Biodiversity in a changing Oosterschelde: from past to present

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Signature:		*Signature:*	
Date:	30 March 2011	*Date:*	30 March 2011

WOT Working Document **288** presents the findings of a research project commissioned by the Netherlands Environmental Assessment Agency (PBL) and funded by the Dutch Ministry of Economic Affairs, Agriculture and Innovation (EL&I). This document contributes to the body of knowledge which will be incorporated in more policy-oriented publications such as the National Nature Outlook and Environmental Balance reports, and thematic assessments.

Biodiversity in a changing Oosterschelde: from past to present

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De biodiversiteit onder vogels in de Oosterschelde neemt significant toe van 84 soorten in 1987 tot 105 soorten in 2008. Met name de herbivore en piscivore vogels zijn verantwoordelijk voor deze toename. Broedvogels nemen toe in aantal vanaf 1994. Vissen vertonen echter weinig verandering in de gemeten periode (1970-2008) en vertonen een lichte significante toename in het aantal soorten in de periode 1996-2001. De macrofauna-gemeenschap vertoont een constant hoge Shannon Wiener-index tussen de 2,5 en 3,5, maar de aantallen tussen soorten zijn erg ongelijk verdeeld doordat er veel soorten met relatief lage aantallen zijn en een paar soorten voorkomen in relatief hoge aantallen. De aantallen individuen voor suspensie- en filter feeders en oppervlakte deposit- en facultatieve suspensie feeders nemen significant af over de gehele gemeten periode (1993-2008). Zeehonden (twee soorten) nemen in aantallen toe. Met name Gewone zeehond (*Phoca vitulina*) vertoont een forse stijging in aantallen en ook de Grijze zeehond (*Halichoerus grypus*), hoewel minder abundant, vertoont een stijging in aantal waargenomen individuen. Bruinvissen *(Phocoena phocoena)* zijn niet beschouwd in de analyse. Het areaal aan zeegras vertoont een sterke daling in 1984-1993 van 657 tot 63, een afname van 90%. Ook het schorareaal neemt af.

Trefwoorden: Biodiversiteit, Oosterschelde, Gewone zeehond, Grijze zeehond, Zeegras, Schor

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1 Introduction

A large-scale engineering project, the 'Delta project', caused drastic changes in the ecosystems of the different estuaries of the South-western delta in the Netherlands. Estuarine ecosystems with extensive intertidal habitats (mud and sand flats, marshes) were changed into stagnant fresh, brackish and salt water lakes. Although the Delta Works provided protection and brought safety following the flood disaster of 1953, the Delta Works also have their downsides for the natural environment, water quality and the economy. While some environmental drawbacks were expected at the time, the Delta currently faces many ecological problems, indicating a lack in robustness. Examples are: erosion of tidal flats in the Oosterschelde estuary (Van Zanten and Adriaanse 2008) and oxygen deficiency in Lake Grevelingen (Lengbeek, Bouma *et al.* 2007). To address these problems, as well as future effects of climate change and sea level rise, possibilities for restoring estuarine dynamics, salinity gradients and connectivity between water bodies are currently investigated (Zuidwestelijke Delta 2010).

To be able to predict consequences for species biodiversity we need to know todays biodiversity, as well as how biodiversity of the different water bodies, and the delta area as a whole, changed due to the long-term effects of the 'Delta project'. This project has led to a dramatic reduction of estuarine dynamics and to a fragmentation of large-scale estuarine nature into multiple, largely isolated systems. All of these systems developed in different directions. For the area as a whole, the overall species biodiversity seems to have increased. By restoring estuarine dynamics, what will be gained and what will be lost?, commissioned by the Ministry of Economic Affairs, Agriculture and Innovation (Dutch: EL&I), IMARES is conducting a study in which the development of overall biodiversity of the South-western Delta area is compared to that of the separate water bodies (Westerschelde and Oosterschelde estuaries, the lakes Veerse Meer, Grevelingenmeer, Haringvliet, Krammer-Volkerak, Zoommeer and Markiezaat) (Project BO-11-015-004). Discussed will be how the biodiversity of some main species groups (birds, fish, benthos, etc.) in each subsystem evolved into today's state, and how this relate to the biodiversity of the entire Delta area as a whole. Based on these results it is questioned whether restoration of estuarine dynamics will lead to an increase or decrease in biodiversity, species richness, and overall robustness.

In addition to, and to complement, the above mentioned project, the PBL Netherlands Environmental Assessment Agency (Planbureau voor de Leefomgeving) commissioned a more detailed study on changes in biodiversity, species richness, functional groups and key species and habitats in a subset of water bodies in the Southwestern Delta: the Oosterschelde estuary, and the lakes Grevelingenmeer, Veerse Meer and Haringvliet. This project is also funded by the Ministry of Economic Affairs, Agriculture and Innovation (Project WOT-04-011-007). The current report is a report in progress, which shows what kind of results can be obtained by analysing these long-term datasets, based on the Oosterschelde as an example. The other three systems will be combined with the Oosterschelde results in a final report in 2012.

We used available long-term datasets on macrobenthos, fish, birds, vegetation and key species. We also analysed trends in abundance within functional subsets of shorebirds, fish and benthos. These were related to the timing of the Delta project and other major changes.

2 Methodology

2.1 Description of the Oosterschelde

An important aspect of the Delta project was the closure of the Oosterschelde. The original plan was to close of the Oosterschelde completely, so it would become a freshwater basin. Soon, a campaign started to keep the Oosterschelde open, to maintain the unique intertidal saltwater environment. The Dutch government agreed to an alternative plan. Instead of closing the Oosterschelde, an open barrier would be built. This barrier (Figure 1) would be closed during storms and high water levels. The construction of the Delta works (Figure 2) started to affect the Oosterschelde in 1959 with the separation of the Veerse Meer. The Grevelingen was closed off by the construction of the Grevelingen dam (1958-1965) and the Krammer-Volkerak was closed off by the Volkerakdam (1957-1969). These constructions cut off the freshwater discharge into the Oosterschelde.

The Delta works changed the hydrodynamic characteristics of the Oosterschelde. The construction of the storm surge barrier diminished the cross sectional area of the channels of the inlet of the Oosterschelde from 80,000 m^2 in 1984 to approx. 17,900 m^2 in 1987. During the construction works of this barrier, the tidal volume, tidal current velocities and the tidal range gradually decreased. Later on, the closure of the Oesterdam (1986) and the Philipsdam (1987) led to a decrease of tidal volume of almost 30 %, but led to an increase in tidal range. Due to the decrease in the tidal volume the current velocities in the Oosterschelde are reduced by about 30%. In total, the tidal range is reduced by about 12 %. As a consequence of this tidal reduction, wave energy dissipation is concentrated on a smaller part of the intertidal flats and salt marshes.

Figure 1: The Oosterschelde storm surge barrier

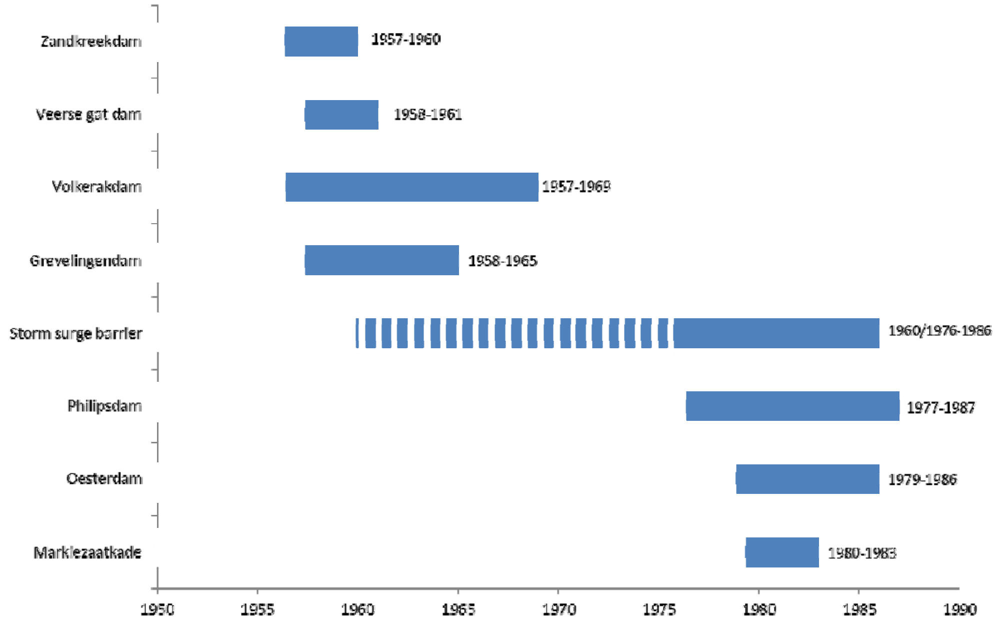


Figure 2: An overview of the construction period of the Deltawerken that affected the Oosterschelde. The construction of the storm surge barrier had a long preparation time where there were years of no action because of the debate on the design of the dam: closable if necessary of completely closed.

The Oosterschelde (South-western Netherlands) is nowadays a tidal system of 350 km^2 with intertidal flats (110 km^2), deep gullies, artificial rocky shores for dike defence, and shallow water areas (Figure 3). A storm surge barrier between the estuary and the North Sea protects the area from flooding but is normally open, allowing a tidal range varying from 2.5 m at the entrance to 4 m at the eastern boundaries. The system has an average freshwater load of 25 m^3/s and is mesotrophic with an average salinity of 30 ppt; there are no untreated waste water discharges (Nienhuis and Smaal 1994).

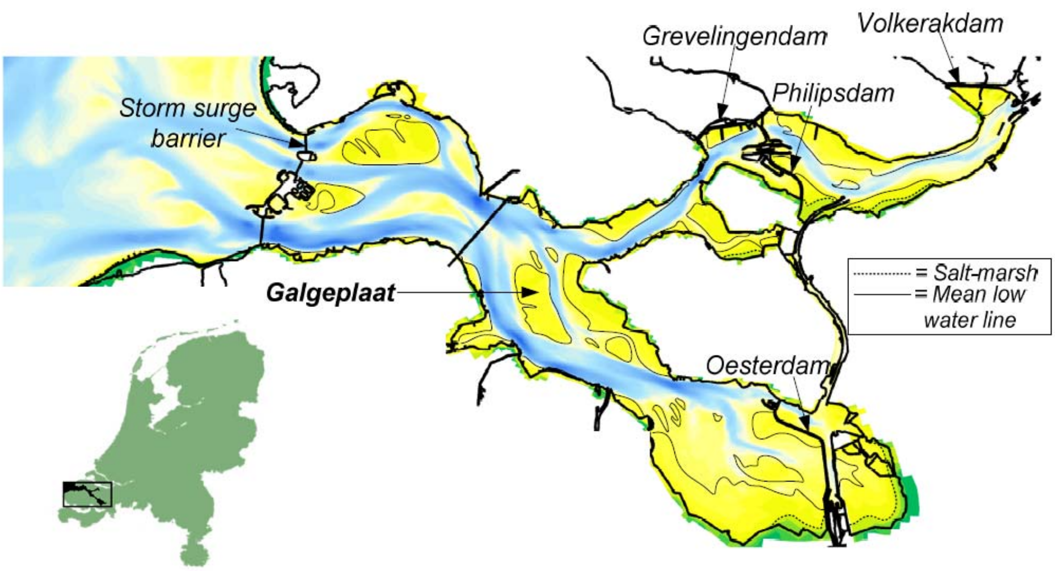


Figure 3: An overview of the Oosterschelde estuary, showing the different coastal engineering works that are part of the Delta project: the storm surge barrier and different compartmentalization dams.

Despite the Oosterschelde remained an open, tidal ecosystem, the geomorphology of the area is still changing as a result of the infrastructural works of the Delta project. The compartmentalization dams and the storm surge barrier decreased the tidal water volume going in and out the Oosterschelde, as well as the tidal currents. As a result, the gullies are too wide for the reduced water volume. During storm events, sediment of the tidal flats is eroded away, whereas tidal currents are too weak to bring back the sediments on the tidal flats. As a consequence the sediments are transported from the higher intertidal zone into the gullies, and many tidal flats are slowly eroding. This process is known as the 'sand starvation' problem of the Oosterschelde. Until 2001, on average 0.5 km^2 of the intertidal permanently eroded per year (Van Zanten and Adriaanse 2008). According to Jacobse *et al.* (2008), between 1990 and 2007, 6 km^2 of intertidal flats was lost. Each year, an estimated total of 1 million m^3 sand is disappearing into the gullies. More than 50% of the entire intertidal of the Oosterschelde estuary is predicted to have disappeared by 2045 (Van Zanten and Adriaanse 2008). Jacobse *et al.* (2008) mention an expected loss of 40 km^2 in the coming century.

The Oosterschelde is important as nature conservation area and of particular relevance for wader birds such as Oystercatcher, Dunlin, Grey Plover and Curlew that overwinters in large numbers (Troost and Ysebaert 2011). The Oosterschelde is protected under the international Ramsar convention as wetland of international importance and is part of the Natura 2000 network under the European Birds and Habitats Directive. The area is extensively used for shellfish bottom culture and cockle fishery. There are 1,550 ha oyster culture plots, all located in the eastern part (Figure 4). The Pacific Oyster was introduced to the Oosterschelde in 1964 by fishermen for culture purpose, but started to expand in the wild since 1976. Since then a rapid expansion of the Pacific Oyster was observed, but the increase appears to have stabilised. The percentage of the intertidal area covered by oyster beds increased to around 9% in 2005 (Smaal, Kater *et al.* 2009). Figure 5 shows an overview of changes and events in the Oosterschelde.

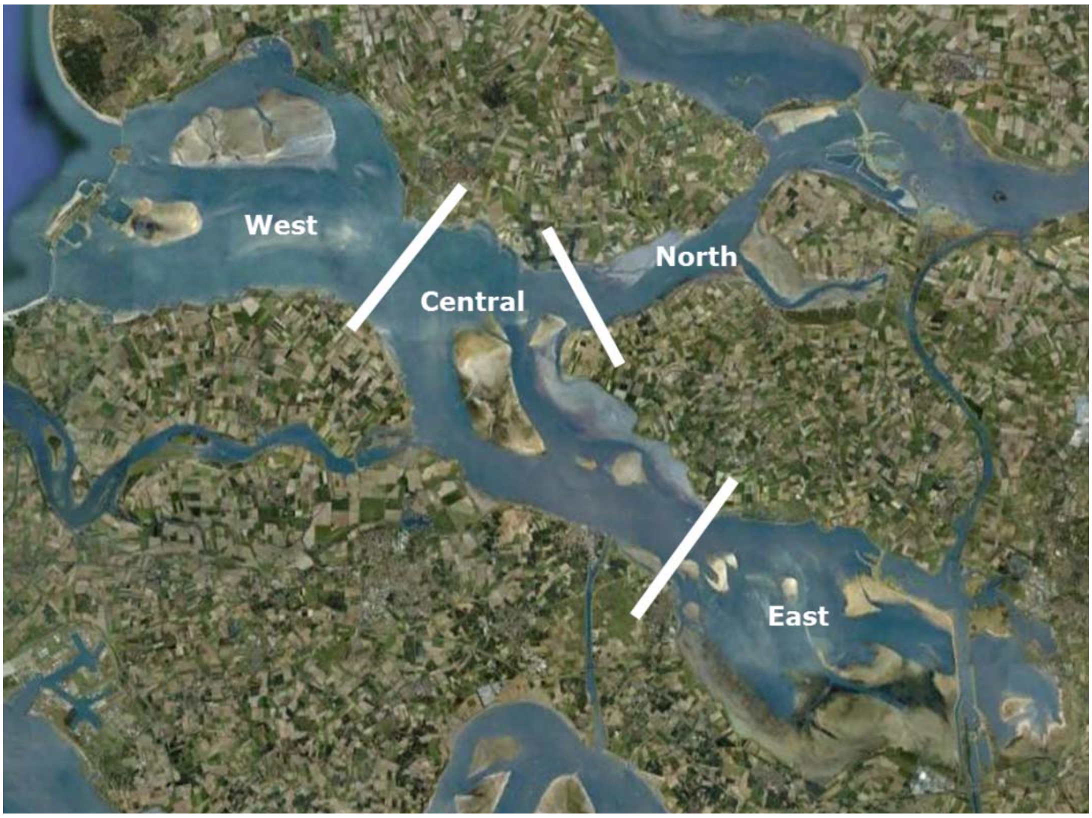


Figure 4: The Oosterschelde estuary, divided into four compartments: North, East, Central and West.

