Analysis of 13C and 15N isotopes from Eurasian Quaternary fossils: Insights in diet, climate and ecology

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CHAPTER 4

FOSSIL BONES FROM THE NORTH SEA: STABLE ISOTOPES

The research described in this chapter is based on the following studies:
Kuitems, M., van der Plicht, J., forthcoming. Fossil bones from the North Sea: stable isotopes. *Paleontos*, accepted.

van der Plicht, J., Kuitems, M., forthcoming. Fossil bones from the North Sea: radiocarbon dates. *Paleontos*, accepted.

Kuitems, M., van Kolfschoten, T., De Loecker, D., Busschers, F.S., 2015. Geoarchaeological and palaeontological research in the Maasvlakte 2 sand extraction zone and on the artificially created Maasvlakte 2 beach: a synthesis. B*OORrapporten* **48**.

4.1 Introduction

The North Sea is today a domain of mammoth tankers, but once it was dominated by the woolly mammoths and other Ice-Age creatures. During the Weichselian, when the sea level was much lower than today, the North Sea area was land and thousands of recovered fossil remains witness the past occurrence of hominins and mammals.

This chapter presents an inventory of the stable isotope values of North Sea finds that have been measured by the Centre for Isotope Research in Groningen. A general overview of the stable isotope results is given, and some aspects are discussed in more detail.

4.1.1 The North Sea basin in the Pleistocene

Alternations of cold and warm periods are characteristic for the Pleistocene epoch. During glacials, large volumes of water were stored in continental ice caps. Each glacial/interglacial climatic cycle changed the eustatic sea level significantly. Since the southern North Sea shelf has a rather flat surface, sea level changes affected the North Sea Basin palaeolandscapes dramatically (Peeters *et al.*, 2009; Cohen *et al.*, 2011; Hijma *et al.*, 2012). Sea level fluctuations resulted in temporal changes in the palaeocoastline and the tributaries of large river systems. During the Weichselian, the sea level dropped more than 100 meters below the current sea level, and the area of the present-day North Sea and the English Channel was part of the mammoth steppe ecosystem. The changes in climate had also a major impact on the local flora and fauna.

4.1.2 The North Sea finds

In the last few decades, thousands of Pleistocene and Holocene animal remains have been recovered from the North Sea bottom. Indeed, the North Sea can be regarded as one of the richest palaeozoological sites in the world. The site also yielded hominin remains (Roebroeks, 2014; Meiklejohn *et al.*, 2015; van der Plicht *et al.*, 2016). Occasionally, recovered fossils show traces of human modification, or even have been made into bone and antler artefacts. Also, lithic tools have been found, in particular near the coast of Great Yarmouth (see for example Glimmerveen *et al.*, 2004, 2006; De Loecker, 2010; Pieters *et al.*, 2010; Momber *et al.*, 2011; Tizzard *et al.*, 2014, 2015; Niekus *et al.*, 2019). These finds witness the presence of humans in this area during the Palaeolithic and Mesolithic era. Moreover, excavations at coastal sites near Happisburgh (Norfolk) and Pakefield (Suffolk) (UK) revealed that hominins lived in the North Sea area as early as the late Early Pleistocene (Happisburgh) and during the early Middle Pleistocene (Pakefield; Parfitt *et al.*, 2005, 2010).

Numerous human skeletal remains have been found, but finds of Pleistocene hominin fossils from the North Sea bottom are extremely rare. About ten years ago, the first Neanderthal remains (*Homo neanderthalensis*) ever found in Dutch North Sea waters were brought to the surface. It was a skull fragment of a young male, probably Late

Pleistocene in age (Hublin *et al.*, 2009). Many human fossils date to the Mesolithic era, when humans inhabited a delta landscape that developed during the Early Holocene.

Natural history museums such as Naturalis Biodiversity Centre in Leiden and Het Natuurhistorisch in Rotterdam store a large collection of North Sea fossils. But also extensive private collections exist. These collections consist of abundant amount of species, varying in age from Pliocene up to modern. They include spectacular finds, such as fossils with carnivore gnawing marks, coprolites, and fossils of specimens that are rare in the fossil record such as the sabre tooth cat (*Homotherium* species), and artefacts. Numerous finds have been published in (prominent) journals (see for example, Parfitt *et al.*, 2005; Tizzard et al, 2014; Niekus *et al.*, 2019).

4.1.3 Lack of (primary) context data

The recovered finds inform us about the past biota in the now submerged landscape. However, the (stratigraphical, geographical, and archaeological) context of the vast majority of the finds is missing due to the methods in which the archaeological and palaeontological material was retrieved (Peeters, 2011). Most fossils are found when fishermen, coincidentally, catch them in their nets (see for example, van Kolfschoten and Laban, 1995; Mol and de Vos, 1995; Glimmerveen *et al.*, 2004; Mol *et al.*, 2007). Others are collected on the artificial beaches formed by sediments dredged from the bottom of the North Sea (see for example, Hublin *et al.*, 2009; Peeters *et al.*, 2009; Tizzard *et al.*, 2014, 2015). These circumstances hamper the assignment of the palaeontological and archaeological finds to a specific stratigraphical unit. The original geographical position of a number of finds collected during special private 'fossil hunting' boat trips or those carried out in the frame of the expansion of the Port of Rotterdam- the construction of Maasvlakte 2- (Mol and Post, 2010; Kuitems *et al.*, 2013) is roughly known. However, these rather detailed data about the location and depth are far from precise enough to link a find to a specific stratigraphical layer (Kuitems *et al.*, 2015b).

