Cah. Biol. Mar. (1993), **34 :** 187-200
Roscoff

The hyperbenthic Amphipoda and Isopoda of the Voordelta and the Westerschelde estuary.

A. Cattrijsse, J. Mees & O. Hamerlynck
University of Gent, Zoology Institute, Marine Biology Section,
Ledeganckstraat 35, 9000 Gent, Belgium
and Centre for Estuarine and Coastal Ecology,
Vierstraat 28, 4401 EA Yerseke, the Netherlands

Abstract : Data are reported on the amphipods and isopods taken in a sledge-type hyperbenthos sampler in the subtidal of the Voordelta, a shallow coastal area and the Westerschelde, the last true estuary of the delta area (SW Netherlands). More than 300 samples were collected between 1988 and 1991. Two salt marshes in the brackish part of the estuary were sampled monthly with a flume net in 1990 and 1991.

A total of 46 amphipod species (42 gammarideans, 3 caprellids and 1 hyperiid), 19 of which are new for the area were recorded. The dominant amphipod species in the Voordelta and the marine part of the Westerschelde estuary are *Atylus swammerdami* and *Gammarus crinicornis.* Estimated densities of both species are high comparison to these estimated from macrobenthos samples taken in the same area. This suggests that an important part of the population swims above the bottom and is subsequently overlooked in benthos surveys using only grabs or corers. Some amphipod species that had not been previously recorded from the area were found to be quite common inhabitants of the hyperbenthal.The dominant species in the brackish part of the estuary are *Corophium volutator, Gammarus salinus, Pleusymtes glaber* and *Bathyporeia* species. In the salt marshes the same species are dominant but densities are much higher than in the main estuarine channel. *Gammarus zaddachi is* only present in the salt marshes.

The only abundant Isopoda are *Idotea linearis* in the Voordelta and *Paragnathia formica, Eurydice pulchra* and *Lekanesphaera rugicauda* in the salt marshes. From a total of 8 species, there were no new records for the study area.

Résumé : Ce travail présente des données sur les amphipodes et les isopodes échantillonnés avec un traineau suprabenthique dans la partie sous tidale du Voordelta, une zone côtière peu profonde, et dans l'Escaut occidental, le dernier véritable estuaire de la région du delta (SW des Pays Bas). Plus de 300 échantillons ont été récoltés entre 1988 et 1991. Deux marais maritimes situés dans la partie saumâtre de l'estuaire ont également été échantillonnés en 1990 et 1991 grâce à un filet à cadre placé dans les chenaux de marée.

Un total de 46 espèces d'amphipodes (42 gammaridés, 3 caprellidés et 1 hyperriidé), dont 19 nouveaux pour la région, ont été recensés. Les espèces dominantes d'amphipodes dans le Voordelta et la partie marine de l'estuaire de l'Escaut sont *Atylus swammerdami* et *Gammarus crinicornis*. Les densités de ces deux espèces sont fortes comparées à celles estimées pour le macrobenthos dans la même région. Ceci suggère qu'une part importante de la population nage au-dessus du fond et est donc sous-estimée lors des prélèvements de benthos utilisant uniquement des bennes ou des carottiers. Quelques espèces d'amphipodes qui n'avaient pas encore été récoltées dans la région se sont révélées être tout-à-fait commun dans le suprabenthos. Les espèces dominantes dans la partie saumâtre de l'estuaire sont *Corophium volutator, Gammarus salinus, Pleusymtes glaber* et *Bathyporeia* sp. Dans les marais maritimes les mêmes espèces sont dominantes mais en densités bien plus élevées que danss le chenal principal de l'estuaire. *Gammarus zaddachi* est présent uniquement dans le marais maritime.

Les seuls isopodes abondants sont *Idotea linearis* dans le Voordelta et *Paragnathia formica, Erydice pulchra* et *Lekanesphaera rugicauda* dans les marais maritimes. Sur un total de 8 espèces recensées, aucune n'est nouvelle pour la région.

Contribution N° 621 of the Centre for Estuarine and Coastal Ecology, Yerseke.

INTRODUCTION

Three main European rivers, the Rhine, the Meuse and the Scheldt, enter the North Sea in the so-called Dutch Delta in the southwest of the Netherlands (Fig. 1).

Information on the amphipod species present in the area is rather scarce. Hartog (1963, 1964) discussed the presence of the Tallitridae and Gammaridae. Amphipods are also included in the list of the crustaceans of the Dutch Delta in Wolff (1973).

Since these studies were completed major engineering works have altered most of the estuarine branches of the Delta (Heip, 1989). The Westerschelde remains a true estuary, the Oosterschelde has become a marine bay, the Grevelingen is now a saline Lake and the Haringvliet is a freshwater basin.

More recent data on the amphipods of some subareas can be found in macrobenthic studies (Buijs *et al.*, 1989 on the Voordelta ; Meire *et al.*, 1991 on Oosterschelde and Westerschelde ; Craeymeersch *et al.*, 1992 on the Westerschelde).

Some data on the isopods can be found in the synopses of Holthuis (1956), Huwae (1977) and Pinkster & Platvoet (1986) and the study of Wolff (1973).

All studies mentioned used Van Veen grabs or boxcorers as sampling gear. In contrast, the data in this study were obtained with a hyperbenthic sledge and a flume net. Besides providing information on the presence and the abundance of amphipods and isopods in part of the Dutch Delta, a comparison with the densities obtained with grabs and corers is given.

