Initial Assessment for the Belgian marine waters

Marine Strategy Framework Directive - Article 8, paragraphs 1a and 1b

CONTENTS

1. INTRODUCTION

The European Marine Strategy Framework Directive (2008/56/EC) lays down common principles based on which the Member States must implement their own policies to achieve good environmental status in the sea by 2020. Its aim is to protect and, if necessary, restore the marine ecosystems in all of Europe.

The Member States must begin by describing the initial status of their waters: what is the current status and which human activities affect that status? Next, the "good environmental status" of the marine areas must be determined. This describes the situation we want to/have to evolve towards in the near future. Finally, the Member States must define measures to achieve the good environmental status.

This document provides an analysis of the initial status in the Belgian waters, describing the physical, chemical and biological characteristics of our marine areas, as well as the human activities that affect those areas. The report gives a limited reflection of the current status and does not hold an assessment about the 'good environmental status' as described in the report mentioned in articles 9 and 10. The 2010 Quality Status Report published by OSPAR (OSPAR, 2010) forms the reference for the report.

The Belgian Continental Shelf (BCS) has two distinct features: it is open and "very busy". As for the openness: the status of the BCS depends more on the transboundary currents than on the processes taking place within the zone itself. This means that Belgian responsibility for the quality of its marine ecosystems is not without limits, which again illustrates the importance of European and international collaboration. Although the area is small (3 454 km²), it hosts a large variety of activities: busy international sea routes; port activities; wind farms; fishery; sand and gravel reclamation; mariculture; dredging and dumping of dredged materials; military activities; recreational boating, etc.

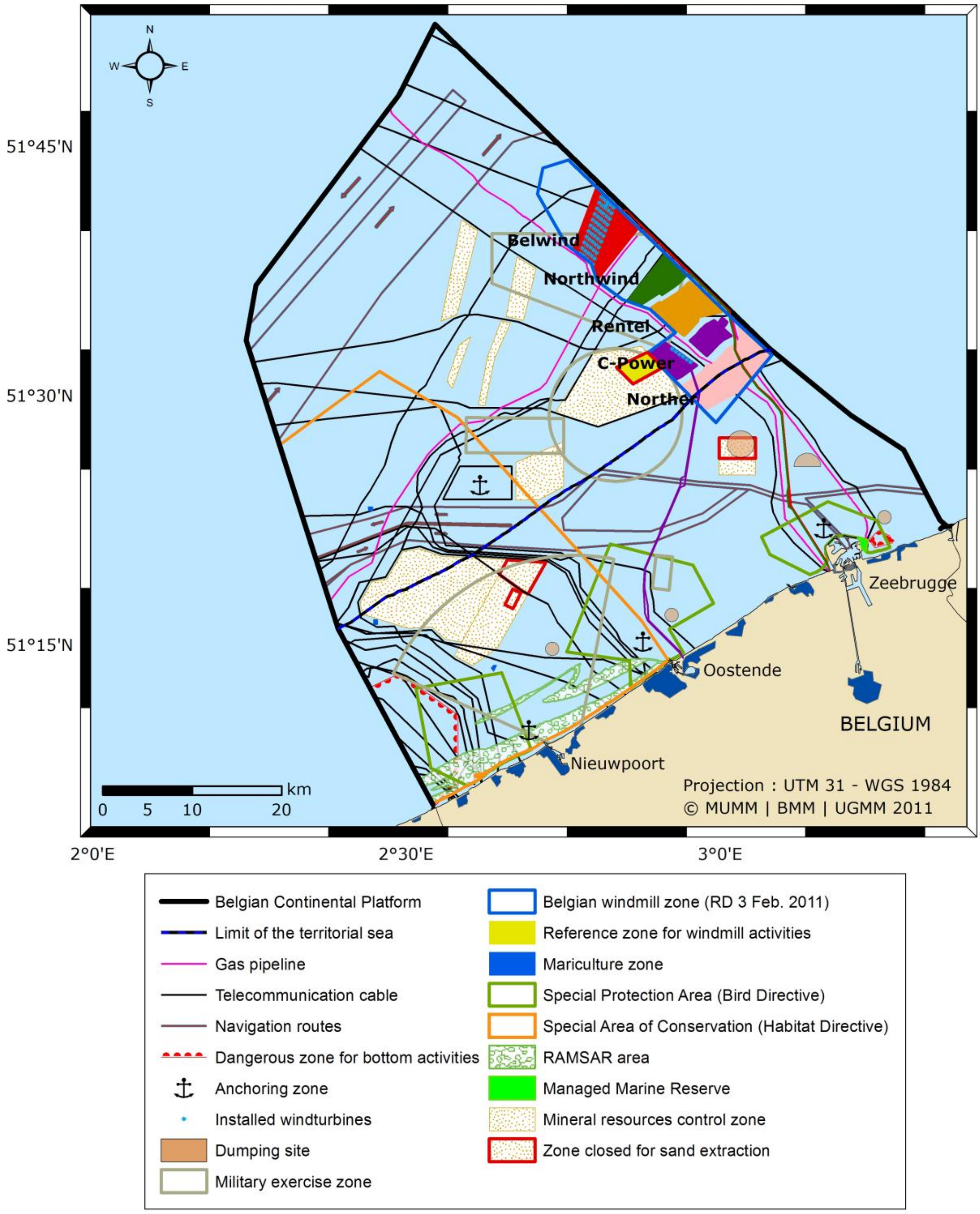


Figure 1: the Belgian Continental Shelf.

2. CHARACTERISTICS OF THE BELGIAN PART OF THE NORTH SEA
2.1. Physical and chemical characteristics
2.1.1 Seabed relief and bathymetry

Figure 2.1 shows the bathymetry of the seabed across the 3 454 km^2 of Belgian coastal waters. In the near coastal area the water depth is usually less than 20 m, increasing to approximately 45 metres further off the coast. Characteristic of the seabed is the existence of sandbanks that run in a parallel to upward slanting pattern relative to the coast. Stretching 15 to 30 km, they can reach heights of approximately 20 metres from the bottom of the sea.

The substrate of the BCS consists mainly of sand and added clay, silt and gravel. Silt deposits occur in the coastal area between Ostend and the Dutch border and originate from the Holocene period, while Tertiary clay layers outcrop in a few deeper channels (Le Bot *et al*. 2005; Fettweis *et al*. 2009). The sandbanks coarsen from fine to coarse sand in a seaward direction (Verfaillie *et al*. 2006).

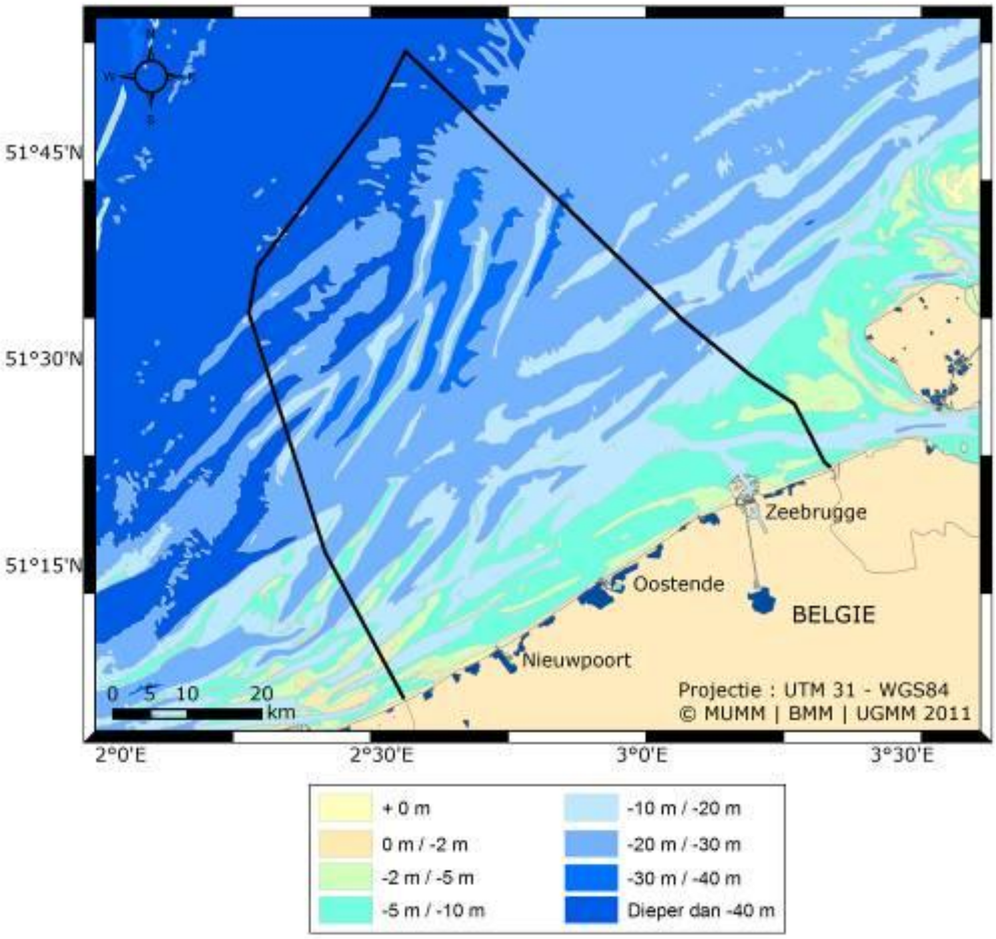


Figure 2.1: Bathymetry of the BCS.

Putting together sedimentological, bathymetric and hydrodynamic data also allows for distinguishing a few marine landscapes, often with ecological relevance (Verfaillie *et al*. 2009), see figure 2.2. Landscape 1 (yellow) is shallow and consists mainly of clay and silt. Landscape 2 (light green) is shallow and consists of fine sand. Landscape 3 (dark green) differs from zone 2 largely in that its sand is a gradient coarser. These landscapes mainly match the slopes of the shallow, south-west facing sandbanks. The landscapes 4 (light brown) and 5 (dark brown) consist of medium-coarse sand and they coincide with deep terraces and the foot of the slopes of distant sandbanks (on the north-western and south-eastern slopes, respectively). Landscapes 6 (light blue) and 7 (dark blue) coincide with the ridges and the upper part of the slopes of deep sandbanks. Finally, landscape 8 (light grey) consists mostly of gravel and pieces of shell. Fine-scale geomorphological mapping of sandy substrates shows that slopes often coincide with higher biodiversity (Van Lancker *et al.* 2012).

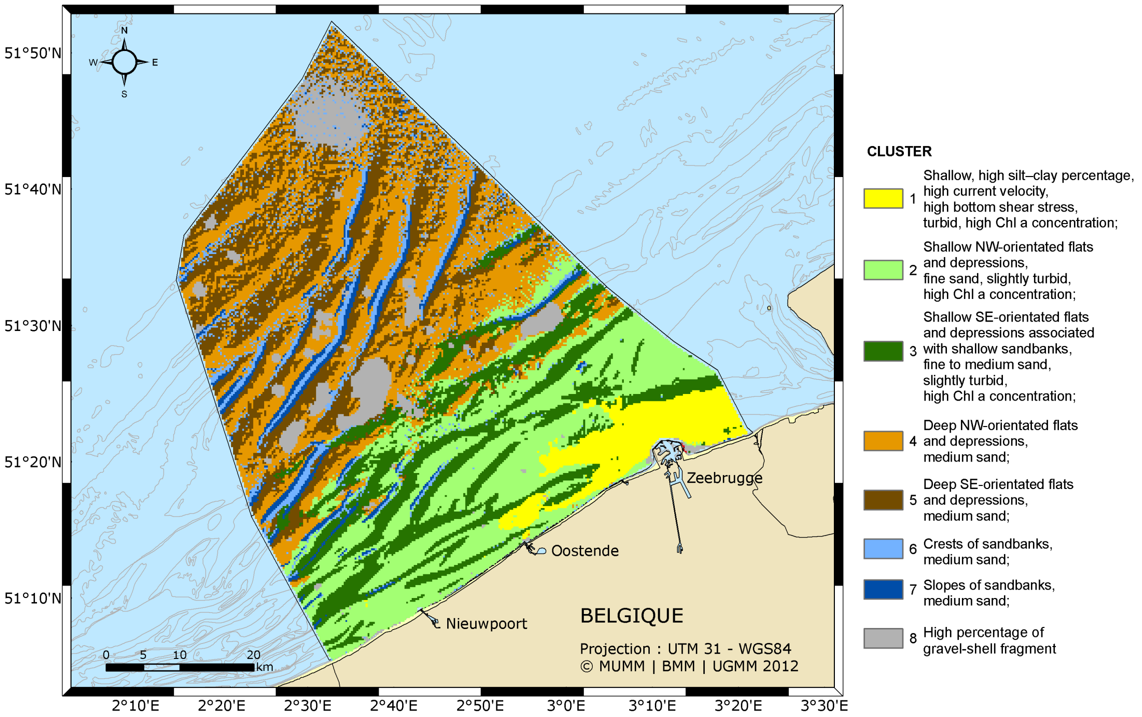


Figure 2.2: Categorisation of the seabed into eight marine landscapes (Verfaillie *et al.* 2009).

2.1.2. Hydrodynamics

The hydrodynamics of the BCS is dominated by the daily tides, which can vary from as much as 3 metres during neap tide to over 4.5 metres at spring tide. The tidal streams are intense, often more than 1 m/s and in the coastal area they mainly occur parallel to the coast. The presence of sandbanks changes the orientation in places, creating tide channels that differ at ebb and flow. In addition, human activities such as the Zeebrugge port expansion and the deepening of the sea lanes towards the ports of Ostend, Zeebrugge and the Scheldt estuary have also affected the streams locally. These changes in hydrodynamics have in turn caused or enhanced other phenomena, including the silting up of the Paardenmarkt east of Zeebrugge (Van den Eynde *et al.* 2010).

Apart from the tides, wind and storms exert considerable impact on hydrodynamics. For instance: a depression can change water transport, salinity, warmth or nutrients; it can cause water level rises of several metres (2.25 m in Ostend before the 1953 Storm, Dehenauw 2003), bring about considerable increases in wave height and turbulence within the water column and suspend large amounts of sediment.

Finally, the combination of the shallowness of the BCS and strong currents ensures continuous mixing of the water column. If we exclude the extraordinary dynamics of the estuaries and of the Rhine and Meuse plume from the equation, the density gradients of sea water are too small to cause important baroclinic currents.

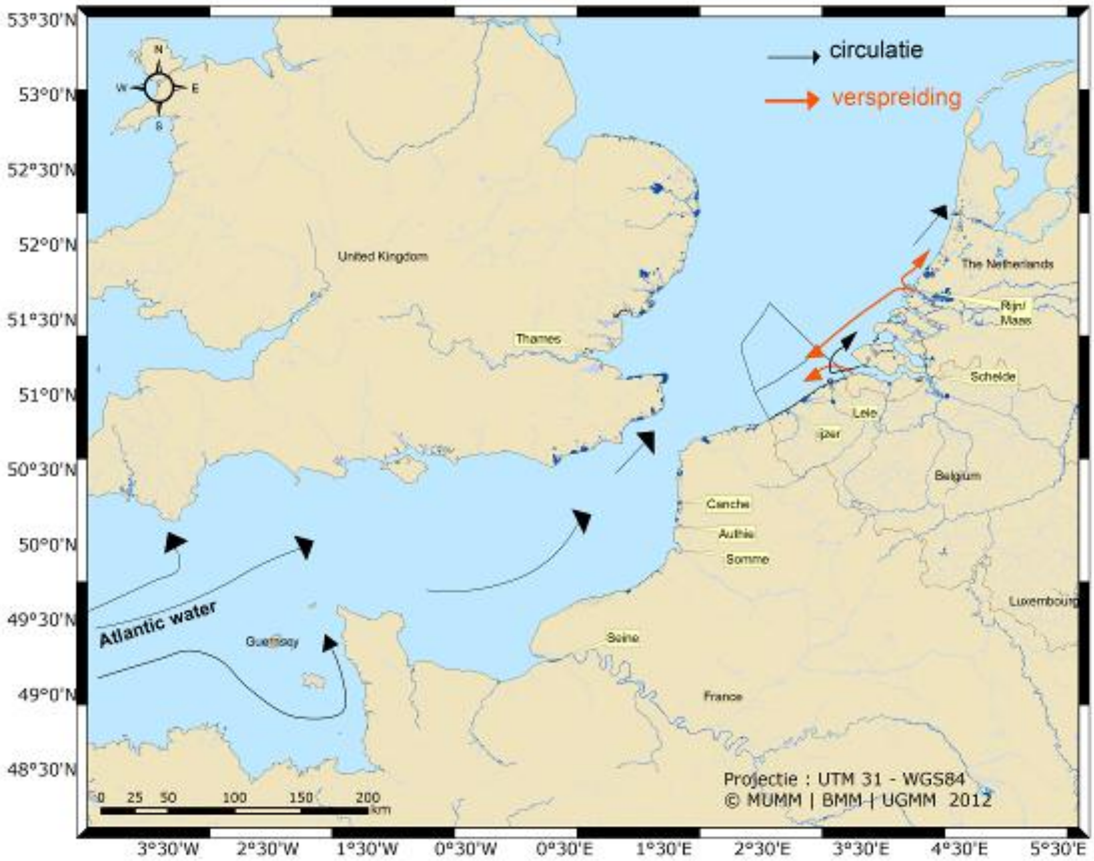


Figure 2.3: General diagram of the circulation in the Channel and the southern part of the North Sea. The black arrows represent the annual average residual circulation. The red arrows show the horizontal dispersion, caused by the tide, on the transport of the Scheldt and Rhine/Meuse water masses.

2.1.3. Wind and wave action

Besides the tides, meteorological conditions such as wind, precipitation, clouds, air temperature near the marine surface, etc., are the most important causes of the physical processes along our coastline. They usually follow a seasonal cycle, including a significant variability of a few hours to several days that is associated with the passage of depressions. The latter can have a significant impact on hydrodynamics. The inter-annual variability of the meteorological parameters is correlated to the NAO index (North Atlantic Oscillation). This variability also explains the differences in many oceanographic parameters such as the temperature or transport of water masses in Belgian waters (Breton *et al.* 2006). However, the flow rate of rivers such as the Scheldt is not correlated to the NAO index (Levy *et al.* 2010).

Figure 2.4 reflects the climatology of the winds, measured between 2000 and 2009 at the Zeebrugge meteorological station. The average wind speed is 5.5 m/s. Weaker winds

(<5 m/s, 30% of the time) do not come from any particular direction, whereas storms (> 15 m/s, 5% of the time) mainly come from the west and south-west. The waves are closely connected to the wind. The Belgian waters are considered to be moderately exposed to the waves.

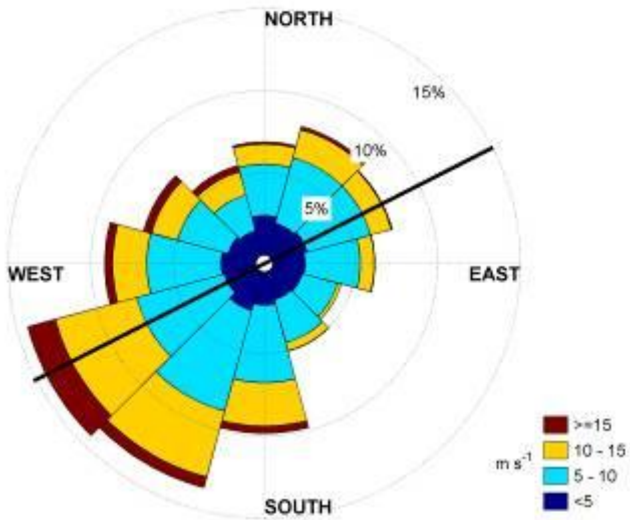


Figure 2.4: Wind rose for Zeebrugge from 2000 to 2009. The black line indicates the orientation in relation to the coast (Baeye *et al.* 2011).

Figure 2.5 shows the significant wave height between 1999 and 2009, adjusted from Delgado *et al*. (2010) and Matthys *et al*. (2011). Wave distribution at the offshore station Westhinder is bimodal with a dominant direction caused by winds from the south-west and a second direction caused by the winds blowing parallel to the North Sea axis (from north-north-east to south-south-west). Wave distribution at the coastal station Bol van Heist is unimodal and oriented towards the south-east.

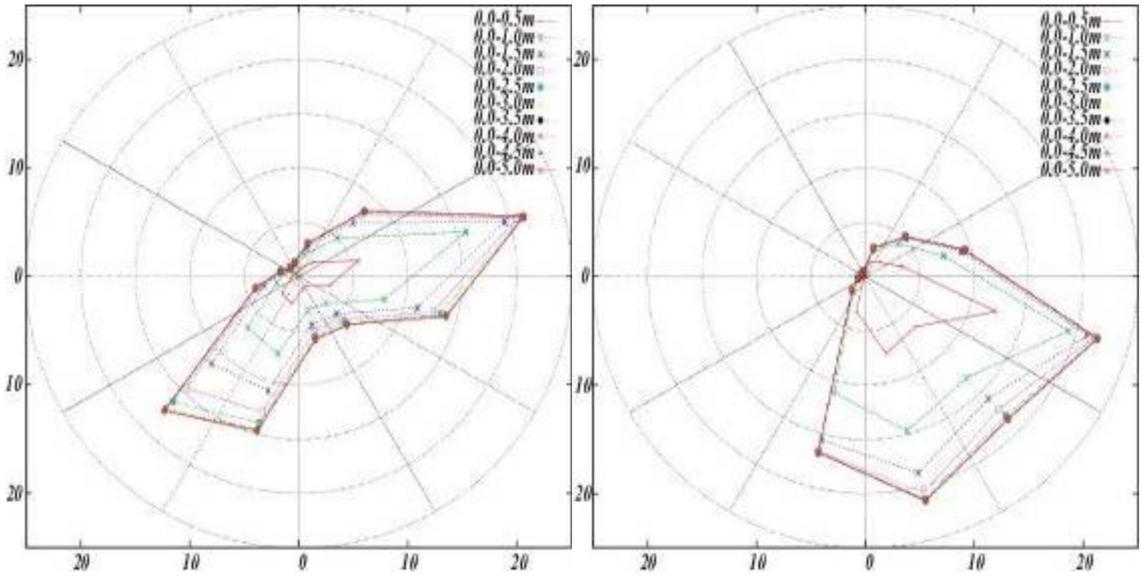


Figure 2.5: Cumulative distribution of the significant wave height at Westhinder (left) and Bol van Heist (right) in the period 1999-2009 (Fernandez *et al.* 2010).

