

Hunting, gathering, fishing and herding: Animal exploitation in Sandy Flanders (NW Belgium) during the second half of the fifth millennium BC

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At Doel, in the lower basin of the river Scheldt, excavations have revealed camp sites of the Swifterbant culture dating back to the second half of the fifth millennium BC. They document the transition period from the Late Mesolithic to the Early Neolithic in Sandy Flanders (NW Belgium). The sites were situated on the top of sandy ridges which were covered with an alluvial hardwood forest vegetation and surrounded by wetlands. Only burnt animal remains survived at the sites, illustrating (seasonal) fishing and hunting. In addition, botanical evidence indicates the herding of domestic mammals. The finds are of importance for the reconstruction of the chronological development of the food economy of the Swifterbant culture.

Keywords: Mesolithic – Neolithic transition, Swifterbant culture, Animal husbandry, Wetland ecology

The Swifterbant Economy in the Rhine-Meuse-Scheldt Area

The last hunting societies in the Rhine-Meuse-Scheldt area belong to the Swifterbant culture, named after the iconic sites found near the village of Swifterbant (the Netherlands). Dwelling places of this cultural group, generally dating between 5000 and 3400 BC (Louwe Kooijmans 2007b), are found in the wetlands of the coastal areas of Lower Saxony (Germany) and the Netherlands, and in the lower Scheldt basin in NW Belgium (Raemaekers 1999; Crombé *et al.* 2009) (Fig. 1; all dates presented are calibrated using OxCal v 3.10: Bronk Ramsey 1995, 2001, and IntCal09 calibration data: Reimer *et al.* 2009). As far as is presently known (taking into account that the dataset is heavily biased towards wetland sites, Louwe Kooijmans 2007a, b), the Swifterbant people largely relied on hunting, gathering and fishing for their subsistence. Hunting concentrated on red deer (*Cervus elaphus*), wild boar (*Sus scrofa*), beaver (*Castor fiber*) and otter (*Lutra lutra*) as most important game (Raemaekers 1999, 114, table 3.49) while fishing

consisted of the catch of freshwater species (Van Neer *et al.* 2005). The gathering of plants clearly relied upon the production of the lowland forests, and open spots within that vegetation (Out 2009a, 346–364). However, the Swifterbant economy differed from older Mesolithic groups by their use of pottery, of own fabric, and, at some point in their development, as witnessed by animal and plant remains, by the consumption of domesticated mammals and cereals. The animal species involved are cattle (*Bos primigenius* f. *taurus*), pig (*Sus scrofa* f. *domestica*), sheep (*Ovis ammon* f. *aries*) and goat (*Capra hircus* f. *aegagrus*) (Raemaekers 1999, 114, table 3.49), while the cereals include mainly emmer wheat (*Triticum dicoccum*) and six-rowed barley (*Hordeum vulgare*) (Raemaekers 1999, 113, table 3.48).

It is now clear that the appearance of domestic animals and plants in the Swifterbant sites represents a gradual, slow evolution through time. According to recent literature, the introduction of cereals should be dated between 4300 and 4000 BC (Cappers and Raemaekers 2008; Out 2008, 2009b) (Fig. 1), while these crops are absent in the older Swifterbant sites. For domestic meat providers to appear at Swifterbant sites the earliest date would be ‘around 4700 BC’ (Cappers and Raemaekers 2008; Out 2008,

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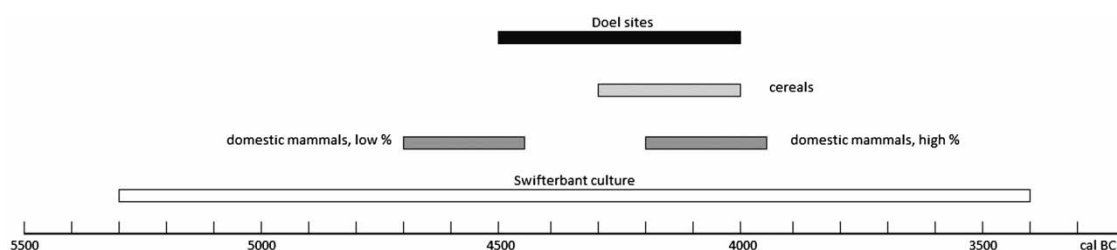


Figure 1 Chronological overview of the Swifterbant culture, Doel sites and events mentioned in the text (for the Swifterbant culture and the Doel sites the chronological distribution is given, for the two phases in the introduction of domestic mammals and for the onset of cereal cultivation the dating ranges are depicted).

but see the discussion below). This introduction was indeed gradual, as exemplified by the very low percentages of the remains of domestic mammals in the last phase (3) of the Hardinxveld-De Bruin site (lasting until 4400 BC, Louwe Kooijmans 2001; Oversteegen *et al.* 2001) and the significantly higher percentages of domestic mammals at the Swifterbant S3 site (starting around 4200 BC, Van der Waals 1977; Zeiler 1997). Unfortunately, in the Dutch archaeological record the period between both sites is not documented.

Moreover, the true nature of the use of agricultural products by the Swifterbant people is still much debated, certainly when the gradual nature of the introduction is taken into account. The main discussion turns around the question whether crops and animals were raised locally at the wetland sites or were imported from (presumed but not yet attested) more inland Swifterbant sites, or from inland sites belonging to another, clearly agricultural group (Raemaekers 1999, 113–115; Louwe Kooijmans 2001, 523). On Belgian territory, examples of the latter could be found in the inland loamy region, where, around the middle of the sixth millennium BC, Linear Bandkeramic people had arrived with their herds of cattle, sheep, goats and pigs, and their knowledge to grow cereals (Crombé 2010).

Regardless of their true meaning (in the different sub-periods), the finds of domestic plant and animal remains at Swifterbant sites have helped to alter the traditional image of the last hunter-gatherers surviving on the margins of the inhabitable world, secluded in impenetrable swamp forests. Now, the Swifterbant economy is seen as relying on diversity, thus minimising risk and optimising landscape exploitation (see Raemaekers 2006). Certainly, the floodplain environment, with its sandy ridges, channels and low-lying grounds, was not a marginal area but instead a very productive and therefore attractive biotope (Louwe Kooijmans 1993). It can be hypothesised that the presumed introduction of crop and animal raising into this landscape added to the diversity of the economy and the efficiency of landscape exploitation (Louwe Kooijmans 2007a, b).

The Swifterbant Culture at Doel

Until now, the southernmost Swifterbant sites were found at Doel, in the lower basin of the river Scheldt (Fig. 2), in Sandy Flanders (NW Belgium), and date back to the second half of the fifth millennium BC (Crombé 2005; Crombé *et al.* 2009). Starting in 2000, they were discovered when the construction of the ‘Deurganck dock’, as part of the harbour of Antwerp, caused the destruction of a wide, covered prehistoric landscape at Doel. This landscape consisted of a succession of Pleistocene coversand ridges that, due to rising sea levels, became drowned and covered by peat and alluvial clay. The peat above the ridges dates back to the beginning of the fourth millennium BC (Van Strydonck 2005, 133).

Between 2000 and 2003, only small-scale rescue excavations could be undertaken that, among others, revealed three Swifterbant sites situated on the relatively narrow coversand ridges (Bats *et al.* 2003; Crombé *et al.* 2004, 2009; Crombé 2005). The absence of finds on the slopes indicates that the tops of the sandy ridges represented the only dry dwelling places in a wetland environment most probably characterised by swamps and channels. Pollen data from the region document a vegetation in the fifth millennium BC, consisting of extensive wetlands dominated by alder (*Alnus*) woodland, resulting in the formation of wood peat (Deforce 2011). Between 4600 and 3690 BC, however, this peat growth was locally interrupted by the deposition of estuarine (peaty) clay but for the Swifterbant sites of Doel themselves, no precise dates for this clay deposition are available (Deforce 2011). The top of the sand ridges shows the presence of a brunified soil (Louwagie and Langohr 2005).

The Swifterbant site first discovered at Doel, in 2000, was located in a sector of the harbour works labelled ‘B’. The environmental archaeology of this site has been studied and published in detail (Crombé 2005), including analyses of the plant and animal remains (Bastiaens *et al.* 2005; Van Neer *et al.* 2005). Later on, in 2003, another site from the same period was found at sector ‘J/L’ but this location could hardly be investigated and ecological data are lacking (Bats *et al.* 2003; Crombé 2005). Finally, also