MATERIALS AND METHODS

The Voordelta stretches from the Dutch-Belgian border in the south to the Hoek van Holland in the north. Offshore, the area is arbitrarily defined by the Mean Tidal Level (MTL) -15 m depth contour. The study covers only the central part of the Voordelta (Fig. 1) at the mouth of the former Grevelingen and Oosterschelde estuaries. The abiotic environment is discussed in Louters *et al.* (1991). Between August 1988 and July 1989 ten surveys were conducted at approximately monthly intervals in 12 localities : station 1-4 in the ebb-tidal delta of the Grevelingen, stations 8-12 in the ebb-tidal delta of the Oosterschelde and stations 5-7 in the more seaward Banjaard area between both ebb-tidal deltas. In each station 2 samples were taken : one in the gully at a depth of about MTL-10 m and one on the sandbank slope at a depth of about MTL -5 m. As no consistent differences were found between these two depth strata, the number of individuals caught in both samples were pooled and divided by 2 for the purpose of this paper.

The Westerschelde estuary (Fig. 1) is the lower part of the river Schelde. The maritime zone of the tidal system is about 70 km long from the North Sea (Vlissingen) to the Dutch-Belgian border near Bath. The Westerschelde is characterised by a marked-salinity gradient. The abiotic environment is discussed in Heip (1988) and Van Eck *et al.* (1991). Between April 1990 to April 1991 thirteen surveys were conducted. Each survey comprised 14 sta-

tions along the salinity gradient. On 3 occasions (March, April and May 1991) 5 additional samples were taken upstream from Bath up to the city of Antwerp. All samples were taken in the subtidal channels. Where possible, the MTL - 10 m isobath was followed. Besides the subtidal surveys, monthly samples were taken at two intertidal stations in the salt marshes of Saeftinghe and Waarde (S and W in Fig. 1) from March 1990 to March 1991. The salt marsh of Waarde (107 ha) is a long-drawn marsh situated on the right bank of the estuary. It is drained by one major creek which runs parallel to the main channel of the estuary. The salt marsh of Saeftinghe (2 760 ha), situated on the left bank north of the harbour of Antwerp, is one of the largest of western Europe. It is drained by several large creeks which run perpendicular to the main estuarine channel.

All samples were taken during daytime. The samples were collected with a hyperbenthic sledge (Hamerlynck & Mees, 1991) which consists of a heavy metal frame equipped with two nets one above the other. The sledge is one metre wide. Both nets are 4 m long and have a mesh size of 2*2 mm in the first 3 m and 1*1 mm in the last 1 m. The contents of both nets were pooled for this study. The total area of the nets' mouth is 0.8 m^2 and it samples the hyperbenthal from 20 to 100 cm above the bottom. The sampler was towed for approximately 1 000 m (radar readings from fixed points) at an average ship speed of 4.5 knots relative to the bottom. The total area sampled was 1 000 m^2. Trawling was always done with the tide. Thus, the maximal amount of water filtered in one trawl was 800 m^3.

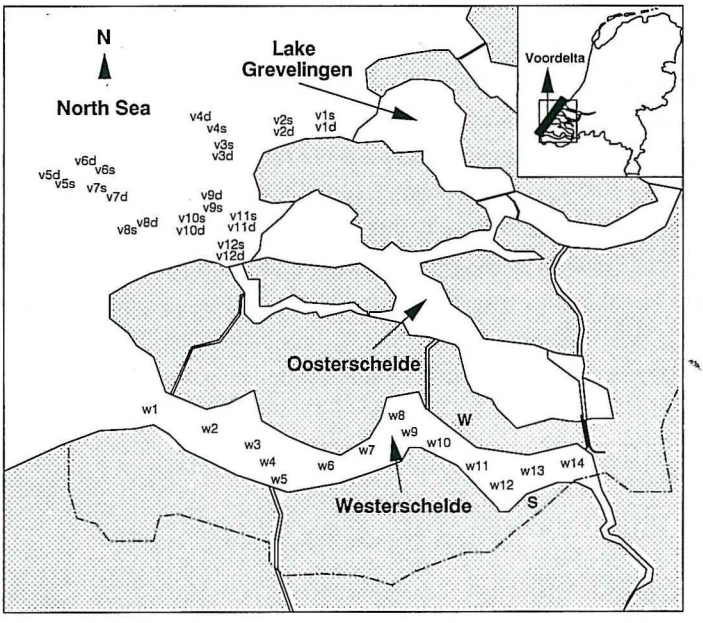

Fig. 1 : Map of the study area, showing subareas and sampling stations. The salt marsh sites are denoted with W (salt marsh of Waarde) and S (Salt marsh of Saeftinghe).

The salt-marsh samples were taken passively with a fyke net modified after McIvor & Odum (1986). The net is 5 m long with a 1*1 mm mesh and has a weir at the end. The mouth area of the net is 1*1 m. It was mounted on an iron frame and two heavy weights were attached at the lower end in order to keep the frame on the bottom of the creek. Ropes attached to the frame prevented lateral movement of the gear. The net was installed in the creek at low water, its mouth facing the current. Sampling covered a whole tidal cycle, the orientation of the gear evidently being changed at high tide. The net was emptied every 1 hour. Simultaneous measurements (every 15') of water height and current velocity in the creek allowed calculation of the volume of water filtered by the net.

During sampling temperature, salinity and dissolved oxygen content of the water were measured near the bottom.

The samples were preserved in a buffered formaldehyde solution, 7 % final concentration. In the laboratory all amphipods and isopods were sorted out, identified to species level (except for the *Bathyporeia* species) and counted. The identification key of Lincoln (1979) was used for the amphipods, the key of Naylor (1972) for the isopods.

The reported densities in each station are the mean number of individuals per sample taken in that station expressed as individuals per 1 000 m^3 filtered.

The temporal patterns in the densities of the amphipod and isopod populations are presented as the variation of average densities over all stations per subarea (Voordelta, Westerschelde, both salt marshes) per sampling campaign. In order to describe the migrations and seasonal patterns in the Westerschelde, the main channel of the estuary is divided into a western (marine) and eastern (brackish) part on the basis of community analyses in previous work (Mees & Hamerlynck, 1992 ; Mees *et al.*, in press). The marine part of the estuary comprises the 8 downstream stations and the brackish part comprises stations 10 to 14. Station 9 is a transitional situation between the two communities and was eliminated for the purpose of this analysis. The seasonal variations in abundance in the salt marshes of Waarde and Saeftinghe are also presented separately.

