

DEINSEA



History and future of paleontological surveys in the Westerschelde Estuary (Province of Zeeland, the Netherlands)

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ABSTRACT

Sediments of the Westerschelde Estuary are renowned for their abundance of mammalian fossils. The staggering numbers of fossils, however, contrast sharply with the lack of knowledge of the fossil faunas and of their stratigraphic context. In order to increase data on Westerschelde fossils, the sites and their stratigraphy, the Natural History Museum of Rotterdam organised three fishing trips in 2014. Various localities were prospected and 5461 mammal fossils with an estimated weight of over 15 metric tons were collected. The majority of the fossils (5308) belong to marine mammals (mostly Mysticeti, few Odontoceti, one Pinnipedia); just 153 fossils represent terrestrial mammals. The fossils of marine mammals originate from the Breda Formation (Langhian - Zanclean) and/or the Oosterhout Formation (Zanclean - Piacenzian), while all terrestrial mammal fossils are remains from the Late Pleistocene Weichselian mammoth steppe fauna. One hitherto unknown but promising site was discovered, yielding lumps of glauconitic sandstone matrix that contain well-preserved (parts of) skeletons of marine mammals.

Keywords Westerschelde, Miocene, Pliocene, Pleistocene, Cetacea, Mysticeti

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INTRODUCTION

Since the nineteenth century the Westerschelde Estuary has been known as a rich source of vertebrate fossils. Publications by De Man (1875, 1878, 1880), Weber (1917), Van Deinse (1943/1944), Van der Feen (1968), Hooijer (1975, 1982), Van Bree (1997), Bosscha Erdbrink & Van Bree (1999a, 1999b), Bosselaers & Post (2010), Post & Bosselaers (2010), and Bosselaers (2014) mentioned or described *ex situ* finds

made by commercial fishermen. From 1996 onwards, the Koninklijk Zeeuwsch Genootschap der Wetenschappen (KZGW) has organised a special annual fishing day trip with a mussel cutter. These trips confirm the amazing fossil potential of a particular site offshore of the city of Terneuzen.

The stratigraphy of (parts of) the estuary bottom has been subject of several studies (Drees 1986, Ebbing *et al.* 1993, Du Four *et al.* 2006) that confirm that Oligocene, Miocene, Plio-

cene and Pleistocene strata subcrop in the estuary. Moreover, strata are north-south tilted and therefore older strata are more frequently exposed in southern parts of the estuary (and at some terrestrial sites in Zeeuws Vlaanderen and North Belgium). Specific biostratigraphic studies and sequence stratigraphic models based on sediments of the easternmost part of the estuary (the Antwerp harbours) are provided by Louwye *et al.* (2004).

Given the complicated geology of the Westerschelde Estuary, the indication 'Westerschelde' (as is often encountered in both private and museum collections) provides limited stratigraphic information and often none at all. Unfortunately almost all fossils that have been collected in the past were isolated - and often damaged - skeletal elements which came to shore without a precise finding location and - usually - without any matrix attached. Hence their stratigraphic designation in literature was just roughly indicated as 'Pleistocene' (for the large vertebrates of the mammoth steppe fauna), or Miocene-Pliocene (for the large spectrum of fossils of marine mammals). In addition to this speculative dating, the marine mammal fossils rarely allowed identification to species and/or genus level. All this is quite unsatisfactory, and therefore the marine mammal fossil resources of the Westerschelde were (and are to date) considered of lesser scientific interest.

MATERIAL AND METHODS

In 2014 the Natural History Museum Rotterdam decided to (re) check the potential of various fossiliferous sites of the Westerschelde Estuary (we prefer to use the Dutch wording 'Westerschelde' instead of the sometimes used English 'Westerscheldt' or 'Western Scheldt'). The aim was to note all finds per location, to study important finds, and to make relevant information

accessible to science and the general public.

The fishing vessel (euro-cutter) UK 190 (86 GT, 300 HP) was leased from February 10-13, 2014 and June 3-5, 2014. From December 15-18, 2014 another ship, the UK 12 (48 GT, 300 HP) was used. Both vessels were equipped with specially constructed four meter beams and nets without chains in order to avoid damage to bottom and fossils. Positions and depths were administrated with the relevant equipment on board of the vessels.