2.1.4. Temperature

The temperature of the sea water at the BCS shows a seasonal cycle with a clear difference of approximately 15 °C between winter and summer temperatures (figure 2.6).

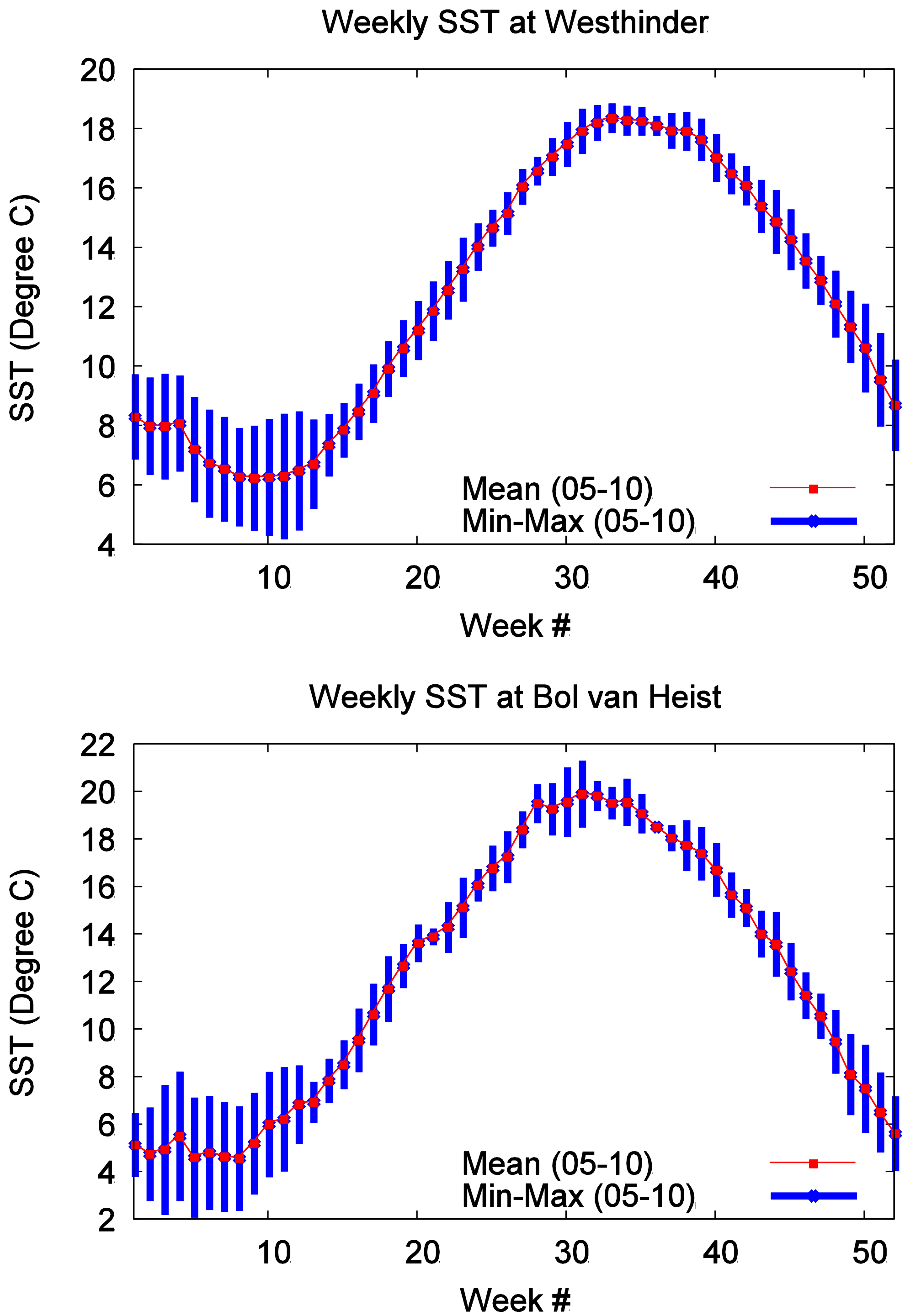


Figure 2.6: Average surface temperature in the period between 2005 and 2010 at the stations Westhinder (above) and Bol van Heist (below). Source: "Meetnet Vlaamse Banken" (Monitoring Network Flemish Banks) (Agency for Maritime Services, Coast Division).

The seawater temperature has an inter-annual variability of 1 to 4 °C and is strongly correlated to the NAO index (Tsimplis *et al*. 2006).

Figure 2.7 shows the spatial variation of the monthly averages of the surface temperature at the end of the winter (February) and in the summer (August). In winter, the warmer water masses originating from the Channel cause a temperature difference of 1 to 3 °C between the centre part of the southern bay of the North Sea and the coastal area. A turnaround can be perceived in the summer – with warmer water in the coastal area – as a result of the quick rise in temperature of the water in the more shallow coastal waters (Ruddick and Lacroix 2006).

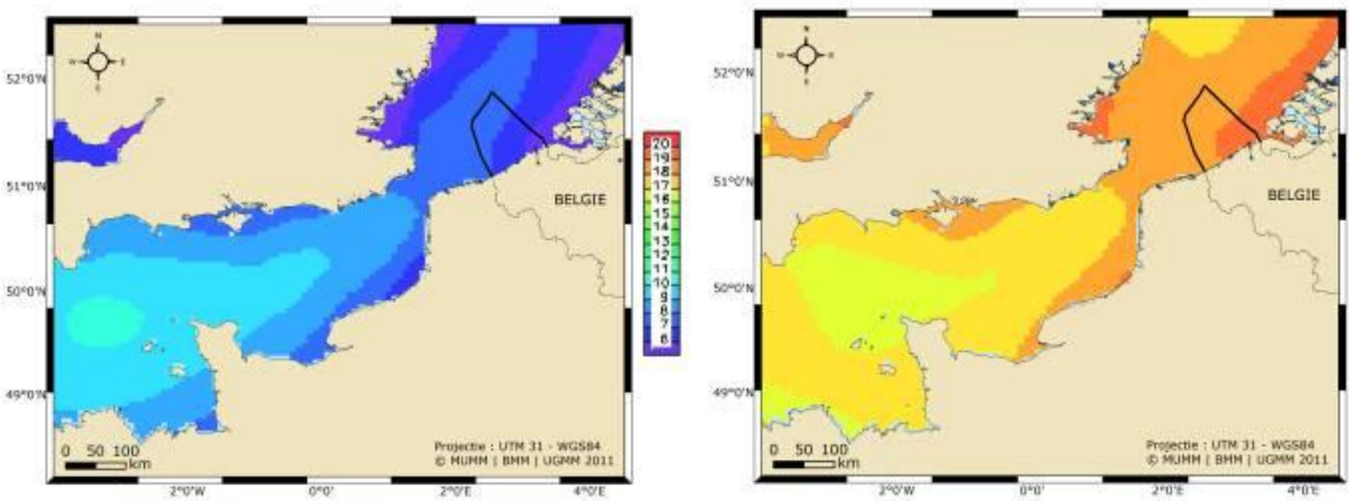


Figure 2.7: Monthly average surface temperature in the period 1995 to 2010. Left: February; right: August. Source: Bundesamt für Seeschiffahrt & Hydrographie (Loewe 2003).

In general, the water at the BCS is well-mixed vertically with vertical temperature variations usually smaller than 0.5 °C.

2.1.5. Turbidity

The BCS is characterised by a turbidity maximum along the entire coast. Turbidity is an optical parameter (the opposite of transparency) and is determined mainly by the concentration of suspended particulate matter SPM in our coastal waters. Here, concentrations of these mineral and organic substances are always high: from 100 mg/l up to several thousands of mg/l. There is also a transition area where SPM concentrations can be high (5-50 mg/l) and an offshore area where SPM concentrations are always low (<5 mg/l). (Van den Eynde *et al*. 2007; Fettweis *et al*. 2007).

Figure 2.8 shows the average surface SPM concentration and turbidity derived from MERIS satellite data. The main sources of suspended matter in the Belgian coastal area are the French rivers, erosion from the chalk rocks at Cap Griz-Nez and Cap Blanc-Nez, and erosion from the Holocene silt layer outcropping in the coastal area between Ostend and the Dutch border (Fettweiss and Van den Eynde, 2003). An outspoken vertical gradient in SPM concentration occurs in the turbidity maximum, making the concentration significantly higher at the bottom than at the surface. Highly concentrated silt suspensions with SPM concentrations of several grams/litre can develop close to the bottom during spring tide and/or storms (Fettweis *et al*. 2010; Baeye *et al*. 2011).

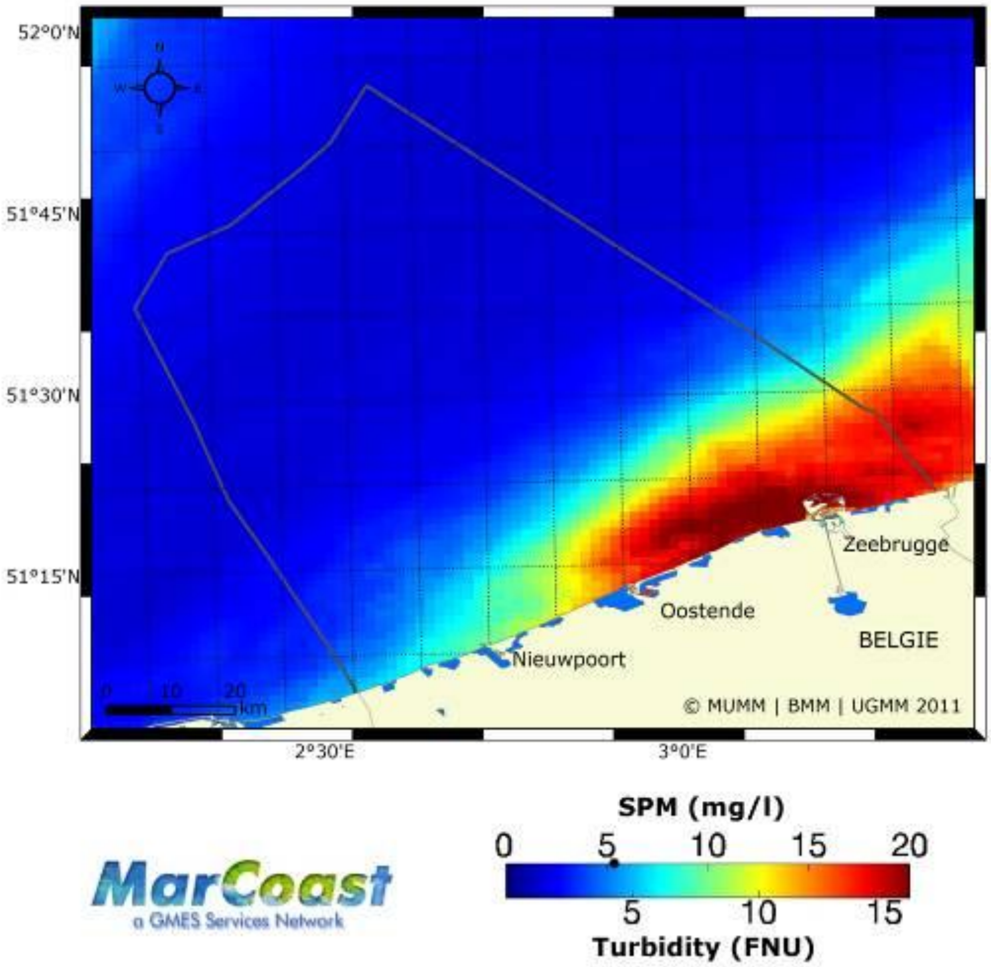


Figure 2.8: Turbidity map of the BCS - averages over the period 2003 until 2010. Turbidity was calculated from the water reflectance that was measured by the MERIS satellite in the 665 nm band, using the tele-detection algorithm of Nechad *et al.* (2010) on MarCoast data. The SPM concentration is in proportion with the turbidity.

2.1.6. Salinity

Figure 2.9 shows the long-term average salinity distribution in the southern part of the North Sea and in the Channel. At this scale the difference between precipitation and evaporation is negligible and therefore salinity in the coastal zone is affected mainly by the inflow of fresh water from the big rivers.
The river plumes of the Scheldt, the Seine, the Rhine and the Meuse, with widths of up to 40 km, and of a few smaller rivers are visible along the coast. Here, salinity may vary between 25 and 32. For comparison: seawater entering the Channel has a salinity of approximately 35.

Changes in salinity in the long term are subject to the wind that may either push the river plumes far into the sea, or stop them along the coast. The seasonal wind cycle, precipitation and the flow rate of the rivers also cause seasonal changes in salinity along the Belgian coast. Because the coastal area is well mixed vertically, vertical variations in salinity are usually limited too (< 0.2).

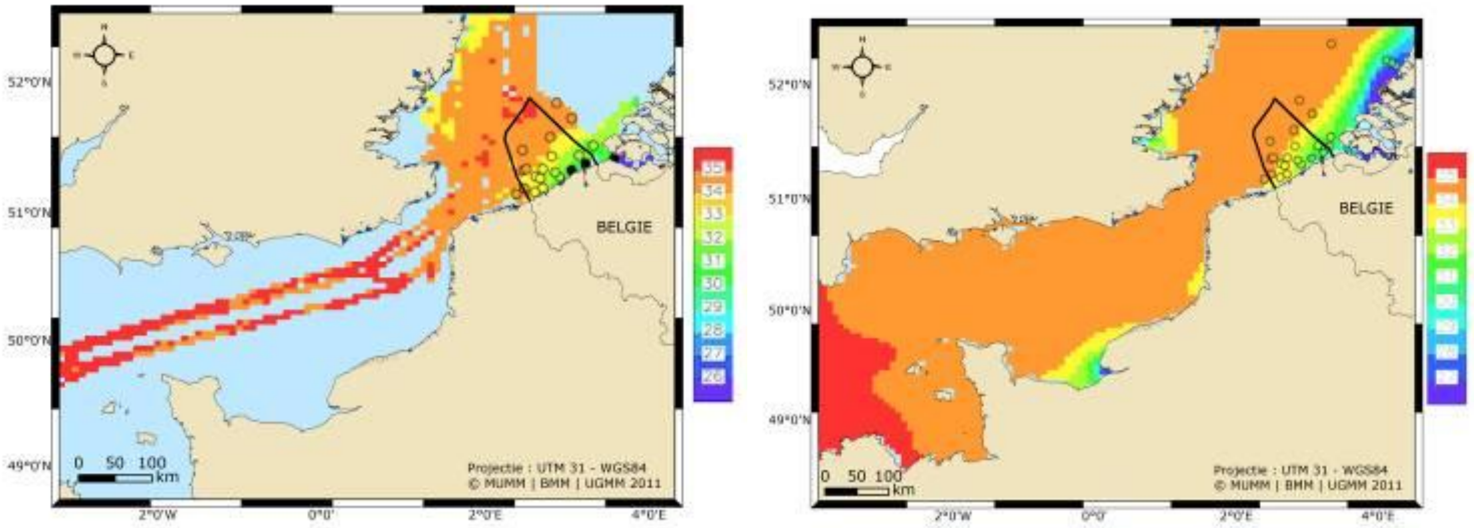


Figure 2.9: Salinity in the long term in the southern part of the North Sea and the Channel. Left: average salinity measured on board the Belgica in the period 2005-2010. Right: modelled average salinity in the period 1993-2010 (recalculated according to Lacroix *et al.* 2004). The figures in the circles represent the average *in situ* measured values.

2.1.7. Water masses and persistence

In the coastal zone, it is useful to define the concept of 'water mass' in relation to its origin. This enables defining the origin of several polluting passive substances, dissolved in seawater.

The transport of water masses is controlled mainly by residual tidal currents on the one hand and currents caused by the wind on the other. In a weak wind, the residual transport in the Belgian coastal zone typically flows from France to the Netherlands. However, the half-daily oscillation of the tidal currents significantly increases the horizontal spread of the water masses (Lacroix *et al.* 2004). This spread is more significant in the direction parallel to the coast and may be the cause of transport of a water mass, salt and other nutrients in the direction opposite to the residual currents (see figure 2.3).

Models show that water from the Atlantic Ocean is the main ingredient – 95% – in seawater samples taken far from the coast. The remaining elements originate from freshwater from the Scheldt, Rhine/Meuse, Seine and other small rivers (Lacroix *et al.* 2004).

The relative importance of the contribution of the Seine increases significantly in samples taken further away from the coast. Also, for the larger part of the Belgian coastal zone, the influence of the Rhine and the Meuse water masses at least equals that of the Scheldt water masses.

Residence time θ_r is the average time needed by a water mass within a domain, to leave that domain for the first time. Exposure period θ_e is the average time a water mass remains within an area. Exposure time exceeds residence time if – once away from the area – the water mass returns into the area. The return coefficient can be defined as $(\theta_r - \theta_e)/\theta_e$ (de Brye *et al.* 2011). The coefficient is 0 if not one single water part returns to the area, and 1 if all water masses return to the calculated area.

As shown in figures 2.10 and 2.11, the residence time for the BCS is somewhere between 0 and 7 days. Exposure time is between 1 and 11 days and the return coefficient lies between 0.2 and 0.9. These figures show that the BCS is an open area with great influences from the neighbouring areas.

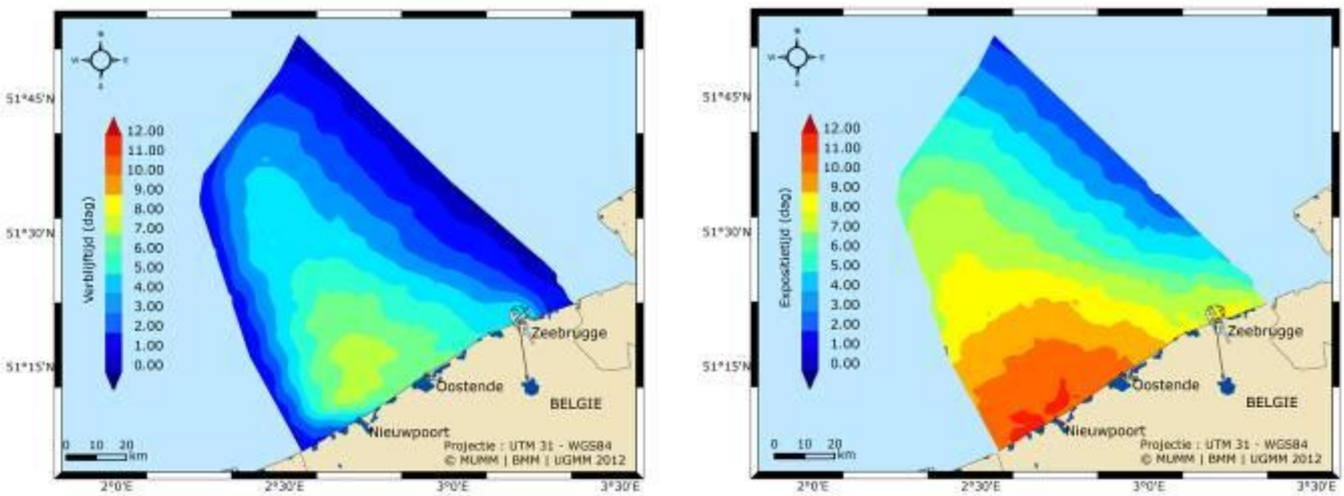


Figure 2.10: Residence time (left) and exposure time (right) for the BCS.

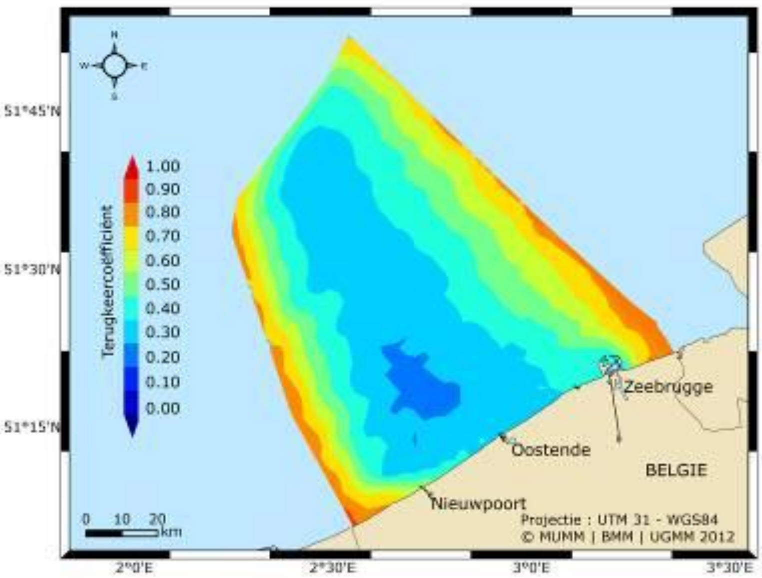


Figure 2.11: Return coefficient for the BCS.

2.1.8. Nutrients and oxygen

Nutrients and oxygen are two of the main elements supporting the marine ecosystem. To be able to perform photosynthesis and hence to grow, phytoplankton needs light and nutrients (Nitrogen N, Phosphorus P, and for the diatoms dissolved Silicon Si). Although the biomass of water plants constitutes no more than 1% of the biomass of all plants on earth, 40% of the annual photosynthesis takes place in an aqueous environment. Despite considerable aquatic productivity, this storage difference has to do with the fact that unicellular marine algae grow and die within a short time span (week-season-year), whereas the biomass of onshore plants can be stored year after year. Similar to the systems on the shore, part of the organic material created during the photosynthesis is transferred to higher levels in the food chain (zooplankton, zoobenthos, fish, marine mammals, birds). When phytoplankton dies, the organic material that is not transferred to the food chain is broken down by bacteria. Dissolved oxygen is consumed during this recycling process and the organic material is again transformed into inorganic nutrients (N and P).