Other faunal components of the hyperbenthos included mysids, euphausiids, larval decapods, fish eggs, larval and postlarval fish, cumaceans, chaetognaths and a variety of other, less abundant groups. For full species lists we refer to Hamerlynck & Mees (1991) and Mees *et al.* (in press). Data on the mysids and euphausiids were reported separately (Mees *et al.* 1993).

RESULTS AND DISCUSSION

All amphipod and isopod species recorded during the study are listed in Table 1. The symbols used give a rough indication of the abundance.

TABLE I

List of the Amphipoda and Isopoda species caught.

	VOORDELTA	WESTERSCHELDE Marine	WESTERSCHELDE Brackish	WAARDE	SAEFTINGHE
AMPHIPODA					
Gammaridea					
Orchomene nana	oo				
Amphilochus neapolitanus	o				
Ampelisca brevicornis	oo				
Metopa alderi	o				
Metopa pusilla	o				
Stenothoe marina	oo	o			
Stenothoe valida	o				
Orchestia gammarellus				●●	●
Chaetogammarus marinus				oo	
Gammarus crinicornis	●●●	●●●		o	
Gammarus duebeni				o	
Gammarus salinus	oo		●●	●●	●●
Gammarus locusta	●				
Gammarus oceanicus	oo				
Gammarus zaddachi				●●	●●
Maera grossimana	o				
Melita hergensis	oo				
Melita obtusata	oo				
Melita palmata	oo			o	
Bathyporeia Species	●●	oo	●●	●●●	●●
Haustorius arenarius	oo			o	o
Urothoe brevicornis	o				
Urothoe poseidonis	oo				
Monoculodes carinatus	o				
Pontocrates altamarinus	oo	oo			
Pontocrates arenarius	oo				
Megaluropus agilis	o				
Apherusa ovalipes	o				
Pleusymtes glaber		o	●●	●●	●●
Atylus falcatus	●●				
Atylus swammerdami	●●●	●●	oo		o
Gammaropsis nitida	o				
Microprotopus maculatus	o				
Corophium arenarium		o	oo		o
Corophium lacustre				o	●
Corophium volutator		●	●●●	●●●●	●●●●
Ischyrocerus anguipes		o			
Jassa falcata	●●	o			
Jassa marmorata	oo	oo			
Jassa pusilla	o				
Parajassa pelagica	o				
Dyopedos porrectus	o				

	VOORDELTA	WESTERSCHELDE Marine	WESTERSCHELDE Brackish	WAARDE	SAEFTINGHE
Caprellidea					
Phtisica marina	oo				
Pariambus typicus	••				
Caprella linearis	oo	oo			
Hyperiidea					
Hyperia galba	oo	oo			
ISOPODA					
Paragnathia formica				••	••
Eurydice pulchra	oo	oo	oo	••••	•••
Lekanesphaera rugicauda		oo	•	•	••
Idotea baltica	oo				
Idotea chelipes				o	
Idotea emarginata	•				
Idotea linearis	••	oo			
Jaera albifrons				oo	

Legend

o	caugth only once
oo	density < 0,5 ind./1 000 m³
•	density > 0,5 ind./1 000 m³ < 1 ind./1 000 m³
••	density > 1 < 10 ind./1 000 m³
•••	density > 10 < 100 ind./1 000 m³
••••	density > 100 100 ind./1 000 m³

One clear feature is the high number (33) of gammaridean amphipod species recorded in the Voordelta and the low number (6) recorded in the eastern part of the Westerschelde. The western part of the estuary has an intermediate number of species (12). Taking the caprellid and the (only) hyperiid amphipods into account this difference becomes even more pronounced. The saltmarshes have about the same number of species as the western part of the estuary. This is due to the presence of intertidal species, which also reach high abundances. Typically, low species diversity coincides with high abundances in the brackish part of estuaries (Remane, 1958).

The opposite picture emerges for the isopods for which equal numbers were recorded in the different subareas. It are again the intertidal isopods which reach the highest densities.

AMPHIPODA

New records for the Voordelta are *Orchomene nana, Amphilochus neapolitanus, Metopa alderi, M. pusilla, Stenothoe valida, Gammarus oceanicus, Maera grossimana, Melita hergensis, Monoculodes carinatus, Apherusa ovalipes, Gammaropsis nitida, Jassa marmorata, Parajassa pelagica* and *Dyopedos porrectus* for the gammarideans, *Caprella linearis* for the caprellids and *Hyperia galba* for the hyperiids. Most of these are rare species in the hyperbenthos samples except for *O. nana* which occurs regularly, though always in low

numbers, in the Voordelta stations furthest from the shore. The species is a widely recorded marine species and it may locally be very common (Lincoln, 1979). Possibly this species spends a substantial proportion of its time in the hyperbenthal.

The marine amphipods *Cheirocratus sundevalli* and *Leptocheirus pilosus* were recorded by Wolff (1973) but were not found in this study. Hartog (1964) mentions *C. sundevalli* as a rare amphipod of Lake Veere and the Oosterschelde. *L. pilosus* was found a few times in the intertidal by Wolff (1973). *Microprotopus maculatus*, which was caught only once in this study, was recorded in low numbers in the Voordelta by Buijs *et al.* (1989). Again, Wolff (1973) found it to be a scarce representative of the benthic fauna. This species was also found in the stomachs of gobies (*Pomatoschistus minutus* and *P. lozanoi,* collected in the Voordelta (Hamerlynck, unpubl.). In the Belgian coastal area *M. maculatus* is very abundant in goby stomachs especially in association with the caprellid *Pariambus typicus* and the radiole crowns of *Lanice conchilega* (Hamerlynck *et al.*, 1986, Hamerlynck *et al.*, 1990). The absence of the species from the hyperbenthos samples suggests the species does not often leave the cover of the *Lanice* beds, at least not during the daytime.

