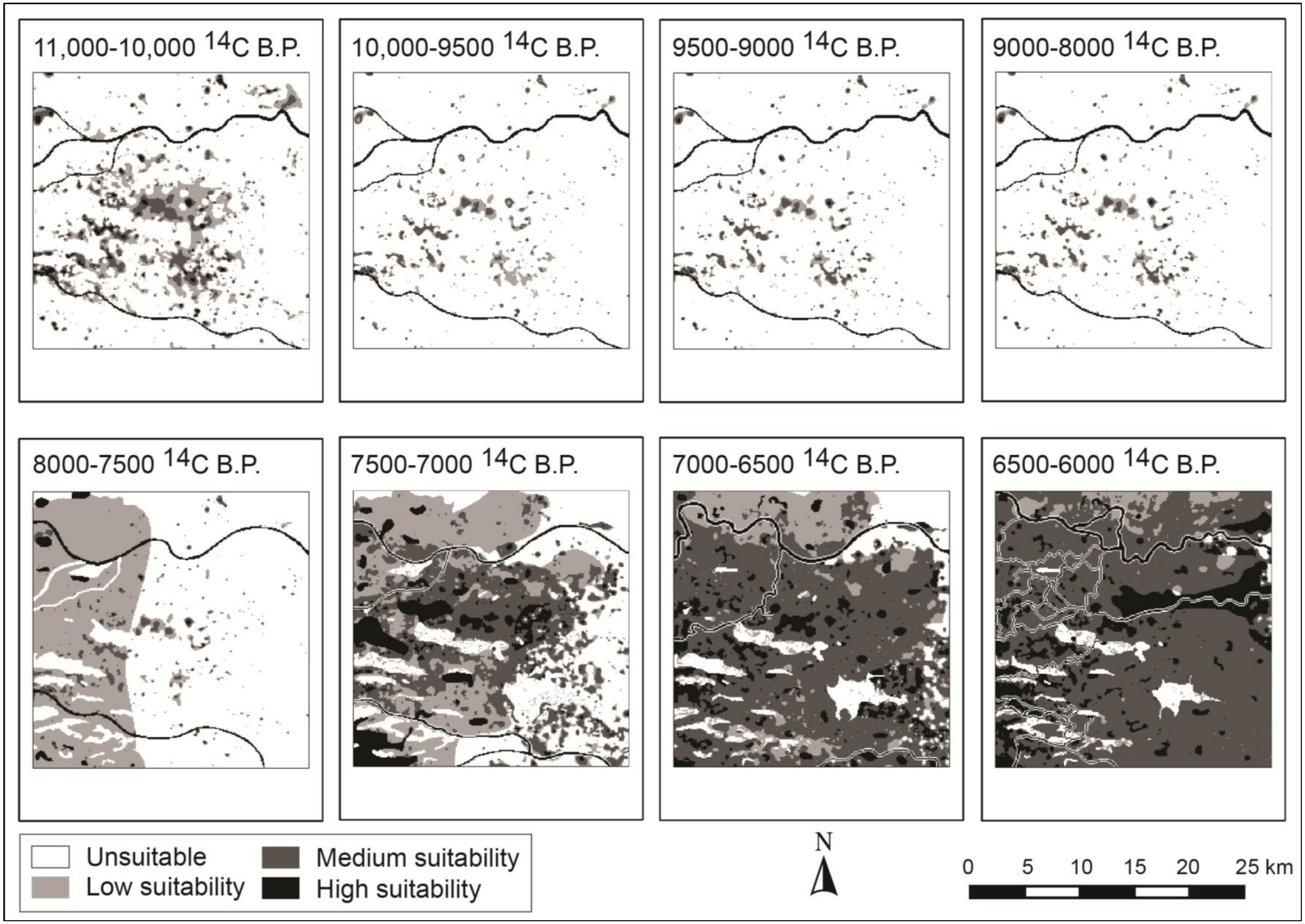

Figure D.7 Suitability Distribution for Freshwater Fish in the Polderweg Area.

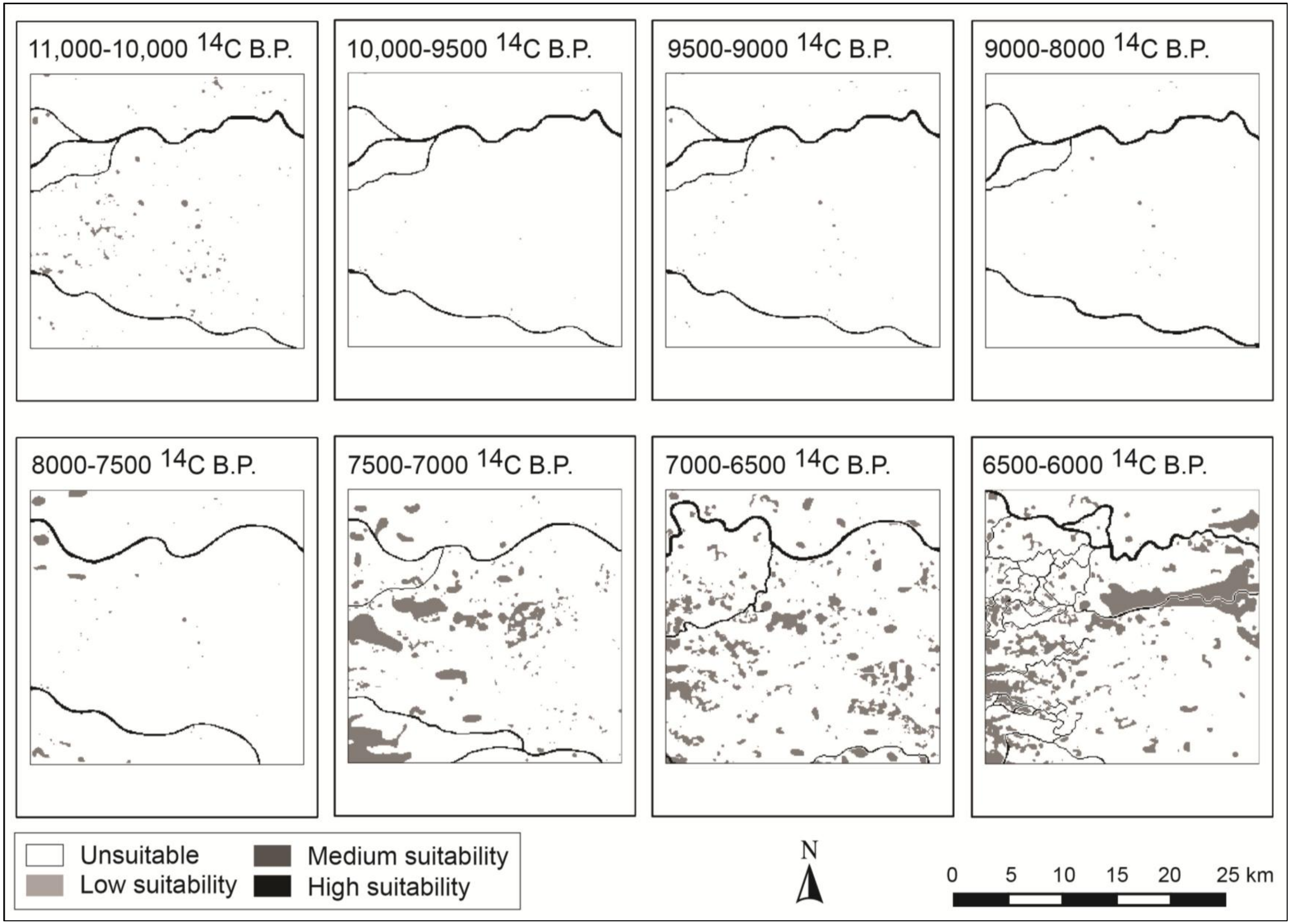

Figure D.8 Suitability Distribution for Anadromous Fish in the Polderweg Area.

D.2 Deest Area

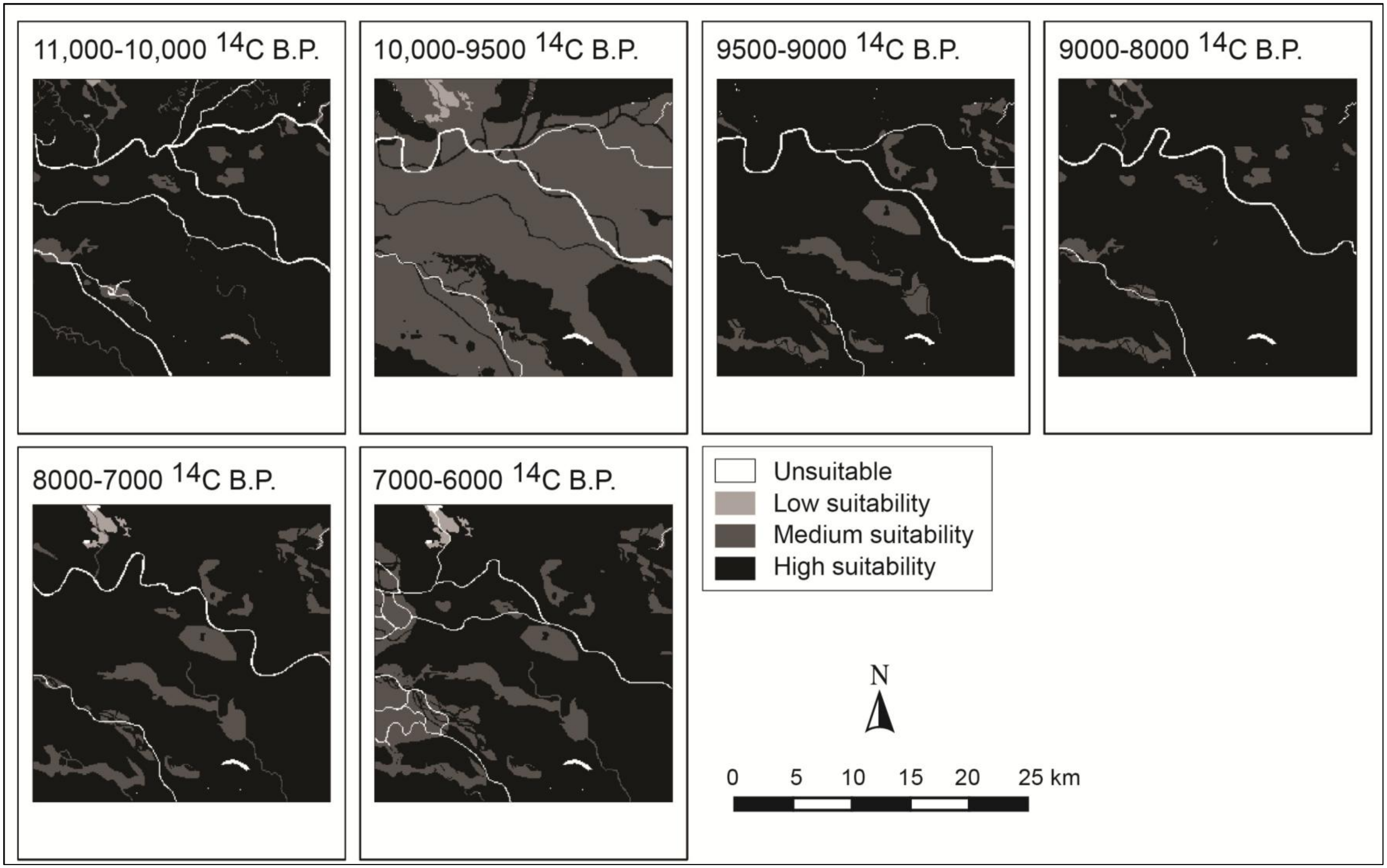

Figure D.9 Suitability Distribution for Large Game Species in the Deest Area (i.e., red deer, roe deer, and aurochs).

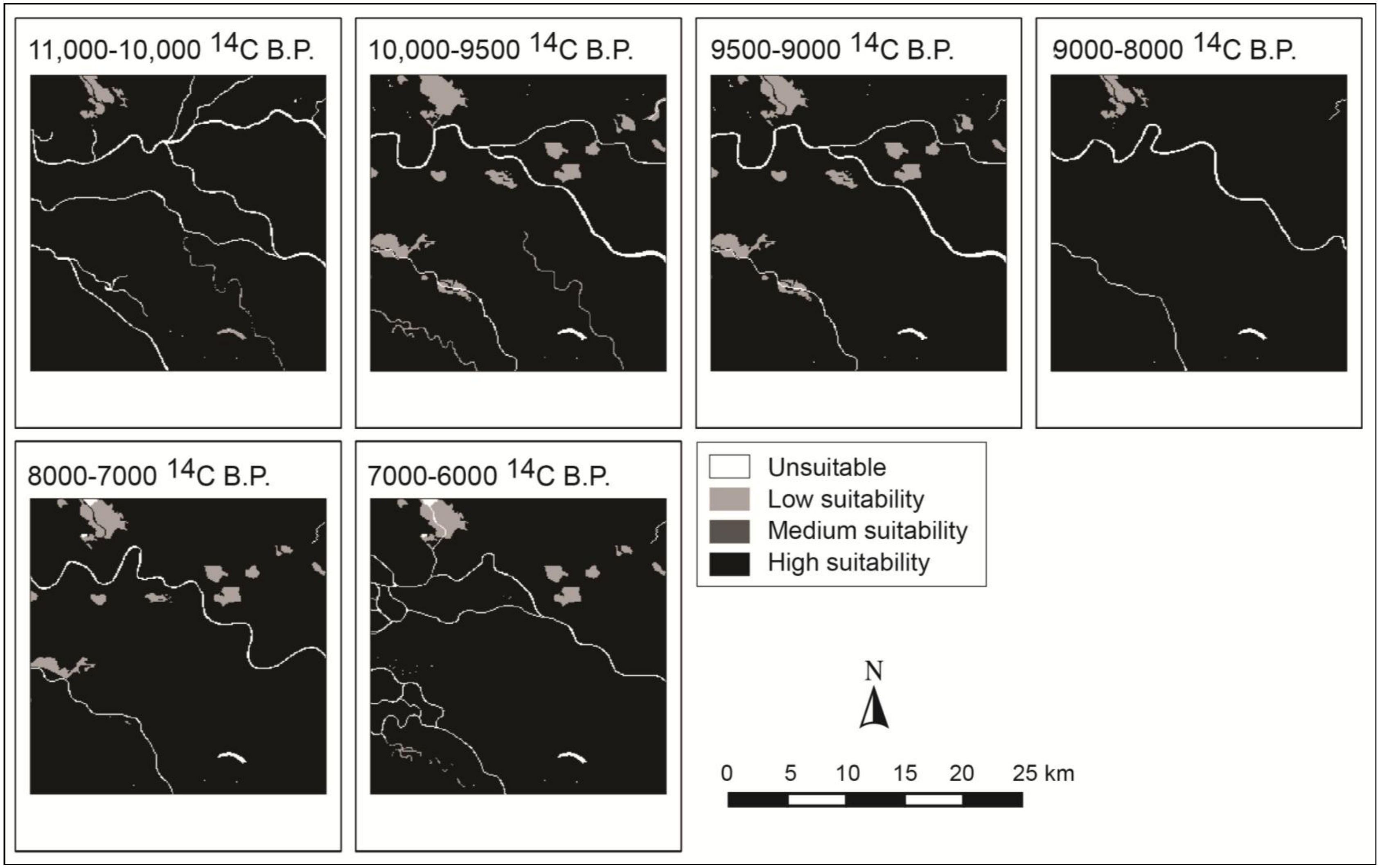

Figure D.10 Suitability Distribution for Wild Boar in the Deest Area.

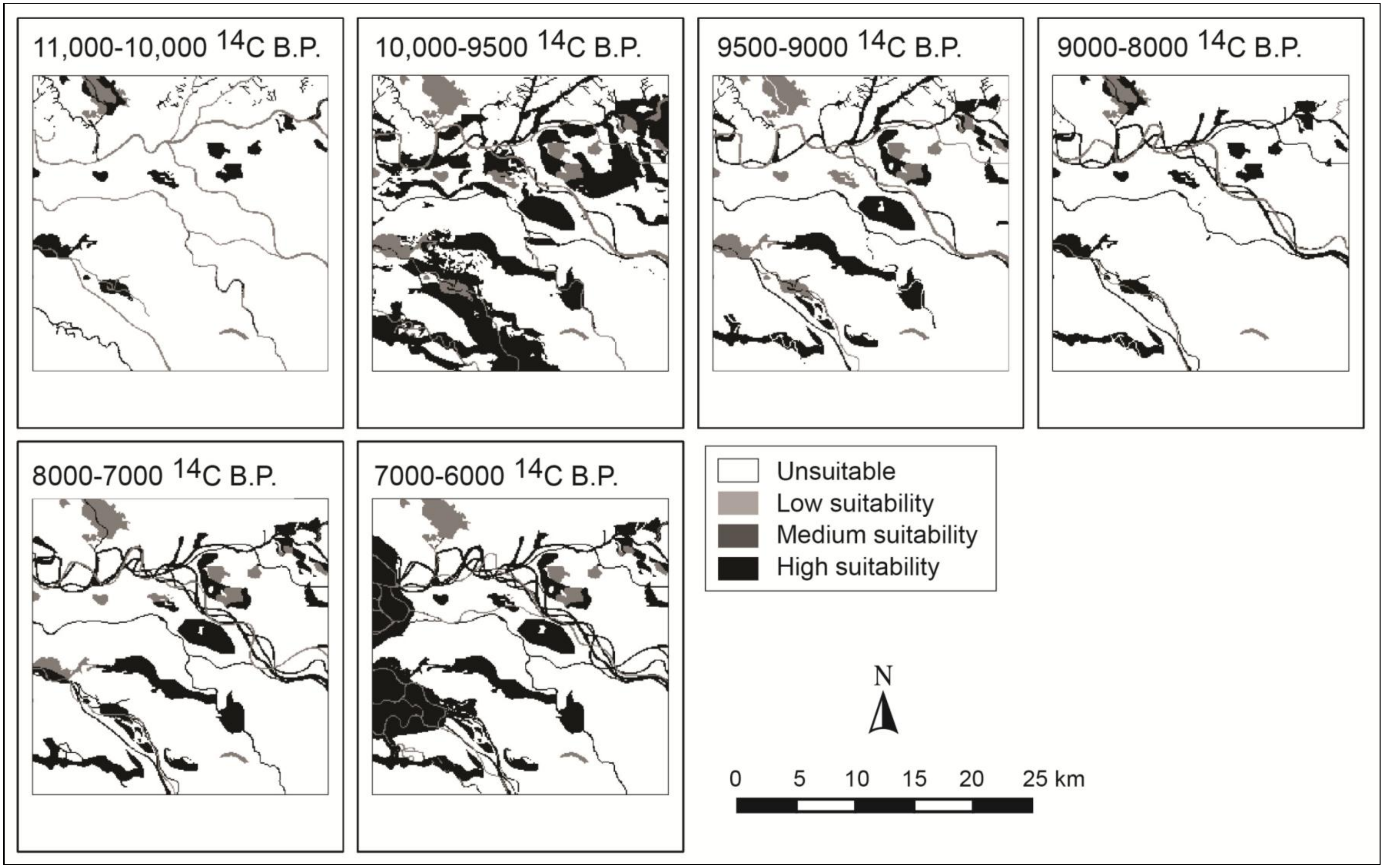

Figure D.11 Suitability Distribution for Beaver in the Deest Area.

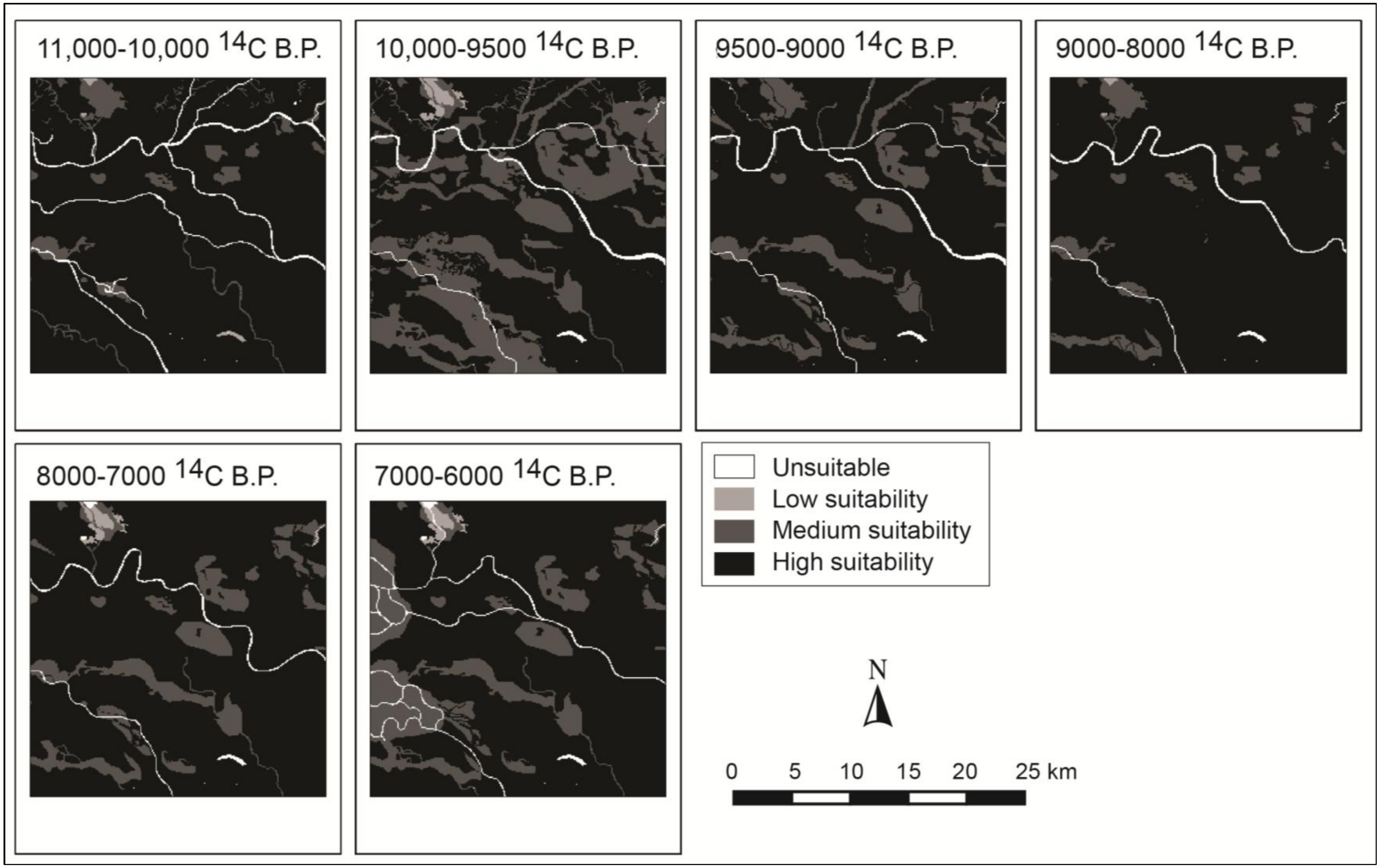

Figure D.12 Suitability Distribution for Small Terrestrial Mammals in the Deest Area.

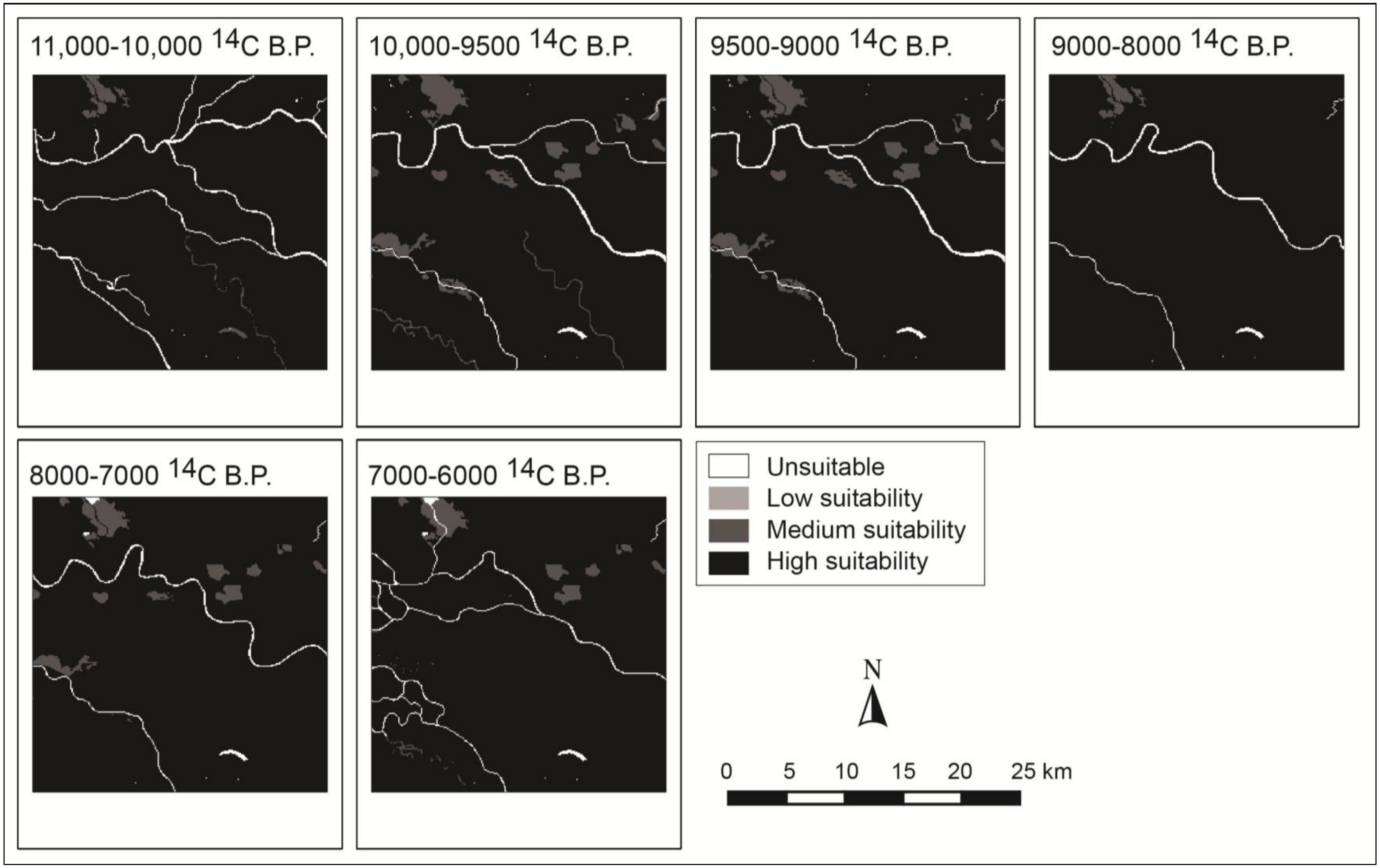

Figure D.13 Suitability Distribution for Terrestrial Birds in the Deest Area.

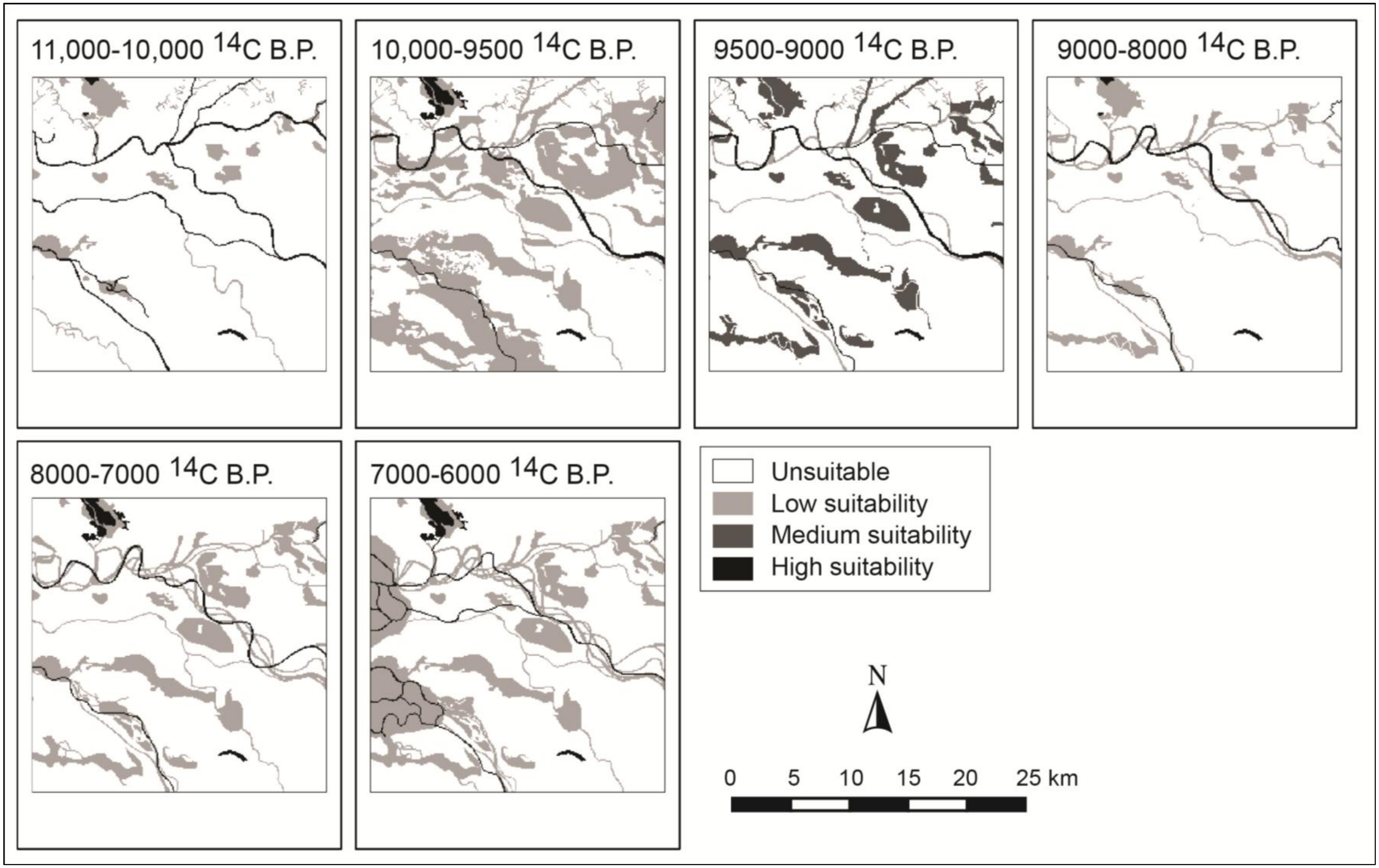

Figure D.14 Suitability Distribution for Aquatic Birds in the Deest Area.

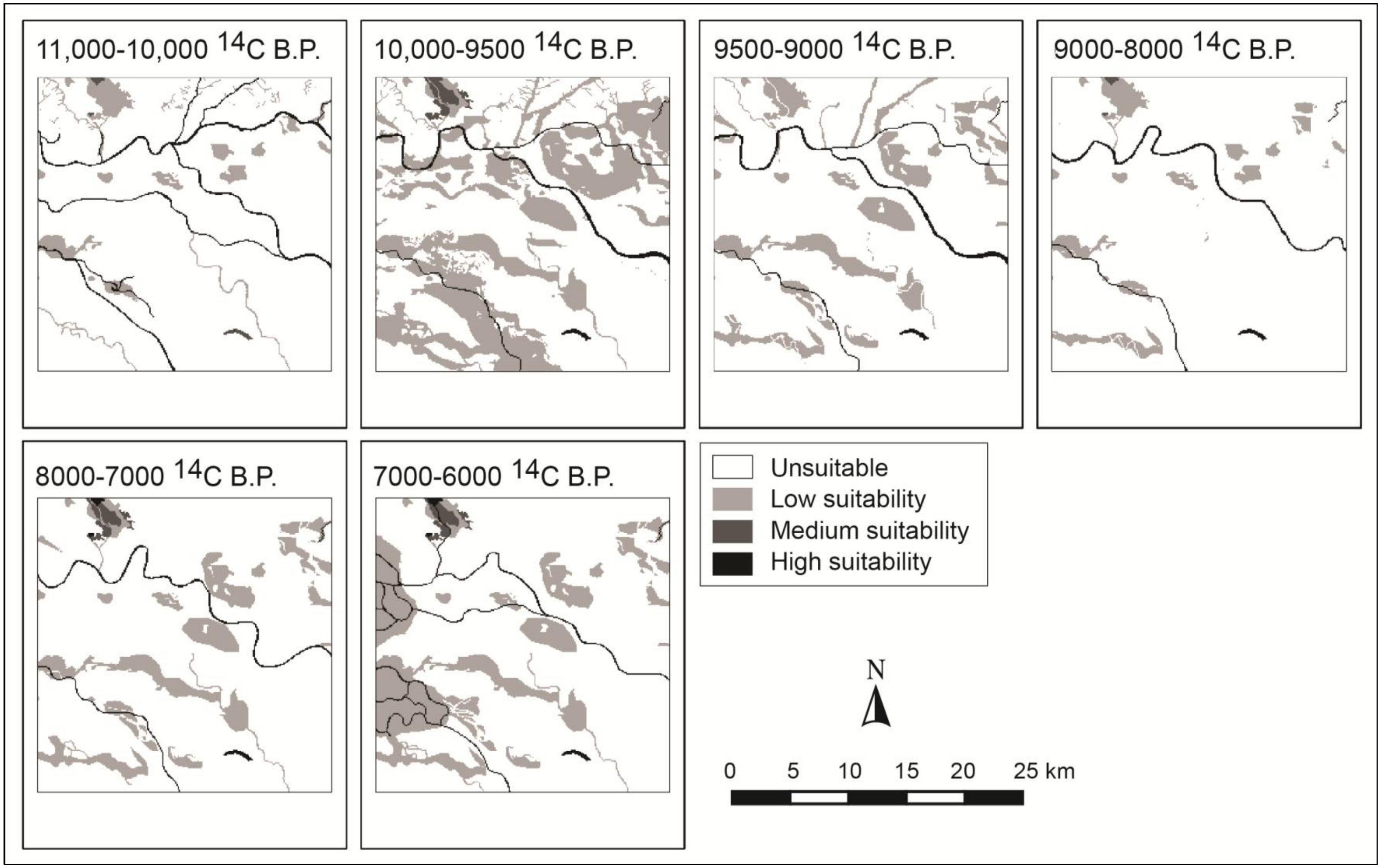

Figure D.15 Suitability Distribution for Freshwater Fish in the Deest Area.

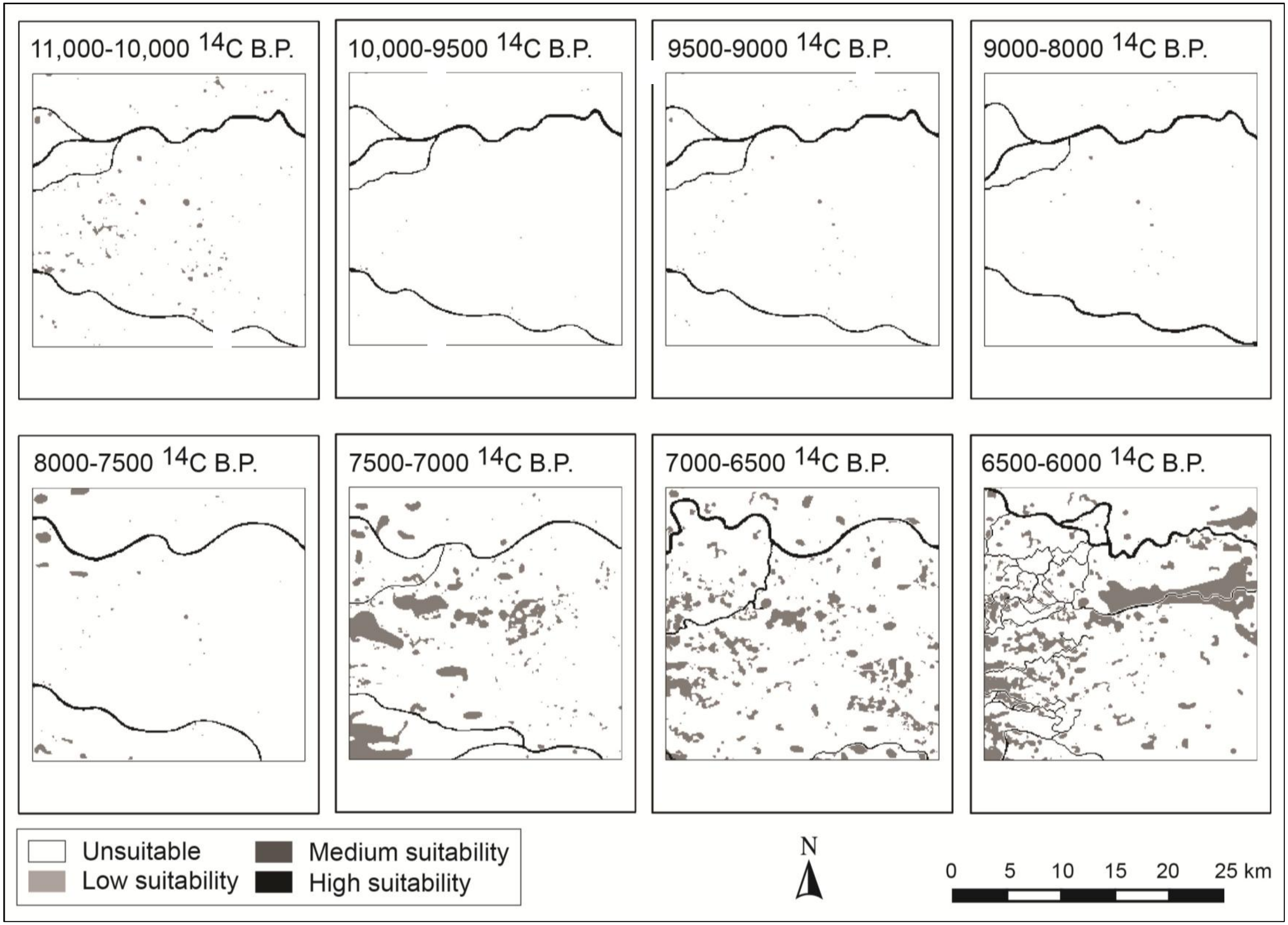

Figure D.16 Suitability Distribution for Anadromous Fish in the Deest Area.

