

Data report:
The effect of dyke reinforcement
on benthic species in the
Westerschelde: T0 Cluster 2 and
T1 Cluster 1.

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Samenvatting

In dit rapport zijn de data van de huidige bodembewonende levensgemeenschappen beschreven voor zes locaties in de Westerschelde in de periode voorafgaand aan oeverversterkingen (T0) en één locatie na oeververdediging (T1). Deze data dienen als vergelijkingsmateriaal (T0) voor in de toekomst uit te voeren monitoring en een eerste beschrijving van effecten van oeververdedigingsactiviteiten op bodembewonende levensgemeenschappen.

Bemonsteringslocaties zijn onderverdeeld in clusters. Het cluster geeft aan wanneer de oeververdediging plaatsvindt. Locaties binnen Cluster 1 zijn versterkt in de periode 2009-2010. Oeververdediging voor de locaties binnen Cluster 2 zijn gepland voor 2011-2012.

Bodemmonsters zijn op één Cluster 1 locatie (Ritthem/Zuidwatering-west) verzameld in juni 2010 ten behoeve van de T1. Daarnaast zijn eind juli tot september 2010 op zes Cluster 2 locaties (Borssele, Ellewoutsdijk-midden, Ellewoutsdijk-west, Hoedekenskerke-haven, Hoedekenskerke-noord and Hoedekenskerke-zuid) bodemonsters verzameld ten behoeve van de T0, op drie dieptes (3 m, 7 m en 15 m). Van elke locatie is een duplomonster genomen. In het lab zijn de bodemdieren gedetermineerd op soort- of taxonniveau.

In deze monitoring is een grote variatie in de bodemdiergemeenschap te zien binnen locaties, en tussen locaties, dieptes en replica's. Een aantal grote lijnen is echter wel zichtbaar. Met name de dominantie van Annelida (wormen) is duidelijk op de meeste locaties. Daarnaast zijn er veranderingen in levensgemeenschap zichtbaar per diepte.

Er is een grote spreiding in dichtheid (aantal per m²) tussen de drie locaties, transecten en dieptes per locatie. In het algemeen, maar niet in alle gevallen, neemt de dichtheid toe met de diepte. Het enige monster van de Cluster 1 locatie in 2010 (T1)(Ritthem/Zuidwatering-west) heeft een hogere dichtheid dan alle monsters van de Cluster 2 locaties in 2010 (T0).

Van de Cluster 2 locaties heeft Hoedekenskerke-haven (15 m) in 2010 de hoogste gemiddelde dichtheid (6981 per m²). De laagste gemiddelde dichtheid is gevonden bij Ellewoutsdijk-midden - 15 m (100 per m²) en Hoedekenskerke-zuid (301, 251, 201 per m² voor 3 m, 7 m en 15 m respectievelijk).

Soortenrijkdom varieert eveneens sterk tussen de locaties, transecten en dieptes. Er is geen duidelijke trend zichtbaar.

Diversiteit is naast soortenrijkdom ook uitgedrukt aan de hand van een aantal diversiteitsindices (Shannon-Wiener Index en Evenness), waarbij niet alleen het aantal soorten, maar ook de verdeling van de individuen over de soorten in rekening wordt gebracht. De diversiteitsindices variëren tussen locaties en dieptes zonder een duidelijk zichtbare trend.

Clusteranalyse laat zien dat er drie hoofdgroepen en twee soortenarme varianten aanwezig zijn op de bemonsterde locaties in de Westerschelde, met uitzondering van één station (Hoedekenskerke-zuid), waar geen infauna is aangetroffen in het sediment. In het gebied rond Ellewoutsdijk en Hoedekenskerke zijn op veel diepten de soortenarme varianten gevonden. Het aantal soorten en de dichtheden in dit gebied past niet in de gradiënt die verwacht kan worden in dit deel van de Westerschelde. De samenstelling van de bodemsedimenten en die van het aanwezige macrobenthos wijst op een reeds bestaande verstoring, waarvan de oorzaak niet bekend is.

Een T0-inventarisatie ontbreekt voor Cluster 1. Tijdens de T1-monitoring van Cluster 1 in 2010 is op één station voldoende sediment aanwezig om een monster te nemen ten behoeve van infauna analyse. In dit monster zijn 13 soorten aangetroffen, met een dichtheid van 7283 individuen per m². Ondanks een ontbrekende T0-monitoring kan geconcludeerd worden dat er binnen een half jaar kolonisatie van bodemsoorten heeft plaatsgevonden op een plek, waar zich een sediment laag op de nieuwe ondergrond heeft gevormd.

Deze data vormen een geschikte basis om toekomstige monitoringsdata mee te vergelijken en een eerste beeld van rekolonisatie van nieuw gesedimenteerd materiaal te krijgen. Wel zal er in de toekomst rekening gehouden moeten worden met de grote spreiding in resultaten binnen locaties, en tussen locaties, transecten, dieptes en replica's. Aanbevolen wordt om een groter aantal replica's te bemonsteren, waardoor er een meer betrouwbaar beeld van de aanwezige en zich ontwikkelende benthische levensgemeenschappen ontstaat.

Abstract

In this study we compile data of the current benthic community structure in the Westerschelde Estuary in six locations prior to dyke enforcement activities in the area (T0) and one after dyke enforcement activities (T1). These data are intended for future comparison with data to be collected at the same locations after reinforcement to investigate possible effects on the local benthic community.

Sampling locations were divided into clusters. Clusters indicate the time of dyke reinforcement; locations in Cluster 1 indicate reinforcement carried out in 2009/2010, Cluster 2 indicate reinforcement carried to be out in 2011/2012. Samples of benthic infauna species were collected in 2010 at one Cluster 1 location (Ritthem/Zuidwatering-west) for T1 in June 2010, and six Cluster 2 locations (Borssele, Ellewoutsdijk-midden, Ellewoutsdijk-west, Hoedekenskerke-haven, Hoedekenskerke-noord and Hoedekenskerke-zuid) for T0, and at up to three depths (3 m, 7 m, 15 m) in late July to September 2010 and further analysed in the lab. At each location two replicate samples were taken.

This preliminary study of the benthic infauna surrounding the base of dykes showed a varied diversity between locations, depths and replicates. However, certain trends could be seen. In particular the dominance and diversity of annelids (worms) was obvious in most locations as well as changes in community structure at different depths.

At each location, each sample showed variable total abundance (number per m²) of organisms. In general, but not universally, total abundance increased with depth. The only Cluster 1, T1 location sampled, Ritthem/Zuidwatering-west had higher total abundance than any of the Cluster 2 locations. Of the Cluster 2 (T0) locations Hoedekenskerke-haven at 15 m had the highest mean total abundance (6981 per m²). The lowest total abundance was found at Ellewoutsdijk-midden at 15 m (100 per m²) and Hoedekenskerke-zuid (301, 251, 201 per m² for 3 m, 7 m and 15 m respectively).

There was also a wide variety of species richness between locations and depths, and there was no obvious general trend.

Diversity (expressed as the Shannon-Wiener Index) and Evenness also varied between locations and depths with no obvious trend.

At the investigated locations there were three species rich communities found, with community D and E in the western section of the Westerschelde and community A distributed over the whole area. The species poor variants were found in stations in the section around Ellewoutsdijk and the southern Middelgat at various depths. The total number of species and densities in the species poor variants did not fit in the expected gradient for this part of the Westerschelde.

Data for T0 is missing for Ritthem/Zuidwatering-west (in Cluster 1). During the T1 sampling for Cluster 1 in 2010 there was sufficient sediment for benthos sampling at only one station. In this sample, 13 species were recorded with a density of 7283 individuals per m². Despite the missing T0 data, it can be concluded that colonisation of benthic species has occurred in the area where new sediment has been laid.

This data provides an adequate basis for comparison for future surveys conducted after dyke reinforcement. However the variation seen in the data between locations, depths and replicates must be taken into account during future comparisons. More replicate samples will reduce standard errors in future monitoring campaigns.

1. Introduction

In 2010 the base of several parts of the dykes in the Westerschelde were strengthened. To investigate any changes in species communities that may have occurred due to this activity, it is important to have a reliable basis for comparison. In this study we compile data of the current benthic community structure in seven locations at up to three different depths in the Westerschelde prior to the dyke enforcement. These data are intended for future comparison with data to be collected at the same locations after reinforcement to investigate possible effects on the local benthic community.

This report follows the 'cluster 1' report on the data collected in 2009 in the Westerschelde (Van den Brink and Brummelhuis, 2009) and the 2010 data reported here are also integrated in an overview report describing the outcomes of research on epifauna and heavy metal analyses (Van den Heuvel-Greve et al., 2011).

This research is funded by Rijkswaterstaat Zeeland and Rijkswaterstaat Waterdienst.

2. Materials and Methods

2.1 Sampling

This report follows the same protocol as the 'cluster 1' report on the data collected in 2009 (Van den Brink and Brummelhuis, 2009). Sampling locations were divided into clusters. Clusters indicate the time of dyke reinforcement; locations in Cluster 1 indicated reinforcement carried out in 2009/2010, Cluster 2 indicated reinforcement to be carried out in 2011/2012. Sampling was conducted by Stichting de Zeeschelp in two transects at one location for Cluster 1: Ritthem/Zuidwatering-west (at this location initial sampling was conducted in June 2010, after dyke reinforcement had taken place so only T1 data exist), and six locations for Cluster 2: Borssele, Ellewoutsdijk-midden, Ellewoutsdijk-west, Hoedekenskerke-haven, Hoedekenskerke-noord, Hoedekenskerke-zuid (at these locations sampling was conducted in late July to September 2010, prior to dyke reinforcement – T0).

Three cores per sample were collected using a sediment core (65 mm in diameter). At all locations two replicate samples per depth were collected along a transect, resulting in two replicate samples per depth per location. At Lokkersnol-oost two transects were sampled resulting in four replicate samples per depth. Although the depths sampled were not the exactly same for all locations, they are termed 3 m, 7 m and 15 m here for ease of comparison (Table 1). Samples were stored in formalin and kept at room temperature until further analysis. For further details on sampling methods see De Kluijver & Dubbeldam (2009).

The samples were sorted in the lab of IMARES and species in each sample were identified and counted. Oligochaetes were unable to be identified to species level, and were therefore grouped and labelled under the family name Oligochaeta.

Table 1. Dates and actual depths (m) of sampling and what depths they are referred to in the present report.

Cluster	Sampling Location	Date of sampling	Depth stated in report		
			3 m	7 m	15 m
Actual Depth Sampled (m)					
2	Borssele	24/07/2010	3	7	15
2	Ellewoutsdijk-midden	03/09/2010		7.5	15
2	Ellewoutsdijk-west	13/09/2010	5.5	9.5	
2	Hoedekenskerke-haven	04/09/2010			15
2	Hoedekenskerke-noord	04/08/2010	2.5	6.5	10.5
2	Hoedekenskerke-zuid	19/08/2010	3	7.5	15
1	Ritthem/Zuidwatering-west	08/06/2010			12

Due to either the presence of only a fragment of the individual or a juvenile stage of an individual, a few individuals could not be identified to species level, but only to a higher taxonomic level:

-*Actinaria*: may be consisting of two species.

-*Ensis* spec: the species name could not be identified, possibly *Ensis directus*.

Other individuals which could also not be identified to species level may overlap with other individuals that were identified to species level (see table 1):

-Bivalve spec.: may overlap with *Abra alba*, *Mysella bidentata*, *Petricola pholadiformis*

-*Corophium* spec: may overlap with *Corophium sextone* or unknown.

-Polychaeta indet.: may overlap with several polychaete species.

Of the following species almost all individuals were present as juveniles or subadults: *Capitella capitata*, *Heteromastus filiformis*, *Scoloplos armiger*. This is due to the season of collection (around September), when a lot of young organisms are present in the environment (Beukema, 1974).

On one occasion only an unidentifiable fragment of an organism was recovered, this was subsequently referred to as Unknown.

2.2 Data analysis

2.2.1 Abundance

Total abundance is the total number of individuals in a given area.

From the number of individuals per sample, the number per m² was calculated using the formula:

$$\chi = n / (3 \times (\pi \times 3.25^2)) \times 10000$$

where n is the number of individuals per sample. From this equation it was possible to estimate and compare n/m² between replicates, depths and locations.

2.3 Species richness

Species richness (S) is the number of different species in a given sample.

2.4 Indices

Shannon-Wiener Index

The Shannon-Wiener index is one of several diversity indices used to measure diversity in categorical data. It is simply the Information entropy of the distribution, treating species as symbols and their relative population sizes as the probability. It takes into account the number of species and the evenness of the species and has the base assumptions that all species in the community have been sampled and that the sampling was completely random. The score is increased either by having additional unique species, or by having a greater species evenness.

To gain an indication of species diversity, the Shannon-Wiener Diversity Index was applied to the data with the equation:

$$H = - \sum p_i \ln (p_i)$$

Where p_i is the relative abundance of each species,. This index measures the species composition of a sample by adding the relative abundance of each species. Greater scores indicate higher species diversity.

Evenness

Evenness is the measure of how similar the abundances of different species are. When the proportions of all species in the sample are similar, evenness is high, while when the proportions are very dissimilar (some rare and some common species) the value decreases. Evenness was calculated with the equation:

$$E = H / \log(S)$$

Where S is the species richness (number of species). This formula is based on the Shannon-Wiener Diversity index, but only takes into account the relative abundances of each species within the sample.

2.1 Soft substrate communities in the Westerschelde

To determine whether there was a change at the community level a cluster analysis was conducted by Mario de Kluijver (Stichting Zeeschelp) with the data from the T₀ and T₁ inventory of species for 2009 and 2010. The data was analysed using the program MVSP (Kovach, 1999) with the Bray-Curtis' coefficient in combination with the 'average-linkage' method. Sediment characteristics of the top few centimetres were determined by sieving samples through seven calibrated sieves (mesh size: 2.8-0.053 mm).