Nutrients and oxygen are very important at the BCS in view of the problem of eutrophication, a phenomenon directly resulting from an excess of nutrients and which can lead to a shortage or even total absence of oxygen. Nutrient and oxygen levels have been monitored for many years in the scope of the analysis of and fight against eutrophication throughout the entire OSPAR region.

Despite the fact that nutrient levels exceed the limits, they do not cause shortage of oxygen in the coastal waters, not even during the spring growth. This is illustrated in figure 2.12, showing the evolution of oxygen saturation in the period 1995-2010. The diagram clearly demonstrates that the situation is good (oxygen saturation continues to be over 70%) and stable.

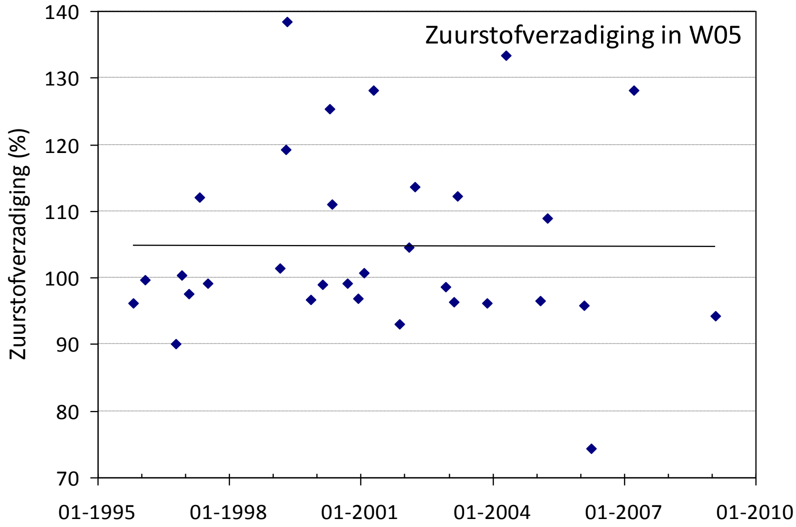


Figure 2.12: Oxygen saturation of the Belgian coastal waters in the period 1995-2010.

Throughout the Belgian coastal waters, concentrations of Dissolved Inorganic Nitrogen DIN and Dissolved Inorganic Phosphorus DIP were compared to their regional background concentrations. The DIN and DIP winter values exceed the limits of 15 µmol/l and 0.8 µmol/l in large parts of the coastal waters. DIN and DIP concentrations as well as silicium concentrations are highest near the Scheldt estuary and decrease in a south-west direction.

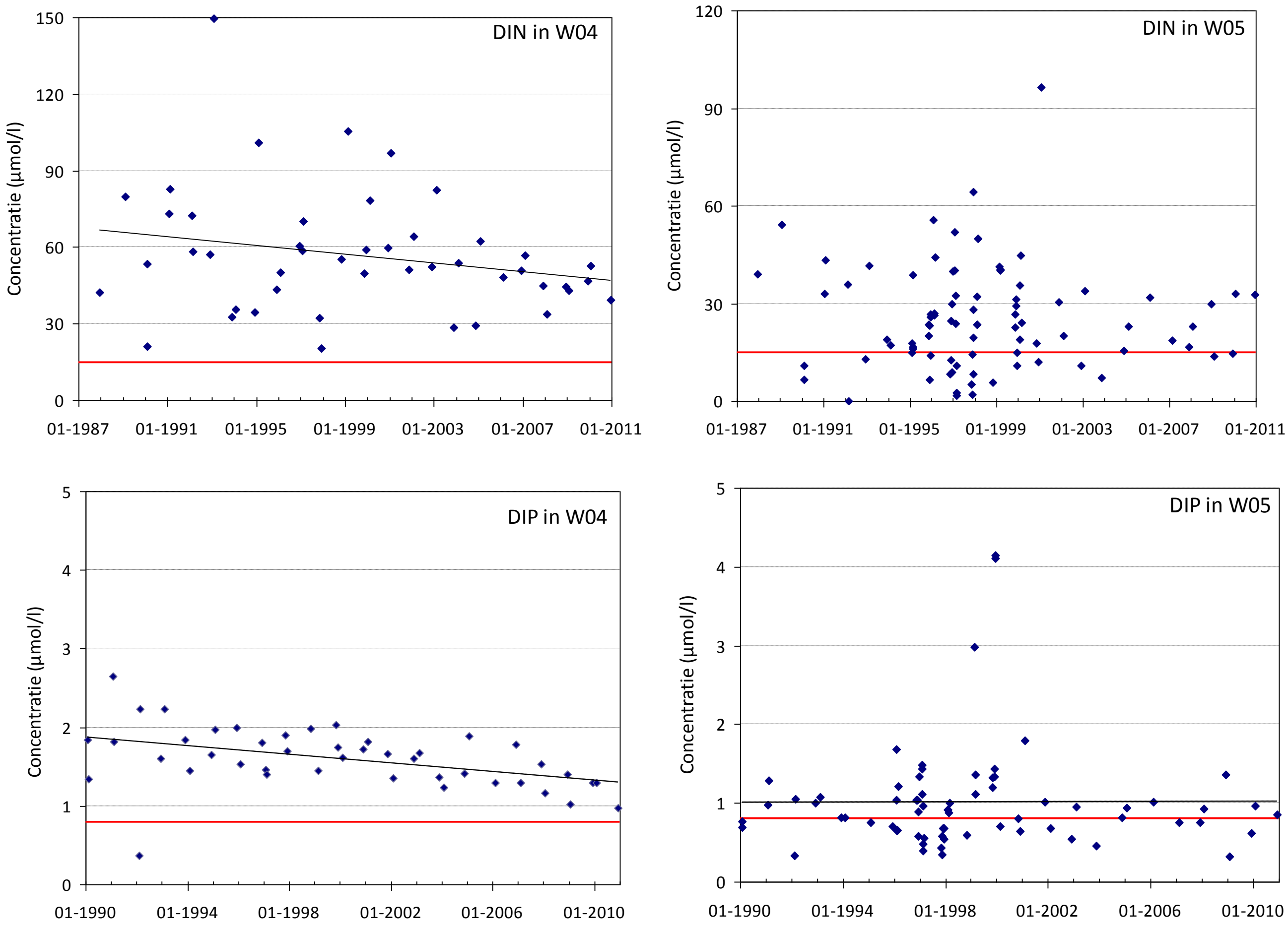


Figure 2.13: DIN and DIP concentrations between 1988 and 2010 at station W04 (Zeebrugge, Scheldt influence) and W05 (further from the coast).

A statistically significant trend in DIN concentrations was not observed between 1974 and 2010. There was, however, a shift in the balance between nitrate/nitrite and ammonium and a slight decrease in silicium concentrations. The most remarkable trend is the significant fall in DIP concentrations, which can be explained from a decrease of P load. This evolution resulted in important shifts in the relationships that determine the growth of phytoplankton and diatoms. The decrease in DIP concentrations resulted in a strong DIN overweight as compared to DIP and Si. In fact, this means that the phosphate concentration currently constitutes the limiting factor for phytoplankton growth and that the silicium concentration is the limiting factor for diatoms.

2.1.9. pH, pCO2 and acidification of the sea

Carbon chemistry was researched using *in situ* measurements (Borges and Frankignoulle 1999; 2002; 2003; Schiettecatte *et al*. 2006; Borges *et al*. 2008) and modelling (Gypens *et al*. 2004; 2009; 2011; Borges and Gypens 2010). Carbon chemistry is strongly influenced by the freshwater plume of the Scheldt estuary, with salinity lying between approximately 29 and 35. This causes strong spatial gradients in carbon chemistry, as is shown in figure 2.14, where data of the Scheldt estuary is compared to data collected further at sea. The water column is well-mixed throughout the year, which eliminates the occurrence of vertical gradients in carbon variables.

The seasonal variations in carbon chemistry parameters are caused by the intake and release of CO_2, as shown in the positive correlation between partial CO_2-pressure (pCO_2) and dissolved inorganic carbon (DIC), and the negative correlation between pCO_2 and pH, and pCO_2 and calcite saturation. The key factors in this context are: the supply of water from the Scheldt estuary with low pH and high CO_2, leading to low pH and high pCO_2-levels in the winter; phytoplankton growth in the spring, leading to low pCO_2 and high pH-levels; the decomposition of organic materials later in the summer and the fall, leading to maximum pCO_2 and minimum pH-levels in the fall. The supply of highly alkaline water from the Scheldt not only controls CO_2, but also the DIC-levels (Frankignoulle *et al.* 1996; Borges *et al.* 2008).

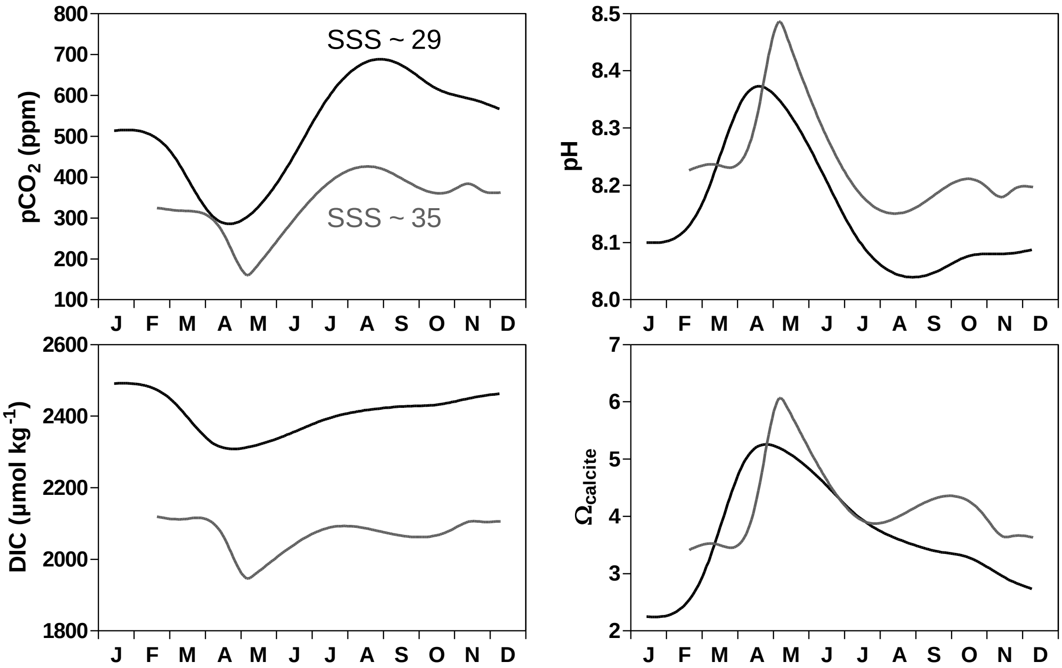


Figure 2.14: Climatological seasonal variations of partial CO_2-pressure (pCO_2), pH, dissolved inorganic carbon (DIC) and calcite saturation ($\Omega_{calcite}$) at the Scheldt estuary (surface salinity approximately 29) and the furthest offshore part of the BCS (surface salinity approximately 35) (Borges and Frankignoulle 1999; 2002; Borges *et al.* 2008).

The existing time series do not allow for studies of long-term (10-100 years) changes in carbon chemistry. Biogeochemical models, however, permit the creation of historical reconstructions. Changes in the carbon cycle in the period 1951 to 1998 as a result of an increase in atmospheric CO_2 and of the nutrient supply by rivers were studied using the R-MIRO-CO_2 model (Gypens *et al.* 2009; Borges and Gypens 2010). Three periods can be distinguished between 1951 and 1988 based on the N and P loads in rivers, the quality of nutrient enrichment (defined as the relation DIN:PO_4 during the winter), the gross primary production (GPP), the net community production (NCP) and the air-sea CO_2-fluxes.

From 1951 to 1965, the annual increase in both the nutrient supply from rivers and the GPP was small, and NCP and air-sea CO_2-fluxes remained stable. From 1965 to 1990, nutrient supply increased and the winter relation DIN:PO_4 roughly met the phytoplankton needs (Redfield relation = 16:1), causing the GPP and NCP to increase and BCS to change from a source of CO_2 to a pit for atmospheric CO_2. From 1990 to 1998, the decreased P load of the rivers – mainly due to the removal of polyphosphates from washing detergents – led to winter relations DIN:PO_4 exceeding the Redfield relation, causing P to become a limiting factor and resulting in a decrease in primary production. The BCS changed from a net autotrophic system into a net heterotrophic system and from a pit into a source of atmospheric CO_2.

Between 1965 and 1990, when nutrient supply from rivers grew and the winter relation DIN:PO_4 roughly coincided with the Redfield relation, pH and $\Omega_{calcite}$ increased as a result of the rise in GPP. After 1990, GPP fell, as did pH and $\Omega_{calcite}$. As a result, eutrophication and the corresponding changes in the carbon cycle (rise of GPP and a shift from net heterotrophy to net autotrophy) affected the marine carbon chemistry, which in turn neutralised the carbon chemistry of the acidification of oceans.

After 1990, when GPP again fell, the decrease in pH and $\Omega_{calcite}$ was significantly greater than could be expected from the simple increase in atmospheric CO_2. The post-1990 trends can be explained from the ecosystem's quick change from net autotrophic to net heterotrophic, in relation with the – limiting, in terms of primary production – rise of the rise of the DIN:PO_4. This shift to net heterotrophy led to a net annual CO_2-production at the ecosystem level, with a strong effect on the marine carbon chemistry. This emphasises the fact that changes in river nutrient load as a result of management measures can alter the carbon cycle in the coastal zone considerably, even to an extent that temporarily, greater changes would arise in the carbon chemistry than the ones caused by the acidification of the ocean.

Based on existing data (see above as well as non-published data from Borges), the current situation shows the same patterns as those in the late 1990s: net heterotrophy; net CO_2 emissions into the atmosphere; changes in carbon chemistry occur quicker than might be expected from the increase of atmospheric CO_2 only. In other words: the net biomass consumption exceeds net biomass production, resulting in the sea emitting CO_2.

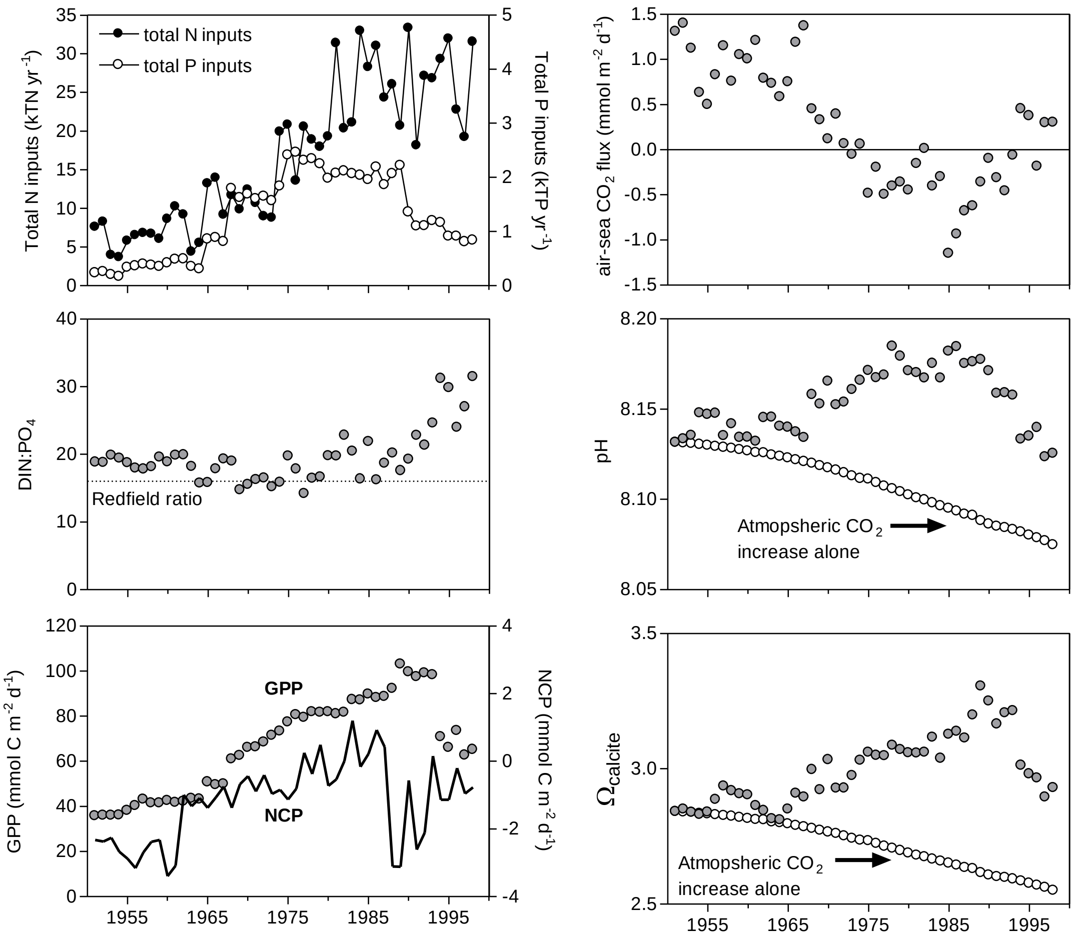


Figure 2.15: Evolution between 1951 and 1998 of the annual total N and P loads from the Scheldt, winter DIN:PO_4, calculated using the R-MIRO-CO_2 model; total primary production (GPP), net community production (NCP), air-sea CO_2-fluxes, pH and calcite saturation ($\Omega_{calcite}$) (according to Gypens *et al* 2009; Borges and Gypens 2010).

2.2. Types of habitat

Characteristic for the BCS is its complex system of sandbanks that, based on their orientation and depth, can be categorised into four different types. The closest system, the Kustbanken [Coast banks], lie parallel to the coastline and stretch from the beach several kilometres into the sea. At low tide, the peaks of these sandbanks are only a few metres deep. Some of them even fall dry at low tide. The Vlaamse Banken consist of a series of parallel, south-west to north-east oriented banks. They are located some 10 to 30 metres from the coast. At low tide, the tops of these banks are at a depth of four metres on average. Parallel to the coastline and at a distance of 15 to 30 kilometres are the Zeelandbanken or Zeeuwse Banken (Zeeland banks). With very few exceptions, the tops of these banks lie below the 10 m isobath. And lastly, there is the Hinderbanken system, some 35 to 60 kilometres from the coast. These sandbanks have a south-west to north-east orientation and just like the Zeeland Banks, are located below the 10 m isobath.

2.2.1 Seabed

The mobile substrates of the Belgian Part of the North Sea BPNS consist of a gradient of sediment types, varying from cohesive silt via fine sand towards coarser permeable sediments. This strong gradient in sediment composition is responsible for the relatively high diversity of benthic biotopes. There are four subtidal benthic biotopes, each named after their characteristic macrobenthic organisms: the *Macoma balthica* biotope; the *Abra alba* biotope; the *Nephtys cirrosa* biotope and the *Ophelia borealis* biotope. Each of these biotopes is inhabited by a specific macrobenthic, epibenthic and fish fauna.

Besides these mobile substrates, non-mobile beds such as tertiary clay and turf beds and gravel beds outcrop in several places. These types of habitat are also characterised by a specific fauna, based on which several biotopes were distinguished. The *Barnea candida* biotope is known from tertiary clay banks in the coastal area, but can also occur in offshore turf banks. Whereas the aforementioned biotopes are typically inhabited by burrowed fauna and free-living surface dwellers, the gravel beds form the biotope of attached and associated organisms.

Many areas also contain artificial structures, such as breakwaters, shipwrecks, port walls and the more recent wind turbine parks. In terms of structure, the fauna of these biotopes is closely associated to that of the natural hard substrates, i.e. the gravel beds. Differences as compared to the gravel beds are related to the type of substrate, their geographic location and their exposure to currents.

