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PALAEONTOLOGICAL INVESTIGATION OF A BRACKISH-MARINE LATE HOLOCENE DEPOSIT AT WERVERSHOOF (PROVINCE OF NORTH-HOLLAND, THE NETHERLANDS)

by

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Noordwijk

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In a temporary exposure in the northern part of the province of North-Holland a deposit of Subboreal age (Dunkirk 0) was studied. Investigation of 11 samples demonstrates the occurrence of pollen and spores, seeds, Foraminifera, Annelida, Ostracoda, Acarina, Mollusca, Bryozoa, Echinodermata and Pisces. The environmental developments in the Dutch coastal area near Wervershoof about 3,500 years ago is discussed.

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SAMENVATTING

Tijdens een opgraving bij Wervershoof (tekstfig. 1a-b) in 1976 werd een aantal grondmonsters van 1 liter uit een mariene afzetting verzameld. Het doel was een overzicht te krijgen van de flora en fauna in deze afzetting (Subboreaal - Duinkerke 0) en van mogelijke veranderingen in de loop van de tijd.

De afzetting is ongeveer 3500 jaar geleden gevormd. Het profiel (tekstfig. 2) kon o.a. vergeleken worden met gegevens van Dekker & De Weerd (1975). De publikaties van Pons et al. (1963) en Ente et al. (1975) geven een indruk van de palaeogeografische situatie in noordelijk Noord-Holland. Langs de toenmalige kust zien we zandbarrières. Bij Bergen bevond zich hierin een opening waardoor de zee toegang had tot het achterliggende gebied. Dit was een soort waddengebied met geulen en platen. Naast dit door de zee beïnvloede gebied waren er tevens zoetwater- en landmilieus aanwezig.

Van de plantenresten werden zowel pollen en sporen als zaden geanalyseerd. Stuifmeelonderzoek van twee monsters leverde vrij veel pollen van bomen op (tabel 1). Het grootste deel van het pollen zal uit de omgeving afkomstig zijn zodat we hierin de aanwijzingen zien voor boomgroei op zowel hoger gelegen plaatsen (eik, hazelaar) als op lagere plekken (els). Van verder weg kwam het beukenpollen: het is namelijk niet te verwachten dat deze boom in de direkte omgeving een geschikte groeiplaats kon vinden. Wel kon de beuk heel goed in het meer naar het westen gelegen duingebied gegroeid hebben. De boom komt in ons land in het Holoceen pas na circa 1500 v. Chr. voor. De aanwezigheid van zoetwater in de omgeving wordt gedemonstreerd door o.a. gele plomp en de alg *Pediastrum*. Het hoge percentage ganzevoetachtigen is de enige indikatie voor mariene invloed. Evenals het pollen zijn de zaden (tab. 2, Pl. 1) voornamelijk afkomstig van planten die niet ter plekke gegroeid hebben. Slechts ruppia heeft hier gegroeid. Deze plant geeft een mesohalien milieu en ondiep rustig water aan. De andere soorten wijzen op diverse milieuomstandigheden. Zo groeien zeekraal, schorrekruid en zilte rus op land dat onder invloed van zout water staat. De meeste andere soorten komen uit vegetaties die langs oevers of op drassige plekken met zoet voedselrijk water staan. Slechts waterdrieblad en veenmos wijzen op de aanwezigheid van voedselarmere milieu's.

Van de dierenresten konden diverse groepen gedetermineerd worden. De conservatietoestand was van de meeste fossielen goed. In tegenstelling tot de plantenresten hebben bijna alle soorten ter plaatse geleefd.

De afzetting was vooral onderin rijk aan mollusken, foraminiferen en ostracoden. Van vier monsters werden foraminiferen en ostracoden geanalyseerd. Een overzicht van de gevonden soorten en hun aandeel in de betreffende fauna is in de engelse tekst te vinden. De fauna's zijn kenmerkend voor mesohaliene milieu's. Voorwerpen zoals afgebeeld in tekstfig. 3 bleken de kaken van een zeeduizendpoot te zijn. De beide mosmijten *Hydrozetes thienemanni* en *Carabodes labyrinthicus* zijn duidelijk verspoeld, zij leven namelijk respektievelijk in voedselrijk zoet water en in bos. Tabel 3 geeft het overzicht van de molluskenfauna. Kenmerkend voor het onderste deel van de afzetting is een fauna met voornamelijk *Hydrobia ventrosa, H. neglecta, Littorina saxatilis tenebrosa* en *Cerastoderma glaucum* (Plaat 2, tekstfig. 4-6). Deze fauna is karakteristiek voor rustige mesohaliene milieu's. In drie monsters waren zoetwaterslakken aanwezig (*Bithynia tentaculata, Planorbis planorbis*). Het wat hoger gelegen monster K 13 sluit gedeeltelijk aan op deze fauna. *Peringia ulvae* en *Mytilus edulis* treden hier echter met wat grotere aantallen op. Het hoogste monster (K 12) bevatte voornamelijk *Scrobicularia plana*. De dubbelkleppige exemplaren stonden grotendeels nog in leefstand. De bryozoënfauna werd gevormd door *Conopeum seurati* en *Electra crustulenta*. Beide waren ongetwijfeld vrij algemeen op planten en dieren (schelpen). Een detail van hun kolonies geven tekstfig. 7 en 8. De tientallen stekeltjes van de zeeklit (*Echinocardium cordatum*) zijn volgens mij afkomstig van

dieren die meer in de richting van open zee hebben geleefd. Het milieu ter plaatse was niet zo geschikt voor deze soort. Visresten waren aanwezig in de vorm van enige tientallen botjes en twee otolieten (tekstfig. 9) van een grondelsoort (*Pomatoschistus* sp.); de botjes konden niet op naam gebracht worden.

Aan de hand van de gevonden fossielen kan een reconstructie van het milieu gemaakt worden. Het onderste deel van de afzetting (3,91 - 3,41 m-NAP) is onder lagunaire omstandigheden afgezet. Het water was mesohalien met vooral jaarlijks grote verschillen in chloorgehalte. Het gemiddelde zal rond de 8‰ Cl^- gelegen hebben. Er was aanvoer van zoet water. Het getijverschil was zeer gering, het water schoon, helder en kalkrijk. De vrij zachte bodem viel niet droog tijdens laagwater. De waterdiepte zal in de buurt van een half tot één meter gelegen hebben. Halverwege de afzetting (3,15 m-NAP) wijst de fauna op een toegenomen waterbeweging en een wat hoger chloorgehalte. Waarschijnlijk lag het gebied in een mesohalien of op de overgang van een mesohalien naar een polyhalien gebied. Het gemiddelde chloorgehalte bedroeg circa 10‰. De afzetting is mogelijk gevormd nabij een geul in een gebied halverwege een lagune en een waddenzee met wat meer invloed van de open zee. De top van de afzetting (2,67 m-NAP) is in het bovendeel van de getijdenzone gevormd. De bodem viel droog tijdens laagwater en de waterbeweging was gering.

INTRODUCTION

A survey after settlement-traces from the Carolingian period at Wervershoof (6 km south-east of Medemblik) was carried out in 1976. The excavation-site was situated c. 1 km south-west of the mill 'De Hoop' and c. 80 m north-west of the river Kromme Leek (Text-fig. 1a-b). The survey was conducted by Dr. D. P. Hallewas of the A. E. van Giffen Instituut voor Prae- en Protohistorie (University of Amsterdam).