Wolff (1973) also recorded a number of strictly intertidal species and some species of very low salinity waters, e.g. *G. pulex*, not found in this study. Hartog (1964) recorded *Chaetogammarus stoerensis*, *C. obtusatus* and *Gammarellus angulosus* but these were not found in the present study. In the Voordelta Buijs *et al.* (1989) recorded three relatively rare amphipod species (average density below 0.1 ind./m^2) that were not found in the present study, namely : *Ampelisca gibba*, *A. spinipes* and *Perioculodes longimanus*. On the other hand seventeen amphipod species found in the Voordelta in the present study were not recorded by Buijs *et al.* (1989). The commonest of these : *Gammarus locusta, Melita palmata* and *O. nana* may be truely hyperbenthic. Still, the studies of Buijs *et al.* (1989) were restricted to autumn and as *M. palmata* and *G. locusta* were recorded by Hartog (1964) this may be a seasonal rather than a distributional effect.

New records for the Westerschelde estuary are *Corophium lacustre, Ischyrocerus anguipes* (single record) and, more importantly, *Pleusymtes glaber*. Though *P. glaber* was recently also recorded in Van Veen grab samples in the Westerschelde (Ysebaert, T. pers. comm.), it seems to spend a substantial proportion of its time in the hyperbenthal. According to Lincoln (1979) *P. glaber* is a rocky shore species. In contrast, the species was quite abundant in the eastern part of the Westerschelde and in the salt marshes of Waarde and Saeftinghe (densities of 8, 2 and 7 ind./1 000 m^3, respectively).

The Voordelta

Dominant species in the hyperbenthos of the Voordelta are : *Atylus swammerdami, A. falcatus, Gammarus crinicornis, G. locusta, Jassa falcata* and *Bathyporeia* spec. The temporal pattern in the recorded densities of four of the most abundant species is shown in Fig. 2.

Atylus swammerdami is the most important amphipod in the hyperbenthos of the shallow coastal area. Locally it reached peak densities of almost 1 500 ind./1 000 m^3. Average densities in the Voordelta and western part of the estuary were 47 and 2 ind./1 000 m^3, respectively. The species was also recorded occasionally in the brackish part of the estuary and there was a single record in Saeftinghe. There is a clearly bimodal abundance pattern

(Fig. 2) with a peak in June (160 ind./1 000 m^3) and one in September (145 ind./1 000 m^3). These two peaks may represent two cohorts.

Buijs *et al.* (1989) recorded densities of 4 ind./m^2 in the Voordelta in autumn. This means that in September at least 3 % (assuming 100 % efficiency of the hyperbenthic sledge) of the population is present in the hyperbenthal.

Gammarus crinicornis is the second most abundant amphipod in the coastal area of the Dutch Delta, with a mean density of 8 ind./1 000 m^3 in the Voordelta and 15 ind./1 000 m^3 in the western part of the estuary. Peak density in the Voordelta is recorded in April (40 ind./11 000 m^3). Buijs *et al.* (1989) recorded densities of 1 ind./m^2 in autumn. In this study the autumn (sept.-nov.) density was 5 ind./1 000 m^3, meaning that about four times as much animals were sampled with the sledge than with a bottomsampler. In beam trawl samples of epibenthic animals in the Voordelta (Hamerlynck *et al.*, submitted) the species is often found in high numbers among colonies of hydrozoans and bryozoans, together with *A. swammerdami* (Mees, unpubl. data). *G. crinicornis* is an important component of the hyperbenthos in the marine part of the Gironde estuary (Sorbe, 1981). The species is probably mostly epibenthic but commonly swims about in the hyperbenthal. Lincoln (1979) characterizes the species as intertidal on exposed sandy beaches, but this study shows the species also occurs abundantly in the shallow subtidal.

Both *A. swammerdami* and *G. crinicornis* are important in the food web of this coastal ecosystem as they are both frequently eaten by fish (Hamerlynck, unpubl. data). In the stomachs of *Pomatoschistus* species, the most abundant fish in the area (Hamerlynck *et al.*, submitted), several dozens of individuals of *A. swammerdami* were found per stomach (Hamerlynck, unpubl. data).

Atylus falcatus is the next most abundant species in the Voordelta (1 ind./1 000 m^3). This species is only present in the hyperbenthos from April till June. In the Van Veen grab and boxcore samples (Buijs *et al.*, 1989) the species is more abundant than *A. swammerdami*, which suggests it is more endobenthic. *A. falcatus* seems to have a preference for the ebb tidal delta of the former Grevelingen estuary where the sediment is fine sand with 5 to 20 % mud (Hamerlynck *et al.*, 1992). The species also figures prominently in the food of gobies in the area (Hamerlynck, unpubl.).

Jassa falcata is a typical fouling organism that builds tubes. It occurred regularly in the hyperbenthic samples (0.7 ind./1 000 m^3). Highest abundances were recorded in May and June. In contrast to the former species it has a preference for the more dynamic areas of the Voordelta.