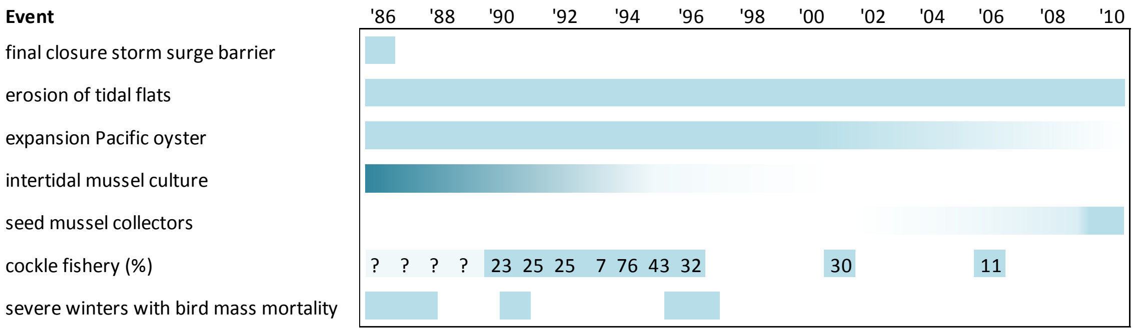


Figure 5: Schematic overview of changes and events in the Oosterschelde estuary that has, or may have, influenced the abundance of birds and benthic species in the estuary. There have been several episodes of cockle fishery, expressed as the percentage of the total cockle stock fished.

2.2 Data collection and availability

Data on species occurrence and abundance of birds, fish, benthic macrofauna, sea mammals and surface area of seagrass and salt marshes used in this study originated from several datasets. Data were largely collected or commissioned by Rijkswaterstaat (RWS) and kindly made available for this study by RWS Waterdienst. A list of species can be found in Annex 1. Figure 6 shows the data availability and Annex 2 shows a table with an overview and specification of the datasets used in this study.

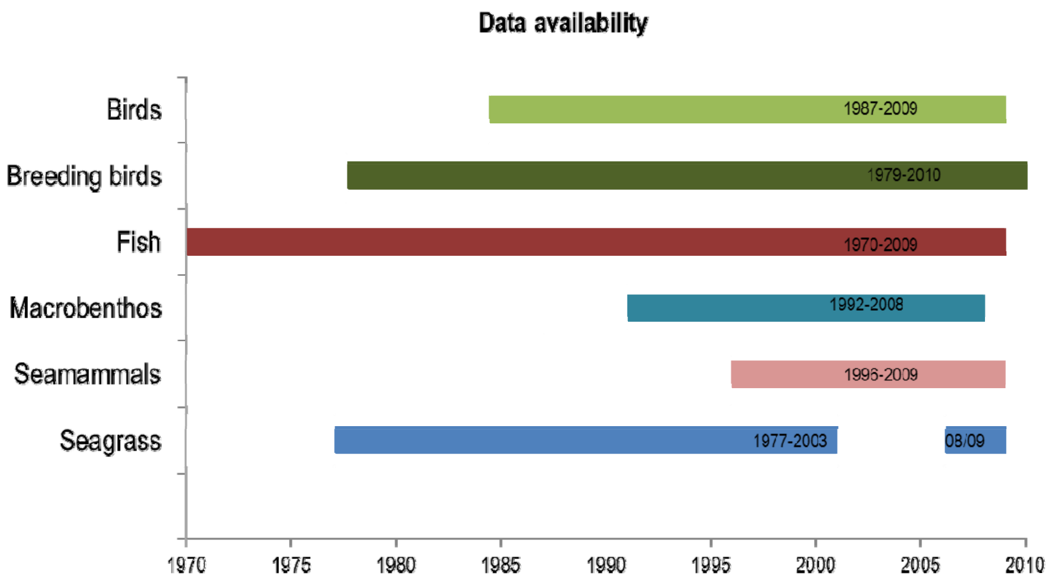


Figure 6: Data availability of different species groups and seagrass in the Oosterschelde in the period of 1970-2010.

Birds

Numbers of water birds are counted monthly in the saltwater bodies of the South-western Delta, including the Oosterschelde estuary, since 1978/1979. Since 1990 this is part of the biological monitoring programme of the saltwater bodies in the Netherlands (MWTL: "Monitoring van de Waterstaatkundige Toestand des Lands"), since 1990 commissioned by Rijkswaterstaat (presently Rijkswaterstaat Waterdienst, part of the Ministry of Infrastructure and the Environment). The results are reported annually (e.g. Strucker *et al.* (2010) for the season 2008/2009).

Shorebird numbers are counted once per month, during a series of high tides. During high tide, the birds are concentrated on high tide roosts, where they are relatively easy to count. The entire shore of the Oosterschelde estuary is split up into smaller areas, that cover all high tide roosts. The large intertidal flats of Roggenplaat and Neeltje Jans are counted from a boat. Bird data before 1987 were extracted from studies carried out by Meininger *et al.* (1985) and used as reference data.

Fish
The Dutch Demersal Fish Survey (DFS) survey covers the coastal waters from the southern border of the Netherlands to Esbjerg, including the Wadden Sea, the outer part of the Ems-Dollard estuary, the Westerschelde and the Oosterschelde (Van Beek, Rijnsdorp *et al.* 1989). This survey has been carried out in September-October since 1970. In this study, data of the Oosterschelde estuary were used. The Oosterschelde is sampled with a 3m-beam trawl. Fishing is restricted to the tidal channels and gullies deeper than 2 m because of the draught of the research vessel.

Benthic macrofauna
Within the monitoring programme MWTL, the benthic macrofauna of the Oosterschelde estuary has been monitored since 1990. Sampling is carried out each spring and autumn by the Monitor Taskforce of NIOO-CEME (Netherlands Institute of Ecology – Centre for Estuarine and Marine Ecology), commissioned by the Ministry of Infrastructure and the Environment. Methods are given by Escaravage *et al*. (2003).

Sea mammals
Numbers of sea mammals in the Oosterschelde, Grevelingen and Westerschelde were counted yearly in June - July since 1996 until present by Rijkswaterstaat Waterdienst. Sea mammals in the Oosterschelde mainly include seals (Common seal and Grey seal) and Harbour porpoises. Harbour porpoise was left out of the analysis because there were not enough data.

Seagrass
Mapping of seagrass was done by Rijkswaterstaat using false colour aerial photography (scale 1:10000 and 1:20000 and GPS/INS scale 1:2500). Field measurements included mapping in the field and subsequent analysis using GIS. Data were collected in the Oosterschelde in 1977-2003 and in Grevelingen in 1973-2003. Mapping was done based on three vegetation types. Data of 2009-2008 were extracted from studies by Damm (2009; 2010).

Saltmarshes
There were no continuous time series of saltmarsh coverage available. Therefore these data were collected from a study by Van der Pluijm & De Jong (1998) for the years1865, 1910, 1938, 1960, 1978, 1988, 1995. Due to the construction of compartmentalisation dams, the surface area of the Oosterschelde proper was reduced. The Oesterdam cut off the most Eastern part of the Oosterschelde, and through construction of the Philipsdam and Grevelingendam the Oosterschelde was cut off from the Grevelingen and Krammer-Volkerak. Therefore, the area of saltmarshes outside the current limits of the Oosterschelde were left out.

2.3 Data processing, statistics and presentation

2.3.1 General

Datasets were checked for synonyms in species names. Incomplete determinations were either deleted or scaled back to a higher taxonomic level. In the bird dataset, missing values were replaced by modelled values through imputing (Underhill & Prys-Jones 1994 in Strucker, Arts *et al*. 2008). We used the dataset from 1987/1988, when the closure of the Oosterschelde estuary was completed. From this year on, all data have been checked, validated, and missing data imputed.

Each species or taxonomic endpoint level of birds (including breeding birds), fish and macrobenthos were categorized in feeding guilds (Table 1). A list of determined species and their classification in feeding guilds can be found in Annex 1.

Table 1: Categorization in feeding guilds

Birds	**Breeding birds***	**Fish**	**Benthos**
Benthivores	Benthivores	Benthivores	0. not determined to species level
Carnivores	Omnivores	Bentho-piscivores	1. suspension or filter feeder
Herbivores	Piscivores	Piscivores	2.interface- , surface deposit- and facultative suspension feeder
Omnivores		Planktivores	3.subsurface deposit feeder, grazer
Piscivores			4.predator, omnivore, scavenger

* only breeding birds that are strictly related to marine habitats were counted. These did not include herbivores (duck and geese) and carnivores (birds of prey).

2.3.2 Indices

Biodiversity and evenness is expressed by using the Shannon Wiener index for biodiversity and species evenness index to show how equal the group of species are numerically.

The Shannon Wiener index is one of several diversity indices used to measure diversity in categorical data. Typically the value of the index ranges from 1.5 (low species richness and evenness) to 3.5 (high species evenness and richness), though values beyond these limits may be encountered. Because the Shannon Wiener index (H) gives a measure of both species numbers and the evenness (J) of their abundance, the resulting figure does not give an absolute description of a site's biodiversity. It is particularly useful when comparing similar ecosystems or habitats, as it can highlight one example being richer or more even than another. Below the calculations for both indices are elaborated.

Shannon Wiener index $$H = -\sum_{i=1}^{S} Pi * Ln \cdot Pi$$

Evenness $$J = \sum_{i=1}^{S} \frac{H}{LnS}$$

n_i = the number of individuals in species i; the abundance of species i.
N = the total number of individuals.
Pi = number of Pilou. The relative abundance of each species, calculated as the proportion of individuals of a given species to the total number of individuals in the community: n_i/N.
S = the number of species (species richness).

In this report we will refer to the Shannon Wiener index as Shannon-diversity. In this report Shannon-diversity and evenness were determined for birds, fish and macrobenthos data. The macrobenthos data showed presence of very high numbers of *Hydrobia ulvae* in 2001 and 2002. The Shannon Wiener index is sensitive to large differences in evenness between species and therefore can give a misleading impression of low species richness. Therefore data of this species were removed in all years.

Besides biodiversity and evenness, species richness and abundance are also expressed, where richness is the number of species and abundance the amount of individuals within a group or subgroup.

2.3.3 Statistical analysis

Time series were analysed for species groups and feeding guilds in the Oosterschelde using TrendSpotter version 6.4. This is a program that is based on structural time series analysis in combination with the Kalman filter. The program identifies periods with significant increases or decreases from annual fluctuations, by estimating smoothed population numbers for a time series with equidistant measurements over time. TrendSpotter also estimates the standard deviations of the smoothed population numbers. Finally, it estimates the standard deviations of the differences between consecutive time points. The estimation of confidence intervals is based on the deviations of time point values from the smoothed line. A more detailed description of the method can be found in Visser (2004) and Soldaat *et al.* (2007). The advantage is that this method takes account of serial correlation and provides confidence limits that enable to test changes in abundance, richness, Shannon-diversity and evenness. R (version 2.13.1) was used for batch processing and for the statistical analyses and production of graphs.

When considering trophic guilds of fish, detritivores were left out of the analysis because only one taxa (*Mugilidae*) was recorded in three years only (1973, 1977 and 2001) which do not result in representative data using TrendSpotter.

Calculated indices were analysed in TrendSpotter and modelled values were plotted and are shown in the Chapter 3 (Results). Some time series in model values were expressed as 'relative change'. Values were set to 100% in the first year, and for the following years the relative change in percentage of the value in the first year was plotted. The aim was to make proportional changes more apparent, and to be able to compare changes in different groups. The relative change was calculated as follows:

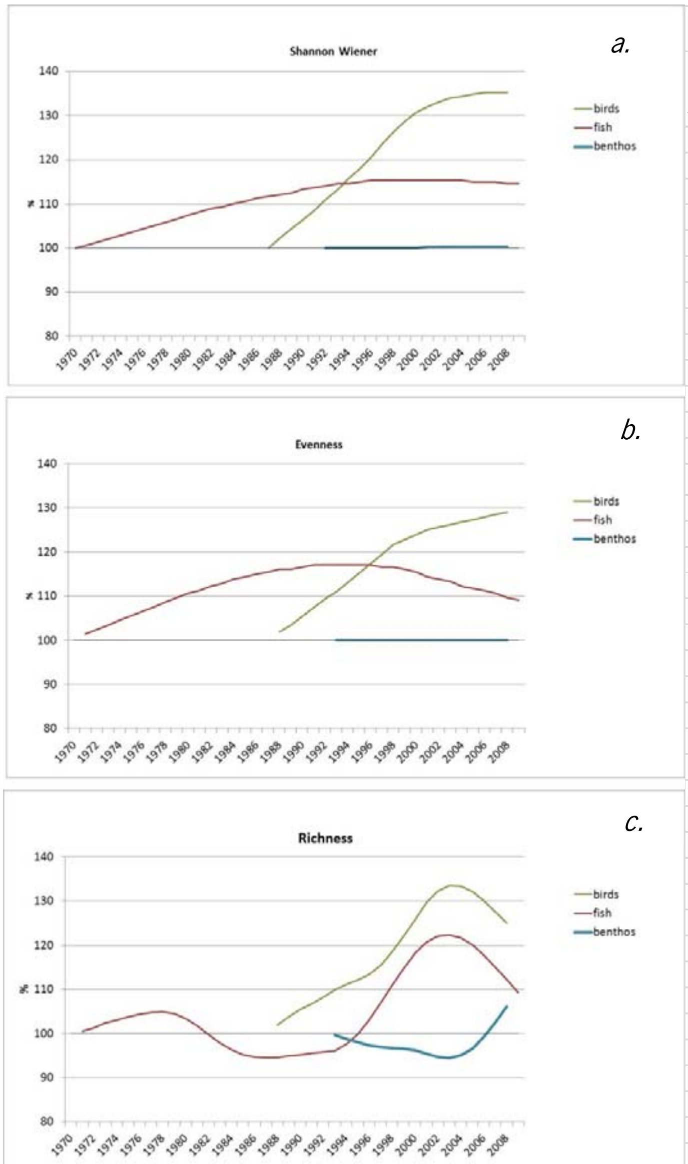
$$D_i = 100\% + \left(\frac{y_i - y_o}{y_o} \text{ x } 100\% \right)$$

Where D_i is the relative change in year i, y_i is the value in year i, and y_0 is the value in the first year (for which the relative change is set at 100%).

3 Results

3.1 General overview of birds, fish and benthos

Figure 7 displays time series of birds, fish and benthos showing trends in Shannon-diversity, evenness and richness. Birds show a significant increase in Shannon-diversity and evenness for the period of 1988-2002, after which the trend levelled off. For the years 1998 - 2001 this corresponds with an increase in species richness. The figures show a slight decrease in fish species richness in the period of 1980-1989 (non-significant), which coincides with the construction of the storm surge barrier and Oesterdam in the period 1979 – 1986. Species richness among fish increased again in the period 1996-2000. Species richness among birds and fish seem to decrease from 2003 onward where benthos data show an increase. These changes, however, were not significant.