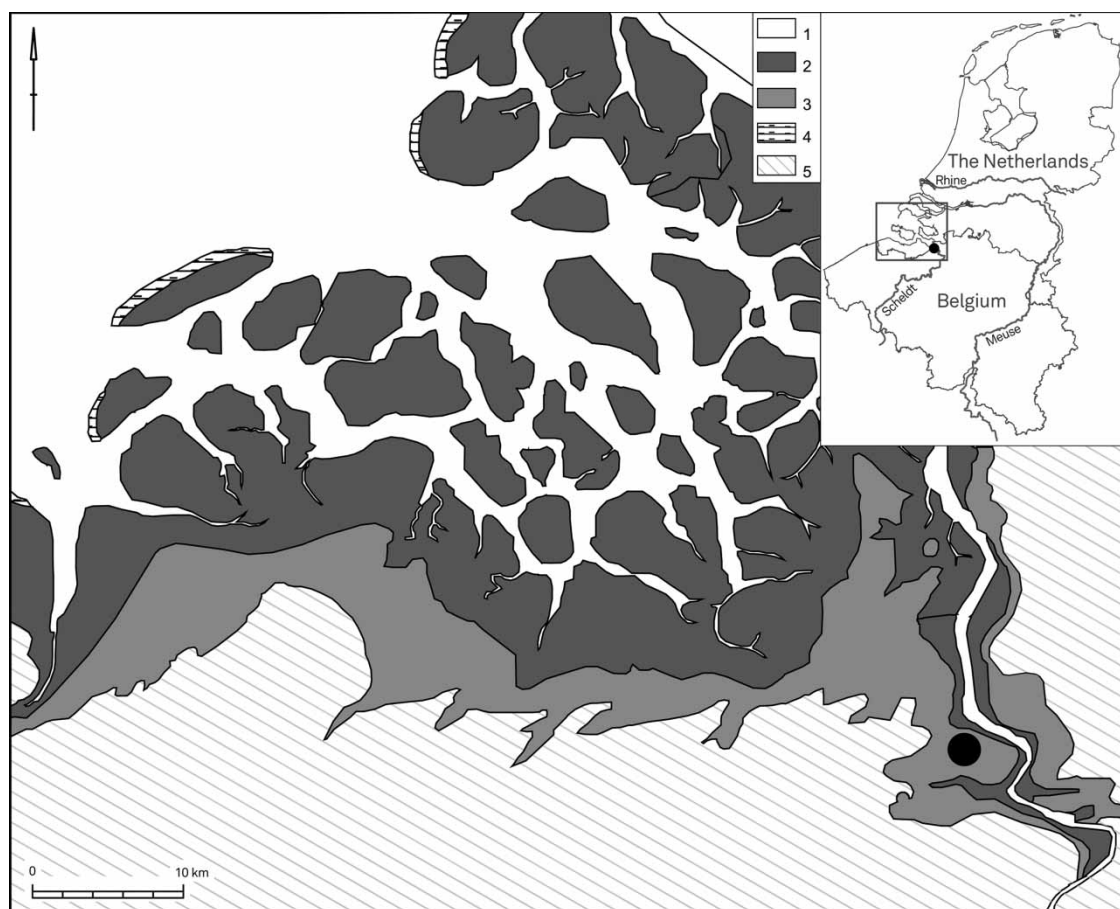


Figure 2 Location of the site (●) and palaeogeographical map of the Scheldt estuary around ca. 4350 BC (modified after Vos and Van Heeringen 1997). 1: North Sea, tidal inlets and tidal channels; 2: tidal area (mudflats and saltmarshes); 3: peatland; 4: beaches and dunes; 5: Pleistocene coversand area.

in 2003, at a third location labelled 'sector M', additional evidence for Swifterbant occupation was found (Crombé *et al.* 2004).

The main features at the three Swifterbant sites are surface hearths and hearth dumps. From these contexts, a significant assemblage of charred plant and burnt animal remains, pottery and lithic material could be collected. The pottery from the sites shows affinities with artefacts from Dutch Swifterbant sites dating back to the first half of the fifth millennium BC (Crombé 2005, 2010). However, radiocarbon dates extracted from charred seeds and charcoal point to an occupation during the second half of the fifth millennium BC (see Boudin *et al.* 2010 for a review). Radiocarbon dates from charred food residues attached to pottery fragments again point to the first half of the fifth millennium, but this pattern is hypothetically explained by the (yet not established but assumed) reservoir effect of freshwater fish products that became part of the food crusts (Van Strydonck and Crombé 2005; Boudin *et al.* 2010). This dating bias has produced some confusion: in their discussion of the animal remains from the first Swifterbant site discovered at Doel, Van Neer *et al.* (2005, 288) situate the finds collection in the first

half of the fifth millennium, an interpretation based upon the radiocarbon analysis of the charred food residues. However, the dates obtained from the charcoal and charred seeds, placing the sites in the second half of the fifth millennium BC, are now considered to be the only reliable ones. Interestingly, the date range of the Doel sites covers the time gap between the Dutch sites Hardinxveld-De Bruin phase 3 (Louwe Kooijmans 2001) and Swifterbant S3 (Van der Waals 1977), the period in which domestic mammals must have risen from accidental appearances to a permanent presence, in meaningful numbers, at the Swifterbant sites (Fig. 1).

This paper will discuss the animal remains from the Doel sites, focusing on the exploitation of the environment. The analysis relies on the published archaeozoological results from sector B (Van Neer *et al.* 2005) and introduces new data from sector M. The interpretations will also briefly take into account the archaeobotanical data from both sites (Bastiaens *et al.* 2005; Deforce *et al.* 2013).

Doel, sector B

The surface hearths from sector B were sampled for animal material by wet sieving (2 mm mesh width),

using a powerful water jet. The samples for botanical remains were sieved over 0.5 mm meshes using slow running tap water. This yielded a collection of charcoal, charred seeds and fruits, and cremated animal bones (Crombé 2005). The plant remains are, radiocarbon dated between 4500 and 3990 BC (97.5% probability: Boudin *et al.* 2009). Clearly, the local soil conditions prevented the survival of ecological material that has not been burnt. This pattern produced a strong bias in the information about the activities on site. Material that has not been deposited within the reach of flames escaped our attention, while the preservation of burnt material strongly differs per animal group. The skeletal elements of large mammals have been splintered into tiny fragments, mostly rendering them unidentifiable. In contrast, the survival of many cremated fish bones was surprising. Except for the loss of some external structures (mostly spines), they are not severely fragmented, resulting in a condition good enough to allow rather high identification ratios. The end result is that more information is available about the exploitation of the animal group with the most friable skeleton (fish) compared to species with much more robust bones (mammals) (Van Neer *et al.* 2005). In general, it should be noted that the taphonomical nature of the finds concentrations associated with the surface hearths still remains unclear. While the presence of charred seeds raises no questions, the abundance of tiny cremated mammal and fish bones is more complex to explain. Hypotheses put forward range from the use of bone as fuel, the accidental exposure of material to fire, to the deliberate burning of food leftovers in order to avoid attracting scavengers (Van Neer *et al.* 2005).

Regarding the local Swifterbant economy, the excavation results from sector B document the contribution of hunting, mainly wild boar and red deer (as far as the limited finds collection permits to state this) and fishing, almost exclusively of freshwater fish, such as roach (*Rutilus rutilus*), rudd (*Rutilus erythrophthalmus*), bream (*Abramis brama*), etc. The gathering of wild plants and fruits included hazelnuts (*Corylus avellana*), crab apples (*Malus sylvestris* subsp. *sylvestris*), sloe plums (*Prunus spinosa*), acorns (*Quercus* sp.), hawthorn berries (*Crataegus* sp.), etc. (Bastiaens *et al.* 2005; Van Neer *et al.* 2005). Except for a single (and thus difficult to interpret) cereal grain, tentatively identified as bread or durum wheat (*Triticum aestivum/durum*: Bastiaens *et al.* 2005; but see Out 2008, S134; Out 2009a, 401–407), no evidence for the consumption of domesticated plant or animal products has been found. For the analysis of the material from sector B all samples have been treated together as a single assemblage. Intra-site patterns have therefore not been evaluated. When a new site

was discovered at 'sector M', these uncertainties thus prompted a sampling campaign even more detailed than had been the case during previous excavations.

Doel, sector M

In 2003, at another rescue operation during the harbour works, an area of ca. 1000 m² was excavated on top of a sand ridge, in a sector of the building site labelled 'M' (Crombé *et al.* 2004). Amid a wide scatter of pottery fragments and lithic artefacts, six small clusters (< 1 m²) of burnt organic material were found, which are interpreted as the remains of surface hearths and/or hearth dumps (Crombé *et al.* 2004). Five of these clusters showed the presence of white, burnt bone and have been retained for archaeozoological analysis.

Radiocarbon dates fall in a range between 4575 and 4038 BC (97.5% probability range: Deforce *et al.* 2013, after Boudin *et al.* 2010) proving the structures to be broadly contemporaneous with the Swifterbant site explored earlier. However, the calculated dating ranges for sectors B and M only depend upon the maxima and minima while the interquartile (or floruit) ranges indicate that the focus of the occupation in sector B was situated earlier (between ca. 4435 and 4334 BC) than in sector M (between ca. 4368 and 4156 BC) (Boudin *et al.* 2010, Fig. 2) (see also Fig. 3).

Within sector M the radiocarbon dates also prove that the hearths were not used simultaneously but represent separate diachronic events. Hearth 5, be it only represented by a single radiocarbon date, could belong to one of the earliest occupation phases compared to the younger hearths 2 and 4. The chronology of the other hearths 1 and 3 is much less clear as for both there is no overlap within the 2 σ range of the two dates obtained per structure (Fig. 3), which suggests that these are not single event depositions but have accumulated over some time, be it continuously or as a succession of short events (Deforce *et al.* 2013, based upon Boudin *et al.* 2010, Table 2).

From the six clusters, bulk samples (25 l), in each case corresponding with a 10-cm thick layer taken from 21 units of a grid of 50 × 50 cm squares, were wet sieved (0.5 mm mesh size) using tap water. Although they all cover multiple units of the grid, the individual hearths are treated here as single contexts. The residues yielded wood charcoal, charred seeds and cremated bones. The results of the study of the wood charcoal and other charred botanical macroremains have been discussed by Deforce *et al.* (2013).

That extreme care has been taken while handling the samples, using only the gentle impact of slow running tap water, was a step taken in order to evaluate the possible effect of the previous, somewhat less sophisticated treatment of animal remains as part of the