The choice of sites was based on oral information of fishermen and the sites were plotted on International Chart map 1475: 'Westerschelde van Vlissingen tot Antwerpen met Kanaal van Terneuzen naar Gent' (Fig. 1). All fossils of any importance found during the expeditions are stored in the collection of the Natural History Museum Rotterdam (NMR), Rotterdam, the Netherlands.

STRATIGRAPHIC INFORMATION

As indicated in the introduction, several authors discussed the stratigraphy of (parts of) the Westerschelde. Drees (1986) provided two cross-sections without giving exact coordinates, one through the mouth of the estuary near or at site 1, and one east of site 7 (Fig. 2). Based on publications and maps published by the Dutch Geological Service in 1965, 1970, 1972 and 1975, he concluded that the following marine strata may be exposed on the bottom of the estuary: the Maassluis Formation (Gelasian), the Oosterhout Formation (Zanclean - Piacenzian), the Breda Formation (Langhian - Zanclean) and the Rupel Formation (Rupelian).

More recent publications reconfirm the presence of the above mentioned formations in the Southern North Sea basin (Ebbing

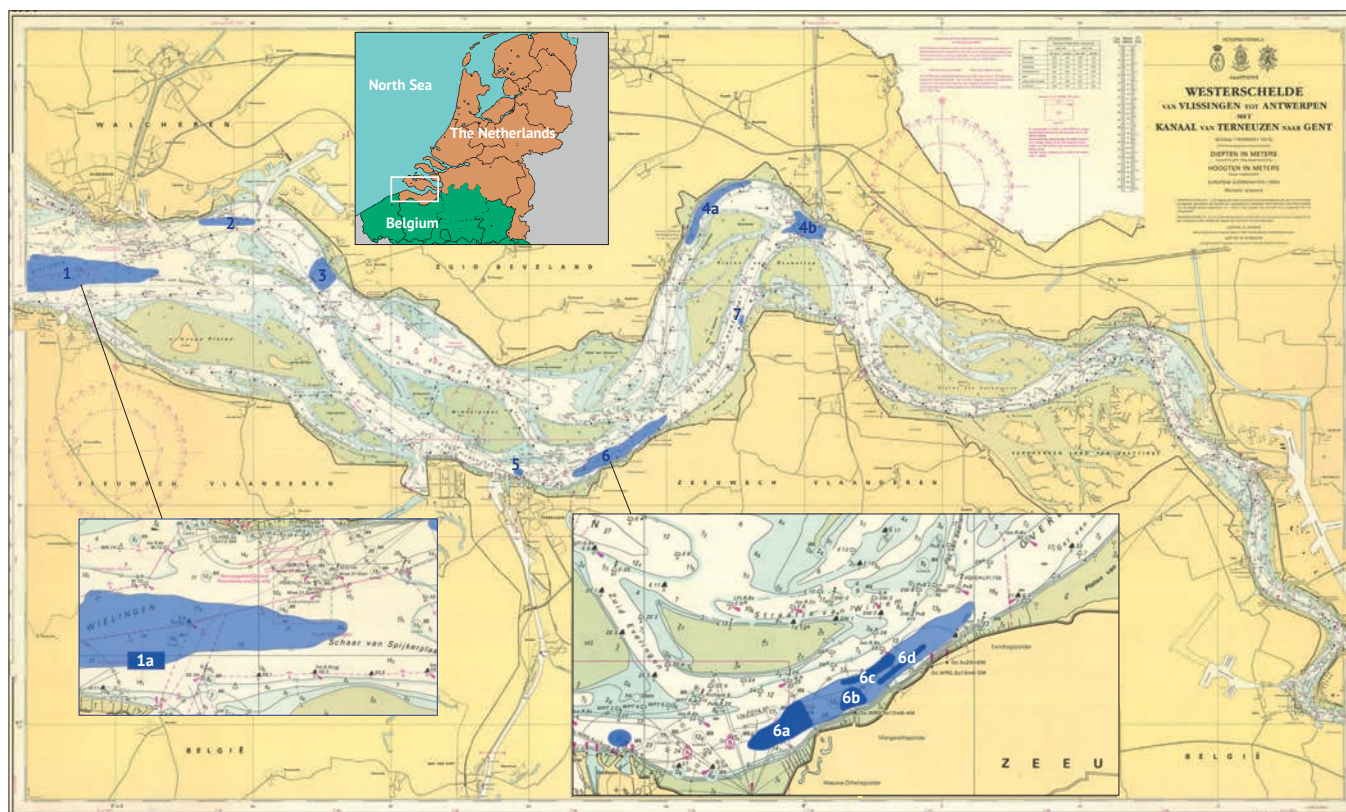


Figure 1 Map of the Westerschelde Estuary with the sites (pits), numbered 1-7, sampled in February, June and December 2014.