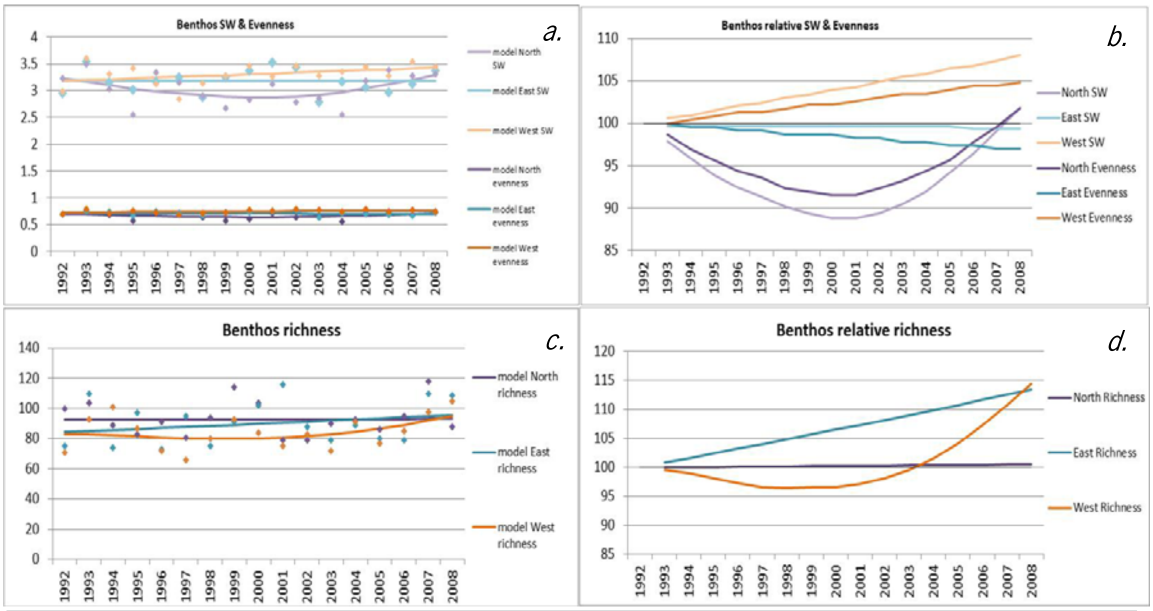


	SW			Evenness			Richness		
year	birds	fish	benthos	birds	fish	benthos	birds	fish	benthos
1970		0			0			0	
1971		0			0			0	
1972		0			0			0	
1973		0			0			0	
1974		0			0			0	
1975		0			0			0	
1976		0			0			0	
1977		0			0			0	
1978		0			0			0	
1979		0			0			0	
1980		0			0			0	
1981		0			0			0	
1982		0			0			0	
1983		0			0			0	
1984		0			0			0	
1985		0			0			0	
1986		0			0			0	
1987	0	0		0	0		0	0	
1988	+	0		+	0		0	0	
1989	+	0		+	0		0	0	
1990	+	0		+	0		0	0	
1991	+	0		+	0		0	0	
1992	+	0	0	+	0	0	0	0	0
1993	+	0	0	+	0	0	0	0	0
1994	+	0	0	+	0	0	0	0	0
1995	+	0	0	+	0	0	0	0	0
1996	+	0	0	+	0	0	0	+	0
1997	+	0	0	+	0	0	0	+	0
1998	+	0	0	+	0	0	+	+	0
1999	+	0	0	+	0	0	+	+	0
2000	+	0	0	+	0	0	+	+	0
2001	+	0	0	+	0	0	+	0	0
2002	+	0	0	+	0	0	0	0	0
2003	0	0	0	0	0	0	0	0	0
2004	0	0	0	0	0	0	0	0	0
2005	0	0	0	0	0	0	0	0	0
2006	0	0	0	0	0	0	0	0	0
2007	0	0	0	0	0	0	0	0	0
2008	0	0	0	0	0	0	0	0	0
2009		0	0		0	0		0	0

Figure 7: Time series of birds, fish and benthos showing Shannon Wiener (a) and evenness (b) index and species richness (c). Data series are expressed in relative in- or decrease over time. Significant changes are indicated as follows: + green = significant increase, - red = significant decrease, 0 = no (detectable) trend.

Benthos

Shannon-diversity of benthic macrofauna, subdivided by the Northern, Eastern and Western compartments remains high between 2.5 and 3.5 in the period of 1992-2008 (Figure 8). The benthic community is relatively uneven with an evenness around 0.5-1.0. A high species richness causes the high score in Shannon diversity. A lower evenness is explained by many rare species which occur at very low number and few species that occur in very high numbers. Relative richness in the Western and Eastern compartments increases with 14% and 13% respectively but these changes were not significant.



year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Benthos North																	
SW	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Evennes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Richness	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Benthos East																	
SW	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Evennes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Richness	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Benthos West																	
SW	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Evennes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Richness	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 8: Time series of benthos in different areas of the Oosterschelde (north, east and west) showing Shannon-diversity/evenness and relative Shannon-diversity/evenness (a,b) and richness and relative richness (c,d). Shown here are the TrendSpotter models (a,c) and relatives changes in modelled values (b,d). Significant changes are indicated as follows: + green = significant increase, - red = significant decrease, 0 = no (detectable) trend.

3.2 Birds trophic groups

Figure 9 shows time series of bird abundance and richness (absolute and relative values) and breeding bird abundance, for the different trophic guilds. Benthivores are highest in number followed by herbivores, omnivores, piscivores and carnivores. For the breeding birds, the omnivores were counted most frequently. Annex 3.1 and 3.2 shows time series of counted values and changes in abundance in species per trophic group of birds and breeding birds respectively.

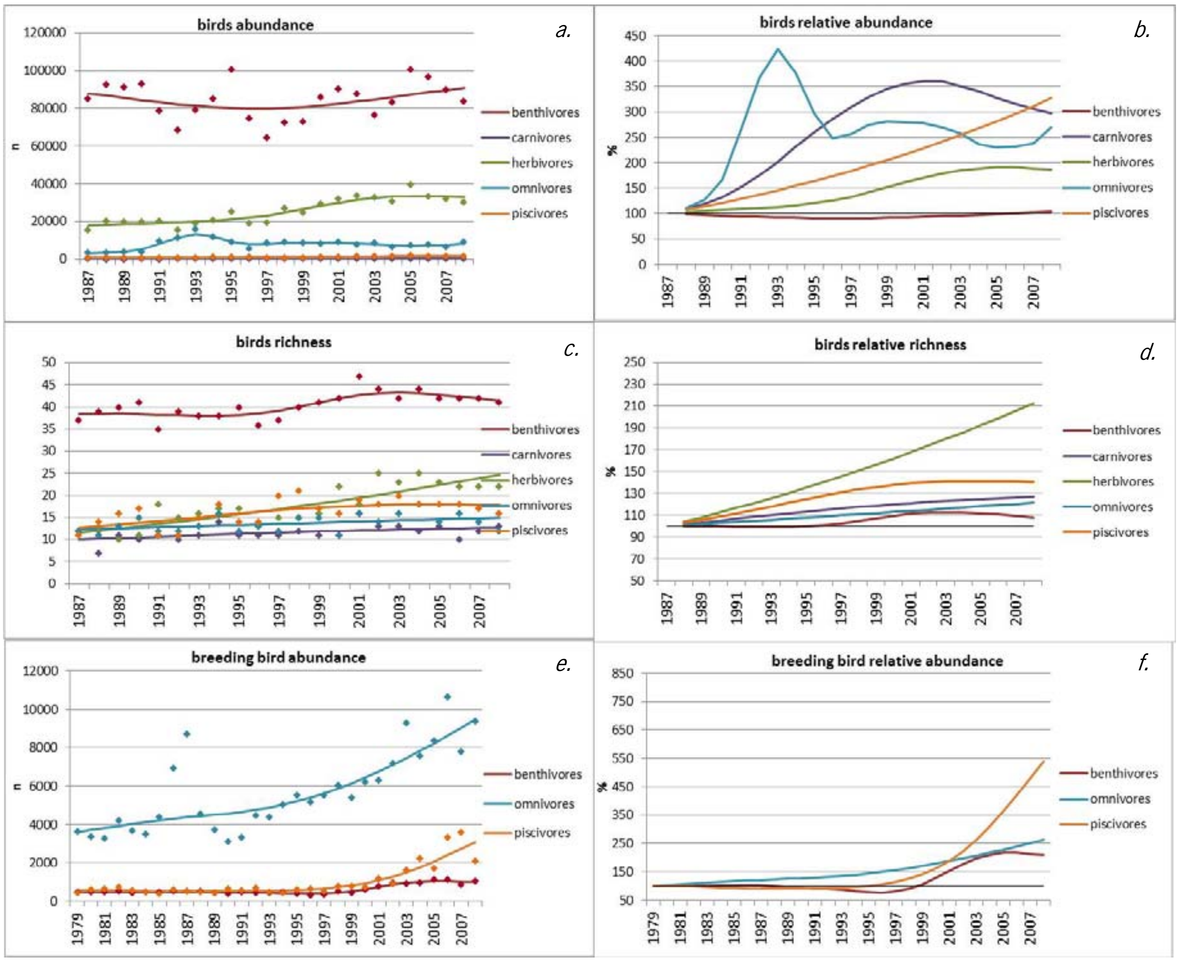
Benthivore abundance remains constant over time. Dominant species are Oystercatcher, Dunlin, Knot, Curlew, Lapwing, Bar-tailed Godwit and Grey Plover. Despite the stable trend in benthivore abundance, Oystercatchers show a remarkable decline of 51% in the period of 1987-2008. On the other hand, numbers of several other species increased significantly, such as Curlew, Knot and Sanderling. Benthivore breeding birds show a significant increase between 1998-2004 mainly caused by an increase in numbers of the Avocet. Richness also remains constant over time with a slight increase in 1998-2000.

Carnivores are low in number but show a significant increase in abundance in 1990-1998. Dominant species are Kestrel, Buzzard and Marsh Harrier. Richness also increases in 1992-1998.

Dominant species of herbivores are Wigeon, Brent Goose and Mallard. Herbivore abundance gradually increases/d (1996-2001) mainly caused by growing numbers of Barnacle Goose, Greylag Goose and Wigeon.

Omnivore richness increases significantly in 1988-2008. Dominant species are Black-headed Gull, Common Gull, Shoveler, Coot, Great black-backed gull, Black-backed gull and Tufted Duck. Abundance in omnivores shows a remarkable peak between 1990-1995 caused by exceptionally high counts of Herring gull (see Annex 3.1). Breeding birds also show a peak in 1983-1989 caused by the Black-headed Gull. Both peaks are probably caused by irregular methods and conditions during field counts. Also gull are counted in January which is in a time of the year that conditions are less ideal for counting. The significant increase in omnivore breeding bird numbers is mainly caused by Black-headed Gull, Herring Gull and Lesser black-backed gull.

Piscivore abundance increase significantly in 1988-2008. Also breeding birds show significant increase in 1997-2008. Dominant species of piscivores are Red-breasted Merganser, Great-crested Grebe, Cormorant, Little Grebe, Black-necked Grebe, Little Egret and Grey Heron. These species are mainly responsible for the increase in bird abundance. The Common Tern and Sandwich Tern are responsible for the increase in breeding bird abundance, although Sandwich Tern shows a remarkable peak which suggests irregular counts. Piscivore richness increased in 1993-1998.



year	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Birds abundance																															
benthivores									**0**	**0**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
carnivores									0	0	0	+	+	+	+	+	+	+	+	+	0	0	0	0	0	0	0	0	0	0	
herbivores									0	0	0	0	0	0	0	0	0	+	+	+	+	+	+	+	0	0	0	0	0	0	
omnivores									0	0	0	+	+	+	0	0	-	0	0	0	0	0	0	0	0	0	0	0	0	0	
piscivores									0	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	
Breeding bird abundance																															
benthivores	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+	+	+	+	+	+	+	0	0	0	0	
omnivores	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	
piscivores	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+	+	+	+	+	+	+	+	+	+	+	+	
Birds richness																															
benthivores									0	0	0	0	0	0	0	0	0	0	0	+	+	+	0	0	0	0	0	0	0	0	
carnivores									0	0	0	0	0	+	+	+	+	+	+	+	0	0	0	0	0	0	0	0	0	0	
herbivores									0	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	
omnivores									0	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	
piscivores									0	0	0	0	0	0	+	+	+	+	+	0	0	0	0	0	0	0	0	0	0	0	

Figure 9: Time series of birds and breeding birds categorized in trophic groups showing bird abundance/richness (a,c) and relative abundance/richness (b,d) and breeding bird abundance (e) and relative abundance (f) of trophic groups. Due to the low number of species of breeding bird couples, richness is not considered. Significant changes are indicated as follows: + green = significant increase, - red = significant decrease, 0 = no (detectable) trend.

3.3 Fish trophic groups

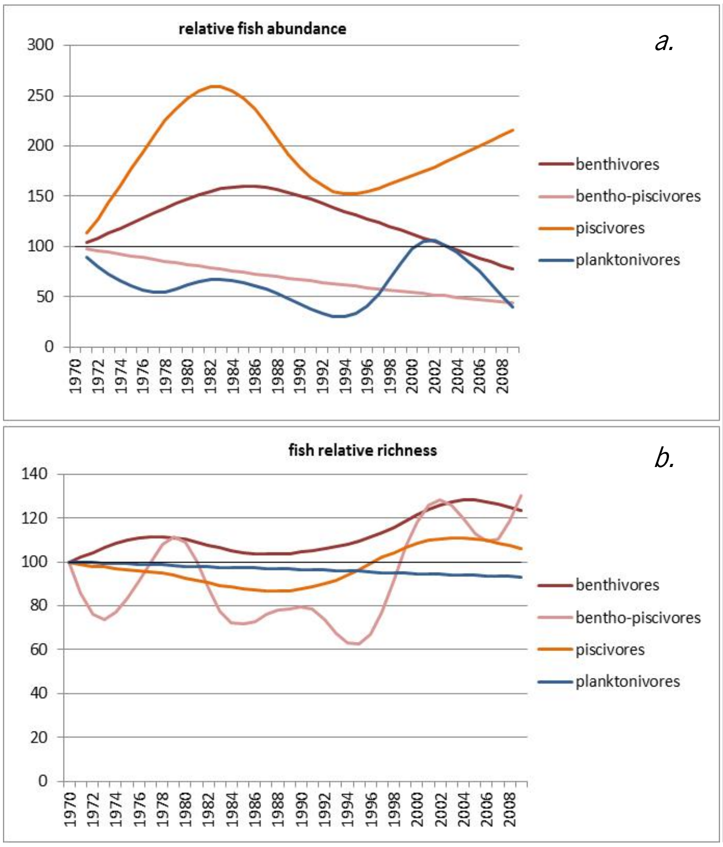
Figure 10 shows time series of fish relative abundance (a) and relative richness (b). Community structure is composed of a large number of benthivores followed by planktonivores, bentho-piscivores/piscivores and detritivores respectively. Annex 3.3 shows time series of changes in abundance in species per trophic group of fish.

Benthivore abundance shows no significant change. Dominants species are European plaice (*Pleuronectes platessa*), Common dab (*Limanda limanda*), Common sole (*Solea solea*) and Pouting (*Trisopterus luscus*). Richness showed a significant increase between 1998-2001.

Bentho-piscivore also show no significant change in abundance. Most abundant species are European eel (*Anguila anguila*) and Shorthorn sculpin (*Myoxocephalus scorpius*). Richness showed a significant increase between 1997-2001.

Piscivore abundance as shows no significant change. Whiting (*Merlangius merlangus*) is most abundant and to a lesser degree followed by Cod (*Gadus morhua*), Horse mackarel (*Trachurus trarchurus*) and Sea bass (*Dicenthrarchus labrax*). Richness showed a significant increase between 1995-1998.

Planktivore abundance shows a significant increase in 1997-1999 and remains constant in richness. This increase in abundance could be related to higher algae availability as a consequence of increased visibility. Dominant species are *Pomatoschistus* sp. followed by Herring (*Clupea harengus*) and Sprat (*Sprattus sprattus*).