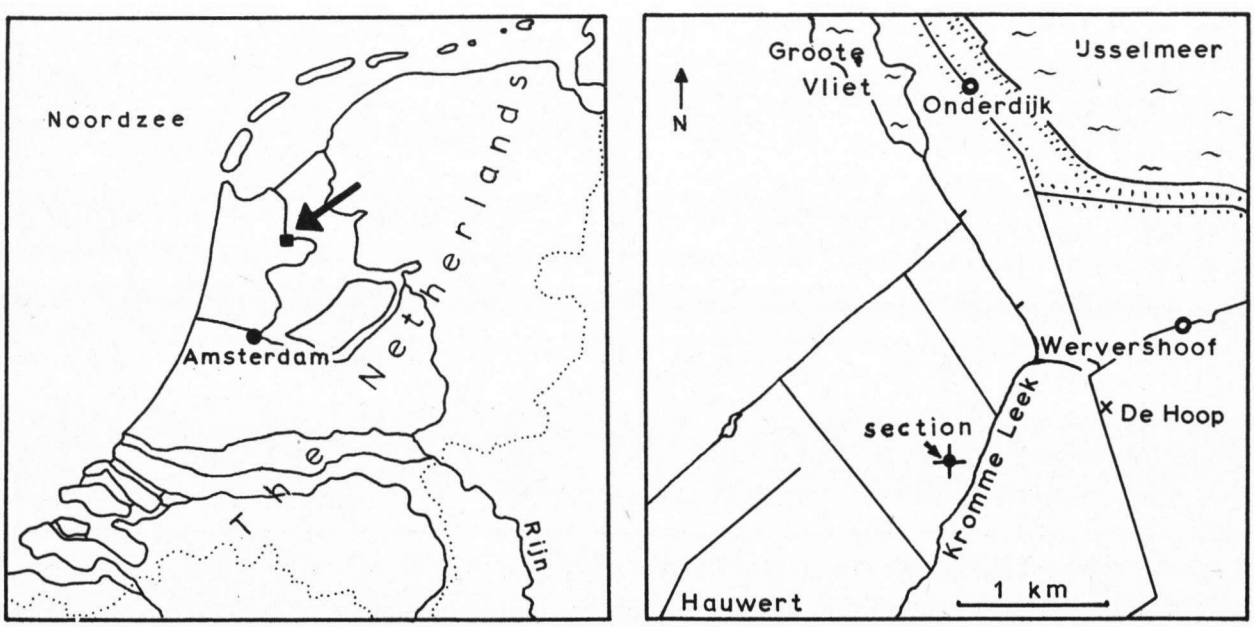


Fig. 1a-b. Location of the investigated section. / Ligging van het onderzochte profiel.

In this excavation shell-bearing Late Holocene deposits were visible. I collected several samples from this section for a malacological study; also the non-mollusc fossils were evaluated. Text-fig. 2 gives the location of 14 samples (of which 11 from the marine deposit) taken at several places between 2.62 and 3.91 m-NAP with the purpose to trace possible changes in the composition of the fauna. Sample-size always amounted to one liter of sediment, the thickness of the sampled layer was about five cm. After washing the sample on a 0.5 mm mesh in water the residu was dried and picked out with the aid of a binoculair microscope.

The samples described here could be collected thanks to the support of Dr. D. P. Hallewas on June 4th, 1976. He also supplied information for the composition of text-fig. 2. Several identifications were kindly done by the following specialists: Dr. P. A. M. Gaemers, Leiden (Pisces, otoliths), Mr. A. W. Lacourt, Leiden (Bryozoa), Mr. J. J. Lobenstein, Leidschendam (Foraminifera and Ostracoda) and Dr. L. van der Hammen, Rijksmuseum van Natuurlijke Historie (RMNH), Leiden (Acarina). I am most grateful for their help. The material is kept in the collection of the author, the Foraminifera and Ostracoda in the collection Lobenstein and the Acarina in the collection RMNH (Leiden).

GEOLOGY

Several publications on the genesis, lithostratigraphy, vegetation, etc. of northern North-Holland are available. So, for example, the section of Wervershoof (text-fig. 2) may be compared with the Vier Noorder Koggen area, as described by Dekker & de Weerd (1975, compare especially their figs. 1 and 2).

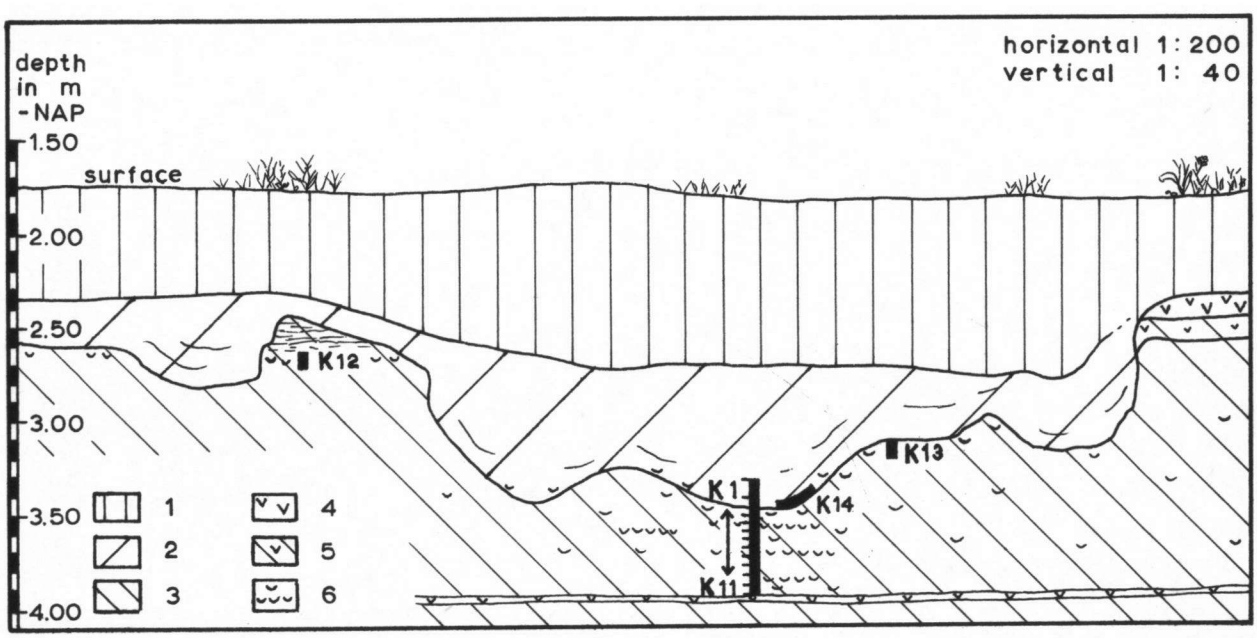


Fig. 2. Lithological sequence of the Wervershoof section with the position of the samples. / Lithologische opeenvolging van het profiel te Wervershoof met de ligging van de monsters. 1. 'kiek'clay/-kiekklei; 2. detritus-gyttja, partly clayey/detritus-gyttja, deels kleihoudend; 3. clay, fine sandy/klei, fijnzandig; 4. peat/veen; 5. dark layer/donkere laag; 6. shells/schelpen.

The top layer with a thickness of half a meter, deposited during the sedimentation stage Dunkirk III (600 - 1,400 A.D.), is known as 'kiekklei'. The underlying irregular layer of (clayey) detritus-gyttja was deposited under the influence of the river Kromme Leek. The section of text-fig. 2 is situated near to the point where this river flew into the former Lake of Wervershoof (Voorrips & Jansma, 1974, fig. 1). So, this deposit developed in a former course of the Kromme Leek or in the Wervershoof Lake. At the basis of the lowermost indentation plant remains and molluscs indicate a freshwater environment with moving water (samples K 1, K 2 and K 14, which are not treated in more detail here). At those places where the detritus-gyttja was absent a peatlayer was visible on top of the underlying marine deposit. Unfortunately I have no data on the age of this deposit. According to Dekker & de Weerd the fine-sandy clay (of which the lower 0.50 meter consists of clay with only a few sand-grains up to c. 100 - 200 μm) and clayey fine sand (with my samples K 3 to K 13) were deposited during the Dunkirk 0 (1,800 - 1,000 B.C.) sedimentation stage.

Palynological investigation of the samples K 5 and K 11 (of the lower part of the deposit) gives information about the age. The spectra of these two samples fit in the pollendiagram of Oostwoud (van Duinen & van Zeist, 1960) at the 3.25 m-NAP level. They suppose this level to have an age of 1,500 B.C.

Beech (*Fagus*) is represented in sample K 11 with 1.9% and in K 5 with 3.4% of the arboreal pollen. This tree immigrated in the Netherlands c. 1,500 B.C. (Westhoff et al., 1973, p. 46 - 47). Van Duinen & van Zeist (1960, p. 135), Ente (1963, p. 156) and others suppose that the deposition of clay in this part of the country did not continue to beyond c. 1,150 B.C. Regarding the above data it may be concluded that the whole investigated deposit indeed originated during the Dunkirk 0 period.