3. Results

3.1 Species composition

The abundances and type of species varied between locations and depths (Table 2). There was also variation between replicates and depths (see appendices A and B for raw data). Most of the locations were dominated in abundance by annelid polychaetes (worms), but there were generally also bivalve molluscs (shell fish) and crustaceans present along with some cnidarians (such as anemones), echinoderms (such as seastars) and other taxonomic groups.

Table 2. The mean number per sample and number per m² of each species in each sample.

Location	Phylum	Species	Depth					
			3 m		7 m		15 m	
			Mean n per sample	Mean n per m ²	Mean n per sample	Mean n per m ²	Mean n per sample	Mean n per m ²
Borssele Cluster 2 (T0)	Annelida	<i>Aphelocheata marioni</i>			0.5	50.2		
		<i>Glycera tridactyla</i>	0.5	50.2				
		<i>Heteromastus filiformis</i>			1	100.5	0.5	50.2
		<i>Lanice conchilega</i>	0.5	50.2	1.5	150.7	5	502.3
		<i>Nephtys</i> (spec)	1	100.5				
		<i>Nephtys hombergii</i>	0.5	50.2				
		<i>Nereis succinea</i>			0.5	50.2	0.5	50.2
		Oligochaeta			1.5	150.7	0.5	50.2
		Polychaeta (spec.)	0.5	50.2				
		<i>Polydora pulchra</i>					0.5	50.2
		<i>Pygospio elegans</i>	0.5	50.2				
		<i>Scoloplos armiger</i>	1.5	150.7	1.5	150.7	2	200.9
		<i>Spiophanes bombyx</i>	1	100.5	1	100.5		
	Arthropoda	<i>Carcinus maenas</i>			0.5	50.2	0.5	50.2
	Cnidaria	Actiniaria			1.5	150.7		
	Echinodermata	<i>Asteria rubens</i>					0.5	50.2
		<i>Echinocardium cordatum</i>					0.5	50.2
	Mollusca	<i>Abra alba</i>					0.5	50.2
		<i>Macoma balthica</i>			1	100.5	0.5	50.2
		<i>Mytilus edulis</i>			1.5	150.7		

Location	Phylum	Species	Depth					
			3 m		7 m		15 m	
			Mean n per sample	Mean n per m ²	Mean n per sample	Mean n per m ²	Mean n per sample	Mean n per m ²
	Phoronida	Phoronida					8	803.6
Ellewoutsdijk-midden Cluster 1 (T0)	Annelida	<i>Aphelochoaeta marioni</i>			9	904.1		
		<i>Heteromastus filiformis</i>			4.5	452.0	0.5	50.2
		<i>Lanice conchilega</i>			0.5	50.2		
		<i>Nephtys</i> (spec)			0.5	50.2		
		<i>Nephtys cirrosa</i>			0.5	50.2		
		<i>Nereis diversicolor</i>			1	100.5		
		<i>Oligochaeta</i>			11	1105.0		
		<i>Scoloplos armiger</i>			0.5	50.2		
		<i>Streblospio benedicti</i>			2	200.9		
	Cnidaria	Actiniaria			4	401.8		
Ellewoutsdijk-west Cluster 1 (T0)	Mollusca	<i>Ensis</i> (spec.)			0.5	50.2		
		<i>Mytilus edulis</i>			1	100.5		
	Annelida	<i>Aphelochoaeta marioni</i>			0.5	50.2		
		<i>Heteromastus filiformis</i>	2.5	251.1	0.5	50.2		
		<i>Nereis succinea</i>			0.5	50.2		
		Oligochaeta			1	100.5		
		Polydora (spec)			0.5	50.2		
Hoedekenskerke-haven Cluster 1 (T0)	Echinodermata	<i>Asteria rubens</i>	0.5	50.2				
	Mollusca	<i>Mytilus edulis</i>			23.5	2360.6		
	Annelida	<i>Aphelochoaeta marioni</i>					16	1607.2
		<i>Capitella capitata</i>					0.5	50.2
		<i>Heteromastus filiformis</i>					21	2109.5
		<i>Nephtys</i> (spec)					1.5	150.7
		<i>Nephtys caeca</i>					0.5	50.2
		<i>Nereis diversicolor</i>					0.5	50.2
		<i>Oligochaeta</i>					25	2511.3
		<i>Polydora cornuta (ligni)</i>					0.5	50.2
		<i>Streblospio benedicti</i>					1	100.5
	Cnidaria	Actiniaria					0.5	50.2
	Mollusca	<i>Ensis</i> (spec.)					1	100.5
		<i>Macoma balthica</i>					1.5	150.7
Hoedekenskerke-noord Cluster 1 (T0)	Annelida	<i>Aphelochoaeta marioni</i>	6.5	652.9	6.5	652.9	14.5	1456.6
		<i>Heteromastus filiformis</i>	10	1004.5	3.5	351.6	3	301.4
		<i>Nephtys</i> (spec)					0.5	50.2
		<i>Nephtys hombergii</i>			0.5	50.2		
		<i>Oligochaeta</i>	4.5	452.0	2	200.9	0.5	50.2
		<i>Scoloplos armiger</i>					1.5	150.7

Location	Phylum	Species	Depth					
			3 m		7 m		15 m	
			Mean n per sample	Mean n per m ²	Mean n per sample	Mean n per m ²	Mean n per sample	Mean n per m ²
		<i>Streblospio benedicti</i>					1	100.5
	Arthropoda	<i>Crangon crangon</i>					0.5	50.2
		<i>Palaemon macrodactylus</i>	1	100.5				
	Mollusca	<i>Macoma balthica</i>	1	100.5	0.5	50.2	2	200.9
		Unknown					0.5	50.2
Hoedekenskerke-zuid Cluster 1 (T0)	Annelida	<i>Heteromastus filiformis</i>					0.5	50.2
	Arthropoda	<i>Corophium</i> spec.			0.5	50.2		
		Decapoda			1	100.5		
	Mollusca	<i>Macoma balthica</i>					0.5	50.2
Ritthem/Zuidwatering- west Cluster 1 (T1)	Annelida	<i>Heteromastus filiformis</i>					2	200.9
		<i>Malacoceros fuliginosus</i>					0.5	50.2
		Oligochaeta					0.5	50.2
		<i>Scoloplos armiger</i>					3.5	351.6
	Arthropoda	<i>Crangon crangon</i>					0.5	50.2
	Cnidaria	Actiniaria					1	100.5
		Decapoda					0.5	50.2
	Echinodermata	<i>Asteria rubens</i>					1	100.5
	Mollusca	<i>Abra alba</i>					5.5	552.5
		Bivalve spec.					6	602.7
		<i>Ensis</i> (spec.)					0.5	50.2
		<i>Macoma balthica</i>					0.5	50.2
	Phoronida	Phoronida					50.5	5072.9

In the following analyses of community composition, not all species could be identified to species level (as is particularly the case with oligochaetes), but for ease of reading, all higher taxonomic groups are also referred to as 'species'. Care should therefore be taken when interpreting the results to avoid invalid comparisons between different taxonomic groups.

3.1.1 Cluster 1 (T1): Location Ritthem Zuidwatering-west

At Ritthem Zuidwatering-west at 15 m depth various species were present at all depths (Figure 1). The majority of the community was comprised of species of the phylum Phoronida (70%). Bivalve molluscs and the annelid polychaete *Abra alba* were the next most abundant species (8% each) followed by other species and groups comprising 1-5% of the community including annelid polychaetes and oligochaetes, bivalve molluscs, actinarians (phylum: Cnidaria) and decapod crustaceans (phylum: Arthropoda).

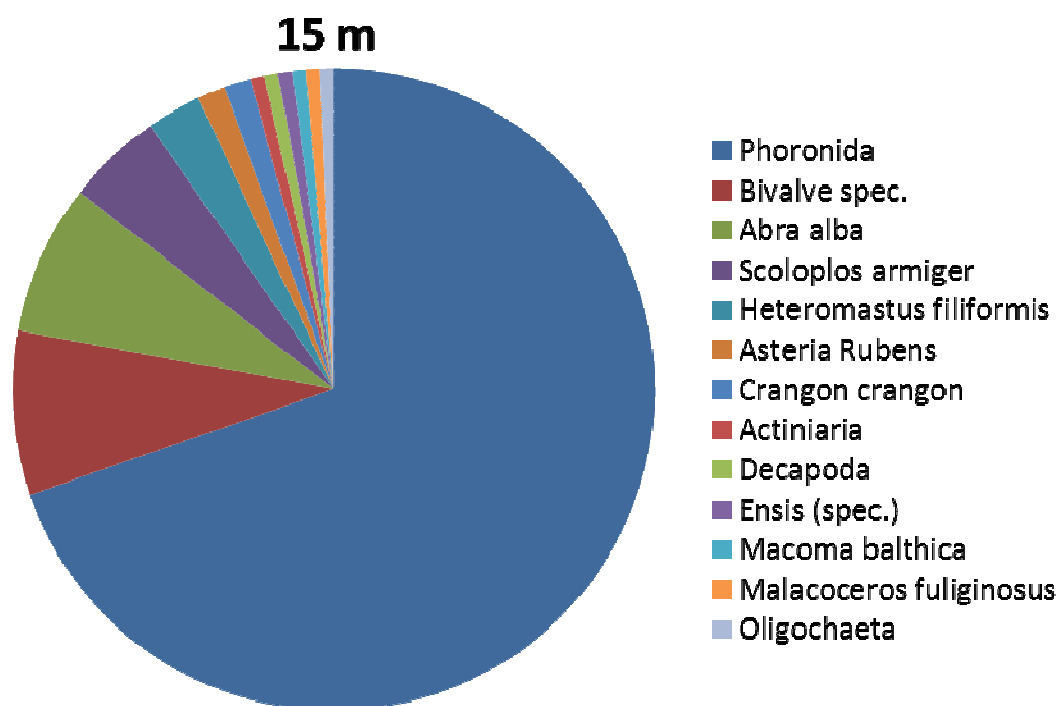


Figure 1. Community composition (number of individuals of species per m²) at Ritthem Zuidwatering-west at 15 m (total from two replicate samples) for Cluster 1, T1.

3.1.2 Cluster 2 (T0): Location Borssele

At Borssele there various taxonomic groups found in at all depths, but the communities were generally dominated by annelid polychaetes (Figure 2). At 3 m only annelid polychaetes were present, which *Scoloplos armiger* the most abundant at 25 % followed by *Spiophanes bombyx* and *Nephtys* spec. (17% each) and other species each comprising 8 % of the community.

At 7 m, annelid polychaetes comprised 50 % of the community, the most abundant species being *Lanice conchilega* and *Scoloplos armiger* (both 13 %). Other species present included the bivalve mollusc *Mytilus edulis*, the decapod crustacean *Carcinus maenas* (phylum: Arthropoda) and the group of annelid oligochaetes each comprising 13 % of the community.

At 15 m polychaetes were the most abundant phyla, comprising 46 % of the community with *Lanice conchilega* the most abundant polychaete species (26 %) followed by *Scoloplos armiger* (10 %). The other groups and species present included were species from the phylum Phoronida (41 %), actinarians (phylums: Cnidaria), annelid oligochaetes, echinoderms, and the bivalve mollusc *Macoma balthica* (3 % each).

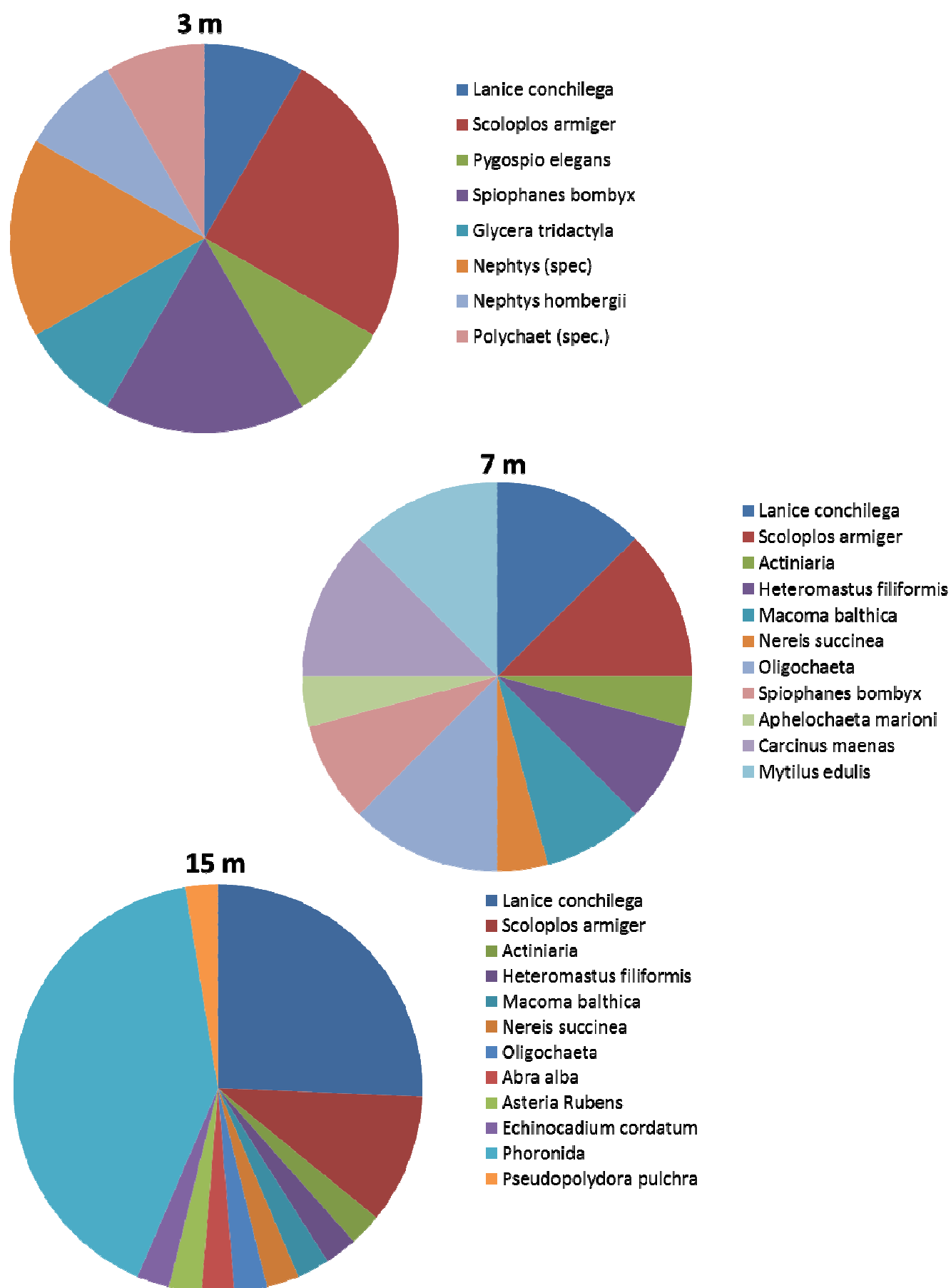


Figure 2. Community composition (number of individuals of species per m²) at Borssele at 3, 7 and 15 m (total from two replicate samples) for Cluster 2 (T0).