	Fish abundance					Fish richness				
year	benthivores	bentho-piscivores	detritivores	piscivores	planktonivores	benthivores	bentho-piscivores	detritivores	piscivores	planktonivores
1970	0	0	0	0	0	0	0	0	0	0
1971	0	0	0	0	0	0	0	0	0	0
1972	0	0	0	0	0	0	0	0	0	0
1973	0	0	0	0	0	0	0	0	0	0
1974	0	0	0	0	0	0	0	0	0	0
1975	0	0	0	0	0	0	0	0	0	0
1976	0	0	0	0	0	0	0	0	0	0
1977	0	0	0	0	0	0	0	0	0	0
1978	0	0	0	0	0	0	0	0	0	0
1979	0	0	0	0	0	0	0	0	0	0
1980	0	0	0	0	0	0	0	0	0	0
1981	0	0	0	0	0	0	0	0	0	0
1982	0	0	0	0	0	0	-	0	0	0
1983	0	0	0	0	0	0	-	0	0	0
1984	0	0	0	0	0	0	0	0	0	0
1985	0	0	0	0	0	0	0	0	0	0
1986	0	0	0	0	0	0	0	0	0	0
1987	0	0	0	0	0	0	0	0	0	0
1988	0	0	0	0	0	0	0	0	0	0
1989	0	0	0	0	0	0	0	0	0	0
1990	0	0	0	0	0	0	0	0	0	0
1991	0	0	0	0	0	0	0	0	0	0
1992	0	0	0	0	0	0	0	0	0	0
1993	0	0	0	0	0	0	0	0	0	0
1994	0	0	0	0	0	0	0	0	0	0
1995	0	0	0	0	0	0	0	0	+	0
1996	0	0	0	0	0	0	0	0	+	0
1997	0	0	0	0	+	0	+	0	+	0
1998	0	0	0	0	+	+	+	0	+	0
1999	0	0	0	0	+	+	+	0	0	0
2000	0	0	0	0	0	+	0	0	0	0
2001	0	0	0	0	0	+	0	0	0	0
2002	0	0	0	0	0	0	0	0	0	0
2003	0	0	0	0	0	0	0	0	0	0
2004	0	0	0	0	0	0	0	0	0	0
2005	0	0	0	0	0	0	0	0	0	0
2006	0	0	0	0	0	0	0	0	0	0
2007	0	0	0	0	0	0	0	0	0	0
2008	0	0	0	0	0	0	0	0	0	0
2009	0	0	0	0	0	0	0	0	0	0

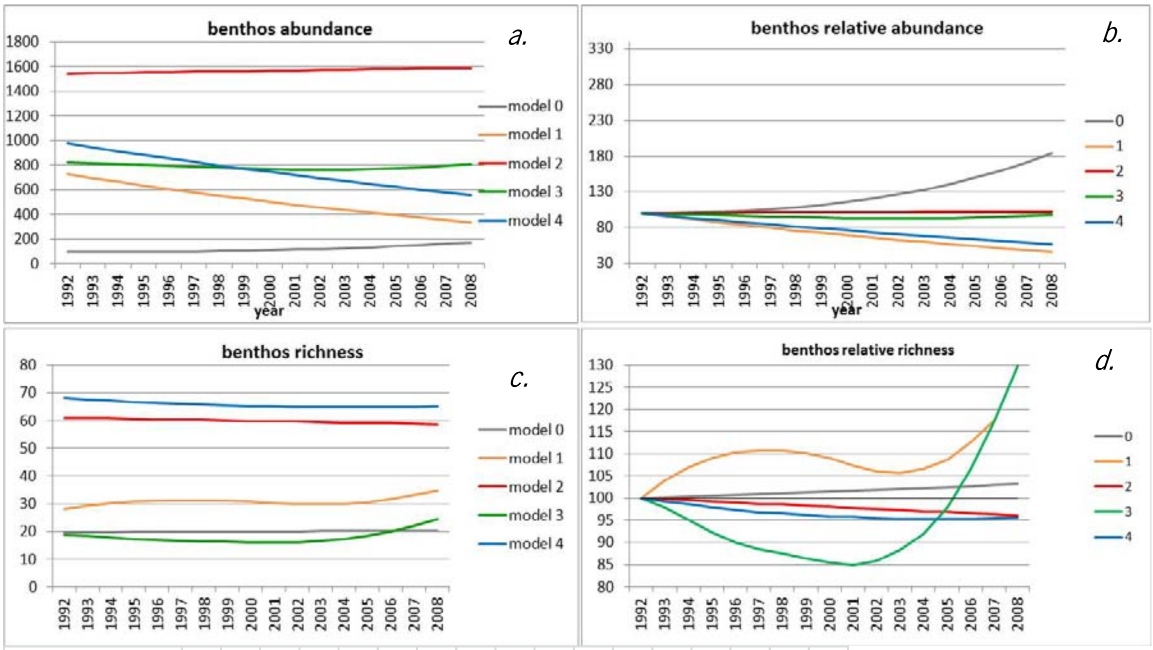
Figure 10: Time series of fish categorized in trophic groups showing relative abundance (a) and relative richness (b) trophic groups. Significant changes are indicated as follows: + green = significant increase, - red = significant decrease, 0 = no (detectable) trend.

3.4 Benthic macrofauna trophic groups

Figure 11 shows time series of benthos abundance and richness. Figure 11a gives insight in abundance distribution. Interface-/subsurface deposit-/facultative suspension feeders are most abundant followed by subsurface deposit feeders, predators/omnivores/scavengers and finally suspension-/filter feeders. Annex 3.4 shows time series of changes in abundance in species per trophic group of fish.

Category 0 contains miscellaneous taxa that were not identified to species level and/or were not assigned to a trophic guild. This group contained species and taxa like *Aora typica*, *Myrranida langerhansi*, Caprellidae and *Microdeutopus anomalus* and were recorded in very low numbers.

Category 1 suspension-/filter feeders show no change in richness and a significant decrease in abundance over the whole sampled period (1993-2008). The dataset shows a high abundance of Sea squirt (*Styela clava)* Basket shell (*Corbula gibba*) and Pacific Oyster (*Crassostrea gigas)*.



year		1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Benthos abundance																		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	4	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Benthos richness																		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	+	+	+	+
	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 11: Time series of benthos categorized in trophic groups showing abundance and relative abundance (a,b) and richness and relative richness (c,d) of trophic groups: 0= not determined to species level, 1= suspension or filter feeder, 2= interface- , surface deposit- and facultative suspension feeder, 3= subsurface deposit feeder, grazer, 4= predator, omnivore, scavenger. Significant changes are indicated as follows: + green = significant increase, - red = significant decrease, 0 = no (detectable) trend.

Category 2 interface- /surface deposit-/facultative suspension feeders show no change in abundance and richness over time. The dataset shows a high abundance of bristle worms (*Aphelochaeta marioni, Pygospio elegans, Lanic conchilega, Spiophanes bombyx*) and White furrow shell (*Abra alba*).

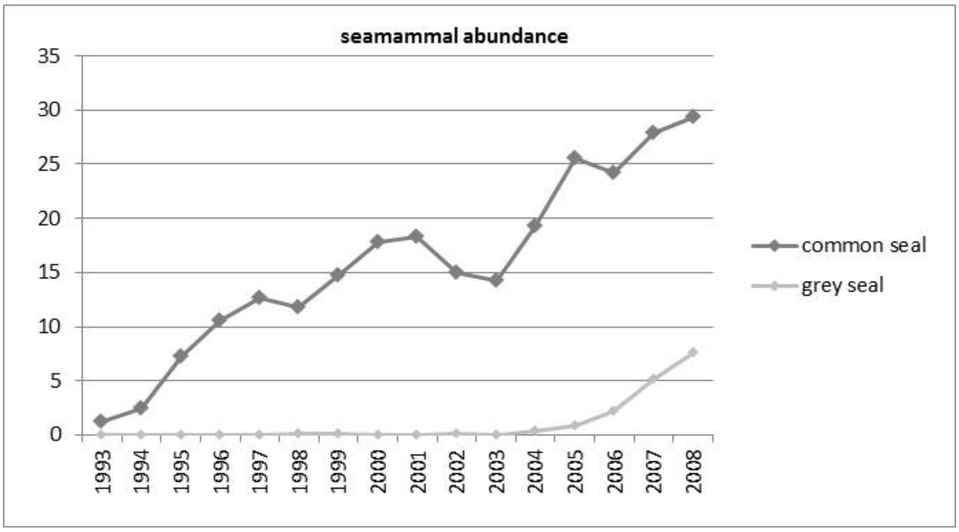
Category 3 subsurface deposit feeders and grazers, show a constant abundance and a significant increase in richness from 2005. The dataset shows high abundance of worms (*Scoloplos armiger, Capitella capitata*), and a mollusc (*Cyanoplax cuverna*).

Category 4 predators, omnivores and scavengers are a relatively large group of species that occur in relatively low abundance. Abundance of species shows a significant decreasing trend in 1993-2008 and no change in richness. Dominant species are polychaete worms (*Lepidonotus squamatus, Nephtys hombergii, Malmgreniella lunulata and Subadyte pellucida*), and anemones (Actiniaria).

3.5 Specific habitats & species

3.5.1 Sea mammals

Common seal (*Phoca vitulina*) and Grey seal (*Halichoerus grypus*) increased significantly over the last decennium (Figure 12). Harbour porpoise *(Phocoena phocoena)* were not included in the analysis because recordings in two years (2007 and 2008) only. However, numbers are increasing in recent years. In the summer of 2011 a population of 61 individuals (Stichting Rugvin 2011) was counted in the Oosterschelde. Also it is known that Harbour porpoises breed in the Oosterschelde.



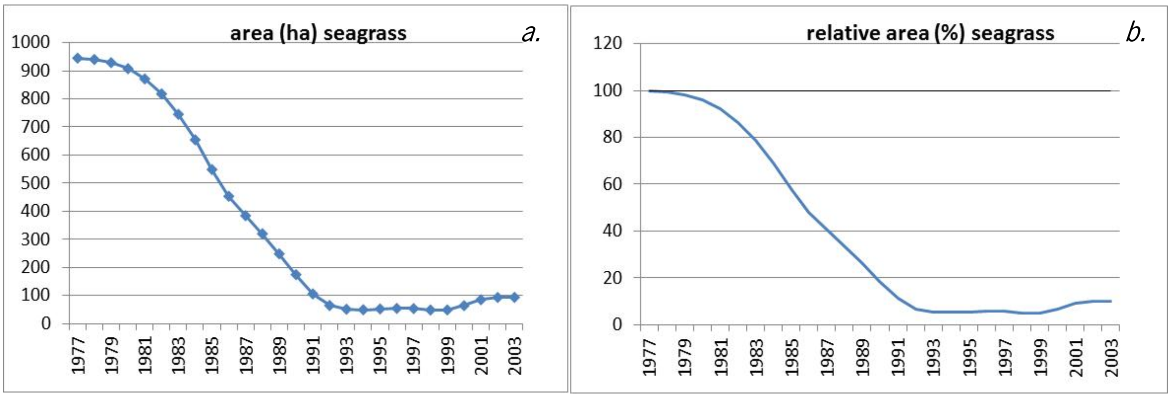
year	Common seal	grey seal
1993	0	
1994	+	
1995	+	
1996	+	
1997	+	
1998	0	0
1999	+	+
2000	+	0
2001	0	0
2002	0	0
2003	0	0
2004	+	+
2005	+	+
2006	0	+
2007	0	+
2008	0	+

Figure 12: Time series of sea mammal abundance of Common seal and Grey seal. The values are based on seasonal averages based on counts. Significant changes are indicated as follows: + green = significant increase, - red = significant decrease, 0 = no (detectable) trend.

3.5.2 Seagrass

The area of seagrass (Figure 13a,b) decreased significantly in 1984-1993 from 657 to 63 hectares, a decline of 90%.

Mapping of Seagrass vegetations was done based on three vegetation types: vegetation with Dwarf eelgrass (*Zostera noltii*), vegetation with Eelgrass (*Zostera marina*) and vegetation with Widgeon grass (*Ruppia maritima*) with dominant species Sea lettuce (*Ulva lactuca*), other green algae (*Chlorophyta*), and brown algae (*Phaeophyta*).



year	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Seagrass	0	0	0	0	0	0	0	-	-	-	-	-	-	-	-	-	-	0	0	0	0	0	0	+	+	0	0

Figure 13: Time series of area of seagrass (a) and relative change in area of seagrass (b). Significant changes are indicated as follows: + green = significant increase, - red = significant decrease, 0 = no (detectable) trend.

3.5.3 Saltmarshes

Figure 14 shows time series of saltmarsh coverage in different regions of the Oosterschelde (a,b,c) and of the total Oosterschelde (d). North and Kom show an increase in 1938-1978 and 1910-1960 respectively. After this period data show a constant decline. Overall area of salt marshes in the whole Oosterschelde showed a decreasing trend (R^2 = 0,72).

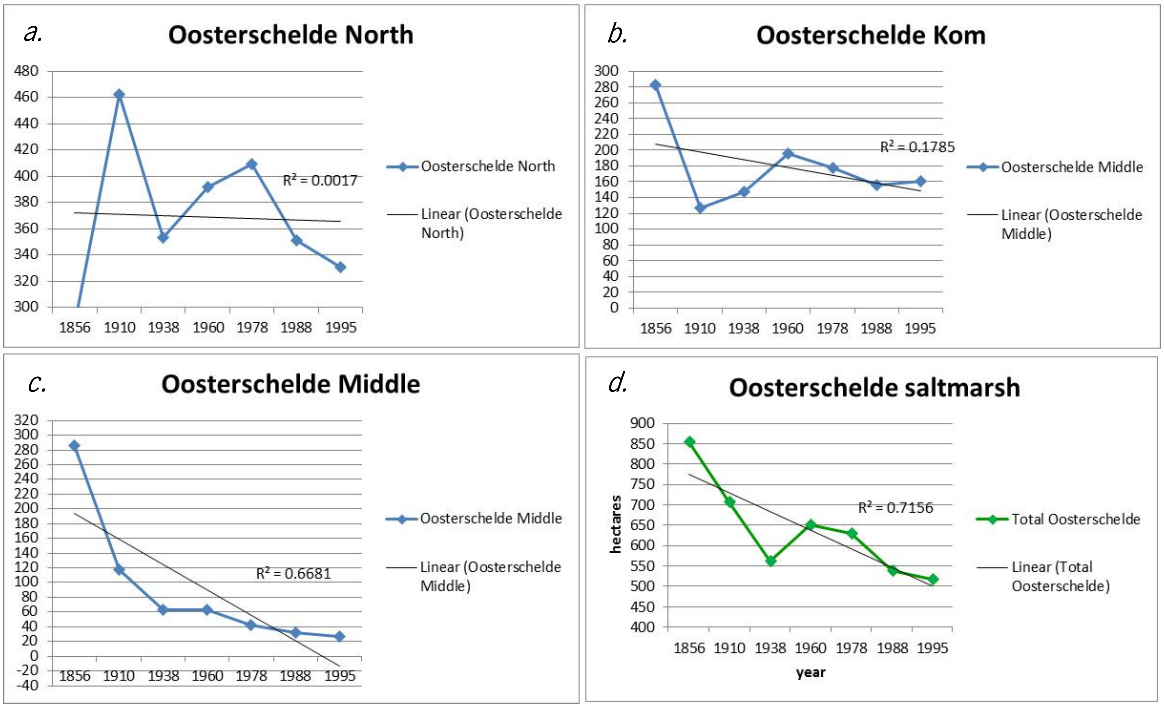


Figure 14: Area of saltmarshes in hectares based on a study by Van der Pluijm and De Jong (1998). Subareas of the Oosterschelde North (a), Kom in the east (b) and Middle (c) and of the whole Oosterschelde (d).

4 Conclusions and discussion

This chapter describes the preliminary conclusions and discussion.

Monitoring of birds, benthos en sea mammals started after completion of the storm surge barrier. It is therefore not possible to study direct effects of (construction of) the storm surge barrier on these groups from the available dataset. We did include bird counts from the period before completion of the storm surge barrier (Meininger *et al.* (1985)), but these data were not suitable for calculation of Shannon-diversity, evenness and richness because only a selection of bird species seemed to have been counted. These data will be added in the final report in 2012. The area of saltmarshes and seagrass meadows has been monitored for a longer period, and both show a decline which may be caused by long-term changes in tidal currents and erosion of tidal flats ('sediment starvation'), as well as other long-term physical and chemical changes (e.g. salinity, turbidity, …) as a consequence of the Delta project.

Birds

Bird biodiversity increased significantly, from a Shannon index of 2.15 in 1988 to 2.9 in 2002. Species richness also increased, from 84 species in 1987 to 105 species in 2008.

