DISTRIBUTION OF BENTHIC MACROFAUNA IN THE WESTERN SCHELDT ESTUARY (THE NETHERLANDS)

by

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Résumé

Distribution de la macrofaune benthique dans l'estuaire de l'Escaut. Dans vingt stations distribuées en quatre secteurs Ouest de l'estuaire de l'Escaut, ont été relevés des échantillons de la communauté des invertébrés benthiques dont la structure a été examinée. Deux groupes principaux ont ainsi été identifiés : 1 - un assemblage de sables vaseux et fins dans les parties superficielles avec prédominance de la communauté à *Macoma balthica;* 2 - un assemblage de sables moyens dans les parties plus profondes.

La distribution et l'abondance de ces espèces sont liées principalement aux facteurs sédimentaires mais sont également influencées par le gradient de salinité.

Introduction

The Western Scheldt is the most southerly situated estuary of the Delta area, connecting the river Scheldt with the North Sea. It is a coastal plain estuary with partial mixing (Nihoul and Wollast, 1977).

Until 1970, little research has been carried out on the fauna of the Western Scheldt. On the Belgian side Leloup and Konietzko (1956) studied the benthos and plankton in neighbouring mudflats of the zone Antwerp-Zandvliet. The hydrographical and physico-chemical aspects of the Western Scheldt were studied by Peters and Sterling (1976). De Pauw (1975) investigated the plankton and Heip *et al.* (1979) and Van Damme *et al.* (1980) studied the meiobenthos. On the Dutch side, Wolff (1973) studied the macrofauna of the whole Delta-area. However, macrobenthos of this estuary has not been investigated quantitatively before.

We have analysed the faunal data from twenty stations in an attempt to analyse the relationships between the distributional pattern of macrobenthic infauna and certain environmental factors. This study forms part of the benthos research in the Southern North Sea and the Western Scheldt carried out at the laboratories of the State University of Gent and of the K.B.I.N. (Brussels).