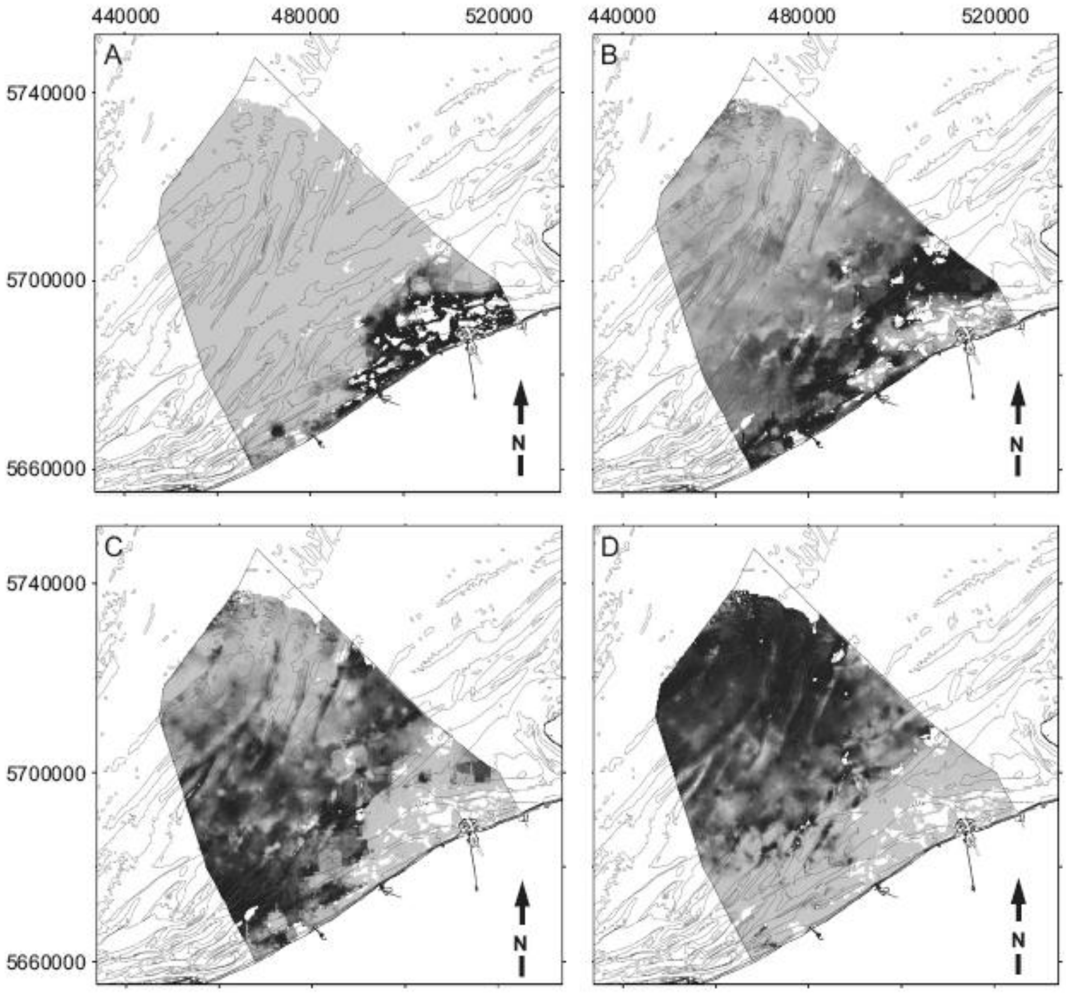


Figure 2.16: Predicted spread of the four subtidal macrobenthic biotopes: light grey: low chance of occurrence; dark grey: high chance of occurrence; white: not predicted. A: *Macoma balthica* biotope; B: *Abra alba* biotope; C: *Nephtys cirrosa* biotope; D: *Ophelia borealis* biotope (Degraer *et al.* 2008). Projection UTM 31N – WGS84.

2.2.2. Water column

The water column, also known as the pelagia, is the largest maritime biotope in Belgium. At the top of the pelagia is the photic zone, where vegetable phytoplankton performs its photosynthesis. This phytoplankton forms the basis of the pelagic food chain and is predated by zooplankton, which in turn plays a crucial role for higher trophic levels (fish). The zooplankton consists of small animal organisms free-floating in the water column. We distinguish holoplankton (that live in the water column their entire life) and meroplankton (that only spend part of their life cycle in the water column). Many benthic organisms have meroplanktonic larvae, creating a clear connection between the pelagic and benthic ecosystems. At the BCS we find several plankton communities closer to the coast, as well as in deeper waters where the water column contains less detritus and the inflow of Atlantic water ensures a greater presence of oceanic zooplankton species (e.g. krill). The holoplankton is dominated mainly by calanoid copepods (*Temora longicornis, Acartia clausi, Centropages hamatus, Paracalanus parvus, Calanus helgolandicus*). Jellyfish constitute a second large holoplanktonic group, such as the greatly expanding comb jelly *Mnemiopsis leidyi*. Significant meroplanktonic groups are the larvae of crabs, shrimp, fish and echinoderms.

Migrating pelagic fish species such as herring, sprat, mackerel and horse mackerel feed on zooplankton. Juvenile herring and sprat inhabit our coast banks throughout the year. Adult herring can be found here later in the year, when the fish are passing on their way to their spawning grounds in the Channel (large schools of fish). Two other key pelagic species show up during summer and autumn: the mackerel and horse mackerel. Horse mackerel breeds on the BCS, with juveniles abundant in the offshore pelagic fish community.

Due to its function as a breeding ground and high turnover, the pelagia plays a key role in the operation of our marine food chain, but it is highly affected by changes in seawater temperature, oceanic inflow and nutrient concentrations.

2.2.3 Special habitats (Habitat Directive)

Two types of habitats as laid down in Annex 1 of the Habitat Directive occur at the BCS: sandbanks slightly covered by seawater all the time (habitat type 1110) and reefs (habitat type 1170).

Habitat type 1110 is described as the structurally and functionally indivisible aggregate of sandbank top and flanking channels such as they can be distinguished morphologically on bathymetric maps. Since from a morphological point of view, practically the entire BCS can be considered as a system of sandbanks and channels, this habitat type stretches a distance of 3148 km². Only in the northern part do the sandbanks gradually roll into a sand wave field, which is the reason why this area is not classified as Habitat type 1110. We distinguish 24 different sandbank systems.

Two habitat types 1170 associated with habitat type 1110 occur as well: the geogenic gravel beds and the biogenic *Lanice conchilega* aggregates. Gravel beds are generally recognised as areas of special ecological value: they are home to a rich flora and fauna and contain a high biodiversity of stones. For instance, the European oyster *Ostrea edulis*, a reef forming species from the southern North Sea that is now threatened with extinction, appears to be highly dependent on gravel beds. Gravel beds also have a key function as breeding and growing area for various fish species.

Aggregates of the sand mason worm *L. conchilega* cause local sediment accumulations, creating clearly marked structures with specific physical characteristics. Within these aggregates, the macrobenthic biodiversity is four to six times higher than the surrounding sediment, while the macrobenthic density exceeds it by 34 times. Furthermore, the aggregates are an important foraging and shelter area for, among others, juvenile flat fish.

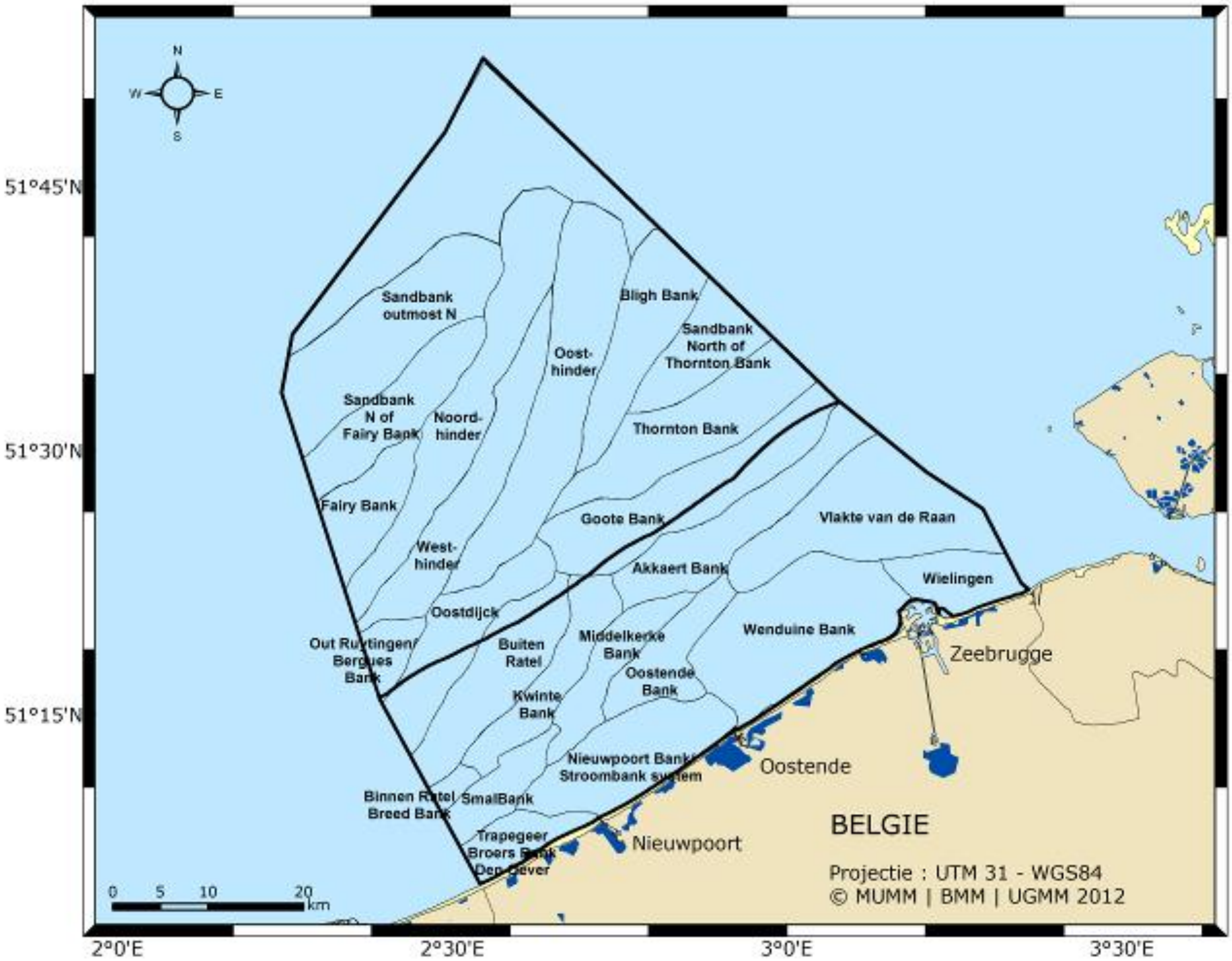


Figure 2.17: Spatial distribution of habitat type 1110 indicating the 24 sandbank systems (Degraer *et al*. 2009).

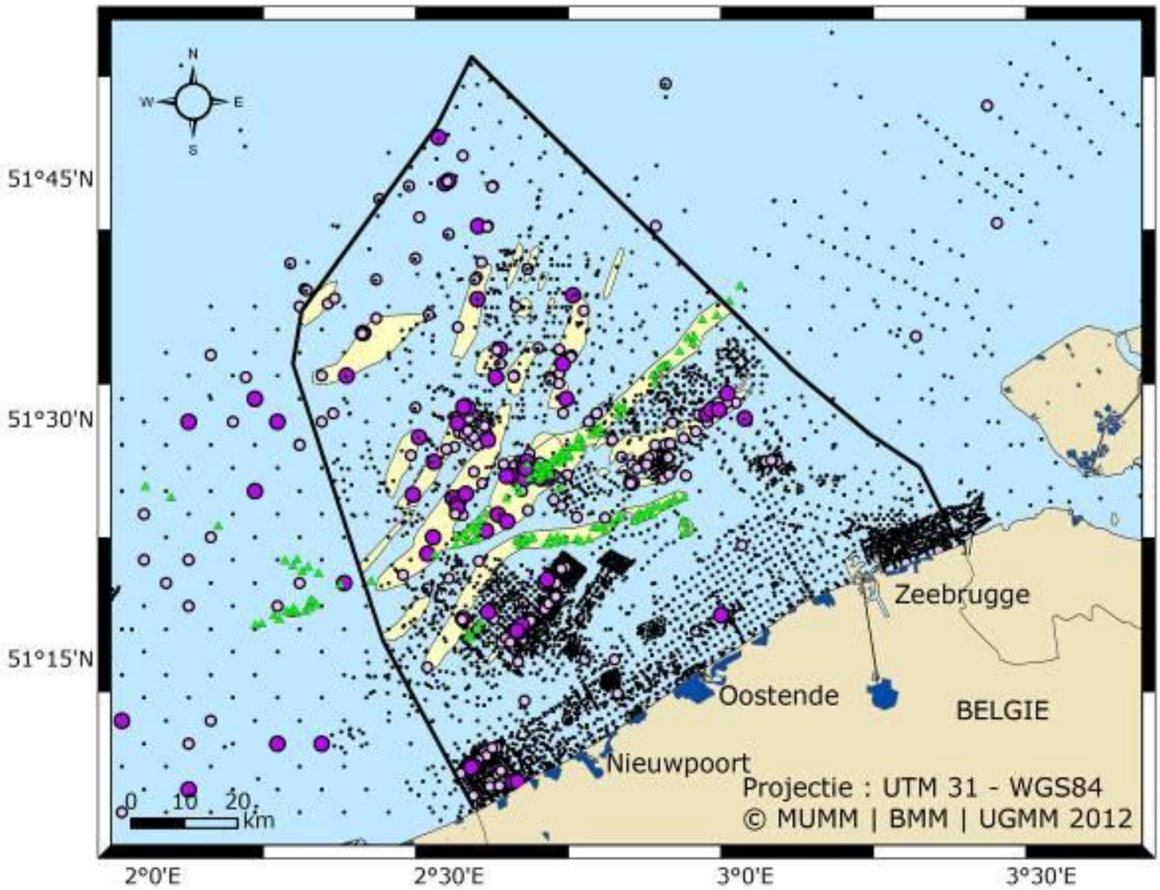


Figure 2.18: Mapping of potential gravel areas (yellow zones), sample areas (purple), observed gravel areas (green) (Degraer *et al.* 2009).

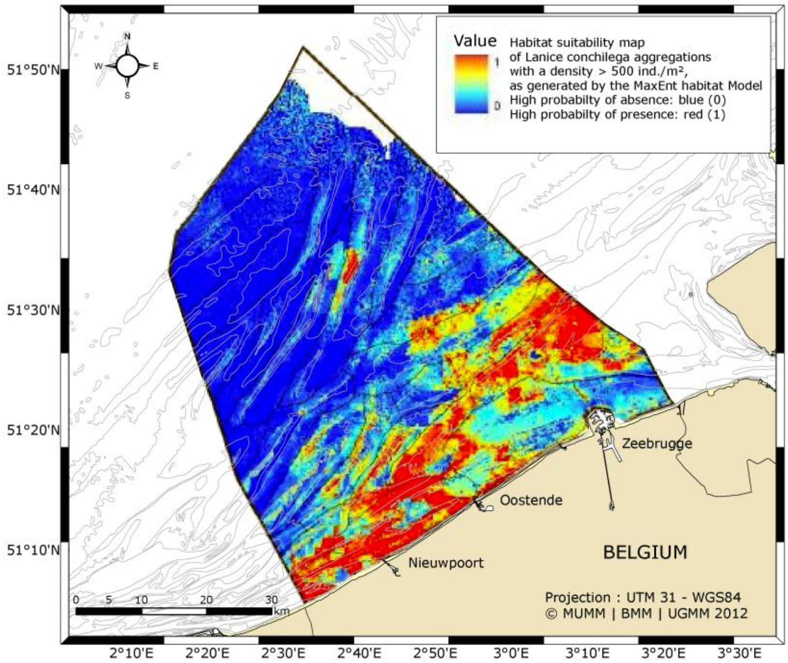


Figure 2.19: Habitat suitability map for *Lanice conchilega* aggregates with a density of > 500 ind/m² as generated using the MaxEnt programme for habitat suitability modelling. Most likely absent: blue (0); most likely present: red (1) (Degraer *et al*. 2009).

2.2.4 Habitats requiring a specific protective regime

Based on the occurrence and spread of the habitat type from Annex 1 of the Habitat Directive: "sandbanks slightly covered by seawater all the time" (habitat type 1110), two marine protected areas were already indicated in 2004: the Trapegeer-Stroombank area and Vlakte van de Raan. In February 2008, the Belgian Council of State rescinded the establishment of the Vlakte van de Raan. In 2010, the Trapegeer-Stroombank area was expanded at the request of the European Union: the indicated Vlaamse Banken area comprises both habitat type 1110 and the associated habitat type 1170.

Table 2.1: Absolute surface of Habitat types 1110 "sandbanks slightly covered by seawater all the time", including characteristic benthic biotopes, and 1170 "reefs" as described in the Habitat Directive area "Vlaamse Banken" (Flemish Banks).

Habitat type / Biotope	**Surface area**
Habitat type 1110	1,107 km²
Macoma balthica biotope	24 km²
Abra alba biotope	245 km²
Nephtys cirrosa biotope	521 km²
Ophelia borealis biotope	292 km²
Habitat type 1170, associated with habitat type 1110	
Gravel beds	221 km²
Lanice conchilega aggregates	± 285 km²

The selected sandbanks within the suggested Habitat Directive area all fall in the range of sandbanks with the highest ecological value in terms of one or more of the four benthic biotopes. The area also comprises a considerable part of the surface of habitat type 1170. Besides its benthic importance, the area of the Habitat Directive is also known as a breeding ground for, among others, fish species of commercial importance.

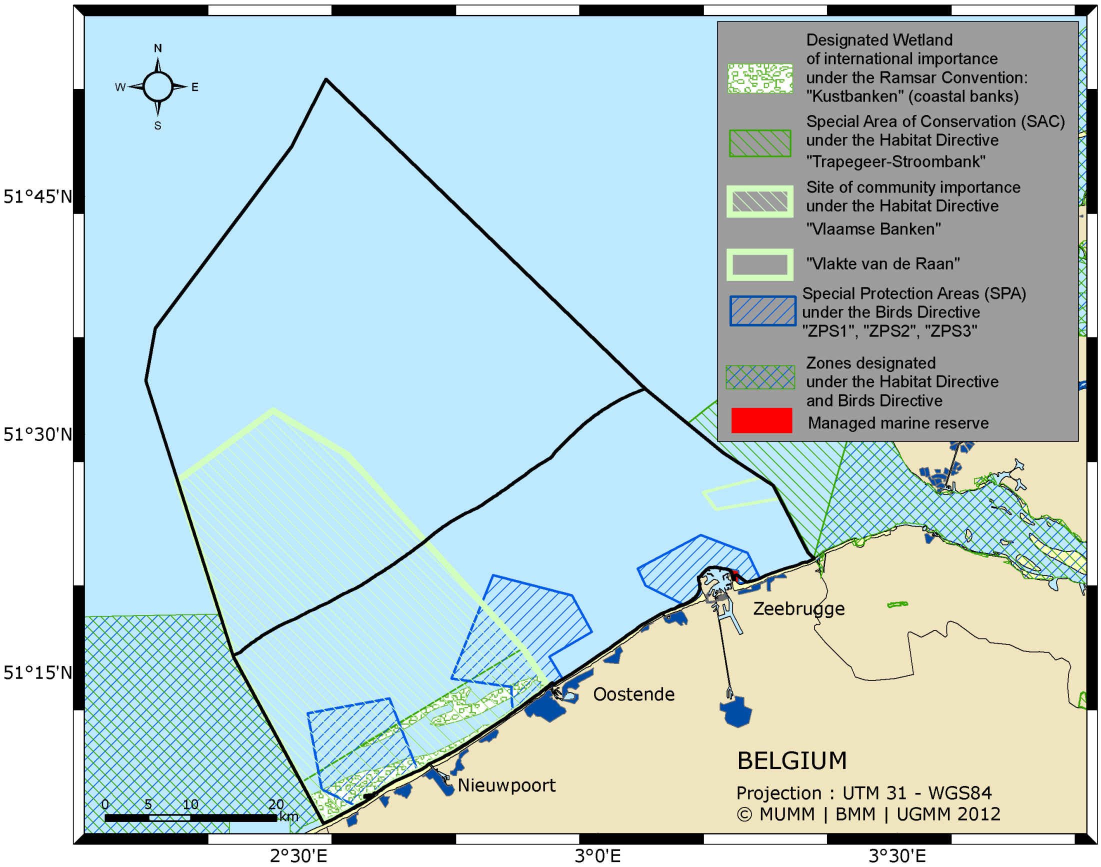


Figure 2.20: Geographical location of the protected areas.

2.3. Biological characteristics

Marine biodiversity can be defined as the variety of living marine organisms and the ecological complexes they form part of. It is hard to estimate the species richness of marine organisms at the BCS. Some one hundred thousand species have been identified in the North Sea basin, but estimates put the number of species inhabiting the area at no less than three million. 2,187 marine species were counted at the BCS (Vandepitte 2010). Zooming in on the macrobenthos (i.e. macroscopic organisms living in and on the seabed), the BCP is definitely not one of the richest systems in the North Sea basin (Rees *et al.*, 2007) and it has a regionally typical low species richness. Still, in 2005 the number of observed macrobenthic species was estimated at 265 for the mobile substrates and 224 for the non-mobile substrates (Degraer *et al.* 2006, Zintzen and Massin 2010).

2.3.1. Seabed

The Belgian part of the North Sea consists of three large substrate types that in ecological terms coincide with a EUNIS level 3 habitat classification (figure 2.21). EUNIS is a hierarchic system for classifying habitats in Europe and its surrounding seas. There are six levels with marine habitats discriminated mainly according to biological zone (littoral, infralittoral, circalittoral, etc.), substrate type, hydrodynamic energy (wave exposure, tidal force), oceanographic variables (salinity) and the typical biological species.

EUNIS A5.1 habitats are coarse-grained sediments; A5.2 is the sand to muddy sand category; A5.3 is mud to sandy mud; and A5.4 is the mixed sediment category (Van Lancker 2012). The coarse-grained substrates comprise the gravel beds, except for the large blocks that have been included in the gravel mapping (figure 2.18). The reliability of the demarcation of these substrate types decreases in a seaward direction. The occurrence of EUNIS level 3 marine habitats is available for the north-eastern part of the Atlantic Ocean (Cameron and Askew 2011).