Bathyporeia species are burrowing amphipods which pose considerable identification difficulties. Mean abundance for the genus is 0.8 ind./1 000 m^3 in the Voordelta and 0.2 ind./1 000 m^3 in the marine part of the Westerschelde. Two species were identified with certainty : *B. elegans*, which is the most abundant species by far, and *B. guilliamsoniana*, whose adults can easily be identified by their large size. Other occurrences in the Voordelta are most probably *B. pelagica* and *B. sarsi*. Highest abundances were recorded in April and May (3.2 ind./1 000 m^3). *Bathyporeia* species reach densities of over 100 ind./m^2 in the Van Veen grab samples on the sandbanks which are exposed to the strongest wave impact (Buijs

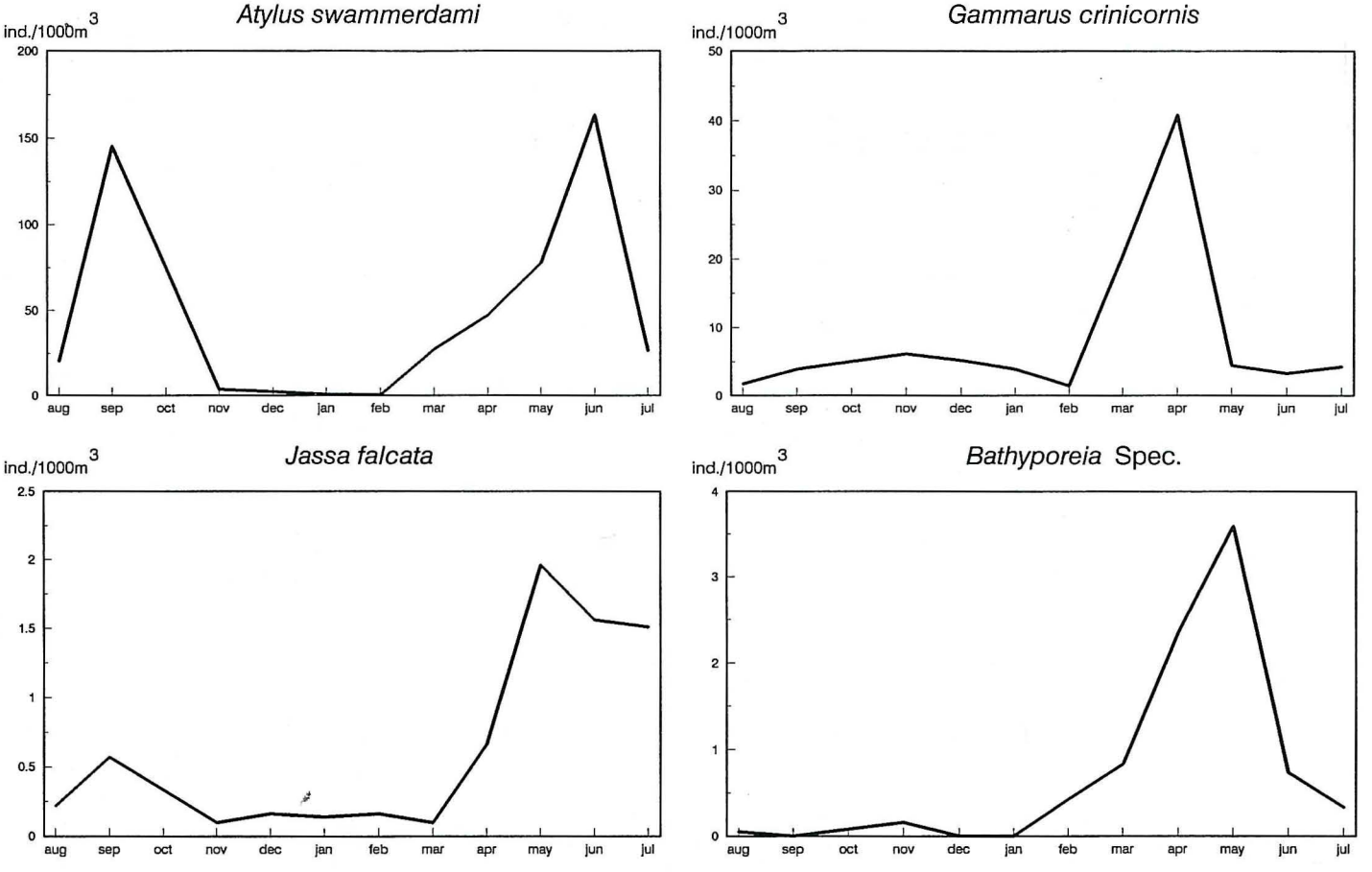

Fig. 2 : Seasonal variation in density of the *Atylus swammerdami, Gammarus crinicornis, Jassa falcata* and *Bathyporeia* species in the Voordelta.

et al., 1989). Another burrowing amphipod *Haustorius arenarius* was rarely found in Voordelta though, according to Buijs *et al.* (1989) it is quite abundant (2 ind./m²). The species is also a common inhabitant of the sandbanks in the brackish part of the Westerschelde (14 ind./m²) (Mees, unpubl. data). The single records from the saltmarshes may refer to animals washed in from the estuary.

Gammarus locusta is the last species to reach relatively high densities in the hyperbenthos of the Voordelta (0.54 ind./1 000 m³). Peak abundance is in September (9 ind./ 1 000 m³). According to Lincoln (1979) the species is restricted to fully marine habitats. Still a single individual was caught in the Salt Marsh of Waarde and Hartog (1964) recorded it in mid estuary. Buijs *et al.* (1989) did not record this species, so it may be epibenthic or hyperbenthic.

Hartog (1964) and Pinkster & Platvoet (1986) doubted the occurrence of *Gammarus oceanicus* in the Dutch Delta, and stated it is restricted to the Eems-Dollard estuary in the north of The Netherlands. However, two individuals were caught at 5 m depth in the ebb-tidal delta of the former Grevelingen estuary.