The increase in abundance in breeding birds could be related to a large scale nature development project, called "Plan Tureluur", that was executed in 1999. This plan was designed to compensate for the loss of intertidal flats as a consequence of sand starvation. The total plan aims to develop 850 hectares of salt, inland nature along the borders of the Oosterschelde mainly on Schouwen-Duivenland. Between 1999 and 2009, 510 hectares of nature divided over numerous larger and smaller areas was developed. These areas are of high importance as foraging and breeding grounds for birds. It is likely that the growth of breeding bird couples was supported by this increase in habitat. Especially the Pied avocet showed high increase in abundance. It has to be underlined here that Plan Tureluur concerns inland, saltwater nature areas lacking tidal influence and not to be confused with saltmarshes that are part of the estuarine ecosystem.

The explanation for the increase in bird abundance is more difficult to relate. The significant increase in piscivore bird abundance ('88-'08) and richness ('97-'08 for birds) could be explained due to the fact that the Oosterschelde became less turbid with the construction of the storm surge barrier. With increased visibility their food source of fish are more easily preyed upon. Carnivores and herbivores also increase in abundance ('90-'98,'96-'01 resp.) and richness ('92-'98, '98-'08 resp.). Omnivores show a constant significant increase in richness but their abundance remains relatively constant. Benthivores show now change in abundance and a slight increase in richness for the period of 1998-2000. The increase in abundance and richness of several trophic guilds could be related to an environmental management aimed at conservation of species. For example more nesting boxes are placed that enhances breeding of carnivores. Also an increase of habitat diversity along the Oosterschelde due to nature development probably contributed.

Benthivore, omnivore and piscivore breeding bird abundance increased significantly ('99-'04, '94-'08, '97-'08 resp.) this could be related to an increase in nature area and a combination of the above mentioned factors.

Fish

Fish show little change. Species richness decreases in the period of 1980-1989, which coincides with the construction of the storm surge barrier and Oesterdam in the period 1979 – 1986. Although this change was not significant, fish may have been affected by the disturbance caused by the construction of dams. Species richness among fish increased significantly in the period 1996-2000.

Abundance and richness within trophic guilds of fish also show little change. Planktivore abundance increases for a short period in 1997-1999. This may be related to increased availability of food (algae) as a consequence of higher visibility in the Oosterschelde. Benthivore, bentho-piscivore and piscivore richness increases ('98-'01,'97-'99 ,'95-'98 resp.) whereas bentho-piscivores already decreased in the period 1982-'83.

The data on fish (obtained from the IMARES database) show a selection of mainly the smaller species due to a combination of low fishing speed and fine mesh size (20 mm) during sampling by 3 m-beamtrawl.

Piscivores are amongst the faster swimming fish. The low fishing speed during sampling could explain why no significant trend in abundance can be concluded, because low numbers were caught. Piscivore richness did increase significantly ('95-'98).

Benthos

Benthic macrofauna show a constant high Shannon index of 2.5 - 3.5. The reason for this score is high species richness. The community is very uneven (0.5-1.0) due to many species with low abundance and few species with high abundance.

Trophic guilds of suspension/ filter feeders (category 1) and predators/predators, omnivores/ and scavengers (category 4) showed a constant significant decrease in abundance (1993-2008). Subsurface deposit feeders and grazers, (category 3) show an increase in richness in 2005-2008. Interface-, surface deposit- and facultative suspension feeders (category 2) showed no change.

It should be kept in mind that sampling methods for macrobenthic fauna within the MAWTL programme do not give a complete picture of macrobenthic fauna present in the Oosterschelde estuary. For larger animals that occur in lower densities (e.g. the lugworm Arenicola marina, shellfish such as cockles *Cerastoderma edule* and *Mya arenaria*), the sampled surface is too small. The method is also not well suited to highly mobile epifauna such as crabs and shrimp. Finally, the sampling points generally do not include hard substrates such as oyster beds, that do harbour a high biomass and high species richness.

Although analysis of the MWTL dataset did not reveal large changes that may be attributed to the Delta project or other human induced changes, this does not necessarily mean that the benthic community did not change. The largest changes may have occurred on hard substrates. Since the 1970's, cover by beds of the Pacific oyster has been increasing. These oyster beds increase habitat heterogeneity on the small scale of the oyster bed, but also on the larger scale of the estuary (Troost 2010). Pacific oysters create structurally complex structures that offer settlement opportunities and shelter for many different organisms. Because in most reefs oyster patches are alternated with bare patches, also many species living in soft sediments are present. De Kluijver and Dubbeldam (2003) monitored hard substrates such as (mainly) dikes. The main changes they found were due to the expansion of the Pacific oyster. They showed that biodiversity on hard substrates decreases with an increasing cover of Pacific oysters. However, Pacific oyster reefs have also been demonstrated to increase species richness and biodiversity when they occur on soft sediments (Kochman, Buschbaum *et al.* 2008; Markert, Wehrmann *et al.* 2009; Troost 2009). They also form a suitable habitat for introduced (exotic) species that are from the same area of origin: the North-West Pacific.

Sea mammals

Sea mammal abundance increased significantly. The Common seal grew in abundance (significant in '94-'97,'99,'00,'04,'05) and although less abundant, in recent years ('04-'08) numbers of the Grey seal also showed a significant increasing trend.

Until the 1970's numbers of Common seal severely declined (Compendium voor de Leefomgeving 2012). The most important cause was the accumulation of heavy metals (PCB's) in fish that was consumed by seals. Also they were hunted upon until 1961. In addition the construction of the Deltaworks also caused disturbance. From 1980 numbers started increasing despite a virus that affected seals in 1988 and 2002 and killed around 50% of the seals, the population recovered (Compendium voor de Leefomgeving 2012).

Seagrass

This study shows that the area of seagrass in the Oosterschelde decreased significantly in 1984-1993 from 657 to 63 hectares, a decline of 90%. The exact cause of this decline is uncertain and could have many causes. A study by Kamermans *et al.* (1999) showed a relation between the increased salinity as a consequence of the Grevelingendam that considerately reduced freshwater inflow (as also in the Oosterschelde) and the decreased area of *Zostera marina* although this relation was not significant.

Saltmarshes

The reduction in area of saltmarshes could be related to the construction of the Deltaworks. The area of saltmarshes grew in some regions of the Oosterschelde in the first half of the 20th century (East until 1960 and North until 1978) by natural accretion by sedimentation and succession. After this period results show a constant decline. Overall area of salt marshes in the whole Oosterschelde showed a decreasing trend (R^2 = 0,72). By the completion of the dams Markiezaatkade (1983), Oesterdam (1986), Oosterschelde storm surge barrier (1986) and Philipsdam (1987) area of saltmarshes decreased due to construction and because a part of the Oosterschelde became a fresh water lake with no tide (Zoommeer and Markiezaat). In the following years erosion occurred in the Oosterschelde causing a gradual decrease in area of saltmarshes (Smaal and Boeije 1991). Later it became apparent that the storm surge barrier caused a sediment shortage due to a decreases tidal water volume and tidal currents (a phenomena called "sand starvation"). During storms sediment of the tidal flats is eroded away, whereas tidal currents are too weak to bring back the sediments on the tidal flats. As a consequence the sediments are transported from the higher intertidal zone, salt marshes, into the gullies, and many tidal flats are slowly eroding.

Follow up

This is a progress report that shows preliminary outcomes and conclusions of trends in biodiversity in the Oosterschelde. These are the first outcomes of the Oosterschelde that are part of a broader research that also concerns similar analysis of lakes Grevelingenmeer, Veerse Meer and Haringvliet. The final report will contain more in depth data analysis and a more elaborated interpretation. We will also focus on the relation of biodiversity trends between water bodies also in relation to the delta as a whole and how the Delta Works have affected these trends. Finally we will discuss the outcomes in the framework of current policy and give implications for management.

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Annex 1 Determined species and their categorization in feeding guilds

Bird species

Scientific name	English name	Dutch name	Trophic guild
Phalacrocorax carbo	Great Cormorant	Aalscholver	piscivoren
Alca torda	Razorbill	Alk	piscivoren
Anas americana	American Wigeon	Amerikaanse Smient	herbivoren
Falco sparverius	American Kestrel	Amerikaanse Wintertaling	omnivoren
Limnodromus semipalmatus	Asiatic Dowitcher	Aziatische Goudplevier	benthivoren
Anas bahamensis	Bahama Pintail	Bahamapijlstaart	omnivoren
Tadorna tadorna	Common Shelduck	Bergeend	benthivoren
Circus cyaneus	Hen Harrier	Blauwe Kiekendief	carnivoren
Ardea cinerea	Grey Heron	Blauwe Reiger	piscivoren
Tryngites subruficollis	Buff-breasted Sandpiper	Blonde Ruiter	benthivoren
Muscicapa boehmi	Böhm's Flycatcher	Bokje	benthivoren
Charadrius hiaticula	Ringed Plover	Bontbekplevier	benthivoren
Grallaria varia	Variegated Antpitta	Bonte Kraai	omnivoren
Calidris alpina	Dunlin	Bonte Strandloper	benthivoren
Falco subbuteo	Northern Hobby	Boomvalk	carnivoren
Tringa glareola	Wood Sandpiper	Bosruiter	benthivoren
Branta leucopsis	Barnacle Goose	Brandgans	herbivoren
Limicola falcinellus	Broad-billed Sandpiper	Breedbekstrandloper	benthivoren
Bucephala clangula	Common Goldeneye	Brilduiker	benthivoren
Circus aeruginosus	Western Marsh Harrier	Bruine Kiekendief	carnivoren
Buteo buteo	Eurasian Buzzard	Buizerd	carnivoren
Branta canadensis	Canada Goose	Canadese Gans	herbivoren
Myioborus cardonai	Saffron-breasted Redstar	Caribische Flamingo	benthivoren
Tadorna ferruginea	Ruddy Shelduck	Casarca	herbivoren
Phoenicopterus chilensis	Chilean Flamingo	Chileense Flamingo	benthivoren
Tachybaptus ruficollis	Little Grebe	Dodaars	piscivoren
Rissa tridactyla	Black-legged Kittiwake	Drieteenmeeuw	piscivoren
Calidris alba	Sanderling	Drieteenstrandloper	benthivoren
Cepphus columba	Pigeon Guillemot	Duikeend	benthivoren
Anser erythropus	Lesser White-fronted Goo	Dwerggans	herbivoren
Larus minutus	Little Gull	Dwergmeeuw	omnivoren
Somateria mollissima	Eider	Eidereend	benthivoren
Meliphaga hindwoodi	Eungella Honeyeater	Europese Flamingo	benthivoren
Phoenicopterus ruber	Greater Flamingo	Flamingo spec.	benthivoren
Acanthis flavirostris	Twite	Frater	omnivoren
Podiceps cristatus	Great Crested Grebe	Fuut	piscivoren
Yuhina nigrimenta	Black-chinned Yuhina	Geelpootmeeuw	omnivoren
Podiceps nigricollis	Black-necked Grebe	Geoorde Fuut	piscivoren
Calidris melanotos	Pectoral Sandpiper	Gestreepte Strandloper	benthivoren
Pluvialis apricaria	European Golden Plover	Goudplevier	benthivoren
Phalaropus lobatus	Red-necked Phalarope	Grauwe Franjepoot	benthivoren
Anser anser	Greylag Goose	Grauwe Gans	herbivoren
Circus pygargus	Montague's Harrier	Grauwe Kiekendief	carnivoren
Tringa nebularia	Common Greenshank	Groenpootruiter	benthivoren
Phalaropus tricolor	Wilson's Phalarope	Grote Franjepoot	benthivoren
Limnodromus scolopaceus	Long-billed Dowitcher	Grote Grijze Snip	benthivoren

Scientific name	English name	Dutch name	Trophic guild
Catharacta skua	Great Skua	Grote Jager	carnivoor
Larus marinus	Greater Black-backed Gull	Grote Mantelmeeuw	omnivoren
Thalasseus sandvicensis	Sandwich Tern	Grote Stern	piscivoren
Mergus merganser	Goosander	Grote Zaagbek	piscivoren
Melanitta fusca	Velvet Scoter	Grote Zee-eend	benthivoren
Egretta alba	Great Egret	Grote Zilverreiger	piscivoren
Limosa limosa	Black-tailed Godwit	Grutto	benthivoren
Accipiter gentilis	Northern Goshawk	Havik	carnivoren
Scolopax rusticola	Eurasian Woodcock	Houtsnip	benthivoren
Gavia immer	Great Northern Diver	IJsduiker	piscivoren
Clangula hyemalis	Long-tailed Duck	IJseend	benthivoren
Calcarius lapponicus	Lapland Bunting	IJsgors	omnivoren
Alcedo atthis	River Kingfisher	IJsvogel	piscivoren
Anser indicus	Bar-headed Goose	Indische Gans	herbivoren
Morus bassanus	Northern Gannet	Jan Van Gent	piscivoren
Anas cyanoptera	Cinnamon Teal	Kaneeltaling	omnivoren
Calidris canutus	Red Knot	Kanoetstrandloper	benthivoren
Philomachus pugnax	Ruff	Kemphaan	benthivoren
Vanellus vanellus	Northern Lapwing	Kievit	benthivoren
Alle alle	Little Auk	Kleine Alk	piscivoren
Tringa flavipes	Lesser Yellowlegs	Kleine Geelpootruiter	benthivoren
Stercorarius parasiticus	Arctic Skua	Kleine Jager	piscivoren
Larus fuscus	Lesser Black-backed Gull	Kleine Mantelmeeuw	omnivoren
Charadrius dubius	Little Ringed Plover	Kleine Plevier	benthivoren
Anser brachyrhynchus	Pink-footed Goose	Kleine Rietgans	herbivoren
Calidris minuta	Little Stint	Kleine Strandloper	benthivoren
Egretta garzetta	Little Egret	Kleine Zilverreiger	piscivoren
Cygnus columbianus	Tundra Swan	Kleine Zwaan	herbivoren
Stercorarius longicaudus	Long-tailed Skua	Kleinste Jager	piscivoren
Recurvirostra avosetta	Pied Avocet	Kluut	benthivoren
Cygnus olor	Mute Swan	Knobbelzwaan	herbivoren
Bubulcus ibis	Cattle Egret	Koereiger	carnivoren
Larus ridibundus	Black-headed Gull	Kokmeeuw	omnivoren
Anser albifrons	White-fronted Goose	Kolgans	herbivoren
Grus grus	Common Crane	Kraanvogel	carnivoren
Anas strepera	Gadwall	Krakeend	herbivoren
Calidris ferruginea	Curlew Sandpiper	Krombekstrandloper	benthivoren
Netta rufina	Red-crested Pochard	Krooneend	herbivoren
Phalacrocorax aristotelis	Shag	Kuifaalscholver	piscivoren
Podiceps auritus	Slavonian Grebe	Kuifduiker	benthivoren
Aythya fuligula	Tufted Duck	Kuifeend	omnivoren
Platalea leucorodia	White Spoonbill	Lepelaar	benthivoren
Aix galericulata	Mandarin Duck	Mandarijneend	omnivoren
Fulica atra	Black Coot	Meerkoet	omnivoren
Stercorarius pomarinus	Pomarine Skua	Middelste Jager	carnivoor
Mergus serrator	Red-breasted Merganser	Middelste Zaagbek	piscivoren
Eudromias morinellus	Dotterel	Morinelplevier	benthivoren
Alopochen aegyptiacus	Egyptian Goose	Nijlgans	herbivoren