D.3 Ooijerhoek Area

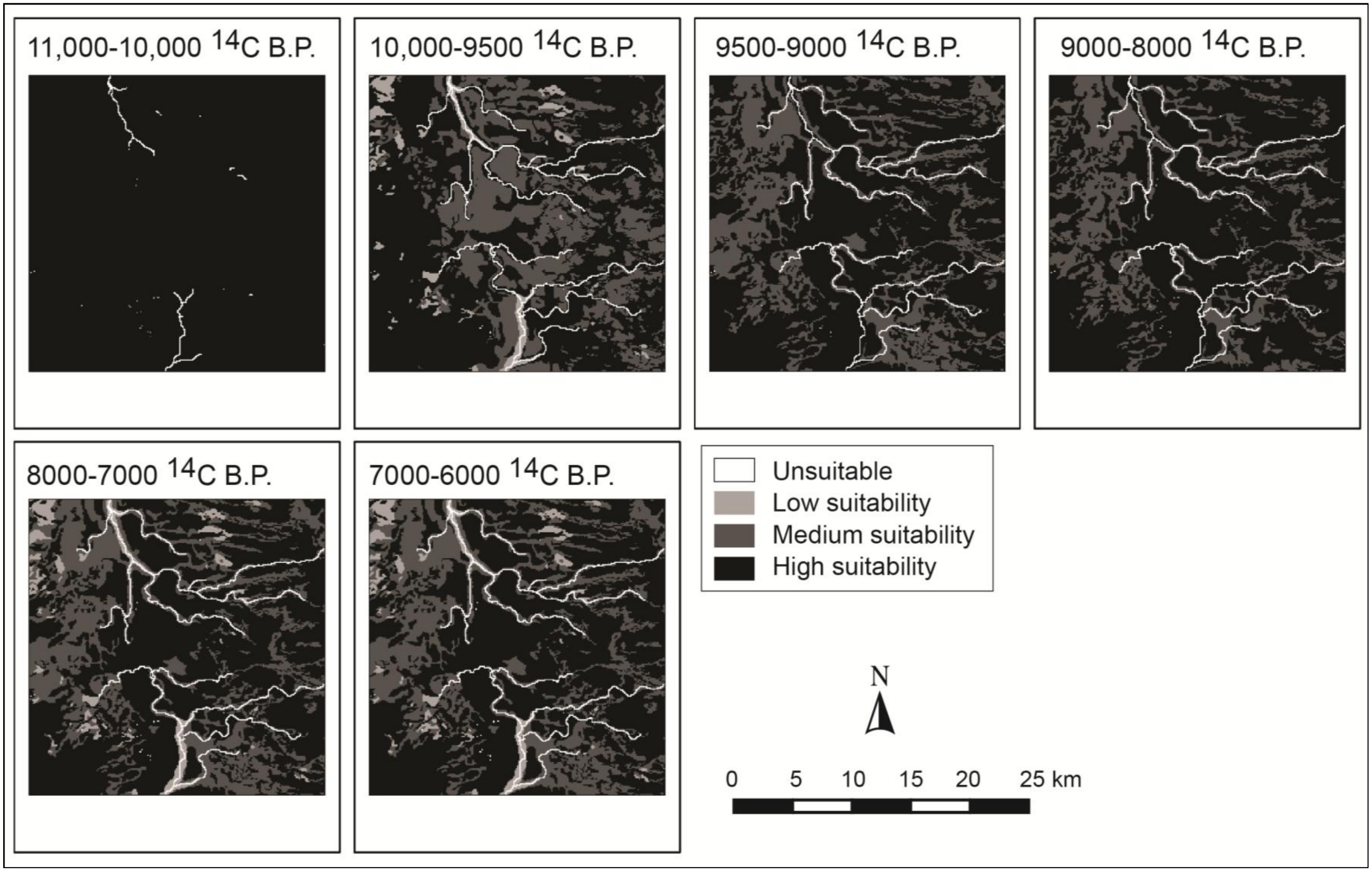

Figure D.17 Suitability Distribution for Large Game Species in the Ooijerhoek Area (i.e., red deer, roe deer, aurochs).

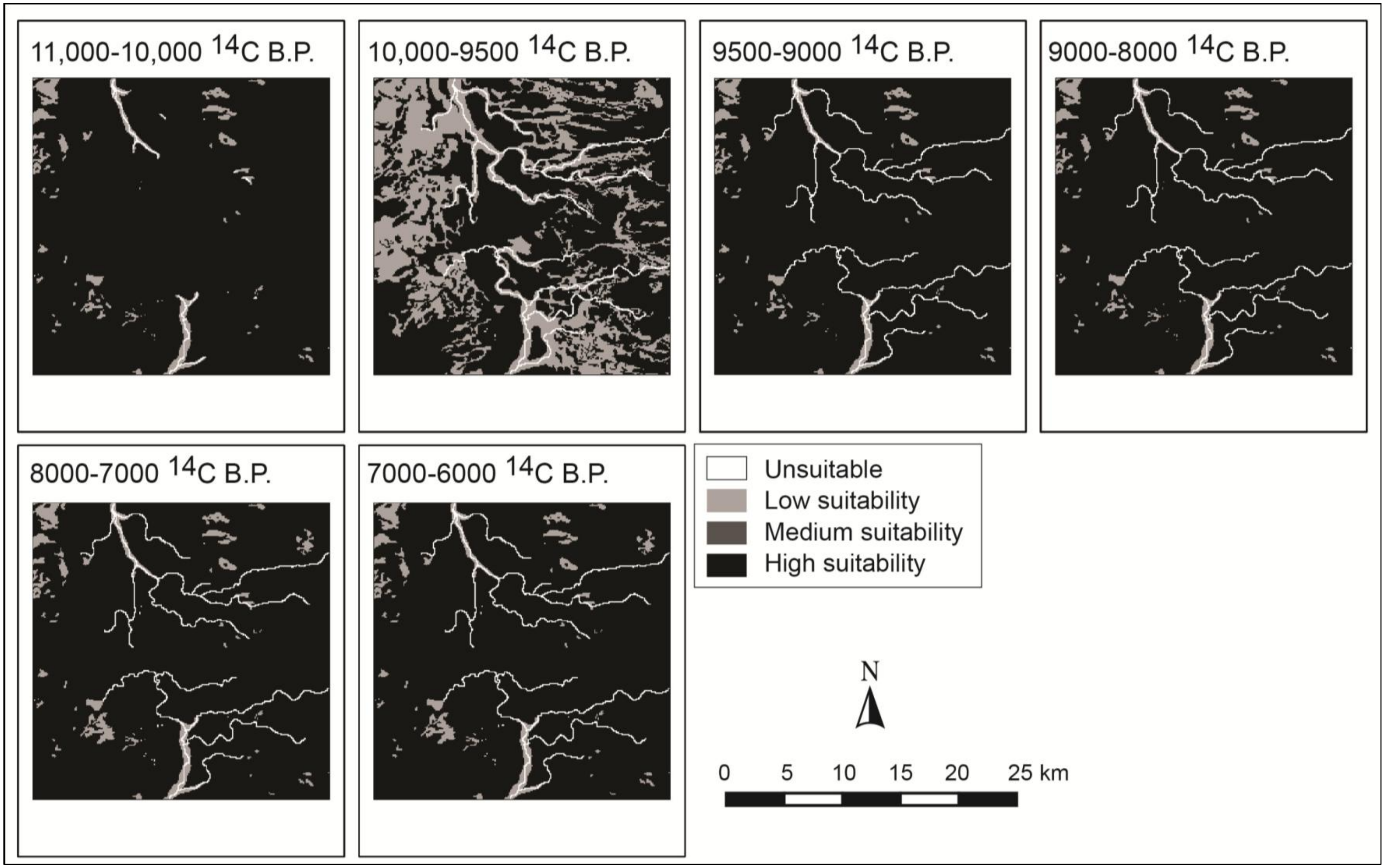

Figure D.18 Suitability Distribution for Wild Boar in the Ooijerhoek Area.

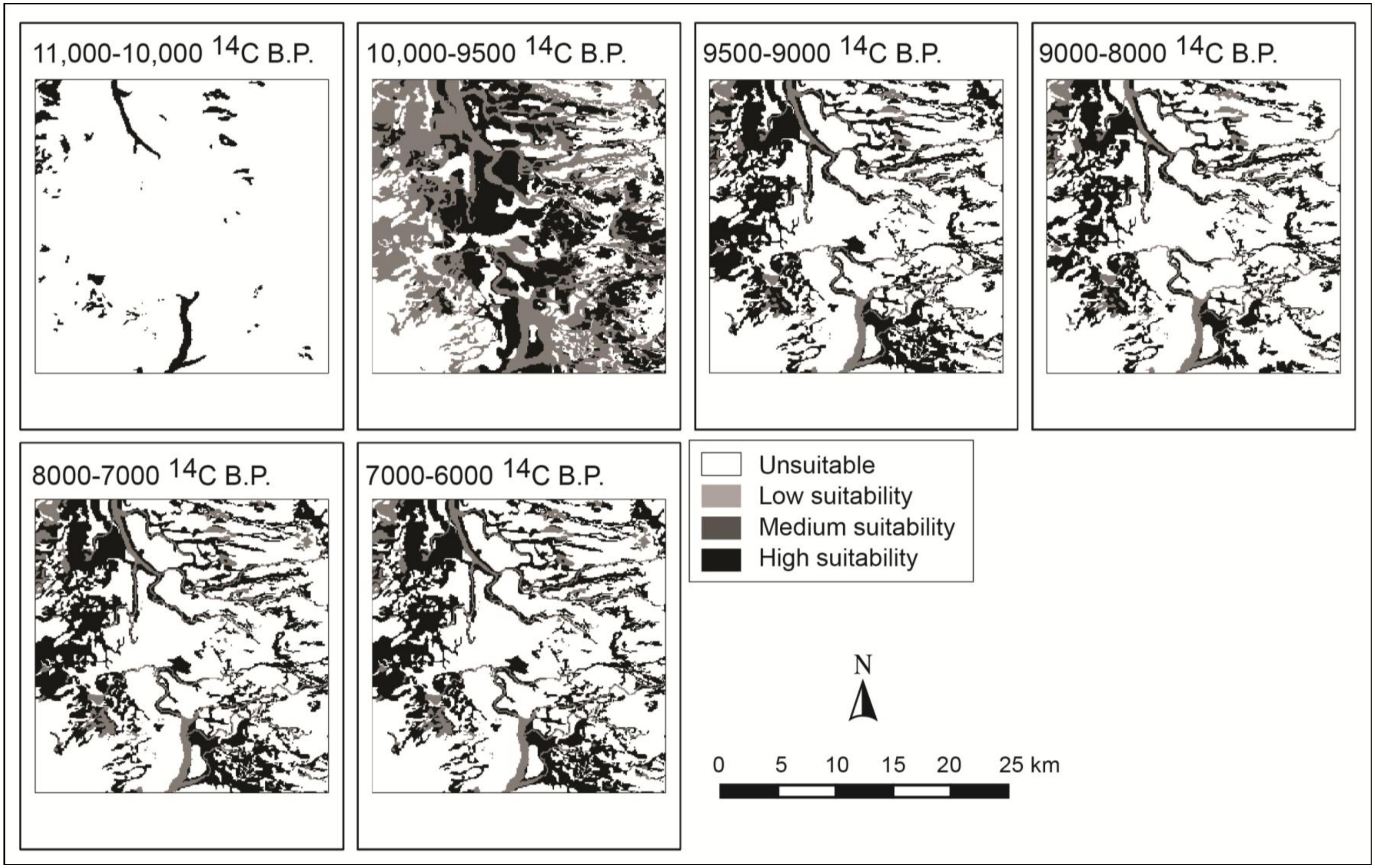

Figure D.19 Suitability Distribution for Beaver in the Ooijerhoek Area.

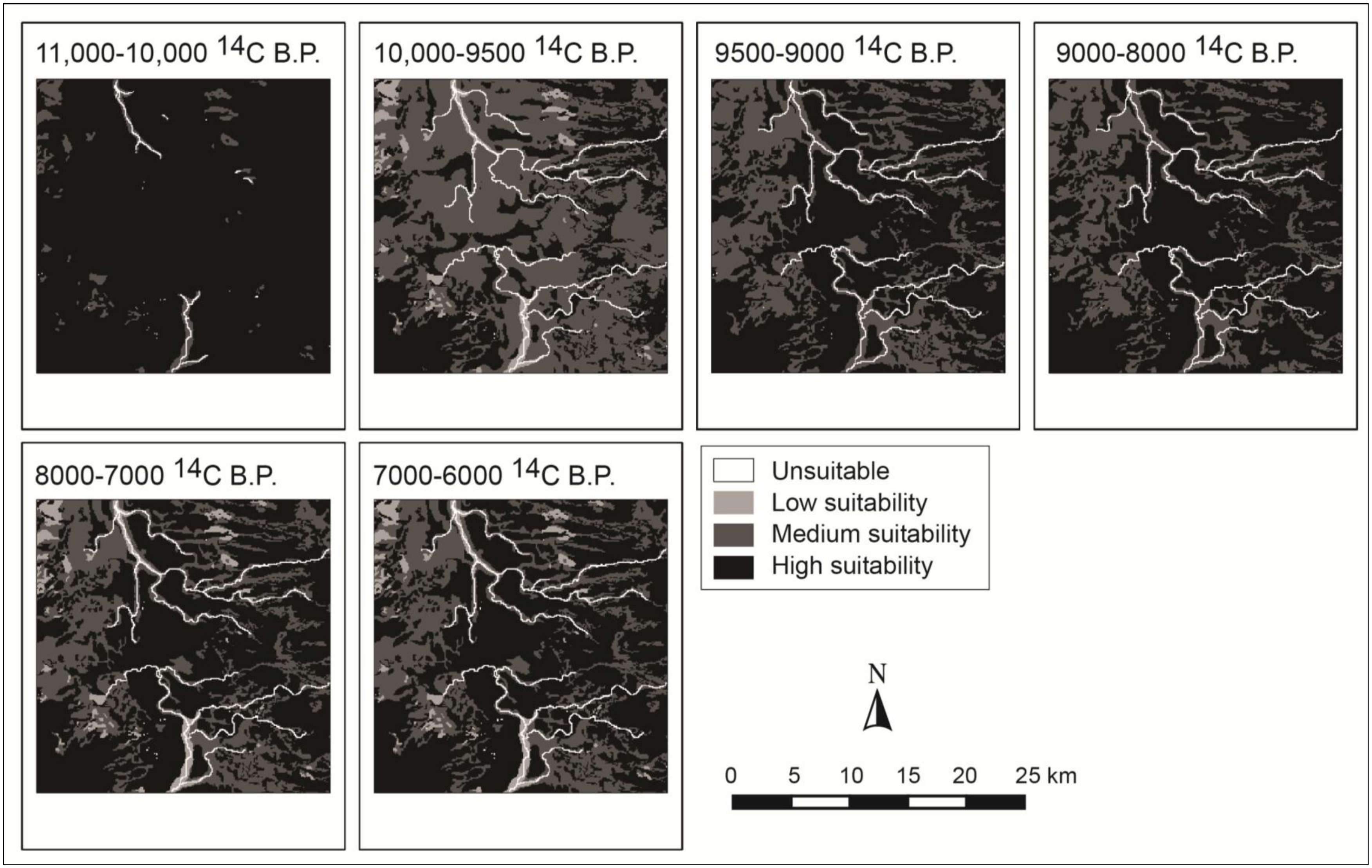

Figure D.20 Suitability Distribution for Small Terrestrial Mammals in the Ooijerhoek Area.

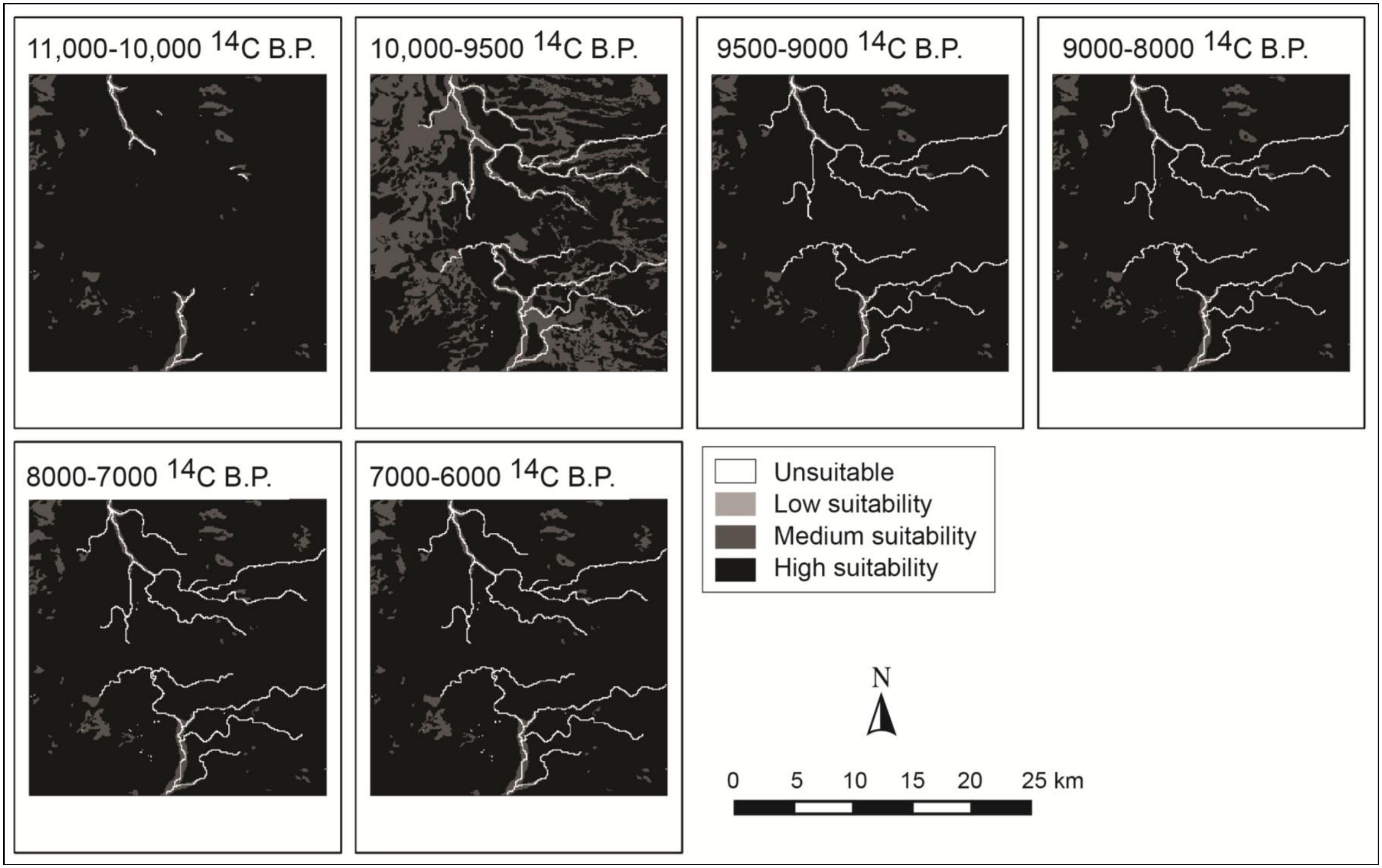

Figure D.21 Suitability Distribution for Terrestrial Birds in the Ooijerhoek Area.

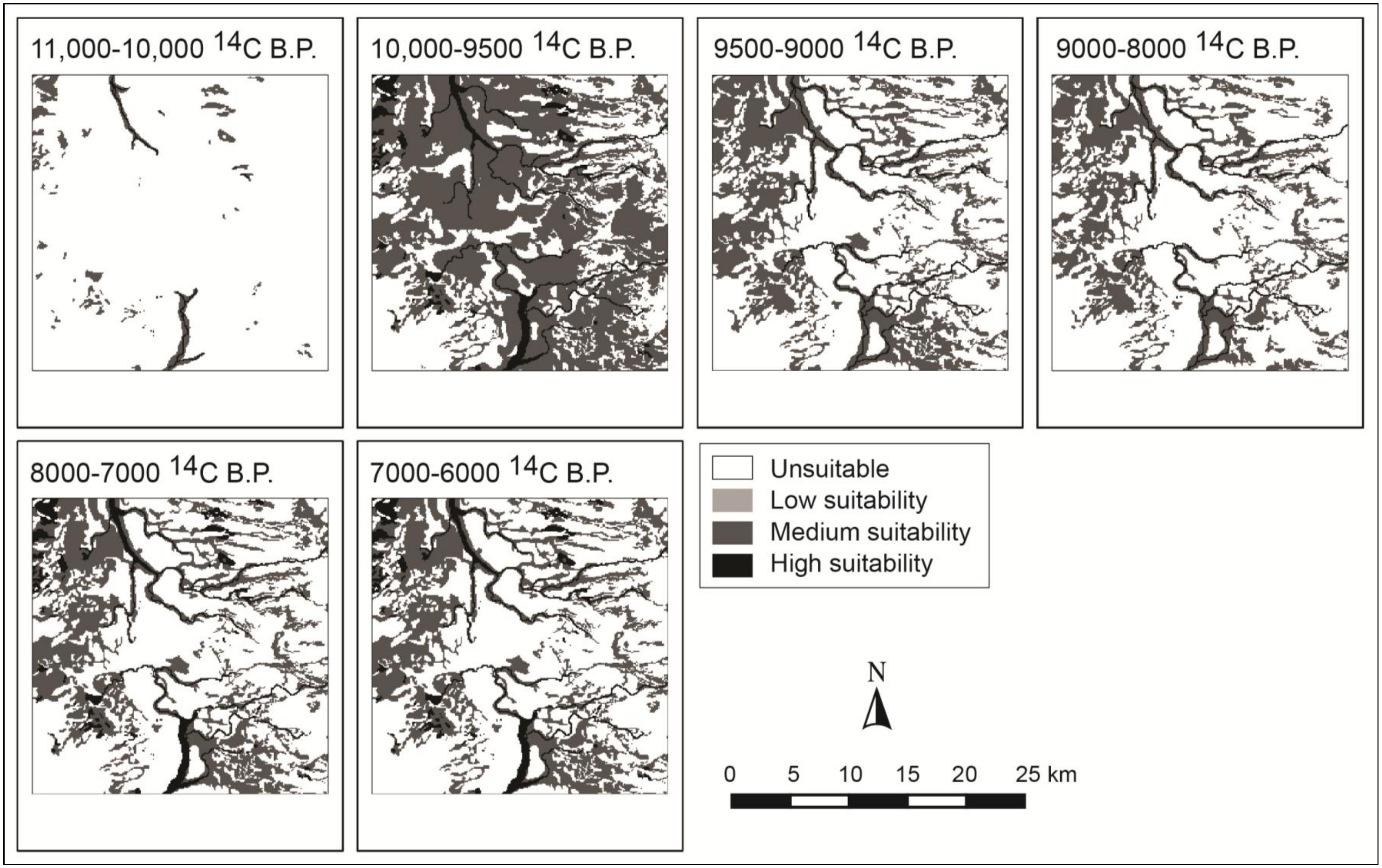

Figure D.22 Suitability Distribution for Aquatic Birds in the Ooijerhoek Area.

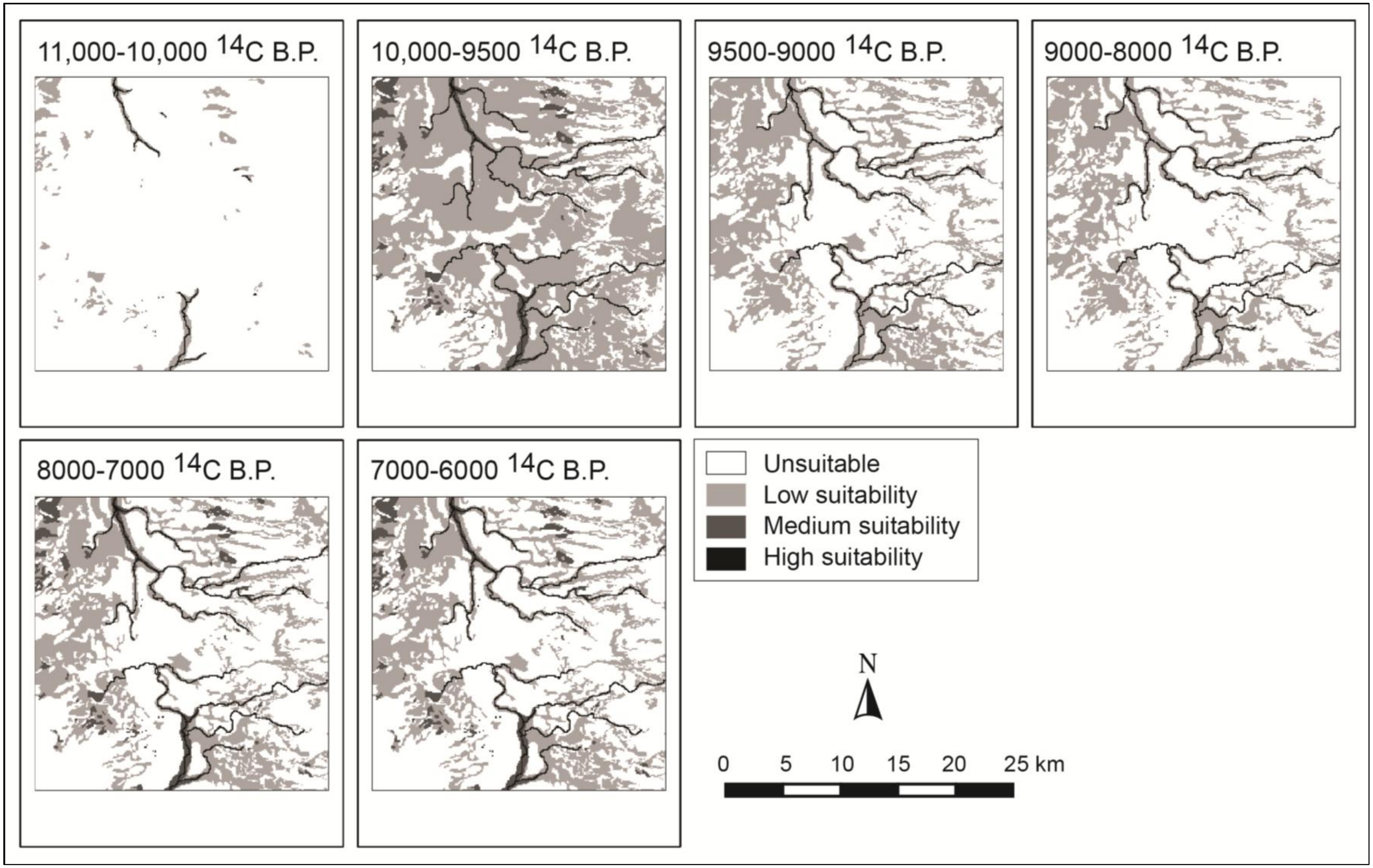

Figure D.23 Suitability Distribution for Freshwater Fish in the Ooijerhoek Area.

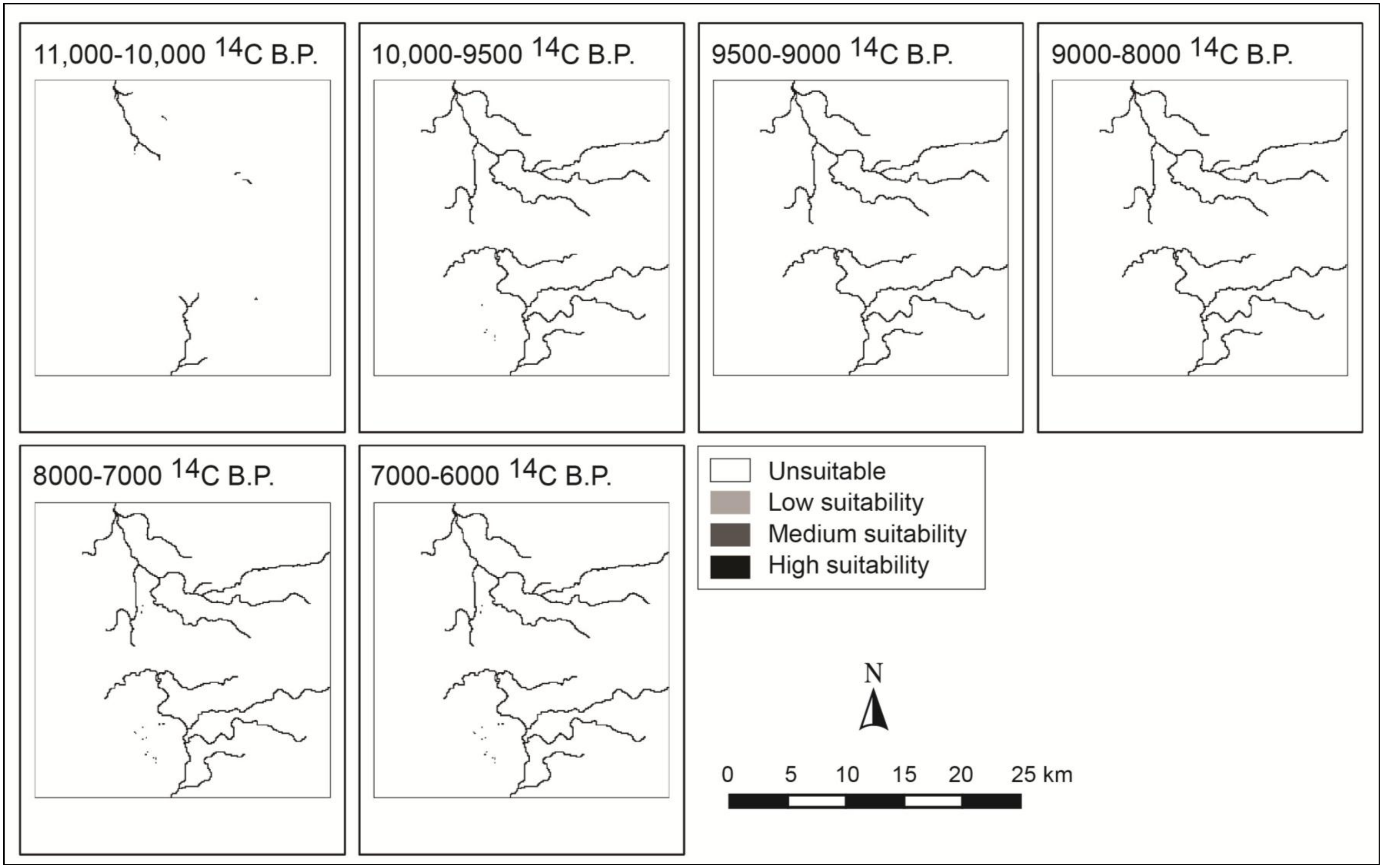

Figure D.24 Suitability Distribution for Anadromous Fish in the Ooijerhoek Area.

Appendix E

DECISION-MODELING COMPONENTS

In the following appendix, the decision-modeling components for resource use models Large Game, General Foraging, and Wetlands are presented. These sections are intended as supplemental material to the information already provided in Chapter 6.

E.1 Model Large Game

E.1.1 Decision-Making Rule. The decision-making rule followed by a hunter-gatherer group would have provided a strategy for meeting resource usage objectives (Eastman 1999). Thus, it is assumed here that a Mesolithic hunter-gatherer group wishing to avoid starvation by attaining the minimum amount of resources necessary for survival would have chosen to focus on large game as the ideal way to meet their resource requirements. Such a hunting strategy would have entailed demands of increased residential mobility. Some examples of resource acquisition statements that may have underlined such decision-making are (taking the form of Whitley's (2000) 'site placement grammar':

- Availability of large game is beneficial for subsistence
- Edge zones of habitats are beneficial for intercepting prey
- Presence of dense forests is costly for visibility, movement, and tracking of prey
- Availability of food resources other than large game is costly for subsistence
- Large tracts of wetlands are costly for large game-focused subsistence
- Clusters of large game are beneficial for subsistence and population aggregation

These statements helped to inform the decision-making rule, which was then used to guide the selection and ranking of the following criteria.

E.1.2 Criteria. The attainment of food and non-food resources was directly affected by the distribution, abundance, and accessibility of these items. When making decisions about food resource acquisition, the most important criteria for Mesolithic hunter-gatherers was knowledge of the current spatial distribution of flora and fauna. It is assumed in this model that information about such distributions was *complete* (rather than *perfect*), meaning that hunter-gatherers had sufficient species knowledge to allow them to predict with good certainty the location and richness of a particular species (Kelly 1995:98). Therefore, it is assumed in this model that the hunter-gatherers would have known approximate how suitable each vegetation zone in their habitat was for certain species. Under Model Large Game, floral food resources will not be considered, as this hypothesis holds that floral contributed only minimally to hunter-gatherer diets.

Although this hypothesis holds that residential mobility was high, this does not preclude that only residential sites were formed. Logistical sites were also an important type of settlement for procuring resources and may have been located at some distance from residential sites, or where resource availability competed in time or space. For this reason, both types of sites will be considered in the Model, as potential locations of resource acquisition. Further, while large game was certainly the focus, it is probable that other types of game were taken at times of the year when deer, boar, and aurochs populations were scattered or depleted. The other species thus considered are beaver and small terrestrial mammals. Also, attainment of non-food resources must also be worked into the model. However, since most non-food resources are also main considerations of settlement placement and patterning, the effect of these criteria on decision-making will be tackled in the following Model segment (see below). Thus, the goal of Model Large Game is to generate a set of cartographic maps depicting areas most able to satisfy Mesolithic hunter-gatherer resource acquisition objectives at both residential and logistical sites. At residential sites, it is assumed that all of the modeled resources contributed to the subsistence goals. At logistical sites, only a single species was the focus of resource acquisition and thus, the ability for each species' to satisfy subsistence needs was considered and then ranked.

For the strategy of residential resource use, three objectives were identified with varying importance regarding their impact on decision-making (see Chapter 6, section 6.4.1.1). For each of these objectives, importance ratings were generated for the six faunal criteria (Appendix F: Tables F.3-F.5). For the objective of attaining minimum resources, faunal ratings were based on the size and/or potential food and non-food yield of the animal (Appendix F: Table F.3). Prey size and yield tend to be positively correlated (Jochim 1998), such that larger animals are assumed to produce both more edible and raw material products. Red deer are larger and more aggressive than roe deer and wild boar, thereby yielding greater resource potential. Both red deer and wild boar outcompete roe deer for food and cover areas, implying that roe deer densities were probably lower than their counterparts. Roe deer also produce smaller antlers, which detracts from their non-food resource potential. Beaver carcasses are nearly as big as roe deer carcasses (minus the lower extremities) and have important non-food uses (e.g., waterproof pelts, claws, and long, curved incisors; Coles 2006). Aurochs was probably hunted opportunistically rather than being as real dietary staple, perhaps due to their large territories (making them few and far between), or their large body size (requiring multiple hunters, processors, and individuals for transport).