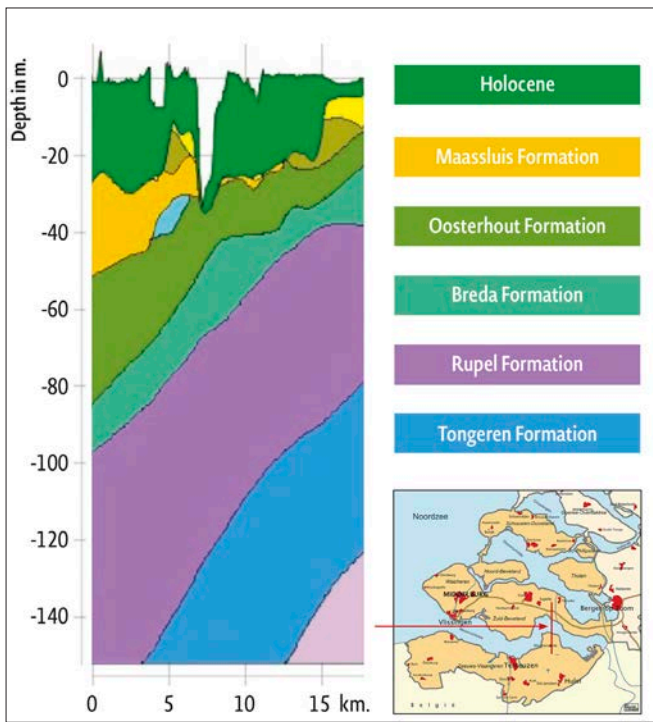


Figure 2 Subsurface strata of the Westerschelde Estuary near Hansweert (north-south).

et al. 1993; Du Four *et al.* 2006; Slupik *et al.* 2007; Slupik & Janse 2008), as do profiles available from the site of the Dutch Geological Service - www.dinoloket.nl (Fig. 2). Data available on this website allow a more detailed cross-section through the western end and the eastern end of site 6d (Fig. 3). The profiles clearly indicate that at this location the river, with a depth of c. 28-32 meters, cuts deeply through (and has partly eroded) the Middle Miocene to Early Pliocene Breda Formation and is touching the top of the Oligocene Rupel Formation (as indicated by Du Four *et al.* 2006). The latter observation is corroborated by the fact that the previously mentioned annual expedition of the KZGW frequently encounters lumps of Rupelian Boom Clay at location 6b (pers. comm. Mark Bosselaers, 2016). The profile implies the probability that the Oosterhout Formation might not have been present at this position, however, the possibility that eroded remains are left on the riverbed must be kept in mind. Also, rare remains of eroded Holocene strata can be found at the estuary bed.

Site 6d differs from all other Westerschelde sites in the fact that the area is rich in large lumps of fossil-containing sediment. Complete and perfectly preserved skulls and postcrania of marine mammals are embedded in anatomic position in glauconitic blue-grey large grained sandstones. Fossils embedded in matrix, or with matrix attached, appeared to be extremely rare until this site was discovered. Bosselaers & Post (2010) described a neurocranium of a fossil rorqual with some matrix