Caprellids and hyperiids were only caught in the marine part of the study area (Voordelta and marine part of the Westerschelde). Caprellids are typically 'Aufwuchs' species attached to colonies of hydrozoans or bryozoans, except for *Pariambus typicus* which also occurs on sandy or muddy bottoms. Mean density in the hyperbenthal was 0.34 ind./1 000 m³. The same value was found for the other regularly caught caprellid *Caprella linearis*. In contrast, Buijs *et al.*, (1991) found very high densities of *P. typicus* (13 ind./m²) in the Voordelta but did not record the other two caprellids, which accords with their life-styles : epibenthic Aufwuchs for *Caprella* species with regular swimming bouts in the hyperbenthal, rnainly endobenthic for *P. typicus*, also with frequent ventures into the hyperbenthal. *P. typicus* is also one of the preferred prey species of *Pomatoschistus* species ; both in the Belgian coastal area (Hamerlynck *et al.*, 1986, 1990) and in the Voordelta (Hamerlynck, unpubl.). Wolff (1973) recorded only *Phtisica marina* which was rare in this study.

The records of the commensal hyperiid *Hyperia galba* coincided with the "bloom" of its host *Aurelia aurita* in May and in September-October.

Westerschelde and salt marshes

In the marine part of the Westerschelde, only the two dominant species from the Voordelta, *G. crinicornis* and *A. swammerdami* remained important. *Corophium volutator* was relatively important in the hyperbenthal (0.8 ind./1 000 m³). These may be animals flushed out from the rich populations in the brackish part and the saltmarshes. The marine part of the estuary contained low abundances of some typical representatives of both the marine and the brackish environment.

In the brackish part of the estuary quite a different amphipod community was found. *Corophium volutator* is the dominant species, becoming very abundant in the salt marshes. It is a tube building amphipod that can occur in densities of over 20 000 ind./m² in benthic core samples taken in the tidal creeks of the marshes (Cattrijsse, unpubl. data) or on the intertidal areas of the estuary (Ysebaert, T., pers. comm.). It was found in the hyperbenthal in high densities (estuary 15 ind./1 000 m³, Waarde 245 ind./1 000 m³, Saeftinghe 229 ind./

1 000 m³) for a large part of the year (Fig. 3). Its high abundance may reflect active dispersal or less likely passive flushing out.

The other Corophium species (*C. arenarium, C. lacustre, C. acherusicum*) are rare occurrences in the hyperbenthal of the brackish part of the estuary and the marshes. *C. arenarium*, is a typical estuarine inhabitant, regularly recorded in intertidal core samples by Meire *et al.* (1989). It occurs in the hyperbenthal only occasionally. According to Lincoln (1979) *C. lacustre* is a typical inhabitant of marshes and ditches but has been recorded only a few times. *C. acherusicum* was only caught on two occasions, once in the seaward part and once in Saeftinghe. Wolff (1973) also listed *C. insidiosum* and *C. multisetosum* for the Dutch Delta.

In the brackish part of the estuary *Bathyporeia* species reaches average densities of 3 ind./1 000 m³, 37 ind./1 000 m³ in Waarde en 2 ind./1 000 m³ in Saeftinghe. As in the Voordelta only a small part of the population of these burrowers is present in the hyperbenthal. Benthic grab samples in this part of the estuary recorded about 100 ind./m² on the sandbanks in August (Mees unpubl. data). Craeymeersch *et al.* (1992) report densities of about 120 ind./m² in the eastern part of the estuary.

Gammarus salinus is a very common gammarid, mostly caught in the salt marshes (45 and 53 ind./1 000 m³ in Waarde and Saeftinghe respectively) and in the eastern part of the estuary (9 ind./1 000 m³). The species was also observed, be it at relatively low densities (0.44 ind./1 000 m³), at some localities in the ebb tidal delta of the former Grevelingen estuary. Hartog (1964) recorded it also in the coastal waters and stated that *G. salinus* expands its range of occurrence to seaward at times of high precipitation. As most of the records of *G. salinus* in the Voordelta were in summer it seems unlikely that the animals were washed out to sea. At that time the sluices connecting Lake Grevelingen to the sea are closed and fresh water inputs to the Voordelta from the Rhine are generally minimal. Hartog (1964) also states the species is rare in the Westerschelde. As with *G. crinicornis* and *A. swammerdami* it is therefore thought that *G. salinus* is mainly epibenthic. Seasonal density fluctuations were generally similar in both salt marshes (Fig. 3) with maxima in late autumn and during spring.

Gammarus zaddachi was recorded by Hartog (1964) exclusively in the very low salinity reaches of the estuary near Antwerp. In this part of the estuary nowadays all hyperbenthic life has disappeared because of hypoxia (Mees *et al.*, 1993). In the present study *G. zaddachi* was only found in the salt marshes (7 ind./1 000 m³ in Waarde, 2 ind./1 000 m³ in Saeftinghe). The absence of the species from the estuarine samples may either be due to the anoxia in the primary habitat or due to the fact that it is an intertidal species.

Within the Tallitridae, in contrast with Hartog (1963) and Wolff (1973), only *Orchestia gammarellus* was recorded in the present study. *O. gammarellus* lives near the high-water mark and was only caught when large amounts of plant material were washed out of the marshes (Waarde 3 ind./1 000 m³, Saeftinghe 1 ind./1 000 m³). Although *O. gammarellus* occurs in relatively low densities in the marsh samples it is frequently found in the stomachs of fishes leaving the marshes during ebb (Cattrijsse, unpubl. data).