Small terrestrial mammals (STMs) would have been the least important resource, although they likely satisfied a 'survival' or fallback food, in the event of shortages in other large prey species. It is also important to note that many hunter-gatherers from the ethnographic sample rank prey by the fattiness of the meat, because meat with more fat tastes better (Kelly 1995:105). The amount of fat on an animal varies throughout the year, and it is assumed that animals would be avoided during lean periods of the year. STMs were probably not preferred resources, as they yielded proportionally smaller quantities of fat. This has been documented among the Hare of the Canadian subarctic, who are forced to rely on rabbit during periods of larger and fatter prey scarcity (Savishinsky 1974:25). While such considerations imply that lean prey such as red and roe deer would not have been favored, it is assumed for this modeling exercise that they were taken mainly during periods of higher body fat.

For the criteria of risk minimization, different rankings were generated for the six faunal criteria (Appendix F: Table F.4). Red deer, roe deer, and wild boar were all considered to be important in terms of mitigating risk. Each was relatively stable and predictable, and acted to balance each other out. Wild boar is especially susceptible to human management, by way of scheduled feeding at specific places in the forest (Peeters pers. comm.). Thus, when red deer populations were high in the Early Holocene, roe deer populations were somewhat decreased. Conversely, wild boar populations benefitted when red and roe deer populations decreased in the Middle Holocene. Red deer remains are the most common in the archaeological record, and may have been the most important resource for risk minimization due to their high yield in food and non-food resources. They are also relatively predictable, favoring edge zones (which may have been managed by Mesolithic hunter-gatherers; however, red deer have larger territories, with an average of only 4-8 deer/km^2 (Jochim 1976:102). Roe deer are similarly predictable but yield smaller quantities of food and non-food resources. Modern populations average around 12 deer/km^2. Wild boar was probably somewhat more stable because of their ability to eat a wide variety of foodstuffs and adapt to different environments. Modern populations of wild boar also average around 12 animals/km^2. However, wild boar are known to be confrontational and likely posed more risk of bodily harm to hunters than deer (Anonymous 1976). For this reason, wild boar was ranked as moderately less important than red or roe deer.

Aurochs could also impart bodily harm due to their large size. This fact, along with the supposition that these large animals likely had larger requisite territories, suggests that aurochs may also have been dispersed relatively thinly on the landscape, although they did seem to live in small groups. While a single aurochs kill would go far towards staving off the risk of starvation and would have provided an abundance of raw materials for tools and structural materials, the risk involved in bringing down an aurochs led to a ranking of the aurochs being strongly less important in risk minimization. However, as will be discussed below, taking such a large and potentially dangerous animal could also bestow status on an individual. Beaver is considered a relatively stable species, being early colonizers and making suitable habitats for themselves if none exist (Coles 2006). They are generally quite predictable in their preferred habitats, their territories ranging about 0.5 km along streams and rivers. Thus, beavers were ranked as somewhat less reliable than red deer or roe deer simply because of their small population size, although they were definitely more reliable than the aurochs or small terrestrial mammals (STMs). The latter category was considered to be relatively predictable, although their small body size would have made them only a supplementary source of food. As discussed above, STMs would have served as poor starvation resources during periods of larger prey shortages. Further, STM populations often experience population fluctuations and yield little in the way of food and non-food resources (Jenster and Leeuwenberg 1992; Kelly 1995:105) making them strongly less important to the objective of minimizing subsistence risk.

For the criteria of population aggregation, more rankings were generated for the faunal species (Appendix F: Table F.5). Red deer, roe deer, and wild boar are all known to aggregate into relatively large groups for the breeding season. As red deer are largest in body size, they are ranked strongly more important, while roe deer and wild boar are ranked moderately more important for population aggregation purposes. The presence of aurochs clustering may also have been an important decision-making factor guiding population aggregation, especially given the large yields of group aurochs hunts. However, the low number of aurochs bones found throughout Europe suggests that the population was sufficiently low to preclude frequent group hunting of this species. Beaver, although high in fat and non-food content, are ranked as very strongly less important in guiding population aggregation, most notably because beaver do not aggregate at certain times of year, nor could a group of 25 hunter-gatherers or more survive on a family of beaver for an extended period. The same logic is used to assign STMs an extremely less important role in motivating population aggregation, as body sizes are even smaller and less fatty than beaver.

Principle eigenvector values were evaluated for each table (see Appendix F), multiplied by the standardized range for each species (on a 0-10 scale), and then these surfaces were added to obtain spatial raster depictions of the most suitable locations within the study areas for each particular species.

For the strategy of logistical resource acquisition, the objectives and criteria remain the same as with residential resource acquisition; however, population aggregation is not considered as logistical movement specifically entails a small number of people with the explicit intent of procuring a resource. Furthermore, because logistical resource acquisition generally targets a single resource (and recognizing that opportunistic encounters of other resources also occur), the modeling was carried out for three sub-scenarios: one in which red deer were targeted, one in which aurochs were targeted, and one in which other resources were targeted (see evaluation section below).

The species weights generated above in Tables F.4 and F.5 (Appendix F) were translated into percent rankings because each objective had a single criterion, which needed to be consistent with the format of the previous comparison matrices. This rank represents how well each resource satisfies the objectives of this strategy. The percent rankings were undertaken using a conversion table, in which the highest and lowest importance weights were set at 0 and 100%, with nine rankings in between (Appendix F: Table F.6).

With this conversion table, species could be ranked based on how well each satisfied the objectives of attaining a minimum amount of resources (both food and non-food; Appendix F: Table F.7), as well as minimizing risk (Appendix F: Table F.8). These importance rankings were then used to adjust the weight of the suitability values produced in Chapter 4, where the original faunal suitability maps were generated.

E.1.3 Evaluation. A weighted linear combination, multi-criterion model was used to combine the criteria weights and importance rankings developed above for both residential and logistical resource acquisition. The suitability maps for each species' were weighted according to the pairwise matrices. For each area and time period, the weighted maps were overlaid. This meant that every cell within the study areas contained multiple values representing the suitability of satisfying the objective with any of the given species. These values were then added, the result of which represents the suitability of all cells in terms of satisfying the objective. Some cells are thus much more likely to satisfy the objective than others, and these are the areas most likely to contain the material correlates of residential or logistical resource acquisition.

When a suitability map for each objective was generated, another weighted overlay was run, this time based on the comparison matrices for the objectives. The resulting cartographic maps depict the suitability of each study area for Mesolithic hunter-gatherer residential resource acquisition, based on how well the available resources satisfy the initial objectives. The areas with the highest suitability values represent locations likely to successfully satisfy all of the objectives, while areas of lower suitability represent locations that failed to successfully satisfy one or more objectives.

To investigate the suitability of the study areas for logistical resource acquisition within Model Large Game, another weighted linear combination was undertaken, this time taking into consideration the fact that only two main objectives were of interest (see Appendix F, Table F.2; Appendix G, Figure G.1). Here, the suitability of individual species was considered in terms of how well they satisfied the initial objectives. A search was made in which the highest individual suitability value was depicted for each cell, thereby identifying which resource was most likely to satisfy the objectives at any given location. A minimum threshold value was set, such that only areas with very high species suitability were identified. This map can also be used to identify which areas had the least risk associated with resource acquisition, as the areas most likely to have species in them are not very risky, and vice versa. It is assumed that the areas with high resource suitability were probably targeted by hunter-gatherers on either logistical forays or when following prey with a residential mobility pattern.

E.2 Model General Foraging

E.2.1 Decision-Making Rule. The generalized foraging adaptive strategy assumes that small hunter-gatherer groups would have covered their territories in a thorough manner through the use of frequent and short residential moves. While logistical mobility was undoubtedly undertaken, it was far less frequent. Boreal and temperate forest resources tend to occur in low-density patches, although the same general array of resources may be found scattered throughout a territory. Game within such forests live in small groups and move freely about the landscape. In more open grasslands and marshes, resources can be found in greater concentrations, depending on the season (e.g., warm growing season or cold dormant season). Moving between the forests, grasslands, and marshes would have provided a number of different types and abundances of resources to hunter-gatherers. The choice to follow a generalized foraging economy would have been risk reducing (such that resource depletion or shortages could be buffered through diet broadening), and would have been a profitable choice for foragers particularly when the environment was most heterogeneous (by the Boreal and into the Atlantic period).

Some of the resource acquisition statements that can be formulated to guide this decision-making rule are:

- Availability of a broad spectrum of resources is beneficial for subsistence and spreading risk
- Presence of homogeneous resource patches is beneficial for small group foraging
- Presence of heterogeneous resource patches is costly for small group foraging
- Presence of open areas is beneficial for subsistence

These statements were considered in the evaluation of the suitability of the criteria in terms of satisfying the overall objectives.

E.2.2 Criteria. The criteria likely considered by hunter-gatherers following a generalized foraging pattern are presented in Tables F.12-F.18 (Appendix F). Each criterion was ranked based on its overall ability to satisfy residential and logistical resource acquisition needs. The criteria considered here included the habitat projections for red deer, roe deer, wild boar, aurochs, beaver, terrestrial birds, water birds, freshwater fish, and anadromous fish. Further, the distribution of hazel and oak trees, nettle, arrowhead, European cranberrybush, and cattail were considered to be part of the plant component of the diet. These species were only modeled during their growing seasons, as were anadromous fish and migratory water birds modeled during their periods of seasonal abundance. Neither tool stone nor wood was considered a criterion for this modeling exercise, as it was assumed that hunter-gatherers using this highly mobile strategy would have encountered sufficient amounts of these non-food resources in the course of their yearly rounds. For logistical resource acquisition, percent rankings were generated, as only single criteria were considered (see above for discussion of percent rankings under Model Large Game).

For the objective of attaining a minimum amount of resources, no single species was given the highest weight, as it was assumed that throughout the course of the year, the productivity and thus importance rates would fluctuate. Instead, Jochim’s (1976) table depicting expected dietary importance of resources over the course of a year in the Southwest German Mesolithic was used as an approximation (Jochim 1976:108; Appendix F: Table F.11). This table was used to inform the weighting of the pairwise comparison matrix depicted in Table F.12 (Appendix F). Some additional considerations were made when filling in the matrix, such that beaver and birds were given more emphasis (from extremely less important to strongly less important than large game), as the central Netherlands during the Mesolithic period was far wetter than Southwestern Germany. Roe deer, too, was upgraded from extremely less to strongly less important, on account of the large number of roe deer remains from the archaeological record. Aurochs was considered to have been as important as wild boar in terms of attaining a minimum resource threshold. It is assumed that the short-term abundances of migratory birds and anadromous fish at certain times of year would even out with the year round presence of terrestrial birds and freshwater fish; thus, the fish subcategories were given the same weight, as were the bird subcategories.

For the objectives of maximizing efficiency (and thereby limiting energy and time expenditure), net return rates can be used to approximate the relative ease with which certain resources can be acquired. This is, unfortunately, a difficult task, and has been undertaken in the past by referencing modern resource populations in order to establish factors such as aggregation sizes, prey weights and usable calories, and mobility (Jochim 1976, 1998; Kelly 1995:81-82). Not only do individual resources vary in terms of their net yield, return rates also vary from season to season and from forager to forager (Kelly 1995:80). The type of technology and processing methods utilized also greatly affect net return rates. Furthermore, it is exceedingly difficult--if not impossible--to approximate foraging efficiency rates for prehistoric hunter-gatherers. Nevertheless, to provide a baseline from which more refined foraging models can be developed, this study uses generalized efficiency rankings derived from return rate calculations (kcal/hr) described by Kelly (1995:81-82). While some of these estimates are taken from ethnographic samples in environments very different from the Early Holocene of the Netherlands, these values can at least provide a baseline for evaluating the relative ranking of resources in terms of maximum efficiency. Unlike some previous attempts to approximate efficiency rankings for past foragers (e.g., Jochim 1976, Keene 1981), this study will focus instead on identifying general relationships between resource categories and the amount of time and energy required to procure them.

In general, large game (e.g., deer and moose) has very high return rates (e.g., 17,971-31,450 kcal/hr for Great Basin deer kills; average of 8,800 kcal/hr for Boreal forest moose kills). Similarly, Winterhalder (1981) found that large game have the highest return rates in a boreal forest environment. As large game also preferred edge zones and are generally quite efficient to procure (Jochim 1976), it is assumed here that these species would have been the most efficient in terms of residential resource procurement through much of the Holocene (Appendix F: Table F.13). Roe deer is the only large game species ranked moderately less important because of its smaller body size. Beaver, small mammals, and birds are considered to be somewhat less efficient to procure than large game, as they require additional pursuit time to amass the same amount of energy as a single large mammal. Beaver is useful not only for food, but also for non-food resources such as their pelts, incisors, claws, and tails (Coles 2006). However, Winterhalder (1981) reports that they return relatively low return rates depending on the season (e.g., 1,640-5,280 kcal/hr; it should be noted, however, that most animals have variable food value on a seasonal basis, which may also be altered by storage). Thus, beaver are scored as strongly less important than large game, although adult beavers approach roe deer in weight. Small game return rates from Boreal forest contexts also yield lower return rates (1,900 kcal/hr for hare, 1,125-1,850 kcal/hr for muskrat). These resources are scored as very strongly less important than large game.

For birding return rates, an average return rate of 1,975-2,709 kcal/hr was found for ducks in the Great Basin. In the Early Holocene of the Netherlands, bird populations would have fluctuated throughout the year, and thus birds were ranked as very strongly less important than large game in terms of maximizing efficiency. During periods of running or spawning, fish can be a highly efficient resource to procure (e.g., Storck 1997). Winterhalder (1981) reports that fishing with nets can yield return rates between 1,060 and 9,680 kcal/hr, with winter being the scarcest month for fish. Using nets to take minnows in the Great Basin returned rates between 750-7,514 kcal/hr. On average, then, nearly 4,274 kcal/hr can be obtained through fishing, making it strongly less important than large game. While acorns and hazelnuts required time consuming processing, their large numbers and calorie-rich content likely made them a worthwhile resource to procure in the fall. The roots of semi-aquatic plants like cattail and bulrush yield return rates between 128-267 kcal/hr, whereas berries from the European cranberrybush may have yielded as much as 250 kcal/hr (estimate for blueberries from Winterhalder 1981). Cattail can also be used for pollen extraction (2,750-9,360 kcal/hr), and bulrush for seed extraction (302-1,699 kcal/hr). Other leafy greens may have been taken, such as nettles, ferns; however return rates for these were probably as low as for cattail and bulrush. For this reason, plant resources are ranked as moderately less important than game, despite the fact that certain plant extraction practices can lead to greater return rates than game (e.g., during the fall when hazelnuts and acorns become ripe). Table F.13 (Appendix F) depicts rankings of the differing efficiency rates associated with different species. Species with the same rankings (e.g., red deer, wild boar, and aurochs) have been grouped to save space.

For the objective of minimizing risk, rankings generated for Model Large Game were used as a base (Appendix F: Table F.14). Similar reasoning was used to rank wild boar and aurochs as moderately and strongly more risky than red and roe deer. Beaver lodges are generally predictable and can be exploited year round, whereas small mammals are harder to find as they are generally quite dispersed over the landscape. Birds and fish were treated in composite groups, respectively. In general, neither birds nor fish are terribly risky resources. In fact, some species are highly predictable and reliable, such as migratory species or species that always gather in certain habitats at given times of the year to mate. Fish tend to be somewhat easier to procure and process (plucking feathers can potentially become very time consuming); therefore, fish were ranked as strongly less important than large game and birds were ranked as very strongly less important. Plants likely supplied a reliable and abundant source of food for Mesolithic hunter-gatherers. However, the fact that plants were only available during the summer months makes them very strongly less important than large game. Similarly, hazelnut collection and processing could supply a wealth of fats and protein, although this resource was only available in the fall, making it very strongly less important.

For the objective of population aggregation, rankings generated for Model Large Game were again used as a base (Appendix F: Table F.15). Red deer were given the highest rating, since they tend to cluster in the fall for the rut (see Appendix C), were relatively widespread, and return the largest net yields (notwithstanding aurochs). Mesolithic hunter-gatherers likely knew the approximate locations of previous ruts and would surely target them. Roe deer and wild boar are also known to gathering into groups, roe deer in the winter and wild boar in the late fall. The former species are given a moderately less important role to red deer. Aurochs, which are thought to have lived in small family groups (see Appendix C), necessitated a larger group of experienced hunters. However, aurochs do not appear to have been widely distributed throughout the region and are thought to have been relatively unpredictable in terms of habitat locations. Thus, aurochs are also scored as a moderately less important criteria driving population aggregation. Beaver and small mammals do not tend to congregate and thus are not considered as factors in population aggregation. The presence of migratory birds in the spring and fall could certainly have been a factor driving population aggregation, although the generally low yield and intensive labor of birds makes this resource strongly less important than red deer (although group aggregation can reduce processing time). Fish tend to spawn and run in the spring and summer, are highly efficient resources to procure (Storck 1997), and can also yield very high return rates (Winterhalder 1981). Fish processing also requires a good deal of infrastructure (construction and maintenance of fish weirs, nets, traps, drying racks, and storage containers or features), which would be facilitated by a larger and more variegated group of foragers (i.e., in age and sex). Thus, fish are scored as moderately less important than large game, along with roe deer and wild boar.

It is not likely that plant species availability motivated population aggregation to a great extent, with the exception of hazel nut production. During the fall months, Mesolithic hunter-gatherers likely gathered in stands of hazel, pooling their efforts and knowledge of the detailed processing procedure. As trees do not move around, the location of this resource would have been very predictable and reliable for the most part[25]. However, foragers would have had to compete with other animals, most notably wild boar, which are also known to target hazel stands in the fall months (see Appendix C). For humans, aggregating for the fall hazel crop may have been an important part of the seasonal found, perhaps undertaken just before, or in conjunction with, the fall rut. As such, hazel nuts will be considered in their own category, as strongly less important than red deer. No other plants are considered as direct motivators of population aggregation.

For the objective of taste, the fat content and/or sweetness of all resources was estimated (Jochim 1976). Beaver and aurochs were assumed to have the highest levels of fat, especially in the early winter months (Coles 2006). These species were assigned the highest rank (Appendix F: Table F.16). Similarly, red deer, roe deer, and wild boar would have been fattest going into the cold months, after a summer of grazing. These species were ranked as moderately less important to taste than aurochs or beaver. Small terrestrial mammals are notoriously low in fat and are often considered to be secondary or starvation resources by recent hunter-gatherer groups (Honigmann 1949:104; Jochim 1981:78-87; Savishinsky 1974:25; Speth and Spielmann 1983). Water birds tend to be quite fatty, their fat stores serving to keep them buoyant. These resources also would have tasted “good” to hunter-gatherers. Fish vary in fattiness, anadromous fish having higher fat contents than freshwater fish. For this reason, they are ranked as very strongly less important. Nuts and seeds would have provided fat, while berries, and fruits likely provided sweetness. Thus, plants likely served as the primary source of sweetness; they are scored as moderately less important to taste than large game. It bears mention that honey could periodically be found, probably embedded in residential or logistical moves. This resource served as the ultimate source of sweetness and hunter-gatherers are known to consume honey (e.g., !Kung San [Lee 1976, 1978; Sih 1972; Isaac 1990]; Hadza [Hawkes 1991; Woodburn 1968]; Ache [Hawkes 1982; Hill 1983; 1987]).

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[25] It should be noted, however, that most mast trees produce in cycles, and that periodically there are regional level troughs.

For the objective of achieving sufficient dietary variety, each criterion was initially given an equal weight. In doing this, suitability output maps are produced that show how many different resources may occur in any given location (Krist 2001:202). Further consideration revealed that complex and large mammalian species often provide a number of different food resources for hunter-gatherers to consume, such as marrow, internal organs, and stomach contents (Spiess 1979). Red deer and aurochs are scored the highest for variety, as they are large and their stomach contents were likely large enough to constitute a meal. Conversely, plants were scored strongly less important because in general, humans only use one part of the plant, such as the rhizome, leaves, or fruit (Appendix F: Table F.17).

For the final objective of prestige, large game was ranked the highest score due to the known reputation of meat and hunting among hunter-gatherer societies (see discussion above; Appendix F: Table F.18). All other resources were scored as very strongly less important, as obtaining such items does not typically involving prestige.

Areas most likely to have been used for logistical resource use we calculated using the same floral and faunal distributions for each objective other than dietary variety and population aggregation (Appendix F: Tables F.19-F.23). These rankings were then transformed into percent rankings, using Table F.6 (Appendix F).

E.2.3 Evaluation. In PCRaster, weighted surfaces were generated for each criteria ranking. Then, a multi-criteria evaluation (MCE) combination was run for each objective given its associated criteria. The resulting weighted surfaces were further combined with another MCE, resulting in a final spatial surface, depicting areas most likely to have been used by Mesolithic hunter-gatherers for residential and logistical resource use (see Chapter 7). The model flowchart resembled that for Model Large Game (Figure 6.1), although seven objectives were used to determine areas of probable residential resource use and five objectives were used to determine areas of probable logistical resource use areas.

E.3 Model Wetland Focus

E.3.1 Decision-Making Rules. Choosing to focus on seasonally abundant resources in wetlands, hunter-gatherers would have benefitted from aggregating into band-sized groups in order to efficiently extract these foodstuffs, any of which were high in fat content and therefore presumably quite desirable for their taste. By fusing into large groups risk was also minimized, as a large amount of potentially storable food could be put away for times of future resource need. Groups using this adaptive strategy would have moved their residential camps infrequently, and preferred to send out small task groups to exploit available resources in the hinterlands (i.e., at some distance away from the central living area). Residential mobility was thus low, with camp movement occurring perhaps only a few times per year. During the Early and Middle Holocene, population density is assumed to have remained relatively low and thus, larger distances could be moved in both the dimension of residential and logistical mobility. It would not, therefore, be unrealistic to image a group living along the coast in the winter, and moving perhaps 50-100 kilometers inland during the warmer months (in fact, the approximate distance between the Polderweg and De Bruin sites and the contemporary Atlantic coastline was about 75 kilometers). Longer-distance logistical forays were made in order to obtain resources unavailable in the wetlands or along the coasts (e.g., wood for lumber and canoes, large and small game, and tool stone material). Resource use statements that condition this decision-rule are:

- Availability of aquatic resources and migratory/water birds is beneficial for subsistence
- Large tracts of wetland are beneficial for subsistence and logistical forays
- Proximity to inland woods is beneficial for technological and structural goals
- Dry landforms within deltaic areas (e.g., barrier and river dunes, and levees) are beneficial for subsistence pursuits

E.3.2 Criteria. A number of food criteria were likely involved in the decision-making process of where to undertake residential and logistical resource use under the wetland focused strategy. These included large game, beaver, water birds, freshwater and anadromous fish, and plants. In addition, two non-food criteria was considered: the location of tool stone and wood. All stone within the Netherlands is non-native, and in the downstream wetland and coastal areas, all stone would have come from upstream locations, where river cobbles can be found, or from sources further afield (e.g., the Wommersom quartzite outcrops to the south or glacial till from moraines in the northeast. Below, each criterion is evaluated in terms of its relative ability to satisfy the previously discussed resource acquisition objectives. These criteria are compared in a series of pairwise comparison matrices for residential (Appendix F: Tables F.26-F.32) and logistical resource use (Appendix F: Tables F.33-F.37).

The most important objective of hunter-gatherers was to obtain a minimum amount of food and non-food resources (Appendix F: Table F.26). In the wetlands, it is assumed that aquatic species and water birds would have been targeted, due to their periodic abundances, low-risk nature, and general reliability. Thus, anadromous fish, freshwater fish, and water birds were given the highest rank. While freshwater fish do not contain fat levels as high as those of anadromous fish or water birds, they are available for longer portions of the year and are thus considered to balance out the drastic fluctuations in these other resources. Further, fishing in general is seen as a highly efficient activity, and would therefore have supplied hunter-gatherers with an easy way to obtain the minimum amount of resources. Large game, as high return-rate resources, may have been an important criterion; however, game prefer dryland contexts with sufficient edge zones for their habitat. Thus, wetlands were probably unlikely to contain dense game populations. However, the archaeological record reveals that game was brought back to some wetland site (Louwe Kooijmans 2001a, 2001b), so game was scored as strongly less important than fish or water birds. Beaver are also attractive food resources, since they have a high bodily fat content (Coles 2006), especially in the winter. However, beaver require some perennial dryland, in the form of levees or dunes, in order to build lodges and dams. Further, beaver are territorial and do not aggregate. Thus, while beaver was probably an important component of the diet, beaver kills had to be contained, lest all the beaver in one area was killed off. For this reason, beaver is also scored as strongly less important. Terrestrial birds and small mammals would also have been present in wetlands in small densities, and may have provided a set of fallback resources. They are thus scored as very strongly less important. A variety of plants would also have been available in wetlands. A number of semi-aquatic plants are edible to humans (e.g., cattail, bulrush, arrowroot, water lily), and some can return very high yields (see below). Other shrubs and wetland trees produce food resources for human consumption, such as the European cranberrybush and hazel tree. At certain times of the year, production of berries, nuts, and fruit can yield large gains. Thus, plants were scored as moderately less important than fish and water birds. The last criterion to consider is tool stone, which would have been very scarce in the wetland. The majority of stone for implements and other purposes must have been acquired from elsewhere and brought to wetland. Furthermore, most fish and water birds could be captured using tools made of organic materials (e.g., nets and baskets made from reed and sedge, weirs and traps made from bent saplings, etc.). Tool stone would have mainly been important for logistical forays targeting large game, and it is quite possible that the gathering of raw stone material was embedded in such forays. For this reason, tool stone was ranked as very strongly less important to obtaining the minimum amount of resources. The availability of wood was also probably an important criterion in wetlands, as woodlands are usually distributed in a patchy manner. Many types of tools are made of wood, which is also necessary for shelter material and firewood. While wood could be gathered on logistical forays, it was likely somewhat of a concern for residential resource use. However, other resources like sedge, reed, bone, and peat can also perform some of these objectives. For this reason, the availability of wood is considered as strongly less important.

As was in Model General Foraging, net return rates were used to approximate the efficiency with which certain resources could be acquired (see discussion above for caveats and drawbacks of this method). It is assumed here that fish (both freshwater and anadromous) were the most efficient resource to procure (Storck 1997), requiring some invested energy up front to install nets and weirs (Appendix F: Table F.27). After these implements are set, however, little further time or energy is required, other than to collect the catch and clean the fish. An average of 4,274 kcal/hr can be obtained in fishing pursuits. Further, wetlands provided ample fish habitat. Water birds would also have been regularly available in wetlands. Generally, birding yields slightly lower return rates, and thus, birds are scored as moderately less important than fish. A number of plant species would also have been available, especially in the wetlands. Species like cattail and bulrush could be utilized for their pollen, seeds, and rhizomes, yielding high return rates in certain seasons. However, because of the seasonal variation in plant abundance, plants will be considered moderately less important than fish or water birds. Beaver, too, would have been an important food and non-food resource, especially in the winter, when body fat content was highest. Beavers tend to be easy to find (one has only to look for a dam and nearby lodge), although depending on the season, will return very different rates. Thus, beaver is scored as strongly less important than fish.

While large game generally yield high return rates (Kelly 1995:81-82; Winterhalder 1981), population densities would have been low in wetlands. Hunter-gatherers would thus have had to spend more time and energy tracking the kills and bringing them back to camp. For this reason, large game were scored as strongly less efficient. Terrestrial birds and small mammals may also have been taken from time to time, although their populations would have been low, making them very strongly less important toward achieving the objective of maximizing efficiency. The availability of tool stone was likely a consideration for hunter-gatherers wishing to maximize their efficiency, as stone tools (especially geometric microliths) are generally more lethal to prey than arrows made by sharpening sapling ends. This means that prey shot with stone tool tipped arrows would bring down prey more quickly and require less tracking. However, many resources could have been as efficiently procured with implements made of organic materials. For this reason, tool stone is scored as strongly less important than the criteria of fish, water birds, and plants. Sufficient wood would also have improved efficiency, as many different implements for catching prey were constructed of this raw material. Further, the availability of wood for canoes would have greatly increased traveling costs, as longer-distances could be covered by more people over a shorter period of time. Thus, wood was scored as moderately less important.

Rankings for the objective of risk minimization were based on those developed for Model Large Game and Model General Foraging (Appendix F: Table F.28). As with the objective of maximizing efficiency, fish were scored as the highest-ranking resource to satisfy risk minimization, as fish are ubiquitous in wet environments. The bountiful seasonal abundances of spawning fish would have been known by hunter-gatherer groups, and likely parts of the seasonal round were dedicated to fish exploitation. Water birds would also have been available year round, with dense aggregations occurring at predictable times of year. Thus, birds were also scored as a highly risk minimizing resource. Terrestrial birds and small mammals, by contrast, would have been dispersed in low numbers throughout wetlands, making them very strongly less important. In fact, these species are often considered as starvation species. Targeting large game involves some inherent risk, not only to the individual hunter (as in the case of confrontational wild boar or large-bodied aurochs), but also because game species common in the Holocene tend to be dispersed throughout the landscape. Especially in the wetlands, large game were likely not common, making this resource strongly less important in risk minimization than fish. Beavers were probably evenly distributed throughout the wetlands; however, they do not constitute a resource that can be intensively targeted due to their low numbers. Thus, beavers are scored as very strongly less important to risk minimization. Plants would have served as important secondary resources to fish and water birds, especially in wetland contexts. However, since plants were only available during the warm half of the year, they are scored as strongly less important. Stone tools likely served to streamline many different processing techniques, such as cutting and skinning of prey, as well as the production of items necessary for human survival (e.g., clothing, tent components, and wooden and bone implements). However, many of these activities could still be undertaken with organic implements, leading to a tool stone score of strongly less important in risk minimization. The availability of wood would also help to prevent risk, in terms of providing sufficient raw material for tools and implements, structures, and firewood. Wood is thus scored as moderately less important.

For the objective of population aggregation, it was assumed that the clustering of aquatic, water bird, and plant resources during the summer months would have been a major driver guiding the location of residential and logistical resource acquisition events (Appendix F: Table F.29). At these times, abundant resources would have drawn hunter-gatherers from far and wide, with the additional opportunity to reify economic, social, and ritual bonds, as well as exchange information, marriage partners, and other items. Fish and water birds are thus given the highest rankings in terms of their ability to satisfy the objective of population aggregation. Plants are scored are moderately less important simply because of their lower overall return rates. As a species, beaver do not aggregate and would have been a very strongly less important motivation for population aggregation. Large game do aggregate at certain times of year, although they tend to do so in dry areas, usually at the end of the warmer months. Further, large game numbers were never very dense in wetlands, making this resource very strongly less important in terms of motivating population aggregation. The same reasoning can be applied to terrestrial birds and small mammal, and they are also scored as very strongly less important. Tool stone was scarce in wetlands, making this criterion extremely less important. In fact, hunter-gatherers were likely forced to leave the wetlands altogether to find tool stone. The same reasoning applies to the criterion of wood, which was very scarce and most likely did not influence decisions regarding where to aggregate the population. These last two criteria were scored as extremely less important.

The objective of prestige was not ranked highly for hunter-gatherers focusing on wetland resources. This is primarily based on ethnographic accounts that demonstrate the high prestige value of hunting and meat (see discussion above). Therefore, large game would be ranked the highest of all resources, although this resource was very patchily distributed throughout wetland. Despite this fact, large game was still scored the highest in terms of satisfying the objective of prestige (Appendix F: Table F.30). It may be that logistical forays to the hinterland were undertaken with the primary goal of gaining prestige through the acquisition of a large game kill, which are high in both dietary variety and taste (see below). Proficient fisherman and birders may also have gained some prestige through prowess in these pursuits. However, because fish and birds are not considered as prestigious as large game, they received a score of strongly less important. Also, the possession of exotic tool stone (e.g., Wommersom quartzite) may have conferred some prestige on its owner, undoubtedly related to the long distances required to obtain such material, as well as the political skills and negotiating power involved in the material transaction. Thus, tool stone was ranked as strongly less important than large game. All other resources were considered to be extremely less important.

Dietary variety was ranked as a moderately important objective to hunter-gatherers targeting wetland resources. As in Model General Foraging, each criterion was given an equal weight to represent the variety of available dietary components (Appendix F: Table F.31). Since large game were scarce in wetlands, no provision was made to give this resource more weight due to their range of usable body parts. Despite the large number of plants in wetlands, they were scored slightly lower (moderately less important) because of their availability only during the warmer months. Tool stone and wood were not considered in relation to this objective.

For the objective of obtaining sufficiently tasty foods, weights generated in Model General Foraging were used as a base, in which fat content and sweetness were used as estimates. Beaver, anadromous fish, and water birds were considered the most likely to satisfy this objective, based on their high fat contents (Appendix F: Table F.32). Plants would have supplied the only source of sweetness in diet and thus, plants are ranked moderately less important. Large game species like aurochs, wild boar, and red and roe deer would also have provided good taste; however, their low numbers in wetlands make them strongly less likely to satisfy this objective. Terrestrial birds, small mammals, and freshwater fish are notorious for being low in body fat content, making them very strongly less important. Tool stone and wood not considered in relation to this objective.

Areas most likely to have been used for logistical resource acquisition were determined by transforming criteria ranks into importance rankings (Appendix F: Tables F.33-F.378).

E.3.3 Evaluation. As in Models Large Game and General Foraging, weighted surfaces were generated for each criteria ranking in PCRaster. Then, a multi-criteria evaluation (MCE) combination was run for each objective given the associated criteria. The resulting weighted surfaces were further combined with another MCE, resulting in a final spatial surface, depicting areas most likely to have been used by Mesolithic hunter-gatherers for residential and logistical resource use (see Chapter 7). The model flowchart resembled that for Model Large Game (Figure 6.1), although seven objectives were used to determine areas of probable residential resource use and five objectives were used to determine areas of probable logistical resource use areas.

Appendix F

DECISION-MODELING TABLES

F.1 Model Large Game

Table F.1 Objective Rankings for Residential Resource Acquisition (Model Large Game).

	Attain minimum resources	Minimize risk	Aggregation of population	PEV*
Attain minimum resources	1	1	5	0.45
Minimize risk	1	1	5	0.45
Aggregation of population	1/5	1/5	1	0.10

*PEV: principal eigenvector value.

Table F.2 Objective Rankings for Logistical Resource Acquisition (Model Large Game).

	Attain minimum resources	Minimize risk	PEV
Attain minimum resources	1	1	0.5
Minimize risk	1	1	0.5

Table F.3 Criteria Rankings for Attainment of Minimum Resources within a Residential Resource Use Strategy (Model Large Game).

	Red deer	Roe deer	Wild boar	Aurochs	Beaver	STMs	PEV
Red deer	1	5	3	5	7	9	0.47
Roe deer	1/5	1	1/2	1	2	4	0.12
Wild boar	1/3	2	1	2	4	6	0.20
Aurochs	1/5	1	1/2	1	2	5	0.12
Beaver	1/7	1/2	1/4	1/2	1	2	0.06
STMs	1/9	1/4	1/6	1/4	1/2	1	0.03

Table F.4 Criteria Rankings for Minimization of Risk within a Residential Resource Use Strategy (Model Large Game).

	Red deer	Roe deer	Wild boar	Aurochs	Beaver	STMs	PEV
Red deer	1	1	3	5	5	7	0.35
Roe deer	1	1	1	5	5	7	0.30
Wild boar	1/3	1	1	2	2	4	0.17
Aurochs	1/5	1/5	1/2	1	1	2	0.07
Beaver	1/5	1/5	1/2	1	1	2	0.07
STMs	1/7	1/7	1/4	1/2	1/2	1	0.04

Table F.5 Criteria Rankings for Population Aggregation within a Residential Resource Use Strategy (Model Large Game).

	Red deer	Roe deer	Wild boar	Aurochs	Beaver	STMs	PEV
Red deer	1	3	3	5	7	9	0.44
Roe deer	1/3	1	1	2	4	6	0.19
Wild boar	1/3	1	1	2	4	6	0.19
Aurochs	1/5	1/2	1/2	1	2	4	0.10
Beaver	1/7	1/4	1/4	1/2	1	2	0.05
STMs	1/9	1/6	1/6	1/4	1/2	1	0.03

Table F.6 Conversion Table (Importance Weights to Percent Rankings).