Moreover, most of the fossil remains were, when collected, not in primary context due to natural erosion and sedimentation processes. Recent investigations have increased our insights into geographical aspects of this now submerged landscape (Gaffney *et al.*, 2007; Sturt *et al.*, 2013; Cohen *et al.*, 2014; van Heteren *et al.*, 2014). A detailed stratigraphic framework has been made for the Eurogully region (Hijma *et al.*, 2012) and for the Maasvlakte 2 area (Busschers *et al.*, 2013). The defined lithostratigraphic units show signs of repeated, severe reworking during various fluviatile and/or marine depositional phases.

The geological data presented by Hijma *et al.* (2012) indicate that all Late Pleistocene terrestrial mammals that are older than ca. 30,000 years must have been redeposited. The skeletal remains from the North Sea are, however, rather well preserved with only minor signs of weathering and little or no rounding (Kuitems *et al.*, 2013); taphonomic features that indicate that the skeletal material was not exposed for a long time, nor that it was transported over large distances. Therefore, many finds may derive from eroded, large lumps of reworked or frozen sediments (Hijma *et al.*, 2012; Kuitems *et al.*, 2015b). One can, therefore, assume that most of the North Sea assemblages, including the samples discussed in this chapter, are mixed. Nonetheless, several areas in the southern North Sea, for instance the Brown Bank and Eurogully, known as palaeontological and/or archaeological 'hot spots', have been subject to targeted 'fishing' expeditions. An exception is the *in situ* research carried out in the Yangtzehaven (Rotterdam-Maasvlakte 2, the Netherlands) (Moree and Sier, 2015).

Due to the lack of context data, it is, however, impossible to carry out an in-depth study of for example the correlation between human subsistence and the palaeolandscape. But a number of finds may be assigned to a specific lithological unit if one combines a) the age of the finds, b) geological information of the area and the coordinates of the original place where it has been collected, and c) the knowledge of the ecological preference and restriction of a species.

4.1.4 Isotope investigation

It is uttermost important to know the age of the fossil finds and hence, many fossils have been ^{14}C dated. This resulted in an extensive dataset, including different species dating from Pleistocene up to modern. An overview of ^{14}C dated fossils from the North Sea is presented by van der Plicht and Kuitems (forthcoming). It is a catalogue of samples dated by ^{14}C, both by the conventional method and by AMS. Most samples are dated at Groningen.

Along with ^{14}C, $\delta^{13}C$ and $\delta^{15}N$ values have been measured for many of the skeletal remains. These isotope data provide additional information about for example the palaeoenvironmental conditions, the diet of organisms and ^{14}C reservoir effects. The stable isotope dataset of fossils from the North Sea is extensive. The majority consists of data from mammal fossils, which can shed light on ecological aspects of the North Sea area in the past. Moreover, in particular together with stable isotope data of similar species from adjacent areas, the Late Pleistocene data enhance our knowledge of the western part of the mammoth steppe ecosystem. The dataset also contains data of numerous Holocene human remains, which can shed light on (changes in) human subsistence in the North Sea region.

4.2 Material and methods

Sample preparation and isotope measurement were performed at the Groningen Centre for Isotope Research (CIO) following the standard CIO procedures described in Chapter 2 (section 2.4). The current dataset consists of directly ^{14}C dated samples of numerous mammalian species, representing marine carnivores, terrestrial carnivores, omnivores (incl. humans), herbivores, and one bird (Table 4.1). A grand total of 281 samples is presented: 157 animals, and 124 humans.

Table 4.1 Overview of analysed species, environment and average values of the stable isotope ratios δ^{13}C and δ^{15}N.

species (English)	species (Latin)	environment & diet	n	δ^{13}C (‰)	n	δ^{15}N (‰)
hare	*Lepus* sp.	terrestrial herbivore	1	-21.3	0	
beaver	*Castor fiber*	terrestrial herbivore	1	-22.1	1	4.8
dog/wolf	*Canis lupus*/sp.	terrestrial carnivore	2	-22.5	2	9.0
arctic fox	*Alopex lagopus*	terrestrial carnivore	1	-20.7	1	8.5
bear	*Ursus arctos*/sp.	terrestrial omnivore	2	-21.3	2	5.6
cave hyena	*Crocuta crocuta spelaea*	terrestrial carnivore	1	-20.1	0	
cave lion	*Panthera spelaea*	terrestrial carnivore	2	-19.3	2	8.5
wolverine	*Gulo gulo*	terrestrial carnivore	1	-21.2	0	
otter	*Lutra lutra*	freshwater carnivore	2	-25.5	1	8.6
walrus	*Odobenus rosmarus*	marine carnivore	5	-13.3	4	12.1
grey seal	*Halichoerus grypus*	marine carnivore	2	-13.6	1	14.5
harp seal	*Pagophilus groenlandica*	marine carnivore	2	-15.4	0	
woolly mammoth	*Mammuthus primigenius*/sp.	terrestrial herbivore	24	-22.0	20	7.1
straight-tusked elephant	*Palaeoloxodon antiquus*	terrestrial herbivore	7	-20.7	7	9.9
horse	*Equus caballus*/sp.	terrestrial herbivore	6	-21.2	6	4.3
woolly rhinoceros	*Coelodonta antiquitatis*	terrestrial herbivore	3	-20.7	1	4.5
Balaenidae	*Balaenidae*	marine carnivore	1	-16.7	1	9.3
bowhead whale	*Balaena mysticetus*	marine carnivore	1	-14.8	1	14.3
common rorqual	*Balaenoptera physalus*	marine carnivore	1	-12.6	0	
grey whale	*Eschrichtius robustus*	marine carnivore	14	-14.3	12	14.2
white-beaked dolphin	*Lagenorhynchus albirostris*	marine carnivore	2	-12.2	2	15.9
killer whale	*Orcinus orca*	marine carnivore	2	-12.0	2	16.4
bottlenose dolphin	*Tursiops truncatus*	marine carnivore	2	-11.9	2	15.4
beluga whale	*Delphinapterus leucas*	marine carnivore	4	-15.5	3	15.2
wild boar	*Sus scrofa*	terrestrial omnivore	3	-21.7	2	5.1
giant deer	*Megaloceros giganteus*	terrestrial herbivore	4	-20.0	3	4.9
red deer	*Cervus elaphus*	terrestrial herbivore	14	-21.6	9	3.5
moose	*Alces alces*	terrestrial herbivore	5	-21.0	5	3.2
reindeer	*Rangifer tarandus*	terrestrial herbivore	16	-19.9	12	3.8