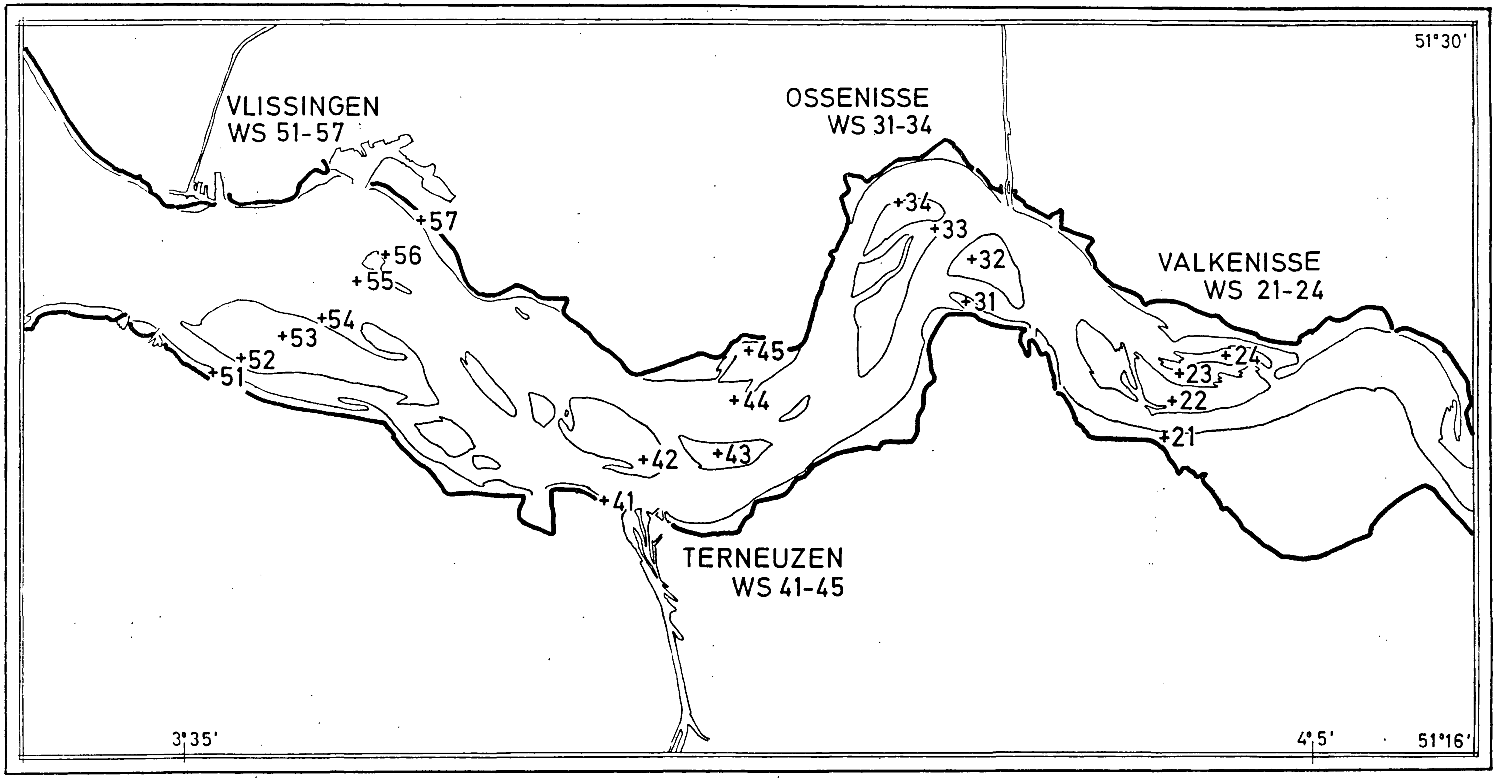

FIG. 1

Location of the twenty sampling sites distributed over four transects in the Western Scheldt.

Material and methods

Description of the study area.

The Western Scheldt has a length of about 80km up to Antwerp, where the boundary of the brackish water is found. Its width varies between 7.5km and 1km. Maximal depth is 57m near Terneuzen (Wolff, 1973).

Samples were taken at twenty stations distributed over four transects (Fig. 1). All stations are situated in the shallow parts of the estuary and none in the channel itself, since sampling in one of the busiest marine traficlanes of the world was not without great danger for ship and crew. Moreover regularly dredging of the deeper parts of the Scheldt does not allow development of stable benthic populations, therefore sampling the channel seemed unsuitable in view of the purpose of this study. Most stations are located on the tidal flats (Table 1): WS22 and WS24 on the 'Platen van Valkenisse", WS32 on the 'Plaat van Ossenisse', WS34 on the 'Brouwersplaat', WS42 on the 'Middelplaat', WS21, WS41 and WS51 are situated on a mudflat close to the dyke, WS52 and WS53 on the 'Hooge Platen'. WS44 and WS45 on the border of the 'Plaat van Baarland', WS54 on the border of the 'Hoge Platen', WS55 and WS56 on the border of the 'Spijkerplaat'. In the last two stations, Dunkerquian clays underlie the thin sandcover. All other stations lie in the deeper parts of the Western Scheldt.

TABLE 1

Depth and sediment measures.

Station	median size (phi)	sorting coeff.	sand percent	silt-clay percent	gravel percent	organic carbon percent	depth (m)
WS21	2.951	0.490	85.68	14.32	0.00	0.769	—2.0
WS22	2.936	0.382	97.36	2.64	0.00	0.305	+1.0
WS23	2.316	0.266	99.99	0.01	0.00	0.021	—2.5
WS24	2.445	0.391	96.95	3.05	0.00	0.215	+0.5
WS31	2.206	0.496	99.92	0.08	0.00	0.062	—2.5
WS32	2.290	0.324	99.96	0.04	0.00	0.018	—0.5
WS33	2.267	0.346	99.73	0.27	0.00	0.044	—2.0
WS34	2.529	0.419	99.19	0.81	0.00	0.100	—0.5
WS41	3.013	0.533	86.67	13.33	0.00	0.343	—2.5
WS42	2.845	0.375	96.84	2.07	1.09	0.166	+0.5
WS43	2.391	0.354	99.89	0.11	0.00	0.021	0.0
WS44	1.808	0.585	97.88	0.02	2.10	0.037	—5.0
WS45	2.294	0.375	98.27	1.73	0.00	0.169	—0.4
WS51	3.316	0.471	95.30	4.70	0.00	0.334	+0.5
WS52	2.678	0.497	94.41	5.59	0.00	0.172	+0.5
WS53	2.730	0.456	89.33	4.12	6.55	0.159	+0.5
WS54	2.444	0.663	74.60	25.40	0.00	0.226	—3.0
WS55	1.614	0.379	99.81	0.00	0.19	0.032	—3.5
WS56	2.078	0.464	99.96	0.04	0.00	0.022	—3.0
WS57	1.895	0.420	96.04	0.46	3.50	0.153	—1.0

Sampling and sorting.