Importance rank	Percent rank (%)
Most important (1)	100
(1/2)	90
Moderately less important (1/3)	80
(1/4)	70
Strongly less important (1/5)	60
(1/6)	50
Very strongly less important (1/7)	40
(1/8)	30
Extremely less important (1/9)	20
(1/10)	10
N/A	0

Table F.7 Criteria Rankings for Attaining Minimum Resources within a Logistical Resource Acquisition Strategy (Model Large Game).

	Importance Ranking
Red deer	100
Roe deer	20
Wild boar	50
Aurochs	20
Beaver	10
Small terrestrial mammals	0

Table F.8 Criteria Rankings for Risk Minimization within a Logistical Resource Acquisition Strategy (Model Large Game).

	Importance Ranking
Red deer	80
Roe deer	70
Wild boar	40
Aurochs	10
Beaver	10
Small terrestrial mammals	0

F. 2 Model General Foraging

Table F.9 Objective Rankings for Residential Resource Acquisition (Model General Foraging).

	Attain minimum resources	Maximize efficiency	Minimize risk	Taste	Variety	Prestige	Aggregation	PEV
Attain minimum resources	1	1	1	3	3	3	3	0.23
Maximize efficiency	1	1	1	3	3	3	3	0.23
Minimize risk	1	1	1	3	3	3	3	0.23
Taste	1/3	1/3	1/3	1	1	1	1	0.08
Variety	1/3	1/3	1/3	1	1	1	1	0.08
Prestige	1/3	1/3	1/3	1	1	1	1	0.08
Aggregation	1/3	1/3	1/3	1	1	1	1	0.08

Table F.10 Objective Rankings for Logistical Resource Acquisition (Model General Foraging).

	Attain minimum resources	Maximize efficiency	Minimize risk	Taste	Prestige	PEV
Attain minimum resources	1	1	1	3	3	0.27
Maximize efficiency	1	1	1	3	3	0.27
Minimize risk	1	1	1	3	3	0.27
Taste	1/3	1/3	1/3	1	1	0.09
Prestige	1/3	1/3	1/3	1	1	0.09

Table F.11 Expected Dietary Importance of Resources (adapted from Jochim 1976:108).

Resource	Percentage of yearly diet (Jochim's 1976 expectations)
Red deer	26
Roe deer	3
Wild boar	22
Beaver	1
Fish	13
Small game	13
Birds	2
Plants	20

Table F.12 Criteria Rankings for Minimum Amount of Resources Under Residential Resource Acquisition (Model General Foraging).

	Red deer	Roe deer	Wild boar	Aurochs	Beaver	STMs	Migratory birds	Terrestrial birds
Red deer	1	7	3	3	7	5	7	7
Roe deer	1/7	1	1/4	1/4	1	1/2	1	1
Wild boar	1/3	4	1	1	4	2	4	4
Aurochs	1/3	4	1	1	4	2	4	4
Beaver	1/7	1	1/4	1/4	1	1/2	1	1
STMs	1/5	2	1/2	1/2	2	1	2	2
Migratory birds	1/7	1	1/4	1/4	1	1/2	1	1
Terrestrial birds	1/7	1	1/4	1/4	1	1/2	1	1
Freshwater fish	1/5	2	1/2	1/2	2	1	2	2
Anadromous fish	1/5	2	1/2	1/2	2	1	2	2
Plants	1/3	4	1	1	4	2	4	4

Table F.12 (cont'd).

	Freshwater fish	Anadromous fish	Plants	PEV
Red deer	5	5	3	0.30
Roe deer	1/2	1/2	1/4	0.04
Wild boar	2	2	1	0.13
Aurochs	2	2	1	0.13
Beaver	1/2	1/2	1/4	0.03
STMs	1	1	1/2	0.06
Migratory birds	1/2	1/2	1/4	0.03
Terrestrial birds	1/2	1/2	1/4	0.03
Freshwater fish	1	1	1/2	0.06
Anadromous fish	1	1	1/2	0.06
Plants	2	2	1	0.13

Table F.13 Criteria Rankings for Maximizing Efficiency Under Residential Resource Acquisition (Model General Foraging).

	Large game	Roe deer	Beaver	STMs	Birds	Fish	Plants	PEV
Large game	1	3	5	9	7	5	3	0.39
Roe deer	1/3	1	2	6	4	2	1	0.16
Beaver	1/5	1/2	1	4	2	1	1/2	0.09
STMs	1/9	1/6	1/4	1	1/2	1/4	1/6	0.03
Birds	1/7	1/4	1/2	2	1	1/2	1/4	0.05
Fish	1/5	1/2	1	4	2	1	1/2	0.12
Plants	1/3	1	2	6	4	2	1	0.16

Table F.14 Criteria Rankings for Minimizing Risk Under Residential Resource Acquisition (Model General Foraging).

	Red deer	Roe deer	Wild boar	Aurochs	Beaver	STMs	Birds	Fish	Plants	PEV
Red deer	1	1	3	5	5	7	7	5	7	0.29
Roe deer	1	1	3	5	5	7	7	5	7	0.29
Wild boar	1/3	1/3	1	2	2	4	4	2	4	0.12
Aurochs	1/5	1/5	1/2	1	1	2	2	1	2	0.07
Beaver	1/5	1/5	1/2	1	1	2	2	1	2	0.07
STMs	1/7	1/7	1/4	1/2	1/2	1	1	1/2	1	0.03
Birds	1/7	1/7	1/4	1/2	1/2	1	1	1/2	1	0.03
Fish	1/5	1/5	1/2	1	1	2	2	1	2	0.07
Plants	1/7	1/7	1/4	1/2	1/2	1	1	1/2	1	0.03

Table F.15 Criteria Rankings for Population Aggregation Under Residential Resource Acquisition (Model General Foraging).

	Red deer	Roe deer	Wild boar	Aurochs	Birds	Fish	Plants	PEV
Red deer	1	3	3	3	5	3	5	0.36
Roe deer	1/3	1	1	1	2	1	2	0.13
Wild boar	1/3	1	1	1	2	1	2	0.13
Aurochs	1/3	1	1	1	2	1	2	0.13
Birds	1/5	1/2	1/2	1/2	1	1/2	1	0.07
Fish	1/3	1	1	1	2	1	2	0.11
Plants	1/5	1/2	1/2	1/2	1	1/2	1	0.07

Table F.16 Criteria Rankings for Taste Under Residential Resource Acquisition (Model General Foraging).

	Aurochs	Beaver	Wild boar	Red deer	Roe deer	Birds	Fish	Plants	PEV
Aurochs	1	1	3	3	3	5	5	3	0.26
Beaver	1	1	3	3	3	5	5	3	0.26
Wild boar	1/3	1/3	1	1	1	2	2	1	0.09
Red deer	1/3	1/3	1	1	1	2	2	1	0.09
Roe deer	1/3	1/3	1	1	1	2	2	1	0.09
Birds	1/5	1/5	1/2	1/2	1/2	1	2	1/2	0.06
Fish	1/5	1/5	1/2	1/2	1/2	1	1	1/2	0.06
Plants	1/3	1/3	1	1	1	2	2	1	0.09

Table F.17 Criteria Rankings for Variety Under Residential Resource Acquisition (Model General Foraging).

	Red deer	Roe deer	Wild boar	Aurochs	Beaver	Birds	Fish	Plants	PEV
Red deer	1	3	3	1	3	3	3	5	0.26
Roe deer	1/3	1	1	1	1	1	1	2	0.11
Wild boar	1/3	1	1	1/3	1	1	1	2	0.09
Aurochs	1	1	3	1	3	3	3	5	0.22
Beaver	1/3	1	1	1/3	1	1	1	2	0.09
Birds	1/3	1	1	1/3	1	1	1	2	0.09
Fish	1/3	1	1	1/3	1	1	1	2	0.09
Plants	1/5	1/2	1/2	1/5	1/2	1/2	1/2	1	0.05

Table F.18 Criteria Rankings for Prestige Under Residential Resource Acquisition (Model General Foraging).

	Red deer	Roe deer	Wild boar	Aurochs	Beaver	Birds	Fish	Plants	PEV
Red deer	1	1	1	1	7	7	7	7	0.22
Roe deer	1	1	1	1	7	7	7	7	0.22
Wild boar	1	1	1	1	7	7	7	7	0.22
Aurochs	1	1	1	1	7	7	7	7	0.22
Beaver	1/7	1/7	1/7	1/7	1	1	1	1	0.03
Birds	1/7	1/7	1/7	1/7	1	1	1	1	0.03
Fish	1/7	1/7	1/7	1/7	1	1	1	1	0.03
Plants	1/7	1/7	1/7	1/7	1	1	1	1	0.03

Table F.19 Criteria Rankings for Minimum Amount of Resources Under Logistical Resource Acquisition (Model General Foraging).

	Importance ranking
Red deer	100
Roe deer	40
Wild boar	80
Aurochs	80
Beaver	40
STM	60
Migratory birds	40
Terrestrial birds	40
Freshwater fish	60
Anadromous fish	60
Plants	80

Table F.20 Criteria Rankings for Maximizing Efficiency Under Logistical Resource Acquisition (Model General Foraging).

	Importance ranking
Large game	100
Roe deer	80
Beaver	60
STMs	20
Birds	40
Fish	60
Plants	20

Table F. 21 Criteria Rankings for Minimizing Risk Under Logistical Resource Acquisition (Model General Foraging).

	Importance ranking
Red deer	100
Roe deer	100
Wild boar	80
Aurochs	60
Beaver	60
STMs	40
Birds	40
Fish	60
Plants	40

Table F.22 Criteria Rankings for Taste Under Logistical Resource Acquisition (Model General Foraging).

	Importance ranking
Aurochs	100
Beaver	100
Wild boar	80
Red deer	80
Roe deer	80
Birds	60
Fish	40
Plants	80

Table F.23 Criteria Rankings for Prestige Under Logistical Resource Acquisition (Model General Foraging).

	Importance ranking
Red deer	100
Roe deer	100
Wild boar	100
Aurochs	100
Beaver	40
Birds	40
Fish	40
Plants	40

F.3 Model Wetlands

Table F.24 Objective Rankings for Residential Resource Acquisition (Model Wetlands).

	Attain minimum resources	Maximize efficiency	Minimize risk	Aggregation	Taste	Variety	Prestige	PEV
Attain minimum resources	1	1	1	3	5	5	7	0.24
Maximize efficiency	1	1	1	3	5	5	7	0.24
Minimize risk	1	1	1	3	5	5	7	0.24
Aggregation	1/3	1/3	1/3	1	2	2	4	0.09
Taste	1/5	1/5	1/5	1/2	1	1	2	0.06
Variety	1/5	1/5	1/5	1/2	1	1	2	0.10
Prestige	1/7	1/7	1/7	1/4	1/2	1/2	1	0.03

Table F.25 Objective Rankings for Logistical Resource Acquisition (Model Wetlands).

	Attain minimum resources	Maximize efficiency	Minimize risk	Taste	Prestige	PEV
Attain minimum resources	1	1	1	4	7	0.29
Maximize efficiency	1	1	1	4	7	0.29
Minimize risk	1	1	1	4	7	0.29
Taste	1/4	1/4	1/4	1	3	0.08
Prestige	1/7	1/7	1/7	1/3	1	0.05

Table F.26 Criteria Rankings for Minimum Amount of Resources Under Residential Resource Acquisition (Model Wetlands).

	Anadromous fish	Water birds	Freshwater fish	Plants	Large game	Beaver
Anadromous fish	1	1	1	3	5	5
Water birds	1	1	1	3	5	5
Freshwater fish	1	1	1	3	5	5
Plants	1/3	1/3	1/3	1	2	2
Large game	1/5	1/5	1/5	1/2	1	2
Beaver	1/5	1/5	1/5	1/2	1/2	1
STMs	1/7	1/7	1/7	1/4	1/2	1/2
Terrestrial birds	1/7	1/7	1/7	1/4	1/2	1/2
Tool stone	1/7	1/7	1/7	1/4	1/2	1/2
Wood	1/5	1/5	1/5	1/2	1	1

Table F.26 (cont'd).

	STMs	Terrestrial birds	Tool stone	Wood	PEV
Anadromous fish	7	7	7	5	0.22
Water birds	7	7	7	5	0.22
Freshwater fish	7	7	7	5	0.22
Plants	4	4	4	2	0.10
Large game	2	2	2	1	0.05
Beaver	2	2	2	1	0.05
STMs	1	1	1	2	0.03
Terrestrial birds	1	1	1	2	0.03
Tool stone	1	1	1	2	0.03
Wood	2	2	2	1	0.05

Table F.27 Criteria Rankings for Maximizing Efficiency Under Residential Resource Acquisition (Model Wetlands).

	Fish	Water birds	Plants	Beaver	Large game	Terrestrial birds	STMs	Tool stone	Wood	PEV
Fish	1	3	3	5	5	7	7	5	3	0.32
Water birds	1/3	1	1	2	2	4	4	2	1	0.13
Plants	1/3	1	1	2	2	4	4	2	1	0.13
Beaver	1/5	1/2	1/2	1	1	2	2	1	1/2	0.07
Large game	1/5	1/2	1/2	1	1	2	2	1	1/2	0.07
Terrestrial birds	1/7	1/4	1/4	1/2	1/2	1	1	1/2	1/4	0.04
STMs	1/7	1/4	1/4	1/2	1/2	1	1	1/2	1/4	0.04
Tool stone	1/5	1/2	1/2	1	1	2	2	1	1/2	0.07
Wood	1/3	1	1	2	2	4	4	2	1	0.13

Table F.28 Criteria Rankings for Minimizing Risk Under Residential Resource Acquisition (Model Wetlands).

	Fish	Water birds	Large game	Plants	Tool stone	Terrestrial birds	STMs	Beaver	Tool stone	Wood	PEV
Fish	1	1	5	5	5	7	7	7	7	3	0.29
Water birds	1	1	5	5	5	7	7	7	7	3	0.29
Large game	1/5	1/5	1	1	1	2	2	2	2	1/2	0.07
Plants	1/5	1/5	1	1	1	2	2	2	2	1/2	0.07
Tool stone	1/5	1/5	1	1	1	2	2	2	2	1/2	0.07
Terrestrial birds	1/7	1/7	1/2	1/2	1/2	1	1	1	1	1/4	0.03
STMs	1/7	1/7	1/2	1/2	1/2	1	1	1	1	1/4	0.03
Beaver	1/7	1/7	1/2	1/2	1/2	1	1	1	1	1/4	0.03
Tool stone	1/7	1/7	1/2	1/2	1/2	1	1	1	1	1/4	0.03
Wood	1/3	1/3	2	2	2	4	4	4	4	1	0.12

Table F.29 Criteria Rankings for Population Aggregation Under Residential Resource Acquisition (Model Wetlands).

	Fish	Water birds	Plants	Beaver	Large game	STMs	Beaver	Terrestrial birds	Tool stone	Wood	PEV
Fish	1	1	3	7	5	7	7	7	9	9	0.30
Water birds	1	1	3	7	5	7	7	7	9	9	0.30
Plants	1/3	1/3	1	4	2	4	4	4	6	6	0.15
Beaver	1/7	1/7	1/4	1	1/2	1	1	1	2	2	0.04
Large game	1/5	1/5	1/2	2	1	2	2	2	4	4	0.09
STMs	1/7	1/7	1/4	1	1/2	1	1	1	2	2	0.04

Table F.29 (cont'd).

Beaver	1/7	1/7	1/4	1	1/2	1	1	1	2	2	0.04
Terrestrial birds	1/7	1/7	1/4	1	1/2	1	1	1	2	2	0.04
Tool stone	1/9	1/9	1/6	1/2	1/4	1/2	1/2	1/2	1	1	0.02
Wood	1/9	1/9	1/6	1/2	1/4	1/2	1/2	1/2	1	1	0.02

Table F.30 Criteria Rankings for Prestige Under Residential Resource Acquisition (Model Wetlands).

	Large game	Fish	Birds	STMs	Beaver	Plants	Tool stone	Wood	PEV
Large game	1	5	5	9	9	9	5	9	0.45
Fish	1/5	1	1	4	4	4	1	4	0.13
Birds	1/5	1	1	4	4	4	1	4	0.13
STMs	1/9	1/4	1/4	1	1	1	1/4	1	0.04
Beaver	1/9	1/4	1/4	1	1	1	1/4	1	0.04
Plants	1/9	1/4	1/4	1	1	1	1/4	1	0.04
Tool stone	1/5	1	1	4	4	4	1	4	0.13
Wood	1/9	1/4	1/4	1	1	1	1/4	1	0.04

Table F.31 Criteria Rankings for Dietary Variety Under Residential Resource Acquisition (Model Wetlands).

	Large game	Fish	Birds	Beaver	STMs	Plants	PEV
Large game	1	1	1	1	1	3	0.19
Fish	1	1	1	1	1	3	0.19
Birds	1	1	1	1	1	3	0.19
Beaver	1	1	1	1	1	3	0.19
STMs	1	1	1	1	1	3	0.19
Plants	1/3	1/3	1/3	1/3	1/3	1	0.05

Table F.32 Criteria Rankings for Taste Under Residential Resource Acquisition (Model Wetlands).

	Beaver	Anadromous fish	Water birds	Plants	Large game	Freshwater fish	STMs	Terrestrial birds	PEV
Beaver	1	1	1	3	5	7	7	7	0.25
Anadromous fish	1	1	1	3	5	7	7	7	0.25
Water birds	1	1	1	3	5	7	7	7	0.25
Plants	1/3	1/3	1/3	1	2	4	4	4	0.10
Large game	1/5	1/5	1/5	1/2	1	2	2	2	0.06
Freshwater fish	1/7	1/7	1/7	1/4	1/2	1	1	1	0.03
STMs	1/7	1/7	1/7	1/4	1/2	1	1	1	0.03
Terrestrial birds	1/7	1/7	1/7	1/4	1/2	1	1	1	0.03

Table F.33 Criteria Rankings for Minimum Amount of Resources Under Logistical Resource Acquisition (Model Wetlands).

	Importance ranking
Anadromous fish	100
Water birds	100
Freshwater fish	100
Plants	80
Large game	60
Beaver	60
STMs	40
Terrestrial birds	40
Tool stone	40
Wood	60

Table F.34 Criteria Rankings for Maximizing Efficiency Under Logistical Resource Acquisition (Model Wetlands).

	Importance rankings
Fish	100
Water birds	80
Plants	80
Beaver	60
Large game	60
Terrestrial birds	40
STMs	40
Tool stone	60
Wood	80

Table F.35 Criteria Rankings for Minimizing Risk Under Logistical Resource Acquisition (Model Wetlands).

	Importance ranking
Fish	100
Water birds	100
Large game	60
Plants	60
Tool stone	60
Terrestrial birds	40
STMs	40
Beaver	40
Wood	80

Table F.36 Criteria Rankings for Prestige Under Logistical Resource Acquisition (Model Wetlands).

	Importance ranking
Large game	100
Fish	60
Birds	60
STMs	20
Beaver	20
Plants	20
Tool stone	60
Wood	20

Table F.37 Criteria Rankings for Taste Under Logistical Resource Acquisition (Model Wetlands).

	Importance ranking
Beaver	100
Anadromous fish	100
Water birds	100
Plants	80
Large game	60
Freshwater fish	40
STMs	40
Terrestrial birds	40

F.4 Foraging Settlement Model

Table F.38 Objective Rankings for Residential Settlement (Foraging Model).

	Proximity to resources	Shelter	View	Ground dryness	PEV
Proximity to food resources	1	1	5	3	0.40
Shelter	1	1	5	3	0.40
View	1/5	1/5	1	1	0.08
Ground dryness	1/3	1/3	1	1	0.12

Table F.39 Objective Rankings for Logistical Settlement (Foraging Model).

	Proximity to resources	Shelter	Ground dryness	PEV
Proximity to resources	1	5	7	0.68
Shelter	1/5	1	7	0.26
Ground dryness	1/7	1/7	1	0.06

Table F.40 Residential and Logistical Settlement Criteria Rankings for Shelter (Foraging Model).

	River dunes, etc.	Other landforms	Pine/Oak	Other	PEV
River dunes, terraces, ridges	1	9	3	7	0.59
All other landforms	1/9	1	1/6	1/2	0.05
Pine/Oak	1/3	6	1	4	0.27
Other	1/7	2	1/4	1	0.09

Table F.41 Residential Criteria Rankings for View (Foraging Model).

	Suitable landform features	Edge zone	PEV
Suitable landform features	1	5	0.83
Edge zone	1/5	1	0.17

Table F.42 Residential and Logistical Criteria Rankings for Dry Ground (Foraging Model).

Location relation to groundwater	>100 cm above	Between 100-25 cm above	<25 cm above	PEV
>100 cm above	1	5	9	0.73
Between 100-25 cm above	1/5	1	4	0.20
<25 cm above	1/9	1/4	1	0.07

F.5 Collector Settlement Model

Table F.43 Objective Rankings for Residential Settlement (Collector Model).

	Ground dryness	Proximity to resources	Shelter	Ground dryness	PEV
Ground dryness	1	3	5	7	0.58
Proximity to resources	1/3	1	2	4	0.23
Shelter	1/5	1/2	1	2	0.12
View	1/7	1/4	1/2	1	0.07

Table F.44 Objective Rankings for Logistical Settlement (Collector Model).

	Proximity to resources	Shelter	Ground dryness	PEV
Proximity to resources	1	5	7	0.68
Shelter	1/5	1	7	0.26
Ground dryness	1/7	1/7	1	0.06

Table F.45 Residential and Logistical Settlement Criteria Rankings for Shelter (Collector Model).

	River dunes, etc.	Other landforms	Pine	Oak mix	PEV
River dunes, terraces, ridges	1	9	3	7	0.59
All other landforms	1/9	1	1/6	1/2	0.05
Pine	1/3	6	1	4	0.27
Oak mix	1/7	2	1/4	1	0.09

Table F.46 Residential Criteria Rankings for View (Collector Model).

	Suitable landform features	Edge zone	PEV
Suitable landform features	1	5	0.83
Edge zone	1/5	1	0.17

Table F.47 Residential and Logistical Criteria Rankings for Dry Ground (Collector Model).

Location relation to groundwater	>100 cm above	Between 100-25 cm above	<25 cm above	PEV
>100 cm above	1	5	9	0.73
Between 100-25 cm above	1/5	1	4	0.20
<25 cm above	1/9	1/4	1	0.07

Appendix G

RESULTS FIGURES

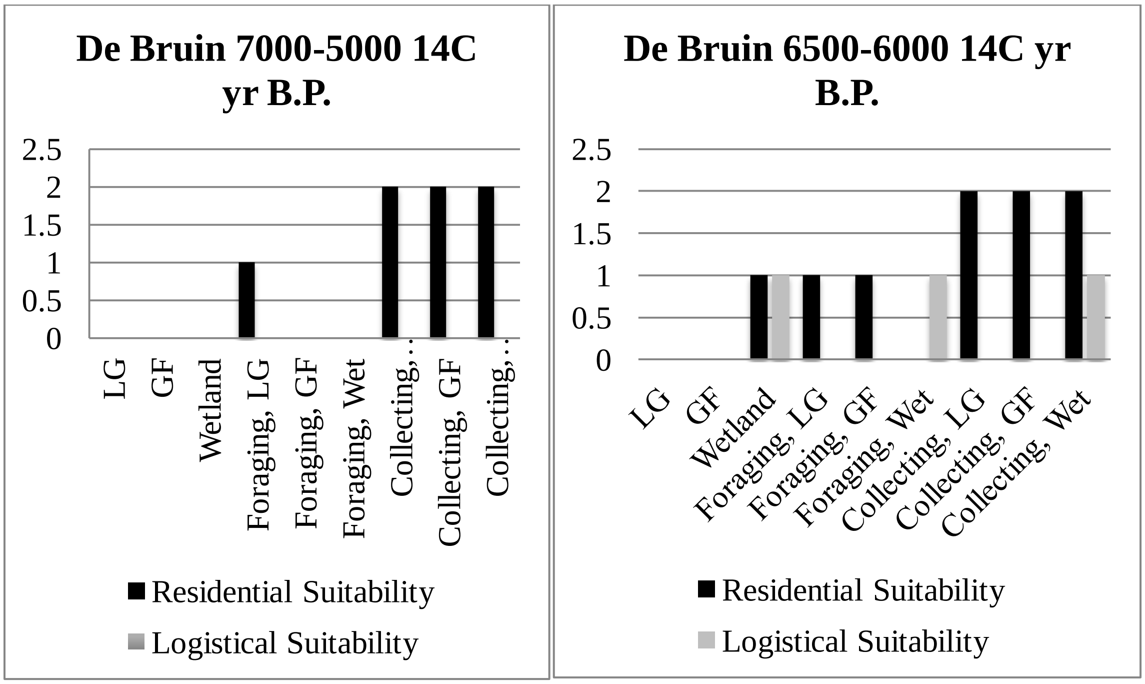
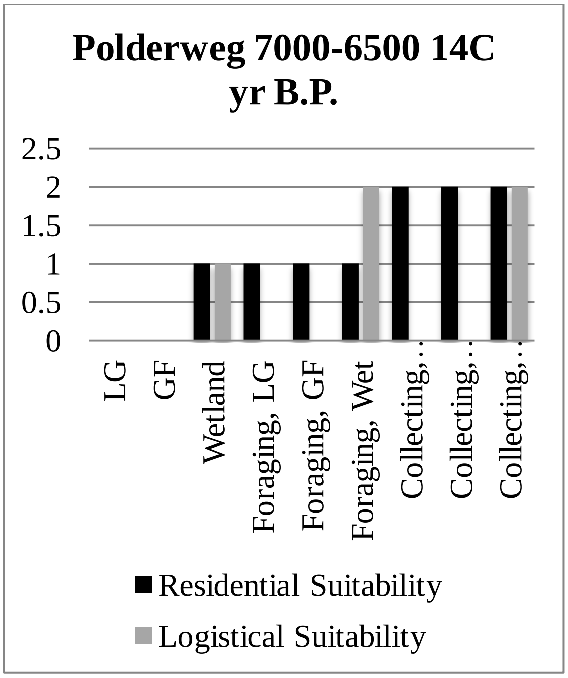


Figure G.1 Predicted Subsistence-Settlement Strategies at the site of De Bruin, 7000-^{14}C yr B.P.



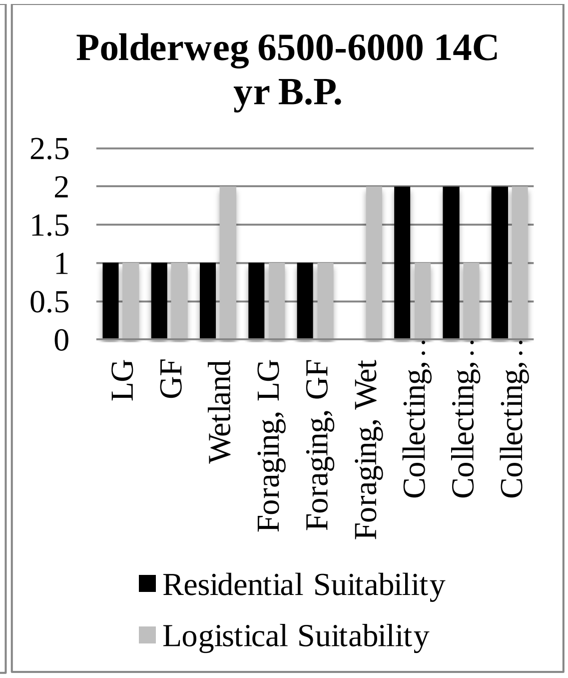


Figure G.2 Predicted Subsistence-Settlement Strategies at the site of Polderweg, 7000-6000 ^{14}C yr B.P.

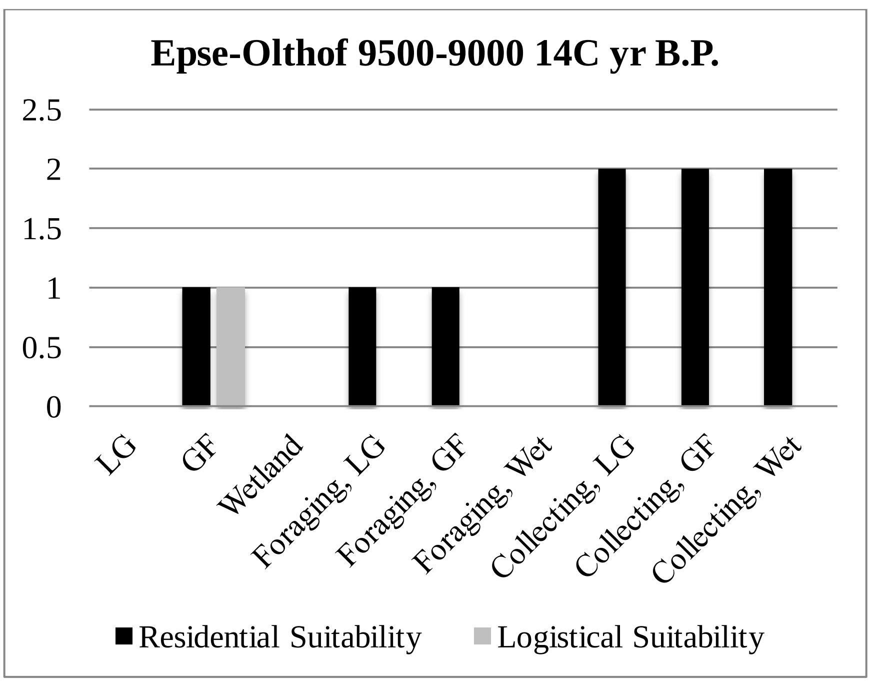


Figure G.3 Predicted Subsistence-Settlement Strategies at the Site of Epse-Olthof, 9500-9000 ^{14}C yr B.P.

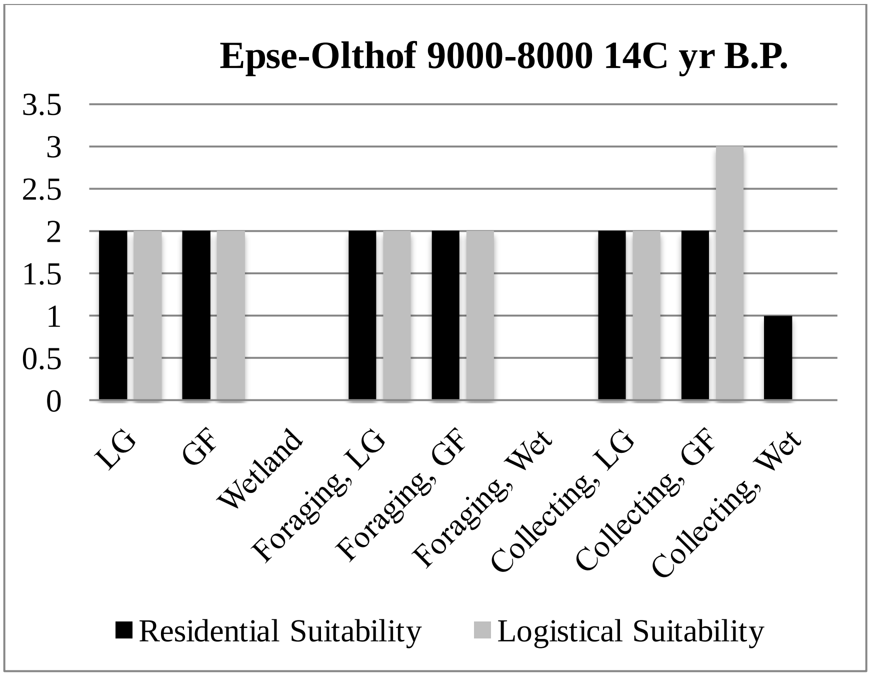


Figure G.4 Predicted Subsistence-Settlement Strategies at the Site of Epse-Olthof, 9000- 8000 ^{14}C yr B.P.

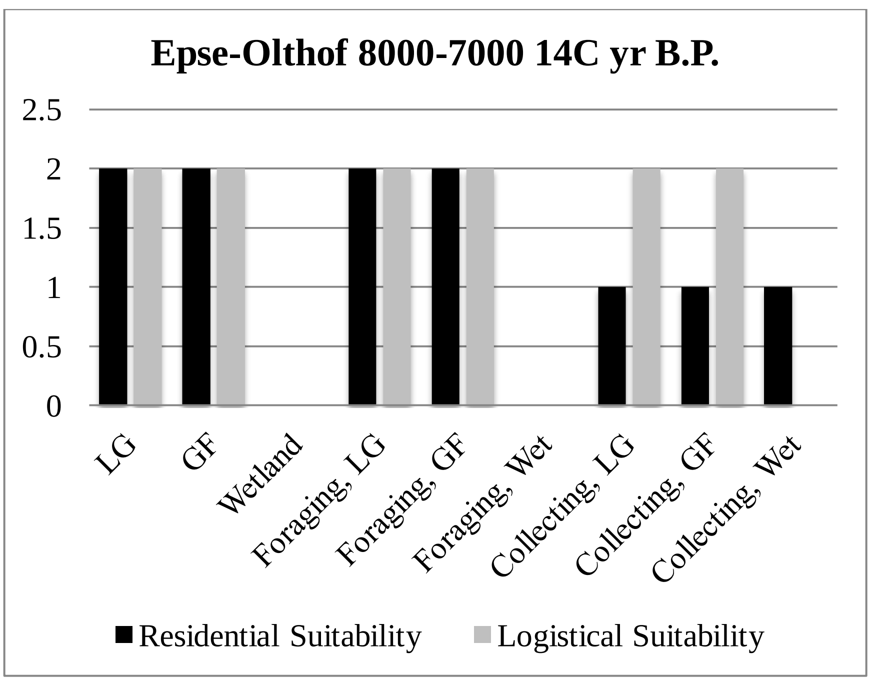


Figure G.5 Predicted Subsistence-Settlement Strategies at the Site of Epse-Olthof, 8000- 7000 ^{14}C yr B.P.

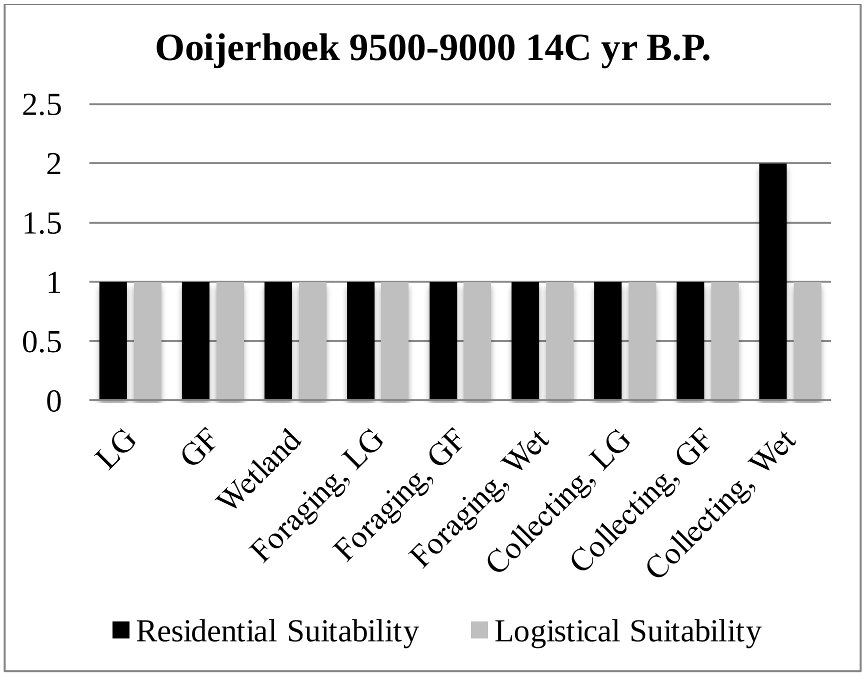


Figure G.6 Predicted Subsistence-Settlement Strategies at the Site of Ooijerhoek, 9500- 9000 ^{14}C yr B.P.