roe deer	*Capreolus capreolus*	terrestrial herbivore	2	-21.8	2	2.7
aurochs	*Bos primigenius*	terrestrial herbivore	5	-22.1	5	5.3
bison	*Bison priscus*/sp.	terrestrial herbivore	3	-20.4	1	3.9
bovids	*Bovidae*	terrestrial herbivore	5	-22.0	5	5.6
muskox	*Ovibos moschatus*	terrestrial herbivore	1	-20.1	0	
Caprinae	*Caprinae*	terrestrial herbivore	1	-19.2	1	7.5
human	*Homo sapiens*	terrestrial omnivore	124	-20.0	123	12.1
great auk	*Pinguinus impennis*	marine carnivore	3	-14.5	3	17.1
unknown	unknown	unknown	6	-21.7	6	5.2
			281		248	

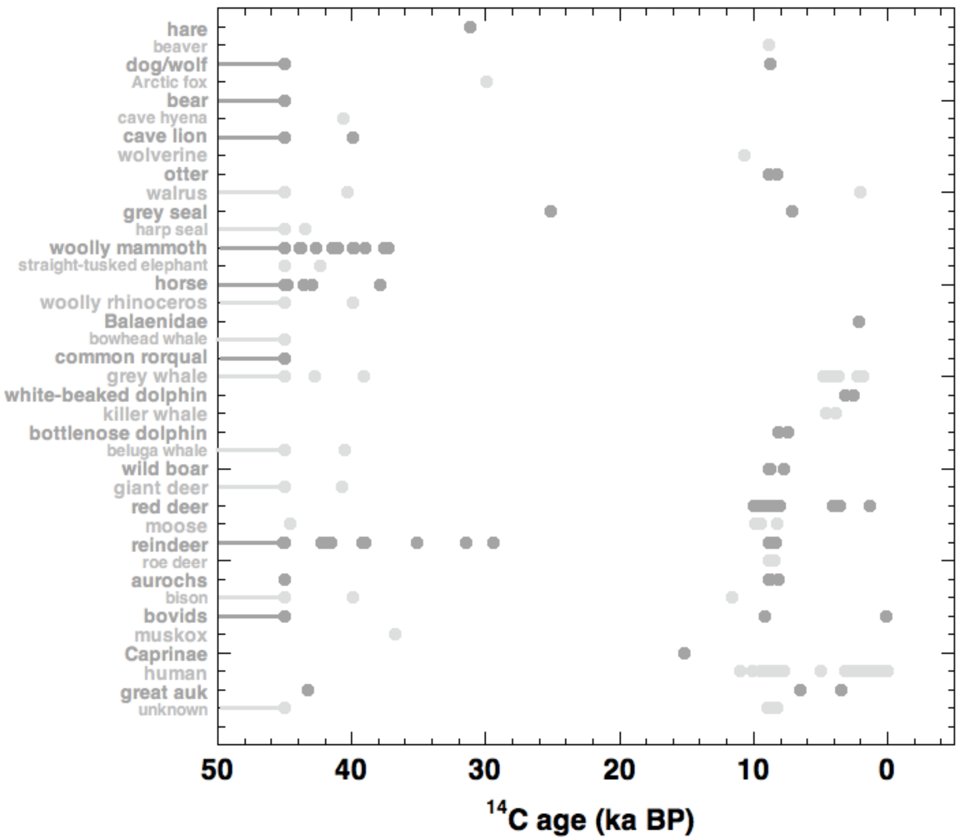

Figure 4.1 Age distribution of all analysed samples from the North Sea, taxonomically ordered. A grand total of 281 dates is plotted. The horizontal lines at the left side of the figure correspond to ages larger than 45,000 ^{14}C yr BP. Dates reported as finite and older than 45,000 ^{14}C yr BP are truncated at 45,000 ^{14}C yr BP.