3.1.3 Cluster 2 (T0): Location Ellewoutsdijk-midden

At Ellewoutsdijk-midden little comparison between depths could be made as only one organism, a polychaete annelid *Heteromastus filiformis*, was found at 15 m depth (Figure 3). At 7 m polychaete annelids made up 53% of the community, and were dominated but *Aphelocheata marioni* (26%) and *Heteromastus filiformis* (13%). Oligochaete annelids were the next most abundant group, comprising 31% of the community followed by actinarians (phylum: Cnidaria). The bivalve molluscs, *Mytilus edulis* and *Ensis spec.* were the only other species present (comprising 3% and 1% respectively).

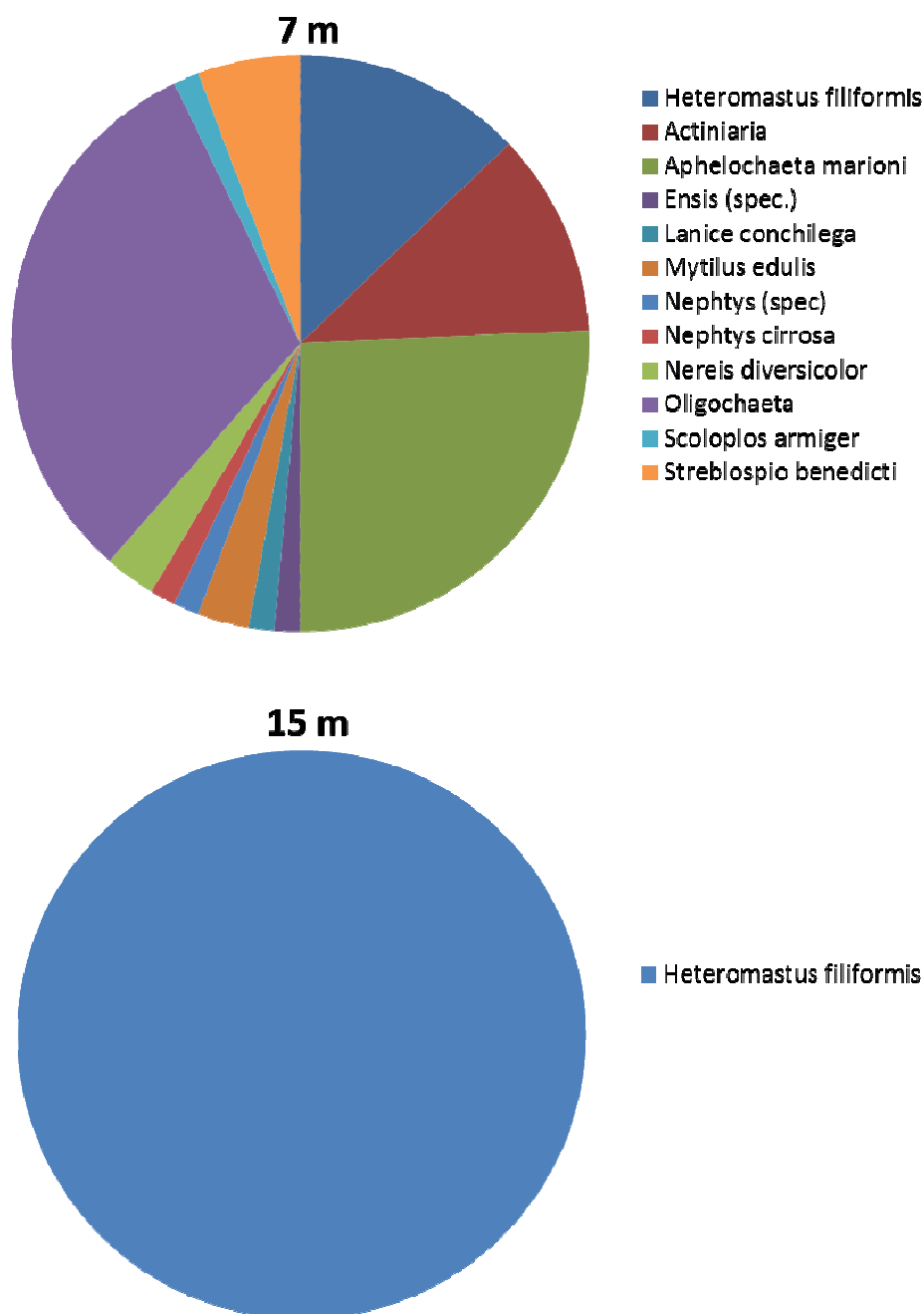


Figure 3. Community composition (number of individuals of species per m²) at Ellewoutsdijk-midden at 7 and 15 m (total from two replicate samples) for Cluster 2 (T0).

3.1.4 Cluster 2 (T0): Location Ellewoutsdijk-west

At Schelphoek-Ellewoutsdijk-west the community composition changed with depth (Figure 4 **Error! Reference source not found.**). At 3 m. only two species were found. The polychaete annelid *Heteromastus filiformis* was the most abundant, comprising 83% of the community, while the seastar, *Asterias rubens* (phylum: Echinodermata) comprised only 17% of the community.

At 7 m the community was dominated by the bivalve mollusc, *Mytilus edulis* (89%) followed by polychaete annelids (7.5%) and oligochaete annelids (3.5%)

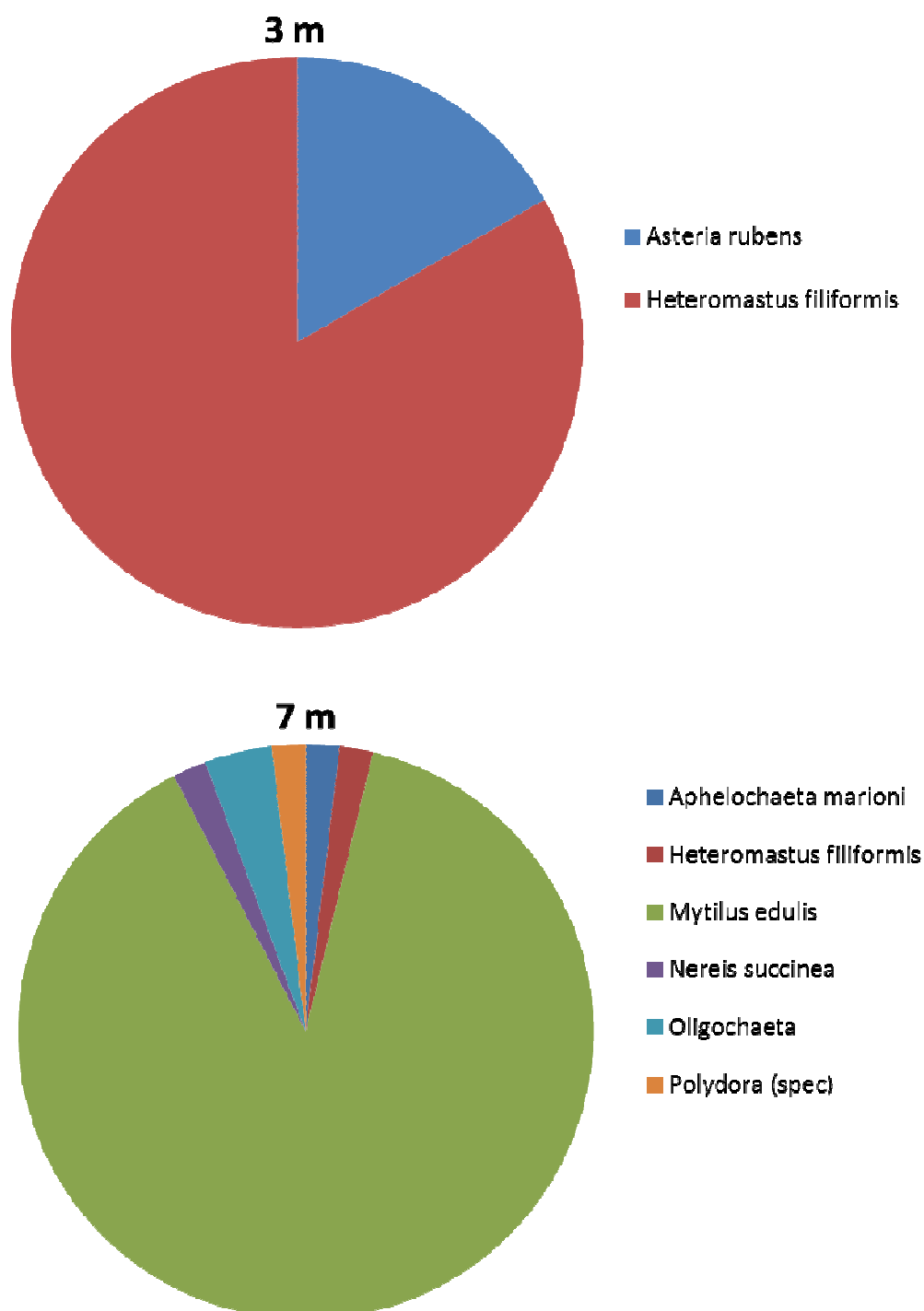


Figure 4. Community composition (number of individuals of species per m²) at Ellewoutsdijk-west at 3 and 7 m for T0 and T1 (total from two replicate samples) for Cluster 2 (T0).

3.1.5 Cluster 2 (T0): Location Hoedekenskerke-haven

At Hoedekenskerke-haven at 15 m depth the community was dominated by polychaete annelids which comprised 59% of the community, the most abundant polychaetes were *Heteromastus filiformis* and *Aphelochaeta marioni* (comprising 30% and 23% of the community respectively). Oligochaete annelids were the next most abundant group, comprising 36% of the community. The only other species present were an actinarian (phylum: Cnidaria) (1%) and the bivalve molluscs *Ensis spec.* and *Macoma balthica* (1% and 2% respectively) (Figure 5).

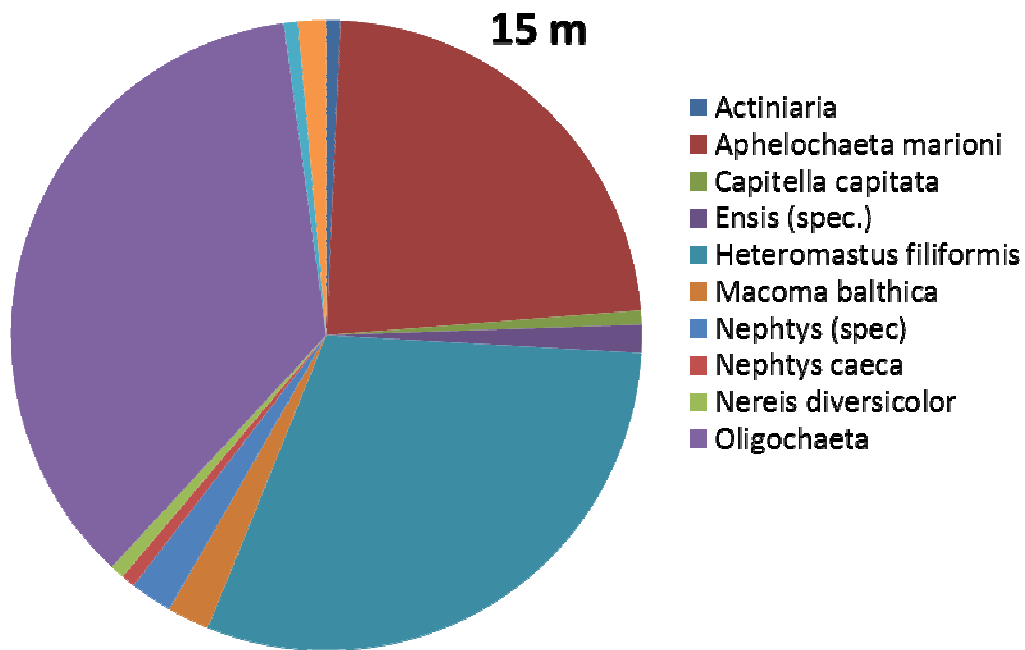


Figure 5. Community composition (number of individuals of species per m²) at Hoedekenskerke-haven at 15 m (total from two replicate samples) for Cluster 2 (T0).

3.1.6 Cluster 2 (T0): Location Hoedekenskerke-noord

At Hoedekenskerke-noord the community composition varied little with depth (Figure 5). At 3 m polychaete annelids comprised 72% of the community. The most abundant species were *Heteromastus filiformis* (43%) and *Aphelocheata marioni* (28%). Oligochaete annelids were the next most abundant, comprising 20% of the community, followed by the crustacean *Crangon crangon* (phylum: Arthropoda) and the bivalve mollusc *Macoma balthica* (4% each).

At 7 m, the community composition was similar to that at 3 m depth. Polychaete annelids comprised 80% of the community, and included *Aphelocheata marioni* (50%) and *Heteromastus filiformis* (27%) and *Nephtys hombergii* (4%). Oligochaete annelids made up 15% while the bivalve mollusc *Macoma balthica* comprised 4% of the community.