Scientific name	English name	Dutch name	Trophic guild
Ciconia ciconia	White Stork	Ooievaar	carnivoren
Calidris maritima	Purple Sandpiper	Paarse Strandloper	benthivoren
Gavia arctica	Black-throated Diver	Parelduiker	piscivoren
Anas acuta	Northern Pintail	Pijlstaart	herbivoren
Tringa stagnatilis	Marsh Sandpiper	Poelruiter	benthivoren
Gallinago media	Great Snipe	Poelsnip	benthivoren
Otus flammeolus	Flammulated Owl	Pontische Meeuw	omnivoren
Porzana porzana	Spotted Crake	Porseleinhoen	omnivoren
Ardea purpurea	Purple Heron	Purperreiger	piscivoren
Numenius phaeopus	Whimbrel	Regenwulp	benthivoren
Milvus milvus	Red Kite	Rode Wouw	carnivoor
Botaurus stellaris	Eurasian Bittern	Roerdomp	carnivoor
Podiceps grisegena	Red-necked Grebe	Roodhalsfuut	piscivoren
Branta ruficollis	Red-breasted Goose	Roodhalsgans	herbivoren
Gavia stellata	Red-throated Diver	Roodkeelduiker	piscivoren
Falco vespertinus	Western Red-footed Falcon	Roodpootvalk	carnivoren
Myiophobus roraimae	Roraiman Flycatcher	Ross Gans	herbivoren
Phalaropus fulicarius	Grey Phalarope	Rosse Franjepoot	benthivoren
Limosa lapponica	Bar-tailed Godwit	Rosse Grutto	benthivoren
Toxostoma rufum	Brown Trasher	Rosse Stekelstaart	omnivoren
Branta bernicla	Brent Goose	Rotgans	herbivoren
Buteo lagopus	Rough-legged Buzzard	Ruigpootbuizerd	carnivoren
Haematopus ostralegus	Palaearctic Oystercatcher	Scholekster	benthivoren
Falco peregrinus	Peregrine Falcon	Slechtvalk	carnivoren
Anas clypeata	Northern Shoveller	Slobeend	omnivoren
Falco columbarius	Merlin	Smelleken	carnivoren
Anas penelope	European Wigeon	Smient	herbivoren
Anser caerulescens	Snow Goose	Sneeuwgans	herbivoren
Plectrophenax nivalis	Snow Bunting	Sneeuwgors	omnivoren
Accipiter nisus	Northern Sparrow Hawk	Sperwer	carnivoren
Arenaria interpres	Ruddy Turnstone	Steenloper	benthivoren
Himantopus himantopus	Black-winged Stilt	Steltkluut	benthivoren
Himantopus himantopus	Black-winged Stilt	Steltloper spec.	benthivoren
Larus canus	Mew Gull	Stormmeeuw	omnivoren
Eremophila alpestris	Horned Lark	Strandleeuwerik	omnivoren
Charadrius alexandrinus	Kentish Plover	Strandplevier	benthivoren
Aythya ferina	Common Pochard	Tafeleend	herbivoren
Calidris temminckii	Temminck's Stint	Temmincks Strandloper	benthivoren
Spizella arborea	American Tree Sparrow	Toendrarietgans	herbivoren
Aythya marila	Greater Scaup	Toppereend	benthivoren
Falco tinnunculus	Common Kestrel	Torenvalk	carnivoren
Tringa totanus	Common Redshank	Tureluur	benthivoren
Oceanodroma leucorhoa	Leach's Storm Petrel	Vaal Stormvogeltje	piscivoren
Asio flammeus	Short-eared Owl	Velduil	carnivoren
Pandion haliaetus	Osprey	Visarend	piscivoren
Gallinula chloropus	Moorhen	Waterhoen	herbivoren
Rallus aquaticus	Water Rail	Waterral	omnivoren
Gallinago gallinago	Common Snipe	Watersnip	benthivoren
Pernis apivorus	Western Honey Buzzrd	Wespendief	carnivoren
Anas platyrhynchos	Mallard	Wilde Eend	herbivoren

Scientific name	English name	Dutch name	Trophic guild
Cygnus cygnus	Whooper Swan	Wilde Zwaan	benthivoren
Anas crecca	Green-winged Teal	Wintertaling	omnivoren
Hodgsonius phaenicuroides	White-bellied Redstart	Witbuikrotgans	carnivoren
Tringa ochropus	Green Sandpiper	Witgatje	carnivoren
Aythya nyroca	Ferruginous Duck	Witoogeend	omnivoren
Numenius arquata	Western Curlew	Wulp	piscivoren
Haliaeetus albicilla	White-tailed Sea Eagle	Zeearend	benthivoren
Uria aalge	Common Guillemot	Zeekoet	benthivoren
Larus argentatus	Herring Gull	Zilvermeeuw	carnivoren
Pluvialis squatarola	Grey Plover	Zilverplevier	herbivoren
Anas querquedula	Garganey	Zomertaling	omnivoren
Ciconia nigra	Black Stork	Zwarte Ooievaar	benthivoren
Phoenicurus ochruros	Black Redstart	Zwarte Rotgans	piscivoren
Tringa erythropus	Spotted Redshank	Zwarte Ruiter	carnivoren
Milvus migrans	Black Kite	Zwarte Wouw	piscivoren
Melanitta nigra	Black Scoter	Zwarte Zee-eend	omnivoren
Cygnus atratus	Black Swan	Zwarte Zwaan	benthivoren
Larus melanocephalus	Mediterranean Gull	Zwartkopmeeuw	carnivoren
Tyrannopsis sulphurea	Sulphury Flycatcher	Zwemeend	benthivoren

Breeding bird species

Scientific name	English name	Dutch name	Trophic guild
Charadrius hiaticula	Ringed Plover	Bontbekplevier	benthivoren
Sterna albifrons	Little Tern	Dwergstern	piscivoren
Yuhina nigrimenta	Black-chinned Yuhina	Geelpootmeeuw	omnivoren
Thalasseus sandvicensis	Sandwich Tern	Grote Stern	piscivoren
Larus ridibundus	Black-headed Gull	Kokmeeuw	omnivoren
Charadrius dubius	Little Ringed Plover	Kleine Plevier	benthivoren
Recurvirostra avosetta	Pied Avocet	Kluut	benthivoren
Larus marinus	Greater Black-backed Gull	Grote Mantelmeeuw	omnivoren
Larus fuscus	Lesser Black-backed Gull	Kleine Mantelmeeuw	omnivoren
Sterna paradisaea	Arctic Tern	Noordse Stern	piscivoren
Himantopus himantopus	Black-winged Stilt	Steltkluut	benthivoren
Charadrius alexandrinus	Kentish Plover	Strandplevier	benthivoren
Larus canus	Mew Gull	Stormmeeuw	omnivoren
Sterna hirundo	Common Tern	Visdief	piscivoren
Larus argentatus	Herring Gull	Zilvermeeuw	omnivoren
Larus melanocephalus	Mediterranean Gull	Zwartkopmeeuw	omnivoren

Fish species

Vissen			
Scientific name	**Dutch name**	**Trophic guild**	
Agonus cataphractus	Harnasmannetje	benthivore	
Alosa fallax	Fint	planktivore	
Ammodytes sp.		planktivore	
Anguilla anguilla	Aal	bentho-piscivore	
Aphia minuta		bentho-piscivore	
Arnoglossus laterna		bentho-piscivore	
Atherina		bentho-piscivore	
Buglossidium luteum	Dwergtong	benthivore	
Callionymus lyra	Pitvis	benthivore	
Callionymus maculatus		benthivore	
Callionymus reticulatus		benthivore	
Ciliata mustela	Vijdradige meun	benthivore	
Clupea harengus	Haring	planktivore	
Dasyatis pastinaca		bentho-piscivore	
Dicentrarchus labrax	Zeebaars	piscivore	
Echiichthys vipera	Kleine pieterman	bentho-piscivore	
Enchelyopus cimbrius	Vierdradige meun	benthivore	
Engraulis encrasicolus	Ansjovis	planktivore	
Entelurus aequoraeus		planktivore	
Eutrigla gurnardus	Grauwe poon	benthivore	
Gadus morhua	Kabeljauw	piscivore	
Gaidropsarus vulgaris		benthivore	
Galeorhinus galeus		piscivore	
Gasterosteus aculeatus		benthivore	
Gobius niger		benthivore	
Hyperoplus lanceolatus	Smelt	piscivore	
Limanda limanda	Schar	benthivore	
Liparis liparis	Slakdolf	benthivore	
Merlangius merlangus	Wijting	piscivore	
Microstomus kitt		benthivore	
Mugilidae	Harderachtige	detritivore	
Mullus surmuletus		benthivore	
Myoxocephalus scorpius	Zeedonderpad	bentho-piscivore	
Osmerus eperlanus	Spiering	bentho-piscivore	
Pholis gunnellus	Botervis	benthivore	
Platichthys flesus	Bot	benthivore	
Pleuronectes platessa	Schol	benthivore	
Pollachius virens		piscivore	
Pomatoschistus sp.	Grondel	planktivore	
Psetta maxima	Tarbot	piscivore	
Raja clavata	Rog	bentho-piscivore	
Raniceps raninus		benthivore	
Sardina pilchardus		planktivore	
Scophthalmus rhombus	Griet	piscivore	
Solea solea	Tong	benthivore	
Sprattus sprattus	Sprot	planktivore	
Squalus acanthias		piscivore	
Syngnathus sp.	Zeenaalden	planktivore	
Taurulus bubalis		benthivore	
Trachurus trachurus	Horsmakreel	piscivore	
Trigla lucerna	Rode poon	benthivore	
Trisopterus luscus	Steenbolk	benthivore	
Trisopterus minutus	Steenbolk	benthivore	
Zeus faber		piscivore	
Zoarces viviparus	Puitaal	benthivore	

Benthos species

Trophic groups: 0= not determined to species level, 1= suspension or filter feeder, 2= interface- , surface deposit- and facultative suspension feeder, 3= subsurface deposit feeder, grazer, 4= predator, omnivore, scavenger.

Scientific name	Trophic guild	Scientific name	Trophic guild
Abludomelita obtusata	2	Bispira crassicornis	1
Abra	2	Bivalvia	1
Abra alba	2	Boccardiella ligerica	2
Abra nitida	2	Bodotria scorpioides	2
Abra tenuis	2	Botryllus schlosseri	1
Acanthocardia	1	Brachyura	4
Acanthocardia echinata	1	Capitella capitata	3
Acanthocardia paucicostata	1	Capitellidae	3
Achelia echinata	4	Caprellidae	0
Actiniaria	4	Carcinus maenas	4
Alitta succinea	4	Caridea	0
Alitta virens	4	Cerastoderma	1
Ampelisca	1	Cerastoderma edule	1
Ampelisca brevicornis	1	Cerianthus lloydii	4
Ampharete	2	Chaetognatha	4
Ampharete acutifrons	2	Chaetozone setosa	2
Ampharete finmarchica	2	Cheirocratus sundevalli	3
Ampharetidae	2	Chironomus salinarius	0
Amphilochus neapolitanus	3	Ciona intestinalis	1
Amphitrite	2	Cirratulidae	2
Anoplodactylus petiolatus	4	Cirratulus cirratus	2
Anthozoa	4	Corbula gibba	1
Aora typica	0	Corophium	2
Aoridae	2	Corophium arenarium	2
Aphelochaeta marioni	2	Corophium multisetosum	2
Apherusa bispinosa	2	Corophium volutator	2
Aphrodita aculeata	4	Cossura	3
Arenicola	3	Cossura longocirrata	3
Arenicola defodiens	3	Crangon	4
Arenicola marina	3	Crangon crangon	4
Aricidea	2	Crassicorophium bonellii	2
Aricidea minuta	2	Crassostrea	1
Ascidiacea	1	Crepidula fornicata	1
Ascidiella aspersa	1	Cumacea	0
Asterias	4	Cumopsis goodsir	2
Asterias amurensis	4	Cyanoplax caverna	3
Athanas nitescens	4	Cyathura carinata	0
Atylus	4	Decapoda	0
Atylus guttatus	4	Delavalia	2
Atylus swammerdami	4	Diastylis	2
Balanus crenatus	1	Diastylis bradyi	2
Barnea candida	3	Diastylis lucifera	2
Bathyporeia	2	Diastylis rathkei	2
Bathyporeia elegans	2	Diastylis rugosa	2
Bathyporeia guilliamsoniana	2	Didemnidae	1
Bathyporeia pelagica	2	Didemnum candidum	1
Bathyporeia sarsi	2	Dipolydora coeca	2
Bathyporeia sarsi	2	Dipolydora quadrilobata	2

Trophic groups: 0= not determined to species level, 1= suspension or filter feeder, 2= interface- , surface deposit- and facultative suspension feeder, 3= subsurface deposit feeder, grazer, 4= predator, omnivore, scavenger.

Scientific name	**Trophic guild**	**Scientific name**	**Trophic guild**
Dodecaceria concharum	2	Jaera (Jaera) albifrons	3
Echinocardium cordatum	3	Janira maculosa	3
Elysia viridis	0	Janiridae	3
Ensis	1	Kefersteinia cirrata	0
Ensis directus	1	Kurtiella bidentata	1
Ensis ensis	1	Laevicardium crassum	1
Ensis magnus	1	Lagis koreni	3
Epitonium clathratulum	4	Lanice conchilega	2
Ericthonius brasiliensis	1	Lepidonotus squamatus	4
Eteone	4	Liocarcinus	4
Eteone flava	4	Liocarcinus depurator	4
Eteone longa	4	Liocarcinus holsatus	4
Eualus cranchii	4	Liocarcinus navigator	4
Eulalia viridis	4	Littorina	3
Eumida	4	Littorina littorea	3
Eumida bahusiensis	4	Lumbrineris latreilli	4
Eumida sanguinea	4	Macoma balthica	2
Eunereis longissima	4	Macropodia	4
Eunicidae	4	Macropodia parva	4
Eurydice pulchra	4	Magelona	2
Euspira pulchella	4	Magelona mirabilis	2
Exogone (Exogone) naidina	2	Malacoceros	2
Flabelligera affinis	2	Malacoceros fuliginosus	2
Gammaridae	4	Malacoceros tetracerus	2
Gammaridea	0	Malmgreniella lunulata	4
Gammarus	4	Marphysa sanguinea	4
Gammarus locusta	4	Megaluropus agilis	1
Gammarus salinus	4	Melita	2
Gammarus zaddachi	4	Melita palmata	2
Gastrosaccus spinifer	4	Microdeutopus	0
Gattyana cirrhosa	4	Microdeutopus anomalus	0
Gibbula	3	Microdeutopus chelifer	0
Glycera	4	Microdeutopus gryllotalpa	0
Glycera alba	4	Microphthalmus	3
Glycera convoluta	4	Microphthalmus aberrans	3
Harmothoe	4	Microphthalmus sczelkow	3
Harmothoe imbricata	4	Microphthalmus similis	3
Harmothoe impar	4	Microprotopus	4
Hediste diversicolor	4	Microprotopus maculatus	4
Hesionidae	4	Molgula manhattensis	1
Heteromastus filiformis	3	Mollusca	0
Hippolyte longirostris	4	Monocorophium ascherusi	2
Hippolyte varians	4	Monocorophium insidiosur	2
Hydrobia ulvae	3	Monocorophium sextonae	2
Idotea chelipes	4	Mya arenaria	1
Idotea linearis	4	Myrianida	4
Insecta	0	Myrianida brachycephala	0
Isopoda	0	Myrianida langerhansi	0

Trophic groups: 0= not determined to species level, 1= suspension or filter feeder, 2= interface- , surface deposit- and facultative suspension feeder, 3= subsurface deposit feeder, grazer, 4= predator, omnivore, scavenger.