Figure 4.1 shows the age distribution of all analysed samples from the North Sea area. The majority of the samples have a Pleistocene age (n = 96; all non-humans) and many samples are from species that are part of the typical Late Pleistocene mammoth steppe fauna: woolly mammoth, cave lion, arctic fox, hyena, woolly rhinoceros, horse, giant deer, reindeer and bison. The dataset includes, in addition, 19 marine animals with a Pleistocene age, such as bowhead whale, common rorqual, beluga whale, grey whale, grey seal, harp seal, walrus, and great auk. The rest of the samples (n = 185) are Holocene in age. These include both human (n = 124) and animal fossils (n = 61), the latter including at least 25 artefacts/worked items made of antler and bone.

This dataset gives an impression of the variety of species which lived in this area throughout the last 50,000 years. However, the composition of the current dataset is biased. Aspects such as taphonomic processes, the mesh size of fishing nets but also the selection of sediments used for sand deposition projects and the decision of collectors to focus on specific (rare) species determine the type of North Sea finds that are finally submitted for ^{14}C dating and hence, affects the representation of species.

Many finds come from a relatively limited number of areas in the North Sea basin, specifically locations that are frequently exploited by fishermen and that are suitable for sand extraction purposes (see Table SI Chapter 4). About one third of the samples come from the important fishing areas Brown Bank (n = 53) and Eurogully (n = 43). Also, a large part (n = 38) comes from beaches along the Dutch province South-Holland, where in recent years, several large-scale sand deposition projects took place. The Brown Bank and Eurogully yielded the highest number of species. Human remains are found at different localities, but the majority of them come from the coast of the Dutch province South-Holland and from the Wadden Sea in the North of the Netherlands. Moreover, all main find localities within the North Sea area yielded remains of both marine and terrestrial animals.

4.3 Results

Table 4.1 shows the analysed species, number of samples, the biotope (marine or terrestrial) and trophic level, and the (averaged) $\delta^{13}C$ and $\delta^{15}N$ values. For the results of the isotopic measurements of each individual sample, the reader is referred to Table SI Chapter 4. Figure 4.2 shows the mean $\delta^{13}C$ and $\delta^{15}N$ values for the samples, roughly ordered per trophic level and environment. In general, the isotope signals of most species fit into the broad clusters as shown in Fig. 2.2 (Chapter 2).

As expected, the marine carnivores show the highest $\delta^{13}C$ and $\delta^{15}N$ values. Their $\delta^{13}C$ values range between -16.7 and -11.4‰, and the $\delta^{15}N$ values between +9.3 and +17.7‰. The $\delta^{13}C$ values of the terrestrial herbivores range from -23.3 to -18.9‰. Their $\delta^{15}N$ values cover a large range of 9.9‰, the lowest being +1.7‰ and the higher $\delta^{15}N$ values being higher than those of the terrestrial omnivorous animals and terrestrial

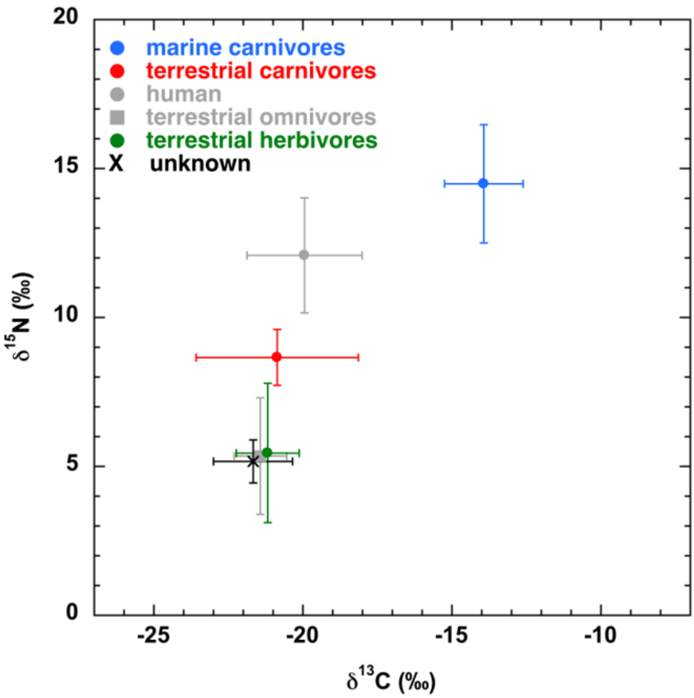

Figure 4.2 Mean $\delta^{13}C$ and $\delta^{15}N$ values with 1 σ-standard deviation for all samples, ordered per trophic level (herbivore, carnivore, omnivore) and habitat (marine, terrestrial).

carnivores in the current dataset. Apart from the humans, the terrestrial omnivores values fall within the range of these of terrestrial herbivores; $\delta^{13}C$ values range between -22.3 and -20.3‰, and $\delta^{15}N$ between +3.5 and +7.7‰. The human samples show large ranges of both isotope values. Their $\delta^{13}C$ values range between -24.7 and -13.4‰, and the $\delta^{15}N$ values range all except one (that is +4.5‰) between +8.0 and +17.4‰. The terrestrial carnivores have $\delta^{13}C$ and $\delta^{15}N$ values between -25.6 and -19.2‰ and between +7.7 and +10.2‰, respectively. The dataset consists of two samples of a freshwater carnivore, an otter, with $\delta^{13}C$ values of -26.2‰ and -24.8‰, and a $\delta^{15}N$ value of +8.6‰ (the $\delta^{15}N$ was measured for only one of these samples).