At 15 m depth polychaete annelids comprised 85% of the community and were dominated by the species *Aphelocheata marioni* (60%) and *Heteromastus filiformis* (13%) as well as several other species comprising 1-6% of the community. Other species present included the bivalve mollusc *Macoma balthica* (8%) and an unknown specimen (2%). Also present was the crustacean, *Palaemon macrodactylus* (phylum: Arthropoda) (2%). This species is not native to the Westerschelde and this is the first reported occurrence of this species in the current survey.

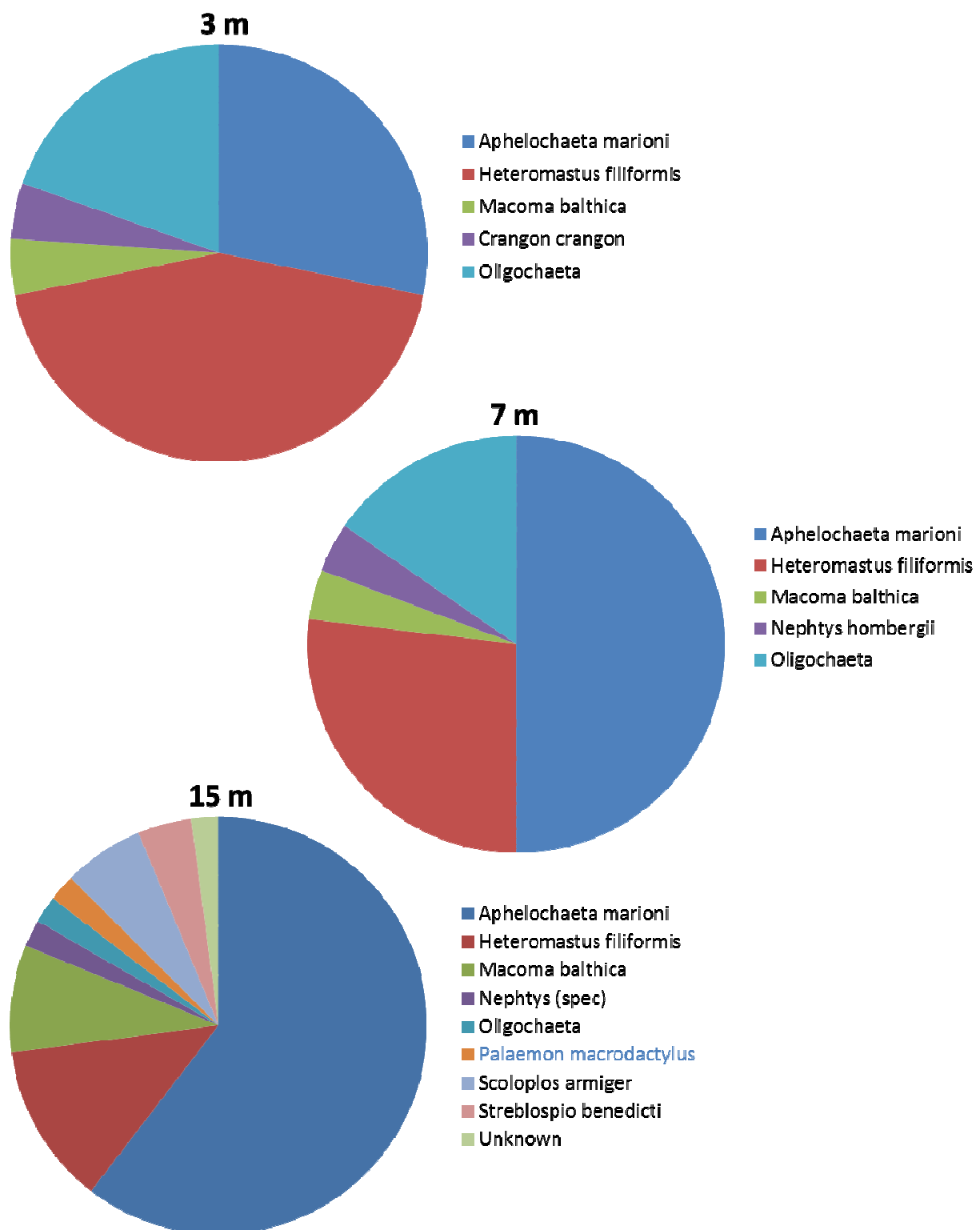


Figure 6. Community composition (number of individuals of species per m²) at Hoedekenskerke-noord at 3, 7 and 15 m (total from two replicate samples) for Cluster 2 (T0).

3.1.7 Cluster 2 (T0): Location Hoedekenskerke-zuid

At Hoedekenskerke-zuid only two species were present in both 7 m and 15 m depth (Figure 7). At 7 m the only species found were crustaceans (phylum: Arthropoda), two decapod crustaceans were found, comprising 67% of the community, while a single amphipod, *Corophium* spec. was found, comprising 33% of the community. At 15 m only two organisms were found; a polychaete annelid *Heteromastus filiformis* and a bivalve mollusc, *Macoma balthica*.

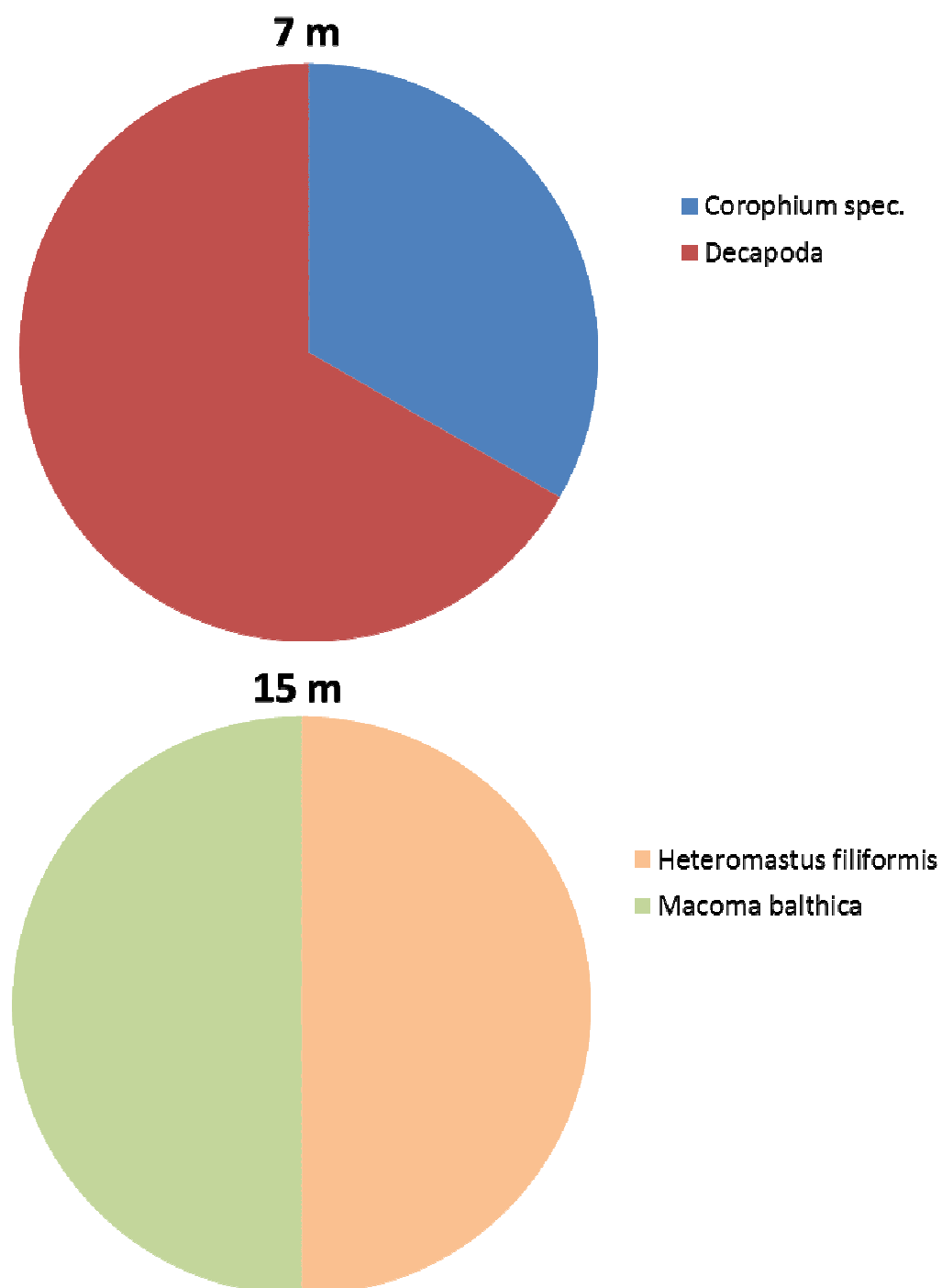


Figure 7. Community composition (number of individuals of species per m²) at Hoedekenskerke-zuid at 7 and 15 m (total from two replicate samples) for Cluster 2 (T0).

3.2 Community Attributes

Cluster 1:

At Ritthem/Zuidwatering-west at 15 m molluscs and annelids were the most and diverse phyla (4 of 14 species each). Two species of Arthropod were also found as well as one species of Phoronida, Echinodermata and Cnidaria.

Cluster 2:

The total number of species from different phyla found in different depths at each location is shown in Figure 8. The largest number of species were found at Borssele at 15 m, Ellewoutsdijk- midden at 7 m and Hoedekenskerke-noord at 15 m (12 species each). The lowest number of species was found at Ellewoutsdijk-midden at 7 m (only one species found).

When comparing the number of species per phylum in different locations and depths, annelids were the most common and diverse phylum in almost all locations except Ellewoutsdijk-west at 3 m (one annelid and one echinoderm was found), Hoedekenskerke-zuid at both 7 m (only two species of arthropod were found) and 15 m (one annelid and one mollusc was found) and 15 m (one annelid and one mollusc found). In locations where annelids were the most diverse, the proportion of annelids ranged from 100% (eight species) at Borssele at 3 m depth to 60% (three of five species) at Hoedekenskerke-noord at 3 m depth. Molluscs were the next most common phylum, and were found in all locations, although not all depths. The phylum Phoronida was the least diverse and common phylum found; only one species was found only in Borssele at 15 m.

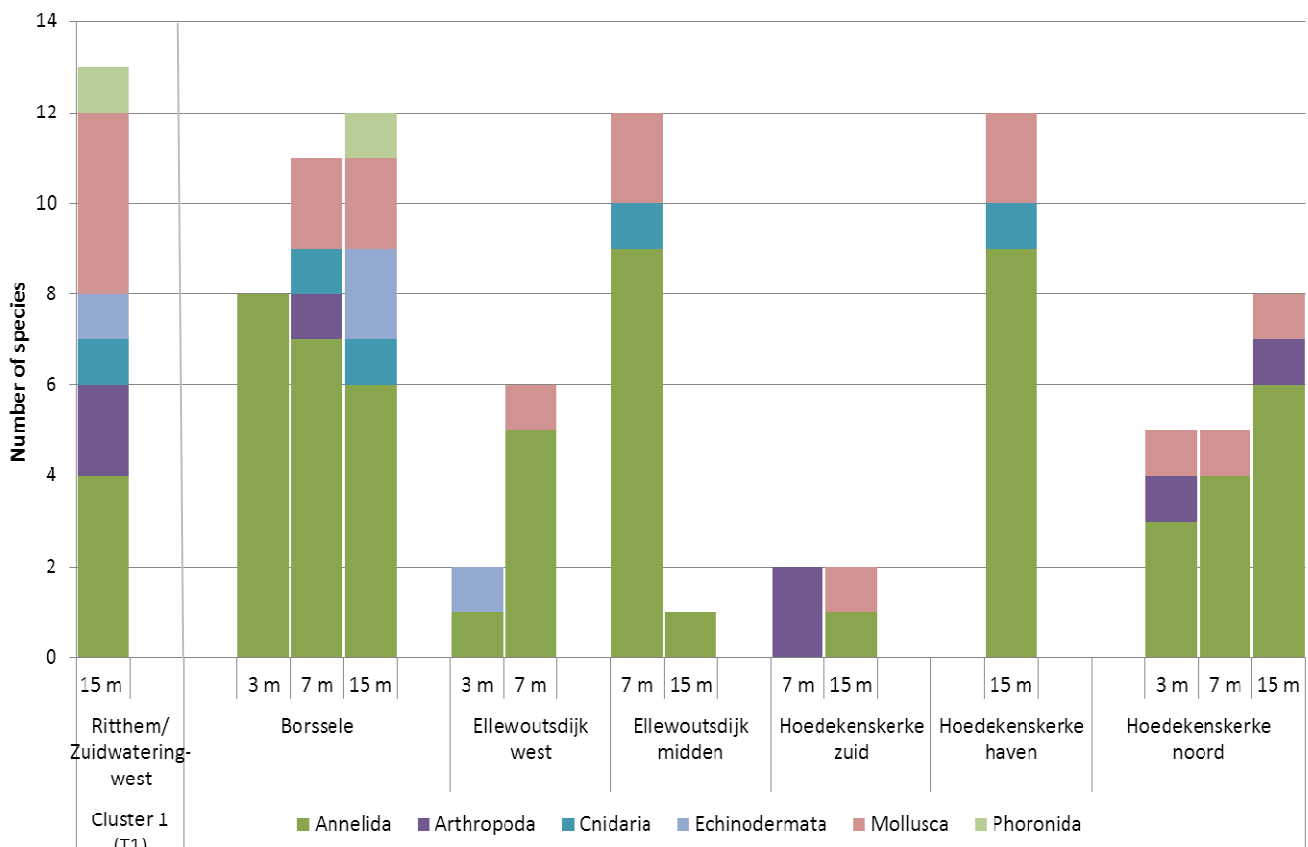


Figure 8. Total number of species of different phyla recorded in the Westerschelde at depths of 3, 7 and 15 m for T0 at all locations for Cluster 1 (Ritthem/Zuidwatering-west) and Cluster 2.