Sampling was done on 27-28 September 1978. The sublittoral stations were sampled with $0.1m^2$ van Veen grab; littoral sampling points were hand-collected with a plastic core (5 cores of $77.8cm^2$ per sample), on each location three samples. Contents of the grab or core were fixed in buffered formaldehyde. In the laboratory, a small subsample was taken for sediment analysis and the rest was sieved through a stainless steel screen with 1mm mesh size. Samples with a lot of shell fragments were elutriated on a 5m long horizontal trough (Vanosmael *et al.*, 1982).

Polychaetes, crustaceans and molluscs were identified to species and counted, oligochaetes and nemerteans were only counted.

Anaitides mucosa, A. maculata and *A. groenlandica* were referred to *Anaitides* spp. (*groenlandica* group), since great doubt remained about the determination at species-level.

Sediment analysis.

After removal of the gravel-fraction, particle size distribution (sand-fraction only) was determined by dry sieving. Particle sizes were expressed in phi-units and the Wentworth scale used for the classification of the sand-fraction. The organic matter content was determined according to the method of Wakeel el and Riley (1957).

Statistical methods.

As measure of species diversity the Brillouin index was used.

TABLE 2

Total number of species, mean density and diversity per station.

Station	number of species	density ($N/0.1m^2$)	diversity H in bits/ind.
WS21	10	390	2.17
WS22	13	3 929	1.48
WS23	7	13	1.94
WS24	2	1	0.50
WS31	7	5	1.94
WS32	5	57	1.27
WS33	11	15	2.53
WS34	16	703	1.44
WS41	22	1 336	1.78
WS42	17	2 490	1.69
WS43	7	8	1.80
WS44	3	3	1.02
WS45	3	1	0.86
WS51	17	2 708	3.15
WS52	20	1 355	2.77
WS53	22	2 686	2.31
WS54	10	30	2.10
WS55	5	7	1.46
WS56	4	2	1.33
WS57	6	26	0.83

H = 1/N (log2 N! — log2 N1! — ...— log2 Nn!), in which N is the total number of individuals and Ni the number of individuals of the i-th species (Brillouin, 1956). The species occurring in more than 5 percent of the stations (32 species, Nemertinea and Oligochaeta excluded) were used for cluster analysis. The analyses were based on matrices of similarity between all possible pairs of stations (Q-mode) and between all possible pairs of species (R-mode). In the Q-mode the Sorensen index was used for binary data and the Canberra metric (Lance and Williams, 1967) for continuous data. The matrices thus obtained were subjected to group-average sorting (Sokal and Sneath, 1963).

The same set of species and stations were also subjected to Detrended Correspondence Analysis (DCA) (Hill, 1979), an improved version of reciprocal averaging.

All raw data were transformed by x = ln (x+1). Spearman rank correlation coefficients were calculated between station coordinates and the measured environmental parameters at the stations. Analysis of variance (ANOVA) was used to test for differences between the transect biota.

RESULTS

Sedimentology

The sediments consist mainly of fine sand. At WS41 and WS51, the substrate is muddy sand, medium sand is found at WS44, WS55 and WS57 (Table 1). All sediments are well sorted except at WS41, WS44 and WS54. The silt-clay and organic carbon content was generally low. A high percentage of mud was found at WS21 (14.5 percent), WS41 (13.5 percent) and WS54 (25.5 percent).

The benthos

Number of species, density, and diversity of the benthic infauna.

A total of 40 species were identified from sixty samples. Polychaetes comprised 50 percent of the species (20 taxa), molluscs 22.5 percent (9 taxa) and crustaceans 27.5 percent (11 taxa). The number of species per station ($3 \times 0.1m^2$) ranged from 2 in WS24 to 22 in WS53 and WS41 (Table 2). There was a statistically significant correlation between the number of species and the median particle size of the sediments in phi-units (Spearman's rank correlation coefficient $r = 0.72$, $p < 0.01$).

The number of specimens per $0.1m^2$ reached a maximum of 3 929 specimens at station WS22 (Table 2). There is a clear tendency for density to increase with increasing particle size (Spearman's rank correlation $r = 0.74$, $p < 0.01$).