Below the Dunkirk 0 deposit, in the lowermost point of the section, a thin peatlayer was visible. Some auger borings demonstrated that this peatlayer was also present in the neighbourhood, always between c. 3.90 and 4.00 m-NAP. Consequently there is an obvious separation from the underlying clay layer, which possibly was deposited during the Calais IV B (2,150 - 1,800 B.C.) sedimentation stage.

The palaeogeographic map of North Holland shows the existance of an important inlet in the coastal barriers near Bergen during the Dunkirk 0 period. Behind these barriers sandy and muddy tidal flats, salt-marshes and gullies were present. Apart from this marine environment the landscape in this part of North-Holland comprised also freshwater- and terrestrial environments (Pons et al., 1963, encl. 7; Ente et al., 1975, fig. 6).

FLORA

Pollen and spores - The pollencontent of two samples from the lower part of the Dunkirk 0 deposit was analysed. The clayey sediment was treated subsequently with 10% KOH, 18% HCl, bromoform-alcohol (sp. gr. 2.0) and acetolysis. The residue contained pollen and spores; their state of preservation turned out to be excellent. Table 1 shows the results.

With van Duinen & van Zeist (1960) I suppose that the spectra of our samples give an impression of the vegetation of the area during the deposition of the clay. In the spectra two components can be distinguished. namely local and regional pollen. Undoubtedly local are the species present in high percentages. The ratio arboreal/non-arboreal pollen points to the existance of a partly forested area in the surroundings. I assume that freshwater was present not far away, bordered by *Alnus glutinosa*. Somewhat higher places (old creek-ridges) could offer a suitable habitat for, among others,

sample	K 5	K 6	sample	K 5	K 6
Alnus	33.0	35.3	*Ranunculus*	0.2	+
Corylus	32.0	36.5	*Urtica*	0.2	-
Quercus	20.2	14.3	cf. *Potamogeton*	0.2	-
Betula	4.7	2.4	Cruciferae	0.2	-
Pinus	1.9	5.3	*Rumex acetosa* type	-	0.4
Fagus	3.4	1.9	*Filipendula*	-	0.2
Tilia	2.6	1.7	*Lysimachia* type	-	0.2
Fraxinus	0.6	1.5	*Campanula*	-	0.2
Ulmus	1.1	0.6	*Typha latifolia*	+	+
Acer	+	0.2	*Potentilla*	+	-
Salix	+	0.2	*Malva*	+	-
Hedera	0.4	-	*Nuphar*	+	-
Hippophaë	0.2	-	*Polygonum persicaria* type	+	-
Picea	+	-	Rubiaceae	+	-
Carpinus	+	-	Gentianaceae	-	+
Sambucus	+	-	*Armeria/Limonium*	-	+
			Plantago cf. *maritima*	+	0.2
AP (= 100%)	534	468	*Plantago lanceolata*	-	+
			Calystegia	-	+
Chenopodiaceae	10.5	3.0	indeterminatae	0.6	0.6
Gramineae	8.2	6.4	Monoletae (psilate)	18.0	30.1
Cyperaceae	3.4	4.7	Monoletae (echinate)	+	-
Ericales	1.7	2.1	*Sphagnum*	2.1	1.9
Sparganium emersum type	0.9	0.6	*Polypodium vulgare*	0.8	0.4
Compositae tubuliflorae	0.9	0.4	Triletae (psilate)	0.4	0.6
Compositae liguliflorae	+	0.2	Triletae (verrucate)	0.2	-
Caryophyllaceae	0.2	0.2	*Pediastrum*	0.2	0.4
Umbelliferae	0.4	+			
Artemisia	0.4	+	NAP	264	249

Table 1. Pollenspectra of two samples of the Dunkirk 0 deposit, Wervershoof.
Tabel 1. Pollenspectra van twee monsters van de Duinkerke 0 afzetting, Wervershoof.

Quercus robur and *Corylus avellana*. The presence of pollen of Ericales and spores of *Sphagnum* and Monoletae psilate is an indication of nutriment-poor, marshy environments. *Nuphar luteum, Typha latifolia, Sparganium emersum* type and the alga *Pediastrum* grow in freshwater. Influence of salt water is probably demonstrated by the presence of 10.5% Chenopodiaceae. Some species are of regional origin. For example *Fagus silvatica* can not be expected in this landscape. This species needs a good, rather dry soil. Zagwijn (in Westhoff et al., 1973, p. 47) demonstrated that forests of beech could grow in the coastal dune area. I expect that this dune area, c. 35 km to the west, was the source of the beech pollen.

Seeds - From the lower part of the exposed Dunkirk 0 deposit seeds of aquatic and terrestrial plants were collected. The samples K 12 and K 13 in the upper half of the deposit did not yield any seeds at all. It has to be mentioned that this research was not carried out for specific botanical purposes. Therefore it is possible that a part of the botanical material was lost during the washing procedure. Drying of the residues caused a partly distortion of the seed material. For those two reasons I did

Eupatorium cannabinum L. (Plate 1, fig. 10)	common
Ruppia maritima L. (Plate 1, fig. 1 - 2)	rather common
Chara sp. (Plate 1, fig. 5)	rather common
Urtica dioica L.	several
Mentha aquatica L. or *Mentha arvensis* L. (Plate 1, fig. 11)	several
Carex cf. *riparia* Curt. (Plate 1, fig. 4)	several
Atriplex hastata L. or *Atriplex patula* L. (Plate 1, fig. 8)	several
Juncus cf. *gerardii* Loisl.	some
Typha latifolia L. or *Typha angustifolia* L. (Plate 1, fig. 6)	some
Sphagnum sp.	few leaves
Carex sp.	few
Scirpus cf. *lacustris* L.	few
Potamogeton sp.	few
Suaeda maritima (L.) Dum.	few
Salicornia europaea L. (Plate 1, fig. 3)	few
Solanum cf. *dulcamara* L.	few
Ranunculus cf. *repens* L.	few
Oenanthe aquatica (L.) Poir.	few
Lycopus europaeus L.	few
Nymphaea alba L.	few
Lemna sp. (Plate 1, fig. 9)	few
Menyanthes trifoliata L.	few
Rumex sp.	few
Lychnis flos-cuculi L.	few
Cirsium cf. *arvense* (L.) Scop. (Plate 1, fig. 7)	few

Table 2. Seeds from the lower part of the Dunkirk 0 deposit, Wervershoof.
Tabel 2. Zaden uit het onderste deel van de Duinkerke 0 afzetting, Wervershoof.

not specify the seedcontent of each sample. Table 2 gives the combined results of the samples K 3 to K 11. In addition to the seeds thin leaves, roots and a few carbonized plantremains were found.

The most striking in number were seeds of *Eupatorium cannabinum* (several hundreds, mainly in K 10 and K 11), *Ruppia maritima* (some tens, in the majority of the samples) and the oösporangia of a *Chara* species (many tens, only in K 10 and K 11). Other plants are represented by only a low number of seeds.

Ruppia maritima is typical for the Ruppion maritimae, a plant-community occurring in brackish waters (Westhoff & den Held, 1969, p. 47). According to van Ooststroom & Reichgelt (1964, p. 82) *Ruppia maritima* occurs in the Dutch coastal area in poikilohaline waters, where chlorinity shows a large, mainly yearly, amplitude with minima of c. 0.5‰ and maxima between 8‰ and 30‰ Cl^-. The species grows on sandy and fine-sandy clay bottoms to a waterdepth of more than one meter; on soft muddy bottoms it lives in waterdepths of not more than 0.60 m, because whirling mud intercepts much of the light. Muus (1967, p. 240) found *R. maritima* in shallow (< 0.50 m), sandy parts of the Danish fjords. It is remarkable that the fauna in a *Ruppia*-vegetation was rather rich in species; in *Zostera* meadows, on the contrary, the fauna was relatively poor, because of the density of the vegetation.