3.3 Total Abundance

Cluster 1 (T1):

Ritthem/Zuidwatering-west at 15 m depth had higher total species abundance than any locations in cluster 2 with a mean of 7282 individuals per m² (Figure 9).

Cluster 2 (T0):

There was a wide range of estimated mean total abundance of organisms between locations and depths (Figure 9). The highest estimated mean total abundance of organisms was found in Hoedekenskerke-haven (7000 individuals per m²), while the lowest was found at Ellewoutsdijk-midden at 15 m depth with a mean of 50 individuals per m². Estimated mean total abundance was highest at 15 m depth at Borssele (1959 individuals per m²), Hoedekenskerke-haven (6981 individuals per m² -although no samples at other depths were taken) and Hoedekenskerke-noord (2411 individuals per m²). Mean total abundance was highest at 7 m depth at Ellewoutsdijk-midden (3516 individuals per m²) and Ellewoutsdijk -west (2661 individuals per m²). Estimated mean total abundance was not highest at 3 m depth at any location.

3.4 Species Richness

Cluster 1 (T1):

At Ritthem/Zuidwatering-west at 15 m depth, the mean species richness was the same as the highest mean species richness in cluster 2 (10.5 species) (Figure 10).

Cluster 2 (T0):

For species richness the term 'species' is used to identify each species as well as higher taxonomic groups where identification was not made to species level. Species richness also varied greatly between locations and depths (Figure 10). The highest mean species richness was found in Ellewoutsdijk-west at 7 m depth with 10 species per m² (although there were considerably wide error bars at ± 10). The lowest mean species richness was found at Ellewoutsdijk-midden at 15 m depth (0.5 species per m²) and Hoedekenskerke -zuid at 3 m depth (one species per m²). Mean species richness was highest at 15 m depth at Hoedekenskerke-haven (9 species per m² -although no samples at other depths were taken) and Hoedekenskerke-noord (8 species per m²). Mean species richness was highest at 7 m depth at Borssele (9.5 species per m²), Hoedekenskerke-zuid (1.5 species per m²) and Ellewoutsdijk-midden (9.5 species per m²). Mean species richness was not highest at 3 m depth in any location.

3.5 Diversity

Cluster 1 (T1):

At Ritthem/Zuidwatering-west at 15 m depth, the mean Shannon Wiener diversity score was 1.12; not considerably different from the scores in cluster 2 (Figure 11). The mean evenness score (0.53) was also not remarkably different to the scores in cluster 2.

Cluster 2 (T0)

According to the Shannon Wiener Diversity Index, diversity varied between locations and depths (Figure 11). Diversity was highest at Borssele at 7 m depth (mean score of score of 2), while it was lowest at Ellewoutsdijk-west at 7 m (mean score of 0.26). The mean diversity scores at Ellewoutsdijk-west and Hoedekenskerke-zuid diversity was considerably lower than at the other locations with mean scores of 0.32 and 0.26 at 3 m and 7 m respectively at Ellewoutsdijk-west, and 0.35 at both 7 m and 15 m at Hoedekenskerke-zuid.

3.6 Evenness

Cluster 1 (T1):

The mean evenness score for Ritthem/Zuidwatering-west at 15 m depth was 0.53, which is close to midrange of the Cluster 2 locations.

Cluster 2 (T0):

Evenness was also variable between locations and depths (Figure 12). Evenness was highest at Borssele at 3 m (mean score of 0.98) and lowest at Ellewoutsdijk-west (mean score of 0.15). Evenness was higher in shallow samples compared to deeper samples in all locations where samples at more than one depth were taken, except

Hoedekenskerke-zuid where evenness was equal for both 7 m and 15 m depth (mean score of 0.5 with considerably large error margins).

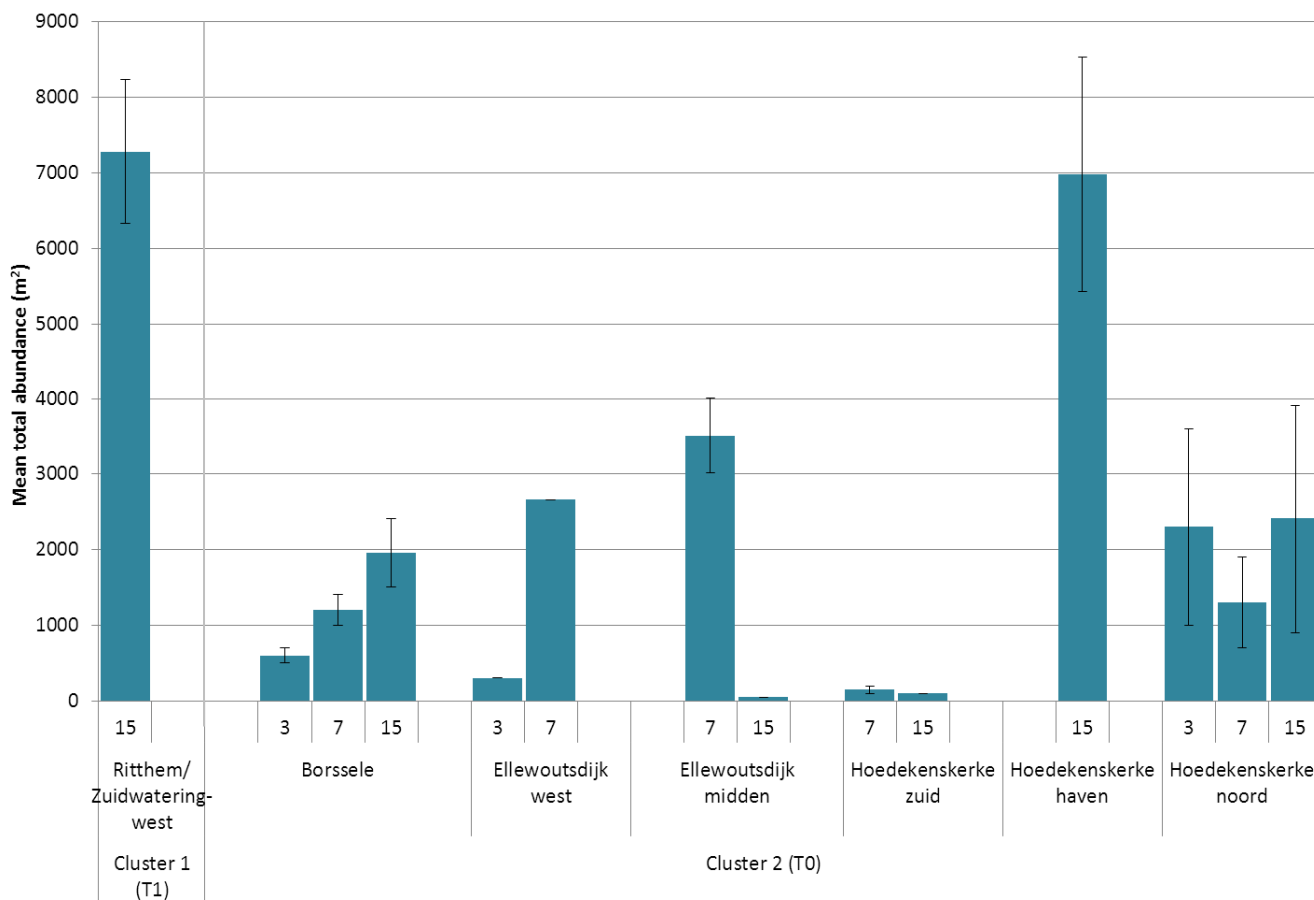


Figure 9 Estimated mean total abundance per m² for T0 at all locations and depths for Cluster 1 (Ritthem/Zuidwatering-west) and Cluster 2. Error bars are $\pm 1SE$.

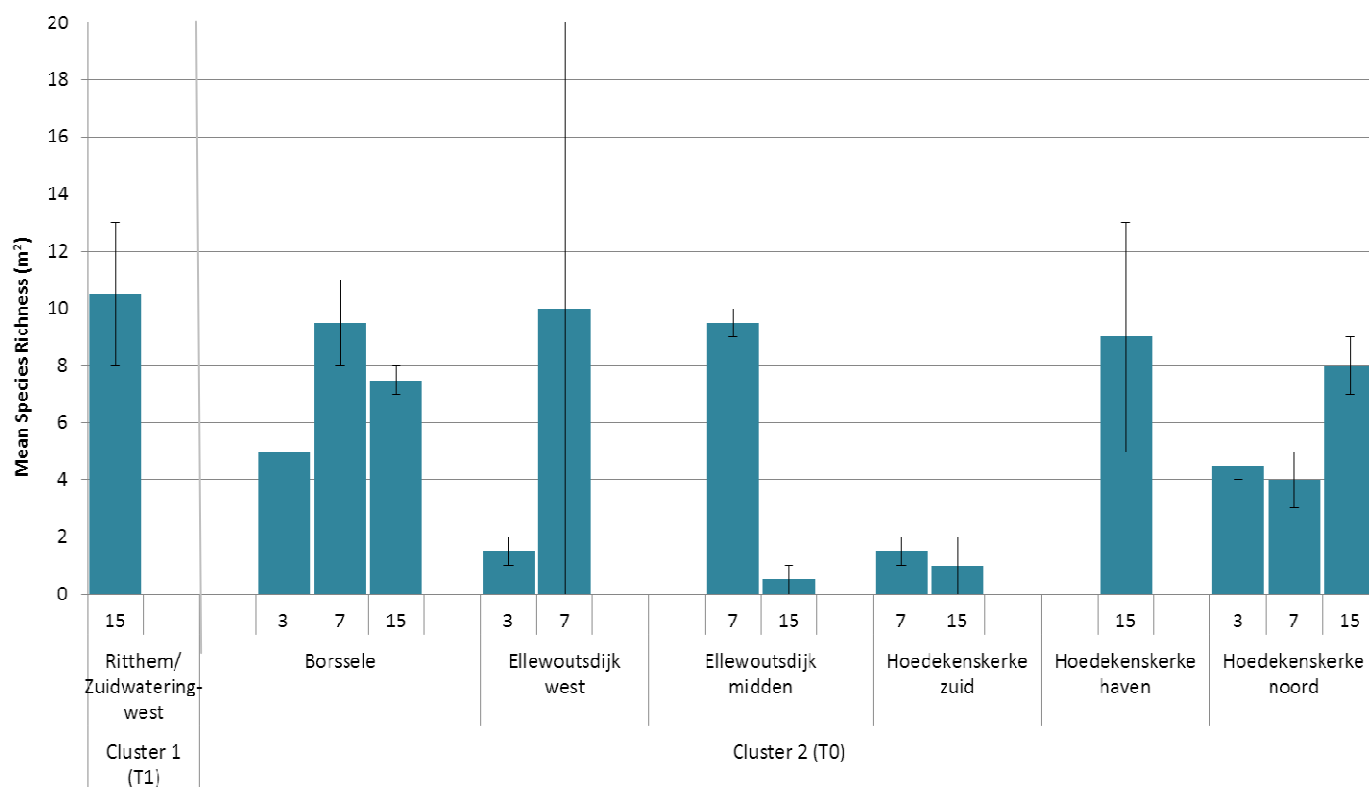


Figure 10. Mean species richness per m² for T0 at all locations and depths for Cluster 1 (Ritthem/Zuidwatering-west) and Cluster 2. Error bars are $\pm 1SE$.

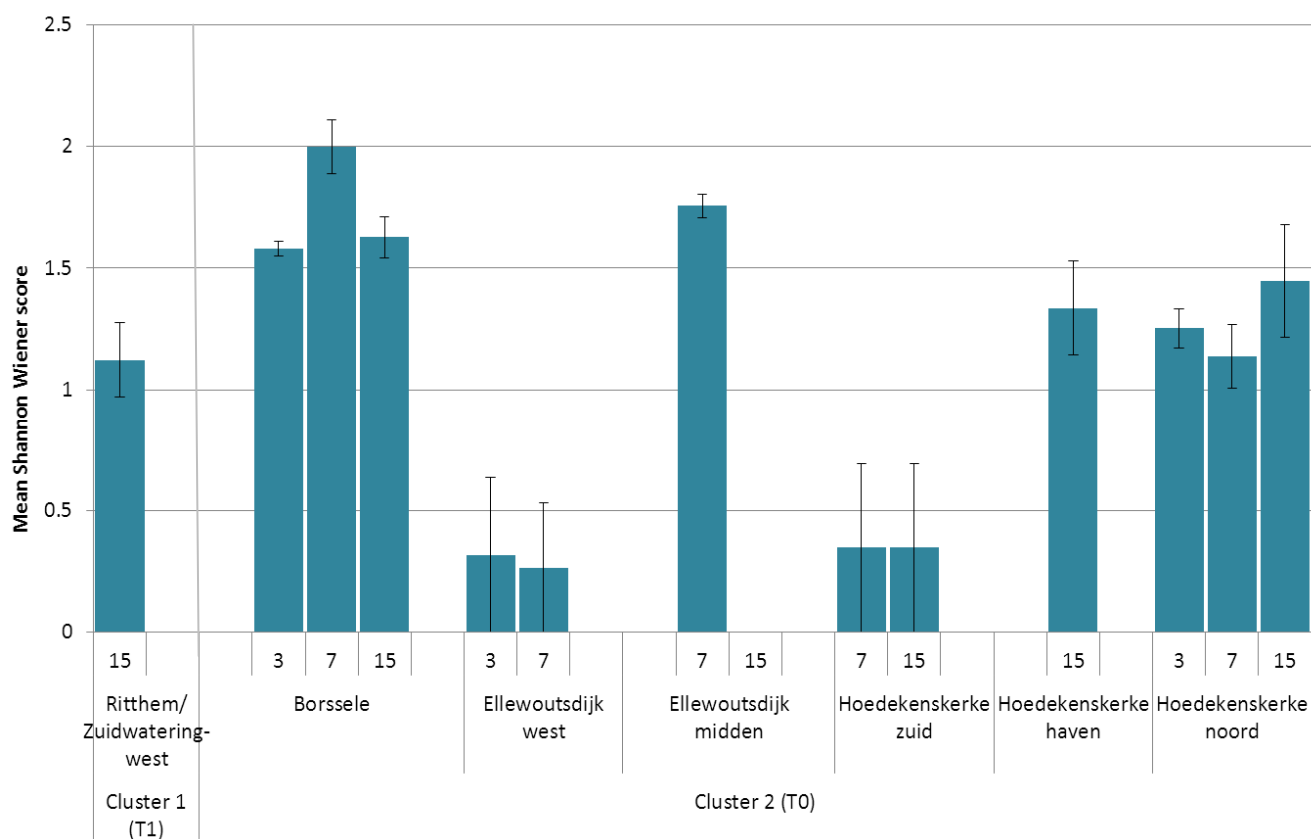


Figure 11. Mean Shannon-Wiener Diversity Index scores for T0 at all locations and depths for Cluster 1 (Ritthem/Zuidwatering-west) and Cluster 2. Error bars are $\pm 1SE$.