The trophic level/habitat clusters are composed of a variety of species from different time periods. The results of certain species will be discussed in more detail in the next paragraph. This selection is primarily based on the number of available samples per species.

4.4 Discussion

4.4.1 Stable isotope signatures of the Pleistocene animals

An overview of the data of the Pleistocene animals is shown in Fig. 4.3. It shows that the $\delta^{15}N$ values of the straight-tusked elephant (+7.5 to +11.6‰) and many of the woolly

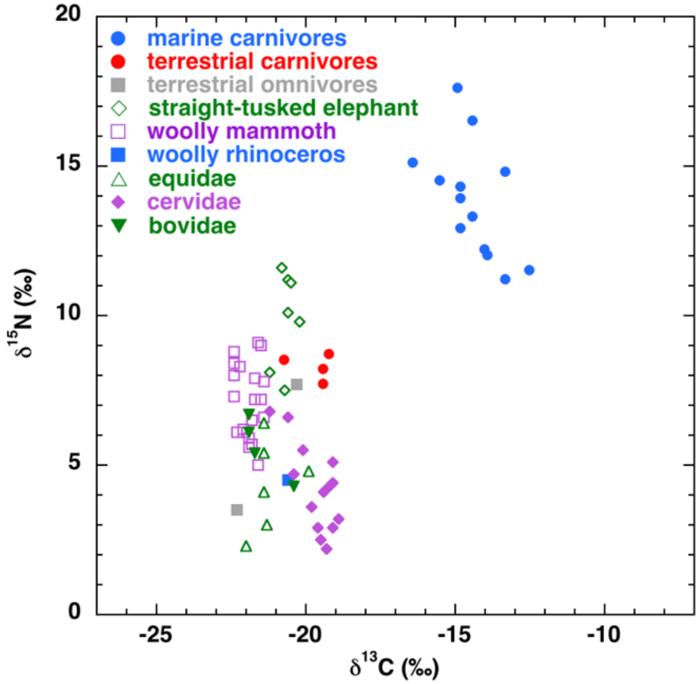

Figure 4.3 $\delta^{13}C$ and $\delta^{15}N$ values for Pleistocene mammal samples from the North Sea.

mammoth (+5.0 to +9.1‰) exceed these of other herbivores. Relatively high $\delta^{15}N$ values are commonly observed for woolly mammoth (for example, Bocherens, 2003; Kuitems *et al.*, 2015c) and have also been observed for Middle Pleistocene straight-tusked elephants from Germany (Kuitems *et al.*, 2015a; see Chapter 6). The current dataset also includes woolly mammoth samples with lower $\delta^{15}N$ values. Relatively low $\delta^{15}N$ values were also observed for Late-Glacial woolly mammoths in the Ukraine (Drucker *et al.*, 2014). The lowering of the values has been associated with changing environments and/or climates and changes in niche occupation after the LGM. Pre-LGM values of mammoths from Europe (including samples from the Ukraine (Drucker *et al.*, 2014)) show higher $\delta^{15}N$ values, ranging between +6.7 and +11.1‰. The current dataset of the North Sea contains only mammoth samples with a pre-LGM age; the majority being older than the ^{14}C background for fossil bone collagen (> 45,000 yr BP). The woolly mammoth samples with the lowest $\delta^{15}N$ values (between +5.0 and +6.0‰) are older than 45,000 years BP.

The $\delta^{13}C$ values of woolly mammoths (-22.4 to -21.4‰) are rather negative, in particular compared to those of other herbivores, including straight-tusked elephants (-21.2 to -20.2‰). Also, this picture (woolly mammoths are depleted in $\delta^{13}C$ compared to other herbivores) is known for other localities, and has tentatively been linked to seasonal metabolism of fat (Bocherens, 2003; Szpak *et al.*, 2010).

A number of the walrus samples have a nitrogen isotope ratio (n = 4; average = +12.1‰) that is low compared to most other marine mammals (average = +14.8‰;

Fig. 4.5). This might be explained by a low trophic level diet, such as clams and other molluscs (Dehn *et al.*, 2007).

As mentioned in Chapter 3, well-defined temporal changes in the distribution of $\delta^{13}C$ and $\delta^{15}N$ values have been observed for several species inhabiting North-western Europe; changes that are related to the climatic and environmental changes during the Late-Glacial and/or at the Pleistocene-Holocene transition. Indeed, the Pleistocene-Holocene boundary is characterised by severe climatic and environmental change in the North Sea region. The onset of the Holocene is, generally speaking, characterised by wetter and warmer climatic conditions, sea level rise and the development of forest. The current stable isotope North Sea record does not allow statements on temporal trends: samples from the last part of the Late Pleistocene, specifically, the LGM and the Late Glacial, are lacking (see Fig. 4.1 and Table SI Chapter 4) and the number of Pleistocene and Holocene records of a specific species is too low to draw solid conclusions.