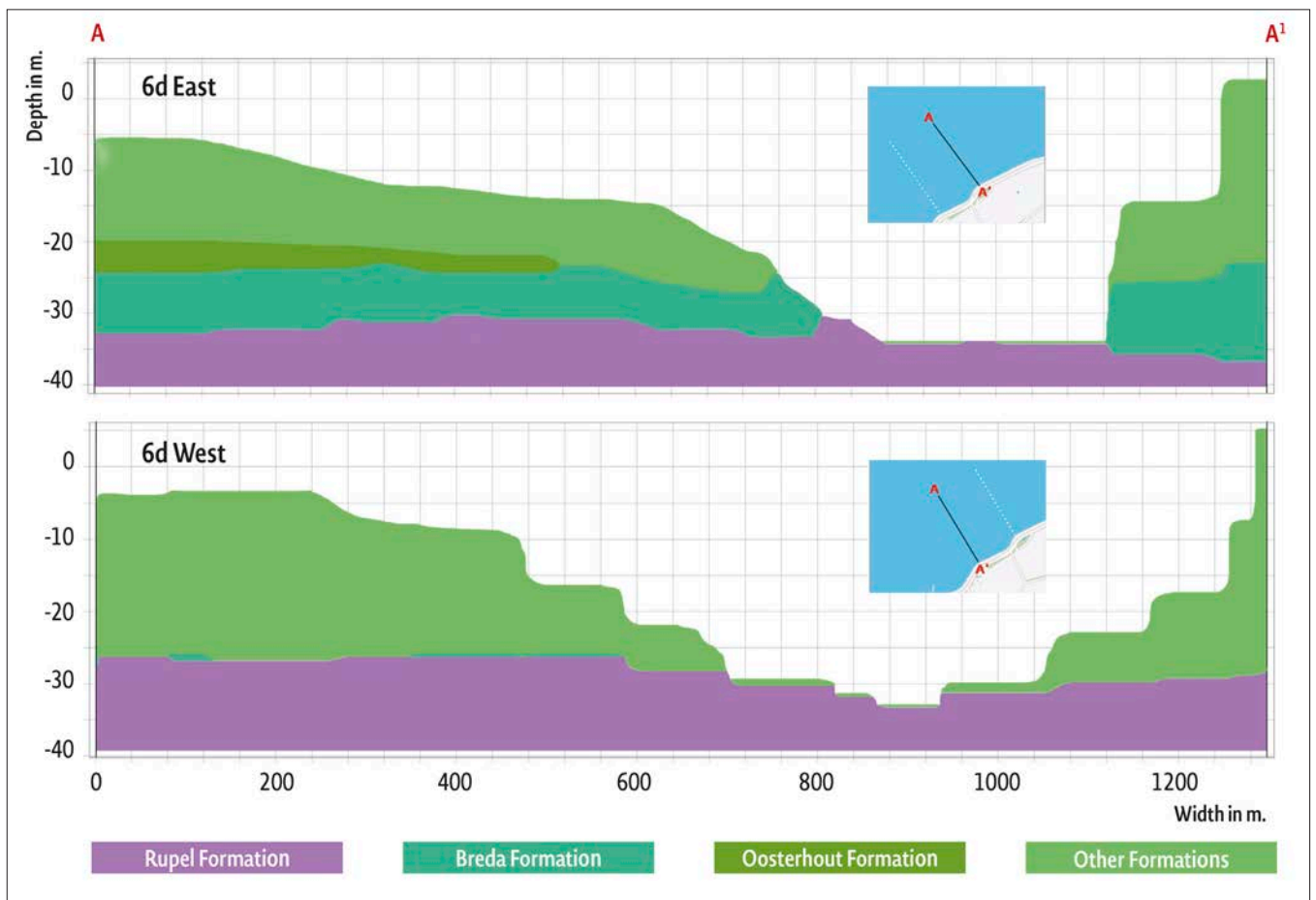


Figure 3 Westerschelde Estuary: profiles at site 6d.



Figure 4 Crew of the UK 190 (first author wearing orange gear) with part of a day's fossil catch at site 6c on June 4, 2014. (Jan Oost)

attached. This cranium was collected by fishermen from the bottom of the Westerschelde during the early twentieth century. An Early Pliocene age was concluded, mainly based on biostratigraphic data on mollusc species that were found in matrix. The assemblage of cranium and cervical vertebrae confirm that this fossil was preserved in anatomical position and had not been re-deposited. Unfortunately, nothing is known on the specific location from where this fossil was retrieved. This matrix differs from the glauconitic sandstones from site 6d. In Belgium just only one record of lumps of sediment containing marine mammal fossils is known. Herman & Marquet (2007) described Burdigalian

conglomerates from the Deurganckdok construction site containing marine mammalian (and other) fossils and named them as a specific lithostratigraphical unit: 'Deurganckdok Sandstones'. A detailed comparison has to be made, but the Deurganckdok Sandstones seem to have a completely different lithological composition in comparison to the sediment lumps of site 6d.