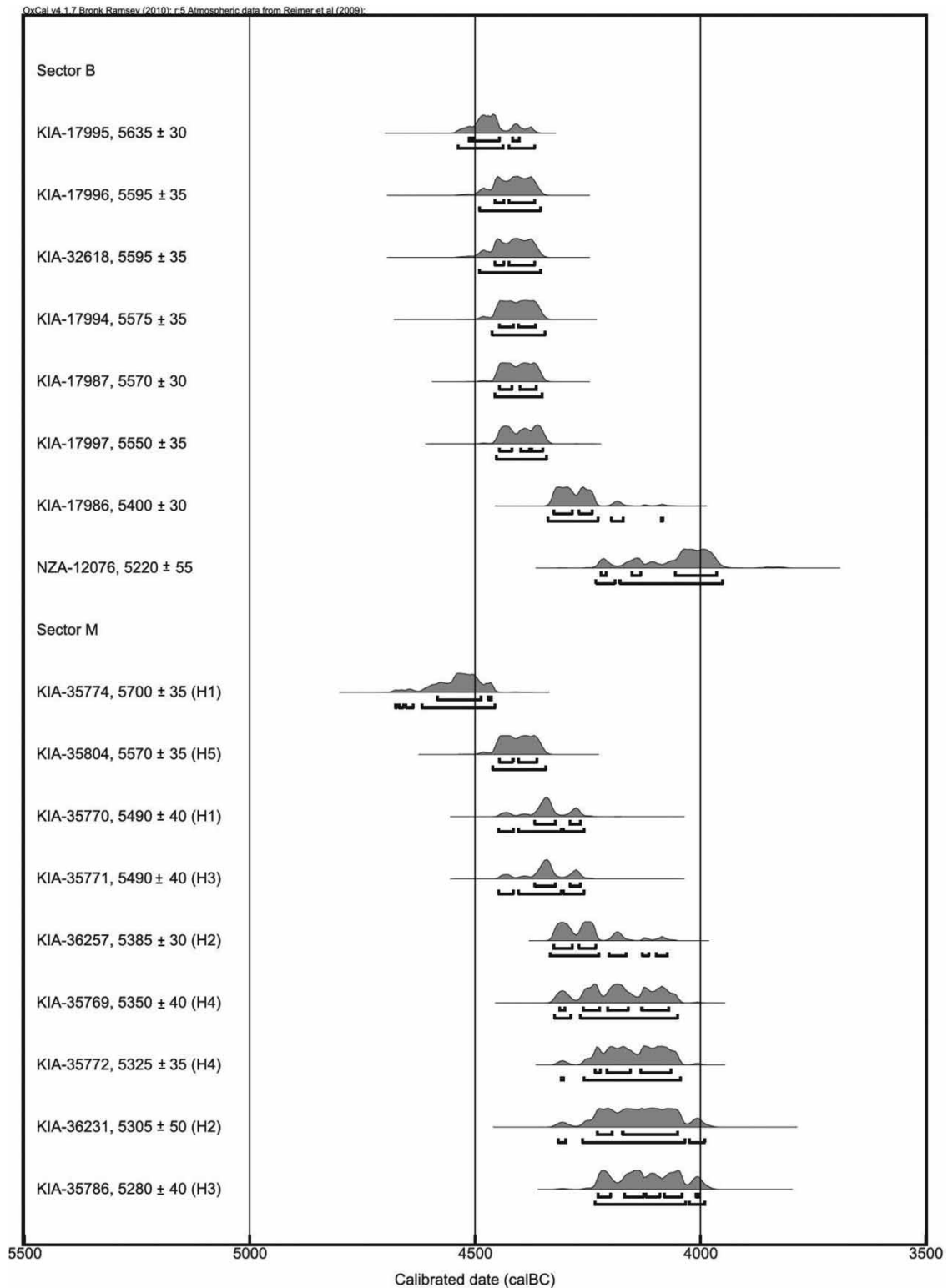


Figure 3 Calibrated radiocarbon dates for sector B and M (data from Boudin *et al.* 2010, Table 2).

investigation of sector B. However, this seems not to have influenced the condition of the finds assemblages. At sector M, no friable material has been found among the sieved residues that was not encountered at sector B. Moreover, the smaller mesh width used while sieving the sediment samples did not produce (identifiable) material previously not documented by the investigation of sector B. That the smallest

species from the whole Doel assemblage, the three-spined stickleback (*Gasterosteus aculeatus*), was found among the material from sector M and not in sector B (see further) has no relationship with mesh width used since some of the skeletal elements are larger than 2 mm. The animal remains from both sectors can thus safely be compared against each other.

The identification of the fish bone was carried out with the aid of the comparative collections housed at the Royal Belgian Institute of Natural Sciences. As carried out for sector B (Van Neer *et al.* 2005, 284), size reconstructions (in broad size classes) were obtained by direct comparison to modern specimens of known standard length (SL: the length from the tip of the snout to the base of the tail), realising that the shrinkage due to burning (of which the extent varies around 10% according to Steffen and Mackie 2005) will in all cases have produced an underestimation. It should be noted that the size reconstructions were only performed in order to compare the animal remains from sectors B and M, and not for comparison with other sites. Unlike the protocol followed during the analysis of the sector B material, only the animal remains that looked identifiable were picked out from the sieved residue. However, as this was done by the archaeozoologists themselves the sampling bias must have been minimal.

Ecological material from sector M

Plant remains

Alder (*Alnus* sp.) is the most important element in the charcoal assemblages comprising 40% of the charcoal fragments analysed. Oak (*Quercus* sp.) is also important (22% of the total assemblage) while mistletoe (*Viscum album*) occurs in all of the hearths (range: 1–22%, 13% of the total collection). Much lower percentages are reached by ash (*Fraxinus excelsior*), apple/pear/hawthorn (Pomoideae type *Malus/Pyrus/Crataegus*), lime (*Tilia* sp.), hazel (*C. avellana*), elm (*Ulmus* sp.), dogwood (*Cornus* sp.), Guelder rose (*Viburnum opulus*), alder buckthorn (*Frangula alnus*), ivy (*Hedera helix*), sloe (*Prunus* type *spinosa*) and traveller's joy (*Clematis vitalba*) (Deforce *et al.* 2013).

Concerning the seeds and fruits, the total number of taxa is limited ($n = 18$). Seeds of ivy and fragments of hazelnuts dominate the assemblage. Acorns (*Quercus* sp.), crab apples (*M. sylvestris* subsp. *sylvestris*) and mistletoe were also important. Very few non-arboreal taxa have been found and all in very low numbers (Deforce *et al.* 2013).

Animal remains

All animal finds collected consist of the white, burnt skeletal remains of fish, amphibians and mammals, of which a majority could not be identified. The material proved to be distributed unevenly between the surface hearths sampled. Only in structures 2, 3 and 5 fish bones have been found, while only hearths 1, 4 and 5 contained mammal bones. Considering the amphibian remains, only structures 2 and 3 yielded finds (Table 1). In terms of the biochemical condition of the bones and the degree of

fragmentation per animal category, preservation seems to be equal between the finds concentrations.

The fish fauna consisted of almost 4000 identifiable remains that can be attributed to at least 11 taxa (Table 1). The proportion of unidentified fish could not be quantified because of the sorting protocol followed (see earlier). However, in the material from sector B the identification rate for the fish bones was about 30% (Van Neer *et al.* 2005) and it is likely that the proportion was comparable in sector M. The newly studied ichthyofaunal material has a similar general appearance in terms of degrees of fragmentation and burning as the material from sector B.

Almost 80% of the identifiable material is from Cyprinidae, i.e. the cyprinids or the carp family, but

Table 1 Inventory of the burnt animal remains (number of finds) from Doel – sector M per hearth. All material has been collected through wet sieving (see text). Note that unidentifiable remains have not been counted

Hearth	1	2	3	4	5	Total
Freshwater fish						
Eel (<i>Anguilla anguilla</i>)	–	5	–	–	6	11
Pike (<i>Esox lucius</i>)	–	4	1	–	2	7
Bream (<i>Abramis brama</i>)	–	2	1	–	–	3
Barbel (<i>Barbus barbus</i>)	–	3	–	–	–	3
Roach (<i>Rutilus rutilus</i>)	–	25	4	–	–	29
Carp family (Cyprinidae sp.)	–	2410	279	–	442	3131
Ruffe (<i>Gymnocephalus cernuus</i>)	–	1	–	–	–	1
Perch (<i>Perca fluviatilis</i>)	–	5	–	–	4	9
Perch family (Percidae sp.)	–	11	–	–	–	11
Marine or estuarine fish						
Allis or Twaite shad (<i>Alosa</i> sp.)	–	712	11	–	17	740
Three-spined stickleback (<i>Gasterosteus aculeatus</i>)	–	–	–	–	29	29
Thin-lipped mullet (<i>Liza ramada</i>)	–	1	–	–	–	1
Plaice, Flounder or Dab (Pleuronectidae sp.)	–	22	1	–	1	24
Amphibians						
Common frog (<i>Rana temporaria</i>)	–	–	12	–	–	12
Frog species (<i>Rana</i> sp.)	–	1	2	–	–	3
Toad species (<i>Bufo</i> sp.)	–	–	4	–	–	4
Frog or toad species (<i>Anura</i> sp.)	–	5	83	–	–	88
Mammals						
Roe deer (<i>Capreolus capreolus</i>)	8	–	–	1	2	11
Red deer (<i>Cervus elaphus</i>)	14	–	–	–	–	14
Marten (<i>Martes</i> sp.)	2	–	–	–	24	26
Rib (medium-sized mammal)	7	–	–	2	4	13
Vertebrae (large-sized mammal)	–	–	–	2	–	2
Vertebrae (small-sized mammal)	–	–	–	–	1	1
Total fish	0	3201	297	0	501	3999
Total amphibians	0	6	101	0	0	107
Total mammals	31	0	0	5	31	67
Total	31	3207	398	5	532	4173

Table 2 Size distributions (%) of the unidentified cyprinids, per hearth

SL (cm)	Hearth 2 (n = 1835)	Hearth 3 (n = 226)	Hearth 5 (n = 331)	All (n = 2392)
0–5	0.0	0.0	0.0	0.0
5–10	0.7	1.3	2.4	1.0
10–15	73.0	77.4	84.3	75.0
15–20	15.3	10.2	11.8	14.3
20–25	6.7	8.8	1.2	6.1
25–30	3.6	0.9	0.3	2.9
30–35	0.6	0.9	0.0	0.5
35–40	0.1	0.4	0.0	0.1
40–45	0.0	0.0	0.0	0.0

among the 3166 bone fragments that could be attributed to this family, only 35 allowed a detailed, species identification. This low identification rate is due to damage to the material (removing diagnostic elements from the bones), to the large number of species within the carp family and to the dearth of studies dealing with diagnostic criteria enabling the identification of isolated bone elements. The remains identified to species level are mainly from roach (*R. rutilus*), whereas from bream (*A. brama*) and barbel (*Barbus barbus*) only three fragments of each were recognised. The three barbel bones, all found in hearth 2, are dorsal fin spines that have a typical serrated posterior margin, and they belong to fish of 30–40 cm SL. The bream remains are from hearth 3, where a basiptyrgium fragment was found from a fish measuring about 40 cm SL, and from hearth 2 where a dentary and a ceratohyal occur of fish of 20–25 cm SL. The remains identified as roach are all pharyngeal plates from fish that are smaller than the bream and barbel: hearth 2 yielded 22 bones from fish of 10–15 cm SL, and 3 specimens of 15–20 cm SL. The

four pharyngeal plates found in hearth 3 are all from fish measuring between 10 and 15 cm SL. The size distribution of the unidentified cyprinids (Table 2), shows a preponderance of fish with a standard length of 10–15 cm, suggesting that roach are dominating here as well. On average, the cyprinid sizes seem somewhat smaller in hearth 5, compared to the two other structures with fish remains. Overall, the skeletal element distribution of the cyprinids is ‘normal’, in a sense that all body parts – head, body, fins, girdles – are represented (Fig. 4).