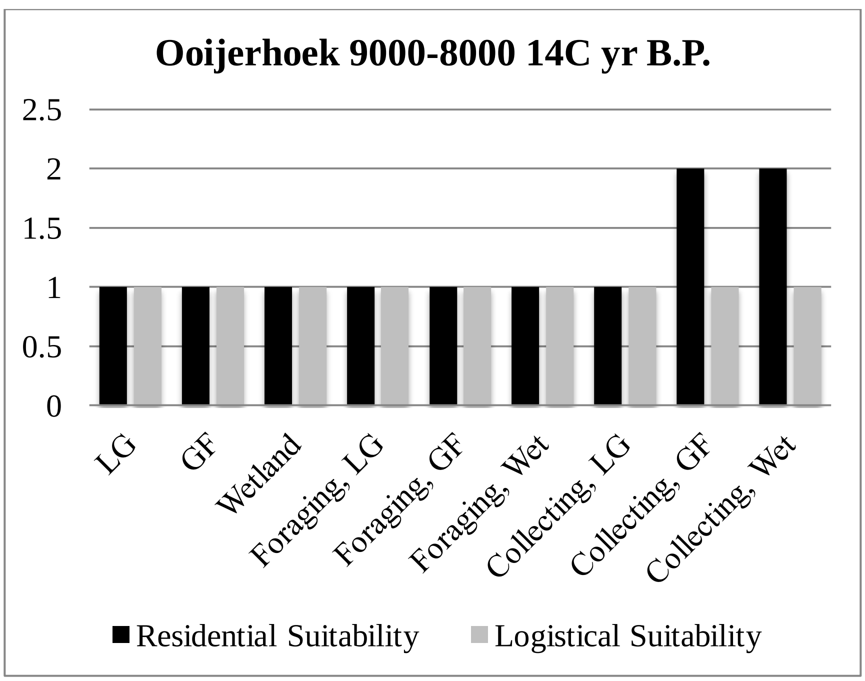


Figure G.7 Predicted Subsistence-Settlement Strategies at the Site of Ooijerhoek, 9000- 8000 ^{14}C yr B.P.

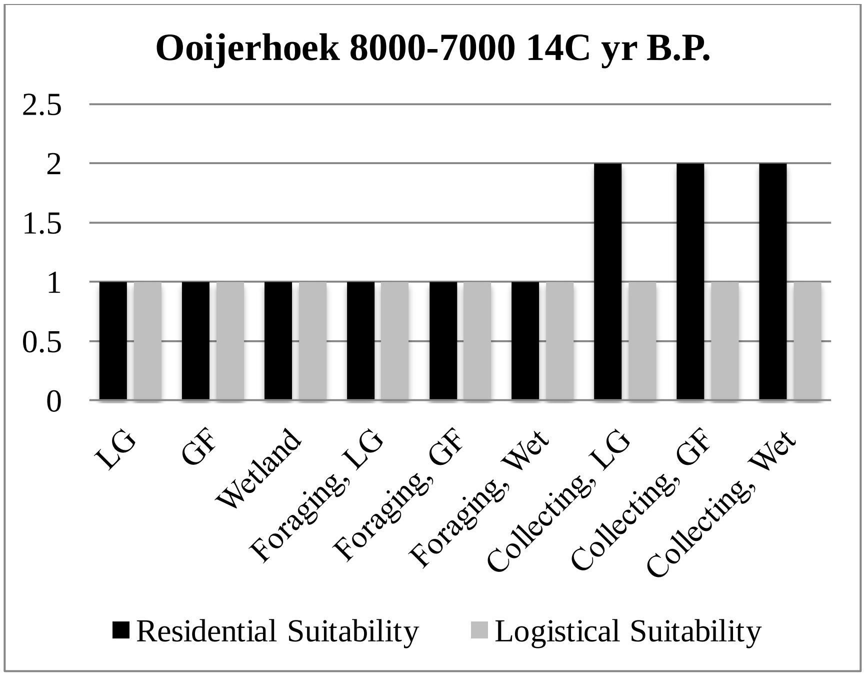


Figure G.8 Predicted Subsistence-Settlement Strategies at the Site of Ooijerhoek, 8000-7000 ^{14}C yr B.P.

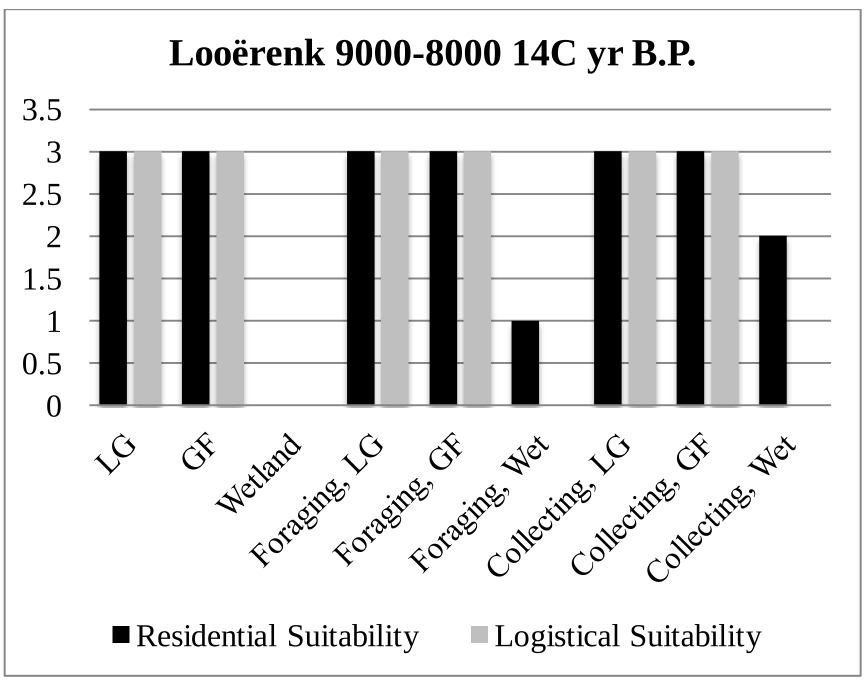


Figure G.9 Predicted Subsistence-Settlement Strategies at the Site of Looërenk, 9000-8000 ^{14}C yr B.P.

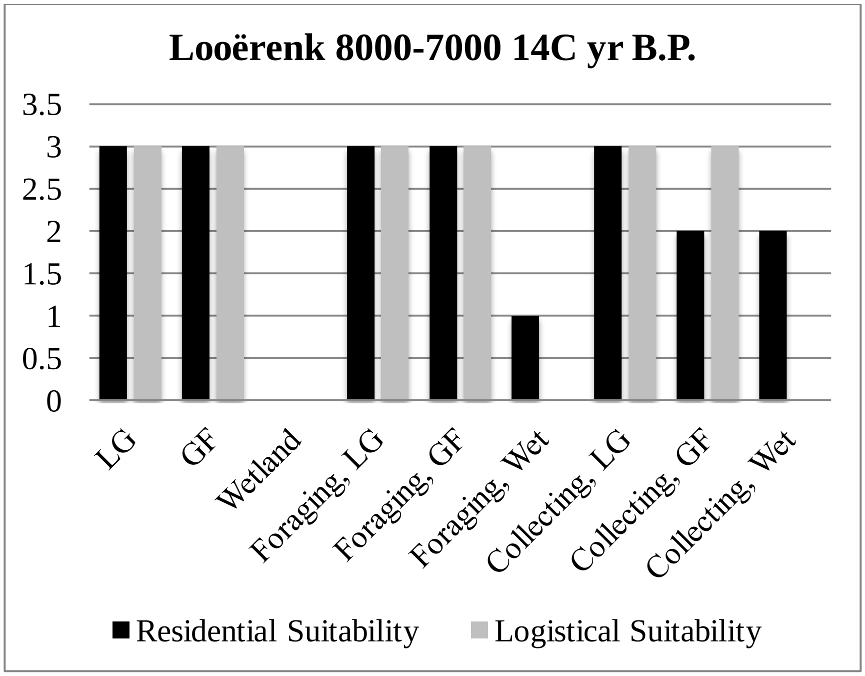


Figure G.10 Predicted Subsistence-Settlement Strategies at the Site of Looërenk, 8000-7000 ^{14}C yr B.P.

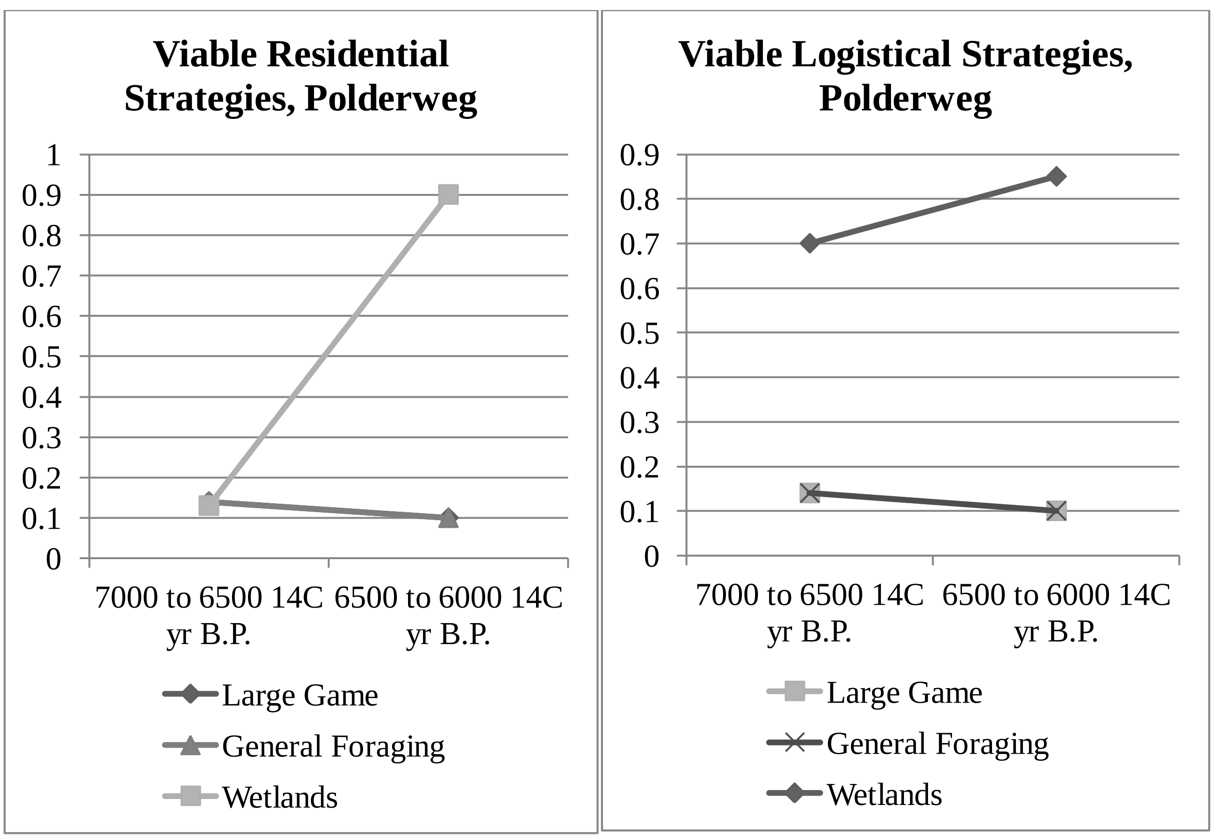
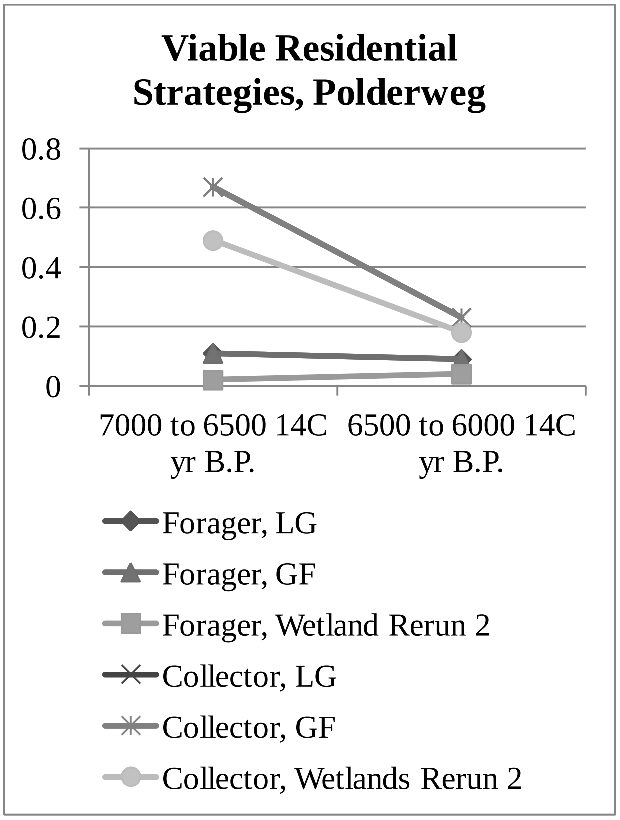


Figure G.11 Subsistence Strategies with High Suitability Values from Polderweg, 7000-6000 ^{14}C yr B.P.



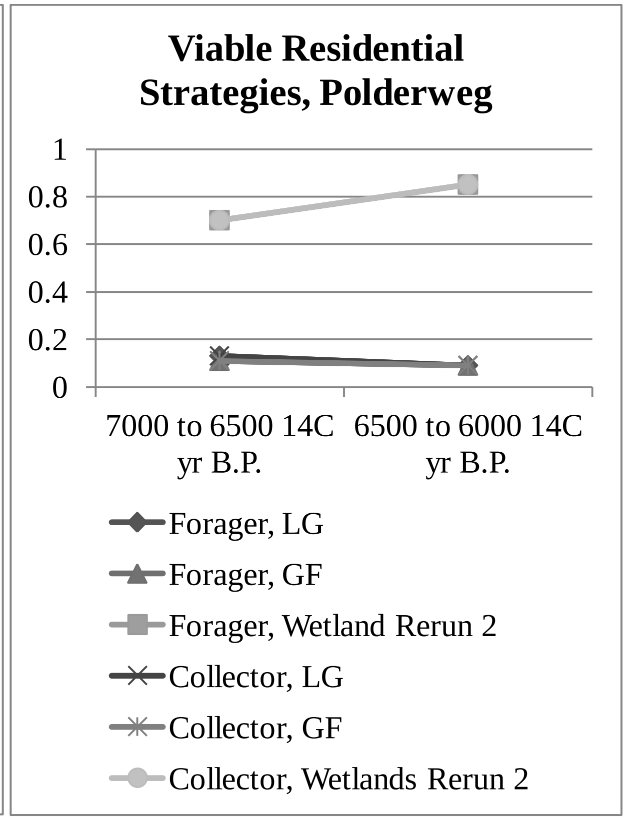


Figure G.12 Settlement-Subsistence Strategies with High Suitability Values from Polderweg, 7000-6000 ^{14}C yr B.P.

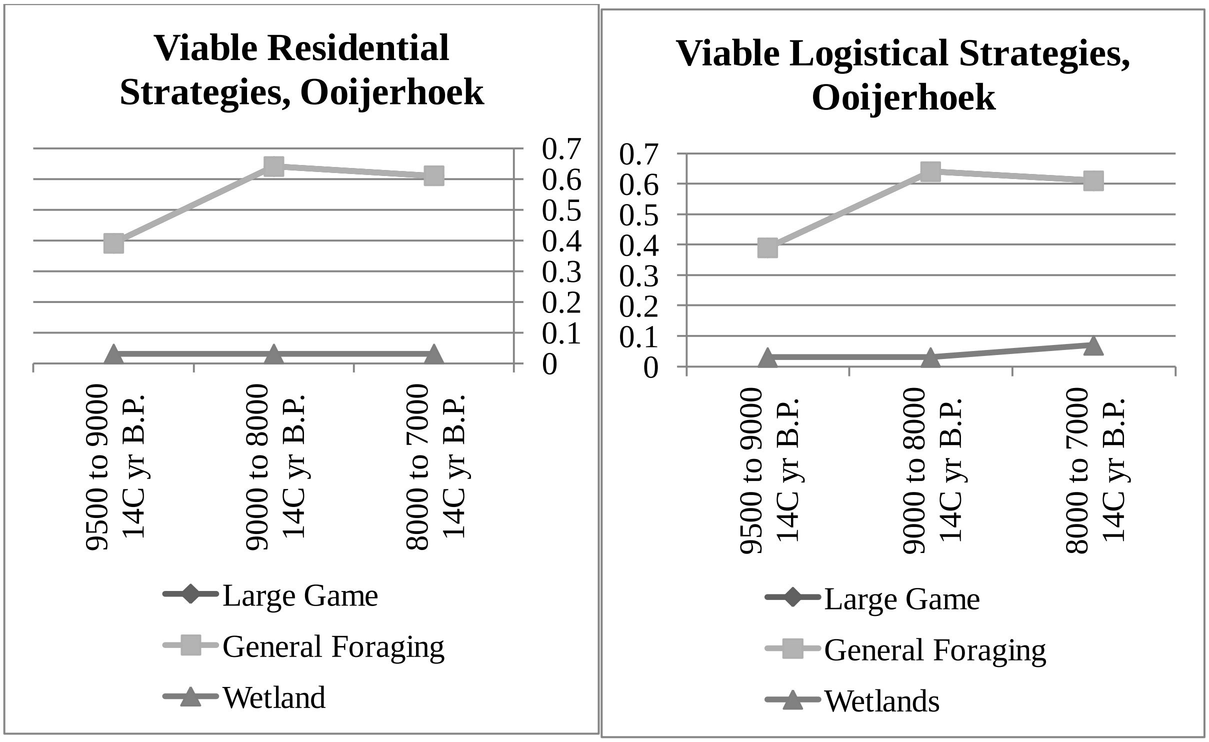


Figure G.13 Settlement-Subsistence Strategies with High Suitability Values from the Ooijerhoek Area, 9000-7000 ^{14}C yr B.P.

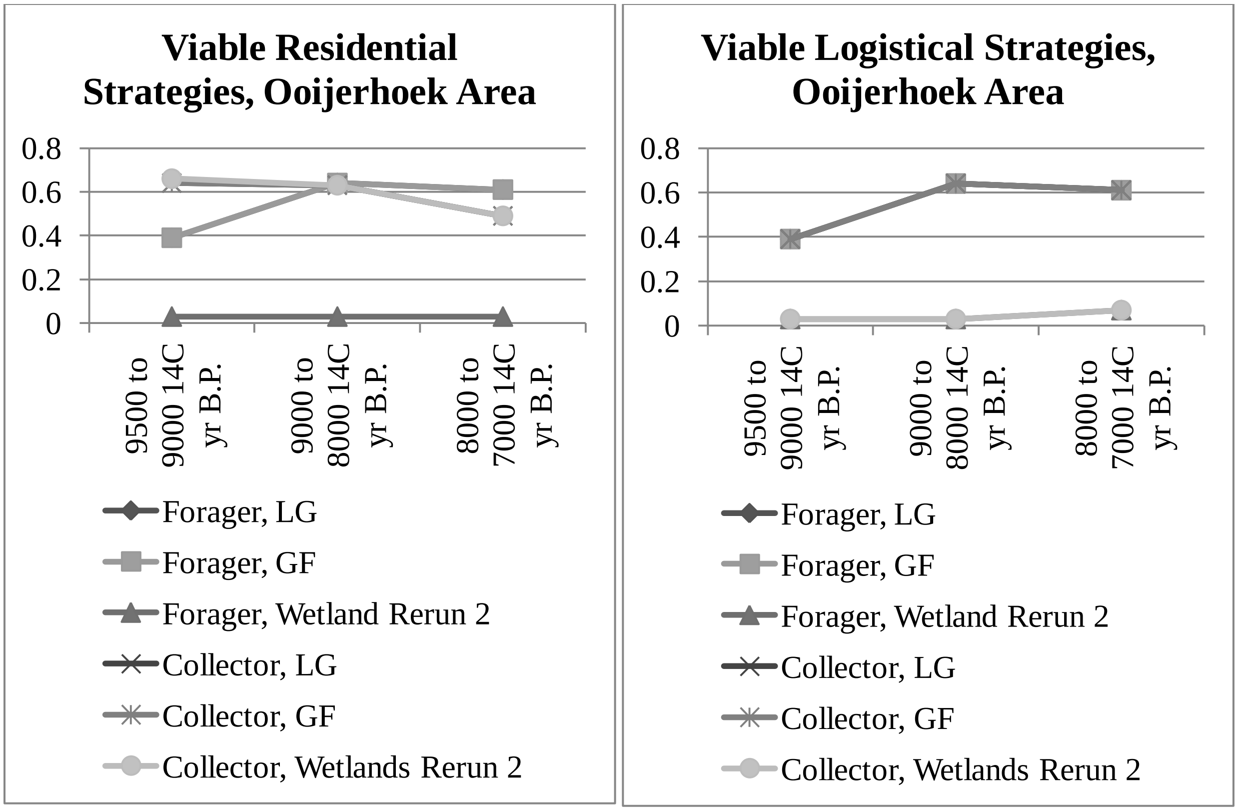


Figure G.14 Settlement-Subsistence Strategies with High Suitability Values from the Ooijerhoek Area, 9000-8000 ^{14}C yr B.P.

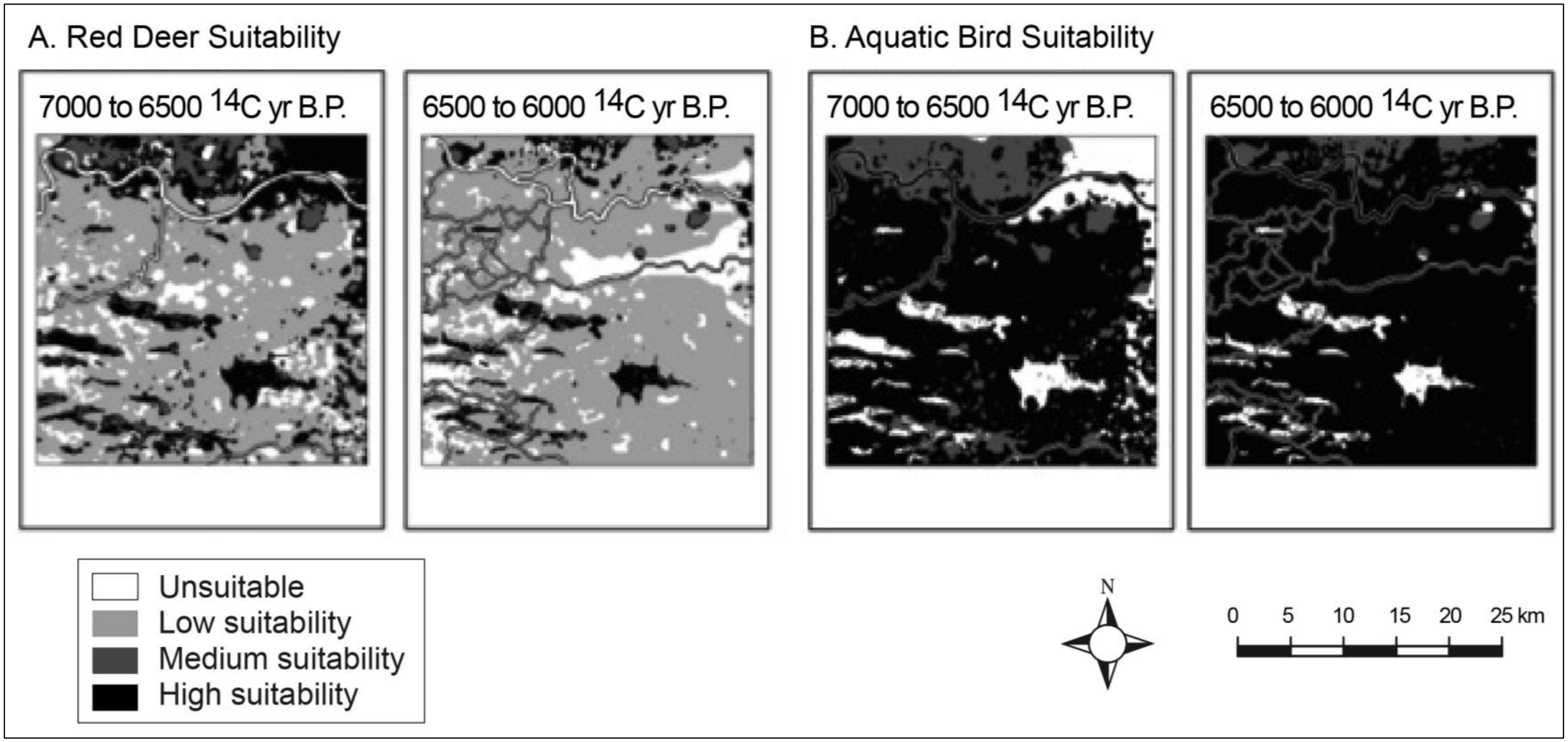


Figure G.15 A. Red Deer Suitability within the Polderweg Area; B. Aquatic Bird Suitability in the Polderweg Area.

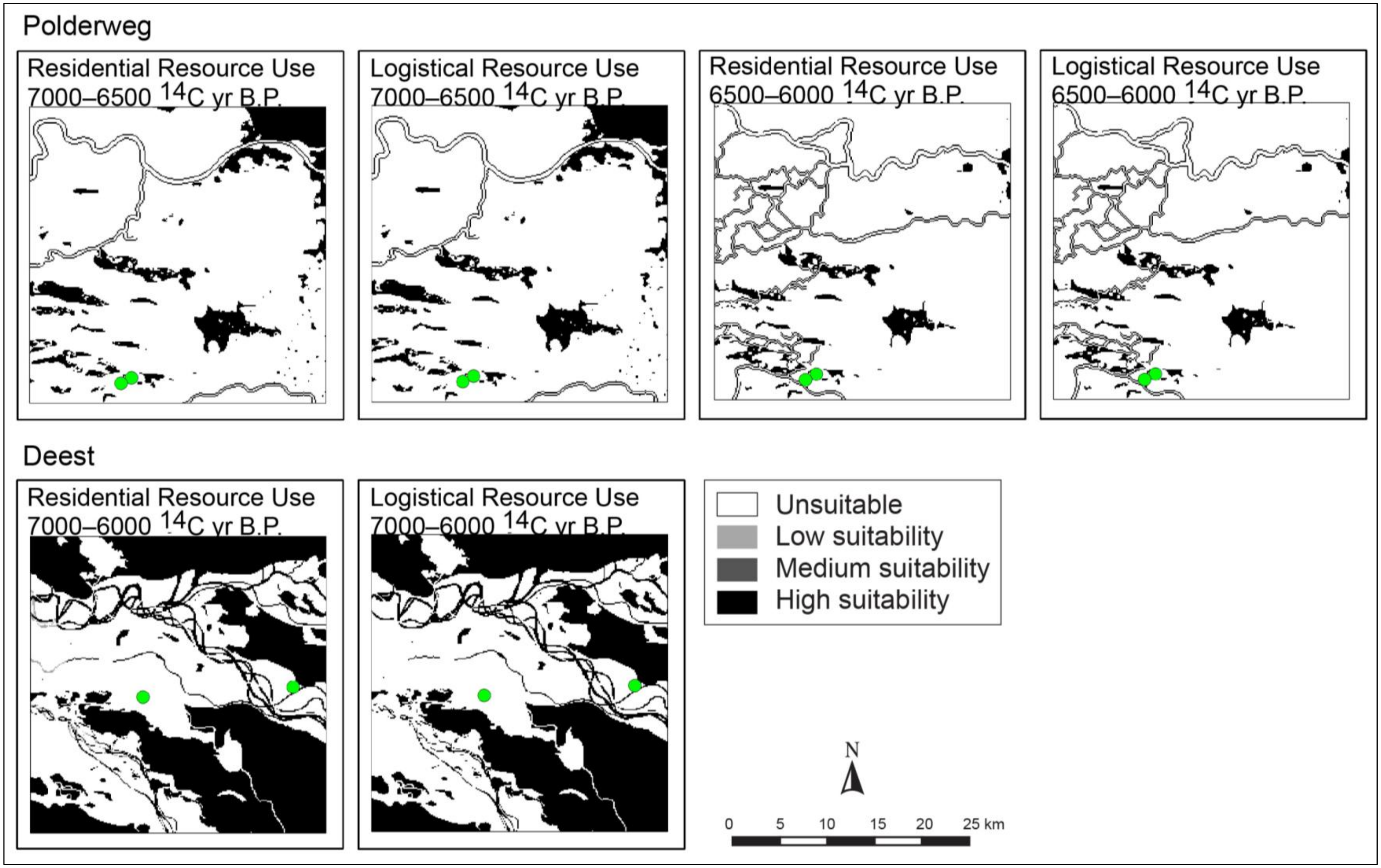


Figure G.16 Suitability of Targeting Large Game in the Polderweg and Deest Areas (on all further maps, green dots represent sites).

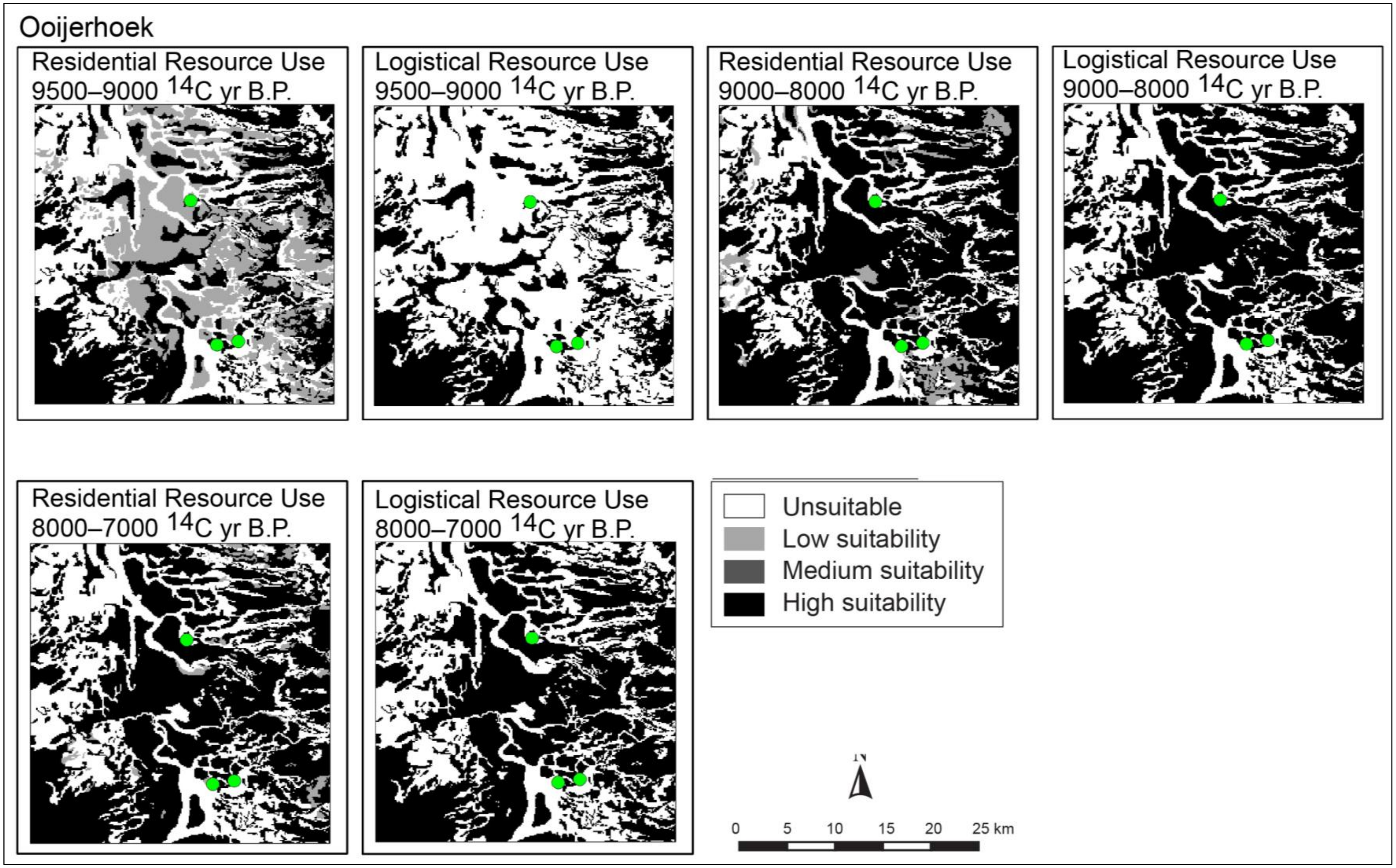


Figure G.17 Suitability of Targeting Large Game in the Ooijerhoek Area.

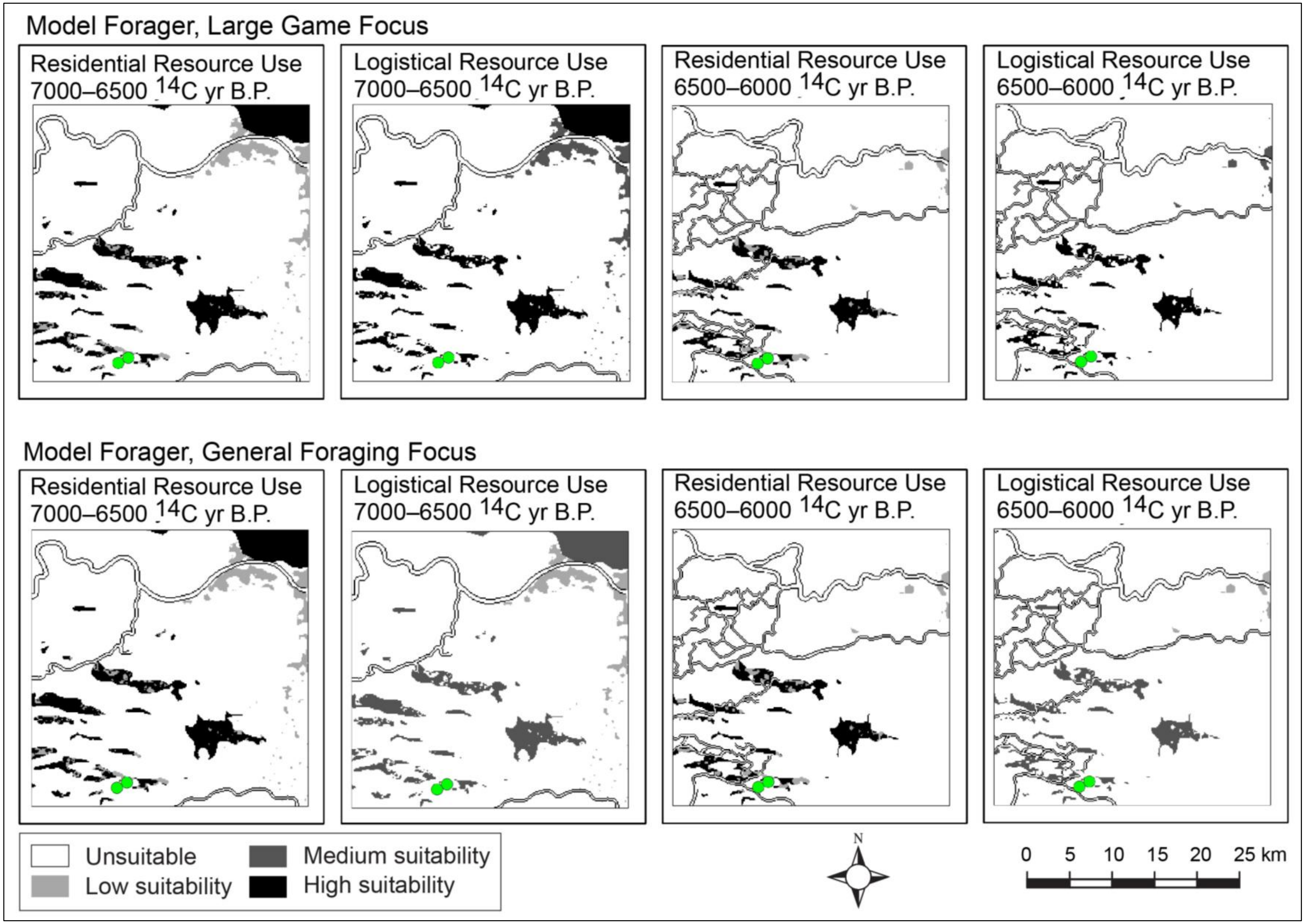


Figure G.18 Foraging Strategy Focused on Large Game and General Foraging in the Polderweg Area.