RESULTS

The bottom of the Westerschelde Estuary proved to be very difficult for demersal trawling, especially at fossil-rich locations. In addition to the busy traffic of large oceangoing vessels and the extremely strong tidal currents, the bottom of the estuary is littered with obstacles. Underneath lots of rubbish (refrigerators, bicycles, steel wire, old anchors and other debris, which are obviously a heritage of the ships steaming to and from Antwerp), the river floor is paved with large stones, or more precisely: large lumps of sediment. Occasionally giant obstacles of over 800 kilos may be encountered. Therefore, fishing for scientific purposes at this river means in reality a maximum of 1 to 3 minutes of fishing, as a result hauling 1 to 3 tons of stones and obstacles on deck, and thereafter spending 30 to 60 minutes moving heavy obstacles and mending nets. During night time, fishing is impossible and too dangerous due to the continuous traffic of ships, the obstacles on the bottom, and crew fatigue.

The harvest: 5461 fossil remains

In 95 fishing tows, in time varying from 1 to 16 minutes, a total of 5461 fossil mammalian remains were collected with a total estimated weight of over 15,000 kilos (Fig. 4). A total of 5308



Figure 5 Scapula, humerus, radius and ulna from an unidentified mysticete-species, freed from its matrix in anatomical position; found at site 6d on February 11, 2014; NMR 9991-012068. (Kees Moeliker)

fossils are from marine mammals (mostly cetaceans) and vary from large lumps of sediment with usually several skeleton parts in anatomical position (such as an almost two meter long and 300 kg heavy pair of mandibles of an as yet unidentified mysticete) to a staggering number of isolated skeletal parts varying from large skull fragments and vertebrae weighing over 10 kg to the sacrum of a fossil seal (Pinnipedia) weighing just a few grams (Table 1). Remains of terrestrial mammals were rarely encountered (n=153), and are restricted to more or less damaged large bones of the Late Pleistocene Weichselian mammoth steppe fauna. However large segments of skull and mandibles of woolly mammoth (*Mammuthus primigenius*), a skull with full dentition of a giant deer (*Megaloceros giganteus*), a neurocranium of a muskox (*Ovibos moschatus*), and a sacrum of a lion (*Panthera spelaea*) are worth mentioning. In addition to remains of mammals, fossils of bivalves, gastropods and some shark teeth were incidental components of the fossil by-catch, as well as a rare sea urchin (with spines), parts of the 'nose' of a moonfish (*Mola* sp.), and three articulated very large shark vertebrae in matrix.

Of special interest are the aforementioned large lumps of fossil rich sediment that are only encountered at one very limited site (6d) and that seem to be of identical lithological nature. The glauconitic blue-grey sandstone matrix always contains skeletal elements from one and the same species of mysticete (skull and/or mandibles and/or forearm parts and/or parts of the vertebral columns [Fig. 5]) or odontocete (skull with or without mandible, and skeletal parts). This locality appears to represent an uncommonly complete preservation of larger marine mammals, at least for Western Europe! So far, Pontoporiidae, Ziphiidae (Fig. 6), Balaenopteroidea and Cetotheriidae have been provisionally identified (Table 2). Although further research is needed and presently being performed, we may conclude that locality 6d is rich and important.

A peculiar observation is the frequent appearance of usually smaller fossils (such as teeth, periotics, vertebrae) that are embedded in, or assembled at, anthropogenic iron-rich objects (such as steel wire or steel bars, see Fig. 7). We so far have no explanation for this observation.

SITES

Below, the investigated sites are reported upon. Their locations are depicted in Figure 1, and Table 3 holds the geographical coordinates of their centres.