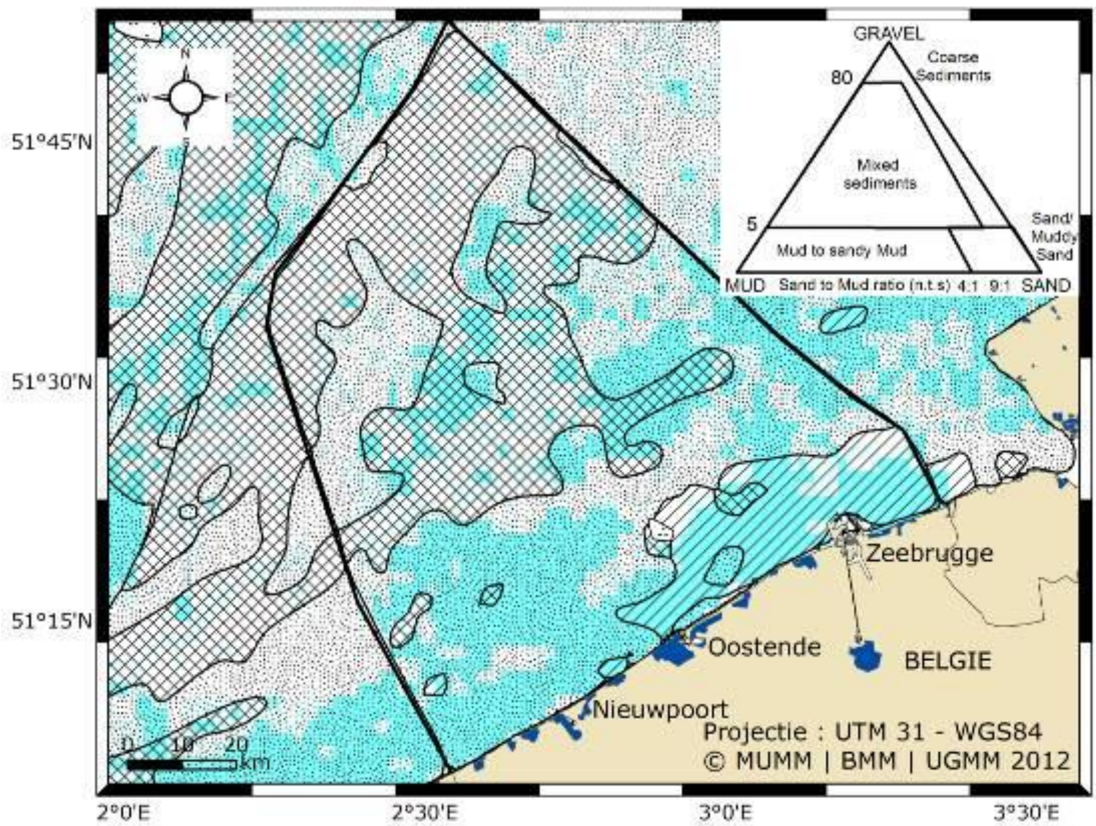
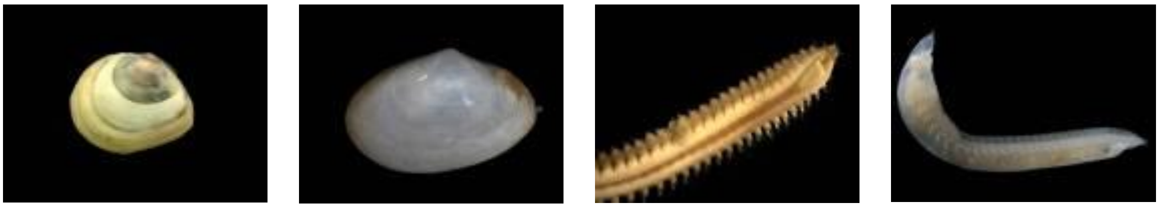


Figure 2.21: The occurrence of EUNIS level 3 habitats at the BPNS. The mapping is based on the relations between the percentages of gravel, sand and mud (see caption) (nts: not to scale): coarse-grained sediments (shaded area) consist of either >=80% gravel, or of sediments with a sand/mud ratio ≥ 9; sand to muddy sand (dots) is made of <5% gravel and a sand/mud proportion ≥ 4; mud to sandy mud (hatched) coincides with < 5% gravel as well as a sand/mud ratio < 4 (Van Lancker, 2012). Further refining of the distribution pattern with acoustic seabed mapping and additional sampling is required. The background colour indicates the mapping reliability: white to light blue: low; cyan: high.

Soft substrates

The macrobenthic communities in the mobile or soft substrates form a key indicator of the health of the marine ecosystem. Four subtidal communities are distinguished, each associated with a specific habitat: the *Macoma balthica* community; the *Abra alba* community; the *Nephtys cirrosa* community and the *Ophelia borealis* community (Degraer *et al*. 2003; 2008; Van Hoey *et al*. 2004). These communities do not occur as isolated entities: there are gradual transitions between them.



Macoma balthica *Abra alba* *Nephtys cirrosa* *Ophelia borealis*

Figure 2.22: Habitus of the characteristic and descriptive types of the four macrobenthic communities living in the non-mobile or soft substrates of the BCS.

A very low density (190 ind/m² on average) and species richness (5 spp/0.1 m² on average) are typical for the *O. borealis* bristle worm community that can be found in medium- to coarse-grained seabeds. Another characteristic species is the interstitial bristle worm *Hesionura elongata*.

The *N. cirrosa* bristle worm community has a low density (402 ind/m² on average) and a low species richness (7 spp/0.1 m² on average) and typically lives in fine to medium sandy sediments that are very low in silt. Other characteristic species include the bulldozer amphipod *Urothoe poseidonis* and the sand digger shrimp *Bathyporeia* spp.

The *M. balthica* (tellin) community features low species richness (on average 7 spp/0.1 m²) but relatively high density (on average 967 ind/m²); its typical finding place is in silty sediments. The *M. balthica* community is closely related to the *A. alba* community: three of the most common species are also found in the *A. alba* community. Characteristic species include: the bristle worms Cirratulidae and *Heteromastus filiformis*. A likely explanation for the lower species richness in the eastern coastal waters is the high concentration of suspended matter.

Finally, the *A. alba* community is characterised by a large density (6,432 ind/m² on average), a high species richness (30 spp/0.1 m² on average) and it is typically found in fine sand rich in silt. Characteristic species include the white furrow shell *Abra alba*, the cut through shell *Spisula subtruncata*, the bivalve mollusc *Mysella (Kurtiella) bidentata*, the caprellid *Pariambus typicus*, as well as bristle worms, including *Stenelais boa* and the "reef" building sand mason worm *Lanice conchilega*. The *A. alba* community also harbours an abundance of the invasive American jackknife *Ensis directus* (Houziaux *et al*. 2012). First found in 1987, this species now displays average densities of 9 ind/m² in coastal waters (Houziaux pers. comm.).

Figure 2.23: After a storm, the shells of the white furrow shell *Abra alba* frequently wash ashore. The photo also shows specimen of the American jackknife *Ensis directus*, as well as a Baltic tellin *Macoma balthica*.

The benthic communities show significant annual variation as a result of seasonal fluctuation, varying degrees of success in recruitment, cold winters and changing sediment composition (Van Hoey *et al*. 2007). Due to, among other things, a lack of continuity in long-term monitoring, the scope and causes of these variations largely remain unknown.

Within the *A. alba* community, for instance, a shift in community structure was observed between the periods 1995-1997 and 1999-2003, probably caused by changes in the hydroclimatic North Sea environment (Van Hoey *et al*. 2007). In the first (unstable) period, the community structure was defined by, e.g., a varying degree of success of recruitment, cold winters and changing sediment composition, while the second (stable) period was characterised rather by regular seasonal fluctuations in community composition. Other examples of long/longer-term variation include the fluctuations in numbers and densities of general species such as the cut through shell *Spisula subtruncata*, the common cockle *Cerastoderma edule*, the banded wedge-shell *Donax vittatus*, the various species of flat shells *Tellina* spp., the trumpet worm *Pectinaria koreni* and the sand mason worm *L. conchilega*.

During the last two decades, the benthic communities in the coastal waters underwent significant changes as a result of the introduction of non-indigenous species. At the same time, several other species such as the otter shell *Lutraria lutraria* and the common netted dog whelk *Nassarius reticulatus* became much more abundant. And finally, several southern species expanded their terrain into the Belgian coastal waters and became increasingly numerous. Despite the fact that many of these species wash onto our shores in great numbers, most of the changes go unnoticed in the current benthos study, probably because the applied technology does not or inadequately sample certain - e.g. deep sea - species.

For the longer term, a comparison of the actual situation to the fauna of bivalved species collected by G. Gilson at the beginning of the 20th century (KBIN collection) shows that the situation has changed (Van Lancker *et al*, 2012). In general we see a regression of the pure sand species (*Donax vittatus, Mactra stultorum, Spisula solida*) and a clear expansion of the species that prefer more silty environments (e.g. *A. alba, M. balthica, Fabulina fabula*, and other species). These observations suggest siltation of the coastal sediments, probably as a result of an increase in maritime and port activities. In addition the average richness of bivalved species seems to have increased. This phenomenon is probably related to the organic enrichment which has been characteristic for the southern part of the North Sea since the second half of the 20th century.

These soft substrates make a significant contribution to the functioning of the ecosystem (Vanaverbeke *et al*. 2011; Braeckman 2011). This mainly has to do with activities of bioturbation and bio-irrigation that also determine the nature of the macrobenthic communities. Bioturbation and bio-irrigation (i.e. functional diversity) are crucial transport mechanisms for the carbon and nitrogen cycles in fine-sanded sediments that are subject to a high influx of organic material. A fall in bioturbators leads to decreased processing of organic materials in the seabed, while a decline in bio-irrigators results in reduced oxygen exchange and denitrification, which largely helps towards compensating nitrogen eutrophication in shallow seas. These characteristics are important for the integrity of the seabed.

Especially the *Abra alba* community contains a number of important bioturbators and bio-irrigators that play a considerable role in the global nutrient cycle and thus can increase the densities and diversities of the infauna (Braeckman, 2011). In this context, *L. conchilega* is a significant bio-irrigator with the strongest impact on oxygen exchange in the sediment. The exchange stimulates mineralisation processes: the release of nutrients and denitrification are doubled as compared to seabeds that have no fauna. High densities of *A. alba* are important for the bioturbation potential, or burying organic material, while *L. conchilega* colonies will lead to continued denitrification. Consequently, both bioturbation and bio-irrigation are key elements in the functioning of the benthic ecosystem (Braeckman, 2011). Because cohesive silt has a more limited pore-water exchange than fine sands, only certain communities can survive (e.g. *M. balthica*).

Natural hard substrates

Several studies have found that gravel beds harbour a rich flora and fauna with a high species richness of both infauna and epifauna on the grit (e.g. Kühne and Rachor 1969; Davoult and Richard 1988; de Kluijver 1991; Dahl and Dahl 2002; Van Moorsel 2003). Those rich communities can only develop if the habitat is not strongly subject to natural and/or andropogenic disturbance.

Studies at the BCS mainly involved the gravel beds near the Hinderbanken and the Vlaamse Banken (Houziaux *et al*. 2008, Van Lancker *et al*. 2007). Gravel is found mainly in between the channels between the banks. The gravel beds near the Hinderbanken have special importance: historical data from the Gibson collection indicates that at the end of the 19th century, gravel beds were the most dominant type of habitat in the channel between the Oosthinder and Westhinder and that they harboured a very high biodiversity (Van Beneden 1883, Houziaux *et al*. 2008). This data further shows a clear correlation between the spread of the gravel beds and that of the European oyster *Ostrea edulis* (Houziaux *et al*. 2008), a species currently practically extinct in the southern North Sea. It is assumed that these oyster beds acted as source population for the intertidal oyster populations (Houziaux *et al*. 2008). Together with the grit, the oysters were colonised by a highly diverse epifauna (e.g. *Pomatoceros triqueter, Sabellaria spinulosa, Haliclona occulata*, *Flustra foliacea*, *Alcyonidium* spp., *Alcyonium digitatum*, *Sertularia cupressina, Nemertesia* spp.), and numerous other smaller and more mobile species lived there as well. As such they constituted the ultimate hot spot of benthic biodiversity at the BCS (Houziaux *et al*. 2008).

Comparisons with the current species composition of the macrobenthos indicate that considerable changes have taken place in species compositions (Houziaux *et al*. 2008), e.g. (1) a probable change from moss animals (Bryozoa, one of them being *Flustra, Alcyonidium* spp.) to a Hydrozoa-dominated system (such as Organ pipe hydroid *Tubularia* spp.) and (2) a change from dominance of long-living species (such as the oyster *Ostrea edulis* and the whelk *Buccinum undatum*) towards shorter-living, opportunistic species (e.g. starfish *Asterias rubens*, serpent star *Ophiura* spp. and brittle star *Ophiothrix fragilis*). The nature of the observed changes shows that they are at least partly related to the constant disturbance of the seabed due to fishery activities. And yet, various typical species are still being found, e.g. painted top shell *Calliostoma zizyphinum* and dead man's fingers *A. digitatum*. Particularly the fauna of species that drill through stones and live in cavities, such as *Barnea parva*, *Gastrochaena dubia*, *Kellia suborbicularis* en *Hiatella* spp.), is unique.

Figure 2.24: Example of a fauna associated with gravel beds.

Recently in two small zones near the Hinderbanken a remarkably well-developed fauna of gravel beds was found, with a well-developed layer of three-dimensional epifauna species, such as sponges, moss animals and hydropolyps, which in turn harbour a more mobile fauna of, among others, sea sludges, small crustaceans and worms (Houziaux *et al*. 2008). It is highly likely that their location gives these places a natural shield against seabed disturbing human activities (beam trawling). This refuge offers an insight into the possible ecological potential of the Belgian gravel banks if the pressure from operations on the seabed were to be reduced.

Finally, another characteristic of the BCS is the sporadic occurrence of turf banks and outcropping banks of tertiary clay. These natural and non-mobile substrates harbour a separate, yet species-poor macrobenthic community, its typical species including drilling bivalves such as the white piddock *Barnea candida* and the (non-indigenous) American piddock *Petricola pholadiformis* (Degraer *et al*. 1999). This community shows a migration in several parts, both in time and in area, due to its direct dependence on the presence of the above-mentioned non-mobile substrates.

Artificial hard substrates

Coastal artificial hard substrates such as breakwaters, dikes and other coastal defence works constitute the habitat for a community similar to that living in natural rock formations, characterised by a high species richness and biomass (Engledow *et al*. 2001). It is the only place where large benthic brown seaweeds Phaeophyta, larger red seaweeds Rhodophyta and green seaweeds Chlorophyta are found. The prevalent community there is typical for a medium-exposed rocky coast, characterised by barnacles (e.g. *Semibalanus balanoides, Balanus crenatus* and *Elminius modestus*), a dense mussel zone (*Mytilus edulis*) and, to a lesser extent, a zone consisting of brown seaweeds. Numerous other invertebrates live among the mussels. This community can be considered as a depleted reflection of the one existing on the French and English Channel coasts as large brown seaweeds such as *Laminaria* spp. and *Himanthalia elongata*, as well as the characteristic low red seaweed zone are absent from the Belgian coast.

231 obstructions were identified on the BCS, most of them shipwrecks (Zintzen *et al*. 2006; Mallefet *et al.* 2008). These artificial hard substrates are often colonised by a community that is different from the ones found in the surrounding areas. In terms of biomass, the fauna on shipwrecks largely consists of Cnidaria (coelenterates), whereas Amphipoda dominate in terms of density (Zintzen *et al.* 2008). Three communities were distinguished: in the coastal area the *Metridium senile* (sea anemone) community with a limited number of species, together with the somewhat richer community of *Tubularia larynx* (organ pipe hydroid); further from the coast, the fouling community is dominated by *Tubularia indivisa* (oaten pipes

hydroid). *Tubularia* spp. (a mixture of *Tubularia indivisa* and *Tubularia larynx*) on the wrecks are always associated with the tube-building amphipod *Jassa herdmani*. A total of about one hundred species were found on and around the shipwrecks, many of them belonging to rare taxa (Zintzen *et al.* 2006).

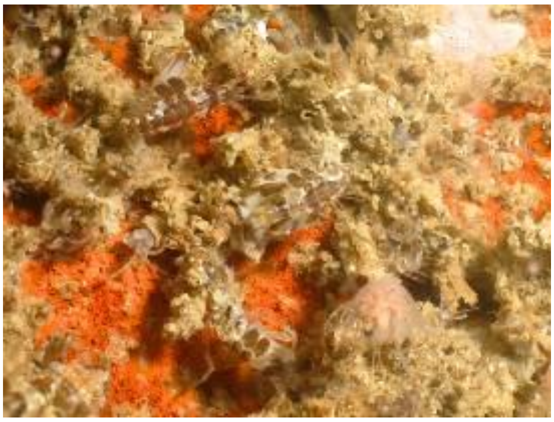


Figure 2.25: Three-dimensional vegetation on the artificial hard substrates associated with the offshore wind farms at the BCS.

Installation of wind parks on the BCS started in 2008. Contrary to the artificial hard substrates in the coastal zone, these substrates are found mainly in clear waters and the hard substrate stretches from the sandy seabed (to a depth of 30 m) and above the supralittoral fringe. This produces a clear zoning pattern, characterised by a higher diversity of biotopes and species (Kerckhof *et al*. 2009, 2010). The deeper parts of the subtidal are dominantly inhabited by the moss animal *Electra pilosa*, amidst smaller mobile species such as the crab *Pisidia longicornis*, the bristle worm *Autolytus* sp. and amphipoda *Jassa* spp. and *Aora gracilis*. This community forms the diet of large numbers of fish, such as the pout *Trisopterus luscus* (up to 30,000 individuals per wind turbine) and cod *Gadus morhua* that are drawn to these parks (Reubens *et al*. 2010, 2011). The shallow subtidal and the low intertidal zones mainly harbour the amphipod *Jassa* spp. and the barnacle *Balanus perforatus*, whereas the species-poor higher intertidal zone houses little more than the marine splash midge *Telmatogeton japonicus* (besides a few macro algae species).

2.3.2. Water column (phytoplankton, zooplankton, gelatinous plankton)

The annual plankton growth cycle starts early spring with a growth of diatoms (Rousseau *et al*. 2002). In April and May, the algal bloom mainly comprises the colony-forming slime algae *Phaeocystis globosa* (Lancelot *et al*. 1987) (Haptophyta) which is capable of producing a large quantity of biomass (foam). In June, both the diatoms and *Phaeocystis* disappear from the water column (Rousseau *et al*. 2002), most probably as a result of nutrient shortage and possibly also of an enhanced predation pressure of heterotrophic plankton species such as the dinoflagellate *Noctiluca scintillans* (Daro *et al*. 2006). A second, less extensive diatom bloom occurs later in the summer and in the autumn (Rousseau *et al*. 2002).

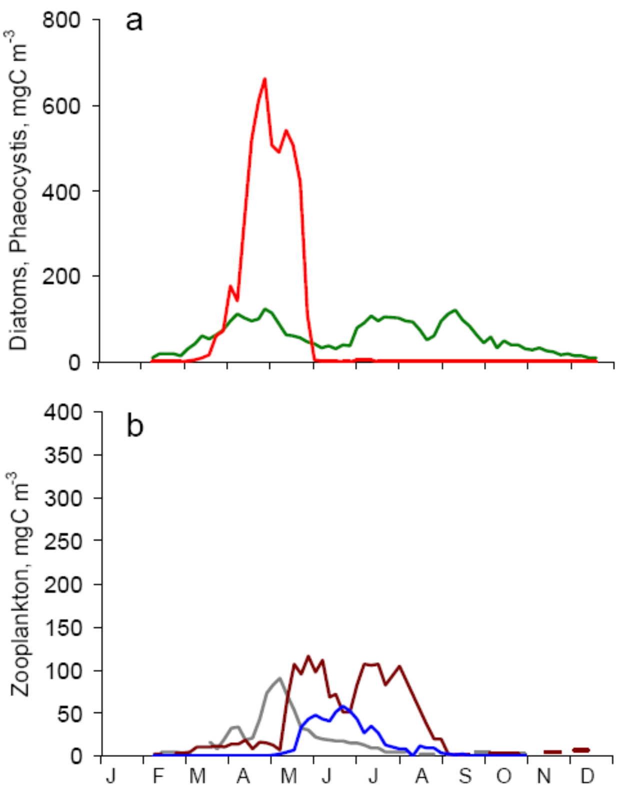


Figure 2.26: Seasonal distribution of the phyto- and zooplankton in the central zone of the BCS: average results over the period 1988-2004, (a) Phytoplankton: colonies of *Phaeocystis* (red) and diatoms (green). (b) Zooplankton: microprotozooplankton (grey), copepods (bruin) and sea sparkle *N. scintillans* (blue) (Daro *et al.* 2006).

The spatial variability of the spring peak in chlorophyll *a* concentrations, which is an indicator of phytoplankton biomass, reflects the spatial variability of nutrients during the winter (Muylaert *et al*. 2006; Brion *et al*. 2006; Rousseau *et al*. 2006). The annual variability in amplitude and period of the diatoms and *Phaeocystis* bloom is affected by meteorological factors (wind, river flow rate) as characterised by the NAO index (Breton *et al*. 2006).

Based on research that was carried out in the scope of the OSPAR strategy "Eutrophication", the Water Framework Directive (WFD European Union 2000) defines the quantity of phytoplankton as one of the elements of biological water quality in relation to eutrophication. For application of the WFD to the coastal waters (European Union 2008), threshold values for chlorophyll *a* of 10 µg/l and 15 µg/l were used to distinguish between a "very good to good" and "good to average" environmental status. These threshold values apply to the 90th percentile of the chlorophyll *a* measurements during the bloom season.

Figure 2.27 shows the indicator as derived from satellite data. The colour red represents an average environmental situation, whereas orange stands for "good" and green for "very good". Blue reflects the oceanographic conditions.