The many oösporangia (Plate 1, fig. 5) of Characeans in the lowermost 0.10 m could not be identified to species level. Most *Chara* species are characteristic for the Charetalia which occurs in

in nutriment-poor to nutriment-rich fresh to mesohaline water. Muus (1976, p. 241) found *Chara*-meadows in the mesohaline Dybsø Fjord, a Danish lagoon with chlorinities of 4.8 - 5.9‰ Cl^-. Other aquatic plants found are *Potamogeton* sp. (occurring in many environments, also mesohaline), *Nymphaea alba* and *Lemna* sp. (both living in freshwater).

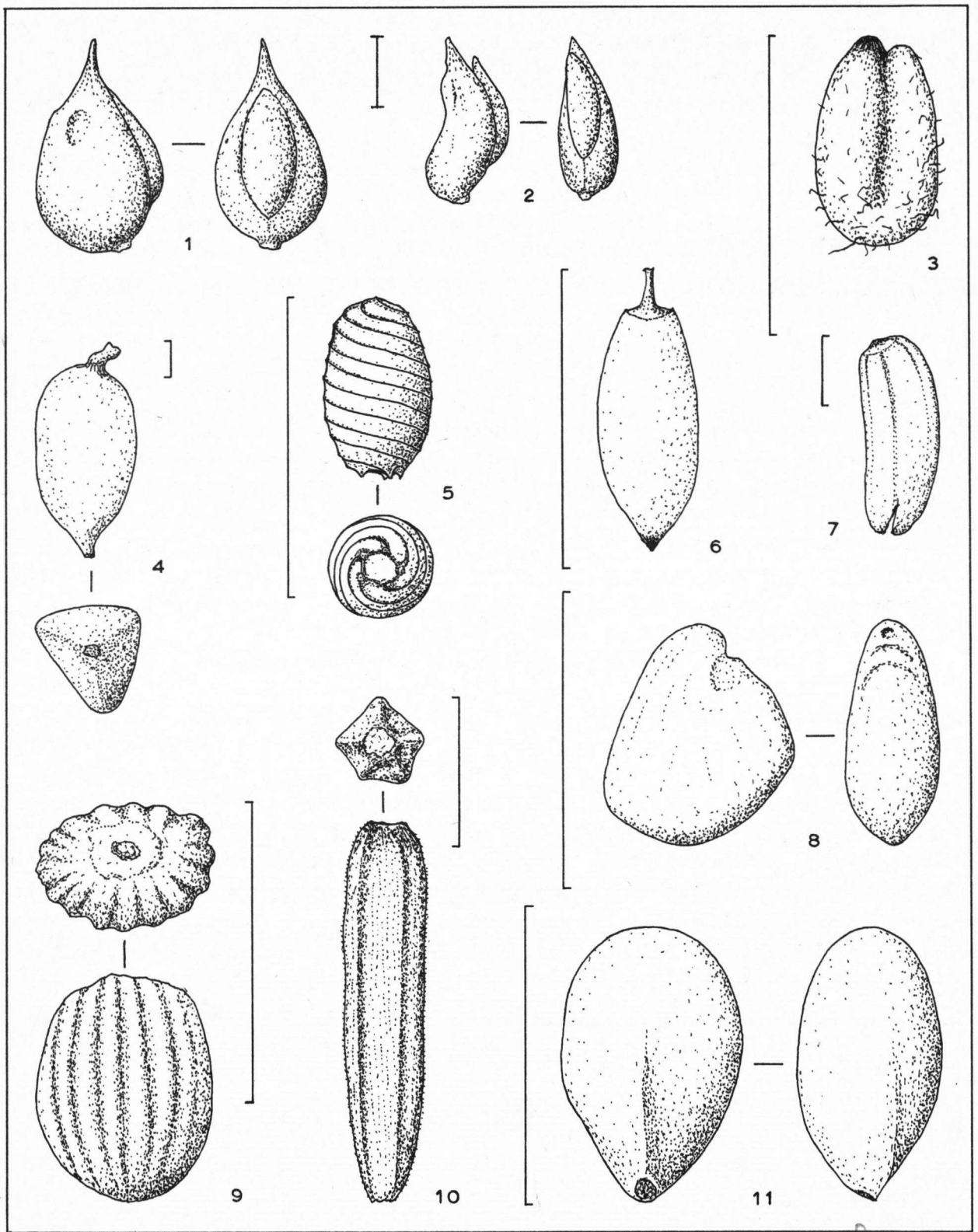
Salicornia europaea grows mainly on open, very saltish areas along euhaline and polyhaline water and is usually overflooded during each high tide. This plant is an indication for the occurrence of the Thero-Salicornion plant-community. Also *Suaeda maritima* and *Juncus gerardii* occur on saltish places, somewhat higher than *Salicornia europaea. Atriplex, Scirpus* and *Carex* species grow in brackish as well as in non-brackish environments. *Eupatorium cannabinum, Carex riparia; Typha angustifolia, T. latifolia, Oenanthe aquatica, Lycopus europaeus, Lychnis flos-cuculi, Mentha aquatica* and *Mentha arvensis* occur in all kinds of moist and wet sites, e.g. along banks, they usually avoid saltish environments. The only species of less nutriment-rich and soft water are *Menyanthes trifoliata* and *Sphagnum* sp. The remaining species grow on many, usually nutriment-rich places.

In how far the encountered plant species grew on the spot itself or originated from other places is difficult to estimate. It is also possible that a part of the seeds is reworked from older deposits, although they are very well preserved. I presume that they are of local origin, and partly brought in by wind and water. Regarding the nature of the deposit *Ruppia maritima* (and *Chara*?) may have grown on the spot, the other species within short distances. Accepting the foregoing the following reconstruction seems acceptable: at the place of the sample-location there was quiet, mesohaline water with (mainly yearly) fluctuating chlorinities. Waterdepth amounted to maximal one meter but probably it was some decimeters less. Along this water a saline zone influenced by the tides occurred. Probably the plant-community Thero-Salicornion was present in the uppermost part of the intertidal zone and, somewhat higher, a saltmarsh or a small strip with saltplants. Also there were higher grounds beyond the influence of the sea. From here there was a supply of freshwater, offering a suitable habitat for border and aquatic plants.

FAUNA

The Dunkirk 0 deposit was locally, especially in its lower part, strikingly rich in molluscs, Foraminifera and ostracods. This lower part was only exposed beneath a younger creek in the deepest part of the section (text-fig. 2). Here also thin layers with abundant molluscs were visible. Although the research was mainly fixed upon the composition of the molluscan fauna, remains of other organisms were collected from the samples as well. Therefore it is possible to give a survey of represented species of the following groups: Protozoa (Foraminifera), Annelida (Polychaeta), Arthropoda (Ostracoda and Acarina), Mollusca (Gastropoda and Bivalvia), Bryozoa, Echinodermata and Chordata (Pisces).

Plate 1. Seeds from the lower part of the Dunkirk 0 deposit, Wervershoof. Bar represents 1 mm. / Zaden van het onderste deel van de Duinkerke 0 afzetting, Wervershoof. Maatstreepje komt overeen met 1 mm.
Fig. 1 and 2 *Ruppia maritima*; fig. 3 *Salicornia europaea*; fig. 4 *Carex* cf. *riparia*; fig. 5 *Chara* sp.; 6 *Typha latifolia* or *T. angustifolia*; fig. 7 *Cirsium* cf. *arvense*; fig. 8 *Atriplex hastata* or *A. patula*; fig. 9 *Lemna* sp.; fig. 10 *Eupatorium cannabinum*; fig. 11 *Mentha aquatica* or *M. arvensis.*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Protozoa, Foraminifera - The samples K 3 to K 11 yielded quite a lot Foraminifera. A small part of the residues of four samples was inspected by Mr. J. J. Lobenstein. The species found and their percentage of the foraminiferal fauna are:

	K 5	K 6	K 10	K 11
Nonion depressulum (Walter & Jacob)	32	30	60	40
Streblus catesbyanus (d'Orbigny)	38	55	27	53
Streblus batavus (Hofker)	26	14	9	2
Elphidium williamsoni (Haynes)	3	1	4	4
Protelphidium anglicum (Murrey)	1	-	-	-
Haplophragmoides wilberti Andersen	-	-	-	1

The fauna is poor in species, but rich in individuals (many thousands of three species and only a few of three others).