Diversity (Brillouin's index expressed in bits/ind.) was highest at stations WS51 (H = 3.15), WS52 (H = 2.77) and WS53 (H = 2.31); lower values were found at WS22 (H = 1.48), WS34 (H = 1.44) and WS41 (H = 1.78). Dominance of *Corophium volutator, Hydrobia ulvae* and *Tharyx marioni* was responsible for these low diversity values (Table 2).

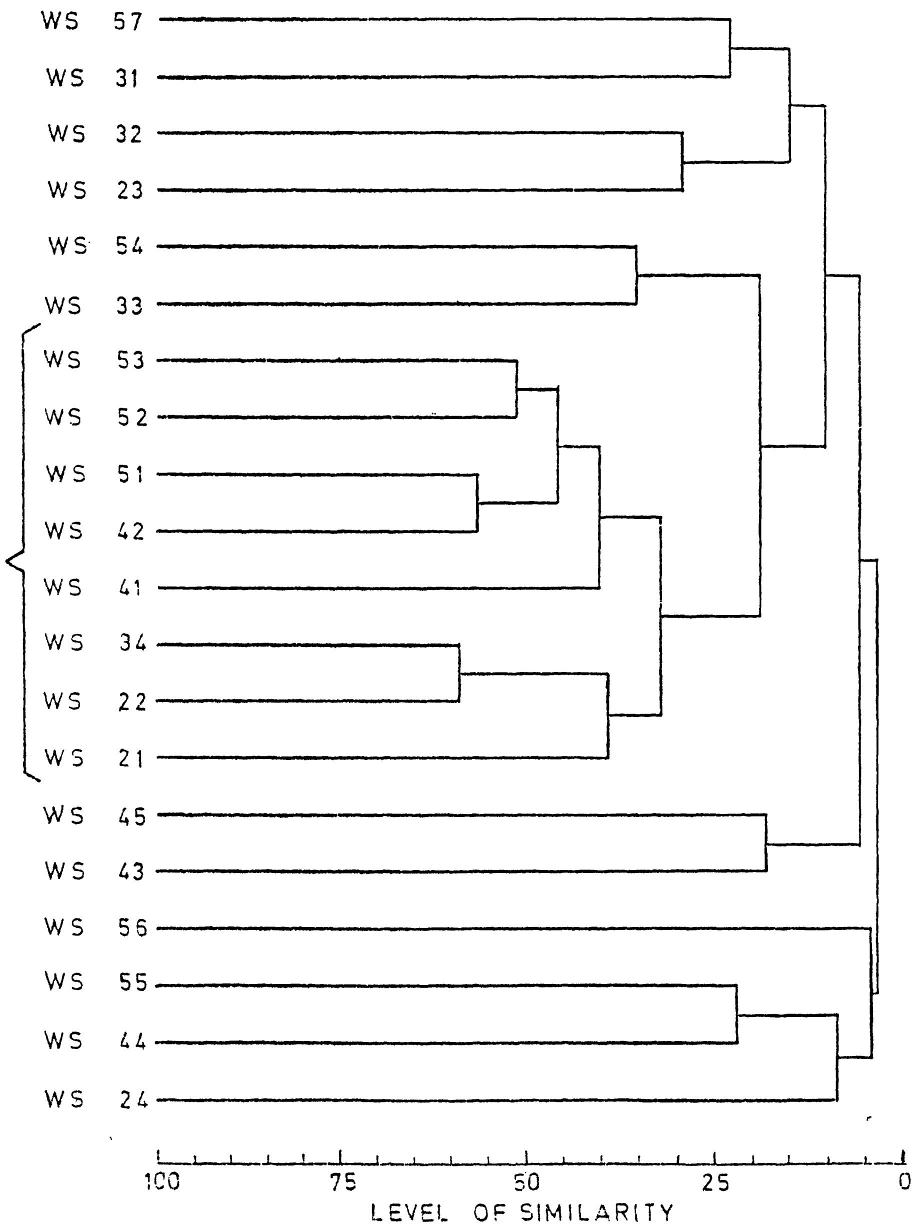

Fig. 2

Dendrogram of faunal affinities between stations based on group-average sorting. Percentage similarity is given by the Canberra metric (in percentage).

The mean diversity and the total number of species per transect showed a significant correlation ($r = 0.97$, $p < 0.01$) so that diversity and number of species increased towards the mouth of the river (Table 3). Nevertheless, we could not find a statistically significant difference (ANOVA) between species numbers, diversity or density of the four transects.