The shad (*Alosa* sp.) are the second most frequent group of fish with an average of 18.5% of the identified remains, but it appears that the contribution of this fish is exceptionally high in hearth 2 where it represents 22% of the identified bones, versus only 3 to 4% in the two other hearths (Table 3). Unfortunately, the numerous remains of shad did not yield any bone allowing the distinction between allis shad (*Alosa alosa*) and twaite shad (*Alosa fallax*), the two species occurring in northwestern Europe (Poll 1947). More than 93% of the shad remains are vertebrae, which are the sturdiest elements of the skeleton. Besides two fin rays, the rest of the material includes only head bones of which the maxilla (17 specimens), the articular (11 spec.) and the quadrate (9 spec.) are the most abundant, followed by the dentary (5 spec.), the basioccipital (2 spec.), the hypohyale (2 spec.) and the ceratohyal (1 spec.). As far as the reconstructed sizes are concerned (370 observations), the shad material is rather homogenous with the majority of the bones belonging to fish between 20 and 30 cm SL. Smaller fish occur only in three instances: one specimen of 15–20 cm SL in hearth 5 and two fish of the same size

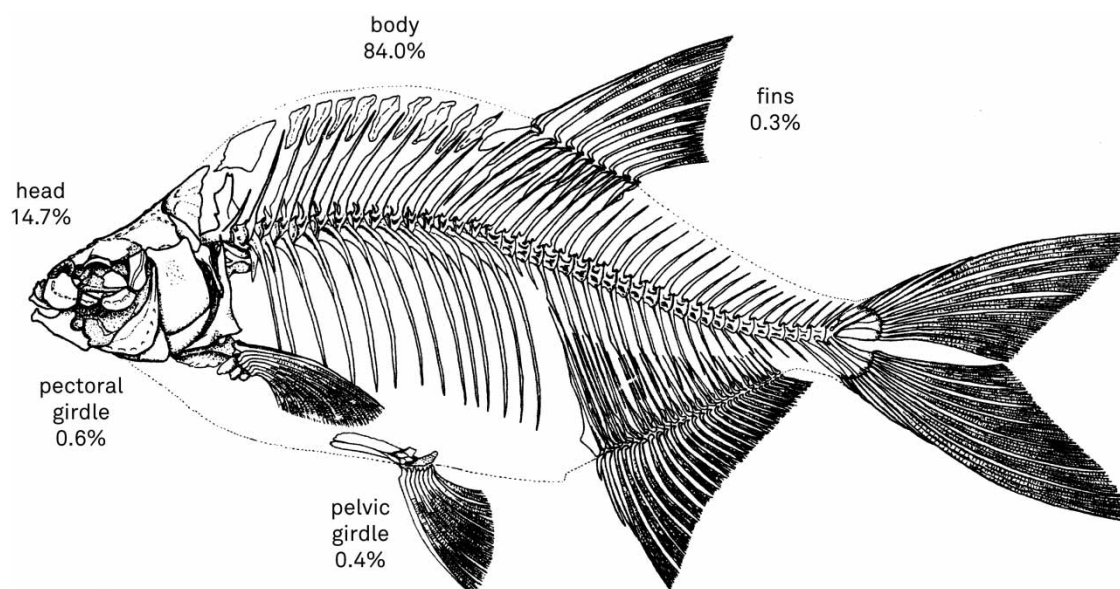


Figure 4 Relative frequency of the skeletal elements of cyprinids found at sector M, per body part (skeleton of a bream (*A. brama*) after Radu (2005), reproduced with permission by the author).

Table 3 Relative frequency (%) of the fish taxa within the hearths of sector M (this study), compared to the overall collection from sector B (after Van Neer et al. 2005) ('0.0' indicates < 0.05, '-' stands for absent)

	Sector M			Sector B
	Hearth 2 (n = 3201)	Hearth 3 (n = 297)	Hearth 5 (n = 501)	All (n = 1200)
Freshwater fish				
Eel (<i>Anguilla anguilla</i>)	0.2	–	1.2	0.6
Pike (<i>Esox lucius</i>)	0.1	0.3	0.4	1.3
Bream (<i>Abramis brama</i>)	0.1	0.3	–	0.1
Silver bream (<i>Abramis bjoerkna</i>)	–	–	–	0.1
Silver bream or Bream (<i>Abramis</i> sp.)	–	–	–	0.2
Barbel (<i>Barbus barbus</i>)	0.1	–	–	–
Orfe, Dace or Chubb (<i>Leuciscus</i> sp.)	–	–	–	0.2
Roach (<i>Rutilus rutilus</i>)	0.8	1.3	–	0.5
Rudd (<i>Rutilus erythrophthalmus</i>)	–	–	–	0.2
Carp family (Cyprinidae sp.)	75.3	93.9	88.2	95.8
Ruffe (<i>Gymnocephalus cernuus</i>)	0.0	–	–	–
Perch (<i>Perca fluviatilis</i>)	0.2	–	0.8	0.3
Perch family (Percidae sp.)	0.3	–	–	–
Marine or estuarine fish				
Stingray (<i>Dasyatis pastinaca</i>)	–	–	–	0.1
Sturgeon (<i>Acipenser</i> spp.)	–	–	–	0.8
Allis or Twaite shad (<i>Alosa</i> sp.)	22.2	3.7	3.4	–
Three-spined stickleback (<i>Gasterosteus aculeatus</i>)	–	–	5.8	–
Thin-lipped mullet (<i>Liza ramada</i>)	0.0	–	–	–
Plaice, Flounder or Dab (Pleuronectidae sp.)	0.7	0.3	0.2	–

in hearth 2. Hearth 3 differs from the two others in that it yielded three bones of fish larger than 30 cm SL.

The other taxa are poorly represented with each less than 1% of the total amount of fish bones identified. Eel (*Anguilla anguilla*) is absent in hearth 3 but occurs in hearth 5 where two head bones and three vertebrae are found, of fish measuring between 30 and 40 cm SL. In addition, there is one vertebra of an eel of 40–50 cm SL in that context. The size variation is somewhat larger in hearth 2 where a vertebra was found of an eel of 30–40 cm SL, besides head bones of fish measuring 50–60 cm SL (3 specimens) and 60–70 cm SL (1 specimen). The presence of pike (*Esox lucius*) is attested in four instances by an isolated tooth that did not allow an accurate size reconstruction. The skeletal elements that permit a body length estimate represent rather small pike: a precaudal vertebra (15–20 cm SL) and two palatines (20–30 cm SL) in hearth 1, and a parasphenoid (30–40 cm SL) in hearth 5. Both freshwater representatives of the Percidae family, namely the perch (*Perca fluviatilis*) and the smaller ruffe (*Gymnocephalus cernuus*), are found in the material from sector M. On a morphological basis it is not always possible to distinguish the skeletal elements of the two species, but in that case the larger sizes that perch can reach are sometimes helpful. The ruffe is attested with certainty in hearth 2 by a supraoccipital from a fish measuring 10–15 cm SL. In the same context the presence of perch is indicated by a premaxilla (10–15 cm SL), three vertebrae (15–20 cm SL) and a dorsal spine of an animal measuring 20–25 cm SL. The bones labelled as 'Percidae sp.'

are mainly precaudal vertebrae of fish measuring 10–15 cm SL. Hearth 5 yielded only perch bones (among the Percidae): a dentary (10–15 cm SL), a precaudal and a caudal vertebra both from a fish of about 15 cm SL, and a post-temporal of a perch of about 20 cm SL.

Except for shad, which are marine fish that enter the rivers for spawning, all species already mentioned are closely linked with freshwater habitats. Eel, a catadromous species living in freshwater but migrating into the sea for reproduction, will also have been caught in inland waters. Still, some other marine taxa occur in sector M that are known to enter brackish and even fresh water. This is the case for the thin-lipped mullet (*Liza ramada*) of which hearth 2 yielded a caudal vertebrae from a fish of 30–35 cm SL. Flatfish remains were found in all three hearths with fish bone, but it was impossible to identify them to species despite the diagnostic criteria that exist for the distinction of plaice (*Pleuronectes platessa*), flounder (*Platichthys flesus*) and dab (*Limanda limanda*) (Wouters et al. 2007). This is due to the fact that the majority of the recovered bones are vertebrae, which are rarely diagnostic. The few other bones were too fragmentary to be identified. The single bone found in hearth 3, a supracleithrum, is from an animal of 20–25 cm SL, and the only flatfish from hearth 5 is a fish of 10–15 cm SL attested by a caudal vertebra. The bones from hearth 2 are mainly vertebrae of fish measuring 15–20 cm SL (17 specimens) and 20–25 cm SL (4 spec.). The three-spined stickleback (*G. aculeatus*), finally, can also be considered a typical inhabitant of brackish waters, although it

also occurs in marine and freshwater environments. This species is only attested in a single square (sq. 21) of hearth 5 in which 24 ventral spine remains were found as well as one basipterygium, that all differ clearly from the 10-spined stickleback (*Pungitius pungitius*) (Libois *et al.* 1987). It is likely that the four cranial fragments also belong to the same species. All the bones are from fish of 3–5 cm SL. Based on the spines, the minimum number of individuals in this small locus is 10.

The remains of sturgeon from sector B, a species absent from sector M, were initially identified as European sturgeon (*Acipenser sturio*), the sole species within that genus previously thought to have occurred in the Low Countries. However, recent literature points towards the possible presence in Western Europe of the Atlantic sturgeon (*Acipenser oxyrinchus*) in former times (Ludwig *et al.* 2002, 2009; Desse-Berset 2009, 2011). Therefore, the Doel-Deurganckdok remains were re-identified based upon the species specific scute ornamentation pattern, originally described by Magnin (1963) and since then used for species identification by several authors (Artyukhin and Vecsei 1999; Desse-Berset 2009, 2011). Based upon this criterion, four out of the nine fragments originally identified as *A. sturio* can now be assigned to *A. oxyrinchus*, one showed the *A. sturio* ornamentation type, while the ornamentation pattern of two remaining fragments could not be determined due to the small size of the fragments. Hence, the finds from sector B are now labelled as ‘*Acipenser* spp.’.