Nomenclatural confusion in literature made it difficult to obtain information about the ecology of the species. *Streblus batavus* is often confused with *Streblus beccarii* (L.) from which it differs distinctly by very constant characteristics (Hofker, 1971, p. 21). In certain cases it is therefore allowed to compare '*S. beccarii*' of older publications with *S. batavus* (and the related *S. catesbyanus*). *Elphidium williamsoni* corresponds to *E. excavatum* (Brady).

Muus (1967, p. 42) found *Nonion depressulum* and *Streblus beccarii* in Danish mesohaline waters, like the Niva Bugt. At a depth of 0.2 to 0.6 m and a clorinity of c. 2.5 - 10.5‰ (prevailing 4.5 - 5.5‰) Cl^-, these species were frequently found on soft bottoms (sand with detritus) with a scattered growth of low *Ruppia*.

I suppose that the Foraminifera of the lower part of the deposit at Wervershoof lived in shallow, sheltered, clear, mesohaline water with a soft bottom and fluctuating salinities.

Annelida, Polychaeta - Some tens of small objects of chitinous material were found in the samples K 3 to K 11. Text-fig. 3 shows one of them. The black dotted part actually is dark brown, the rest is whitish transparent. These are jaws of a ragworm, *Nereis* sp. This species might be either *N. diversicolor* O. F. Müller or *N. virens* (Sars). *N. diversicolor* lives in tubes in the bottom to a depth of half a meter. Investigations in Denmark showed that *N. diversicolor* was missing or exceedingly rare in the oligohalinicum. In shallow mesohaline areas it was a predominating bottom animal. In environments with a chlorinity of more than 12‰ Cl^- it was replaced by *Nereis virens* (Muus, 1967, p. 79). Also in other brackish, shallow water areas in Europe *Nereis diversicolor* is a common species, Our material therefore probably belongs to this species.

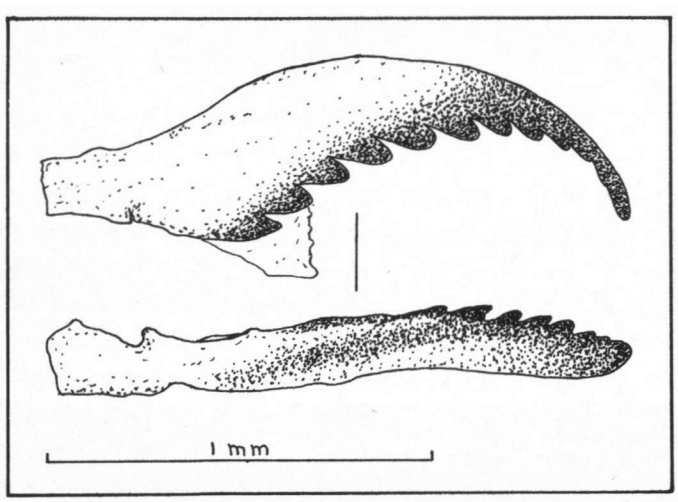


Fig. 3. Jaw of *Nereis* sp. / Kaak van *Nereis* sp.

Arthropoda, Ostracoda - The samples K 3 to K 11 contain a large number of ostracods. A small part of the residues of four samples was inspected by Mr. J. J. Lobenstein. The species found and their percentage of the ostracod fauna are:

	K 5	K 6	K 10	K 11
Cyprideis torosa (Jones)	78	70	56	49
Loxoconcha elliptica (Brady)	18	28	35	31
Cytherura gibba (O. F. Müller)	-	1	6	8
Cytherois fischeri (Sars)	-	1	2	4
Xestoleberis aurantia (Baird)	4	-	-	4
Iliocypris gibba (Ramdohr)	-	-	1	2
Leptocythere castanea (Sars)	-	-	-	2

It is obvious that the ostracod fauna is dominated by the euryhaline *Cyprideis torosa* [synonym *C. litoralis* (Brady)] and, in somewhat smaller quantities, *Loxoconcha elliptica*. Of both species many thousands of carapaces are present. With the exception of *Iliocypris gibba* all ostracods are brackish water species. In the Recent fauna they occur in all kinds of mesohaline water. Several species occur also in oligohaline or polyhaline waters. *Iliocypris gibba* is a freshwater species. This species may tolerate, however, a few promilles of chloride.

When considering the entire ostracod fauna I conclude that it was living in mesohaline water with a fluctuating chlorinity. The animals lived in a lagoon or estuarium with shallow, sheltered water. The bottom was soft, vegetation was present.

Arthropoda, Acarina - Sample K 7 contained two well-preserved, though incomplete, animals. Dr. L. van der Hammen identified them as *Hydrozetes thienemanni* Strenzke and *Carabodes labyrinthicus* (Michael). Both belong to the Oribatidae (moss-mites). *H. thienemanni* lives in nutriment-rich fresh water, like lakes, carrs, etc. *C. labyrinthicus* is a terrestrial species and rather common in forests, where it lives in the soil and at the undersides of trunks.

It is clear, that in view of the nature of the deposit, these mites must have been brought in from other places. If they lived during the genesis of the Dunkirk 0 deposit, they point to the presence of nutriment-rich freshwater and a wooded area in this part of Holland.

Mollusca, general remarks - The greater part of the sample residues consists of molluscs. In general the preservation of the shells is fair, sometimes a part of the periostracum and the ligament of the bivalves is still present. A small part of the material, however, is slightly corroded or covered with bryozoan colonies. I suppose that hardly any transport of the marine/brackish molluscs took place. For the environmental data in the following especially Muus (1967), Rasmussen (1973) and Wolff (1973) were consulted.

Mollusca, Gastropoda - Littorina saxatilis tenebrosa Montagu - Large numbers of specimens under 5½ mm height are present in most of the samples. Only a few shells were higher (to max. 7 mm). The whorls are rather convex and show predominantly a smooth surface. Spiral ribs are visible in a part of the material, especially on a few juveniles (Pl. 2, fig. 2). Pl. 2, fig. 1 and 3 show the most frequent form; the height/width-ratio is reflected in text-fig. 4. The colour of the shells is still visible, many of them are spotted white-brown. Some juvenile specimens are entrirely brown. Referring to Muus (p. 137 and 138) and Rasmussen (p. 241), who give data on *Littorina saxatilis* from the Danish estuaries and lagoons, I reckon the Wervershoof shells to the subspecies *tenebrosa*.

L. saxatilis tenebrosa is characteristic for brackish water areas. In Danish waters, for example,

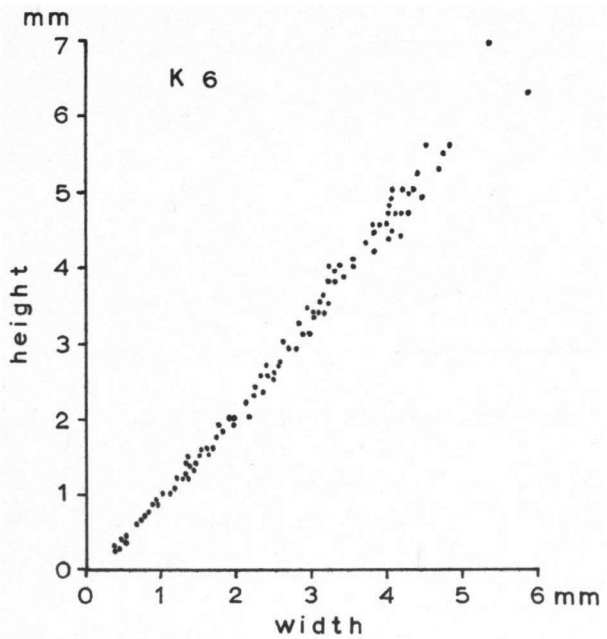


Fig. 4. Height/width-ratio in specimens of *Littorina saxatilis tenebrosa*.
Hoogte/breedte verhouding bij exemplaren van *Littorina saxatilis tenebrosa*.

the animals occur at a chlorinity of c. 3.5‰ Cl^- and higher, but are abundant only at c. 5.5 - 11‰ Cl^-. *Littorina saxatilis saxatilis* occurs at chlorinities over 7.5‰. Contrary to *Hydrobia*, *L. saxatilis tenebrosa* needs a solid substratum. High population densities occur in dense vegetations (e.g. *Ruppia, Potamogeton, Zostera* and *Chaetomorpha*).