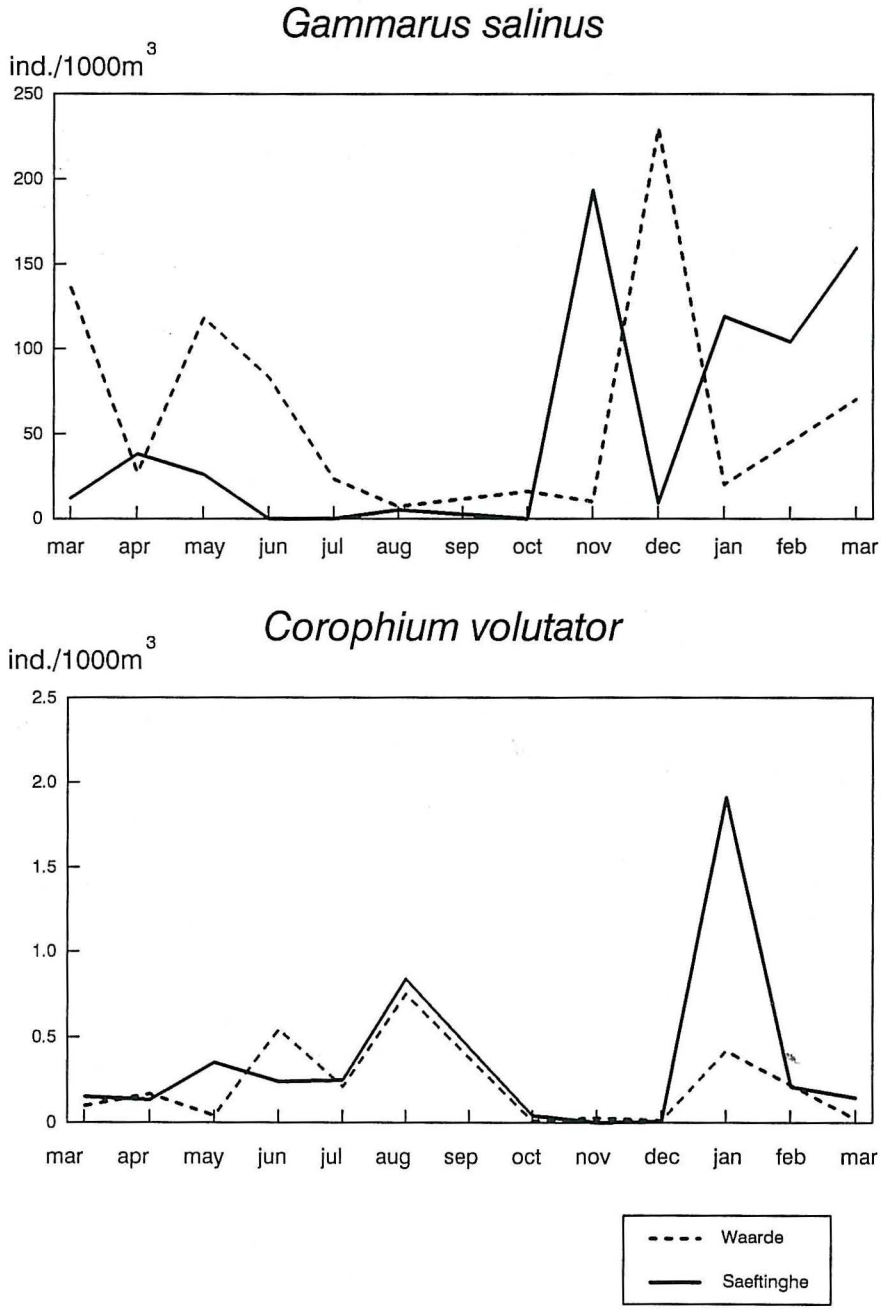

Fig. 3 : Seasonal variation in density of the *Corophium volutator* and *Gammarus salinus* species in both salt marshes.

Chaetogammarus marinus was only recorded in the salt marsh of Waarde. It was observed mostly in spring (0.001 ind./1 000 m^3). The absence of the species from Saeftinghe is in accordance with the findings of Hartog (1964). Still, the sampling techniques used in the present study are less than adequate for intertidal amphipods.

ISOPODA

The number of species of Isopoda recorded in the present study is very low compared with the studies of Holthuis (1950, 1956), Huwae (1977) and Wolff (1973). A lot of these isopods are intertidal and were therefore less than adequately sampled. For example *Jaera albifrons*, the most common littoral isopod in the Netherlands (Huwae, 1977), was only caught a few times in the salt marsh of Waarde. Other intertidal species make extensive use of the hyperbenthal, e.g. the semi-parasitic *Paragnathia formica, Lekanespheara rugicauda* and *Eurydice pulchra*. These species were recorded as common by Holthuis (1950, 1956), Huwae (1977) and Wolff (1973) and were also found abundantly in the present study.

Eurydice pulchra was the only isopod recorded in all subareas. It is was only recorded a few times in the Voordelta (0.0lind./1 000 m^3), but reaches very high densities in the saltmarshes (Waarde 151 ind./1 000 m^3, Saeftinghe 64 ind./1 000 m^3). *E. affinis* was reported from the Oosterschelde by Wolff (1973) and Huwae (1977) classifies it as a common marine species but it was not recorded in the present study.

Lekanesphaera rugicauda (formerly *Sphaeroma*) is recorded regularly in the brackish part of the estuary. It is more abundant in the salt marshes (Waarde 5 ind./1 000 m^3, Saeftinghe 30 ind./1 000 m^3). Holthuis (1956) is unsure about the distribution because of possible confusion With *L. hookeri*, a brackish water species which occurs in non-tidal waters behind the dykes (Huwae, 1977). Using the identification key of Naylor (1972) the species can easily be distinguished.

In the Voordelta only *ldotea linearis* has been caught in substantial numbers (1.14 ind./1 000 m^3). According to Huwae (1977) it is a very common isopod in coastal waters. *I. emarginata* was regularly caught in the Voordelta but in low densities (0.46 ind./1 000 m^3, with a peak of 32 ind./1 000 m^3 in one of the stations most distant from the shore). *I. baltica* was only caught a few times. This is in contrast to the findings of Huwae (1977) who states *I. emarginata* is rare while *I. baltica* is a common sublittoral species. *I. chelipes* was only caught once in the salt marsh of Waarde, although it is a common isopod in brackish water pools.