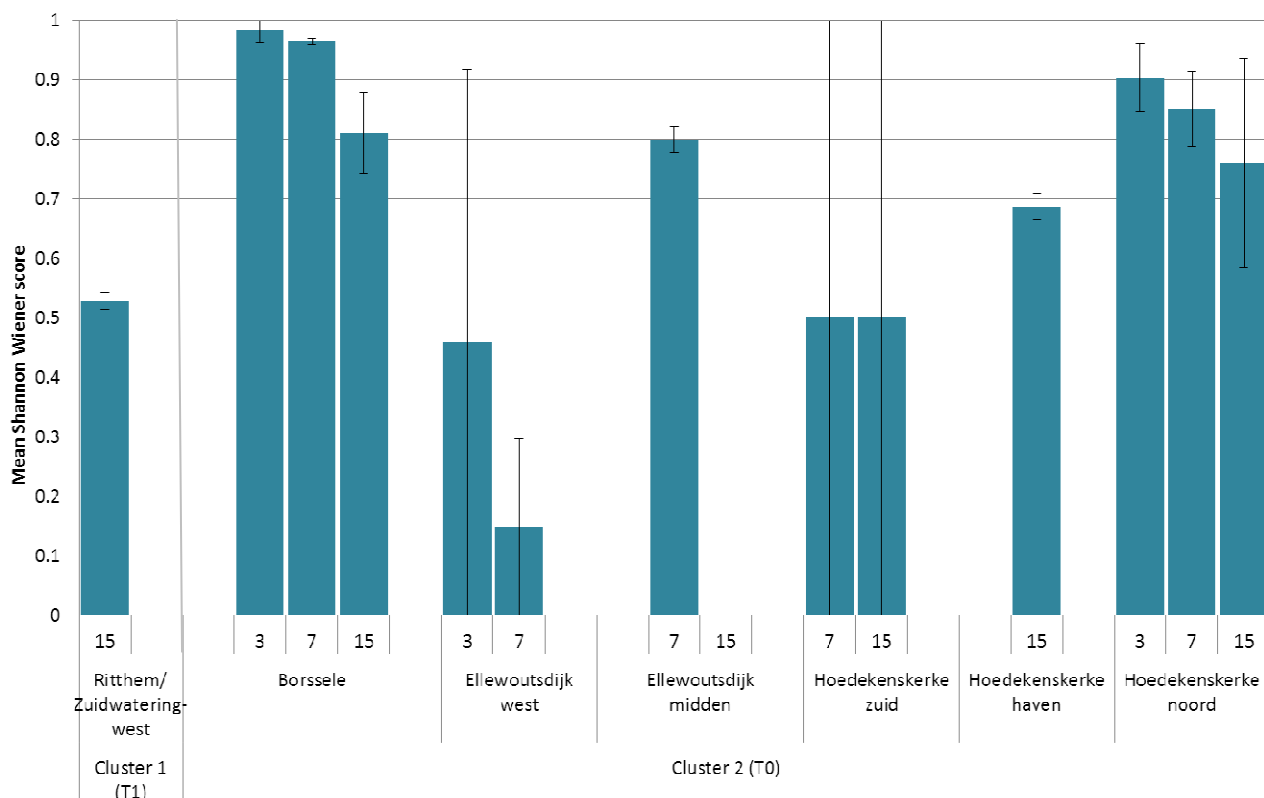


Figure 12. Mean Evenness scores for T0 at all locations and depths (for Cluster 1 (Ritthem/Zuidwatering-west) and Cluster 2. Error bars are $\pm 1SE$.

3.7 Soft substrate communities in the Westerschelde

Four main groups and six species poor variants were identified from the cluster analysis of the community composition in a dendrogram (Figure 13). The inverse analysis is shown in Appendix C.

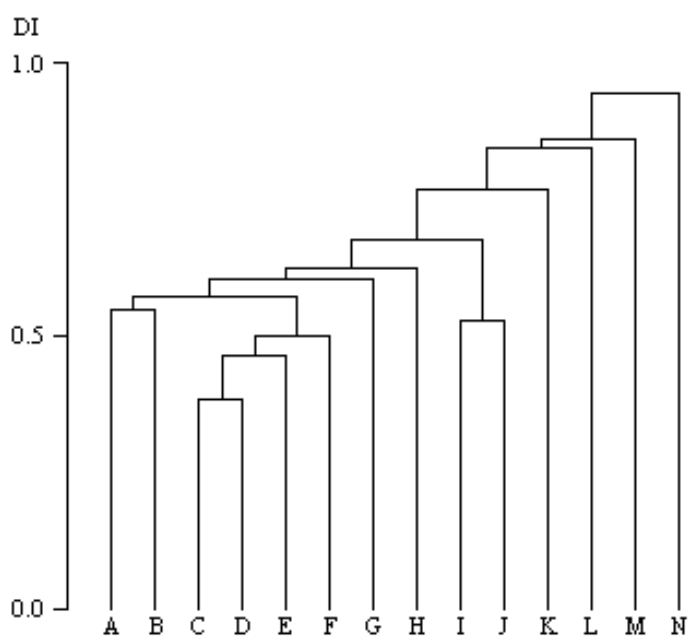


Figure 13. Dendrogram of the clustering of the soft substrate data.

In the T0 situation in 2010 three main groups were observed (A,D and E) and two variants (F and I) in the Westerschelde (Figure 14). In the T1 situation community D was found.

	10-Rit-w	10-Bor	10-Elle-w	10-Elle-m	10-Hoe-z	10-Hoe-h	10-Hoe-n
3 m		E	F		-		A
7 m		A	A	A	I		A
15 m	D	D		F	F	A	A

Figure 14. Schematic distribution of the communities over the locations.

The sediment characteristics of the top few centimeters were determined by sieving sampled through seven calibrated sieves (mesh size: 2.8-0.053 mm). The characteristics were calculated as the percentage of the total dry weight of the different particle sizes. Because sediment particle sizes were not normally distributed, a typology of dominant sediment types of benthic fauna was developed (Table 3). When the sediment showed a bimodal distribution due to recent sediment disturbance, the sediment was presented as 'disturbed coarse' type.

Table 3. Typology of the benthic sediment

Type sediment	I	II	III	IV	V	VI	VII	VIII
Dominant particle size in mm	>2.8	2-8-1.4	1.4-0.6	0.6-0.3	0.3-0.15	0.15-0.09	0.09-0.05	<0.05
Particle name	Shell gravel		Very coarse sand	Coarse sand	Fine sand	Very fine sand	ultra-fine sand	mud

The composition of the benthic sediment within the three different communities is shown in Table 4.

Table 4. Composition of the benthic sediment in 2009 and 2010.

	9-Rit-w	9-Rit-m	9-Rit-o	10-Bor	10-Elle-w	10-Elle-m	10-Hoe-z	10-Hoe-h	10-Hoe-n
3 m	0.0	8.3	5.4	31.1	74.4	43.1			19.4
7 m	19.3	13.1	10.1	12.3	60.7	40.5	50.3	12.3	30.0
15 m	13.1		27.3				50.0		

The salinities of the sampled locations are shown in

Table 5.

Table 5. Salinities at each of the sampling stations

	10-Rit-w	10-Rit-m	10-Rit-o	10-Bor	10-Elle-w	10-Elle-m	10-Hoe-z	10-Hoe-h	10-Hoe-n
3 m	28.7	28.8	28.7	27.8	27.0	26.7			24.0
7 m	28.7	28.8	28.6	28.1	27.0	26.3	25.5	25.3	24.0
15 m	28.8	28.6	28.8				25.5		

From the composition of the benthic communities, the benthic sediment and the salinities, the sampled habitat can be divided into three sections:

- The western section, from Ritthem-Zeelandbrug west to and including Borssele, with a high salinity (>25.5‰ S), with sandy sediment and an increase in particle size ≤90 µm;
- The area around Ellewoutsdijk and the southern Middelgat (Hoedekenskerke-zuid), with a lower salinity (25.5-27.0‰S), and an accumulation of particles ≤90 µm;
- The northern Middelgat (Hoedekenskerke-haven to -noord), with a salinity between 24.0-25.3 ‰, and sandy sediment.

3.7.1 T0 situation in 2010

For the T0 situation in 2010 six transects were sampled. In four stations the macrofauna was not sampled. At the location Ellewoutsdijk-west the 15 m depth could not be reached, at Ellewoutsdijk-midden at 3 m depth the sediment was too hard to sample with corers and at Hoedekenskerke-haven at 3 and 7 m depth there was no sediment on the hard substrate.

In the western section the communities A, D and E were found at Borssele. Community E was found at 3 m depth and there were only polychaetes present (table 5). The polychaetes *Scoloplos armiger*, *Nephtys* spec. and *Spiophanes bombyx* were dominant at this depth. *Glycera tridactyla* was limited to this community (**Error! Reference source not found.**).

Community A was found at 7 m depth and was found in all other sections. The community was dominated by oligochaetes, the polychaetes *Aphelocheata marioni* and *Heteromastus filiformis* and the mussel *Mytilus edulis*. In total there were 36 species in this community.

Community D was found at 15 m depth, and was limited to the western section of the Westerschelde. In comparison with community A, the abundance of oligochaetes sharply decreased and the phoronids and molluscs increased greatly. The mollusc *Abra alba* was dominant within this community.

Table 6. Total species and densities per taxa in the communities in the T0 and T1 inventory of 2010

Community	A	D	E	F	I	-
Total species:						
Polychaetes	18	14	8	1	0	0
Molluscs	7	5	0	1	0	0
Crustacea	5	5	0	0	2	0
Echinodermata	2	3	0	1	0	0
Phoronida	1	1	0	0	0	0
Oligochaeta	1	1	0	0	0	0
Other groups	2	1	0	0	0	0
Total number of species	36	30	8	3	2	0
Density n/m ² :						
Polychaetes	1215	1189	603	117	0	0
Molluscs	251	519	0	17	0	0
Crustacea	27	234	0	0	151	0
Echinodermata	20	100	0	17	0	0
Phoronida	57	1959	0	0	0	0
Oligochaeta	1420	33	0	0	0	0
Other groups	84	100	0	0	0	0
Total density n/m ²	3073.9	4135.3	602.7	150.7	150.7	0.0

In the section around Ellewoutsdijk and the southern Middelgat community A, the variants F and I and one station without any species were found.

At Ellewoutsdijk-west and –midden the community A and variant F was found. At Hoedekenskerke-zuid at 3m depth no species were found, at 7 m depth variant I was found and only the polychaete *Heteromastus filiformis* was dominant. In variant I only two crustacean species were found.

In the sandy sediment in the northern Middelgat only community A was found.

3.7.2 T1 situation

In 2010 the species composition of the macrobenthos was investigated in the locations where dyke reinforcement was carried out. Sufficient sediment for sampling was only found at the station Ritthem-Zeelandbrug west at 15 m depth. Community D was found at this western location. The total number of species was slightly higher than in community D at Borssele, but the density of species was higher. This was due to the phoronids (69 % of the individuals). The sediment in the T1 situation belonged to type V, and only 6.3 % of the particles were $\leq 90 \mu\text{m}$. The mud layer was about 15 cm thus and lay on a layer of fine filler material. Although there is no T0 inventory for comparison, it is likely that within a year the area was colonised.

Table 7. Total number of species (A) and densities (B) at the stations. The colours denote the communities (see Figure 14).

A-Total number of species							
	10-Rit-w	10-Bor	10-Elle-w	10-Elle-m	10-Hoe-z	10-Hoe-h	10-Hoe-n
3 m		8	2		0		5
7 m		11	6	12	2		5
15 m	13	12		1	2	12	9
B-Density per m ²							
	10-Rit-w	10-Bor	10-Elle-w	10-Elle-m	10-Hoe-z	10-Hoe-h	10-Hoe-n
3 m		603	301		0		2310
7 m		1205	2662	3516	151		1306
15 m	7283	1959		50	101	6982	2411

4. Conclusions

This preliminary study of the benthic infauna surrounding the base of dykes showed a varied diversity between locations, depths and replicates. However, certain trends could be seen. In particular the dominance and diversity of annelids (polychaetes and oligochaetes) was obvious in most locations as well as changes in community structure at different depths.

Community composition at almost all locations was dominated by annelids, mostly polychaetes, but oligochaetes were also present. The polychaete species *Aphelochaeta marioni* and *Heteromastus filiformis* were dominant in most locations. Among the non-annelid species, the phylum Mollusca was the most abundant. The most frequently occurring species included the group of actinarians (phylum: Cnidaria) and the group of bivalve molluscs *Mytilus edulis* and *Macoma balthica*. Although these species were frequently present, they were often present in small numbers except in Ellewoutsdijk-west when *M. edulis* was the dominant species.

The only Cluster 1, T1 location, Ritthem/Zuidwatering-west, showed higher total abundance and species richness than any Cluster 2, T0 location. Horseshoe worms (Phoronids) were dominant in this location, indicating that they may be pioneer species; the first to establish in the newly laid substrate. However, diversity and evenness at this location was close to midrange of the Cluster 2, T0 scores. The apparent high numbers of species detected after the dyke reinforcement may be a result of the sampling being done 6-7 months after reinforcement works and in June; during the highly productive summer temperatures, rather than being carried out concurrently with the Cluster 2, T0 sampling around August/September when temperatures were cooling.