Amphibian remains only occur in hearths 2 and 3, only reaching high numbers in the latter structure. From that context, species identifications could be made pointing towards the presence of the common frog (*Rana temporaria*). Other finds within this animal group could only be described to genus level, i.e. as frog species (*Rana* sp.) or toad species (*Bufo* sp.) while the taxonomic position of other material remains even more vague (*Anura* sp.).

As was the case for sector B, almost all of the mammal remains consisted of small (burnt) fragments that could not be identified. This material has also not been quantified. Among the finds that could be described into more detail, the bones of marten (*Martes* sp.) are the most numerous (Table 1). However, almost all finds come from hearth 5 and most likely represent the remains of a single individual. It was also impossible to ascertain whether the bones belong to the pine marten (*Martes martes*) or the beech marten (*Martes foina*, also known as stone marten). Other identifications show the presence of roe deer (*Capreolus capreolus*) and red deer (*C. elaphus*) among the animal remains. Most of these finds come from hearth 1. Comparable to sector B,

no evidence for the presence of domesticated animals has been found.

Taphonomy

The peculiar preservation state of the animal remains from the Doel sites has been described and interpreted by Van Neer *et al.* (2005, 287–288), based on the finds from sector B. Next to the fact that all material preserved has been severely burnt, the most striking characteristics were the severe fragmentation and resulting impossibility of identification for the mammal remains, and the surprisingly good condition of the fish remains (burnt, but not significantly fragmented and hence identifiable in many cases). The pre-depositional processes responsible for this pattern are unknown but the disposal of food leftovers by deliberate burning is a likely candidate.

The material from sector M does not add new taphonomic information, except that now clear differences between the hearths can be observed. However, whether these must be explained in terms of varying preservation conditions or differences in deposition (see further), remains unclear. As already mentioned, the preservation conditions seem to have been equal between the finds concentrations. However, this pattern must without doubt be related with the overall poor chances of bone preservation at the site’s location, resulting in an ‘all or nothing’ situation. When burnt, bone can preserve in these sites, when not, it rapidly disappears from the sandy soil. Of course, the survival of the remains can have been further influenced by processes such as mechanical fragmentation or other unknown factors, possibly (partly?) explaining the varying composition of the animal assemblages from the hearths. At present, however, this cannot be proven.

It is likely that the fish remains from sector M mainly represent consumption refuse. A possible exception seems to be the cluster of stickleback bones found in hearth 5. These small fish could be stomach content from one of the piscivorous species (eel or pike) that were intentionally captured. Alternatively, the stickleback may represent an unintentional by-catch when small meshed fishing gear was used (such as fine-meshed nets or traps, or scooping baskets). However, this seems less plausible since in that case other small fish, such as gobies (*Gobiidae* sp.) or juvenile herring (*Clupea harengus*) and sprat (*Sprattus sprattus*) could also be expected, as well as small-sized cyprinids of less than 5 cm, which is not the case (Table 2). A final explanation could be that the remains derive from fish that died naturally. Such a scenario, involving desiccation of small water bodies that were formed during an exceptional high tide, was used to explain the occurrence of small fish, including sticklebacks, on the Neolithic site

of Schipluiden (Brinkhuizen 2006). However, the reconstruction of the former landscape around the site at Doel sector M does not support this interpretation (see further). Scandinavian sites from the Ertebølle culture show that stickleback were certainly eaten there and even seemed to have been an important part of the diet (see the sites of Ertebølle, Bjørnsholm and Krabbesholm II: Enghoff 1987, 1993, 2011, 114–117). They were even found in graves, in the form of preserved stomach or gut contents, or as food deposits (Jonsson 1986). Also at Doel, they may thus represent consumption refuse, after all.

Whether the bones from amphibians also represent consumption refuse is difficult to decide. However, the fact that they ended up in the surface hearths could well point into that direction. In addition, it appears that common frog is much more common than toad, a ratio that has also been observed on Mesolithic and Neolithic sites elsewhere in Europe where consumption of anurans is accepted on the basis of the skeletal distributions and the observation of chewing marks on the long bones (Bailon 1997, 2005; Chiquet 2005; Kysely 2008). Such an exercise was not possible on the Doel material due to the small number of remains and the poor preservation.

Without doubt, the mammal remains must represent food leftovers, although the marten bones may come from animals initially hunted for their fur. The fact that hearth 5 possibly contained the remains of a single animal could indicate skinning without further fragmentation of the carcass by human consumption.

The Environment

From the study of the botanical remains from sector M, it could be concluded that the botanical taxa identified, the geomorphological position of the site, the synchronicity of adjacent clayey deposits and the presence of a brunified soil on the top of the sand ridges together point towards the presence of an upper river bank forest, composed of hardwood taxa, on the sand ridge (Deforce *et al.* 2013). This interpretation is consistent with the results from sector B (see Bastiaens *et al.* 2005). Alluvial hardwood forests occur under very specific hydrodynamic conditions, i.e. on a terrain only incidentally touched by inundations of short duration (Schnitzler 1994; Wolf *et al.* 1997). The absence of willow (*Salix* sp.) also indicates that no tidal fluctuations occurred in the wetlands directly surrounding the sand ridge in sector M. The botanical remains from sectors B and M certainly do not point towards recurrent or long-term salt or brackish conditions around the sites.

All terrestrial animals of which the remains have been found at both sectors can well have occurred in

this hardwood forest environment. At the same time, however, the ecological characteristics of the species found do not provide additional information for landscape reconstruction.

The aquatic environment can be partly reconstructed by the characteristics of the fish fauna, an interpretation in which the finds from both sectors B and M can be used. Their broadly contemporaneous faunas are both characterised by a heavy preponderance of cyprinids, while the main difference lays in the very pronounced presence of shad in sector M, at least in hearth 2 (Table 3). Without those shad, the cyprinids would represent more than 90% of all the identified bones in all the assemblages from sector M. Within the cyprinid family there are some slight differences in the species composition of both sectors but all the taxa belong to the same ecological zone, the so-called ‘bream zone’ as defined by Huet (1949). This is an ecozone within rivers characterised by slow-running to stagnant water with a sandy or rather muddy substrate and abundant vegetation. The dominant cyprinid species in both sectors B and M remains the roach. Also the distribution of the reconstructed body sizes is strikingly similar (see Van Neer *et al.* 2005, 285).

Based on the fish species composition of the assemblage from sector B, it had been postulated that the landscape consisted of channels with stagnant or slow running water. Assuming that the anadromous sturgeon was locally caught, the waters around sector B must have been connected to the main river system. At the same time, there was no indication of marine influence, with the possible exception of a single skeletal element of a stingray (*Dasyatis pastinaca*). It remains unclear whether this was a locally captured animal or rather a fish brought in from the coast. Stingray is tolerant of brackish water and has been found co-occurring with euryhaline cyprinids such as roach, rudd, bream and tench (*Tinca tinca*) at a Mesolithic site in Denmark (Enghoff 1994). Furthermore, brackish water conditions at sector B should have been indicated by the presence of typical species such as flounder or thin-lipped mullet, but they were lacking. The only possible hint to relatively saline conditions was the remarkably high frequency of pathological, fused vertebrae among the cyprinids (Van Neer *et al.* 2005, 293).

In the new assemblages from sector M only two such pathological cases occur, but the ichthyofaunas yielded, on the other hand, large numbers of marine species that typically enter brackish and even freshwater, namely shad, flatfish and the thin-lipped mullet. Also the three-spined sticklebacks should be seen as anadromous animals. The aquatic environment exploited near sector M was basically a freshwater or a brackish habitat to which anadromous,

marine fish had access. It is unfortunate that none of the shad remains could be identified to species. Allis shad is a marine species that becomes gregarious when it enters a river for spawning. It can migrate far upstream into freshwater but will not enter small tributaries (Poll 1947). Until the end of the 19th century, allis shad used to enter the Scheldt basin massively in April and May. The second species, twaite shad, is also a marine and schooling fish, but will not migrate as far upstream as allis shad. It was, generally speaking, less frequent in freshwater, at least before allis shad became as good as locally extinct in the 20th century. Records of twaite shad are known from the estuary of the Scheldt river, just north of Antwerp in the mid-20th century (Poll 1947). Those specimens were captured in April and in June through August. Worth mentioning is also that both shad species migrate into estuaries only when the water temperature rises above 11°C (Nijssen and de Groot 1987). The preferred substrate for spawning would be rather coarse in the case of allis shad, whereas twaite shad can spawn over sandy and gravelly bottoms (Whitehead 1985). Taking into account this biological information, several possible explanations emerge for the absence of shad in sector B. The fish may not have had access to the exploited waters because there was no passage to them (but then the sturgeon and stingray must represent imported products) or because the site was located along a minor tributary, rather distant from the estuary. Alternatively, the substrate may not have been suitable for spawning, or the fishing may have taken place outside the reproduction season. Within sector M, different proportions of shad remains have been found, with a contribution of 22% to the total amount of identified fish in hearth 2 and only about 4% in hearths 3 and 5. This could be a reflection of fluctuations in the seasonal or long-term abundance of shad near the site. Considering the latter option, it must be remembered that hearth 5 seems to be older than hearth 2, while the dating of hearth 3 is rather vague.

It is unlikely that the differences between the ichthyofaunas from sectors B and M are an effect of varying seasonal use of the sites. Taking into account that the material from sector B derives from a combination of a number of different contexts, upon which seasonal changes most probably have acted (as can be hypothesised for sector M, see further), it is difficult to maintain seasonal variation in fish availability as an explanation for the complete absence of shad from that sector. The aforementioned differing characteristics of the aquatic environment around the sites must thus have been the cause. This was possibly a synchronous phenomenon or, alternatively, was the result of temporal changes in the

geography of the broader area. It has been stated on the basis of the floruit ranges that sector M could represent a somewhat younger phase of habitation than sector B. Perhaps a rise in marine influence occurred through time? This assumption is corroborated by the presence of estuarine (peaty) clay, which ultimately covered the entire sand ridge (Crombé *et al.* 2004). Hearth 2, with a high percentage of shad remains is in any case among the youngest structures investigated in sectors B and M. Of course, if conditions were indeed more saline during the habitation of sector M, then an alternative explanation than salinity must be found for the high proportions of fused cyprinid vertebrae in sector B.