ACKNOWLEDGEMENTS

This study was supported by the European Community, contract n° MAST-0024-C (JEEP 92 project) and by Rijkswaterstaat Dienst Getijdewateren. The first author acknowledges a grant of the Intitute for the Encouragement of Scientific Research in Industry and Agriculture (IWONL). We would like to thank Wim Röber, Piet de Koeyer, Co van Sprundel and Hans Francke, for their excellent seamanship and enthusiastic help on board the R.V. Luctor. This is contribution n° 621 of the Centre for Estuarine and Coastal Ecology.

REFERENCES

BUIJS, J., J.A. CRAEYMEERSCH, R. BRAND, J. VAN DER MEER, A. POUWER & A. SMAAL, 1989. Macrobenthosgemeenschappen in de Voordelta : een analyse van de dichtheden en biomassa's van de najaarsbemonsteringen 1985-1986. DIHO Report, 1989-6 : 63 p.

CRAEYMEERSCH, J.A., E.B.M. BRUMMELHUIS, W. SISTERMANS & E.C. STIKVOORT, 1992. Het rnacrobenthos van de Westerschelde, de Oosterschelde, het Veerse Meer en het Grevelingenmeer. Najaar 1990. Biological Monitoring Programme Report : 44 p.

DEN HARTOG, C., 1963. The Amphipods of the deltaic region of the rivers Rhine, Meuse and Scheldt in relation to the hydrography of the area. Part II. The Tallitridae. *Neth. J. Sea Res.* 2 : 40-67.

DEN HARTOG, C., 1964. The Amphipods of the deltaic region of the rivers Rhine, Meuse and Scheldt in relation to the hydrography of the area. Part III. The Gammaridae. *Neth. J. Sea Res.* 2 : 407-457.

HAMERLYNCK, O. & J. MEES, 1991. Temporal and spatial structure in the hyperbenthic community of a shallow coastal area and its relation to environmental variables. *Oceanologica Acta* Vol. sp. 11 : 205-212.

HAMERLYNCK, O., K. HOSTENS, R.V. ARELLANO, J. MEES & P.A. VAN DAMME, submitted. The mobile epibenthic fauna of soft bottoms in the Dutch Delta (south-west Netherlands) : spatial structure. *Neth. J. aquat. Ecol.*

HEIP, C., 1988. Biota and abiotic environment in the Westerschelde estuary. *Hydrobiol. Bull.* 22 : 31-34.

HEIP, C., 1989. The ecology of the estuaries of Rhine, Meuse and Scheldt in the Netherlands. *Scient. Mar.* 53 : 457-463.

HOLTHUIS, L.B. 1956. De Isopoda en Tanaidadea van Nederland. Fauna van Nederland. Rijksmuseum van Natuurlijke Histone, Leiden : 166 p.

HUWAE, P.H.M., 1977. De Isopoden van de Nederlandse kust. *Wetenschappelijke Mededelingen van de Koninklijke Nederlandse Natuurhistorische Vereniging* 118 : 44 p.

LINCOLN, R.J., 1979. British marine Amphipoda : Gammaridea. British Museum Natural History : 658 p.

LOUTERS, T., J.P.M. MULDER, R. POSTMA & F.P. HALLIE, 1991. Changes in coastal morphological processes due to the closure of tidal inlets in the SW Netherlands. *J. Coast. Res.* 7 : 635-652.

MCIVOR, C.C. & W.E. ODUM, 1986. The flume net : a quantitative method for sampling fishes and macrocrustaceans on tidal marsh surfaces. *Estuaries* 9 : 219-224.

MEES J. & O. HAMERLYNCK, 1992. Spatial community structure of the winter hyperbenthos of the Schelde estuary, the Netherlands, and the adjacent coastal waters. *Neth. J. Sea Res.* 29 : 357-370.

MEES, J., O. HAMERLYNCK & A. DEWICKE, 1993. Seasonal composition and spatial distribution of hyperbenthic communities along estuarine gradients in the Westerschelde. *Neth. J. Aquat. Ecol.* (in press).

MEES, J., A. CATTRIJSSE & O. HAMERLYNCK, 1993. Distribution and abundance of shallow-water hyperbenthic mysids (Crustacea, Mysidacea) and euphausiids (Crustacea, Euphausiacea) in the Voordelta and the Westerschelde, south-west Netherlands. *Cah. Biol. Mar* : 34 : 165-186.

MEIRE, P.M., J.J. SEYS, T.J. YSEBAERT & J. COOSEN, 1991. A Comparison of the macrobenthic distribution and community structure between two estuaries in SW Netherlands. In : Estuaries and Coasts : Spatial and temporal intercomparisons Proceedings ECSA 19 Symposium. ELLIOTT, M. & J.P. DUCROTOY (Eds.). Olsen & Olsen Internat. Symp. Series : 221-230.

NAYLOR, N., 1972. British marine isopods. Synopses of the Brihsh fauna 3. Linnean Society of London. Acadamic Press : 86 p.

PINKSTER, S. & D. PLATVOET, 1986. De vlokreeften van het Nederlandse oppervlaktewater. *Wetenschappelijke Mededelingen van de Koninklijke Nederlandse Natuurhistorische Vereniging* 172 : 40 p.

REMANE, 1958. Ökologie des Brackwassers. *In* : A. THIENEMANN (ed.), *Die Binnengewässer* 22 : 1-216.

SORBE, J.-C., 1981. La macrofaune vagile de l'estuaire de le Gironde. Distribution et migration des espèces. Modes de reproduction, régimes alimentaires. *Oceanis* 36 : 579-592

VAN ECK, G.T.M., N. DE PAUW, M. VAN DEN LANGENBERGH & G. VERREET, 1991. Emissies, gehalten, gedrag en effecten van (micro)verontreinigingen van de Schelde en het Schelde-estuarium. *Water* 60 : 194-181.

WOLFF, W.J., 1973. The estuary as a habitat. An analysis of data on the soft-bottom macrofauna of the estuarine area of the rivers Rhine, Meuse, and Scheldt. *Zool. Verh. Leiden* 126 : 242 p.