1 Wielingen

This vast area situated near and in the estuary of the Westerschelde has been frequented since the 19th century by commercial trawlers fishing for shrimp and Dover sole. The bottom is flat and relatively free of obstacles and in some parts of the area fossils of marine mammals are encountered. The array of fossils from the small investigated area seems to resemble the annual catch of the KZGW expedition near 'De Griete' (in area 6b): abundant isolated vertebrae and skull fragments of Mysticeti, very rare remains of Odontoceti (a few isolated sperm whale teeth) and some nice large fossils of the Late Pleistocene Weichselian mammoth steppe fauna. Most of the skulls

of beaked whales (Ziphiidae) in the collection of the Naturalis Biodiversity Center (Leiden, The Netherlands) were collected in this area during the 19th century, as was the *Choneziphius*-skull described by Weber in 1917. This vast site deserves further sampling.

2 Pit of De Kaloot

Old stories tell about huge amounts of large vertebrae being collected in this area. A more solid fact is the fame of the nearby beach ('de Kaloot') as a treasure trove for collectors of fossil molluscs and vertebrates (Reumer 2008). Due to technical problems just two tows were done during our 2014 expeditions. The deeper part of the pit appeared to be full of obstacles and sharp stones and was therefore difficult for bottom trawling. Apart from some objects and stones, just one fossil was collected: a large fragment of a mysticete mandible which seems morphologically different from all other mandible finds from the Westerschelde so far. This site therefore deserves additional sampling.

3 Pit of Borssele

In the deepest parts of the Pit (> 50 meters) trawling appeared practically impossible because the trench is littered with very large boulders. Fossils are present: some vertebrae and a vertex of *Choneziphius* were collected. The less deep parts are paved with thousands of small rounded boulders and rounded flints, and with lots of isolated skeletal fragments of randomly the same composition as the fauna found in areas 1 and

Table 1 Harvest of marine mammal fossils of the 2014 Westerschelde Expeditions (excluding fossils in matrix of site 6d; see Table 2).

Odontoceti	
cranial fragments including rostra	18
flipper (radius/ulna)	2
teeth	4
vertebra	4
total	28
Mysticeti	
cranial parts including vertex	1927
ear (bullae, perioticum)	53
flipper (scapula, humerus, radius, ulna)	120
vertebra + rib fragments	3141
total	5241
Pinnipedia	
sacrum	1
total	1



Figure 6 Skull with adhering mandible of a beaked whale (Ziphiidae), freed from its matrix, found at site 6d on December 16, 2014; NMR 9991-012016. (Lub Post)

6b and c. Towards the sides the Pit of Borssele becomes shallow, with depths varying between 10-15 meters over a small distance. Fishing is dangerous here because of unstable steep sand walls.

4a, 4b Pits south and west of Hansweert

A vast area of soft bottom with relatively few obstacles. Both of the deeper pits seem paved with large peat lumps, the age of which is unfortunately unknown. Fossils were not encountered.

5 Pit north of Terneuzen (in front of the old harbour)

This deep pit (over 40 meters) seems be filled with construction debris (fragments of brick walls of old buildings). Regular sampling proved impossible and fossils were not found.

Table 2 Harvest of the 2014 Westerschelde expeditions: marine mammal fossils in lumps of sediment from site 6d.

Odontocetes	
crania of beaked whales	3
cranium of pontoporiid	1
cranium of odontocete indet.	1
cluster of vertebra	3
Mysticetes	
crania and partial crania of cetotheres	> 4
crania of balaenopteroidea	3
maxillae and/or mandibulae	> 10
scapula + associated flipper bones	3
clusters of vertebrae	> 15

6a, 6b, 6c, 6d Pit De Griete

A long and narrow pit of at least one km length and 24-35 meters depth runs parallel to the dike and is situated in the main shipping zone. The bottom seems paved with fossils of marine mammals. A few areas with distinctive characteristics are present and are here separately named 6a through 6d.

6a The part most close to Terneuzen

Lots of industrial bricks, stones and debris are found here, but no fossils.

6b The ZZ 10 site

This site is the traditional site of the aforementioned annual KZGW fishing trip. At 28-32 meter depth a wealth of marine

Table 3 Geographical coordinates of the sampled sites in the Westerschelde Estuary, in 2014. See Figure 1 for map.