The Food Economy

Assuming that the absence of larger fish bones is no taphonomical event, fishing at the Swifterbant sites clearly concentrated on small prey. Discussing the finds from sector B, this pattern has been linked with the use of stationary fish gear such as fish traps and, possibly, fish nets (Van Neer *et al.* 2005). The finds from sector M do not contradict these interpretations. Also here fish are small indicating that fishing may have taken place in shallow water bodies or in marginal parts of channels or rivers. The almost total absence of large fish such as sturgeon (*Acipenser* sp.), large pike, salmon (*Salmo salar*) or catfish (*Silurus glanis*) shows that there was no exploitation of deeper waters. Given the small sizes of the fish caught, fishing cannot have been the most important source of animal products. Hunting large mammals must have provided a more significant input of animal protein (and fat). Unfortunately, due to the very fragmented nature of the mammal remains, more information on hunting activities and their contribution to the food supply is not available. Remarkably, remains from wild boar, recovered from sector B, were absent from sector M but the limited number of identifications can also explain this pattern.

Two hearths (1 and 4) only contained mammal remains, while two others (2 and 3) yielded the bones of fish and amphibians but no mammals. From the fifth hearth (5) the remains of fish and mammals were recovered but amphibian bones were lacking (Table 1). It is difficult to evaluate whether this variation has a taphonomic (preservation) background or reflects different food procurement activities. It has been argued that the first option is not very plausible (see earlier), implying that the hearths may represent different activities. In that context, it is striking that it has been concluded from the radiocarbon dates that hearths 1 and 3 represent a combination of multiple events, well separated in time, while they do show a consistent spectrum of animal groups present. Finally, when different activities are

accepted as cause for the differences in composition of animal remains between the hearths, it must be questioned whether these activities happened within the same season, or not (see further).

For reasons of preservation, the possible presence of domestic animals cannot be ascertained, implying that it can neither be excluded. Remarkably, the plant remains from sector M strongly suggest that livestock was herded by the local Swifterbant people. From the exceptionally high numbers of ivy and mistletoe, both found as charcoal and as seeds, it must be concluded that these plants have been collected as leaf fodder, thus indicating the herding of animals near the site (see Deforce *et al.* 2013, for a lengthy discussion of this interpretation). This evidence is present, in varying numbers, in all of the five hearths. Among the seeds analysed from Doel sector B, ivy was also present in high numbers but seeds of mistletoe were lacking, while charcoal of ivy and mistletoe was not attested (Bastiaens *et al.* 2005). However, in the case of the charcoal, some identifications may have been missed and the material is currently under revision.

The evidence for the use of leaf fodder implies more than the consumption of (parts of) domestic mammals at the site alone. These food products could theoretically have been imported in a preserved state, from inland sites (belonging to the Swifterbant people or to other, exclusively agricultural groups). In contrast, leaf fodder implies the presence of living animals at or near the site. Whether these were also killed and consumed at the Doel locations cannot be proven.

The presence of domestic mammals at the Doel sites is important in terms of the chronological development of the Swifterbant culture. It must be remembered that the earliest appearance of the remains of domestic animals at Swifterbant sites has been dated around 4700 BC (Cappers and Raemaekers 2008; Out 2008), based upon the faunal assemblage from phase 3 of the site Hardinxveld-Giessendam 'De Bruin', dated between 4700 and 4450 BC, while the preceding phases (globally dated between 5500 and 4700 BC) did not yield evidence for domesticates (Oversteegen *et al.* 2001). Note that in these publications the lowest boundary of the dating range of phase 3 is taken as the introduction date, a step statistically not justified (since the exact introduction date could well have been near the higher boundary of the dating range). In any case, it remains impossible to prove, on the basis of the animal remains, whether the consumption of domestic animals at the De Bruin site relied on import or local herding. As has been noted by Van Neer *et al.* (2005), other evidence for domestic animals in fifth millennium Swifterbant sites is (still) absent. The Swifterbant deposit 'L30' of the site Brandwijk (4610–4550 BC according to

Raemaekers 1999, 43) contained a bone of a sheep or a goat (Robeerst 1995), but this context yielded only a few animal remains and was covered by younger layers with much higher densities of bones, including those from domestic animals. Possibly, we are thus dealing with an intrusive find within the Swifterbant deposit. According to the first finds reports on the Swifterbant site Almere 'Hoge Vaart' (dated between 5200 and 4530 BC, perhaps to be refined to 4900–4770 BC: Raemaekers 1999, 95), the bones of cattle and perhaps also of pigs have been found (Hogestijn *et al.* 1995a, b, 1996; Raemaekers 1999, 95; Hogestijn and Peeters 2001). However, the final study of this material has shown that this interpretation cannot be maintained (Laarman 2001). In contrast to this rather unconvincing dataset, younger Swifterbant contexts (best illustrated by the Swifterbant S3 site, 4200–3950 BC) have proven to contain the remains of livestock in high frequencies and the local raising of animals seems the only possible explanation for that pattern (Zeiler 1997).

As the sites at Doel cover a gap in the chronology presented by the Dutch Swifterbant sites, separating contexts with hardly any remains of domestic mammals and those where these animals reached high numbers, the hypothesis of local livestock herding at Doel is important. It could suggest that Swifterbant people raised domestic animals well before the onset of the Swifterbant S3 site.

Other aspects of the former economy outside of food procurement are hardly illustrated by the finds from Doel. The exception is the collection of animal furs. Marten was most probably hunted near sector M for that reason, and it could also have caused the death of a polecat (*Putorius putorius*) of which a bone was found at sector B. Again, finds numbers are too low to allow further interpretations.

Seasonality

Most charred seeds and fruits that have been found at the Doel sites have only a limited value for the determination of the season of occupation of the site as they are likely to have been collected for food and might have been stored for a certain period of time (Dark 2004). Mistletoe and ivy seeds are better indicators as the berries, available in winter/early spring, are not edible for humans and are thus not likely to have been stored. The internal wood anatomy of mistletoe twigs does not permit determination of the season when it has been collected. However, the fact that it has been collected (as for ivy) for fodder indicates winter/early spring, as other possible sources of fodder are scarce during that time of the year. During other seasons, taxa far more suitable for use as leaf fodder, as elm and ash, would have been preferred (Deforce *et al.* 2013).

The (scarce) finds of animals most likely hunted for their fur (marten at sector M, polecat at sector B) could indicate a winter activity. The reasoning behind this interpretation is that during that part of the year the fur is thickest and that, possibly, in the barren landscape the animals are then easier to hunt.

The amphibians, present in two hearths at sector M and at sector B, must have been caught outside of the coldest period of the year (during which they hibernate). They may have been most vulnerable to human predation during the reproduction season when they migrate over land.

The presence of shad is a good seasonality indicator because these species start their spawning run in spring, nowadays only when the water temperature rises above 11°C. The twaite shad spawns usually in waters with a temperature range of 15–20°C (Whitehead 1985). As mentioned above, 20th century records of twaite shad in the Scheldt estuary range between April and June–August, whereas allis shad typically spawned in the Scheldt basin in April and May. The flatfish could not be brought to species, but it is most likely that it is euryhaline flounder that typically inhabit the Scheldt estuary in spring (Maes *et al.* 1998). The three-spined stickleback, which can live in both a marine and a freshwater environment, is in fact a marine species. In spring they migrate massively into estuaries for spawning and in winter they return to the sea (Nijssen and de Groot 1987). In the Scheldt estuary, the thin-lipped mullet is nowadays sampled in large numbers in winter and early spring, together with flounder and three-spined stickleback (Maes *et al.* 1998).

This seasonality analysis, pointing towards activities in winter and spring, is best supported by the material from sector M. Remarkably, the major difference between the fish faunas from sectors B and M lays in the absence, in sector B, of the seasonal indicators mentioned above (shad, flatfish, three-spined stickleback and thin-lipped mullet) (Table 3). However, this pattern could be related to differences in the physical environment around that site, perhaps even the result of the diachronic evolution of the landscape, rather than to the season in which the fishing activities took place. The differences between the fish assemblages of the hearths at sector M could also have a seasonal nature, assuming that the dates of these structures do not lay too far apart for landscape evolution to have played a role). Also the fact that two hearths only contained mammal remains, and no fish bones, while two showed the opposite pattern, could reflect seasonal shifts in activities.

In total, following a minimalistic approach, the Doel sites, and especially sector M, yielded indications for activities in (late?) winter and spring. Differences between the fish faunas from sector M, most notable

in the frequencies of shad, suggest a period of activity that lasted somewhat longer than the strict migration time of this anadromous species. The sites could even have been visited outside winter and spring (focusing on hunting instead of fishing, as possibly reflected by hearths 1 and 4 from sector M) but there is no conclusive evidence to prove this. Remarkably, the vague dating of hearths 1 and 3, thought to represent a palimpsest, does not hamper their interpretation in terms of seasonality.

Conclusion

The Swifterbant sites excavated at Doel were situated in an alluvial hardwood forest, located on the top of sandy ridges surrounded by wetlands. Possibly, the sites illustrate a diachronic rise of marine influence in the river basin, during the second half of the fifth millennium BC, but with minimal tidal influence, or salt or brackish water in general, reaching the sites.

In terms of the exploitation of animal resources, the sites have shed light upon local fishing (using traps) and hunting (most probably both for meat and fur), and provided (botanical) evidence for the herding of domestic mammals. The latter observation is of importance for the reconstruction of the chronological development of the food economy of the Swifterbant culture.