TABLE 3

Mean diversity, total number of species and mean salinity per transect.

	transect Vlissingen	transect Terneuzen	transect Ossenisse	transect Valkenisse
H	3.10	2.41	1.90	1.81
n	33	28	20	16
salinity	30.8 (N)	24.9	20.3	15.3
(per mil)	28.0 (S)			

Station groups

A preliminary cluster analysis of all samples revealed a very high similarity among the replicates of each station, so the pooled results of the three samples per station were used in further analyses.

The arrangement of stations produced by cluster analysis with the Sorensen as well as with the Canberra index revealed one large main cluster of eight stations (Fig. 2) situated over different transects in the estuary. All sampling stations of this cluster (WS51, WS52, WS53, WS41, WS42, WS34, WS21 and WS22) lie on the tidal flats or on their slope.

The coordinates of the first two axes (DCA-analysis), together accounting for 82 percent of the total variance, are plotted in figure 3. Axis I (49 percent of the variance) was significantly correlated with the sediment parameters sorting and median particle size and with depth, expressed in relation to the mean tidal level (Tables 1 and 4). The best correlation was obtained with depth. Stations WS56, WS44 and WS55, with the highest positive values on axis I, were situated on a mean depth of respectively 3, 5 and 3.5m at the border of the tidal flats. In comparison with the other permanently submerged or

TABLE 4

Spearman rank correlation matrix for station coordinates on axes 1 to 2 and sediment parameters. Degrees of freedom = 18. Italicized coefficients are significant at the 5 percent level of probability.

	depth (m)	median particle size (phi)	silt-clay percent	organic carbon percent	sorting coeff.
axis I	*0.648*	*0.465*	0.262	0.187	*0.445*
axis II	0.219	*0.668*	*0.697*	*0.666*	*0.535*

tidal sampling locations, these three stations are characterized by coarser sand and less silt, which may be explained by a stronger current.

The second axis (32 percent of the variance) was significantly correlated with all measured sediment parameters (Tables 1 and 4) and the best correlation was found with the silt-content of the sediment. So both axes seem to represent a general gradient of particle size: the first axis separates those deeper stations with a coarse sediment from the rest, and the distribution on the second axis is mainly due to the silt-content of the samples.

Species groups.

Cluster analysis was also applied to the between species matrix of similarity coefficients (Sorensen and Canberra index) in an attempt to identify species groupings (Fig. 4). Combined with the results