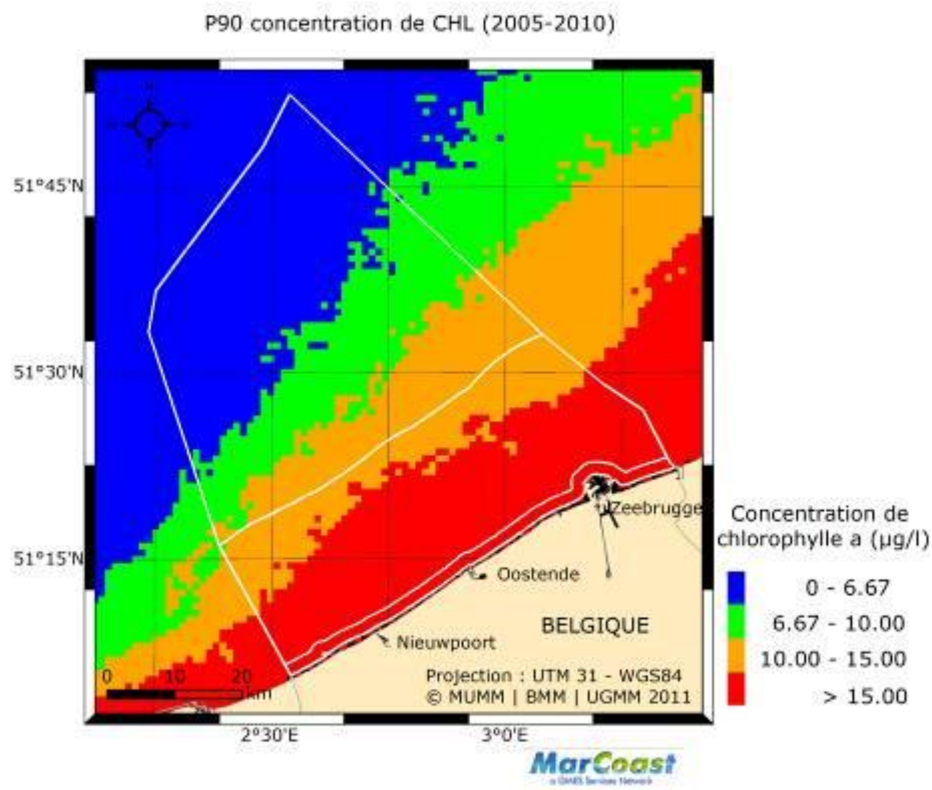


Figure 2.27: 90th percentile of the chlorophyll *a* concentration during the bloom season (March to November) derived from satellite images (sensor MERIS, processor megs 7.5) for the years 2005-2010. Source: BMM.

Intensive phytoplankton monitoring (quantity, species composition) was carried out for the WFD from 2007 to 2010, but later limited to the three stations just off the coast: W01, W02 and W03 (Denayer *et al*. 2010). The ecological quality index in the three stations was 'red' for 2008, 2009 and 2010.

The WFD defines the taxonomic composition of the phytoplankton as an added biological quality element and considers the frequency and intensity of the phytoplankton bloom as indicators for the environmental situation. For application of the WFD to coastal waters, an intercalibration exercise (European Union 2008) has defined threshold values for the percentage of samples whose *Phaeocystis* volume amounts to more than 4×10^6 cells per litre (Lancelot *et al.* 2009; Denayer *et al*. 2010). The threshold values 9% and 17% indicate the distinction between a "very good to good" and a "good to average" environmental situation (European Union 2008). The measured volumes of *Phaeocystis* show significant annual variability (Denayer *et al.* 2010). If the measurements of 2008, 2009 and 2010 are combined, the limits for *Phaeocystis* cell numbers are exceeded in 16.7%, 27% and 27% of the samples in stations W01, W02 and W03, respectively. Based on the spatial variability of chlorophyll *a*, we may assume that these percentages are smaller in the more seaward located areas. Although required in the scope of the MFSD, an evaluation cannot be carried out at present in view of the lack of measurements of phytoplankton species in these areas.

Due to the absence of a monitoring programme for zooplankton, knowledge about species and their temporal and spatial variability is much less for this part of the ecosystem than for phytoplankton. Dominant zooplankton groups are the microzooplankton, copepods and the gelatinous *Noctiluca scintillans*, a heterotrophic dinoflagellate (Daro *et al*. 2006). The latter can occur in large concentrations between May and July.

The average sized gelatinous plankton (1 mm to 3 cm) includes ctenophores such as *Pleurobrachia pileus, Beroe gracilis* and the exotic species *Mnemiopsis leidyi*. The larger gelatinous plankton (1 cm to 1 m) comprises Cnidaria Scyphozoa such as the jellyfish *Aurelia aurita*, *Cyanea lamarckii*, *Chrysaora hysoscella* and *Rhizostoma pulmo*. Here, too, information is lacking due to the absence of a monitoring system for this branch of the ecosystem. Actual information is based on occasional observations of animals that have washed ashore (De Blauwe 2003).

2.3.3. Angiosperms, macroalgae

At the BCS, macroalgae occur almost exclusively on artificial hard structures, such as breakwaters and harbour walls. In most cases, these structures are affected strongly by the billow. The most common species found here are green seaweeds, such as gut weed and sea lettuce species (Ulvacea) and brown seaweeds (*Fucus spp*.). More exposed open coasts are usually inhabited by cosmopolitan species, while more exceptional species only occur in more covered habitats. The species richness is lower than that of the natural rocky coasts of northern France. An increase of green seaweeds such as *Ulva* spp is observed in coastal waters on a global scale as a result of eutrophication. Although at a less spectacular rate, this also applies to the BCS. However, quantitative data is not available.

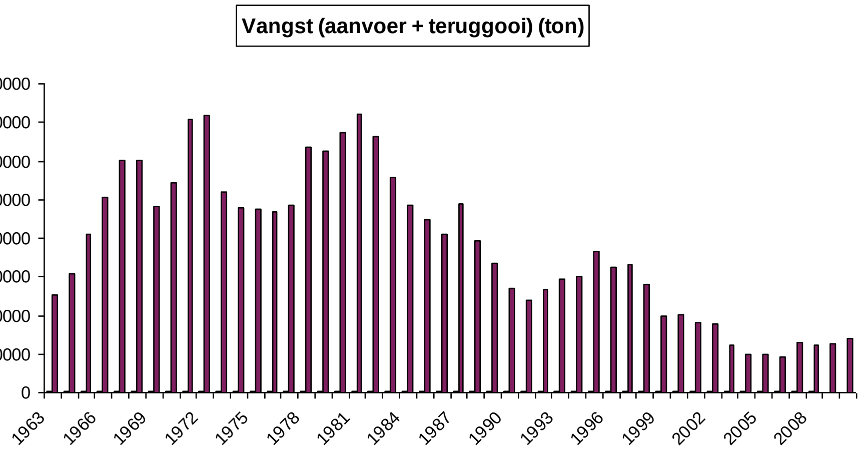
Due to the high water turbidity, there is no red algae zone. Non-indigenous species such as wakame *Undaria pinnatifida* and Japanese weed *Sargassum muticum* can be found particularly within the ports. Contrary to some other regions, the introduced microalgae don't seem to cause any economic damage here. A few non-indigenous red seaweeds also occur within ports. Angiosperms such as seagrass fields are not found in the Belgian waters.

2.3.4. Fish populations

The BCS cannot be considered as a zone with fixed borders as far as fish stocks and currents are concerned and for studies of the development of fish stocks, it forms part of a greater aggregate: the North Sea. For this reason the situation of commercially exploited fish stock is evaluated at a European rather than a national - i.e. Member States - level.

As a result of European policies on fishery, a number of fish stocks in the North Sea – e.g. plaice and sole – are currently evolving in the right direction. Although changes in fishery management occur slowly, they have a clearly positive effect. Long-term management plans are developed for the stocks of a number of key species in the North Sea, including cod, plaice and sole. In addition, attention is paid to reducing seabed disturbing fishery techniques (e.g. beam trawling) and the problematic discards of undersized fish, non-commercial species, invertebrates and waste. Despite these positive developments, some fish stocks – such as cod – are still under enormous pressure. Particularly the targeted fishery for this species has proved harmful. Although Belgium's cod bycatch is limited, it can be expected that a healthier cod stock will lead to higher bycatch. However, cod is not a targeted species in Belgian fishery.

After a period of less intensive cod fishing in the North Sea between 2003 and 2007, an increase in mature individuals was again observed in the past three years (figure 2.28). Despite this development, the population is still 64% smaller than its desired size. The succession of weaker recruitment years also prevented the recovery of the cod stock. For 2012 the management plan stipulates a 20% reduction of Total Allowable Catch (TAC) as compared to 2011, which would mean a 43% decrease in cod fishery as compared to 2010.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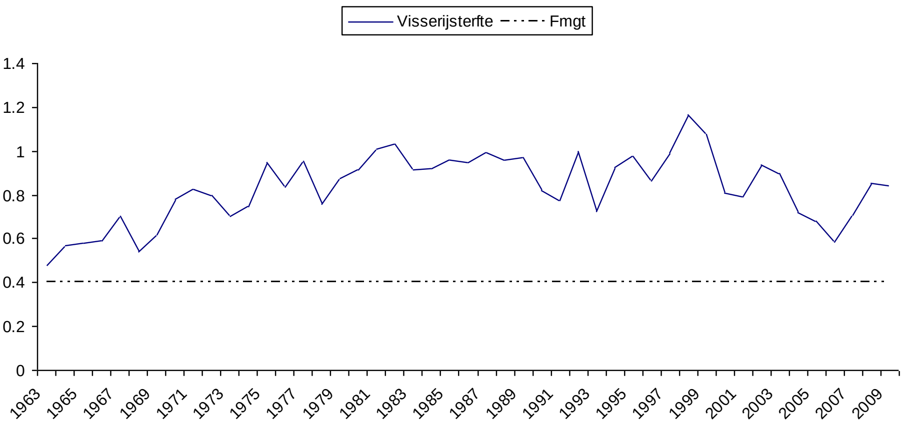
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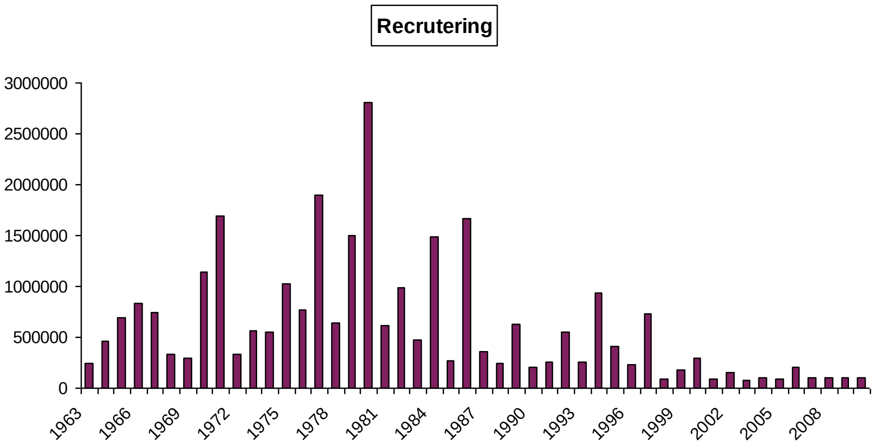
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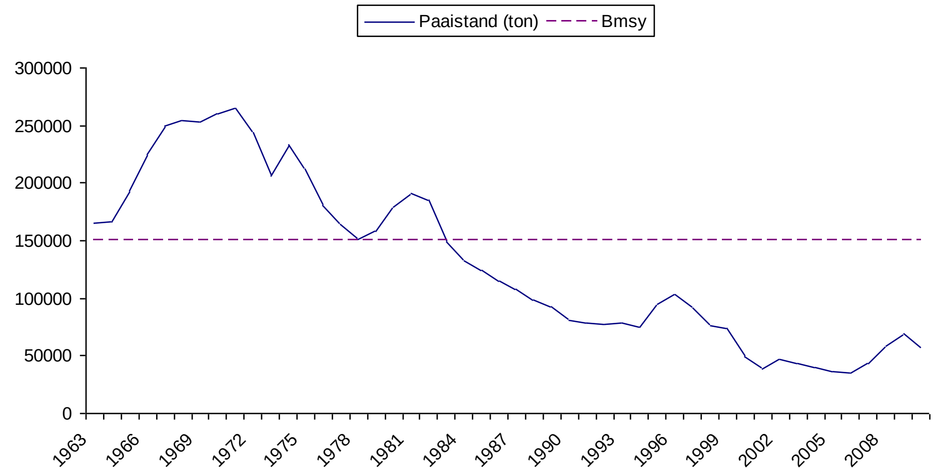


Figure 2.28: a) Catch (supply and discard) (tonnes); b) fish mortality F; c) recruitment (numbers); and d) spawning status (tonnes) of the cod stock *Gadus morhua* in the North Sea. Fmgt = maximum allowed fishing mortality rate for this fish stock according to the management plan; Bmsy = biomass level at maximum sustainable yield.

Both the plaice and sole stocks in the North Sea received a positive evaluation in 2011. Both species are within safe biological limits, with a strongly reducing fishing mortality and increasing (plaice) or stable (sole) spawning stock (of 27% and 4% in excess of the desired population size). In the scope of the management plan, a total catch of 84,410 tonnes of plaice is allowed in 2012, against 15,700 tonnes of sole. Sole and plaice also have a breeding area in the coastal zone of the BCS and as a result, larvae and juvenile individuals (0-1 years old) of both species are found in the BCS.

During sampling activities in the period between 2004 and 2009, 78 fish species were identified across the BCS, mainly involving young, commercial species (sole, cod, plaice, etc.) and non-commercial species (gobies, father lashers, armed bullhead, etc.). The most common juvenile commercial species (>65% of the samples) include dab (90%), plaice (94%), whiting (82%) and sole (69%). At the same time, these are the species with the highest average densities at the BCS, namely 0.5 ind/1000 m^2, 0.15 ind/1000 m^2, 0.23 ind/1000 m^2 and 0.23 ind/1000 m^2, respectively. Relatively high densities also were observed for sprat (0.21 ind/1000 m^2) and herring (0.17 ind/1000 m^2), but beam trawling is not the most suitable fishing equipment for quantitative sampling of these pelagic species.

The most common non-commercial species (>65% of the samples) are the common dragonet (72%), scaldfish (71%), gobies (71%) and the armed bullhead (67%). Looking at the highest average densities we can detect a slightly different pattern, with the small weever being the most abundant species (0.58 ind/1000 m^2), followed by gobies (0.33 ind/1000 m^2), common dragonet (0.3 ind/1000 m^2) and armed bullhead (0.18 ind/1000 m^2).

Of the most common juvenile commercial fish (sole, plaice and whiting), higher densities occur in the coastal area and these decrease rapidly as the distance to the shore increases. Only the dab is found offshore in higher densities throughout the year. Juvenile commercial/non-commercial fish occur in a roughly fifty-fifty proportion in the coastal area, while offshore areas show a greater dominance of non-commercial fish (up to 3 - 10 higher densities). The most dominant offshore species is the small weever, a species not found in the coastal zone but able to locally attain very high densities of up to 5 ind/1000 m^2 on offshore sandbanks.

The seasonal differences are very clear: higher densities in the fall than in the spring are common for all fish species. In addition we generally find higher densities of commercial fish (cod, sea brass, whiting, etc.) in the coastal area in spring, whereas the autumn marks higher densities of juvenile commercial flat fish (sole, brill, turbot, dab, etc.). The spread of whiting is higher in spring than in the autumn as demonstrated by the higher numbers found in offshore locations in the earlier season.

Around the world, cartilaginous fish are having a hard time surviving in increasingly fished seas and oceans. The following rays and sharks used to be common in Belgian waters in the past: thornback ray *Raja clavata*, spotted ray *Raja montagui*, flapper skate *Dipturus intermedia*, stingray *Dasyatis pastinaca*, lesser spotted dogfish *Scyliorhinus canicula*, common smooth-hound *Mustelus mustelus*, spiny dogfish *Squalus acanthias* and angel shark *Squatina squatina* (Gilson 1921, Poll 1947).

Some of these species are still caught nowadays (e.g. lesser spotted dogfish and thornback ray), but they are much less abundant than they were about a century ago. Other species are now extinct in our waters and even in the entire North Sea (e.g. angel shark and flapper skate). The problem of these species is their slow propagation due to a limited number of offspring, as well as late sexual maturity. Furthermore, both the juveniles and adult fish are vulnerable to bycatch due to their size. Some species deposit egg capsules on hard substrates, where they are vulnerable to seabed disturbing fishing techniques, and juveniles grow up in highly fished shallow coastal areas. The thornback ray can serve as an example for the vulnerability of rays in general. They become sexually mature between 7 and 10 years and can reach a length of more than 1 metre. Each year, the females deposit less than 100 egg capsules.

2.3.5. Marine mammals

All the marine mammals found at the BCS are protected species. Although other species are found occasionally, only the following species are regarded as truly indigenous: the harbour porpoise *Phocoena phocoena*, the white-beaked dolphin *Lagenorhynchus albirostris*, the common bottlenose dolphin *Tursiops truncatus*, the common seal *Phoca vitulina* and the grey seal *Halicoerus grypus*.

Resting common seals are sighted frequently on our shores, particularly at a breakwater at Koksijde and at the port of Nieuwpoort, but their numbers remain limited to less than 20 animals (Hassani *et al*. 2011). Our coast is not suitable for seal colonies due to a lack of undisturbed locations. Grey seals are mainly seen at sea and seldom along the coast or on the beach. Each year a number – a few tens at most – of stranded common and grey seal pups that would not survive in the wild are rescued by SeaLife Blankenberge and released back into the sea after a few months.

The common bottlenose dolphin almost totally disappeared from the southern North Sea about half a century ago, probably as a result of pollution, and it has had an effect on its propagation. Given the fact that the number of animals in small residual populations in the Channel and the northern part of the North Sea remains stable or even decreases, chances of recovery are as good as nil in the short term (Haelters 2005). Very sporadically, one or two common bottlenose dolphins are spotted in our waters. Small groups of white-beaked dolphins are seen regularly, mostly relatively far away from the coast.

The harbour porpoise is the smallest and at around 250,000 animals, also the most common of dolphin species found in the North Sea. In the 1950s the animal practically vanished from the southern part of the North Sea, only to make a spectacular comeback in the late 1990s. Nowadays the species is a regular presence in Belgian waters, particularly between February and April, when average densities can climb up to more than 2 animals per km² (Haelters *et al.* 2011). In recent years the harbour porpoise also has become a more regular presence in the area during the summer months.

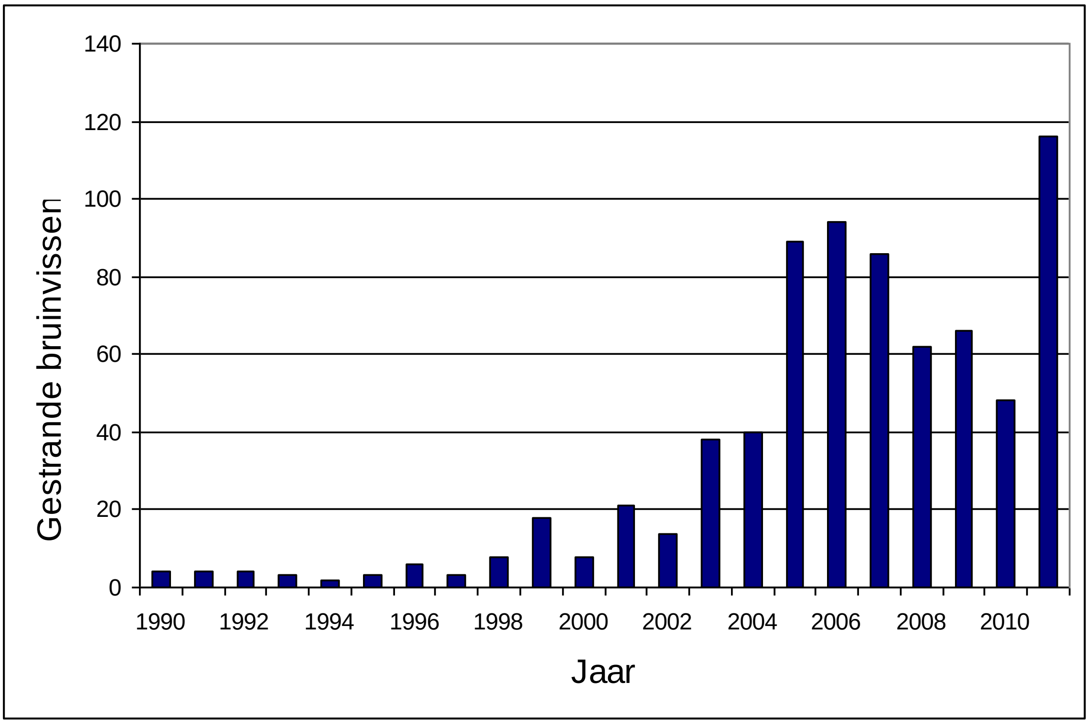


Figure 2.29: Number of harbour porpoise strandings registered in Belgium between 1970 and 2010.

Although the cause of the disappearance of the species in the 1950s remains a mystery, the comeback of the species is caused by a southward shift of part of the North Sea population, probably as a result of worsened nutritional circumstances in the central or northern North Sea. This could be the direct result of subtle climate changes affecting the basis of the food chain.

Research of stranded harbour porpoise revealed one of the principal causes of death: bycatch in fishing nets. Mainly occurring in gill nets and trammel nets, this bycatch is considered as the principal threat to the species in the North Sea and the adjoining Atlantic Ocean. Recreational beach fishery targeted at sole constitutes a problem in spring (Depestele et al. 2012).

Aerial observations and passive acoustic monitoring are used to study the impact of offshore wind farm construction and operation. Pile driving in particular can disturb harbour porpoise.

2.3.6. Sea birds and Birds Directive

The standardised ship and aircraft counts carried out since 1992 have provided a good understanding of the spread and densities of seabirds on the BCS. The counts revealed 47 seabird species in total, 18 of which are common in the area. Despite the limited size of the BCS, eight seabird species qualify for protection based on the European Birds Directive (Table 2.2). These involve the species listed in Annex I to the Birds Directive (79/409/EEG) and spotted regularly, followed by the species of which more than 1% of the biogeographical population is found in the BCS on a regular basis (the so-called Ramsar standard). Both categories also comprise other species than the ones listed in Table 2.2, but for specific reasons these are not included (e.g. herring gull *Larus argentatus* does reach the 1% standard but is mainly active on land and does not or hardly forage at sea; the great skua *Stercorarius skua* is included but is too rare a visitor).

Table 2.2: Overview of the globally important seabird species at the BCS and of the international qualification criteria used. The description of the numbers is based on the numerosity scale as prescribed by the Flemish Avifauna Commission (1989): very small numbers 1-10; small numbers 11-100; rather small numbers 101-1,000; rather large numbers 1,001-10,000; large numbers 10,001-100,000 and very large numbers in excess of 100,000.