At the sites, activities certainly took place in winter and spring, but were most probably not restricted to a very limited time span within that period. Activities may also have taken place in other seasons but, at present, this is impossible to prove. Of course, the function of the Doel sites within the economy of the Swifterbant people on a larger scale remains cryptic. Chances are real that we are dealing with temporary hunting and fishing camps, at which also the herding of livestock was organised. Alternatively, the sites can represent temporary stops for people herding animals, taking the opportunity to perform some hunting and fishing too. In any case, it remains possible that the consumption remains at the sites are only partly representative of the food economy of the Swifterbant people. Unless more inland, perhaps permanent residences, located on higher, drier grounds, are investigated, the image of the Swifterbant economy will remain fragmentary.

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References

- Artyukhin, E. and Vecsei, P. 1999. On the status of Atlantic sturgeon: conspecificity of European *Acipenser sturio* and North American *Acipenser oxyrinchus*. *Journal of Applied Ichthyology* **15**(4–5), 35–7.
- Bailon, S. 1997. La grenouille rousse (*Rana temporaria*). Une source de nourriture pour les habitants de Chalain 3, pp. 711–6 in Pétrequin, P. (ed.), *Les Sites Littoraux Néolithiques de Clairvaux-les-Lacs et de Chalain (Jura)*, III, Chalain Station 3. 3200–2900 av. J.-C. Paris: Editions de la Maison des Sciences de l'Homme.
- Bailon, S. 2005. Les amphibiens du Néolithique moyen du camp de Chasse: un nouvel exemple de la consommation de grenouilles dans le Néolithique français, pp. 423–8 in Thévenot, J.-P. (ed.), *Le Camp de Chasse (Chassey-le-Camp, Saône-et-Loire); les Niveaux Néolithiques du Rempart de "la Redoute"* (*Revue Archéologique de l'Est. Supplément 22*). Dijon: Société Archéologique de l'Est.
- Bastiaens, J., Deforce, K., Klinck, B., Meersschaert, L., Verbruggen, C. and Vrydaghs, L. 2005. Palaeobotanical analyses, pp. 251–78 in Crombé, Ph. (ed.), *The Last Hunter-Gatherer-Fishermen in Sandy Flanders (NW Belgium). The Verrebroek and Doel Excavation Projects. Volume 1: Palaeo-environment, Chronology and Features* (Archaeological Reports Ghent University 3). Gent: Academia Press.
- Bats, M., Crombé, Ph., Perdaen, Y., Sergeant, J., Van Roeyen, J.-P. and Van Strydonck, M. 2003. Nieuwe ontdekkingen in het Deurganckdok te Doel (Beveren, Oost-Vlaanderen): Vroeg- en Finaal-Mesolithicum. *Notae Praehistoricae* **23**, 55–9.
- Boudin, M., Van Strydonck, M. and Crombé, Ph. 2009. Radiocarbon dating of pottery food crusts: reservoir effect or not? The case of the Swifterbant pottery from Doel "Deurganckdok", pp. 727–45 in Crombé, Ph., Van Strydonck, M., Sergeant, J., Bats, M. and Boudin, M. (eds.), *Chronology and Evolution within the Mesolithic of North-West Europe. Proceedings of an International Meeting, Brussels, May 30th–June 1st 2007*. Cambridge: Scholars Publishing.
- Boudin, M., Van Strydonck, M., Crombé, P., De Clercq, W., Van Dierendonck, R. M., Jongepier, H., Ervynck, A. and Lentacker, A. 2010. Fish reservoir effect on charred food residue 14C dates: are stable isotope analyses the solution? *Radiocarbon* **52**(2–3), 697–705.
- Brinkhuizen, D. C. 2006. Fish, pp. 449–70 in Louwe Kooijmans, L. P. and Jongste, P. F. B. (eds.), *Schippluizen. A Neolithic Settlement on the Dutch North Sea Coast c. 3500 cal B.C.* (Analecta Praehistorica Leidensia 37/38). Leiden: Leiden University, Faculty of Archaeology.
- Bronk Ramsey, C. 1995. Radiocarbon calibration and analysis of stratigraphy: the OxCal program. *Radiocarbon* **37**(2), 425–30.
- Bronk Ramsey, C. 2001. Development of the radiocarbon calibration program. *Radiocarbon* **43**(2A), 355–63.
- Cappers, R. T. J. and Raemaekers, D. C. M. 2008. Cereal cultivation at Swifterbant? *Current Anthropology* **49**(3), 385–402.
- Chiquet, P. 2005. Des Mésolithiques amateurs de grenouilles? Une étonnante découverte sur le site de la Baume d'Ogens (Vaud, Suisse). *Revue de Paléobiologie, Genève* Vol. spéc. **10**, 59–67.
- Crombé, Ph. 2005. *The Last Hunter-Gatherer-Fishermen in Sandy Flanders (NW Belgium). The Verrebroek and Doel Excavation Projects. Volume 1: Palaeo-environment, Chronology and Features* (Archaeological Reports Ghent University 3). Gent: Academia Press.
- Crombé, Ph. 2010. Contact and interaction between early farmers and late hunter-gatherers in Belgium during the 6th and 5th millennium cal BC, pp. 551–66 in Gronenborn, D. and Petrasch, J. (eds.), *Die Neolithisierung Mitteleuropas – The spread of the Neolithic to Central Europe*. Mainz: Römisch-Germanisches Zentralmuseum.
- Crombé, P., Bats, M., Wuyts, F. and Van Roeyen, J.-P. 2004. Een derde vindplaats van de Swifterbantcultuur in het Deurganckdok te Doel (Beveren, Oost-Vlaanderen, België). *Notae Praehistoricae* **24**, 105–7.
- Crombé, Ph., Sergeant, J. and Perdaen, Y. 2009. The neolithisation of the Belgian lowlands: new evidence from the Scheldt Valley, pp. 564–9 in McCartan, S. B., Schulting, R., Warren, G. and Woodman, P. (eds.), *Mesolithic Horizons. Papers Presented at the Seventh International Conference on the Mesolithic in Europe*. Oxford: Oxbow Books.
- Dark, P. 2004. Plant remains as indicators of seasonality of site-use in the Mesolithic period. *Environmental Archaeology* **9**, 39–45.
- Deforce, K. 2011. Middle and late Holocene vegetation and landscape evolution of the Scheldt estuary. A palynological study of a peat deposit from Doel (N-Belgium). *Geologica Belgica* **14**, 277–88.
- Deforce, K., Bastiaens, J., Van Neer, W., Ervynck, A., Lentacker, A., Sergeant, J. and Crombé, Ph. 2013. Wood charcoal and seeds as indicators for animal husbandry in a wetland site during the late Mesolithic-early Neolithic transition period (Swifterbant culture, ca. 4600–4000 BC) in NW-Belgium. *Vegetation History and Archaeobotany* **22**, 51–60.
- Desse-Berset, N. 2009. First archaeozoological identification of Atlantic sturgeon (*Acipenser oxyrinchus* Mitchell 1815) in France. *Comptes Rendus Palevol* **8**, 717–24.
- Desse-Berset, N. 2011. Ancient sturgeon populations in France through archaeozoological remains, from prehistoric time until the eighteenth century, pp. 91–116 in Williot, P., Rocard, E., Desse-Berset, N., Kirschbaum, F. and Gessner, J. (eds.), *Biology and Conservation of the European Sturgeon Acipenser sturio L. 1758*. Berlin/Heidelberg: Springer Verlag.
- Enghoff, I. B. 1987. Freshwater fishing from a sea-coast settlement – the Ertebølle locus classicus revisited. *Journal of Danish Archaeology* **5**, 62–76.
- Enghoff, I. B. 1993. Mesolithic eel-fishing at Bjørnsholm, Denmark, spiced with exotic species. *Journal of Danish Archaeology* **10**, 105–18.
- Enghoff, I. B. 1994. Fishing in Denmark during the Ertebølle period. *International Journal of Osteoarchaeology* **4**, 65–96.
- Enghoff, I. B. 2011. *Regionality and Biotope Exploitation in Danish Ertebølle and Adjoining Periods* (Scientia Danica. Series B, Biologica. Vol. 1). Copenhagen: The Royal Danish Academy of Sciences and Letters.
- Hogestijn, J. W. H. and Peeters, J. H. M. 2001. *De Mesolithische en Vroeg-Neolithische Vindplaats Hoge Vaart-A27 (Flevoland)* (Rapportage Archeologische Monumentenzorg 79). Amersfoort: Rijksdienst voor het Oudheidkundig Bodemonderzoek.
- Hogestijn, W. J., Peeters, H., Schnitger, W. and Bulten, E. E. B. 1995a. Bewoningsresten uit de Steentijd langs een voormalige loop van de Eem in zuidelijk Flevoland; de voltooiing van de A27 en de archeologie. *Cultuur Historisch Jaarboek voor Flevoland* **5**, 83–102.
- Hogestijn, W. J., Peeters, H., Schnitger, W. and Bulten, E. E. B. 1995b. Bewoningsresten uit het Laat Mesolithicum/Vroeg Neolithicum bij Almere (Prov. Fl.): verslag van de eerste resultaten van de opgraving 'A27 – Hoge Vaart'. *Archeologie* **6**, 66–89.
- Hogestijn, W. J., Peeters, H. and Schnitger, W. 1996. Bewoningsresten uit het Vroeg Neolithicum bij Almere; Enkele resultaten van de opgraving 'Hoge Vaart'. *Cultuur Historisch Jaarboek voor Flevoland* **6**, 93–115.
- Huet, M. 1949. Aperçu de la relation entre la pente et les populations piscicoles des eaux courantes. *Schweizerische Zeitschrift für Hydrologie* **11**, 332–51.
- Jonsson, L. 1986. Fish bones in late Mesolithic human graves at Skateholm, Scania, south Sweden, pp. 62–79 in Brinkhuizen, D. C. and Clason, A. T. (eds.), *Fish and Archaeology: Studies in Osteometry, Taphonomy, Seasonality and Fishing Methods* (British Archaeological Reports International Series 294). Oxford: Archaeopress.
- Kysely, R. 2008. Frogs as a part of the Eneolithic diet. Archaeozoological records from the Czech Republic (Kutná