4.4.2 Stable isotope signatures of the Holocene animals

In contrast to the characteristic Pleistocene 'mammoth steppe fauna', generally thriving in open landscapes, the Holocene samples represent forest dwellers that lived under temperate conditions. This is clearly illustrated by the North Sea Cervidae samples: Pleistocene samples are mainly from reindeer; other species are giant deer and moose. The Holocene cervid samples are predominantly from red deer; other species are moose and roe deer. As shown in Fig. 4.4, the $\delta^{13}C$ values of samples from Holocene

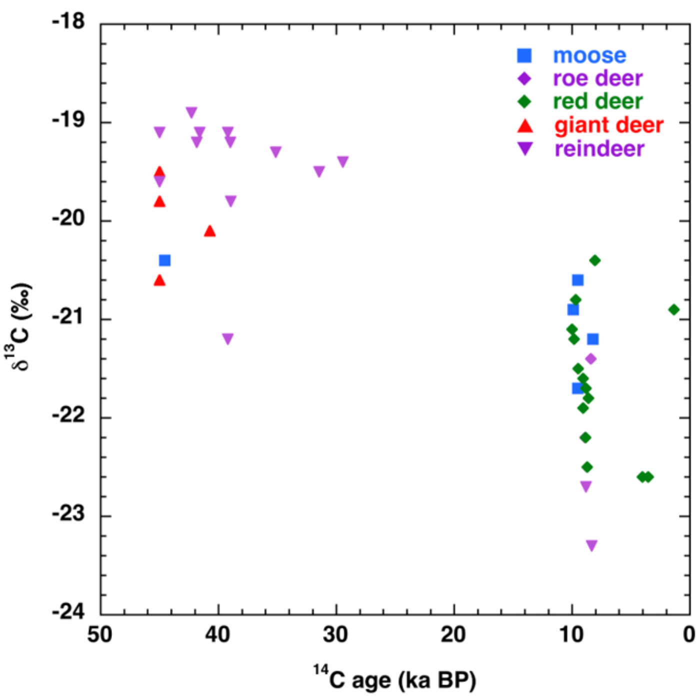

Figure 4.4 $\delta^{13}C$ values for samples of cervids from the North Sea through time.

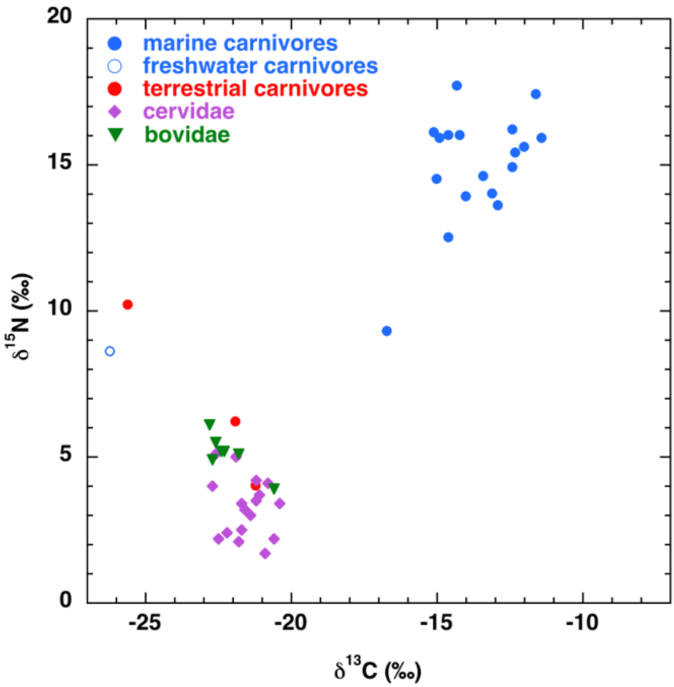

Figure 4.5 $\delta^{13}C$ and $\delta^{15}N$ values for Holocene animal samples from the North Sea.

cervids (n = 22, average = -21.7‰) are considerably more negative than those of the Pleistocene cervids (n = 20, average = -19.7‰). This difference can partly be ascribed to the changed $\delta^{13}C$ values in plants caused by the climate shift from the Pleistocene to the Holocene. Moreover, this difference can be explained by dissimilarities between the species, such as niche occupation, dietary composition, and physiology. For instance, the reindeer diet consists in general, for a significant part of lichens, which commonly yield higher $\delta^{13}C$ values than vascular plants (Ben-David *et al.*, 2001; Drucker *et al.*, 2003b). Fig. 4.4 shows that the $\delta^{13}C$ values from the Holocene reindeer (even though n = 2) are much lower in $\delta^{13}C$ than the Pleistocene ones. This might be explained by a dietary change, but a mistake in species identification cannot be excluded.

Due to the sea level rise, samples of marine mammals recur in the Holocene record. The only Holocene freshwater species is the otter. However, the stable isotopes of the Holocene dog/wolf (*Canis* sp.; GrA-24209) also show a mainly freshwater signal (Fig. 4.5). This is not surprising, since the Holocene dog lived together with humans (Noe-Nygaard, 1983, 1988; Schulting and Richards, 2002; Fischer *et al.*, 2007) and freshwater fish was an important part of the Mesolithic human diet. Dogs might have consumed the 'leftovers' of the human meal (Noe-Nygaard, 1983).