Hydrobia ventrosa (Montagu) and *Hydrobia neglecta* Muus - Both species are abundant in the lower part of the deposit, *H. ventrosa* somewhat more than *H. neglecta*. Because it is difficult to make a 100% separation of all the available material of these species they are grouped together in table 3 and text-fig. 5. The shell-height ranges mainly from c. 0.2 to 4.5 mm. Larger individuals are rare, the highest specimen measures 5.6 x 2.25 mm (Pl. 2, fig. 7-8).

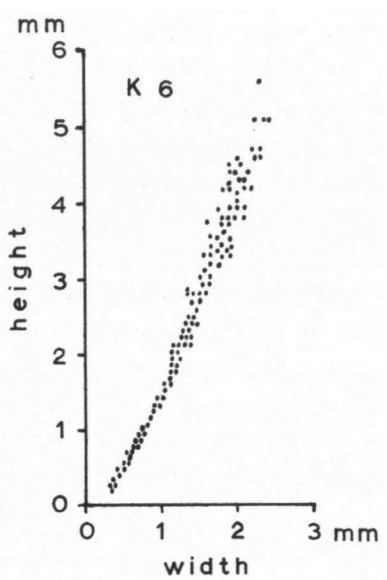


Fig. 5. Height/width-ratio in specimens of *Hydrobia ventrosa* and *Hydrobia neglecta*.
Hoogte/breedte verhouding bij exemplaren van *Hydrobia ventrosa* en *Hydrobia neglecta*.

H. ventrosa is characteristic for euryhaline biotopes. It prefers water with c. 1.5 - 10.5‰ Cl^-. The animals live, often in large quantities, in quiet, shallow water (up to c. 2 meter depth) on both solid and soft bottoms and on plants. *H. neglecta* lives likewise in shallow and quiet brackish water. Especially at places with a rich vegetation the animals may be abundant. In Danish waters *H. neglecta* was encountered at chlorinities between c. 5.5. and 13‰ Cl^-. In this respect the species takes up a position between *H. ventrosa* (living at lower chlorinities) and *Peringia ulvae* (living at higher chlorinities). In Denmark populations of *H. neglecta* were found mixed with populations of *H. ventrosa* and *Peringia ulvae*. All three species, however, do not live abundantly together in the same ecological circumstances. Muus (1962) found that both *H. ventrosa* and *H. neglecta* seem to prefer sheltered mesohaline localities. Frequently they are present in about equal numbers at a chlorinity of about 8‰ Cl^-. At lower chlorinities *H. ventrosa* predominates.

Usually the name *Hydrobia stagnorum* (Gmelin) is used in the Netherlands instead of *Hydrobia ventrosa*. In agreement with the nomenclature of Muus, and because the results of current research on this subject are not yet available, I prefer to use the name *H. ventrosa* here.

Peringia ulvae (Pennant) - *P. ulvae* (Pl. 2, fig. 6) is present in all samples but in none of them in high numbers. Shell height ranges mainly from 3 to 5 mm. The smallest specimen measures 1.7 x 1.1 mm, the largest shell is 6.1 x 3.25 mm. This species is mainly marine. It may occur in ten-thousands of individuals per m^2 on many different kinds of substrate. Sometimes *P. ulvae* penetrates in low quantities mesohaline areas, where it may be present to a chlorinity of about 5.5‰ Cl^-, in preferably quiet water.

Retusa obtusa (Montagu) - The dimensions of this species range from 0.95 x 0.55 mm to 4.9 x 2.7 mm (Pl. 2, fig. 4 - 5). *R. obtusa* is absent in the lowermost samples and K 12. It is a marine species. In the Dutch Delta area it was not found at chlorinities lower than c. 12‰ Cl^-. In Denmark *R. obtusa* was sometimes found in shallow brackish waters with fine-grained bottom sediments.

Bithynia tentaculata (Linné) - One operculum was found in sample K 3 and another in K 10.

Planorbis planorbis (Linné) - One shell was present in sample K 11. This species and the foregoing were common at many freshwater habitats during the Holocene in the Netherlands.

Mollusca, Bivalvia - Cerastoderma glaucum (Poiret) - The brackish water cockle is present in all samples but in large quantities in the lower half meter only. In a part of the material parts of the periostracum are preserved while tens of double-valved specimens still possess their ligament. The dimensions of the double-valved specimens range between c. 1.1 x 0.9 x 0.6 mm and 30 x 25.5 x 22 mm (length x height x thickness). The largest valve measures 32 x 27 x 12 mm. Most shells, however, have a length of less than 20 mm (Pl. 2, fig. 9 - 10 and text-fig. 6).

C. glaucum is mainly known from mesohaline areas (down to c. 2.5‰ Cl^-). The animals may also live in polyhaline environments but there they will soon be replaced by *Cerastoderma edule*. *C. glaucum* lives partly burrowed in the bottom or, very often, just lying on it. Young individuals often crawl in the vegetation.

Cerastoderma edule (Linné) - Only in sample K 13 a double-valved specimen (25 x 14 x 19 mm, length of the ligament c. 7 mm) was found.

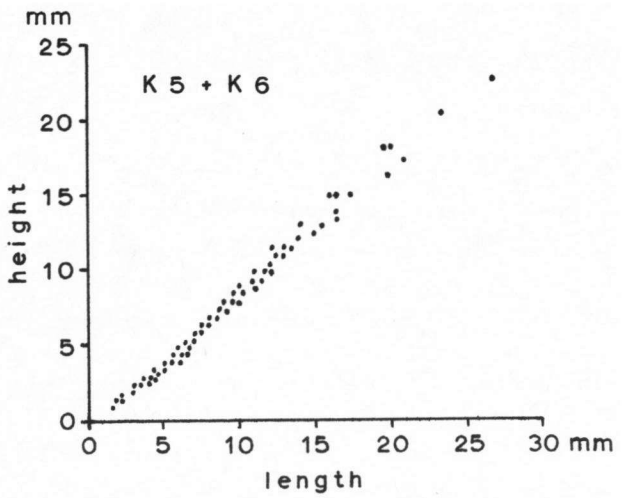


Fig. 6. Height/length-ratio in specimens of *Cerastoderma glaucum* (left valves). / Hoogte/lengte verhouding bij exemplaren van *Cerastoderma glaucum* (linker kleppen).

C. edule lives mainly in fine-grained sediments of areas lying above low tide level. The animals live also below that level, but unlike *C. glaucum* they need moving water in that case. As a rule *C. edule* cannot survive a chlorinity below about 15‰ Cl^- (occasionally to 10‰).

Macoma balthica (Linné) - A few shells of this species were found in the lower half meter of the Dunkirk 0 deposit. The shell-length varies from 2 to 17 mm, but most shells are fullgrown.

M. balthica lives in all kinds of substrates from the littoral zone to depths of many tens of meters. It is mainly a marine species but it penetrates far into brackish areas.