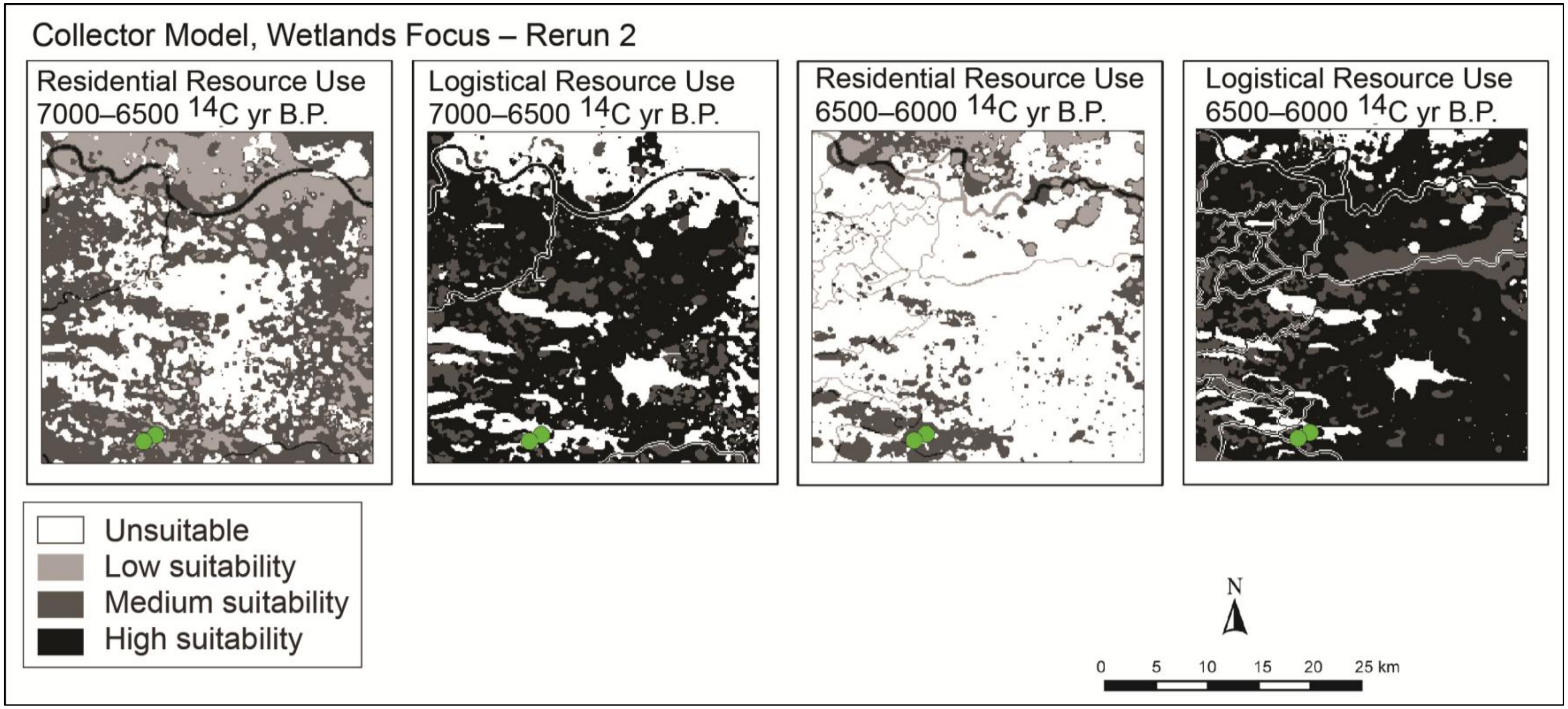


Figure G.19 Collecting Strategy Focused on Wetland Resources in the Polderweg Area.

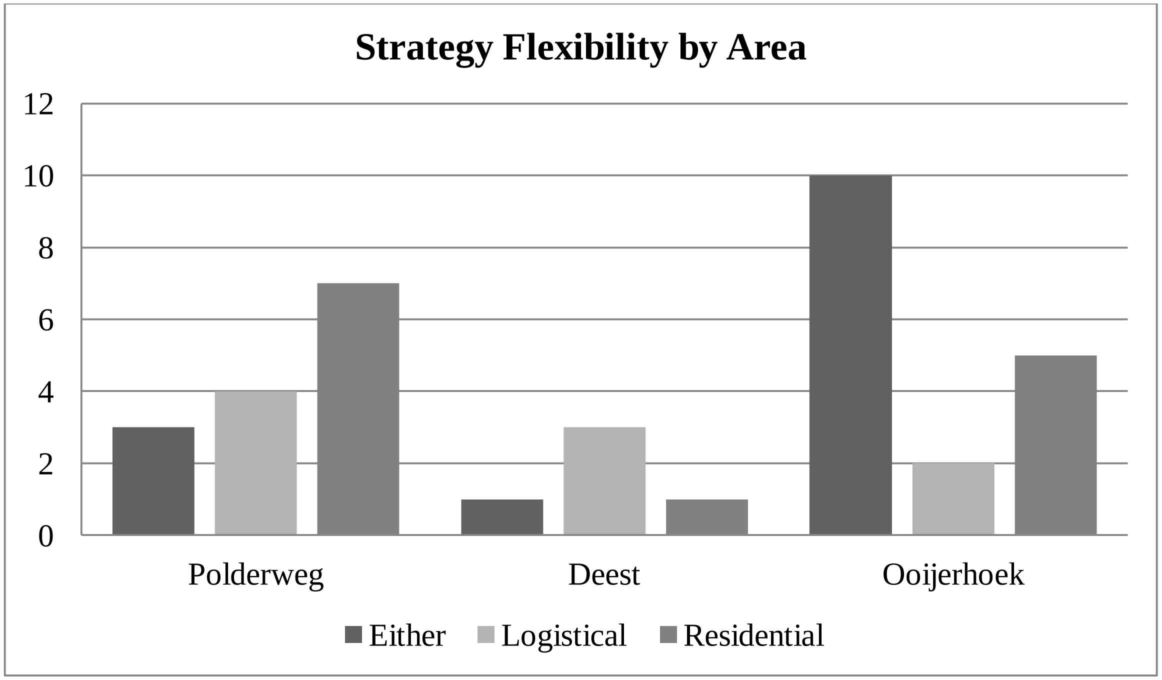


Figure G.20 Trends in the Flexibility of Strategies by Area.

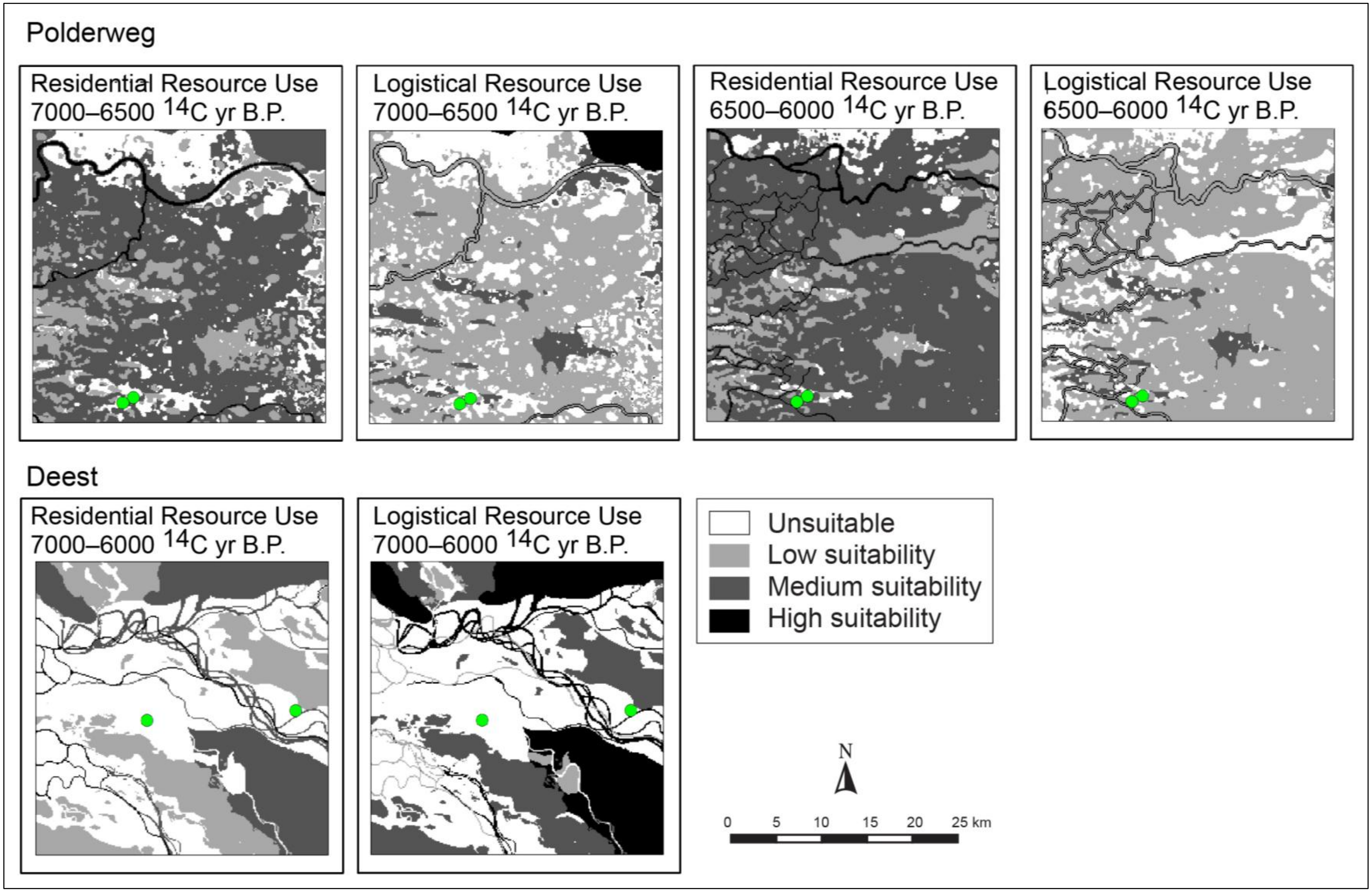


Figure G.21 Initial Run of Model Wetlands, Polderweg and Deest Areas.

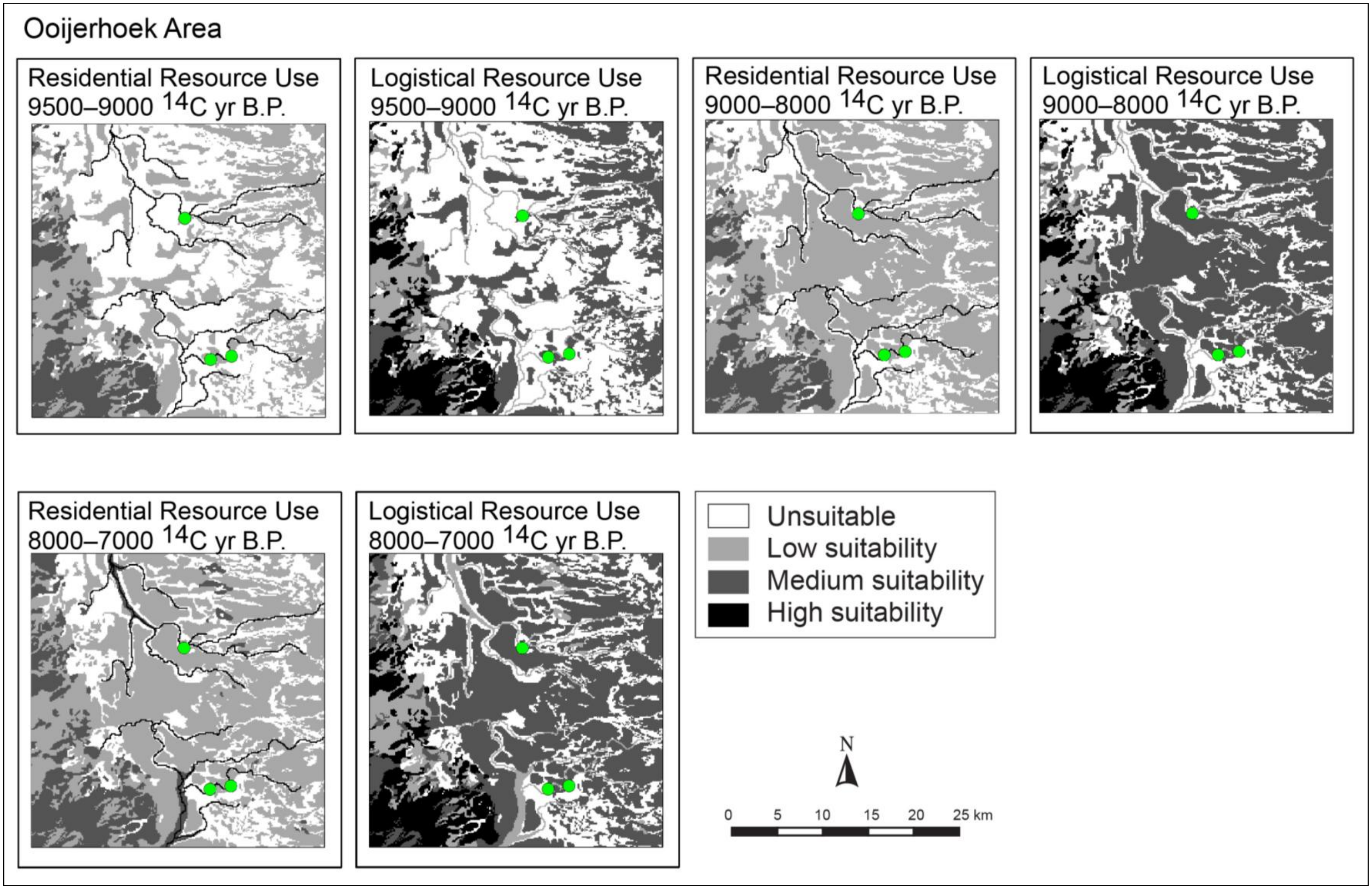


Figure G.22 Initial Run of Model Wetlands, Ooijerhoek Area.

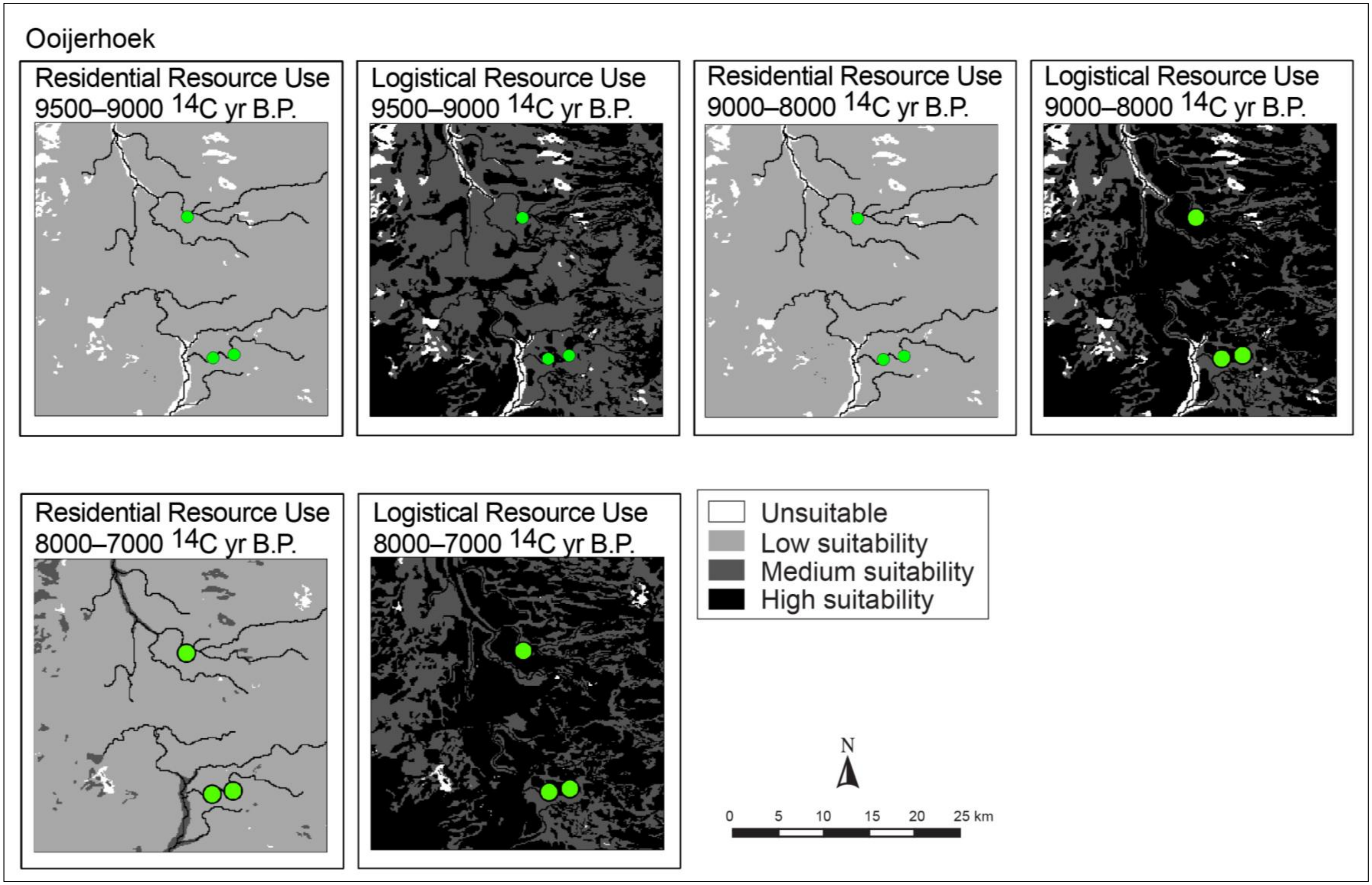


Figure G.23 Second Run of Model Wetlands, Ooijerhoek Area.

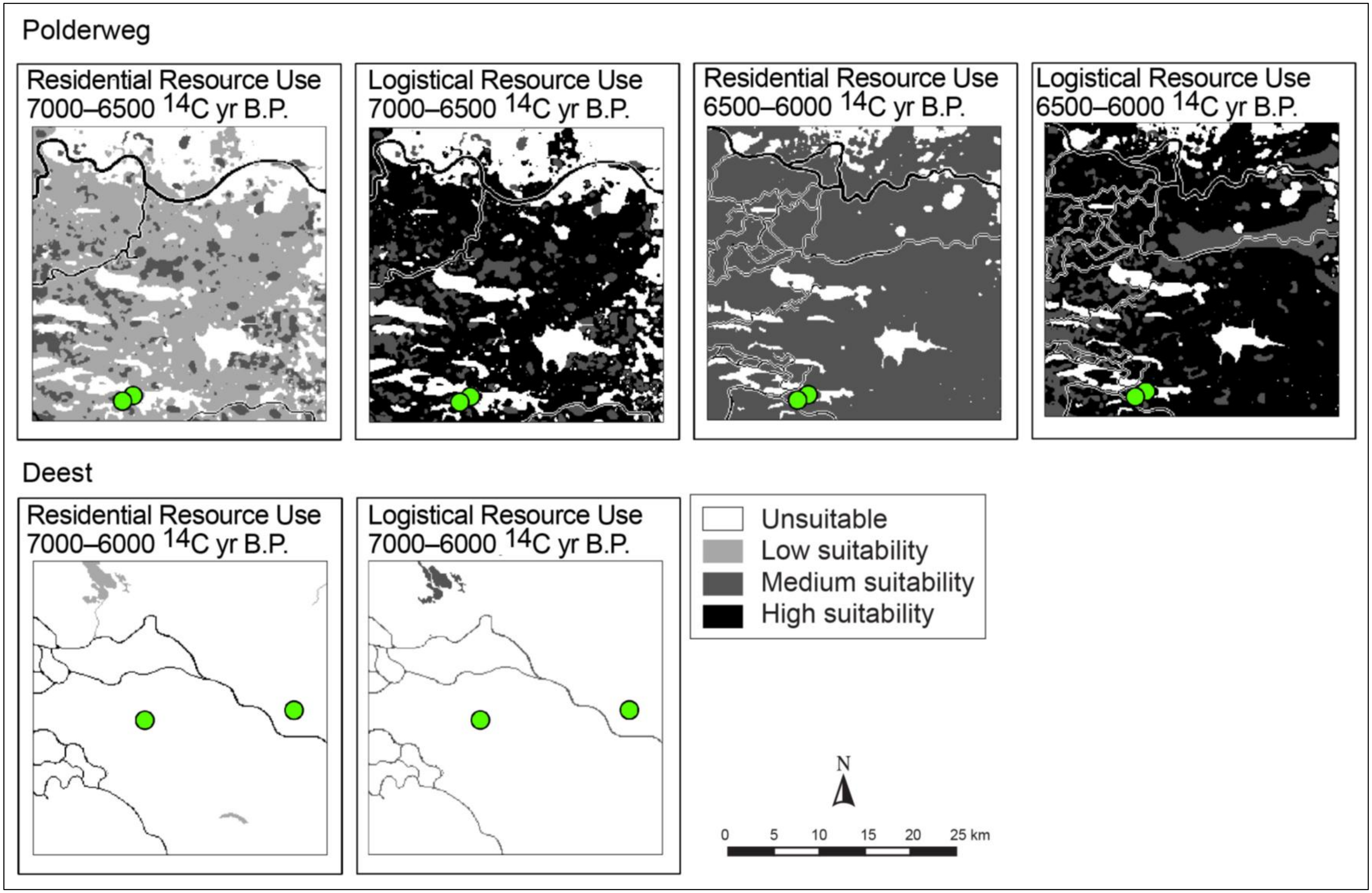


Figure G.24 Final Run of Model Wetlands, Polderweg and Deest Areas.

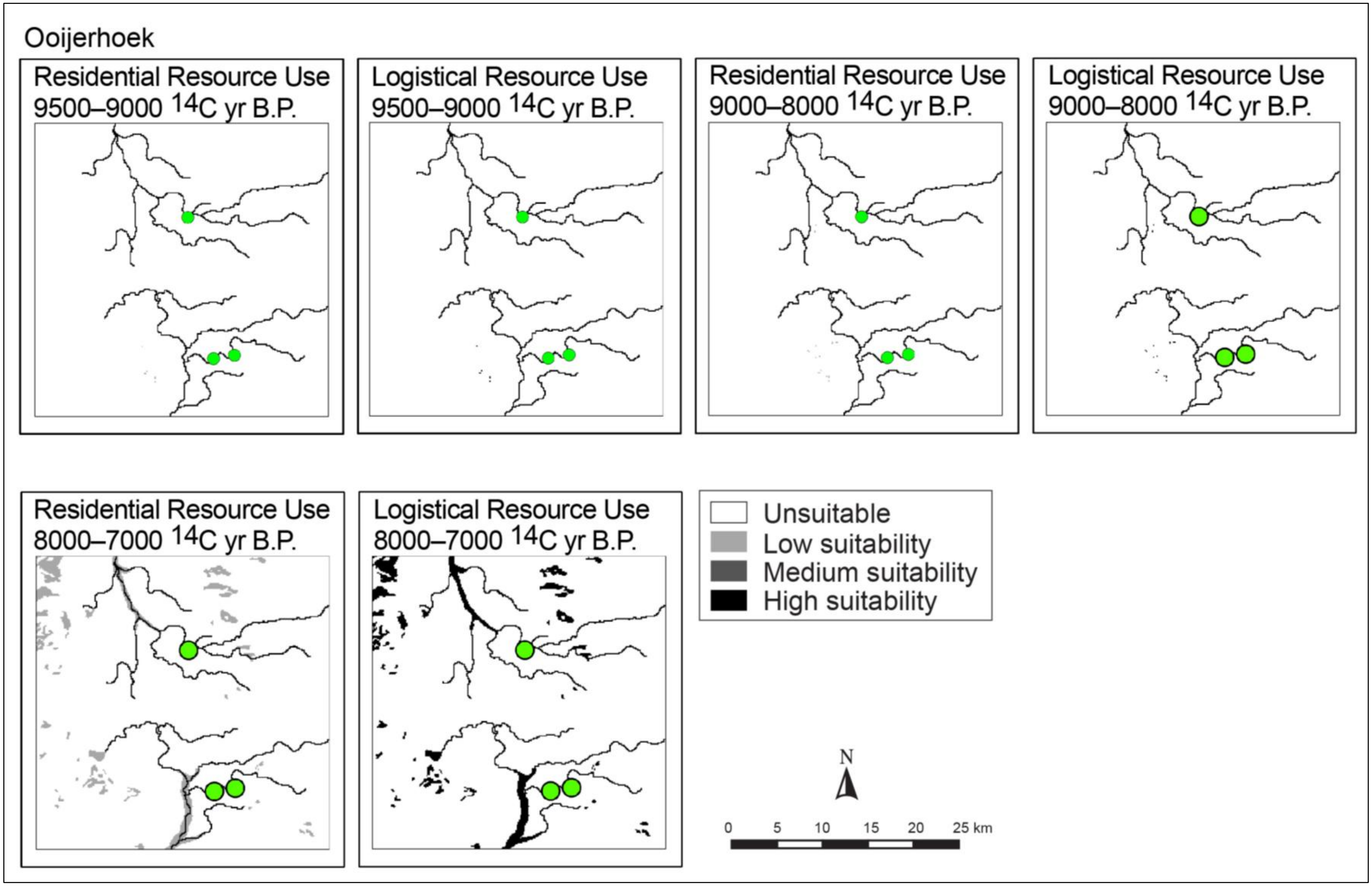


Figure G.25 Final Run of Model Wetlands, Ooijerhoek Area.

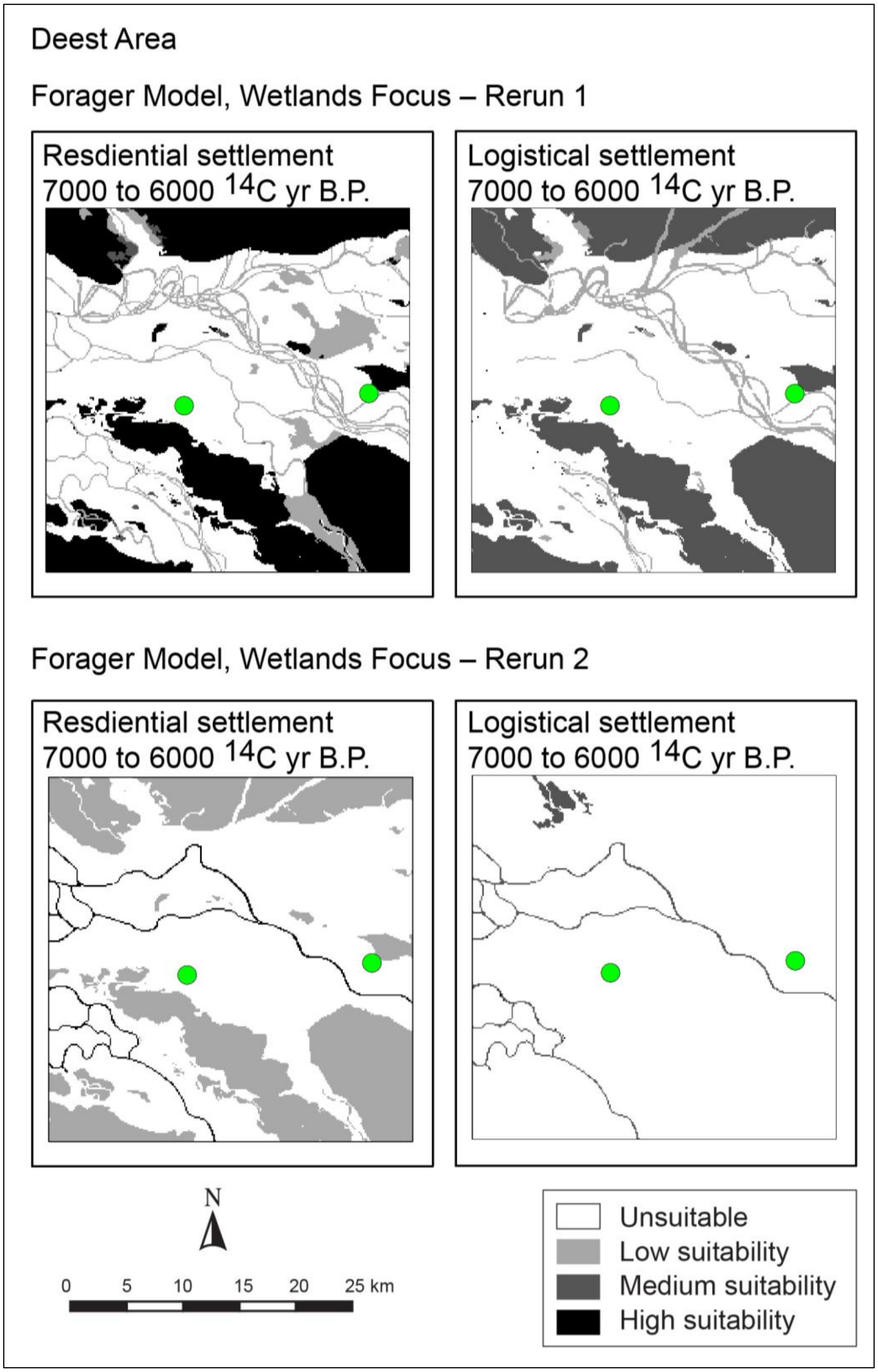


Figure G.26 Forager Model, Wetland Focus for the Deest Area, Reruns 1 and 2.

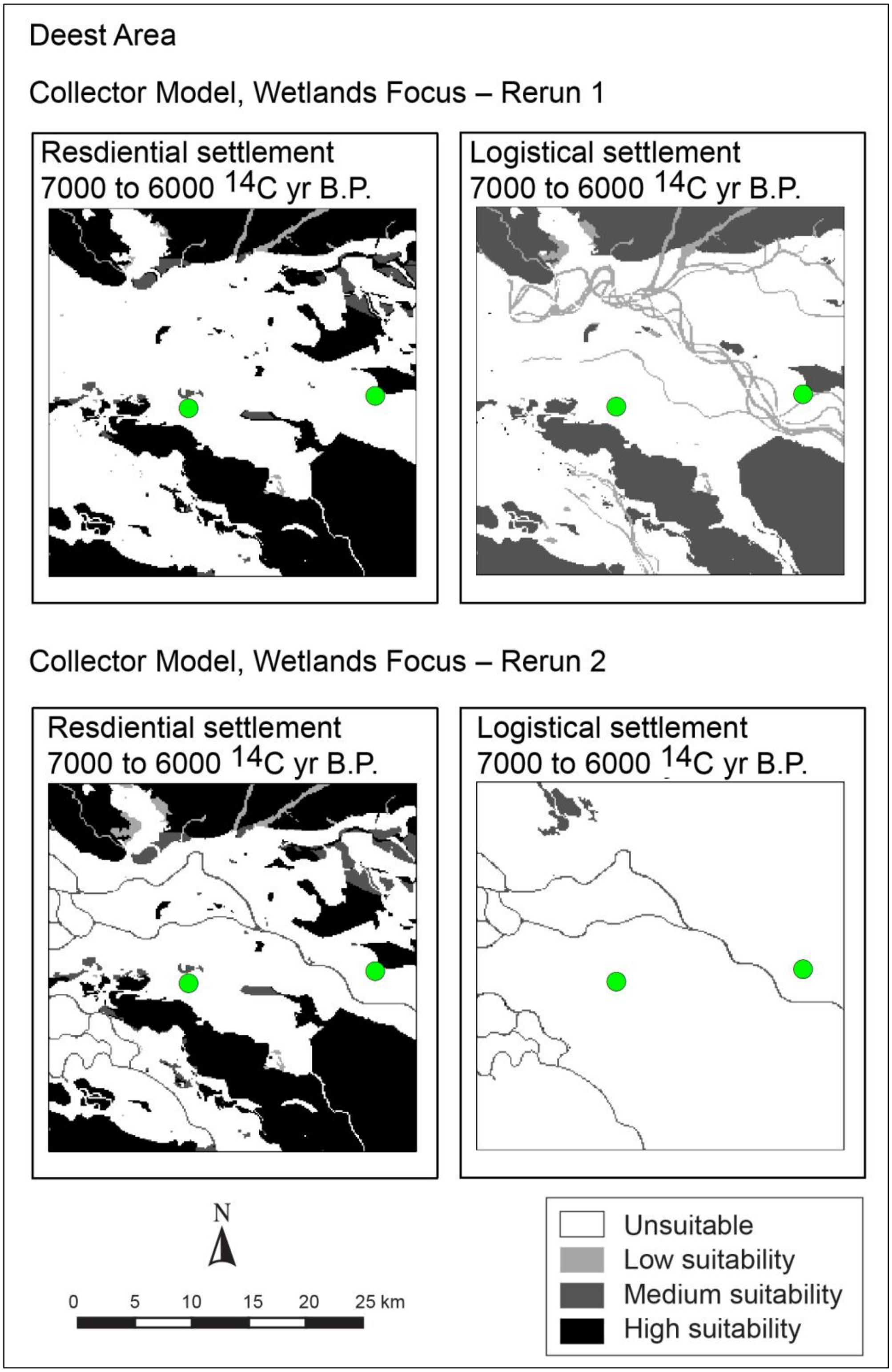


Figure G.27 Collector Model, Wetland Focus for the Deest Area, Reruns 1 and 2.

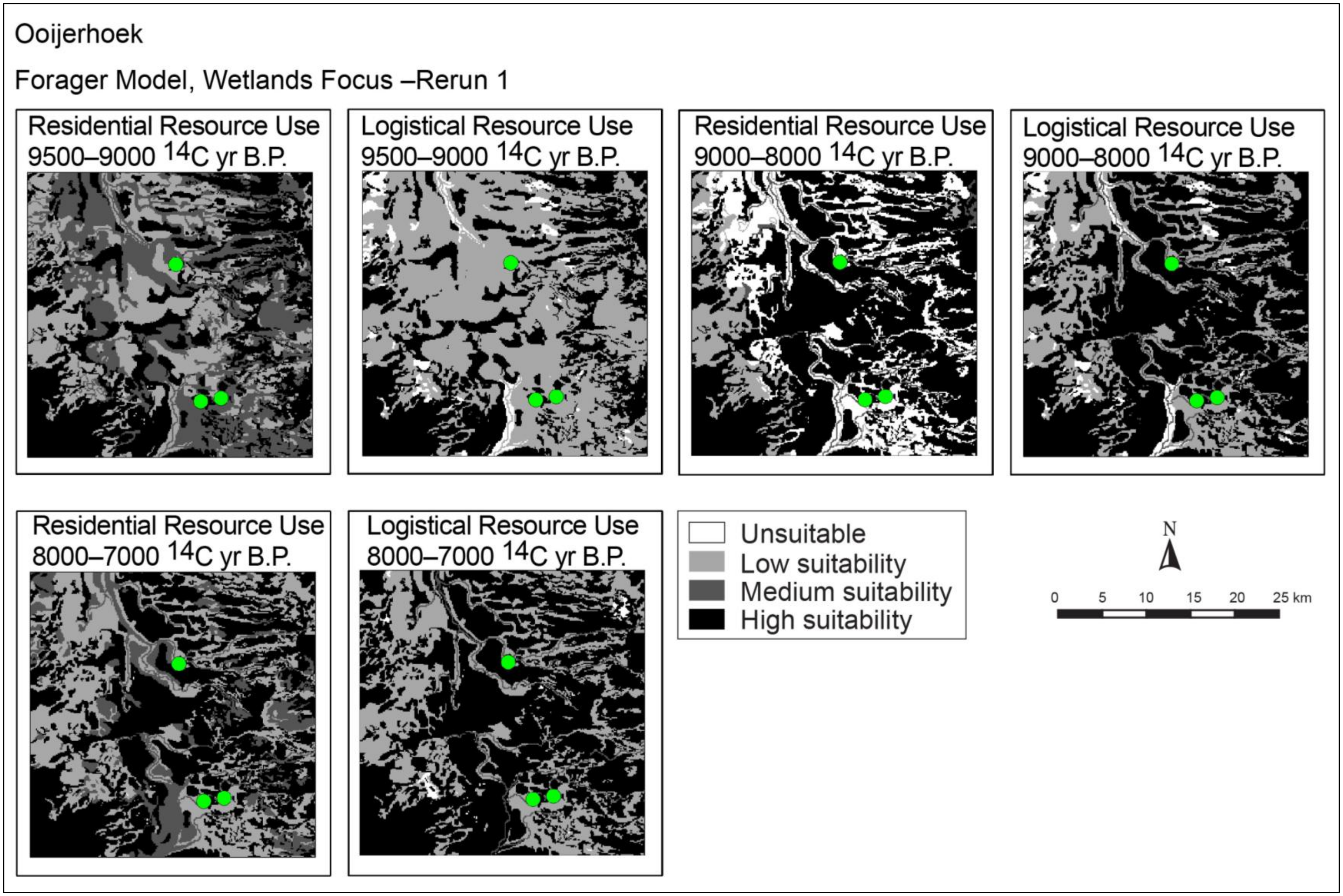


Figure G.28 Forager Model, Wetland Focus for the Ooijerhoek Area, Rerun 1.