Species	Scientific name	Annex I Birds Directive	1% standard exceeded	Occurrence
Red-throated diver	*Gavia stellata*	**Yes**	No	Winter visitor and transmigrant in rather small to rather large numbers
Grebe	*Podiceps cristatus*	No	**Yes**	Winter visitor in rather large to large numbers
Great black-backed gull	*Larus marinus*	No	**Yes**	Transmigrant and winter visitor in rather large numbers
Lesser black-backed gull	*Larus fuscus*	No	**Yes**	Nesting bird and transmigrant in rather large numbers
Little gull	*Hydrocoloeus minutus*	**Yes**	**Yes**	Transmigrant in rather small to rather large numbers and winter visitor in rather small numbers
Great tern	*Sterna sandvicensis*	**Yes**	**Yes**	Nesting bird in rather small to rather large numbers and transmigrant in rather
Common tern	*Sterna hirundo*	**Yes**	**Yes**	Nesting bird in rather large numbers and transmigrant in rather small to rather large numbers
Little tern	*Sternula albifrons*	**Yes**	**Yes**	Nesting bird and transmigrant in small to rather small numbers

For four species a Special Protection Area at sea was already marked in the scope of the Birds Directive: grebe *Podiceps cristatus*, common tern *Sterna hirundo*, large tern *Sterna sandvicensis* and little gull *Hydrocoleus minutus – Larus minutus* until recently. Of two species not included in Annex I of the Birds Directive - the lesser black-backed gull *Larus fuscus* and great black-backed gull *Larus marinus* - more than 1% of the biogeographical population is found regularly at the BCS. Two species – the red-throated diver *Gavia stellata* and little tern *Sternula albifrons* – are included in Annex I of the European Birds Directive and regularly occur in substantial numbers.

The southern part of the North Sea is also an important migration route, its funnel shape due to the Belgian and French coasts and the east coast of England a bottleneck for migrating birds. An estimated 1 to 1.3 million seabirds migrate through this bottleneck each year (Stienen *et al*. 2007). It is assumed that more than half of the great skua *Catharacta skua*, little gull, large tern and common tern populations pass via that route. For the little tern, this could even be a very substantial part of the biogeographical population.

Four functional feeding groups can be distinguished. Sea-ducks, such as the black scoter, velvet scoter *Melanitta fusca* and common eider *Somateria mollissima* dive to the bottom and feed on benthic organisms (mainly bivalved) only. A few other species feed on fish living in the water column (especially gobies, clupeids and sand eels). These include the species from the families of Gaviidae (especially the red-throated diver), Podicipedidae (grebe), Sternidae (great tern, common tern and little tern) and Alcidae (razorbill *Alca torda* and common murre *Uria aalge*). Other seabirds feed mainly on small organisms that live just below the surface (small crustacea and small fish), for instance the northern fulmar *Fulmarus glacialis* and the little gull. Finally, many species rely heavily on debris and bycatch thrown overboard from fishing boats, such as large gulls (herring gull *Larus argentatus*, lesser black-backed gull and great black-backed gull). Of these species, 38-45% of all individuals are counted while trailing fishing boats. Of the smaller gull species, mainly the three-toed gull *Rissa tridactyla* is regularly (26%) spotted trailing fishing boats.

2.3.7. Non-indigenous species introduced through human activities

About one hundred non-indigenous species have been identified in the Belgian coastal areas that were introduced – either intentionally or accidentally – through human activities. The first of this type of observations date back to the 19th century, but archaeological sources show that some introduced species occurred here before then. The number of newly recognised introductions shows an increasing trend with a particularly remarkable rise after 1975, mainly as a result of more studies.

The largest number of introduced species are found among the arthropods (Kerckhof *et al.* 2007 with supplements up to and including 2011). Quite remarkable is the large number of barnacles that live attached to hard substrates. Just like seaweeds they seem to benefit from the increasingly available man-made constructions, including port installations, harbour walls, buoys and wind turbine foundations (Kerckhof and Cattrijsse 2001). Observations mainly involve larger organisms - the smaller species and unicellular organisms are harder to discern and recognise.

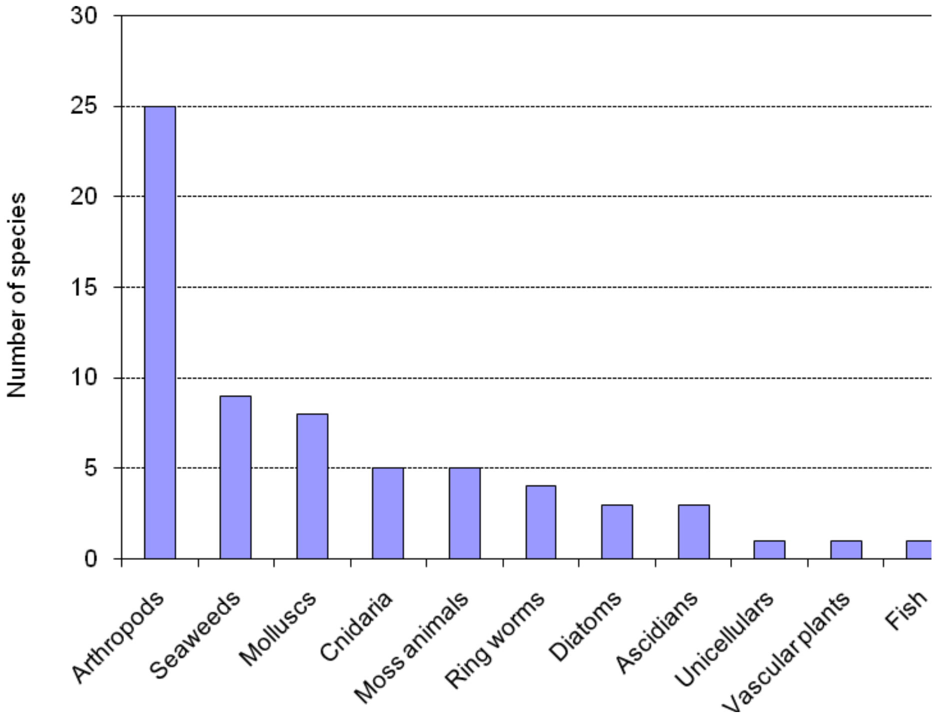


Figure 2.31: Number of non-indigenous species per taxonomic group at the BCS and adjoining estuaries (F. Kerckhof *et al.* 2007 supplemented up to and including 2011).

More recent introductions include the macroalgae *Undaria pinnatifida* (2000) and *Polysiphonia senticulosa* (2001), Harry-clawed shore crab *Hemigrapsus penicillatus* (2003), Asian shrimp *Palaemon macrodactylus* (2004), Asian shore crab *Hemigrapsus sanguineus* (2006) and sea walnut *Mnemiopsis leidyi* (2007). From 2009 to 2010, this comb jelly was found along the coast in average densities of 0.4 ind/m³. Highest densities of up to 17 ind/m³ were found in the Spuikom at Ostend (Van Ginderdeuren *et al.* 2012). At the point of discovery, these species already appeared to be quite numerous and well-settled. Five more species were detected in 2011: two red seaweeds, a moss animal, a cicada and a bristle worm. Just like many other recent introductions, most species originate from the temperate western Pacific zone, or – like the sea walnut for instance – from the eastern shores of America. They reached the Belgian waters after having been introduced in neighbouring countries.

Four of these species appear to be invasive and currently have a dominant presence in the marine coastal habitats: the American jackknife *Ensis directus*, the Japanese oyster*Crassostrea gigas*, the New Zealand barnacle *Elminius modestus* and the common slipper shell *Crepidula fornicata*.

The American jackknife has occurred in all mobile sandy sediments of nearby coastal waters since 1987. Strandings of millions of dying animals and empty shells are a frequently occurring phenomenon and are believed to reach an average density of 9 ind/m² within the twelve-mile zone (Van Hoey 2008).

The introduction and settlement of the Japanese oyster occurred almost simultaneously, however on hard substrates. Imported as early as 1970 for breeding purposes in aquaculture, the species first saw a truly explosive development as a result of the increasing temperatures of recent years. In coastal harbours as well as along the eastern breakwater at Zeebrugge it now forms vast reefs in the intertidal area, with a chance of driving out the indigenous mussel *Mytilus edulis*, as happened in the Wadden Sea (Fey *et al*. 2010, Markert *et al.* 2010). The New Zealand barnacle is now the most prevalent barnacle. This species was imported into England during WWII and quickly colonised hard substrates in the tidal areas across the rest of Europe.

The common slipper shell was introduced in Europe at the end of the 19th century and has been present here since at least 1911. It is now very common in our waters on hard, but also on soft substrates – the species' most recent expansion area. It is believed that trawling fishery adds to further expansion of the species.

The presence of non-indigenous species in the phytoplankton has been studied to a lesser extent. Important phytoplankton species that were introduced include *Coscinodiscus wailesii* and *Odontella sinensis* (as early as the end of the nineteenth century). Both diatom species now constitute a large part of the plankton in the spring and summer.

2.3.8. Other species listed under Community legislation or international conventions

Besides a number of sea mammals, there are a few other animal species included in Annex II of the Habitat Directive that either live, have lived or at some point have been observed at the BCS. They include:
- Sea lamprey *Petromyzon marinus*
- River lamprey *Lampetra fluviatilis*
- European Atlantic sturgeon *Acipenser sturio*
- Twaite shad *Alosa falax*
- Allis shad *Alosa alosa*
- Houting *Coregonus oxyrhynchus*
- Atlantic salmon *Salmo salar*
- Loggerhead sea turtle *Caretta caretta*
- Green sea turtle *Chelonia mydas*

All these species are protected at sea with the exception of the salmon, which falls under Annex II only as regards its freshwater population. Turtles can be considered wanderers - their occurrence in our waters is highly seldom. The Channel and the North Sea border the distribution area of these species.

The fish included in Annex II are all anadromous species: they migrate from the sea to rivers to spawn and temporarily stay at sea. The Belgian coastal zone plays an important role in their migration to the estuaries and rivers. Their numbers have decreased heavily in Belgian waters mainly due to problems in the rivers, such as pollution, degradation of biotopes and inaccessibility of spawning areas as a result of construction works. However, fishery also constitutes a problem for these species.

Of these species, twaite shads are now the most common in Belgian waters, followed by the river lamprey. Houtings (*Coregonus oxyrinchus*) are considered extinct in Europe. The last specimen was caught in the Nether Rhine in 1940 (Freyhof and Schöter 2005). Houtings became extinct as a result of pollution and overfishing. They were rare at sea in the 19th century (De Selys Longchamps 1842). All the specimen currently in the collections of the Royal Belgian Institute for Natural Sciences were collected before 1900 (Poll 1947). The allis shad *Alosa alosa*, which belongs to the clupeids, probably became extinct in Belgian waters in the late 19th/early 20th century due to effective fishery, impoundment of large rivers, bank revetment and gravel reclamation that resulted in the disappearance of spawning places. A closely related species, the twaite shad *Alosa falax*, is in better shape*.* The species had disappeared completely from the Scheldt by the mid-20th century, mainly as a result of bad water quality, but it still occurred in the coastal waters. Today, twaite shads are again caught regularly at sea as well as in the Seascheldt, probably as a result of improved water quality. Although this seemingly indicates a slight recovery, the species are not yet believed to propagate in the Scheldt (Decleer *et al.* 2007) and there is little doubt that the population is still considerably smaller than at the beginning of the 19th century.

Sea lampreys *Petromyzon marinus* migrate from the sea to the rivers for spawning between February and June (Patberg *et al.* 2005). Migration to the sea takes place in December and January. In the salt water, the animals feed on dead fish or live as parasites on other fish species or sea mammals. Contrary to the river lamprey, the sea lamprey also occurs far from the coast. The fish is caught very rarely (recently for the North Sea Aquarium, for instance). On 25 May 2009, a dead specimen was found on the beach between Mariakerke and Raversijde, but such beach discoveries are very rare and this probably involved a specimen caught in a beach net. Given their protected status and low value – in theory, sea lamprey may not be landed or sold – it is possible that most caught specimen are thrown back into the water. In Belgium, sea lamprey used to migrate to the Scheldt and the Meuse, but the species has become extinct here in the 1920s as a result of canalisation, water pollution and biotope destruction (Van Emmerik 2005). It is highly likely that sea lamprey was more common in the past than today (Wheeler 1978), but data is scarce. River lamprey *Lampetra fluviatilis* is bound more to the coast and estuaries than sea lamprey. The former migrates to the rivers in the autumn to spawn; sightings, although few, concentrate around the coastal area and particularly the zone close to the estuary of the Western Scheldt. The river lamprey will undoubtedly have been more common in the past than it is today. In this context, Poll (1947) cites Gustave Gilson, who alleges that the river lamprey was often caught by shrimp fishers, who would throw the animal back into the sea.

The Atlantic sturgeon *Acipenser sturio* spends most of his adult life at sea. In the spring, sturgeons migrate to the rivers to propagate (Van Emmerik, 2004). Until the 19th century the European Atlantic sturgeon occurred frequently in Belgian waters and was caught occasionally until the mid 20th century. The last few decades, catches have become very rare and it is assumed that the species has become extinct in the Belgian waters. The most recent sturgeon catch dates back to 2007; it occurred off the coast of Westende and the fish originated from a breeding programme in the Gironde-Garonne-Dordogne area in France.

2.4. Alarming chemical pollution
2.4.1. Scope and evaluation

Concentrations of hazardous materials in the marine environment have been monitored in Belgium since the late 1970s in the scope of international conventions such as OSPAR. The establishment of the European Water Framework Directive gave a new impulse to the monitoring of chemical pollution in the coastal waters and lead to expansion of the monitoring programme.

Table 2.3: Overview of the parameters, matrices, frequencies and evaluation criteria applied in the current Belgian monitoring programme for chemical pollution.

Parameter	**Matrix**	**Frequency**	**Evaluation criterion**
PCBs	Sediment and marine organisms	Annually	EAC
	Bird eggs	*Annually*	*EcoQO*
PAHs	Sediment and marine organisms	Annually	ERL/EAC
	Water	Monthly	EQS
TBT	Sediment and marine organisms	Annually	EAC
	Water	Monthly	EQS
Hg	Sediment and marine organisms	Annually	EAC/EQS
	Bird eggs	*Annually*	*EcoQO*
Pb	Sediment and marine organisms	Annually	EAC
Cd	Sediment and marine organisms	Annually	EAC
PBDEs	Sediment and marine organisms	Annually	EAC
	Water	Monthly	EQS
TBT effects	*Gastropods*	*Annually*	*EcoQO*
DDT	Bird eggs	Annually	EcoQO
HCB	Marine organisms	Annually	EQS
	Bird eggs	Annually	EcoQO
Nutrients	Water	Three-monthly	?

The Belgian monitoring programme aims at creating an image of the current situation on the one hand and following trends in time on the other. For situation monitoring the measured values are compared to values defined by OSPAR and WFD.

The WFD mainly concentrates on water as a matrix. OSPAR monitoring, however, focuses on the matrices with most relevance for the related substances, particularly sediment and biota. Besides sediment and biota, for substances that have priority for the Belgian coast the water column is also monitored.

2.4.2. Current status quo

A first conclusion is that for a large number of substances, the concentrations in water at the BCS are below the threshold values. This conclusion is based on measurements performed in the past and on measurements carried out in rivers and surrounding coastal areas. Measuring concentrations of heavy metals in sea water, for instance, was stopped as early as the 1990s due to their low levels.

For a number of substances, the threshold values in water were exceeded systematically. For TBT the values exceeded the annual average limits (~1.6 ng/l) on all counts in the past years, and four in five times as regards the acceptable maximum levels (~3.2 ng/l). Threshold values are exceeded for some polycyclic aromatic hydrocarbons (PAHs). On an additional note, threshold values exist for only 8 of the 23 measured PAHs. Finally, standards for a few PBDEs are exceeded at the station located at the top of the Scheldt estuary where industry is a known source of pollution.

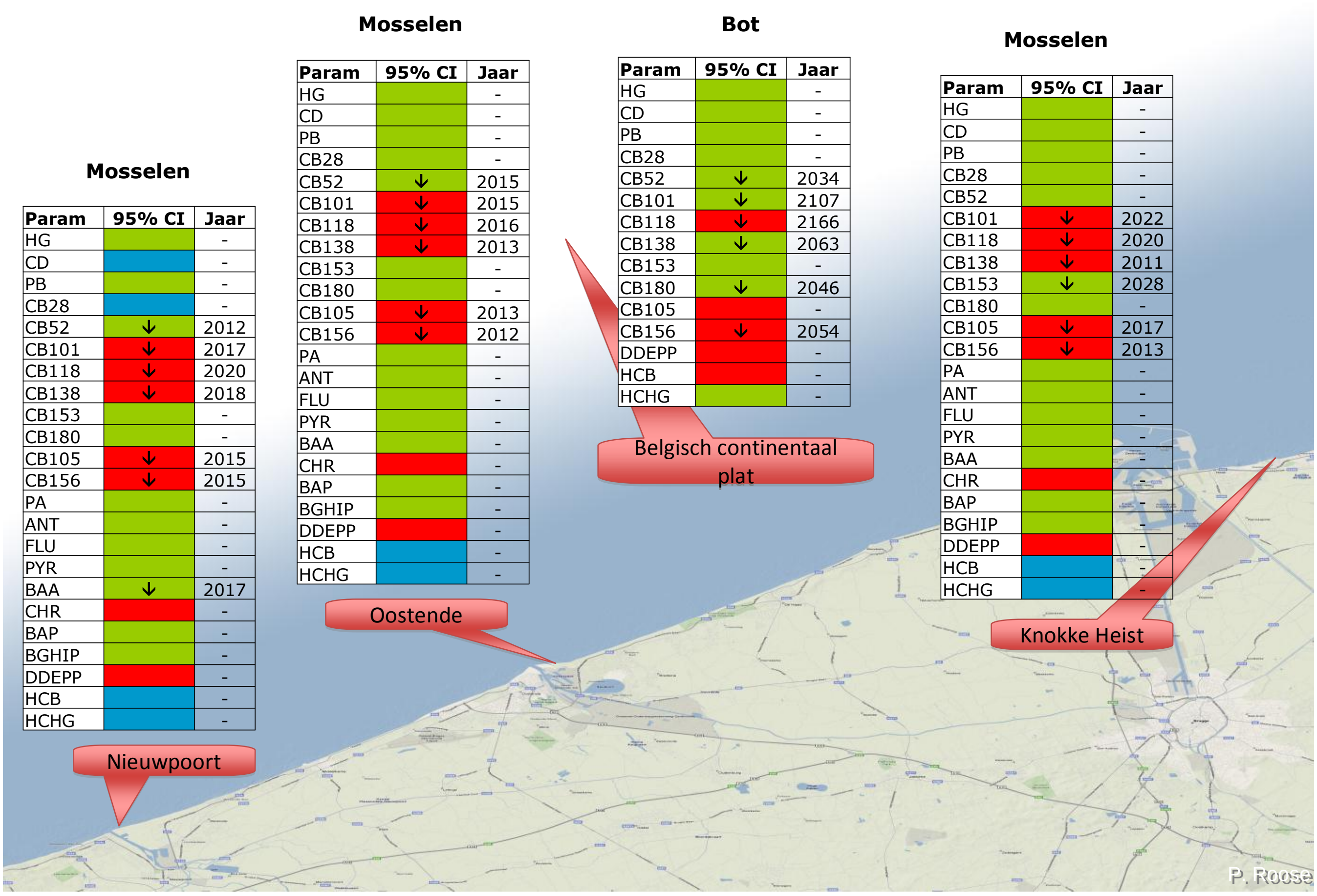
As regards sediment, the situation of measured substances near Zeebrugge and Nieuwpoort is good in 90% of the cases, and unfavourable in 10%. Taking account of natural variability – a more cautious approach – the situation is good in 80% of the cases and unfavourable in 20%. An analysis of the developments based on an assumed linear over time pollution/degradation shows no trend whatsoever in 46% of the cases, meaning that the situation is stable. There is a downward trend in 3% of the cases, but it is so tiny that it cannot serve as a basis for a reliable prognosis for improvement. And finally, a clearly downward trend can be demonstrated in 50% of the cases.

W01			
Param	Data	95% CI	Year
CU			down
CR			-
CD			-
HG			2027
PB			-
ZN			2031
CB28			-
CB52			*
CB101			-
CB118			2037
CB138			2048
CB153			-
CB180			-
BAA			2011
PA			2012
PYR			2023
ICDP			2008
BAP			2010
NAP			*
FLU			-
BGHIP			
ANT			2011
CHR			2012
DDEPP			2029
DIELD			-
HCB			-
HCHG			2021

W03			
Param	Data	95% CI	Year
CU			-
CR			-
CD			-
HG			-
PB			-
ZN			-
CB28			2014
CB52			-
CB101			2017
CB118			2016
CB138			2019
CB153			2027
CB180			2019
BAA			2013
PA			2012
PYR			2015
ICDP			-
BAP			2011
NAP			2022
FLU			2018
BGHIP			
ANT			2013
CHR			-
DDEPP			2024
DIELD			-
HCB			2029
HCHG			2014

W04			
Param	Data	95% CI	Year
CU			-
CR			-
CD			-
HG			-
PB			-
ZN			-
CB28			2028
CB52			-
CB101			2027
CB118			2019
CB138			-
CB153			-
CB180			2018
BAA			2011
PA			2013
PYR			2012
ICDP			2004
BAP			2010
NAP			-
FLU			2012
BGHIP			
ANT			2012
CHR			-
DDEPP			-
DIELD			up
HCB			-
HCHG			2016

Figure 2.32: Contaminants in sediment. Data: comparison of the average 2010 concentration against the evaluation criteria. 95% CI: comparison of the calculated 2010 concentration – increased by the 95% confidence interval (CI) – against the evaluation criteria in order to calculate the natural variability. Year: year that the class is expected to improve provided that the observed significant linear trend persists (-: no trend, up: upward trend, * : small decrease). Blue: comes close to the background concentration. Green: between the background concentration and the concentration below which negative effects are not expected. Red: above the concentration below which negative effects are not expected.