Not only human skeletal remains, also stone and bone tools indicate the presence of Mesolithic humans of the North Sea area. Archaeological sites such as Hardinxveld-Giessendam De Bruin indicate that the Mesolithic inhabitants lived on the higher

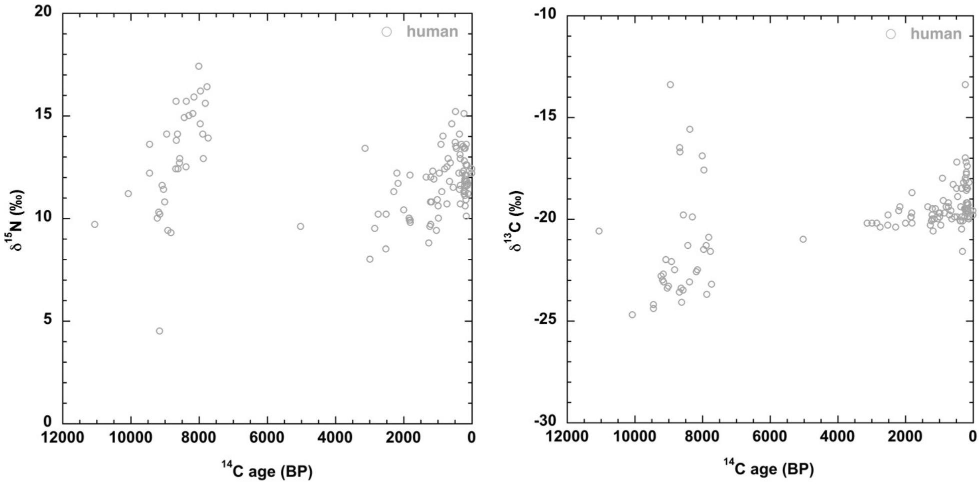

Figure 4.6 $\delta^{15}N$ and $\delta^{13}C$ values of human bones from the North Sea through time. Left: $\delta^{15}N$ versus ^{14}C age (yr BP); Right: $\delta^{13}C$ versus ^{14}C age (yr BP).

areas such as river dunes (Louwe Kooijmans *et al.*, 2001). The worked bone and antler artefacts are made from long bones of bovids, equids, and cervids, and from antler, predominantly of red deer. Six objects could not be assigned to a specific species. The $\delta^{13}C$ and $\delta^{15}N$ values of the bone artefacts fall within those of the terrestrial herbivore ranges.

4.4.3 The human stable isotope signature

The dataset with more than hundred human skeletal remains include bones from the sea floor found by fishing or dredging (Amkreutz *et al.*, 2018a,b) as well as finds collected on the beach (Storm, 2010). Recently, an overview of 56 human bone remains was published (van der Plicht *et al.*, 2016); 33 are Mesolithic in age (including a few Late Palaeolithic), the remaining 23 specimens range between Roman age and recent. The main conclusion of the stable isotope analysis is that the Mesolithic humans were predominantly consumers of freshwater protein (van der Plicht *et al.*, 2016).

Since the publication in 2016, the dataset of human finds has significantly increased. The fossils are either Mesolithic in age, or ranging between late Roman time and recent (see Fig. 4.6 and see Table SI Chapter 4). There is only one exception: a find from the island of Texel with an age of 5,020 ^{14}C yr BP (GrM-10161). The average $\delta^{13}C$ and $\delta^{15}N$ values of the human bones are shown in Fig. 4.2; the $\delta^{13}C$ and $\delta^{15}N$ values for the individual human samples are plotted against time in Fig. 4.6. Abundant fish remains from archaeological coastal sites such as at Hardinxveld-Giessendam reveal that fish may have been the most important dietary resource for Mesolithic humans, in particular pike (Louwe Kooijmans, 2005). Many of the humans have $\delta^{15}N$ values which are often indicative for aquatic dietary resources, in particular those with $\delta^{15}N$ values higher than

+12‰. However, $\delta^{15}N$ values can be affected in many ways. For instance, it is known from other Holocene sites in the Netherlands, that cattle grazing on the coastal salt marshes may have considerably high $\delta^{15}N$ values (Prummel *et al.*, forthcoming; Kamjan *et al.*, forthcoming). These high $\delta^{15}N$ values are passed on to humans who are eating the cattle's meat. Since there is no proper baseline available for isotope values of different food recourses in this area, only cautious statements about dietary resources can be made.

As visible in Fig. 4.6 (right), there is a discrepancy between the Mesolithic and later inhabitants of the North Sea area. The low $\delta^{13}C$ values point to a significant component of freshwater fish in the diet of Mesolithic humans. The $\delta^{13}C$ values of the non-Mesolithic human bones have intermediate $\delta^{13}C$ values, generally indicative of a mixed marine/freshwater/terrestrial food source. This can be expected in a delta region like the coastal Netherlands.

Compared to the other samples of the current dataset, there is one exceptionally low $\delta^{15}N$ value of 4.5‰. This is not necessarily an ingenuine result, as the human $\delta^{15}N$ ranges generally between 4 to 10‰ for terrestrial diets, depending on the trophic level of the food protein (Richards and Hedges, 1999). Such low $\delta^{15}N$ values for human bones have been observed before, for example in Mesolithic bones from Germany (Terberger *et al.*, 2012).