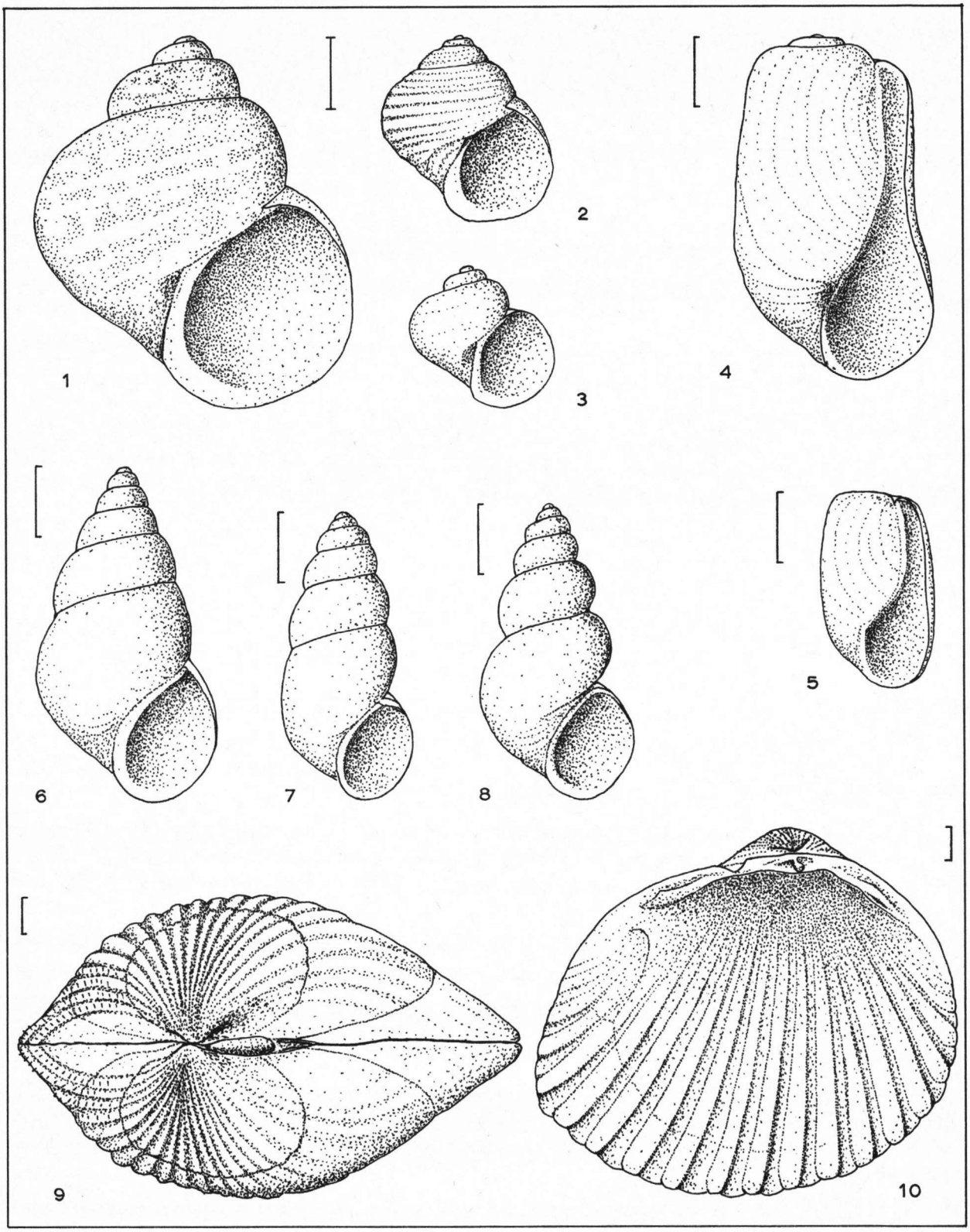
Mytilus edulis Linné - In the lower half meter of the section some shells of this species are present, measuring up to 50 mm in length. Sample K 13 contained some tens of double-valved specimens, the measurements of the largest shell are 64 x 30 x 23 mm. A part of the shells still possess their periostracum. Some were covered by epibiontic Bryozoa.

For a healthy development the mussel needs a chlorinity higher than c. 8‰ Cl^- and moving water, but the animals can also live in brackish areas with a chlorinity of some promilles. *M. edulis* lives on the bottom, attached to a solid substratum.

Scrobicularia plana (Da Costa) - This species is present in almost every sample but in the greater part of the deposit it is not an important component of the fauna. Only near the top of the Dunkirk 0 deposit *S. plana* is rather common. Here double-valved specimens occur in life-position. Shell lengths range from 5 to 40 mm, only some weathered fragments were found of still greater specimens.

The animals live burrowed to a depth of 15 cm in clayey fine sand and in clay. They penetrate rather far into mesohaline areas.

Plate 2. Molluscs from the lower part of the Dunkirk 0 deposit, Wervershoof. Bar represents 1 mm. / Mollusken van het onderste deel van de Duinkerke 0 afzetting, Wervershoof. Maatstreepje komt overeen met 1 mm.
Fig. 1, 2 and 3 *Littorina saxatilis tenebrosa*; fig. 4 and 5 *Retusa obtusa*; fig. 6 *Peringia ulvae*; fig. 7 *Hydrobia neglecta*; fig. 8 *Hydrobia ventrosa*; fig. 9 and 10 *Cerastoderma glaucum.*


1
2
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10

Mollusca, Results - Table 3 gives a summary of the molluscan fauna. It demonstrates that a subdivision in three units is possible: the fauna of the lower half meter (K 3 - K 11), the fauna of the somewhat higher situated sample K 13 and one at the top of the deposit (K 12).

depth in m-NAP	3.91								3.41	3.21	3.11	2.72	2.62
species: sample:	K 11	K 10	K 9	K 8	K 7	K 6	K 5	K 4	K 3		K 13	K 12	
Hydrobia ventrosa and *H. neglecta*	+	*	o	●	x	*	+	+	o		●	-	
Littorina saxatilis tenebrosa	+	x	-	6	+	x	+	+	●		14	-	
Cerastoderma glaucum	+	+	6	3	●	+	+	o	●		3	1	
Peringia ulvae	1	12	●	7	13	●	7	7	7		●	1	
Scrobicularia plana	-	2	11	2	2	4	5	1	1		5	●	
Macoma balthica	1	3	-	-	-	-	5	2	2		-	-	
Mytilus edulis	1	-	1	-	-	1	3	2	1		●	-	
Retusa obtusa	-	-	-	-	-	2	11	14	6		5	-	
Cerastoderma edule	-	-	-	-	-	-	-	-	-		1	-	

Table 3. Mollusc-content of the samples (1 liter) of the Dunkirk 0 deposit, Wervershoof.
Tabel 3. Mollusken inhoud van de monsters (1 liter) van de Duinkerke 0 afzetting, Wervershoof.
* thousands/duizenden; x many hundreds/ vele honderden; + some hundreds/ enkele honderden; ● many tens/ vele tientallen; o some tens/ enkele tientallen; - not found/ niet aangetroffen.

Striking in the lower part of the Dunkirk 0 deposit is a fauna with large quantities of *Hydrobia neglecta, H. ventrosa, Littorina saxatilis tenebrosa* and *Cerastoderma glaucum*. The other five species were found in small quantities. This fauna is characteristic for brackish water. It seems that no important changes in the faunal composition occurred. Sample K 8 and K 9 contained less shells, in K 7 to K 11 *Retusa obtusa* is absent and *Mytilus edulis* and *Macoma balthica* are represented by a few shells only. In the lowermost decimeter, just above a thin peatlayer, two freshwater molluscs were found.

The general impression is, that the lower half meter was deposited in a shallow lagoon. Waterdepth was not over two meter and probably much less. The lagoon was under the influence of tides but not lying above low tide level. Not very important tide-runs caused quiet water movements. The bottom consisted of very fine sediments on which a rather rich vegetation was growing. The chlorinity was not constant (euryhaline), the mean values fluctuated round 8‰ Cl^-. The small changes observed in the composition of the samples K 3 to K 11 may refer to an upwards increasing salt content. The whole sequence fits in the upper part of the mesohalinicum (Venice System). The remains of freshwater snails indicate a supply of freshwater.

Sample K 13 contains many large shells of *Mytilus edulis*. One liter clayey fine grey sand shows a species-composition which point to somewhat more water movement and a somewhat higher chlorinity than the lower samples. The animals lived here at the transition of a mesohaline to a polyhaline environment. Especially the ratio of *Peringia ulvae* to *Hydrobia neglecta/ventrosa*, the quantity of solid shells of *Mytilus edulis* and the presence of *Cerastoderma edule* indicate a mean chlorinity of c. 10‰ Cl^-.

The fauna encountered in sample K 12 differs distinctly from those of the underlying sediments. *Scrobicularia plana* was observed here in life-position, the double-valved shells were not always filled with sediment. In a long profile of the excavation pit these double-valved specimens

were visible at several places, always near the top of the deposit. *S. plana* lived here, burrowed to a depth of 15 cm, in the upper part of an intertidal flat. The chlorinity is difficult to estimate but most probably lies within the polyhalinicum.