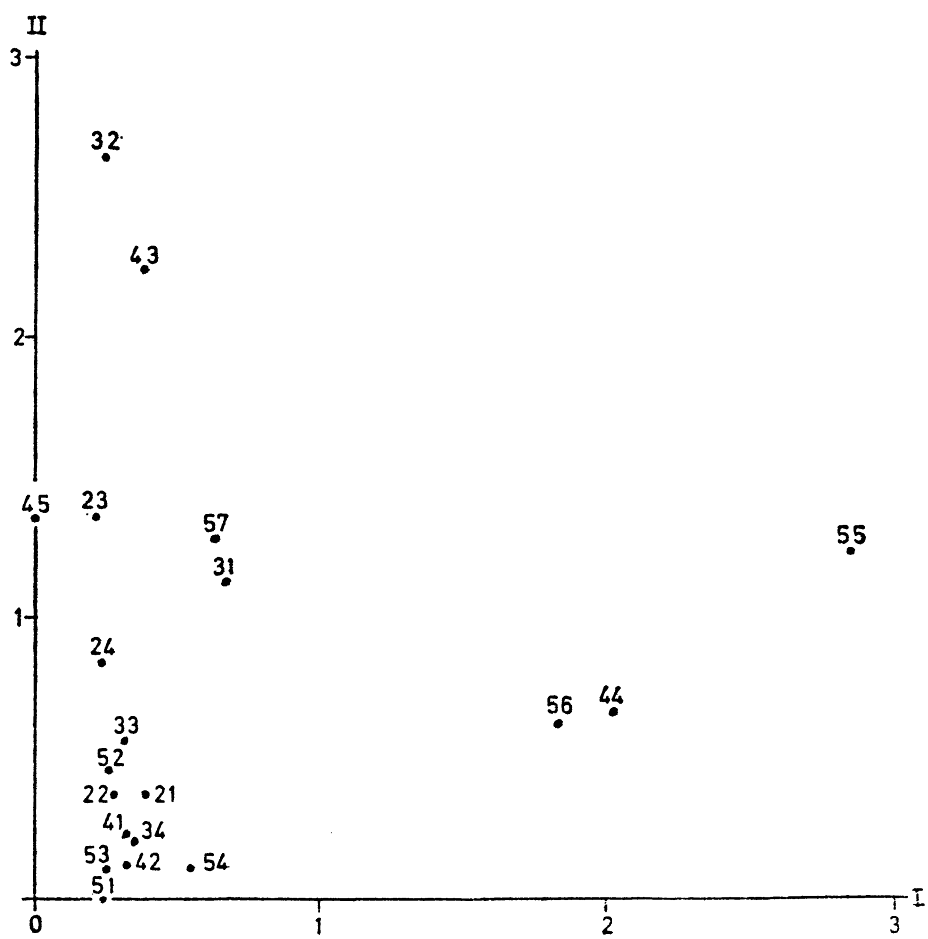

FIG. 3

Detrended correspondence analysis, relative loadings on the first two axes are given (stations only).

of DCA, following distributional patterns could be distinguished. A first cluster contains a number of species abundant in the eight stations formerly clustered by normal classification. The species in this group are: ***Pygospio elegans, Eteone longa, Nereis diversicolor, Tharyx marioni, Capitella capitata, Hydrobia ulvae, Heteromastus filiformis, Macoma balthica, Corophium volutator*** and ***Cerastoderma edule.***

Besides this major cluster, a second, smaller group is formed with species occurring exclusively in the transects Vlissingen and Terneuzen, thus only in the polyhaline zone of the estuary. These species are *Nephtys hombergii, Anaitides* spp. (*groenlandica* group), *Scoloplos armiger,* and *Crangon crangon.*

A third species group contains the species ***Nephtys cirrosa, Ophelia borealis*** and ***Gastrosaccus spinifer*** only found in locations WS44

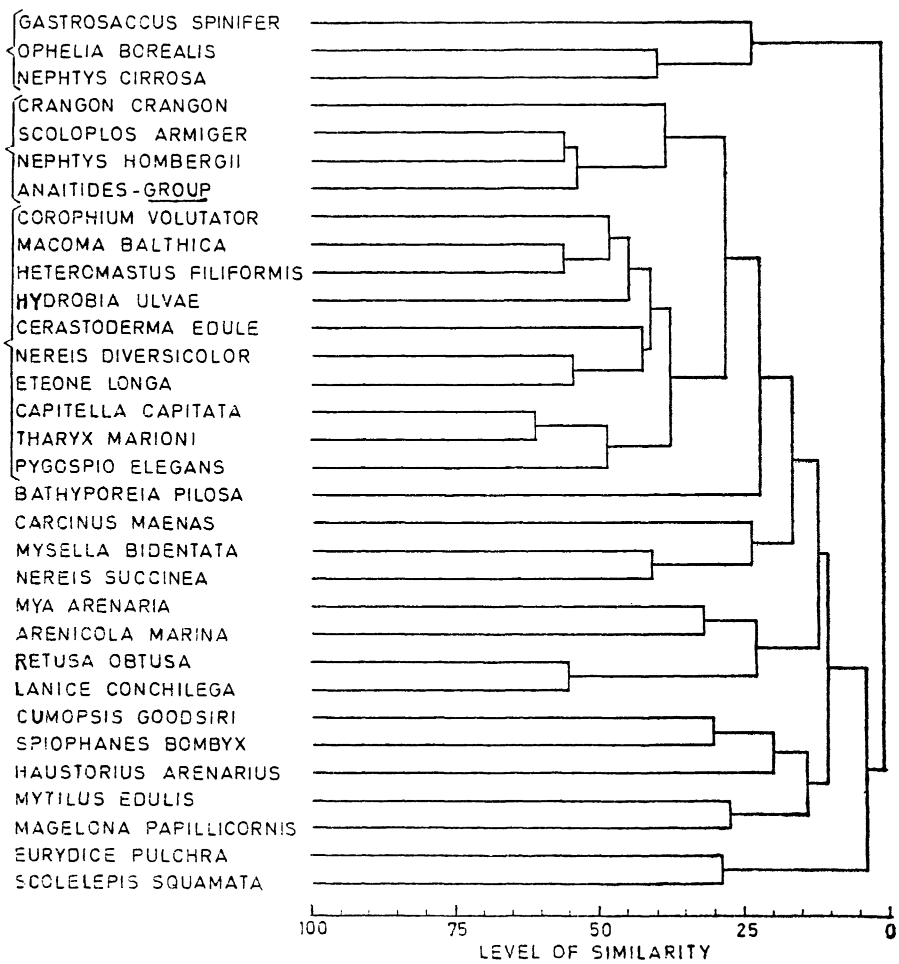

Fig. 4

Dendrogram from inverse cluster (species group) analysis. Percentage similarity is given by the Sorensen index.