4.4.4 Radiocarbon dates of the current dataset

The present tables contain partly published but for a major part of unpublished ^{14}C, ^{13}C, ^{15}N data. The $\delta^{13}C$ and $\delta^{15}N$ dataset discussed in this chapter includes skeletal remains of both terrestrial and aquatic organisms. The age determination of the latter ones needs special attention. The ^{14}C convention is defined for terrestrial material, which is in equilibrium with atmospheric CO_2. Reservoirs like oceans, rivers and lakes generally contain less ^{14}C than the atmosphere. This causes older apparent ages for organisms acquiring their carbon from these reservoirs through the food chain: the so-called 'reservoir effect'. ^{14}C dates of aquatic organisms need a correction for the reservoir effect in order to derive absolute calendar ages. This also applies to terrestrial organisms with a significant amount of aquatic food in their diet. The general marine offset is about 400 years towards older, but riverine or a mixture of marine and fresh water resources may have considerably large and obscure consequences for the age determination. Since the actual share of aquatic versus terrestrial food and the share of marine versus fresh water resources of for instance humans is unknown, the reservoir effect cannot be quantified. Thus, the dates cannot be calibrated. To avoid reservoir effect ambiguities, the age of the samples discussed in this chapter are given in ^{14}C ages (BP) instead of calibrated dates (cal BP).

Figure 4.1 suggests that the LGM is more or less devoid of fossils. There is an ongoing discussion about the conditions in the North Sea area during the LGM, but the absence or scarcity of fossils supports the idea that the North Sea basin has been a harsh environment in this period (Carr *et al.*, 2006). One should note, however, that this dataset reflects a biased composition of inhabitants of the North Sea area in the past. Aspects such as taphonomic processes, choices for sediment used for substantial sand deposition projects, mesh size of fishing nets, detection of finds by (often amateur) collectors, and the glamour of specific finds dramatically determine the type of North Sea finds that are finally submitted for ^{14}C dating. For instance, small, fragile fish and bird bones are just sporadically submitted for ^{14}C dating. The possibility to recover these finds in the North Sea area is very limited and the quantity and/or quality of the collagen from these remains is often not enough to date the remains. In contrast to smaller animals, many human remains have been submitted for ^{14}C dating. A large number of samples are human bones thought to be Neanderthal based on the degree of fossilization. However, none of these appeared Neanderthal; they are all Mesolithic or Late Palaeolithic. Today, the only Neanderthal from the North Sea is 'Krijn' (Hublin *et al.*, 2009), known to be Neanderthal because of its distinctive skull features. Since the fossil did not yield collagen, it is not datable by ^{14}C. Moreover, samples of cervids (often pieces of modified antlers) are represented in relatively high numbers in the ^{14}C dataset.

As expected, many of the (Late) Pleistocene fossils are from species that are part of the so-called mammoth steppe fauna. Moreover, a large number of Pleistocene fossils are from marine mammals. The set of large marine mammal ^{14}C dates have raised questions, which still need to be resolved. Many whales date between 35,000 and 45,000 ^{14}C yr BP and walruses between 25,000 and 30,000 ^{14}C yr BP. However, these ages conflict with the results of geological and stratigraphical studies executed in the North Sea area; studies that show that the sea level was low during these periods and the area where the fossils have been collected was land instead of sea. Hijma *et al.* (2012) show the marine fauna must be either older than ~ 80,000 years or Holocene in age. The obtained ^{14}C dates have, therefore, been criticised, and compared with ^{14}C dates of shells (Rijsdijk *et al.*, 2013; Busschers *et al.*, 2014). The datable fraction of shells is their carbonate. In contrast to bones, fossil corals and shells can recrystallize, enabling exchange of carbon (including ^{14}C) from different sources. Shell ^{14}C dates can, therefore, be in conflict with other dating methods, in particular racemization. It may be worth re-dating a number of the marine mammals remains by compound specific ^{14}C dating.

4.5 Conclusion

The North Sea region was dry land during the last glacial period, and was inhabited by a rich fauna. With the onset of the Holocene, the eustatic sea level raised and Mesolithic people inhabited the higher parts of the new-developed coastal North Sea area. Large quantities of fossil bones have been recovered from the present seabed. Over the years, the $\delta^{13}C$ and $\delta^{15}N$ values of almost 300 human and non-human animal remains have been measured. Since the context of the finds is unclear, the ^{14}C dates are crucial to establish the age of the fossils. The $\delta^{13}C$ and $\delta^{15}N$ values of the dated bone collagen yield information about for example palaeodiet, palaeoclimate and palaeoenvironment.

The isotope signals are, in general, comparable to those that are known from omnivores, herbivores and carnivores inhabiting past marine and terrestrial biotopes elsewhere in North-western Europe. This large North Sea dataset consists of species for which $\delta^{13}C$ and $\delta^{15}N$ data are not abundant such as straight-tusked elephant, otter, wolverine and great auk, numerous large marine mammals and humans.

The stable isotope data can be used to further zoom in on questions related to fossil remains from the North-western mainland and the United Kingdom. Moreover, a vast amount of new stable isotope data for human remains from the North Sea is presented. Most human bones have $\delta^{15}N$ values that point to an aquatic diet. The $\delta^{13}C$ values of the Mesolithic humans are generally indicative for freshwater food resources. The $\delta^{13}C$ values of human bones from later periods point towards a mixed diet of marine, freshwater, and terrestrial food resources. This analysis, based on a large database obtained over the years, illustrates that a collection of stray finds without context nevertheless can lead to inference of inhabitants from past environments in a multidisciplinary approach.


Irtysh River, photo: P. Kosintsev