Scientific name	**Trophic guild**	**Scientific name**	**Trophic guild**
Myrianida prolifera	0	Pectinaria	3
Myriochele	2	Perioculodes longimanus	2
Mysida	4	Petricolaria pholadiformis	1
Mysta picta	4	Pherusa plumosa	2
Mytilicola intestinalis	4	Pholoe minuta	4
Mytilus edulis	1	Phoronida	1
Nassarius	1	Photis pollex	2
Nassarius nitidus	4	Phoxichilidium femoratum	4
Nassarius reticulatus	4	Phyllodoce	4
Natalscia warreni	4	Phyllodoce mucosa	4
Nemertea	0	Phyllodoce rosea	4
Neoamphitrite	2	Phyllodocidae	4
Neoamphitrite figulus	2	Phyllodocinae	4
Nephtys	4	Pinnotheres pisum	4
Nephtys caeca	4	Pisidia longicornis	4
Nephtys cirrosa	4	Platynereis dumerilii	4
Nephtys hombergii	4	Poecilochaetus serpens	2
Nephtys longosetosa	4	Polychaeta	0
Nereis	4	Polycirrus	2
Nierstraszia fragile	4	Polycirrus medusa	2
Notomastus (Notomastus) hedlandica	3	Polydora	2
Nototropis falcatus	4	Polydora ciliata	2
Nudibranchia	4	Polydora cornuta	2
Nymphon	4	Polynoidae	4
Nymphon brevirostre	4	Pontocrates altamarinus	2
Nymphonidae	4	Porifera	1
Obelia bidentata	1	Praunus	1
Oligochaeta	3	Praunus flexuosus	1
Oncis mortoni	0	Proceraea cornuta	0
Ophelia limacina	3	Processa parva	4
Ophiodromus flexuosus	4	Psammechinus miliaris	4
Ophiothrix	1	Pseudochromis fuscus	0
Ophiothrix fragilis	1	Pseudopolydora	2
Ophiura	4	Pseudopolydora pulchra	2
Ophiura albida	4	Pseudopotamilla reniformis	2
Ophiura sarsii	4	Pycnogonida	4
Ophiuroidea	4	Pygospio elegans	2
Ophryotrocha gracilis	4	Retusa obtusa	4
Ostrea chilensis	1	Sagartiogeton undatus	4
Ostreidae	1	Schistomysis kervillei	2
Owenia fusiformis	2	Scolelepis	2
Oweniida	0	Scolelepis (Scolelepis) foli	2
Pagurus bernhardus	4	Scolelepis (Scolelepis) sq	2
Palaemon adspersus	0	Scolelepis bonnieri	2
Palaemon longirostris	0	Scoloplos (Scoloplos) arm	3
Paradoneis fulgens	3	Scrobicularia plana	2
Parahaustorius holmesi	2	Seraphsidae	2
Paraonidae	0	Sigalion mathildae	4

Trophic groups: 0= not determined to species level, 1= suspension or filter feeder, 2= interface- , surface deposit- and facultative suspension feeder, 3= subsurface deposit feeder, grazer, 4= predator, omnivore, scavenger.

Scientific name	**Trophic guild**		
Siriella clausi	0		
Spio filicornis	2		
Spio goniocephala	2		
Spio martinensis	2		
Spionidae	2		
Spiophanes bombyx	2		
Spisula	1		
Spisula subtruncata	1		
Stenothoe marina	1		
Sthenelais boa	4		
Streblospio shrubsolii	2		
Streptosyllis websteri	2		
Styela clava	1		
Subadyte pellucida	4		
Sycon	0		
Syllidae	4		
Syllidia armata	0		
Syllis gracilis	0		
Tellimya ferruginosa	1		
Tellina	2		
Tellina fabula	2		
Tellina tenuis	2		
Tellinoidea	2		
Terebellida	2		
Thia scutellata	4		
Tryphosella sarsi	0		
Urothoe	2		
Urothoe brevicornis	2		
Urothoe poseidonis	2		
Venerupis	1		
Venerupis senegalensis	1		

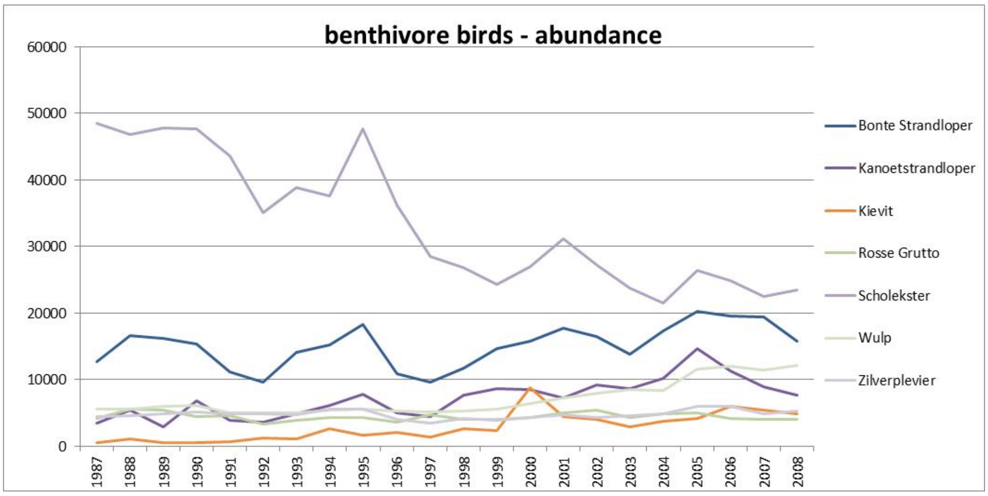
Annex 2 Overview and specification of collected data

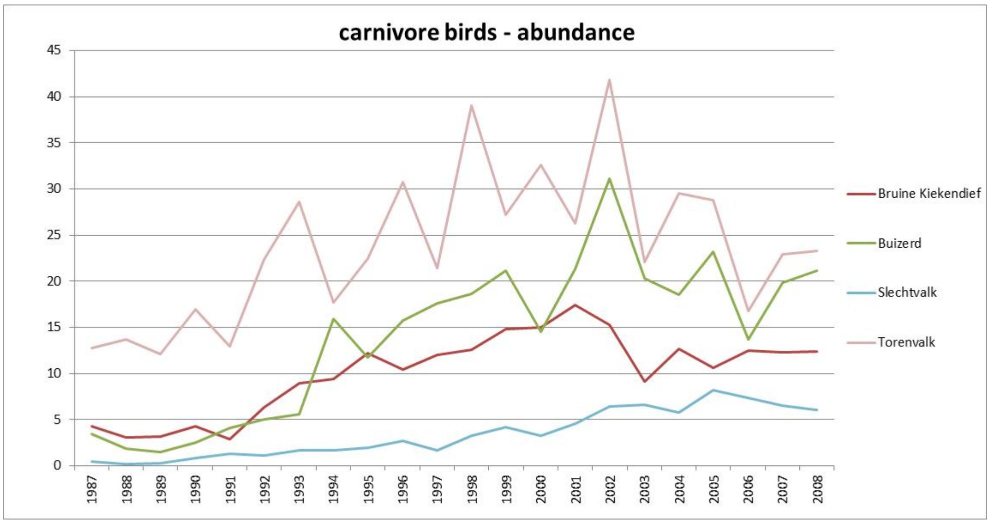
Group	Period	Source	Time of sampling	Sample locations	Method	Data standardization and comments
Birds	1987-2009 1979-2010 for breeding birds	Waterdienst, Rijkswaterstaat, SOVON	-seasonal averages June-July -gulls only in January	Oosterschelde	Counts	Incomplete years ('94,'97,'99,'00,'02,'07,'09) were estimated by imputing
Fish	1970-2009	Dutch Demersal Fish Surveys, IMARES	September-October, only fall data were used	Oosterschelde	Beam trawl 3m, fine mesh 20mm, net size $80m^2$	Data expressed individuals per hectares
Macro-benthos	1992-2008	BIOMON/MWTL, Waterdienst, Rijkswaterstaat & Monitoring Taskforce of NIOO-CEME	Autumn data were used	Oosterschelde North, East and West. Per region multiple strata and 10 samples per stratum	3 pooled sediment Reineck boxcores in combination with a core of 8cm diameter (0.015 m^2, in total), sieved over 1mm mesh size	Mean values of individuals per m^2 locations North, East and West were calculated and summed up.
Sea mammals	1996-2009	Waterdienst, Rijkswaterstaat	July-June	Oosterschelde	Counts	Only data of Grey Seal, Common Seal and Harbour porpoise were collected
Seagrass	-1977-2003 -2008-2009	Waterdienst, Rijkswaterstaat/RIKZ (via Compendium voor de Leefomgeving) -Zeegraskarteringen: Damm (2009; 2010)	variable	Intertidal	False colour aerial photography scale 1:10000 and 1:20000, GPS/INS scale 1:2500 was used, field measurements using enhancements, analysis using GIS	Seagrass in hectares
Salt-marsh	1865, 1910, 1938, 1960, 1978, 1988, 1995	Waterdienst Rijswaterstaat	variable	Intertidal	False colour aerial photography scale 1:5000	Saltmarshes in hectares

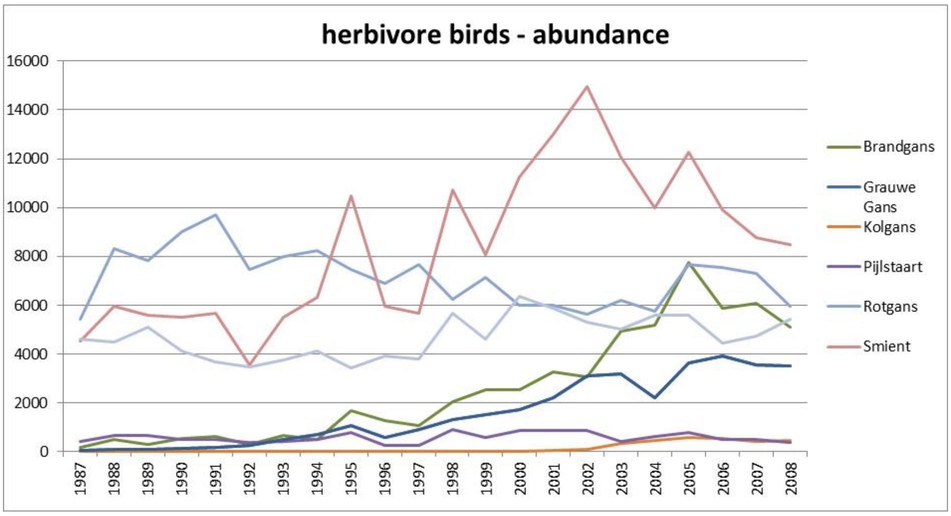
Annex 3 Abundance of species per trophic group

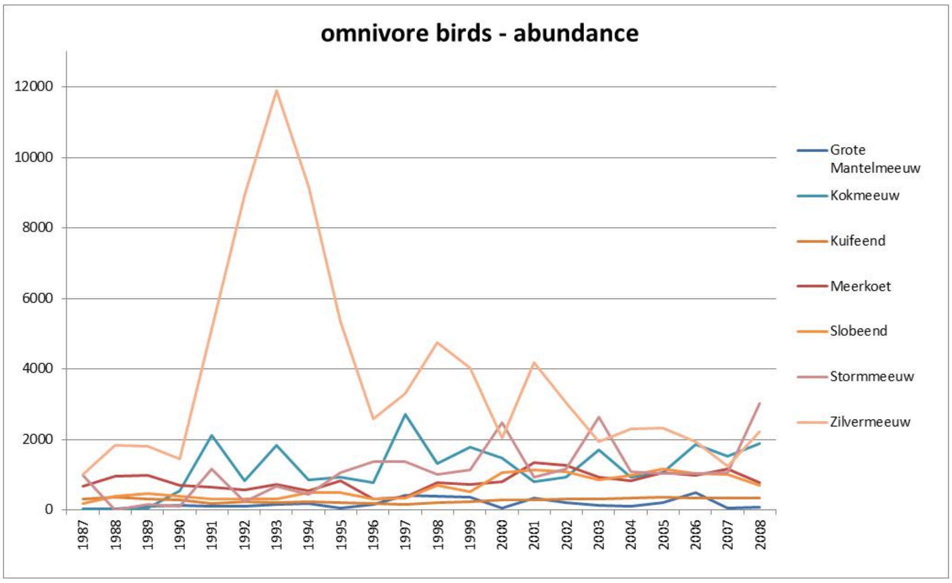
Annex 3.1 Birds: benthivores, carnivores, herbivores, omnivores and piscivores

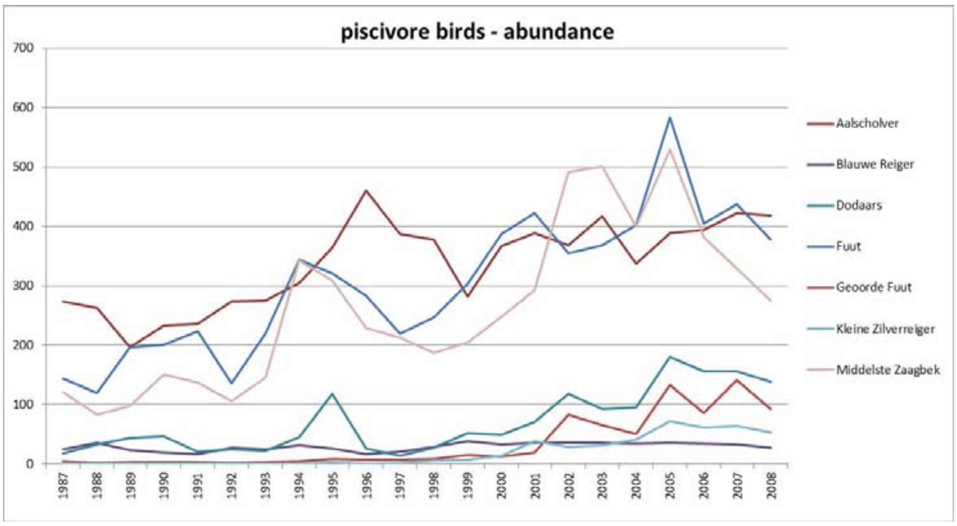
Benthivores: >3500 individuals for one or more years
Carnivores: >5 individuals for one or more years
Herbivores: >500 individuals for one or more years
Omnivores: >100 individuals for one or more years
Piscivores: >35 individuals for one or more years



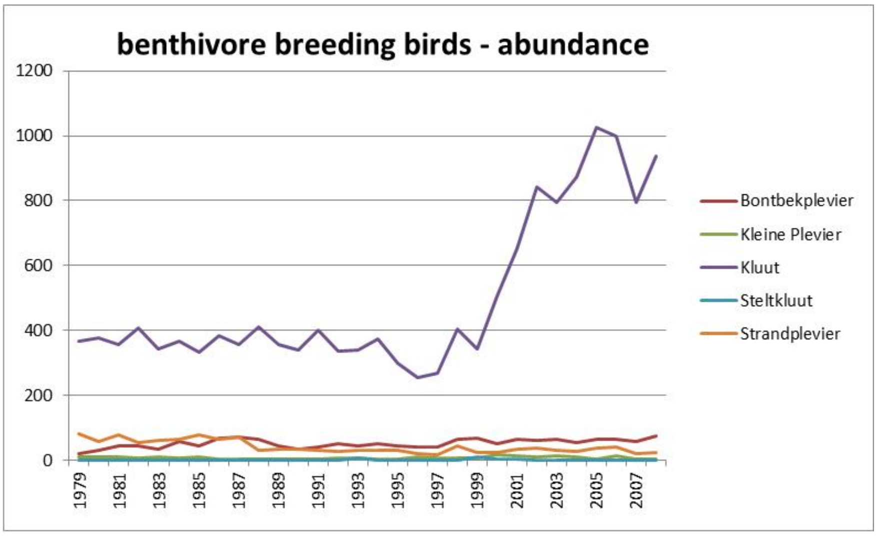


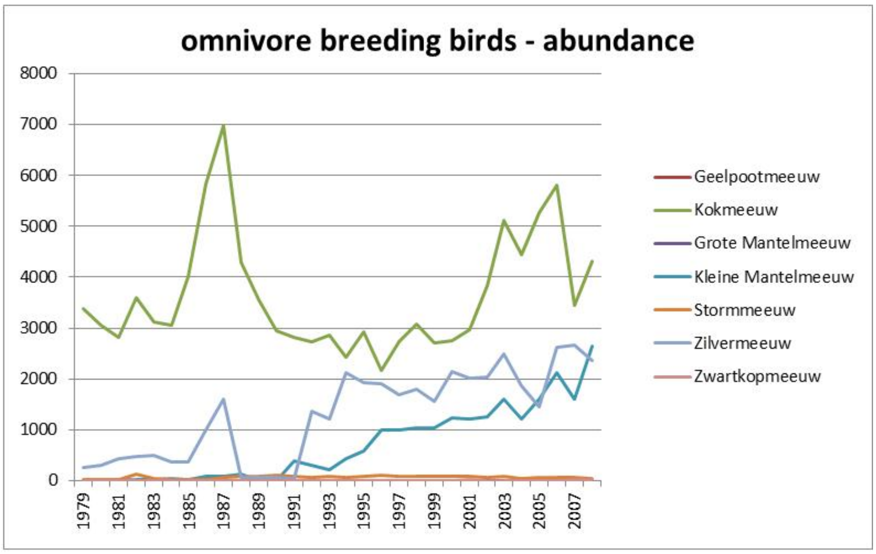

herbivore birds - abundance
16000
14000
12000
10000
8000
6000
4000
2000
0
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
Brandgans
Grauwe Gans
Kolgans
Pijlstaart
Rotgans
Smient