and WS55. Both stations are situated in the euhaline part of the estuary, substrate medium sand with no mud and a very low organic carbon-content.

DISCUSSION AND CONCLUSIONS

The arrangement of stations produced by hierarchical clustering and DCA do show the existence of some station groupings.

The first station cluster groups a number of sampling points (low values on both axes in DCA) characterized by well sorted, muddy and fine sands and located in the undeep parts of the estuary. The second group of stations (high values on first DCA-axis) consists of some deeper stations, substrate medium sand.

The numerical dominant species in the first station cluster are: *Hydrobia ulvae, Corophium volutator, Tharyx marioni, Pygospio elegans, Heteromastus filiformis, Macoma balthica, Capitella capitata, Cerastoderma edule, Eteone longa, Bathyporeia pilosa* and *Nereis diversicolor,* reaching mean abundances (for the whole study area) of respectively 1335, 1292, 1020, 872, 192, 176, 113, 104, 36, 31 and 21 individuals per square metre. Most of these species are typical for estuarine waters. This species composition corresponds with the first clustered species group (R-analysis) and can be defined as belonging to the *Macoma balthica* community (Petersen, 1914) or the 'boreal shallow mud association' of Jones (1950). According to the last mentioned author, it is the usual shore community of more sheltered areas in North West Europe.

A second species cluster is also present in the first station group, but confined to the more saline parts of the estuary, namely: *Nephtys hombergii, Anaitides* spp. (*groenlandica* group), *Scoloplos armiger* and *Crangon crangon.* Less frequently observed *Tellina tenuis, Cumopsis goodsiri, Magelona papillicornis* and *Mysella bidentata.* The distribution of last taxa links up with the *Abra alba* community off the Belgian coast (Govaere *et al.*, 1980).

Only found in the second station cluster are the species of the third species group, containing: *Nephtys cirrosa, Ophelia borealis* and *Gastrosaccus spinifer,* all preferring a coarser sediment type.

Combination of the faunal data of all stations per transect results in a decline of species numbers and diversity from the polyhaline parts (transect Vlissingen) towards the mesohaline reach of the estuary (transect Valkenisse). This has already been demonstrated by Wolff (1973) for the macrobenthos and by Heip *et al.* (1979) and Van Damme *et al.* (1980) for the meiobenthos. Last authors noted 4.3 taxa of meiobenthos on the average at Vlissingen and only 1.5 at Doel; the same trend was shown in the annual mean density, respectively 2.2 millions and 0.16 million individuals per m^2.

In conclusion, the distribution of the infauna is roughly determined by a salinity-gradient, although no significant difference between transects could be demonstrated. The exact distribution of the species and their abundance however, are better fitted in the sediment map.

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Summary

Twenty stations distributed over four transects in the Western Scheldt estuary were sampled, and the benthic invertebrate community structure examined. Based on cluster analysis and Detrended Correspondence Analysis two main species-site groups emerged: (1) a muddy and fine sand assemblage in the shallow parts that featured a dominance of species belonging to the *Macoma balthica* community, (2) a medium sand assemblage in the deeper parts.

The distribution and abundance of the species seemed primarily determined by the sediment factors but are also influenced by the salinity-gradient.

Samenvatting

De struktuur van de benthische gemeenschappen in de Westerschelde werden bestudeerd. Uit de clusteranalyse en de ordinatie kwamen twee soort-plaats groepen tot uiting : (1) een fijn en zeer fijn zand groep in de ondiepe delen gedomineerd door de *Macoma balthica*-gemeenschap, (2) een gemiddeld zand groep in de diepere delen.

De verspreiding en abondantie van de soorten wordt voornamelijk door de aard van het sediment bepaald, daarnaast heeft ook de saliniteitsgradiënt invloed op deze parameters.

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