Bryozoa -Almost all samples (not K 12) contained some colonies on shells and many small isolated fragments of two species. Mr. A. W. Lacourt identified a part of the material (c. 25 colonies). The species found are *Conopeum seurati* (Canu) (fig. 7) and *Electra crustulenta* (Pallas) (fig. 8). On some fragments impressions and narrow perforations were visible, from which I conclude that the animals were attached to plantstems and -leafs. *E. crustulenta* was found on the mollusc-species *Cerastoderma glaucum, Mytilus edulis* and *Littorina saxatilis tenebrosa. C. seurati* was present on *Cerastoderma glaucum* and *Hydrobia ventrosa.*

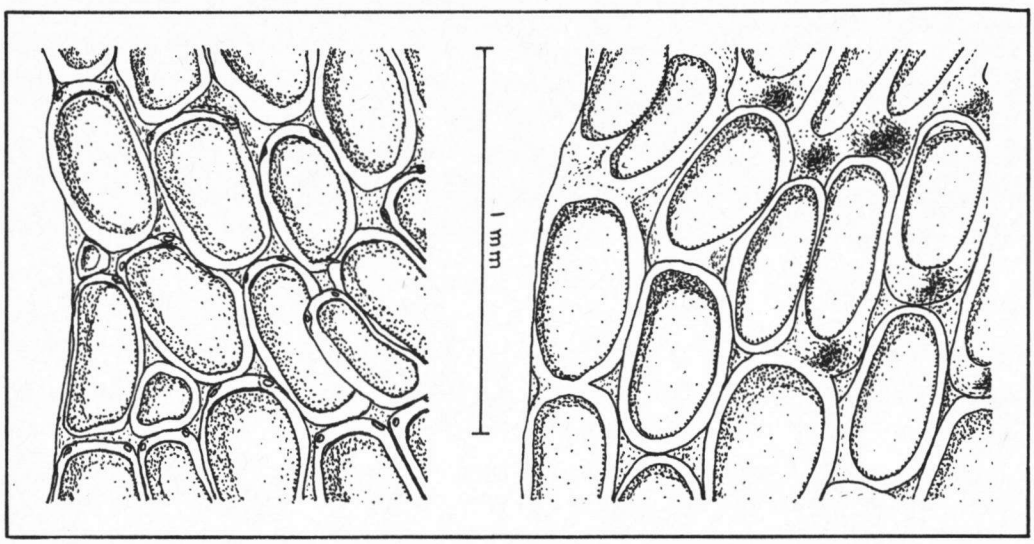

Fig. 7. *Conopeum seurati.* Fig. 8. *Electra crustulenta.*

Both species live in the sublittoral and are typical for brackish water. These two species live, often together, in the recent Dutch brackish water areas (Jebram, 1968; Heerebout, 1970, table 1). In Denmark Muus (1967, p. 165) observed *Electra crustulenta* all over the mesohaline area, where it lives in colonies covering almost any solid substratum. It avoids polluted and troubled water. Rasmussen (1973, p. 322 - 323) mentioned *E. crustulenta* as one of the common species in the Isefjord (Denmark). Here it prefers brackish water (c. 6 - 9‰ Cl^-) and lives on *Fucus, Zostera, Ruppia, Potamogeton, Mytilus edulis, Littorina saxatilis,* boatsides and so on.

From the foregoing it is obvious that the encountered Bryozoa of Wervershoof may have lived in a mesohaline environment. In the sublittoral they were attached to several solid objects (shells, waterplants). The water was clean and clear.

Echinodermata - Tens of spines of irregular sea-urchins were found in most of the samples, they belong to *Echinocardium cordatum* (Pennant).

In the Netherlands *E. cordatum* is common in the coastal waters of the North Sea, the estuaries of the Delta area (not below c. 15‰ Cl^-) and in some restricted parts of the Wadden Sea. The animals live from low tide level downwards, burrowed in all kinds of sediments except for soft mud (Wolff, 1968). Schäfer (1962, p. 545) found accumulated spines in the Jade Bay (Germany), a place at a distance of c. 50 km outside the area of distribution of *E. cordatum*. Muus (1967) and Rasmussen (1973) did not mention this species from the Danish lagoons and estuaries.

With regard to these data I conclude that *Echinocardium cordatum* has not lived at Wervershoof. I suppose that the spines were brought in from places more to the west.

Chordata, Pisces - The samples K 3 to K 11 contained in total some tens of very well preserved, light brown, thin fishbones. Their size was up to some mm, two vertebrae were a half and one mm in length respectively. It was not possible to identify these remains. Sample K 10 and K 11 both contained an otolith (fig. 9) of a small fish. Dr. P. A. M. Gaemers identified them as *Pomatoschistus* sp.

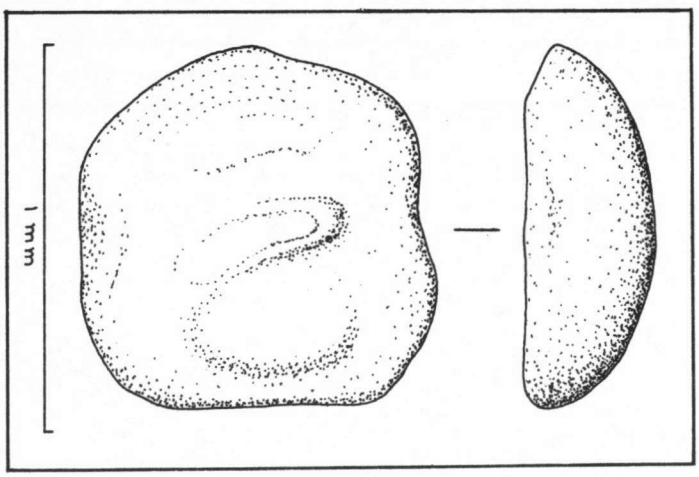

Fig. 9. *Pomatoschistus* sp. (otolith/otoliet).

The dimensions are 0.75 x 0.70 x 0.25 mm and 0.95 x 0.95 x 0.35 mm. They might belong either to *P. microps* (Krøyer) or to *P. minutus* (Pallas).

P. minutus occurs generally deeper than two meters on sandy bottoms, *P. microps* prefers shallow, sheltered brackish water (Muus, 1967, p. 167).

Various - Apart from the fossils described above I found a few insect remains in the lower half meter. They are not listed here. In sample K 5 an ephippium (with one egg) of a water flea and some fragments of calcareous tubes of ½ to 1 mm Ø were found. Sample K 13 contained five pearls, two were cylindrical (1 mm long), the shape of the others was round (½ - 1 mm Ø). Probably they were formed by mussels (*Mytilus edulis*).

FINAL CONCLUSIONS

The analysis of flora and fauna of a deposit from the Dunkirk 0 period at Wervershoof shows that a subdivision in three units is possible.

The lower part of the section (3.41 - 3.91 m-NAP) was deposited under lagoonal circumstances. The plant remains indicate a mesohaline environment. The chlorinity fluctuated on account of, among others, the influx of freshwater. The water movement was quiet, the tidal amplitude small and the water shallow. Along the water saltloving landplants were present. Also freshwater environments must have been present in the area. There were trees at the lower marshy places as well as at the higher places. Evidently several strongly differing environments were present in a small area in this part of North-Holland. Also the faunal remains are characteristic for a mesohaline environment. The chlorinity was strongly fluctuating (especially at yearly intervals). I estimate an average of around 8‰ Cl^- for the lower part of the deposit. A few changes with regard to the species compo-

sition of the fauna indicate a small increase of the salinity during the sedimentation of the deposit. The tidal amplitude in the shallow (½ to 1 meter?) water was small and water movement was rather quiet. From the surroundings there was an influx of freshwater into the basin. Further the water was clean, clear and rich in carbonate. The bottom was rather soft and remained submerged during low tide.

In the middle part of the section, around 3.15 m-NAP, the fauna indicates a somewhat changed environment. The water movement increased and chlorinity was somewhat higher. The animals must have lived here in a mesohaline or on the transition of a mesohaline to a polyhaline environment. At an estimate chlorinity fluctuated around 10‰ Cl^-. The distinct lagoonal characteristics of the foregoing period are no longer present. Possibly the deposit was formed in an area standing midmay between a lagoon and a wadden sea, with more influence from the open sea. The animals may have lived near a gully.

In the upper part of the investigated section (around 2.67 m-NAP) the fauna is completely different. The water movement was quiet and the bottom lay above low tide. Chlorinity is difficult to estimate, presumably poly- or mesohaline. The locality was situated in the upper part of the intertidal zone.

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