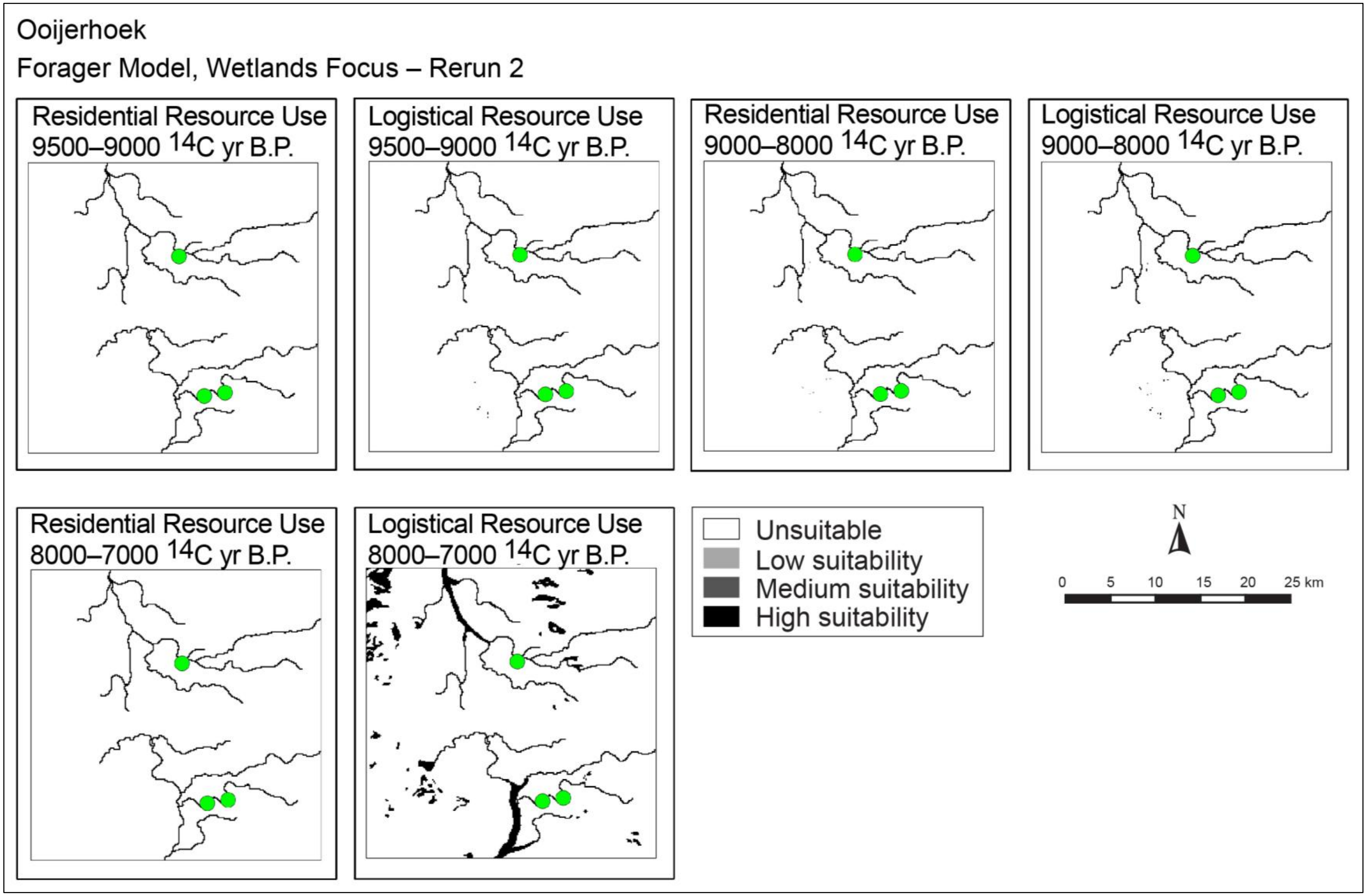


Figure G.29 Forager Model, Wetland Focus for the Ooijerhoek Area, Rerun 2.

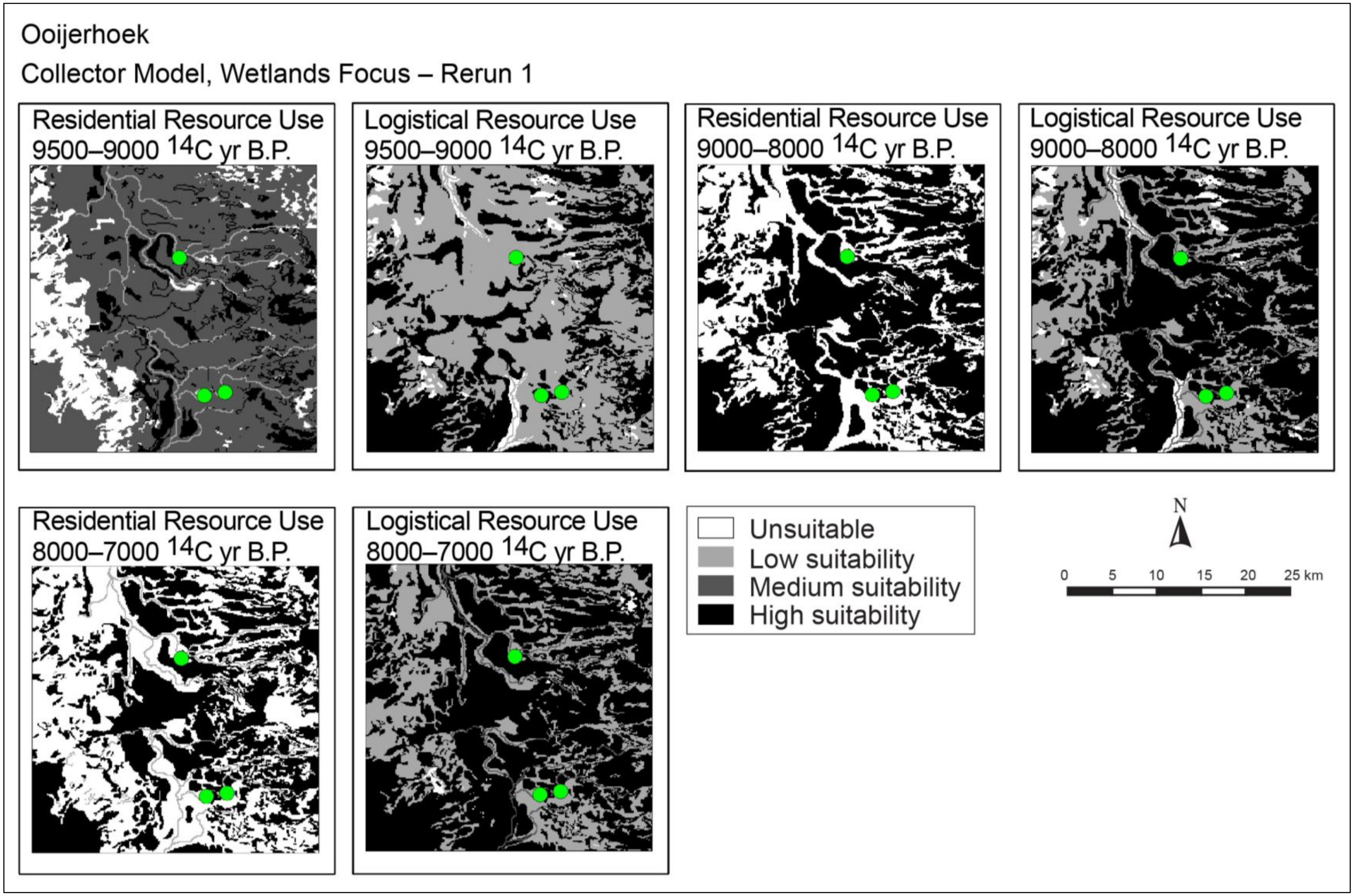


Figure G.30 Collector Model, Wetland Focus for the Ooijerhoek Area, Rerun 1.

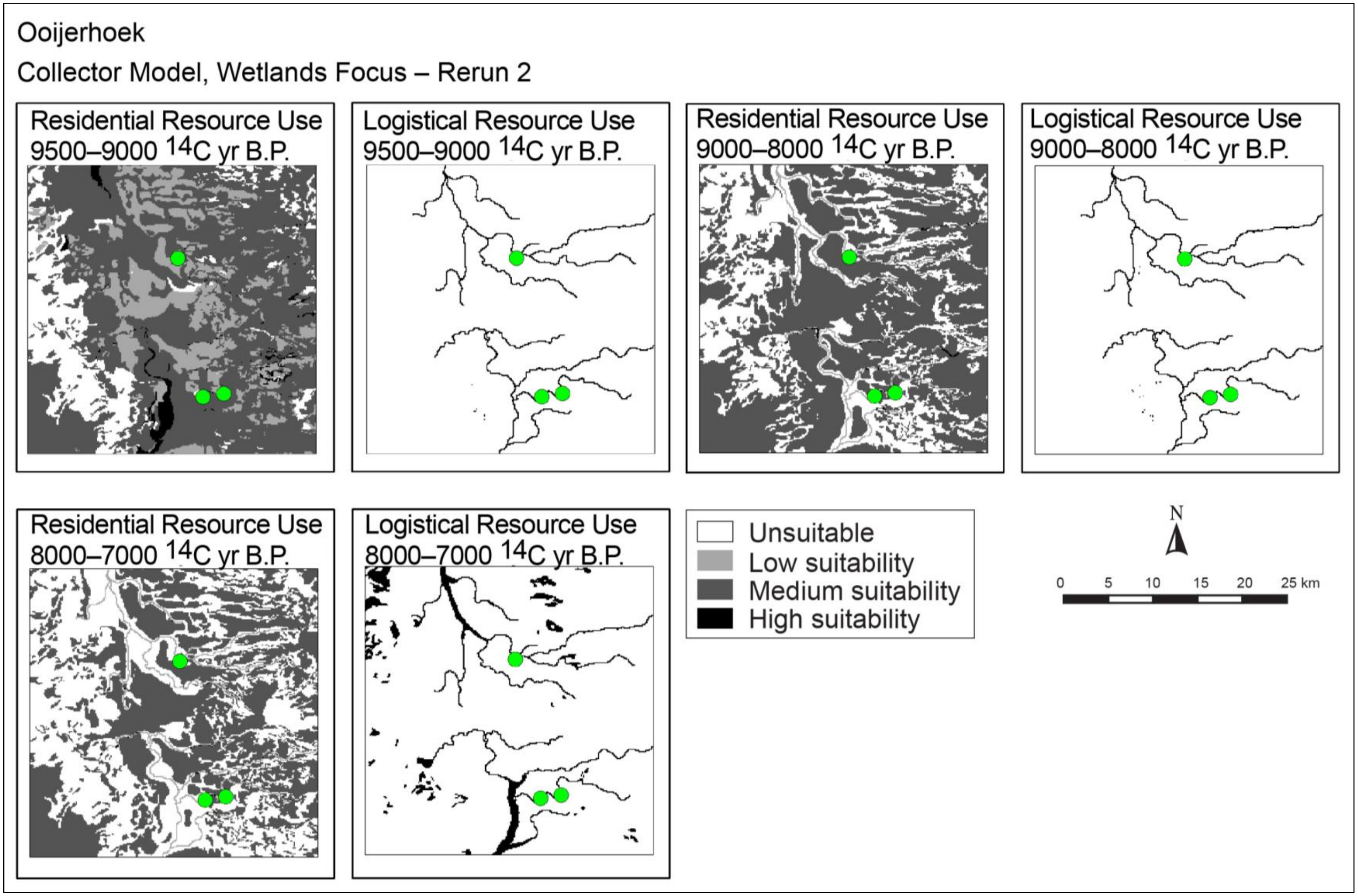


Figure G.31 Collector Model, Wetland Focus for the Ooijerhoek Area, Rerun 2.

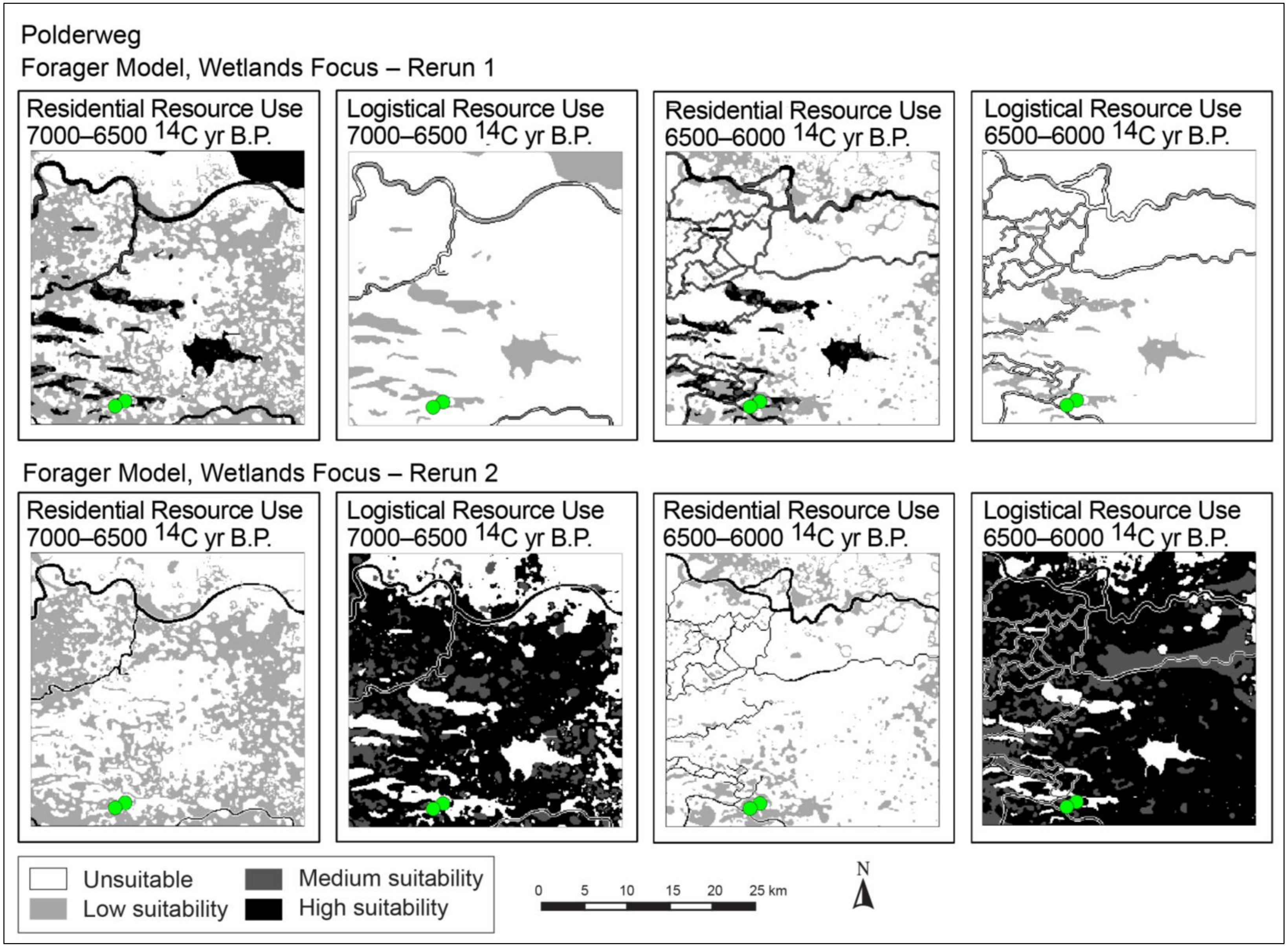


Figure G.32 Foraging Model, Wetland Focus for the Polderweg Area, Reruns 1 and 2.

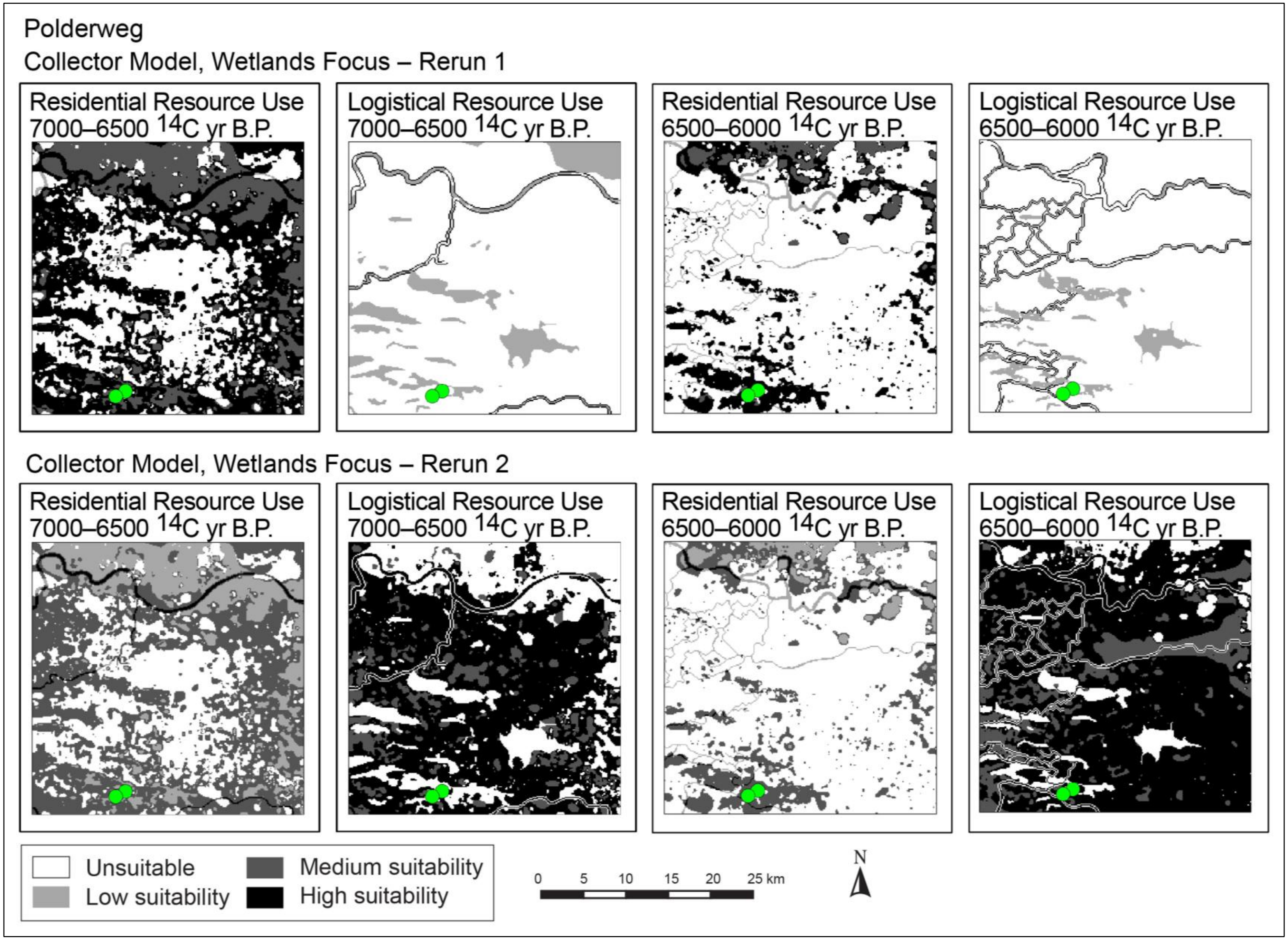


Figure G.33 Collector Model, Wetland Focus for the Polderweg Area, Reruns 1 and 2.

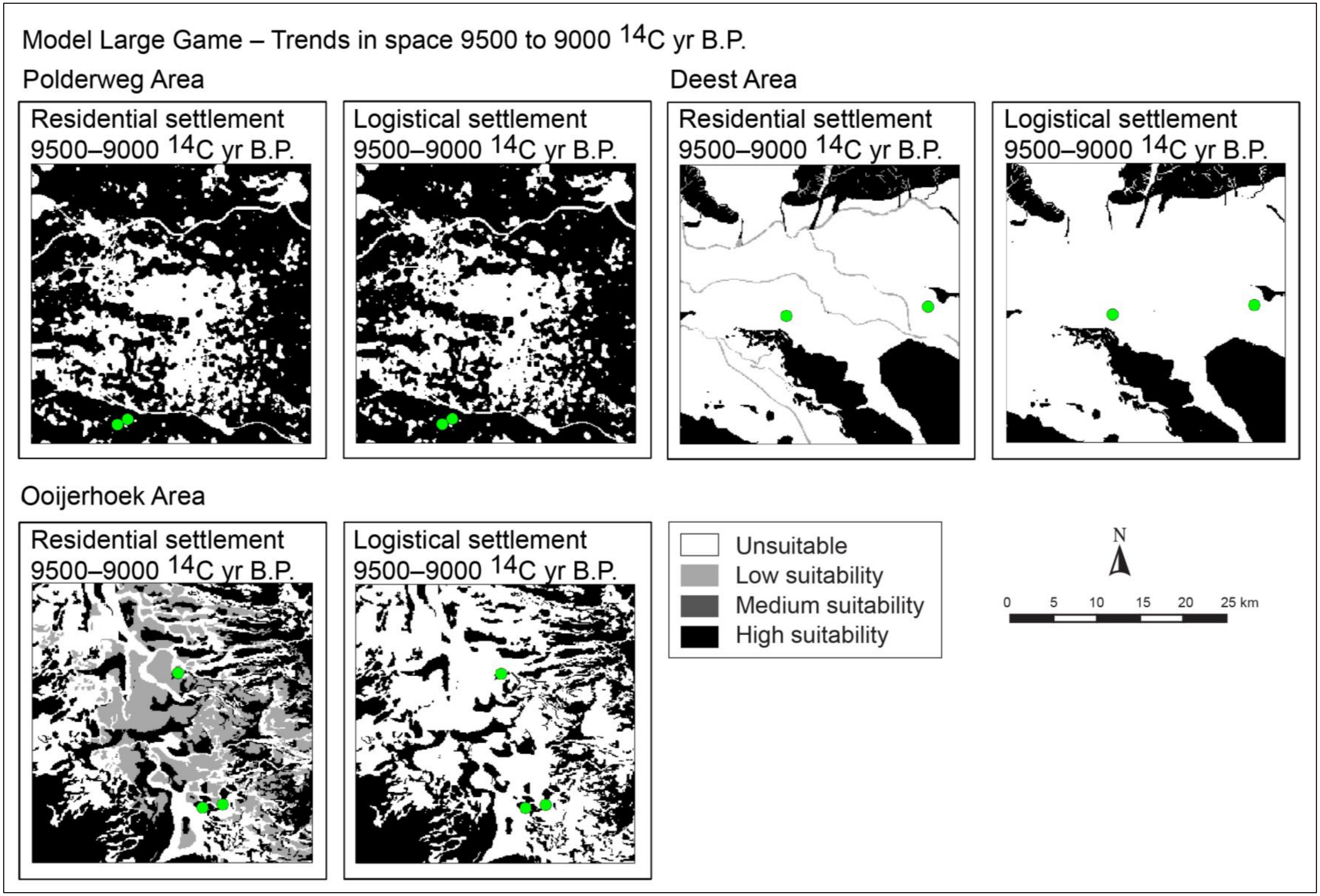


Figure G.34 Suitability of Large Game Extraction During the Preboreal Period.

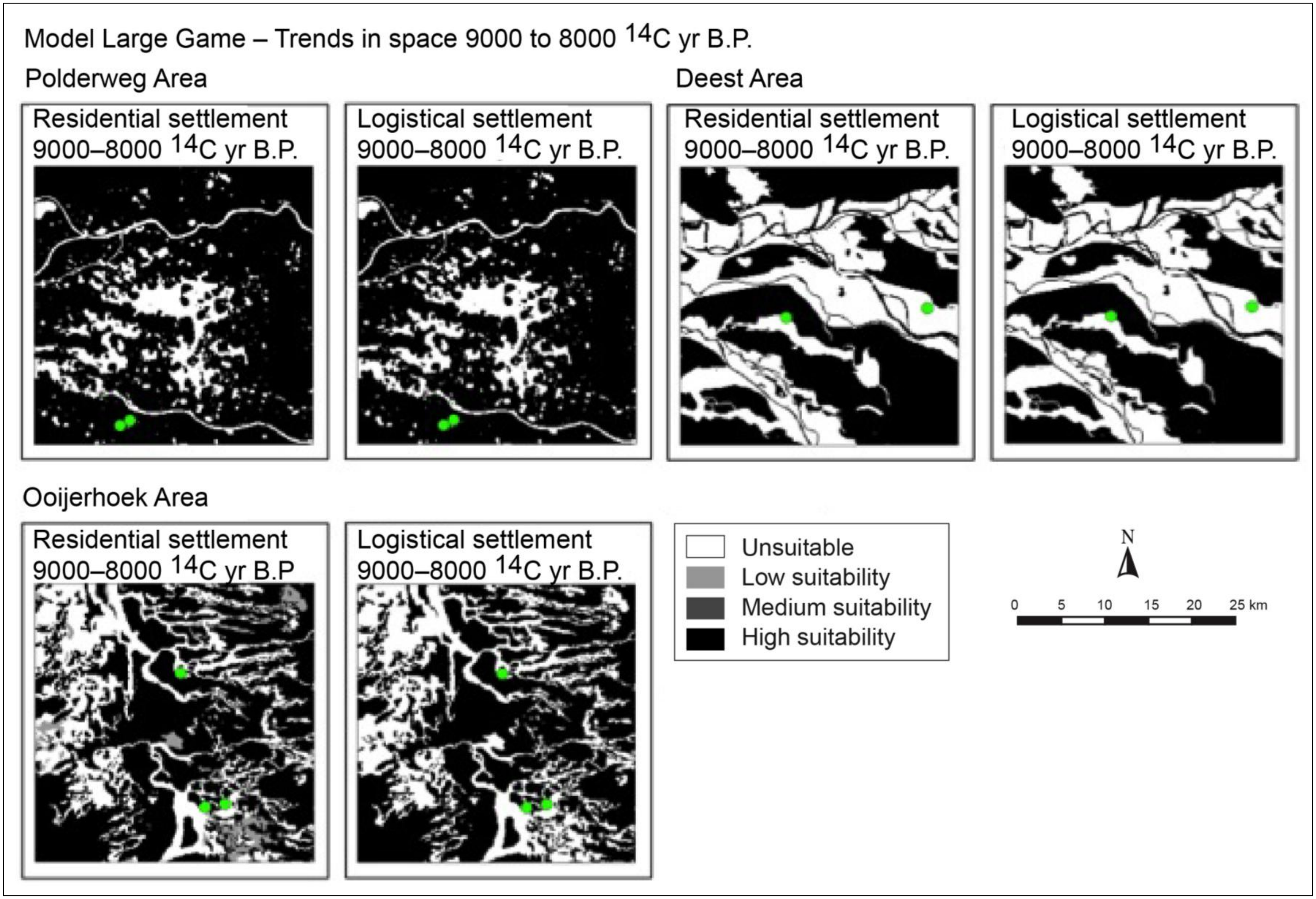


Figure G.35 Suitability of Large Game Extraction During the Boreal Period.

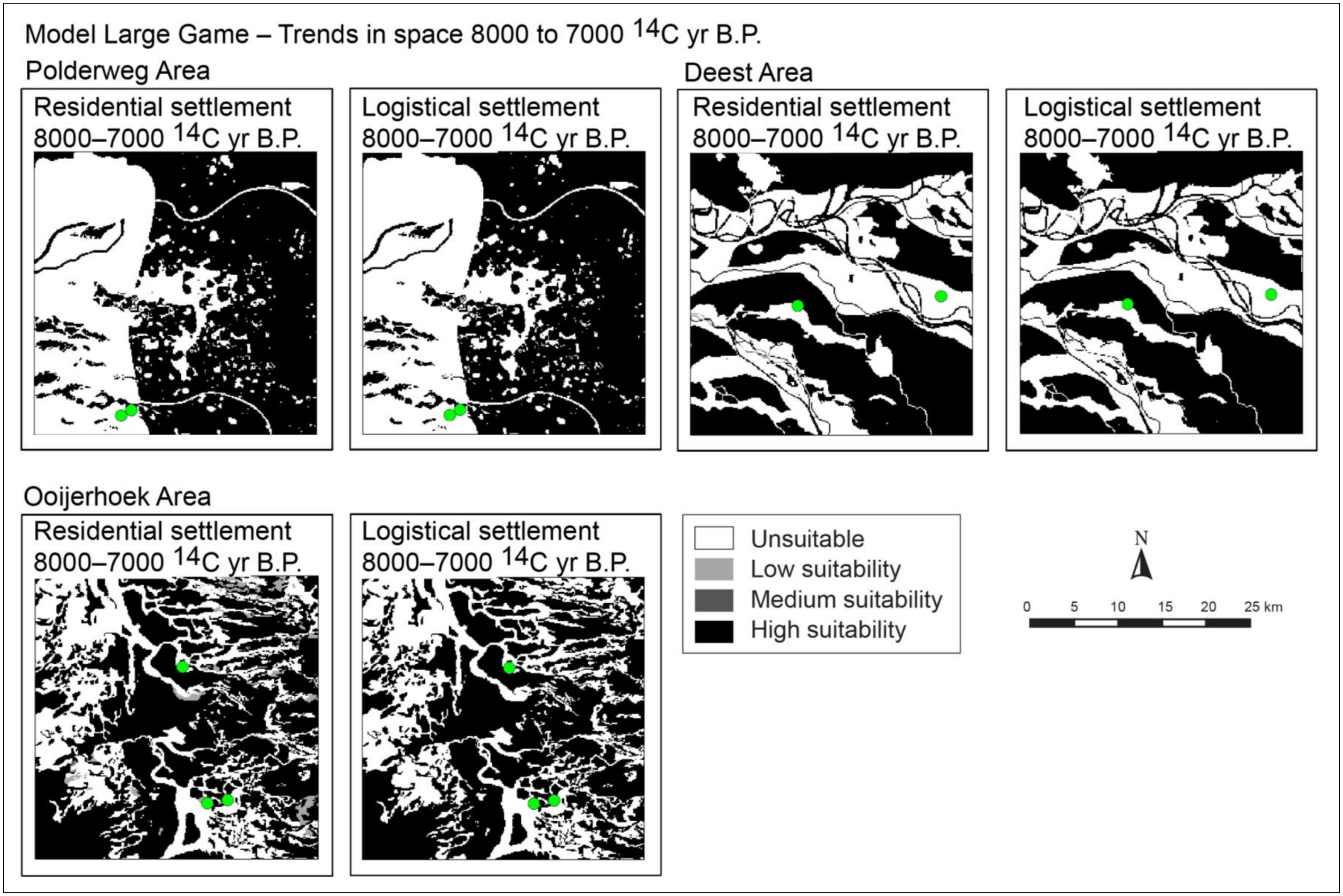


Figure G.36 Suitability of Large Game Extraction During the Early Atlantic Period.

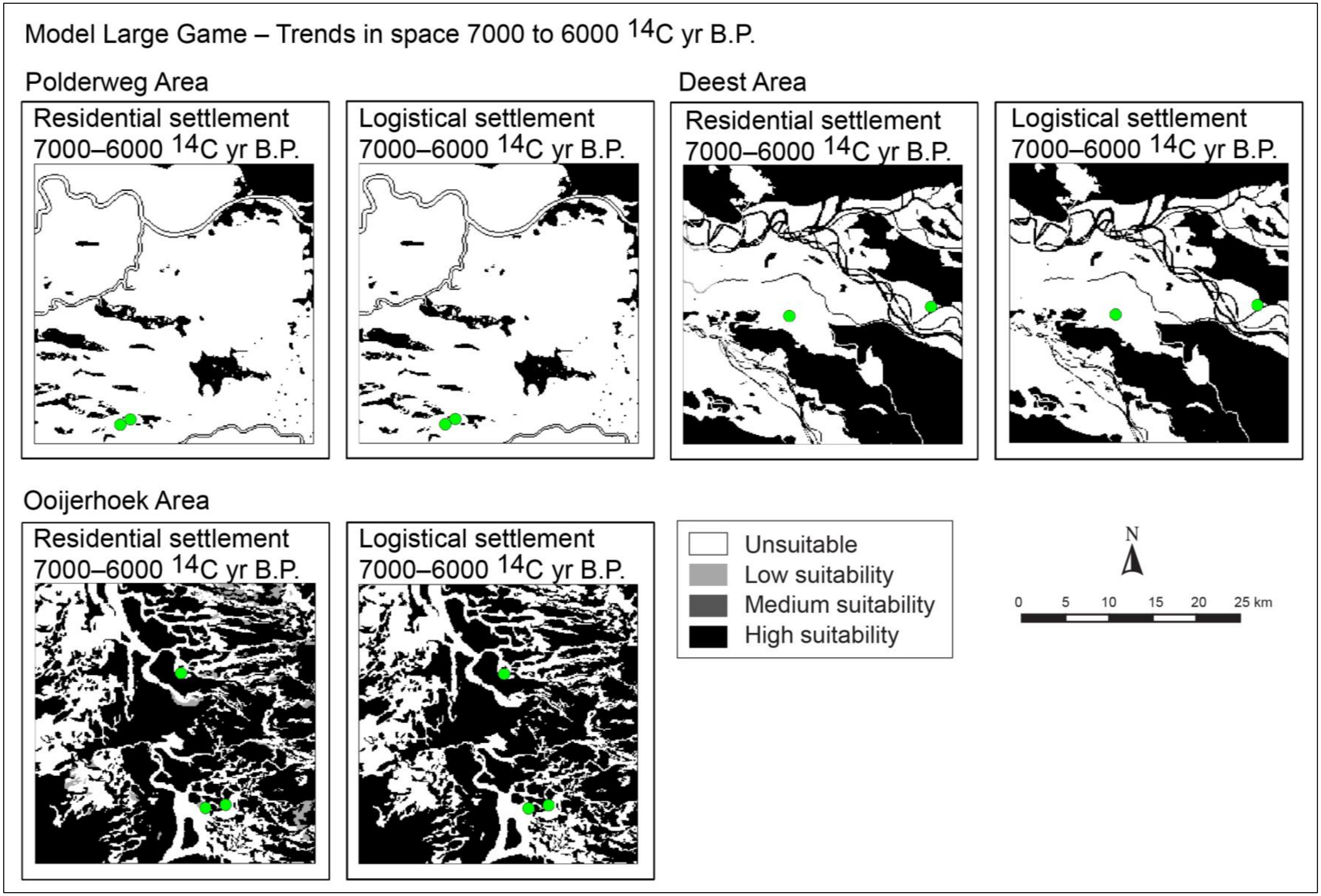


Figure G.37 Suitability of Large Game Extraction During the Middle Atlantic Period.

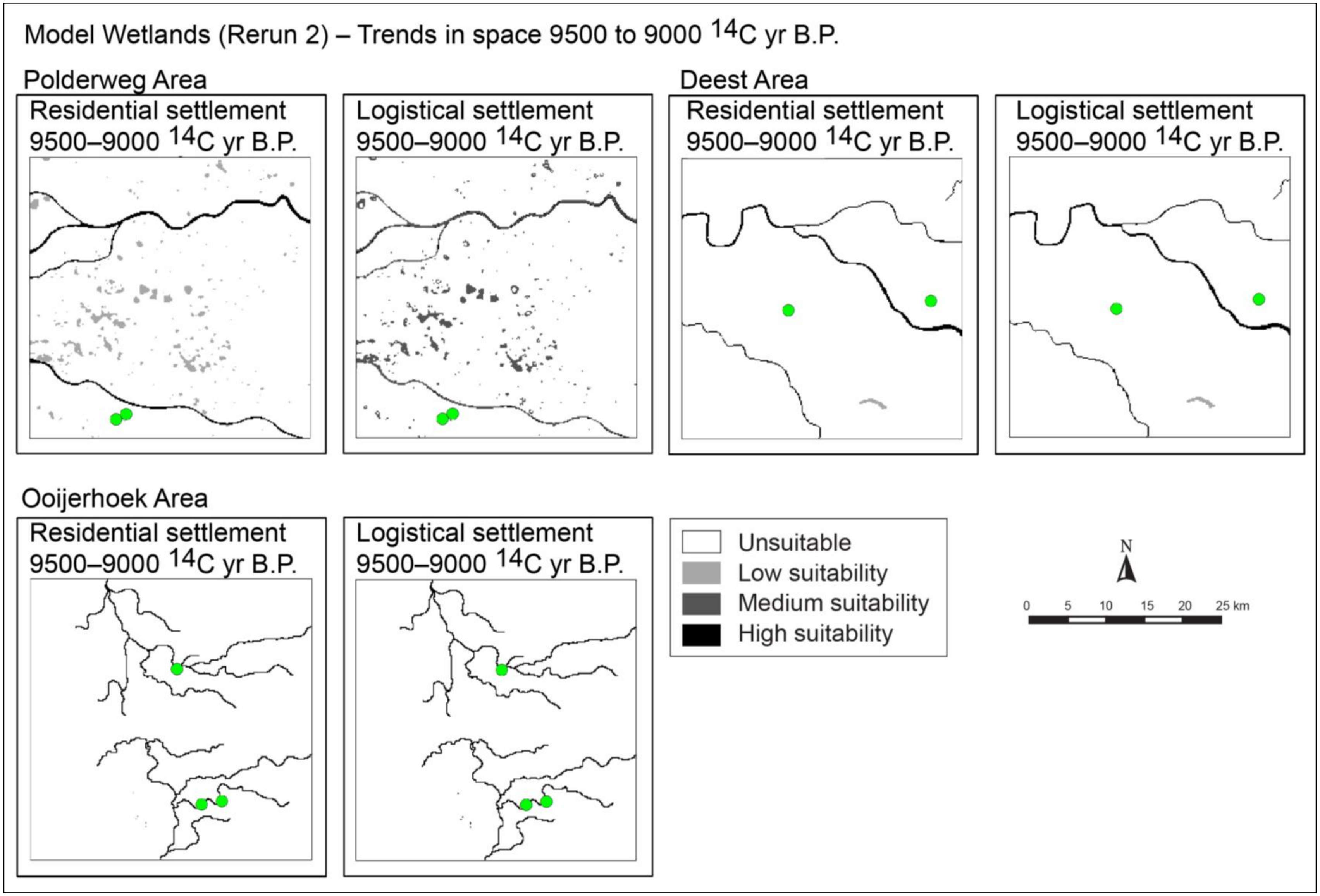


Figure G.38 Suitability of Wetland Resource Extraction During the Preboreal Period.