In the Cluster 2, T0 locations, deeper samples generally showed greater total abundance and species richness than shallow samples (except in Ellewoutsdijk-midden and Hoedekenskerke-zuid). Hoedekenskerke-haven showed the highest total abundance of all the Cluster 2 locations for T0, but as the community at this location was dominated by only a few annelid species, species richness and diversity was not high compared with other locations. Ellewoutsdijk-west at 7 m had the highest species richness (although with a wide error margin) and Borssele had the highest diversity score at 7 m, and the highest evenness score at 3 m and 7 m.

The Asian shrimp, *Palaemon macrodactylus* (phylum: Arthropoda) found in Hoedekenskerke-noord at 15 m depth is not native to the Westerschelde, but to the north-western Pacific Ocean. Although it has been known in the Westerschelde since at least 1999 (d'Udekem d'Acoz *et al.*), this is the first reported occurrence of this species in the current survey.

At the investigated locations there were three species rich communities found, with two communities in the western section of the Westerschelde and one distributed over the whole area. The species poor variants were found in stations in the section around Ellewoutsdijk and the southern Middelgat at various depths. The total number of species and densities in the species poor variants did not fit in the expected gradient for this part of the Westerschelde.

While this data provides an adequate basis for comparison for future surveys conducted after dyke reinforcement, given the current data it is difficult to come to any reliable conclusions about the general effect of dyke reinforcement on the benthic community. The variation in the data between locations, depths and replicates must be taken into account during future comparisons. More replicate samples over a longer period of time will allow the effect of dyke reinforcement on the benthic community to be monitored and detected more reliably.

5. Quality Assurance

IMARES utilises an ISO 9001:2000 certified quality management system (certificate number: 08602-2004-AQ-ROT-RvA). This certificate is valid until 15 December 2009. The organisation has been certified since 27 February 2001. The certification was issued by DNV Certification B.V. Furthermore, the chemical laboratory of the Environmental Division has NEN-AND-ISO/IEC 17025:2005 accreditation for test laboratories with number L097. This accreditation is valid until 27 March 2013 and was first issued on 27 March 1997. Accreditation was granted by the Council for Accreditation.

References

- Beukema, JJ (1974). Seasonal changes in the biomass of the macro-benthos of a tidal flat area in the Dutch Wadden Sea. *Netherlands Journal of Sea Research* 8 (1): 94-107.
- Van den Brink, A.M. & Brummelhuis, E. (2009). Data report: T0 monitoring of benthic species of soft bottoms in the Oosterschelde. Imares Wageningen report Report Number C135/09.
- Van den Heuvel-Greve, M.J., A. van den Brink, S. Glorius, C. Schipper, M. De Kluijver, M. Dubbeldam (2011). Monitoring vooroeververdediging Westerschelde 2010: T1 Cluster 1 / T0 Cluster 2. IMARES-rapport C031/11.
- De Kluijver, M & M Dubbeldam (2009). Levensgemeenschappen op de harde substraten van Schouwen-Duiveland in de Oosterschelde; T0-inventarisatie eulittoraal en vooroever. Report Zeeschelp, draft November 2009.
- Kovach, W.L., 1999. MVSP – A Multi Variate Statistical Package for Windows, version 3.1. Kovach Computing Services, Pentraeth, Wales, UK.
- D'Udekem d'Acoz, C., Faasse, M., Dumoulin, E., De Blauwe, H. (2005). The Asian shrimp in the southern Bight of the North Sea. *Nederlandse Faunistische Mededelingen*. 22.

Justification

Rapport C034/11
Project Number: 4303101401

The scientific quality of this report has been peer reviewed by the a colleague scientist and the head of the department of IMARES.

Approved: Johan Craeymeersch
Ecologist

Signature:

A handwritten signature in black ink, appearing to be 'JC', with a large loop and a horizontal stroke.

Date: 19-05-2011

Approved: Birgit Dauwe
Head of Section Delta

Signature:

A handwritten signature in blue ink, appearing to be 'BD', with a large loop and a horizontal stroke.

Date: 19-05-2011

Appendix A. Number of individuals found per sample in each replicate (A-B), location and depth.

Cluster	Location	Phylum	Species, or lowest level of identification	Depth (m)					
				3		7		15	
				A	B	A	B	A	B
2	Borssele	Annelida	<i>Aphelocheata marioni</i>			1			
			<i>Glycera tridactyla</i>	1					
			<i>Heteromastus filiformis</i>			1	1	1	
			<i>Lanice conchilega</i>		1	2	1	5	5
			<i>Nephtys</i> (spec)	1	1				
			<i>Nephtys hombergii</i>		1				
			<i>Nereis succinea</i>				1		1
			Oligochaeta			2	1		1
			Polychaeta (spec.)	1					
			<i>Polydora pulchra</i>					1	
			<i>Pygospio elegans</i>	1					
			<i>Scoloplos armiger</i>	1	2	1	2	2	2
			<i>Spiophanes bombyx</i>		2		2		
2	Ellewoutsdijk-midden	Arthropoda	<i>Carcinus maenas</i>			1			1
		Cnidaria	Actiniaria			2	1		
		Echinodermata	<i>Asteria rubens</i>					1	
			<i>Echinocardium cordatum</i>						1
		Mollusca	<i>Abra alba</i>						1
			<i>Macoma balthica</i>				2	1	
			<i>Mytilus edulis</i>				3		
		Phoronida	Phoronida					4	12
		Annelida	<i>Aphelocheata marioni</i>			11	7		
			<i>Heteromastus filiformis</i>			1	8	1	
			<i>Lanice conchilega</i>			1			
			<i>Nephtys</i> (spec)				1		
			<i>Nephtys cirrosa</i>			1			
			<i>Nereis diversicolor</i>			1	1		
			Oligochaeta			6	16		
			<i>Scoloplos armiger</i>				1		
			<i>Streblospio shrubsoli</i>			2	2		
		Cnidaria	Actiniaria			5	3		
		Mollusca	<i>Ensis</i> (spec.)				1		
			<i>Mytilus edulis</i>			2			
2	Ellewoutsdijk-west	Annelida	<i>Aphelocheata marioni</i>				1		
			<i>Heteromastus filiformis</i>	2	3		1		
			<i>Nereis succinea</i>				1		
			Oligochaeta				2		
			Polydora (spec)				1		
		Echinodermata	<i>Asteria rubens</i>	1					
		Mollusca	<i>Mytilus edulis</i>				47		
2	Hoedekenskerke-haven	Annelida	<i>Aphelocheata marioni</i>					17	15
			<i>Capitella capitata</i>					1	
			<i>Heteromastus filiformis</i>					27	15
			<i>Nephtys</i> (spec)						3
			<i>Nephtys caeca</i>						1
			<i>Nereis diversicolor</i>						1

Cluster	Location	Phylum	Species, or lowest level of identification	Depth (m)					
				3		7		15	
				A	B	A	B	A	B
			<i>Oligochaeta</i>					8	42
			<i>Polydora cornuta (ligni)</i>						1
			<i>Streblospio shrubsoli</i>						2
		Cnidaria	Actiniaria					1	
2	Hoedekenskerke-noord	Annelida	<i>Ensis</i> (spec.)						2
			<i>Macoma balthica</i>						3
			<i>Aphelocheata marioni</i>	9	4	10	3	26	3
			<i>Heteromastus filiformis</i>	18	2	4	3	5	1
			<i>Nephtys</i> (spec)						1
			<i>Nephtys hombergii</i>			1			
			<i>Oligochaeta</i>	7	2	3	1	1	
			<i>Scoloplos armiger</i>					2	1
			<i>Streblospio shrubsoli</i>					1	1
		Arthropoda	<i>Crangon crangon</i>					1	
			<i>Palaemon macrodactylus</i>	2					
		Mollusca	<i>Macoma balthica</i>	2		1		2	2
2	Hoedekenskerke-zuid		Unknown					1	
		Annelida	<i>Heteromastus filiformis</i>						1
		Arthropoda	<i>Corophium</i> spec.				1		
			Decapoda			1	1		
1	Ritthem/Zuidwatering-west	Annelida	<i>Macoma balthica</i>						1
			<i>Heteromastus filiformis</i>						4
			<i>Malacoceros fuliginosus</i>						1
			<i>Oligochaeta</i>						1
			<i>Scoloplos armiger</i>					4	3
		Arthropoda	<i>Crangon crangon</i>						1
			Decapoda						2
		Cnidaria	Actiniaria						1
		Echinodermata	<i>Asteria rubens</i>					1	1
		Mollusca	<i>Abra alba</i>					9	2
			Bivalve spec.					3	9
			<i>Ensis</i> (spec.)					1	
			<i>Macoma balthica</i>						1
		Phoronida	Phoronida					45	56

Appendix B. Number of individuals found per m² in each replicate (A-B), location and depth.

Cluster	Location	Phylum	Species, or lowest level of identification	Depth (m)					
				3		7		15	
				A	B	A	B	A	B
2	Borssele	Annelida	<i>Aphelocheata marioni</i>			100.5			
			<i>Glycera tridactyla</i>	100.5					
			<i>Heteromastus filiformis</i>			100.5	100.5	100.5	
			<i>Lanice conchilega</i>		100.5	200.9	100.5	502.3	502.3
			<i>Nephtys</i> (spec)	100.5	100.5				
			<i>Nephtys hombergii</i>		100.5				
			<i>Nereis succinea</i>				100.5		100.5
			Oligochaeta			200.9	100.5		100.5
			Polychaeta (spec.)	100.5					
			<i>Polydora pulchra</i>					100.5	
			<i>Pygospio elegans</i>	100.5					
			<i>Scoloplos armiger</i>	100.5	200.9	100.5	200.9	200.9	200.9
			<i>Spiophanes bombyx</i>		200.9		200.9		
		Arthropoda	<i>Carcinus maenas</i>			100.5			100.5
2	Ellewoutsdijk-midden	Cnidaria	Actiniaria			200.9	100.5		
		Echinodermata	<i>Asteria rubens</i>					100.5	
			<i>Echinocadium cordatum</i>						100.5
		Mollusca	<i>Abra alba</i>						100.5
			<i>Macoma balthica</i>				200.9	100.5	
			<i>Mytilus edulis</i>				301.4		
		Phoronida	Phoronida					401.8	1205.4
		Annelida	<i>Aphelocheata marioni</i>			1105.0	703.2		
			<i>Heteromastus filiformis</i>			100.5	803.6	100.5	
			<i>Lanice conchilega</i>			100.5			
			<i>Nephtys</i> (spec)				100.5		
			<i>Nephtys cirrosa</i>			100.5			
			<i>Nereis diversicolor</i>			100.5	100.5		
							1607.2		
			<i>Oligochaeta</i>			602.7	2		
			<i>Scoloplos armiger</i>				100.5		
			<i>Streblospio shrubsoli</i>			200.9	200.9		
		Cnidaria	Actiniaria			502.3	301.4		
		Mollusca	<i>Ensis</i> (spec.)				100.5		
			<i>Mytilus edulis</i>			200.9			
2	Ellewoutsdijk-west	Annelida	<i>Aphelocheata marioni</i>				100.5		
			<i>Heteromastus filiformis</i>	200.9	301.4		100.5		
			<i>Nereis succinea</i>				100.5		
			Oligochaeta				200.9		
			Polydora (spec)				100.5		
2	Hoedekenskerke-haven	Echinodermata	<i>Asteria rubens</i>	100.5					
		Mollusca					4721.3		
			<i>Mytilus edulis</i>						
2	Hoedekenskerke-haven	Annelida	<i>Aphelocheata marioni</i>					1707.7	1506.8
			<i>Capitella capitata</i>					100.5	

Cluster	Location	Phylum	Species, or lowest level of identification	Depth (m)					
				3		7		15	
				A	B	A	B	A	B
			<i>Heteromastus filiformis</i>					2712.2	1506.8
			<i>Nephtys</i> (spec)					301.4	
			<i>Nephtys caeca</i>					100.5	
			<i>Nereis diversicolor</i>					100.5	
			<i>Oligochaeta</i>					4219.0	
			<i>Polydora cornuta (ligni)</i>					100.5	
			<i>Streblospio shrubsoli</i>					200.9	
		Cnidaria	Actiniaria					100.5	
		Mollusca	<i>Ensis</i> (spec.)					200.9	
			<i>Macoma balthica</i>					301.4	
2	Hoedekenskerke-noord	Annelida	<i>Aphelochaeta marioni</i>	904.1	401.8	1004.5	301.4	2611.8	301.4
			<i>Heteromastus filiformis</i>	1808.2	200.9	401.8	301.4	502.3	100.5
			<i>Nephtys</i> (spec)					100.5	
			<i>Nephtys hombergii</i>			100.5			
			<i>Oligochaeta</i>	703.2	200.9	301.4	100.5	100.5	
			<i>Scoloplos armiger</i>				200.9	100.5	
			<i>Streblospio shrubsoli</i>				100.5	100.5	
		Arthropoda	<i>Crangon crangon</i>					100.5	
			<i>Palaemon macrodactylus</i>	200.9					
		Mollusca	<i>Macoma balthica</i>		200.9	100.5		200.9	200.9
	Unknown					100.5			
2	Hoedekenskerke-zuid	Annelida	<i>Heteromastus filiformis</i>					100.5	
		Arthropoda	<i>Corophium</i> spec.				100.5		
			Decapoda			100.5	100.5		
		Mollusca	<i>Macoma balthica</i>					100.5	
1	Ritthem/Zuidwatering-west	Annelida	<i>Heteromastus filiformis</i>					401.8	
			<i>Malacoceros fuliginosus</i>					100.5	
			<i>Oligochaeta</i>					100.5	
			<i>Scoloplos armiger</i>				401.8	301.4	
		Arthropoda	<i>Crangon crangon</i>					100.5	
			Decapoda					200.9	
		Cnidaria	Actiniaria					100.5	
		Echinodermata	<i>Asteria rubens</i>					100.5	100.5
		Mollusca	<i>Abra alba</i>					904.1	200.9
Bivalve spec.						301.4	904.1		
<i>Ensis</i> (spec.)						100.5			
<i>Macoma balthica</i>							100.5		
Phoronida	Phoronida					4520.4	5625.4		

Appendix C. Organised table of the soft substrate communities.