Site	coordinates
1	51°25'11" N - 3°33'21" E
2	51°26'23" N - 3°38'49" E
3	51°25'15" N - 3°42'40" E
4a	51°26'54" N - 3°56'18" E
4b	51°26'15" N - 4°0'34" E
5	51°20'45" N - 3°49'32" E
6a	51°20'49" N - 3°51'59" E
6b	51°21'06" N - 3°53'8" E
6c	51°21'16" N - 3°53'18" E
6d	51°21'56.9" N - 3°54'25.1" E
7	51°24'03" N - 3°57'32" E



Figure 7 Fossil axis of a mysticete attached to a rusted steel bar. (Lub Post)

mammal fossils is encountered, originating from Miocene and Pliocene strata. During every trip a few fossils of Late Pleistocene Weichselian terrestrial mammals are usually found as well. The UK 190 has briefly sampled this area (four tows on February 13, 2014) and a few large mysticete vertebra were found. In contrast to the annual results of the ZZ 10 (which harvests lots of small fossils) smaller elements were not found at all, which proved that the mussel fishing gear of the ZZ 10 is able to sample the top layer of the bottom much more effectively for smaller pieces. The annual trip of 2014 of the ZZ 10 visited site 6b again and this resulted in the spectacular find of a rostrum of the beaked whale *Beneziphius brevirostris*; the first such find in The Netherlands and the third worldwide (Bosselaers 2014).

6c Area towards the northern border of the shipping zone

Site 6c is a fairly long slide parallel to the red buoys of the marine traffic line that varies in depth from 23-29 meters. The bottom is relatively free of stones and conglomerates and is extremely rich in isolated marine mammal fossils. Some tows were harvesting over 200 kg of fossils in just one to two minutes. Large and relatively complete fossils of the mammoth steppe fauna (such as complete jaws of woolly mammoth and the skull of a giant deer) seem more abundant in this area than in other areas of the Westerschelde.

6d Area with large lumps of sediment

At a depth of 28-32 meter many large lumps of sediment were collected. Trawling is difficult and, with sometimes strong currents, often dangerous. Some of the lumps of glauconitic sand-

stones contain remains of turtles, large sharks and especially unusually well preserved fossils of marine mammals, such as skulls with mandibles (Fig. 6) and sometimes associated post-crania (Fig. 5). New taxa (Ziphiidae, Pontoporiidae, Balaenopteroidea and Cetotheriidae) are in the process of being described. At least 40 of these lumps (and fossils) will be housed in the NMR-collection (Table 2). The site is very limited in size. It is the location where two skulls of Odontocetes were found together in one particular tow (tow 3 on December 17, 2014). The fossils in the glauconitic sandstone matrix seem to be different from the isolated fossils found in areas 1, 6b and 6c. Research on dinoflagellates from the adhering matrix is being undertaken by the University of Gent (S. Louwye) and the Utrecht University (B. van de Steenbrugge, J. Reumer, R. Veenhof) and results are being prepared for publication.

7 The pit around the south-eastern bight towards Antwerp

This pit is located eastwards to area 6 (and is of more or less the same depth). Three tows were done and fossils were not encountered.

CONCLUSIONS AND FUTURE WORK

The expeditions prove that careful and precise collection of fossils from a clearly identified and earmarked *ex situ* location in the Westerschelde provides basic information through the staggering number of fossils that are found. The possibility of comparing more than 30 mysticete vertexes from one single location in the Westerschelde was hitherto never possible, and this yields valuable scientific information. Future as well as presently

ongoing work based on the fossils (especially those from area 6d) will give insight in faunal components, in the stratigraphic context of the finds, in the dating or correlation of the sediment, and it will reveal whether one single fauna or a possible mixture of different faunas is encountered. Furthermore, important and complete fossils from these trips may be compared with and/or linked to fossils from museum collections that were collected in the past without clear information of location and depth.

As said, the - by far - most important scientific discovery of these expeditions is the precise location of the large fossil-containing lumps of glauconitic sediment in area 6d. Large and fairly complete remains of pontoporiids, ziphiids, balaenopteroids and cetotheriids are encountered in satisfying quantities. The most important fossils of this site are prepared or will be prepared, and will be identified and described in due time. The sandstone matrix will be studied in order to provide a biostratigraphic and chronostratigraphic framework.

Last but not least it seems advisable to re-sample sites 1 and 2 and some other enigmatic sites at the mouth of the Westerschelde Estuary. Geologically older strata are exposed at the point where the estuary meets the North Sea, and may conceal hitherto unknown mammal taxa or faunae (that is, for the Netherlands).

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