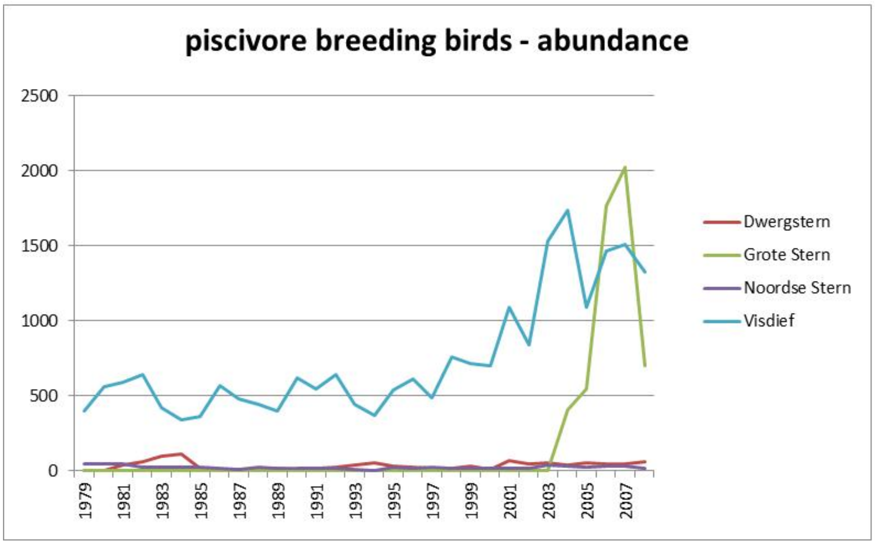

omnivore birds - abundance
12000
10000
8000
6000
4000
2000
0
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
Grote Mantelmeeuw
Kokmeeuw
Kuifeend
Meerkoet
Slobeend
Stormmeeuw
Zilvermeeuw


piscivore birds - abundance
700
600
500
400
300
200
100
0
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
Aalscholver
Blauwe Reiger
Dodaars
Fuut
Geoorde Fuut
Kleine Zilverreiger
Middelste Zaagbek

Annex 3.2 Breeding birds: benthivores, omnivores and piscivores

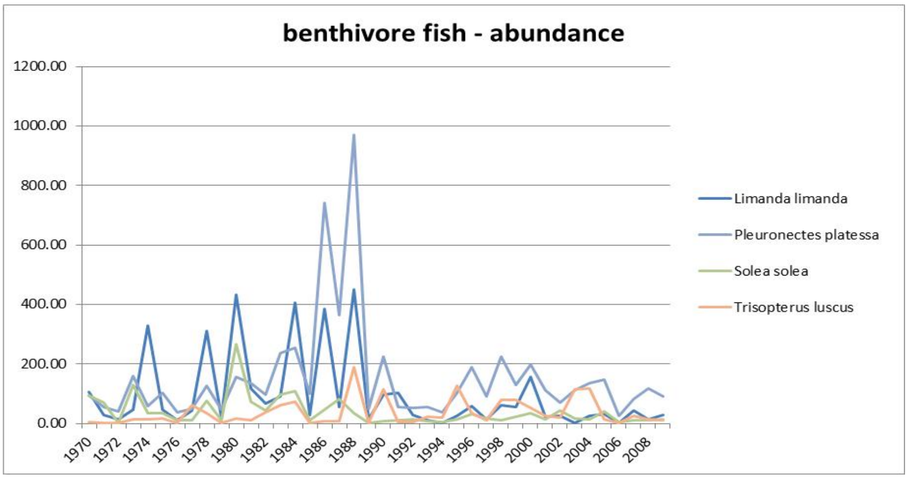


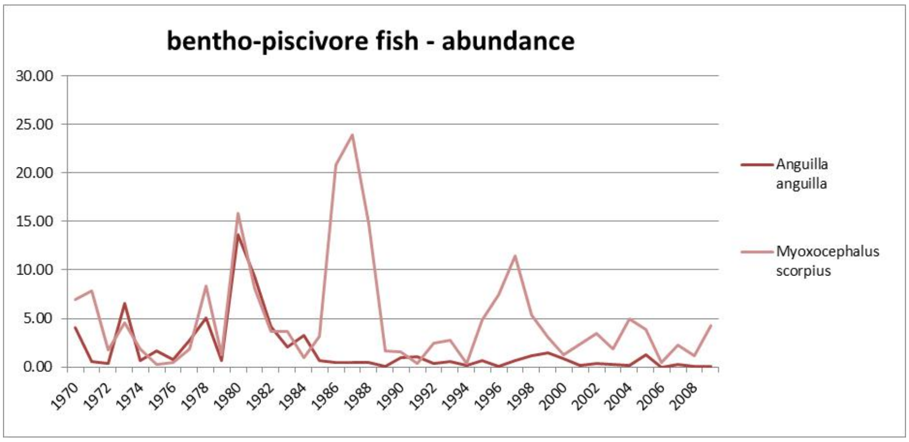


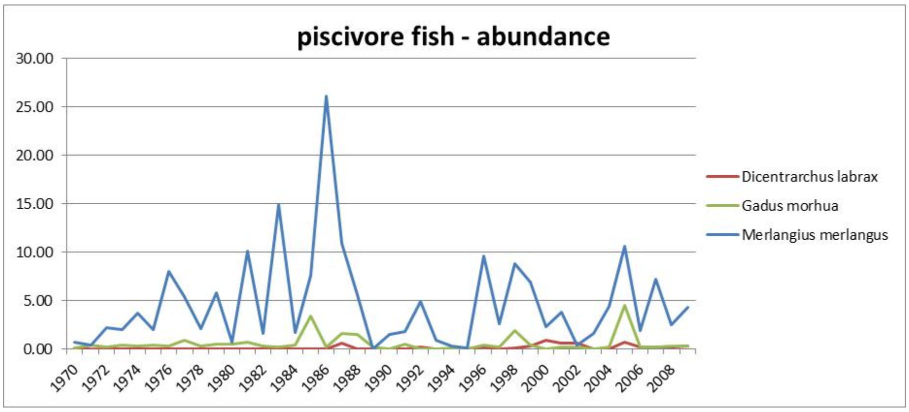


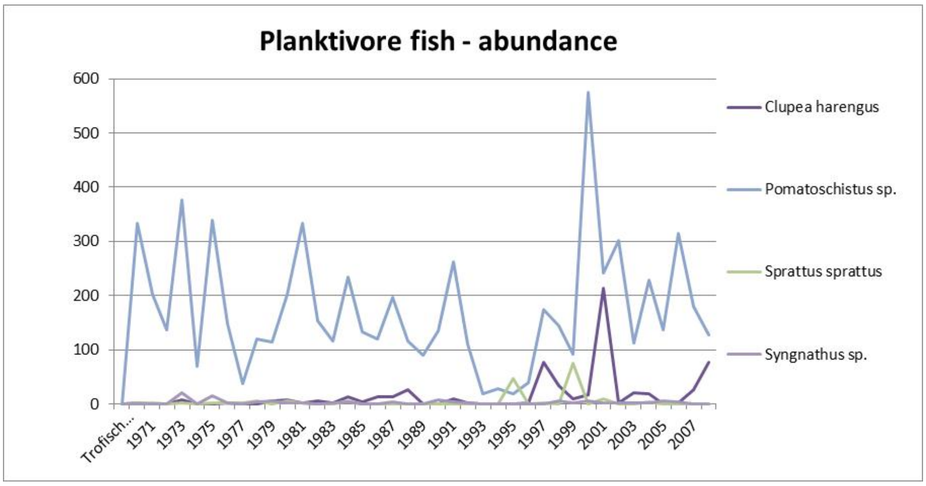
Annex 3.3 Fish: benthivores, bentho-piscivores, piscivores and planktonivores

Detritivores are not shown here (only one taxa determined, Mugilidae).
Benthivores: >60 individuals in one year or more
Bentho-piscivores: >5 individuals in one year or more
Piscivores: >1 individuals in one year or more
Planktivores: >20 individuals in one year or more

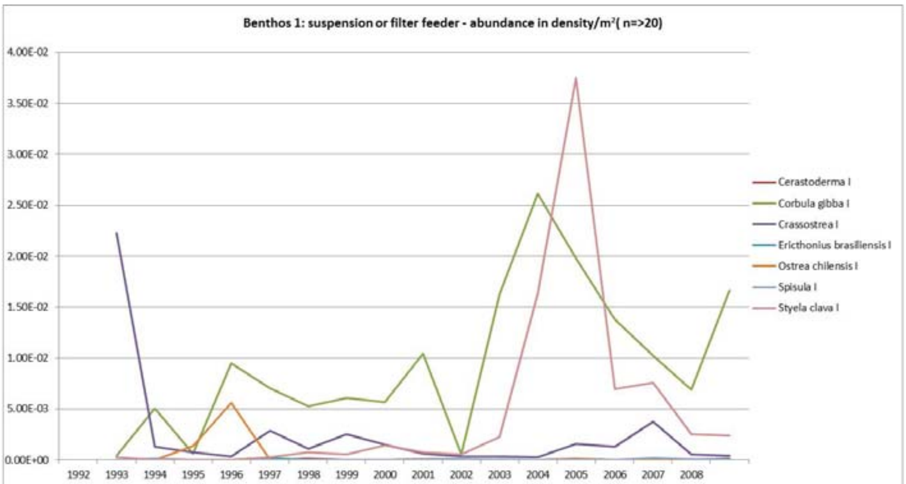


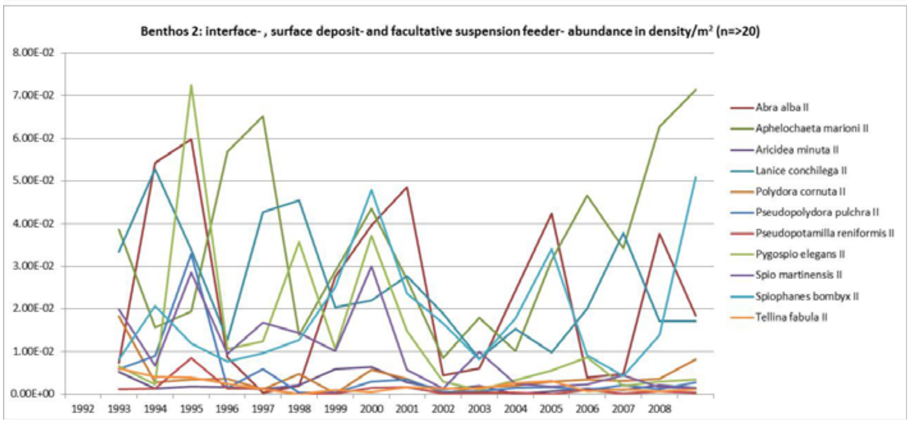


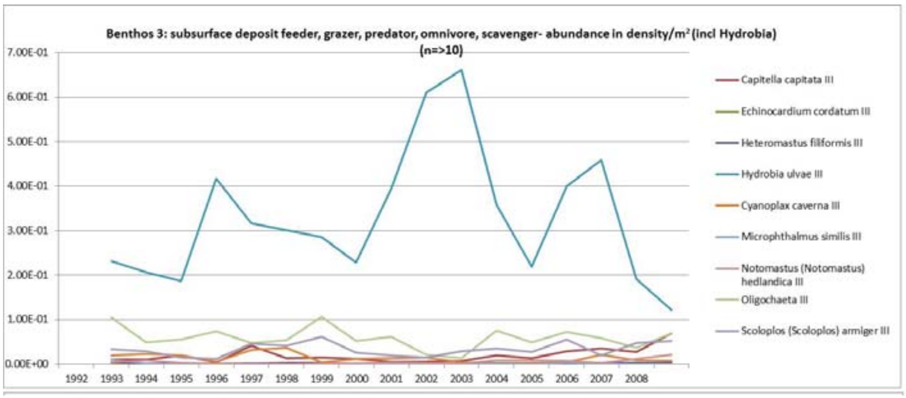


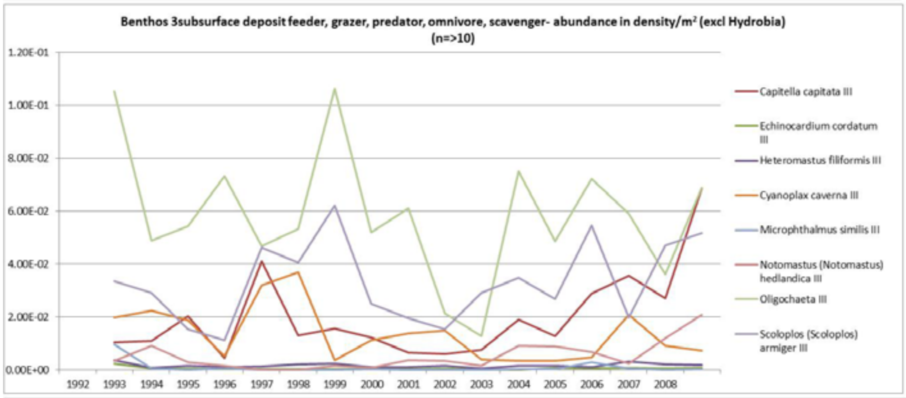


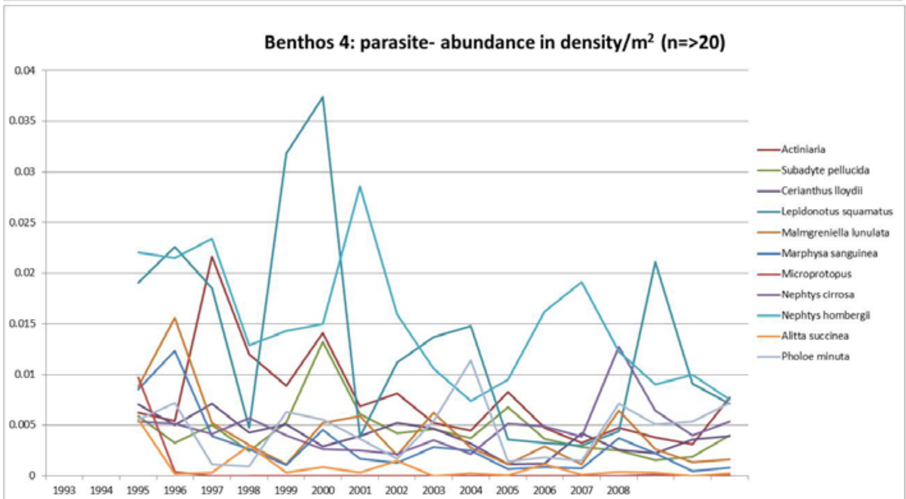
Annex 3.4 Benthos: category 1-4 for most abundant species (n=>10 or n=>20)






Benthos 3: subsurface deposit feeder, grazer, predator, omnivore, scavenger- abundance in density/m² (incl Hydrobia) (n=>10)
7.00E-01
6.00E-01
5.00E-01
4.00E-01
3.00E-01
2.00E-01
1.00E-01
0.00E+00
1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008
Capitella capitata III
Echinocardium cordatum III
Heteromastus filiformis III
Hydrobia ulvae III
Cyanoplax caverna III
Microphthalmus similis III
Notomastus (Notomastus) hedlandica III
Oligochaeta III
Scoloplos (Scoloplos) armiger III


Benthos 3subsurface deposit feeder, grazer, predator, omnivore, scavenger- abundance in density/m² (excl Hydrobia) (n=>10)
1.20E-01
1.00E-01
8.00E-02
6.00E-02
4.00E-02
2.00E-02
0.00E+00
1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008
Capitella capitata III
Echinocardium cordatum III
Heteromastus filiformis III
Cyanoplax caverna III
Microphthalmus similis III
Notomastus (Notomastus) hedlandica III
Oligochaeta III
Scoloplos (Scoloplos) armiger III


Benthos 4: parasite- abundance in density/m² (n=>20)
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008
Actiniaria
Subadyte pellucida
Cerianthus lloydii
Lepidonotus squamatus
Malmgreniella lunulata
Marphysa sanguinea
Microprotopus
Nephtys cirrosa
Nephtys hombergii
Alitta succinea
Pholoe minuta

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