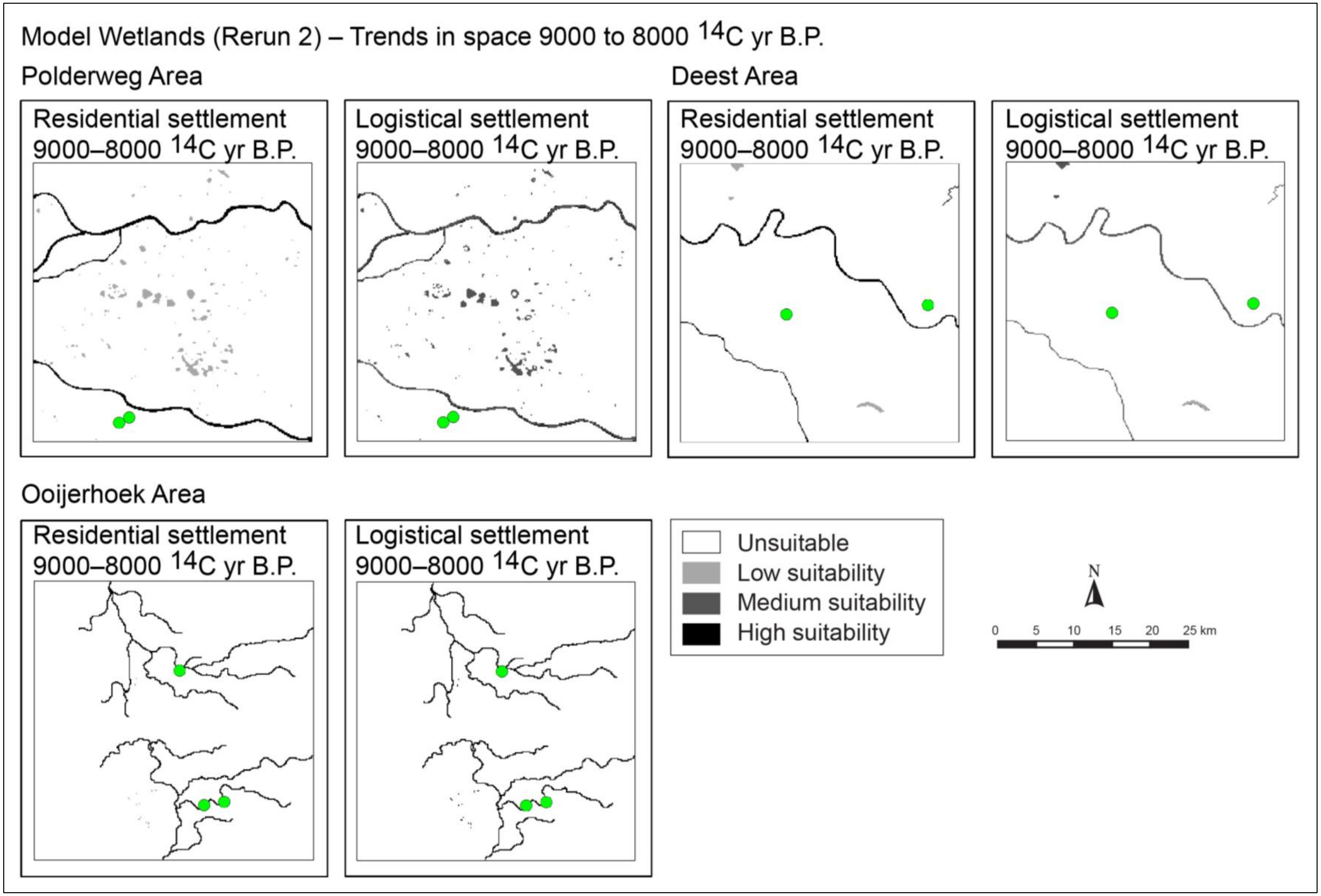


Figure G.39 Suitability of Wetland Resource Extraction During the Boreal Period.

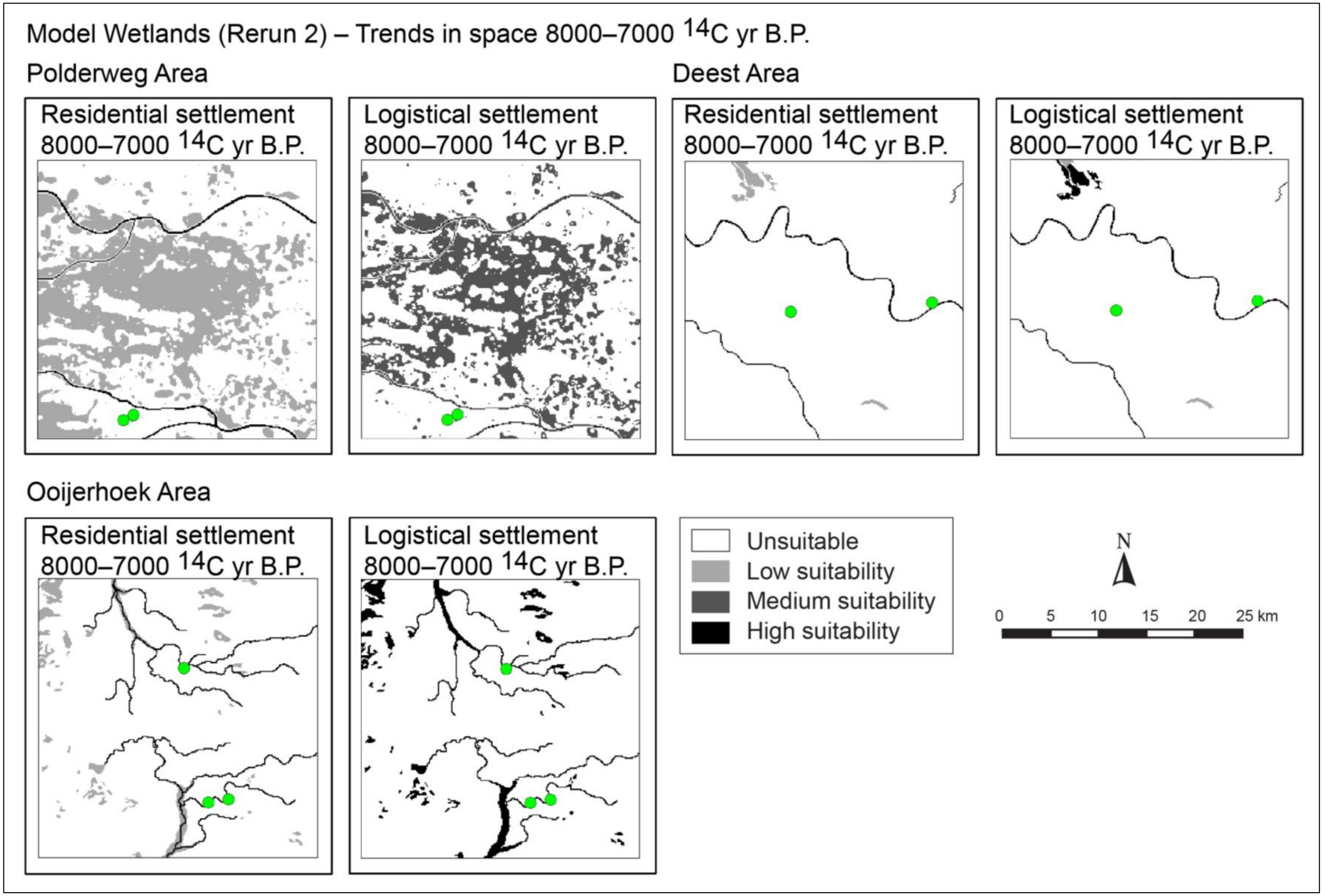


Figure G.40 Suitability of Wetland Resource Extraction During the Early Atlantic Period.

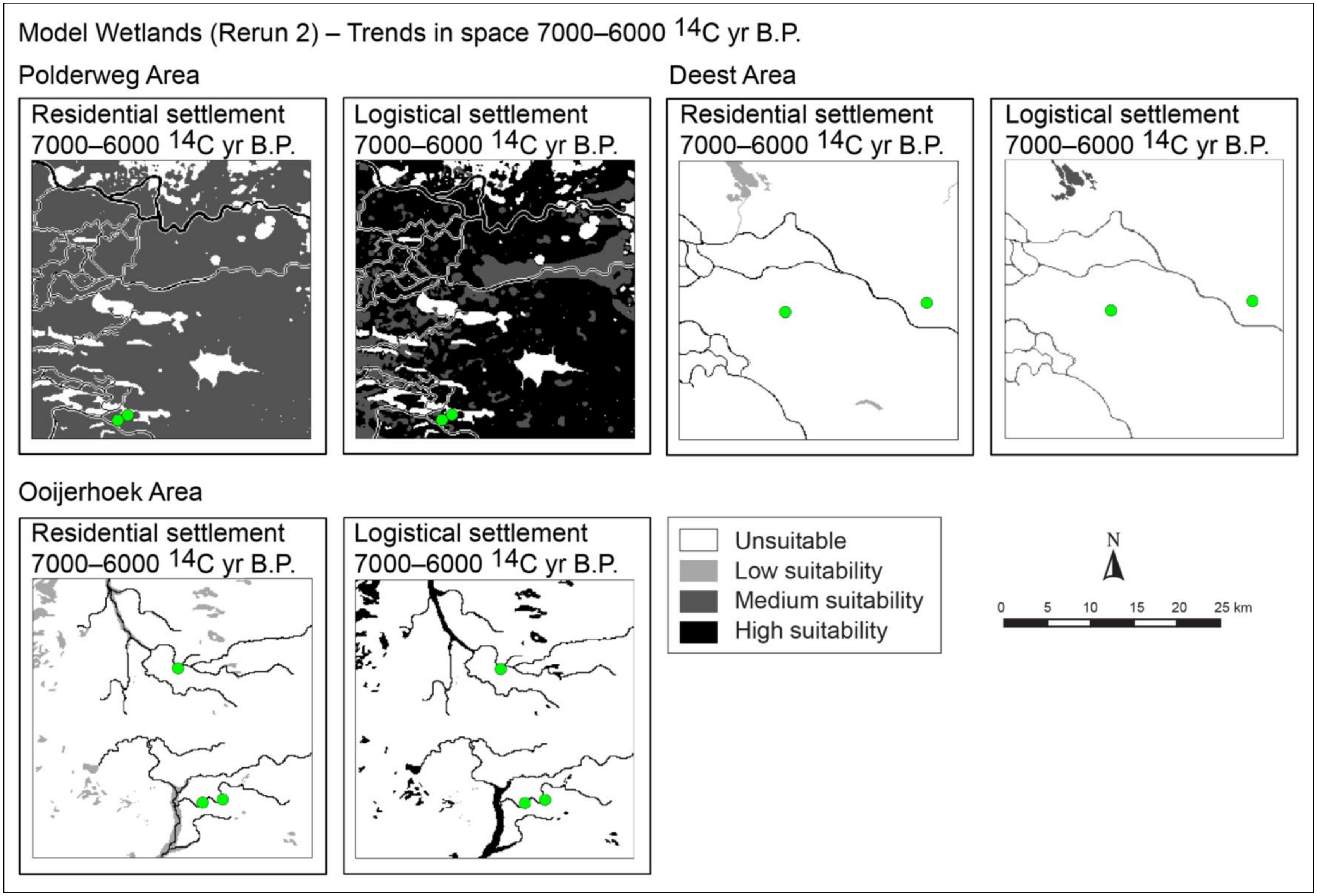


Figure G.41 Suitability of Wetland Resource Extraction During the Middle Atlantic Period.

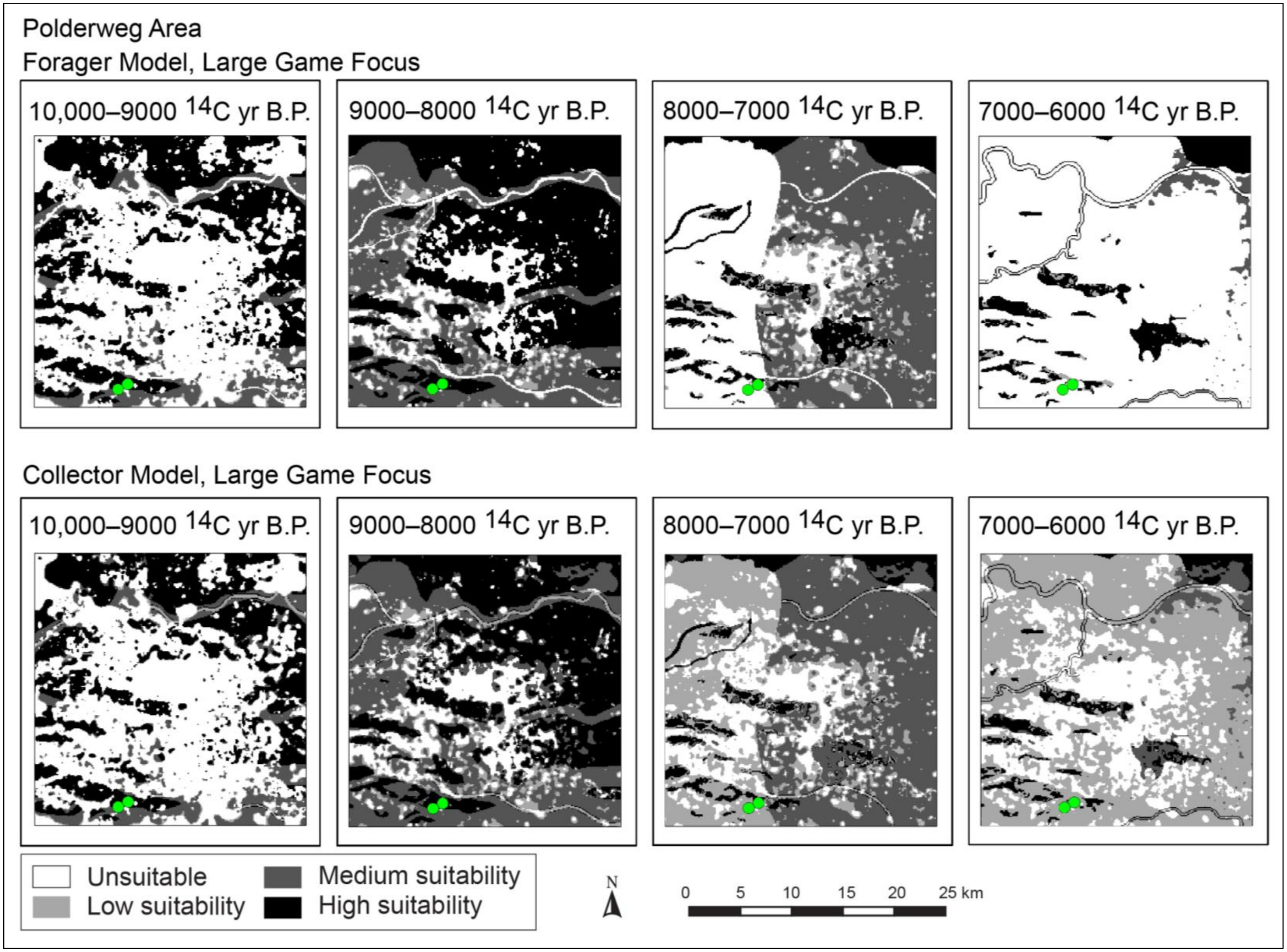


Figure G.42 Areas Predicted to Have Been Used for Hunting and Gathering Large Game and Non-Preferential Species, Polderweg Area.

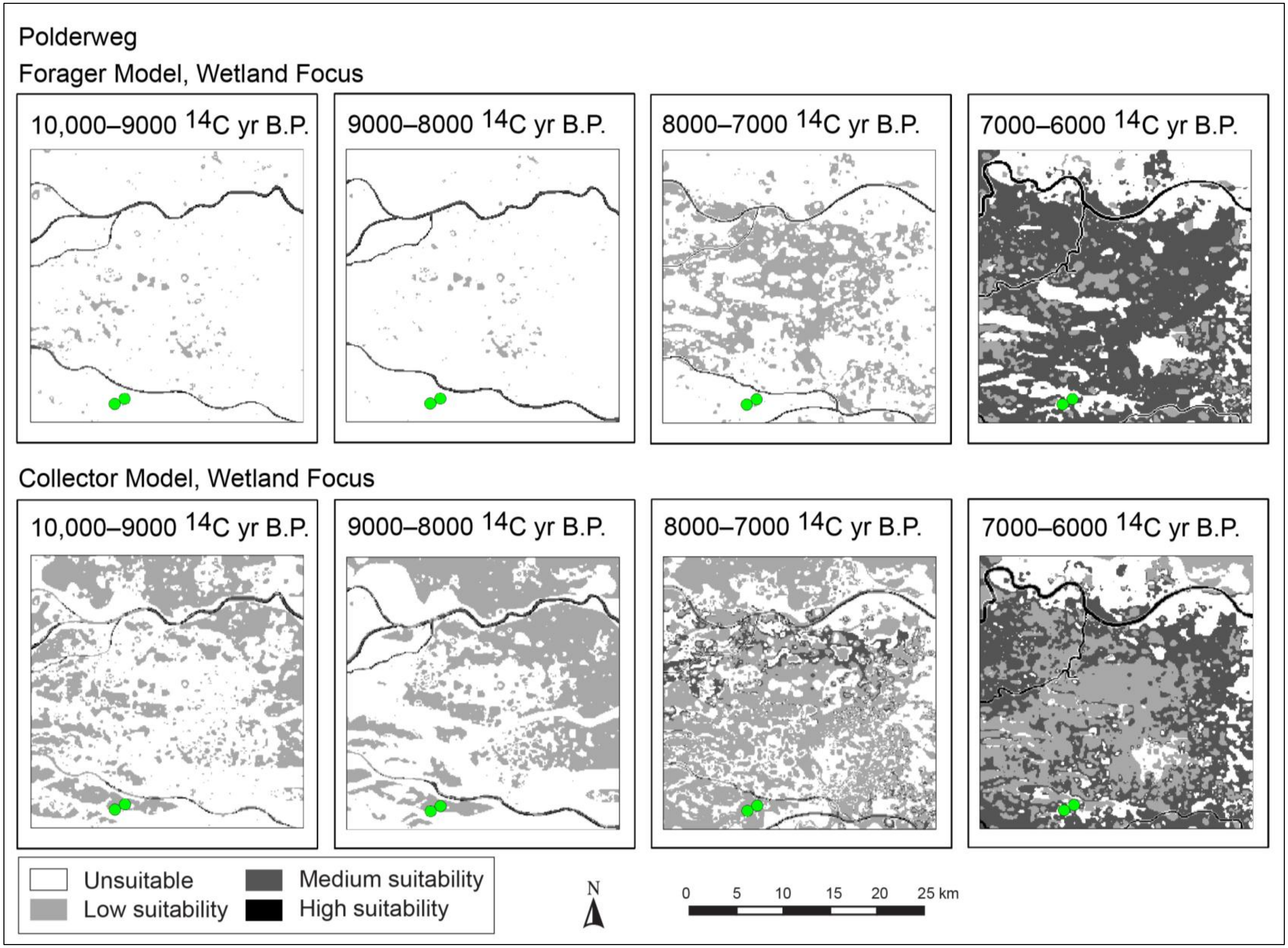


Figure G.43 Areas Predicted to Have Been Used for Extraction of Wetland Species, Polderweg Area.

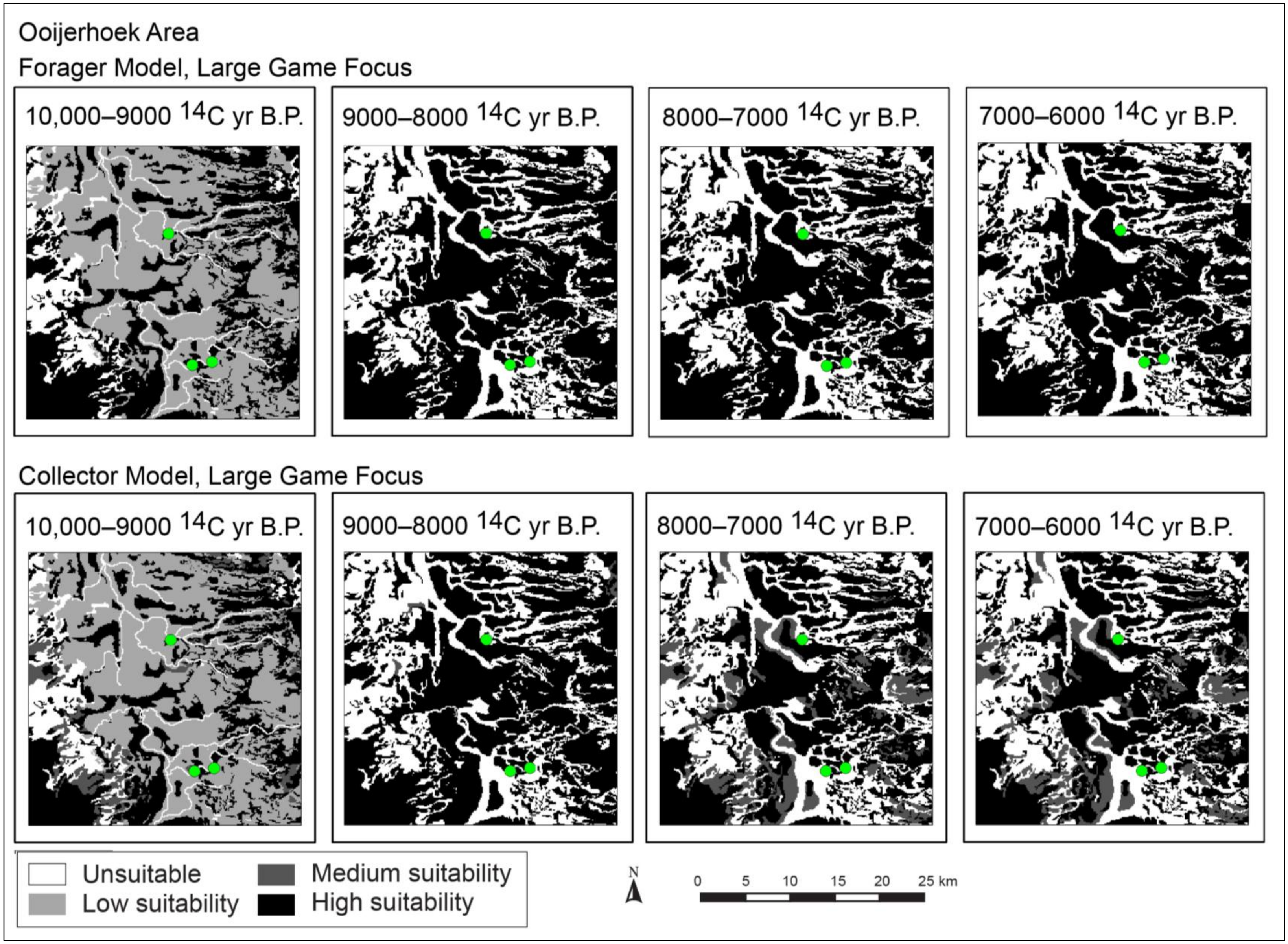


Figure G.44 Areas Predicted to Have Been Used for Extraction of Large Game and Other Species, Ooijerhoek Area.

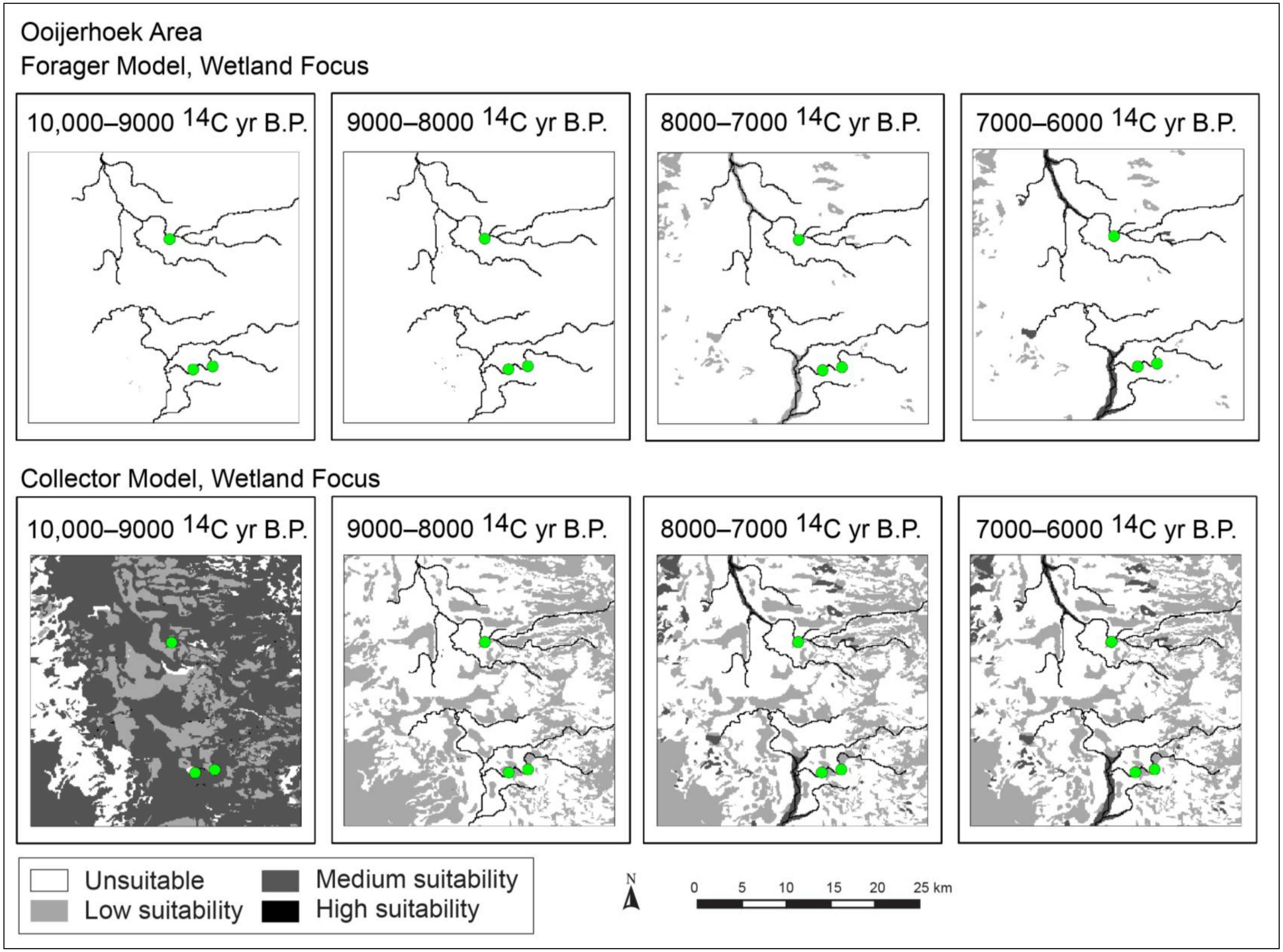


Figure G.45 Areas Predicted to Have Been Used for Extraction of Wetland Species, Ooijerhoek Area.

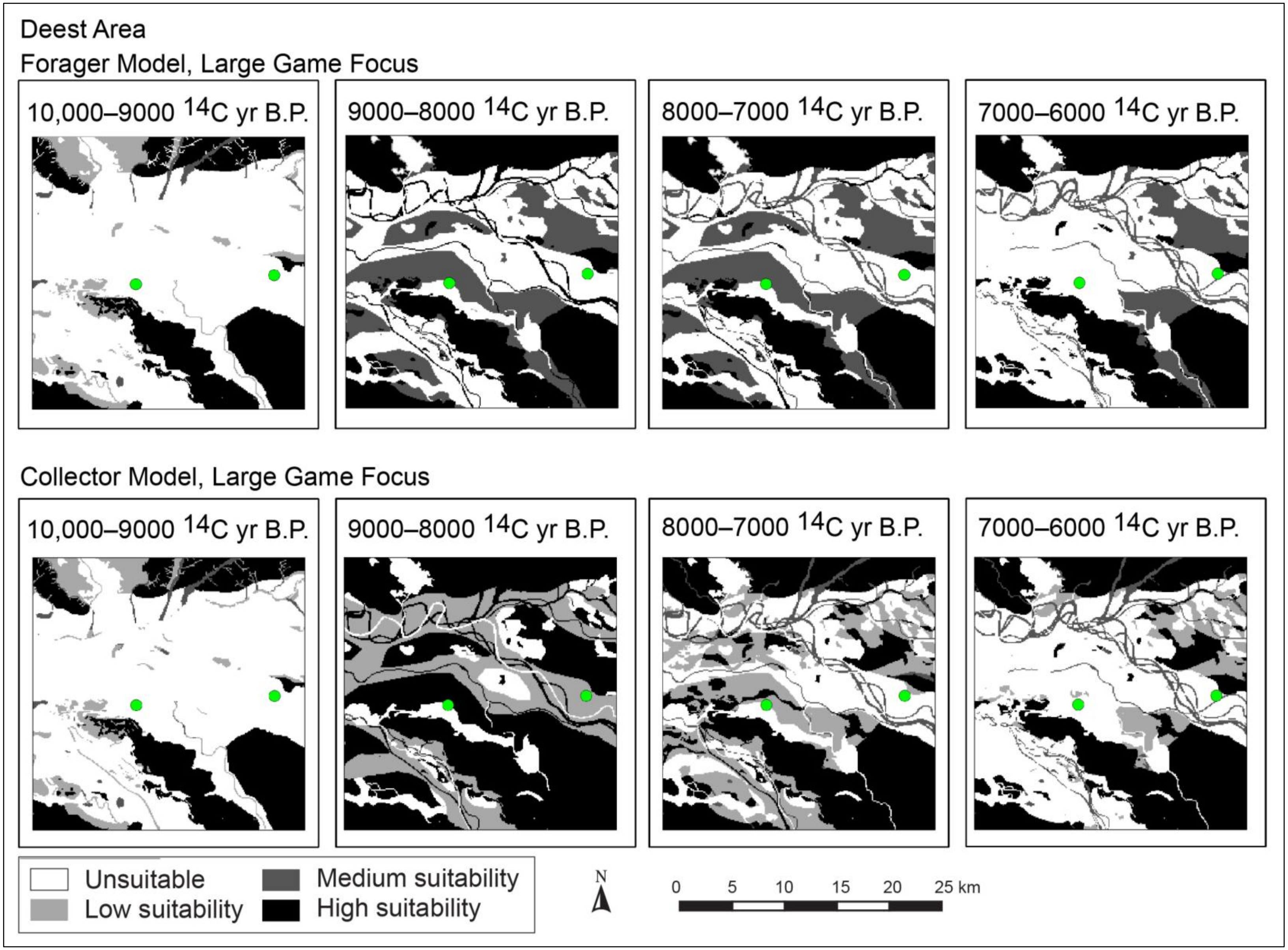


Figure G.46 Areas Predicted to Have Been Used for Extraction of Large Game and Other Resources, Deest Area.

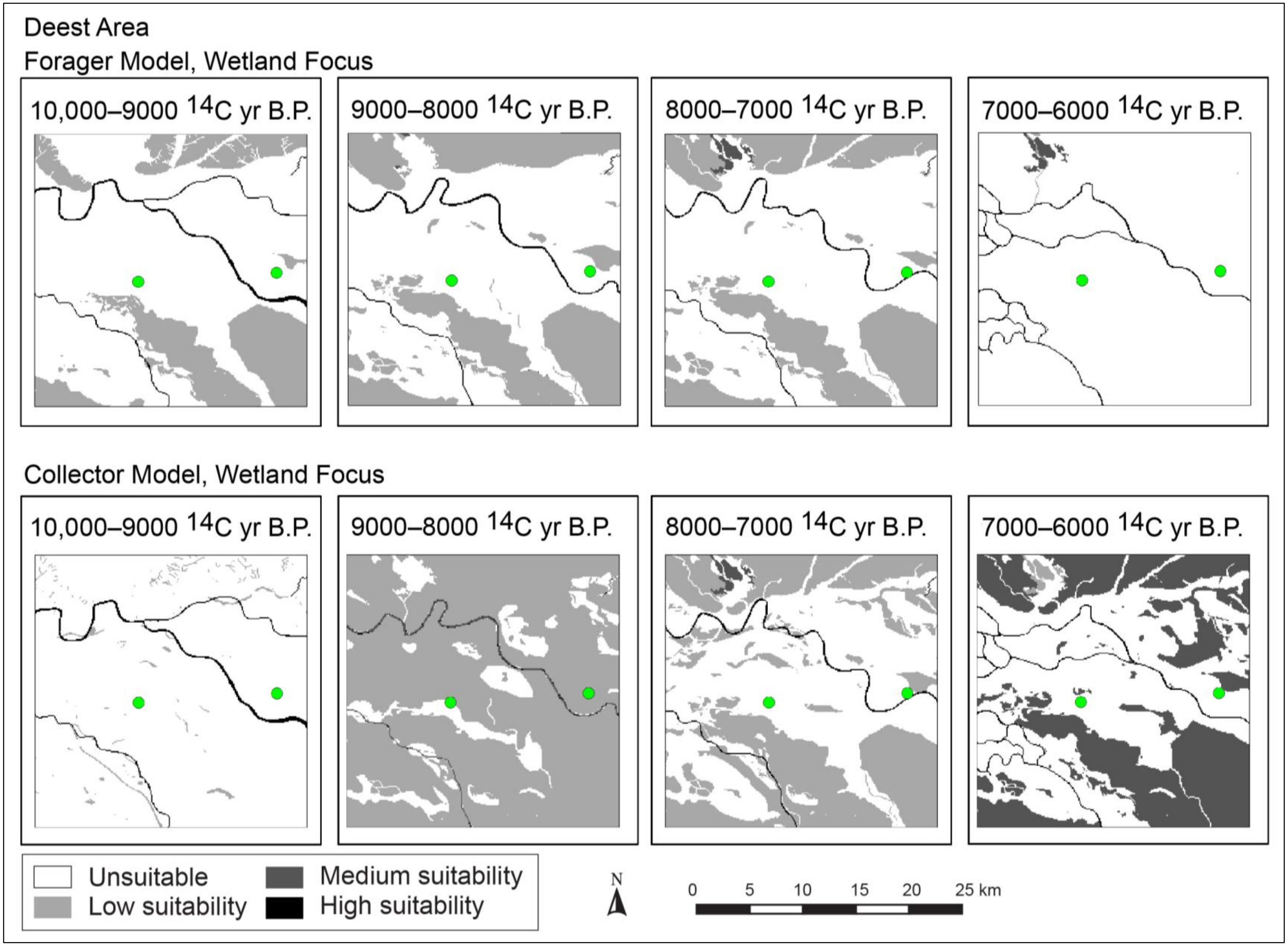


Figure G.47 Areas Predicted to Have Been Used for Extraction of Wetland Species, Deest Area.

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