Densities shown in bold represent species present in the communities of 66.7% of the stations, underlined values represent the presence of a species in a minimum of 90% of the total number of stations studied. Abbreviations: An - Anthozoa, Br - Bryozoa, Cr - Crustacea, Ech - Echinodermata, Mol - Mollusca, Ne - Nemertea, Ol - Oligochaeta, Ph - Phoronida, Pl - Platyhelminthes, Po - Polychaeta, Pyc - Pycnogonida and Tu - Tunicata.

n/m ²		A	B	C	D	E	F	G	H	I	J	Empty
Nudibranchia	Mol	0	0	0	0	0	0	0	0	0	50.23	0
<i>Corophium</i> spec.	Cr	0	0	<u>40.18</u>	0	0	0	0	0	50.23	0	0
Decapoda	Cr	0	0	5.02	117.19	0	0	0	0	100.45	0	0
<i>Mytilus edulis</i>	Mol	<u>174.12</u>	0	<u>35.16</u>	0	0	0	0	50.23	0	0	0
Actinaria	An	<u>80.36</u>	8.37	175.79	100.45	0	0	351.58	0	0	0	0
<i>Malmgreniella lunulata</i>	Po	0	0	<u>15.07</u>	0	0	0	50.23	0	0	0	0
<i>Asterias rubens</i>	Ech	0	0	0	50.23	0	<u>16.74</u>	50.23	0	0	0	0
Ascidacea	Tu	0	0	0	0	0	0	50.23	0	0	0	0
<i>Photis</i> spec.	Cr	0	0	0	0	0	0	50.23	0	0	0	0
<i>Heteromastus filiformis</i>	Po	361.63	75.34	<u>527.38</u>	117.19	0	117.19	0	0	0	0	0
<i>Macoma balthica</i>	Mol	<u>40.18</u>	8.37	<u>10.05</u>	33.48	0	<u>16.74</u>	0	0	0	0	0
<i>Scoloplos armiger</i>	Po	33.48	33.48	482.17	535.75	150.68	0	0	0	0	0	0
<i>Nephtys</i> spec.	Po	<u>30.14</u>	0	0	<u>16.74</u>	100.45	0	0	0	0	0	0
<i>Spiophanes bombyx</i>	Po	6.70	0	<u>20.09</u>	0	100.45	0	0	0	0	0	0
<i>Nephtys hombergii</i>	Po	<u>56.92</u>	58.60	246.11	0	50.23	0	0	0	0	0	0
<i>Lanice conchilega</i>	Po	16.74	0	<u>35.16</u>	217.65	50.23	0	0	0	0	0	0
<i>Pygospio elegans</i>	Po	0	<u>8.37</u>	5.02	0	50.23	0	0	0	0	0	0
Polychaeta	Po	0	0	<u>15.07</u>	0	50.23	0	0	0	0	0	0
<i>Glycera tridactyla</i>	Po	0	0	0	0	50.23	0	0	0	0	0	0
<i>Abra alba</i>	Mol	3.35	<u>41.86</u>	<u>105.48</u>	217.65	0	0	0	0	0	0	0
<i>Ensis</i> spec.	Mol	<u>10.05</u>	<u>8.37</u>	<u>10.05</u>	33.48	0	0	0	0	0	0	0
<i>Anaitides mucosa</i>	Po	0	0	<u>35.16</u>	<u>117.19</u>	0	0	0	0	0	0	0
<i>Ampharete acutifrons</i>	Po	0	0	<u>90.41</u>	<u>33.48</u>	0	0	0	0	0	0	0
<i>Crangon crangon</i>	Cr	<u>6.70</u>	<u>25.11</u>	<u>5.02</u>	<u>33.48</u>	0	0	0	0	0	0	0
<i>Crepidula fornicata</i>	Mol	0	<u>8.37</u>	<u>35.16</u>	<u>33.48</u>	0	0	0	0	0	0	0
<i>Ophiura</i> spec.	Ech	0	0	<u>10.05</u>	<u>33.48</u>	0	0	0	0	0	0	0
<i>Echinocardium cordatum</i>	Ech	<u>10.05</u>	0	0	<u>16.74</u>	0	0	0	0	0	0	0
<i>Nereis diversicolor</i>	Po	<u>10.05</u>	0	<u>15.07</u>	<u>16.74</u>	0	0	0	0	0	0	0
<i>Nereis succinea</i>	Po	<u>6.70</u>	0	0	<u>16.74</u>	0	0	0	0	0	0	0
<i>Pseudopolydora pulchra</i>	Po	0	0	<u>5.02</u>	<u>16.74</u>	0	0	0	0	0	0	0
<i>Notomastus latericeus</i>	Po	0	0	<u>130.59</u>	<u>16.74</u>	0	0	0	0	0	0	0

n/m ²		A	B	C	D	E	F	G	H	I	J	Empty
Phoronida	Ph	56.92	0	125.57	1958.83	0	0	0	0	0	0	0
Bivalvia	Mol	16.74	0	5.02	<u>200.91</u>	0	0	0	0	0	0	0
<i>Cheirocratus sundevallii</i>	Cr	0	0	0	<u>50.23</u>	0	0	0	0	0	0	0
<i>Eumida</i> spec.	Po	0	0	0	<u>33.48</u>	0	0	0	0	0	0	0
<i>Autolytus</i> spec.	Po	0	0	0	<u>16.74</u>	0	0	0	0	0	0	0
<i>Bodotria pulchella</i>	Cr	0	0	0	<u>16.74</u>	0	0	0	0	0	0	0
Brachyura	Cr	0	0	0	<u>16.74</u>	0	0	0	0	0	0	0
<i>Malacoceros fuliginosus</i>	Po	0	0	0	<u>16.74</u>	0	0	0	0	0	0	0
<i>Syllis gracillis</i>	Po	0	0	0	<u>16.74</u>	0	0	0	0	0	0	0
Oligochaeta	Ol	1419.73	1841.64	1421.41	33.48	0	0	0	0	0	0	0
<i>Aphelochaeta marioni</i>	Po	545.79	175.79	<u>326.47</u>	0	0	0	0	0	0	0	0
Nemertea	Ne	0	75.34	<u>175.79</u>	0	0	0	0	0	0	0	0
Aoridae	Cr	0	<u>66.97</u>	<u>85.38</u>	0	0	0	0	0	0	0	0
<i>Streblospio benedicti</i>	Po	<u>93.76</u>	<u>117.19</u>	<u>60.27</u>	0	0	0	0	0	0	0	0
<i>Cossura longocirrata</i>	Po	23.44	334.84	<u>50.23</u>	0	0	0	0	0	0	0	0
<i>Exogone naidina</i>	Po	0	<u>25.11</u>	<u>30.14</u>	0	0	0	0	0	0	0	0
<i>Owenia fusiformis</i>	Po	0	<u>16.74</u>	<u>30.14</u>	0	0	0	0	0	0	0	0
<i>Anatides</i> spec.	Po	0	<u>8.37</u>	<u>25.11</u>	0	0	0	0	0	0	0	0
Hesionidae	Po	0	<u>8.37</u>	<u>25.11</u>	0	0	0	0	0	0	0	0
onbekend	-	3.35	92.08	<u>25.11</u>	0	0	0	0	0	0	0	0
<i>Capitella capitata</i>	Po	3.35	<u>150.68</u>	<u>15.07</u>	0	0	0	0	0	0	0	0
<i>Ophiothrix fragilis</i>	Ech	<u>10.05</u>	0	<u>15.07</u>	0	0	0	0	0	0	0	0
<i>Carcinus maenas</i>	Cr	<u>10.05</u>	0	<u>10.05</u>	0	0	0	0	0	0	0	0
<i>Melita obtusata</i>	Cr	<u>3.35</u>	0	<u>10.05</u>	0	0	0	0	0	0	0	0
<i>Nereis</i> spec.	Po	<u>3.35</u>	<u>8.37</u>	<u>10.05</u>	0	0	0	0	0	0	0	0
<i>Venerupis senegalensis</i>	Mol	0	<u>25.11</u>	<u>10.05</u>	0	0	0	0	0	0	0	0
<i>Neoamphitrite</i> spec.	Po	<u>3.35</u>	0	<u>5.02</u>	0	0	0	0	0	0	0	0
<i>Stenelais boa</i>	Po	0	0	90.41	0	0	0	0	0	0	0	0
<i>Polycirrus</i> spec.	Po	0	16.74	<u>286.29</u>	0	0	0	0	0	0	0	0
<i>Pholoe minuta</i>	Po	0	0	<u>205.93</u>	0	0	0	0	0	0	0	0
<i>Polydora cornuta (ligni)</i>	Po	10.05	0	<u>130.59</u>	0	0	0	0	0	0	0	0
<i>Neoamphitrite figulus</i>	Po	0	0	<u>115.52</u>	0	0	0	0	0	0	0	0
Caprellidae	Cr	3.35	0	<u>90.41</u>	0	0	0	0	0	0	0	0
<i>Gattyana cirrosa</i>	Po	0	0	<u>75.34</u>	0	0	0	0	0	0	0	0
Amphipoda	Cr	0	0	<u>55.25</u>	0	0	0	0	0	0	0	0
<i>Corophium sextonae</i>	Cr	0	0	<u>50.23</u>	0	0	0	0	0	0	0	0
<i>Ampelisca brevicornis</i>	Cr	0	0	<u>45.20</u>	0	0	0	0	0	0	0	0

n/m ²		A	B	C	D	E	F	G	H	I	J	Empty
<i>Ophiura albida</i>	Ech	0	0	<u>30.14</u>	0	0	0	0	0	0	0	0
<i>Aonides oxycephala</i>	Po	0	0	<u>25.11</u>	0	0	0	0	0	0	0	0
<i>Glycera</i> spec.	Po	0	0	<u>25.11</u>	0	0	0	0	0	0	0	0
Eteoninae	Po	0	0	<u>20.09</u>	0	0	0	0	0	0	0	0
<i>Kefersteinia cirrata</i>	Po	0	0	<u>20.09</u>	0	0	0	0	0	0	0	0
<i>Nereis longissima</i>	Po	0	0	<u>20.09</u>	0	0	0	0	0	0	0	0
<i>Bodotria scorpiodes</i>	Cr	0	0	<u>15.07</u>	0	0	0	0	0	0	0	0
<i>Eteone</i> spec.	Po	0	0	<u>15.07</u>	0	0	0	0	0	0	0	0
<i>Petricola pholadiformis</i>	Mol	0	0	<u>15.07</u>	0	0	0	0	0	0	0	0
<i>Plathynereis dumerilli</i>	Po	0	0	<u>15.07</u>	0	0	0	0	0	0	0	0
<i>Abra nitida</i>	Mol	0	0	<u>10.05</u>	0	0	0	0	0	0	0	0
<i>Aora typica</i>	Cr	0	0	<u>10.05</u>	0	0	0	0	0	0	0	0
<i>Bathyporeia</i> spec.	Cr	0	0	<u>10.05</u>	0	0	0	0	0	0	0	0
<i>Melita</i> spec.	Cr	0	0	<u>10.05</u>	0	0	0	0	0	0	0	0
Platyhelminthes	Pl	0	0	<u>10.05</u>	0	0	0	0	0	0	0	0
Bryozoa	Br	0	0	<u>5.02</u>	0	0	0	0	0	0	0	0
<i>Lepidonotus</i> spec.	Po	0	0	<u>5.02</u>	0	0	0	0	0	0	0	0
<i>Mysella bidentata</i>	Mol	0	0	<u>5.02</u>	0	0	0	0	0	0	0	0
<i>Nereis virens</i>	Po	0	0	<u>5.02</u>	0	0	0	0	0	0	0	0
<i>Nymphon</i> spec.	Pyc	0	0	<u>5.02</u>	0	0	0	0	0	0	0	0
<i>Periculodes longimanus</i>	Cr	0	0	<u>5.02</u>	0	0	0	0	0	0	0	0
Polynoidae	Po	0	0	<u>5.02</u>	0	0	0	0	0	0	0	0
<i>Spio martinensis</i>	Po	0	0	<u>5.02</u>	0	0	0	0	0	0	0	0
<i>Tellina fabula</i>	Mol	0	0	<u>5.02</u>	0	0	0	0	0	0	0	0
<i>Mya arenaria</i>	Mol	0	<u>8.37</u>	0	0	0	0	0	0	0	0	0
Gastropoda	Mol	<u>3.35</u>	0	0	0	0	0	0	0	0	0	0
<i>Montacuta ferruginosa</i>	Mol	<u>3.35</u>	0	0	0	0	0	0	0	0	0	0
<i>Nephtys caeca</i>	Po	<u>3.35</u>	0	0	0	0	0	0	0	0	0	0
<i>Nephtys cirrosa</i>	Po	<u>3.35</u>	0	0	0	0	0	0	0	0	0	0
<i>Palaemon macrodactylus</i>	Cr	<u>3.35</u>	0	0	0	0	0	0	0	0	0	0
<i>Polydora</i> spec.	Po	<u>3.35</u>	0	0	0	0	0	0	0	0	0	0
n/m ²		3073.9	3248.0	5956.9	4135.3	602.7	150.7	552.5	50.2	150.7	50.2	0.0
Index		1.998	2.234	3.505	2.623	2.855	0.550	1.673	0.000	0.918	0.000	0.000
Evenness		0.650	0.647	0.780	0.671	0.952	0.550	0.720	0.000	0.918	0.000	0.000
Gemiddeld aantal soorten		8.3	10.5	23.8	15.0	8.0	1.7	5.0	1.0	2.0	1.0	0.0
Totaal aantal soorten		36	26	77	30	8	3	5	1	2	1	0
Aantal stations		15	6	10	3	1	3	1	1	1	1	1