- Hora-Denemark site, Řivnáč Culture). *Journal of Archaeological Science* **35**, 143–57.
- Laarman, F. J. 2001. *De Mesolithische en Vroeg-Neolithische Vindplaats Hoge Vaart-A27 (Flevoland): Archeozoölogie: Aard en Betekenis van de Dierlijke Resten* (Rapportage Archeologische Monumentenzorg 79, part 16). Amersfoort: Rijksdienst voor het Oudheidkundig Bodemonderzoek.
- Libois, R. M., Hallet-Libois, C. and Rosoux, R. 1987. *Éléments pour l'Identification des Restes Crâniens des Poissons Dulçaquicoles de Belgique et du Nord de la France. I – Anguilliformes, Gastérostéiformes, Cyprinodontiformes et Perciformes* (Fiches descriptives animale pour l'archéologie. Série A. Poissons n°3). Juan-les-Pins: Centre de Recherches Archéologiques du CNRS, APDCA.
- Louwagie, G. and Langohr, R. 2005. Podo-lithostratigraphical analyses, pp. 27–107 in Crombé, Ph. (ed.), *The Last Hunter-Gatherer-Fishermen in Sandy Flanders (NW Belgium). The Verrebroek and Doel Excavation Projects. Volume 1: Palaeo-environment, Chronology and Features* (Archaeological Reports Ghent University 3). Gent: Academia Press.
- Louwe Kooijmans, L. P. 1993. Wetland exploitation and upland relations of prehistoric communities in the Netherlands, pp. 71–116 in Gardiner, J. (ed.), *Flatlands and Wetlands. Current Themes in East Anglian Archaeology* (East Anglian Archaeology 50). Norwich: Scole Archaeological Committee for East Anglia.
- Louwe Kooijmans, L. P. 2001. *Hardinxveld-Giessendam De Bruin. Een kampplaats uit het Laat-Mesolithicum en het begin van de Swifterbant-cultuur (5500–4450 v.Chr.)* (Rapportage Archeologische Monumentenzorg 88). Amersfoort: Rijksdienst voor het Oudheidkundig Bodemonderzoek.
- Louwe Kooijmans, L. P. 2007a. Van Hardinxveld naar Schipluiden. Van jager tot boer, pp. 151–66 in Jansen, R. and Louwe Kooijmans, L. P. (eds.), *Van Contract tot Wetenschap. Tien Jaar Archeologisch onderzoek door Archol BV, 1997–2007*. Leiden: Archol.
- Louwe Kooijmans, L. P. 2007b. The gradual transition to farming in the Lower Rhine Basin, pp. 287–309 in Whittle, A. and Cummings, V. (eds.), *Going Over: the Mesolithic–Neolithic Transition in North-West Europe*. Oxford: Oxford University Press.
- Ludwig, A., Debus, L., Lieckfeldt, D., Wirgin, I., Benecke, N., Jenneckens, I., Williot, P., Waldman, J. R. and Pitra, C. 2002. Fish populations: when the American sea sturgeon swam east. *Nature* **0496/620002**, 447–8.
- Ludwig, A., Makowiecki, D. and Benecke, N. 2009. Further evidence of trans-Atlantic colonization of Western Europe by American Atlantic sturgeons. *Archaeofauna* **18**, 185–92.
- Maes, J., Taillieu, A., Van Damme, P. A., Cottenie, K. and Ollevier, F. 1998. Seasonal patterns in the fish and crustacean community of a turbid temperate estuary (Zeeschelde estuary, Belgium). *Estuarine, Coastal and Shelf Science* **47**, 143–51.
- Magnin, E. 1963. *Recherches sur la Systématique et la Biologie des Acipenseridés Acipenser sturio L., Acipenser oxyrinchus Mitchill, Acipenser fulvescens Raf.* Unpublished PhD thesis, Université de Paris, Paris.
- Nijssen, H. and de Groot, S. J. 1987. *De Vissen van Nederland*. Utrecht: Stichting Uitgeverij van de Koninklijke Nederlandse Natuurhistorische Vereniging.
- Out, W. A. 2008. Growing habits? Delayed introduction of crop cultivation at marginal Neolithic wetland sites. *Vegetation History and Archaeobotany* **17**(Suppl. 1), 131–8.
- Out, W. A. 2009a. *Sowing the seed? Human impact and plant subsistence in Dutch wetlands during the Late Mesolithic and Early and Middle Neolithic (5500–3400 cal BC)* (Archaeological Studies Leiden University 18). Leiden: Leiden University Press.
- Out, W. A. 2009b. Reaction to “Cereal cultivation at Swifterbant? Neolithic wetland farming on the North European Plain”. *Current Anthropology* **50**(2), 253–4.
- Oversteegen, J. F. S., van Wijngaarden-Bakker, L. H., Maliepaard, R. and van Kolfschoten, Th. 2001. Zoogdieren, vogels, reptielen, pp. 209–97 in Louwe Kooijmans, L. P. (ed.), *Hardinxveld-Giessendam De Bruin. Een Kampplaats uit het Laat-Mesolithicum en het begin van de Swifterbant-cultuur (5500–4450 v.Chr.)* (Rapportage Archeologische Monumentenzorg 88). Amersfoort: Rijksdienst voor het Oudheidkundig Bodemonderzoek.
- Poll, M. 1947. *Faune de Belgique. Poissons Marins*. Bruxelles: Musée Royal d'Histoire Naturelle de Belgique.
- Radu, V. 2005. *Atlas for the Identification of Bony Fish Bones from Archaeological Sites* (Asociația Română de Arheologie. Studii de Preistorie. Supplementum 1). Bucarest: Editura Contrast.
- Raemaekers, D. C. M. 1999. *The Articulation of a 'New Neolithic'. The Meaning of the Swifterbant Culture for the Process of Neolithisation in the Western Part of the North European Plain (4900–3400 BC)* (Archaeological Studies Leiden University 3). Leiden: Leiden University, Faculty of Archaeology.
- Raemaekers, D. 2006. *De Spiegel van Swifterbant. Rede Uitgesproken bij de Aanvaarding van het ambt van Hoogleraar in de Pre- en Protohistorie van Noordwest-Europa bij de Faculteit der Letteren van de Rijksuniversiteit Groningen op 13 juni 2006*. Groningen: Rijksuniversiteit Groningen.
- Reimer, P. J., Baillie, M. G. L., Bard, E., Bayliss, A., Beck, J. W., Blackwell, P. G., Bronk Ramsey, C., Buck, C. E., Burr, G. S., Edwards, R. L., Friedrich, M., Grootes, P. M., Guilderson, T. P., Hajdas, I., Heaton, T. J., Hogg, A. G., Hughen, K. A., Kaiser, K. F., Kromer, B., McCormac, F. G., Manning, S. W., Reimer, R. W., Richards, D. A., Southon, J. R., Talamo, S., Turney, C. S. M., van der Plicht, J. and Weyhenmeyer, C. E. 2009. IntCal09 and Marine09 radiocarbon age calibration curves, 0–50,000 years cal BP. *Radiocarbon* **51**(4), 1111–50.
- Robeerst, J. M. M. 1995. De Neolithische fauna van de donk ‘Het Kerkhof’ bij Brandwijk, Alblasserwaard. Unpublished report, University of Leiden.
- Schnitzler, A. 1994. European alluvial hardwood forests of large floodplains. *Journal of Biogeography* **21**, 605–23.
- Steffen, M. and Mackie, Q. 2005. An experimental approach to understanding burnt fish bone assemblages within archaeological hearth contexts. *Canadian Zooarchaeology/Zoarchéologie Canadienne* **23**, 11–38.
- Van der Waals, J. D. 1977. Excavations at the natural levee sites S2, S3/5 and S4 (Swifterbant Contribution 6). *Helinium* **17**, 3–27.
- Van Neer, W., Ervynck, A. and Lentacker, A. 2005. Archaeozoological analyses, pp. 279–94 in Crombé, Ph. (ed.), *The Last Hunter-Gatherer-Fishermen in Sandy Flanders (NW Belgium). The Verrebroek and Doel Excavation Projects. Volume 1: Palaeo-environment, Chronology and Features* (Archaeological Reports Ghent University 3). Gent: Academia Press.
- Van Strydonck, M. 2005. Radiocarbon dating, pp. 127–37 in Crombé, Ph. (ed.), *The Last Hunter-Gatherer-Fishermen in Sandy Flanders (NW Belgium). The Verrebroek and Doel Excavation Projects. Volume 1: Palaeo-environment, Chronology and Features* (Archaeological Reports Ghent University 3). Gent: Academia Press.
- Van Strydonck, M. and Crombé, Ph. 2005. Radiocarbon dating, pp. 180–212 in Crombé, Ph. (ed.), *The Last Hunter-Gatherer-Fishermen in Sandy Flanders (NW Belgium). The Verrebroek and Doel Excavation Projects. Volume 1: Palaeo-environment, Chronology and Features* (Archaeological Reports Ghent University 3). Gent: Academia Press.
- Vos, P. C. and Van Heeringen, R. M. 1997. Holocene geology and occupation history of the province of Zeeland (SW Netherlands). *Mededelingen Nederlands Instituut voor Toegepaste Wetenschappen TNO* **59**, 5–109.
- Whitehead, P. J. P. 1985. *FAO species catalogue. Vol. 7. Clupeoid Fishes of the World (suborder Clupeoidei). An Annotated and Illustrated Catalogue of the Herrings, Sardines, Pilchards, Sprats, Shads, Anchovies and Wolf-herrings. Part 1 – Chirocentridae, Clupeidae and Pristigasteridae* (FAO Fisheries Synopsis 125(7/1)). Rome: Food and Agriculture Organization of the United Nations.
- Wolf, R. J. A. M., Vrieling, J. G. and De Waal, R. 1997. Riverine woodlands in The Netherlands. *Global Ecology and Biogeography Letters* **6**, 287–95.
- Wouters, W., Muylaert, L. and Van Neer, W. 2007. The distinction of isolated bones from plaice (*Pleuronectes platessa*), flounder (*Platichthys flesus*) and dab (*Limanda limanda*): a description of the diagnostic characters. *Archaeofauna* **16**, 33–95.
- Zeiler, J. T. 1997. *Hunting, Fowling and Stock-breeding at Neolithic Sites in the Western and Central Netherlands*. Unpublished PhD thesis, Rijksuniversiteit Groningen.