Mosselen (Nieuwpoort)

Param	95% CI	Jaar
HG		-
CD		-
PB		-
CB28		-
CB52	↓	2012
CB101	↓	2017
CB118	↓	2020
CB138	↓	2018
CB153		-
CB180		-
CB105	↓	2015
CB156	↓	2015
PA		-
ANT		-
FLU		-
PYR		-
BAA	↓	2017
CHR		-
BAP		-
BGHIP		-
DDEPP		-
HCB		-
HCHG		-

Mosselen (Oostende)

Param	95% CI	Jaar
HG		-
CD		-
PB		-
CB28		-
CB52	↓	2015
CB101	↓	2015
CB118	↓	2016
CB138	↓	2013
CB153		-
CB180		-
CB105	↓	2013
CB156	↓	2012
PA		-
ANT		-
FLU		-
PYR		-
BAA		-
CHR		-
BAP		-
BGHIP		-
DDEPP		-
HCB		-
HCHG		-

Bot (Belgisch continentaal plat)

Param	95% CI	Jaar
HG		-
CD		-
PB		-
CB28		-
CB52	↓	2034
CB101	↓	2107
CB118	↓	2166
CB138	↓	2063
CB153		-
CB180	↓	2046
CB105		-
CB156	↓	2054
DDEPP		-
HCB		-
HCHG		-

Mosselen (Knokke Heist)

Param	95% CI	Jaar
HG		-
CD		-
PB		-
CB28		-
CB52		-
CB101	↓	2022
CB118	↓	2020
CB138	↓	2011
CB153	↓	2028
CB180		-
CB105	↓	2017
CB156	↓	2013
PA		-
ANT		-
FLU		-
PYR		-
BAA		-
CHR		-
BAP		-
BGHIP		-
DDEPP		-
HCB		-
HCHG		-

Figure 2.33: Contaminants in biota**.** Data: comparison of the average 2010 concentration against the evaluation criteria. 95% CI: comparison of the calculated 2010 concentration – increased by the 95% confidence interval (CI) – against the evaluation criteria in order to calculate the natural variability. Year: year that the class is expected to improve provided that the observed significant linear trend persists (-: no trend, up: upward trend, * : small decrease). Blue: comes close to the background concentration. Green: between the background concentration and the concentration below which negative effects are not expected. Red: above the concentration below which negative effects are not expected.

As regards marine organisms, the situation is positive for the measured substances in 69% of the cases and unfavourable in 31%. It should be noted that flounders meet the health standards required for being sold, whereas mussels collected on breakwaters for monitoring purposes are not suitable for human consumption. Statistical studies of the annual developments over several years do not show a deterioration. 86% of the cases show no development whatsoever, neither up, nor down and as regards the 6 PCBs, concentrations in the muscle tissue of flounders show a decrease, which provides hope for improvement by mid-century.

A first study carried out between 2008 and 2011 in 21 locations in 7 countries of the North Sea into polluting substances in bird eggs looked for concentrations of mercury, PCBs, DDT and HCB in the eggs of the common tern Sterna hirundo, northern stern Sterna paradisaea and oyster catcher Haematopus ostralegus. For Belgium, the study only took samples of the common tern in the breeding colony in Zeebrugge.

Measurements in reference areas indicated that 16 ng/g would be the allowed maximum mercury concentration in tern species. For the studied PBC congeners and for HCB, DDT and HCH, limits were found of 20 ng/g, 2 ng/g, 10 ng/g and 2 ng/gm, respectively. The studied tern eggs from Zeebrugge showed high PCB concentrations, largely exceeding the 20 ng/g limit; these findings coincided with all the other studied locations. Hg concentrations exceeded the 160 ng/g limit considerably, both in Zeebrugge and in all other locations. As regards HCB, DDT and HCH, Zeebrugge was among the least polluted locations in Europe but the port still exceeded the standards of 2 ng/g for HCB and 10 ng/g for DDT. The 2 ng/g limit for HCH was not crossed.

3. PRESSURES AND IMPACTS

A large part of the BCS has a long history of human interference, such as fishery, coastal and harbour construction and the construction of channels, involving physical destruction, damage or disruptions. Infrastructural works such as harbour construction and channel construction are associated with deepening, widening and maintenance dredging works and with the dumping of mainly silt-rich sediments at certain dumping sites at sea. The demand for raw materials as well as energy needs have led to concession areas for marine aggregate extraction and offshore wind farms, as well as the placement of numerous cables and pipelines. Other disturbances involve underwater noise, litter and the possible effects of climate change.

3.1. Physical destruction

3.1.1. Port infrastructures and dredging works

The construction of the port of Zeebrugge in the twentieth century, the recent seaward expansion of the port of Ostend and the widening/deepening of existing channels are the radical human activities that have contributed most to the physical destruction of the seabed. Permanent sealing constructions cover a surface of roughly 12 km² in the case of the outer harbour of Zeebrugge and approximately 0.5 km² as regards the outer port of Ostend. The 'Pas van het Zand' channel dredged at the start of the twentieth century went right through a sandbank (Van Mierlo 1908; Fettweis *et al*. 2009) and was regularly deepened and widened, just like the channel leading to the Western Scheldt (Scheur). Deepening dredging works involved an average 1.5 million tonnes of solids per year from 1997 to 2010 (Lauwaert *et al*. 2011). Today, these channels and the outer harbour of Zeebrugge have a depth of 15.5 m as compared to the Lowest-Astronomical Tide (LAT) reference level and are thus significantly deeper than the surrounding area (<10 m LAT).

3.1.2. Wind farms

In 2010 the total wind farm surface covered an area of 238.5 km², or 7% of the BCS.

The natural soft substrates used for the construction of wind turbines are subject to immense change as a result of dredging, erosion and organic enriching around the turbines, etc. Although the number of wind turbines is limited, a few remarkable insights could be acquired (Degraer *et al*. 2010, 2011).

Depending on the wind turbine's foundation and the local dynamics of the seabed, either a static or dynamic erosion protection was applied, or none whatsoever. Static erosion protection was applied for the first six wind turbines of C-Power (with gravity foundations) and is considered to be destructive of the naturally soft seabed. This type of protection involves a limited area of roughly 0.01 km². Dynamic erosion protection was used for the other wind turbines. Here, the erosion pits are left to develop before being backfilled with stones. This type of protection barely reaches above the seabed level and consequently, long-term destruction of the soft seabed almost exclusively comprises the surface of the foundation pile. The protection covers less than 0.01 km² for the 56 Belwind piles on the Bligh Bank and the 48 Jacket foundations of C-Power at the Thornton Bank.

3.2. Physical damage

3.2.1. Fishery activities

Evaluating the effects of sea fishing on the BCS requires an extensive range of variables, including fishing efforts, fishing techniques and factors such as location, time, management measures and fishermen behaviour. The effects on the seabed were demonstrated by using multibeam measurements.

Fishery activities were localised based on flight data, monitoring campaigns at sea and '*Vessel Monitoring System*' data (VMS) (Depestele *et al.* 2008, 2012). Shrimp fishing mainly takes place in the coastal area (<3 miles), around the Vlakte van Raan, Ostend and the Kustbanken. VMS data allowed for identification of Belgian beam trawling activities (Eurokotter) only and focussed on the period 2006-2009 with respect to the Vlaamse Banken and the area south of the Gootebank. Larger beam trawler vessels are spread throughout the BCS more uniformly, but their intensity is lower.

The physical effects of beam trawling depend on the size and intensity of the interactions between the fishery activities and the sediment/habitat. The significant impact on the seabed from beam trawling is due to the high intensity of the interaction rather than the fished surface (Løkkeborg 2005; Polet *et al.* 2010). The main effects of beam trawling include the removal of physical structures as a result of sediment homogenisation, as well as removal of sand ridges and of accumulations and tubes formed by organisms. Other effects are sediment resuspension with local loss of or coverage by sediment, the loss of three-dimensional structures, changes in turbidity and visibility under water and sediment compression (Løkkeborg 2005, Depestele *et al.* 2012). Beam trawling leaves detectable traces that remain visible for a number of days (Fonteyne 1999, 2000; Van Lancker *et al.* 2009). According to an estimate involving beam trawling activity in an area near the Thornton bank, local damage to the seabed covered 30-73% of the sandbank area (Van Lancker *et al.* 2011). In places, the seabed was completely fragmented as a result of fishery activities. Although this spatial impact data is not yet available for other areas, similar damage as a result of fishery activities may be assumed. Fishery activities generally are concentrated in the channels between the sandbanks and their largest impact can be found alongside the slopes of the banks.

Anglers usually fish in locations unreachable for professional fishermen such as over and close to shipwrecks, breakwaters, quays (recreational anglers) and in the intertidal zone (recreational trammel nets); these are hotspots of biodiversity (hard substrates) and of juvenile or spawning specimen of certain fish species (beach zone). Close to the beach they also catch fish that are in their reproductive period, for instance in trammel nets. The allowed catch must be considered in its entirety to make a correct estimate of the impact of these activities. An obligation to specify species and weight of the landed fish in a database is highly desirable in order to identify that impact.

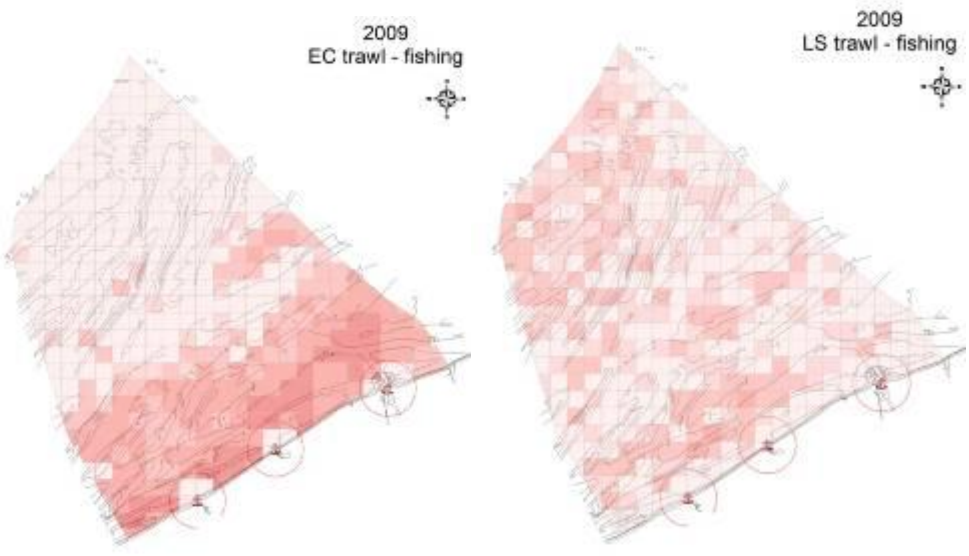


Figure 3.1 Map of fishing efforts of Belgian fishing vessels at the BCS (9 km² cell for 2009 per type of vessel). EC trawl: trawl ≤ 221 kW, LS trawl: trawl > 221 kW). Colours reflect the gradients in numbers of VMS registrations (adapted from Depestele *et al.* 2012)

3.2.2. Aggregate extraction

Aggregate extraction is allowed in four large areas (11 sub-areas), totalling a surface of roughly 321 km². A total of 2 million m³ of sand is extracted each year for coastal protection and commercial purposes (2008-2010). Rather than being distributed proportionally over the concession zones, sand extraction is concentrated in accordance with the desired sediment quality.

Physical damage to the seabed occurs as a result of selective removal of sand and sporadic gravel. Trailing suction hopper dredgers used for this purpose leave 10 to 50 cm deep gullies per extraction (Degrendele *et al.* 2010). Monitoring results based on detailed acoustic depth measurements show the formation of morphological depressions at the seafloor of intensively extracted areas (Degrendele *et al.* 2010). In these areas, activities are stopped once the bottom has been lowered by 5 metres as compared to a reference level. This can imply extraction to the level of a geological boundary, and further extraction may thus lead to other types of substrate (Bellec *et al.* 2010; Van Lancker *et al.* 2010). Still, the physical impact remains local and limited in time and space (Degrendele *et al.* 2010; Roche *et al.* 2011). Nine years after discontinuation of the activities no physical recovery could be demonstrated (Degrendele *et al.* 2010; Roche *et al.* 2011). The long stretches of depression constitute flumes as a result of the canalised tidal stream on the one hand, and traps of fine sediments resulting from slack water sedimentation on the other (Garel 2010; Bellec *et al.* 2010). There was no evidence of 'far field' effects, impact on coastal safety or on sandbank stability (Verwaest 2008; Van den Eynde *et al.* 2010 b; Van Lancker *et al.* 2011).

Due to the low levels of fine-grained sediments in the seabed in these zones, an increase in turbidity during extraction was deemed of minor interest until now. Nevertheless, increased fineness of the sediment was demonstrated for some locations (Bellec *et al.* 2010; De Backer *et al.* 2011).

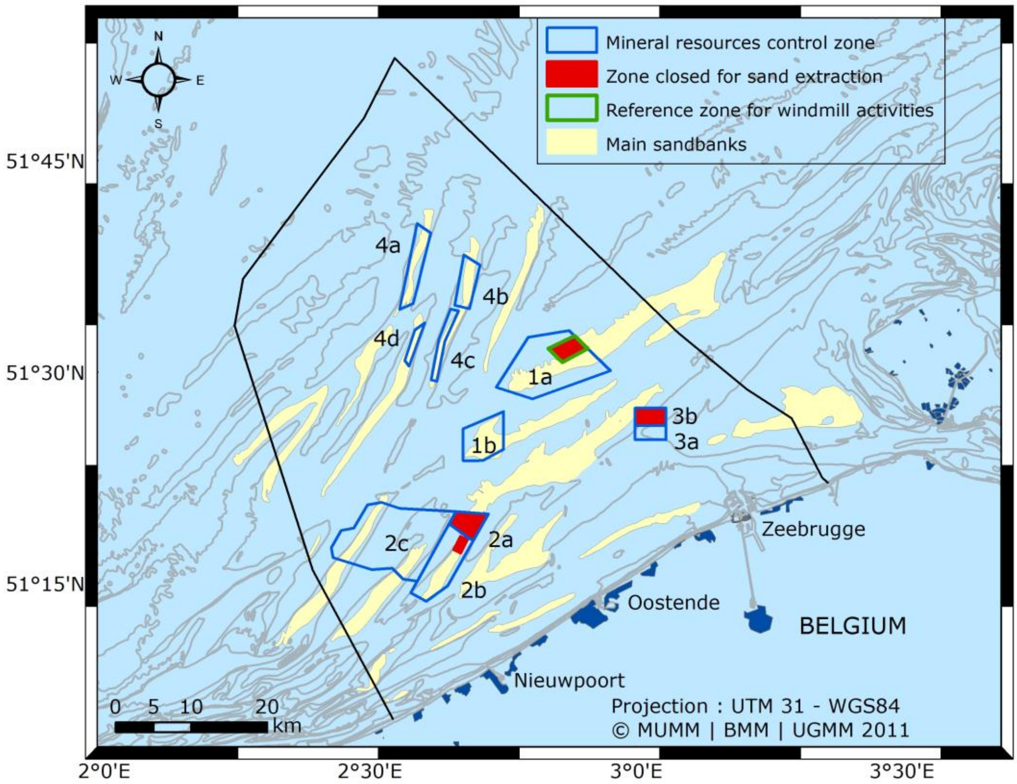


Figure 3.2: Control areas for the extraction of sand and gravel at the BCS in 2011.

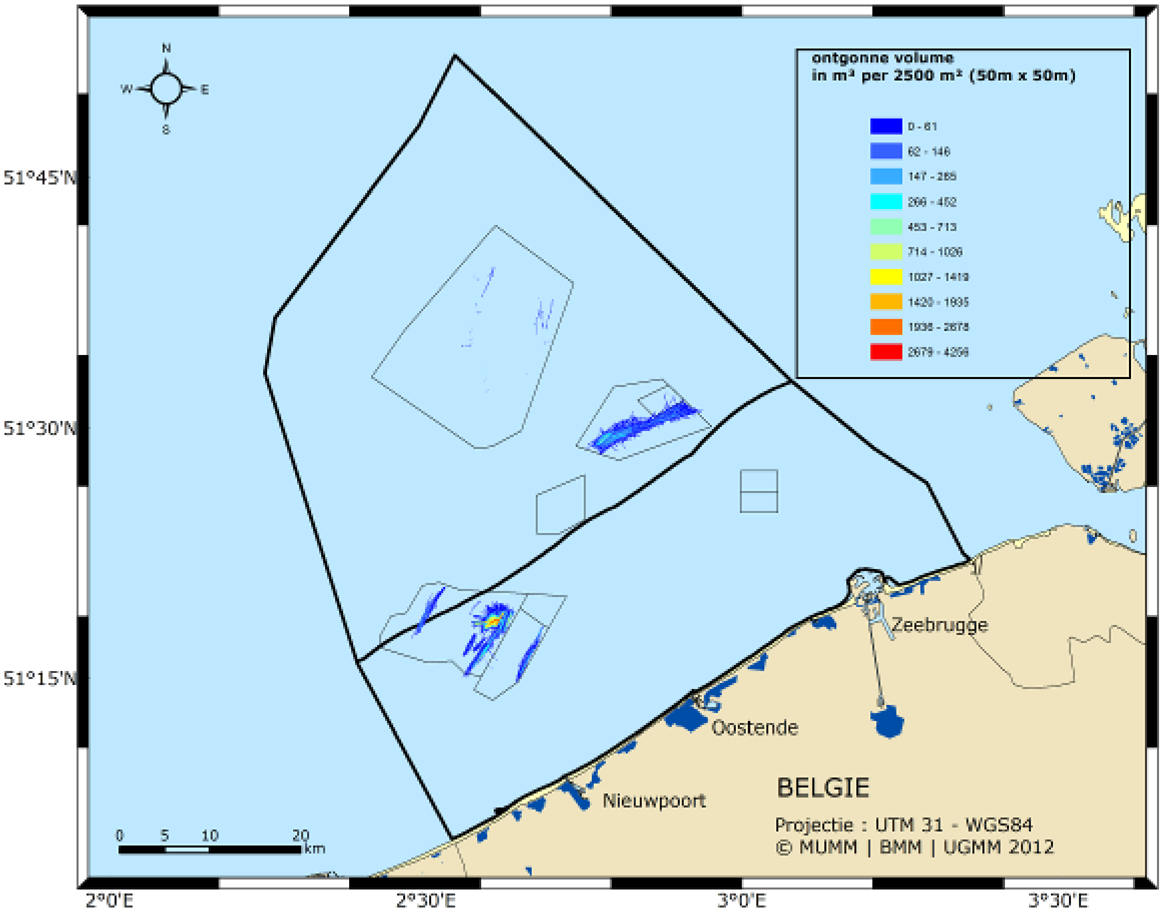


Figure 3.3: Extracted volume in 2010.

3.2.3. Maintenance dredging works and dumping of dredged materials

The harbours and channels are efficient sedimentation locations for sediments (mainly silt, but fine sand, too). For this reason, maintenance dredging works are being carried out regularly to guarantee maritime accessibility of the harbours and the Western Scheldt. During the period 1997-2010, 9.3 million tonnes of solids were dredged and dumped back into the sea each year (Lauwaert *et al.* 2011).

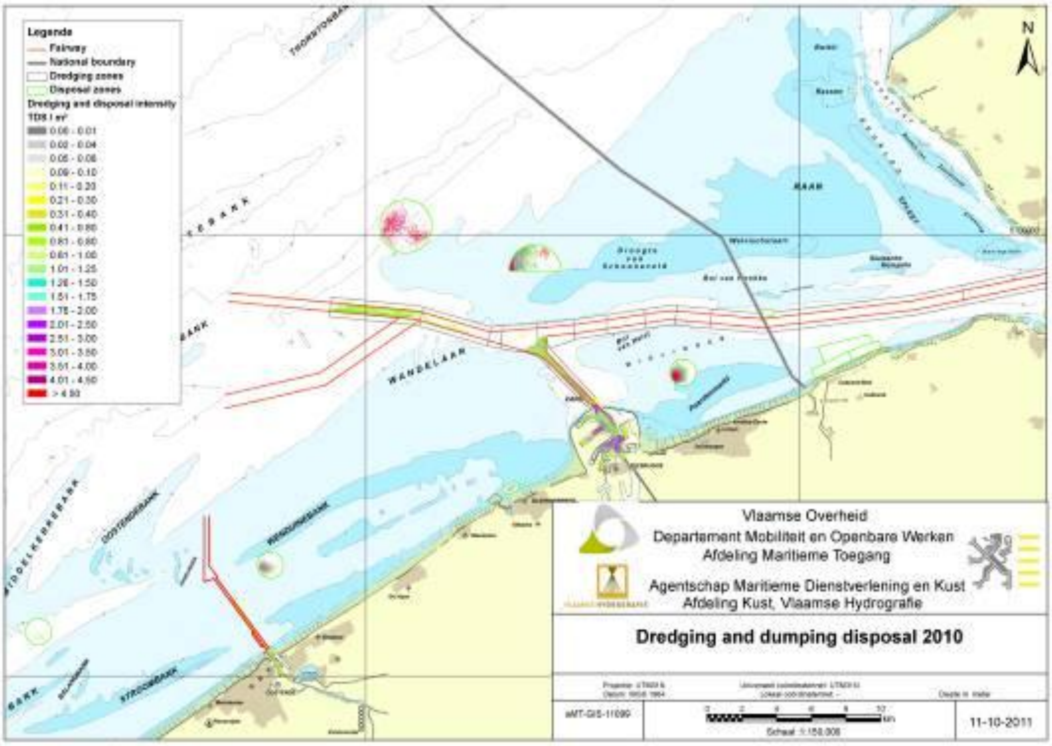


Figure 3.4: Map of dredging and dumping intensity in 2010

Accounts have been kept of the amounts of dredged material dumped into the sea since 1991, the year that marked the first licences for sea disposal of dredged material.

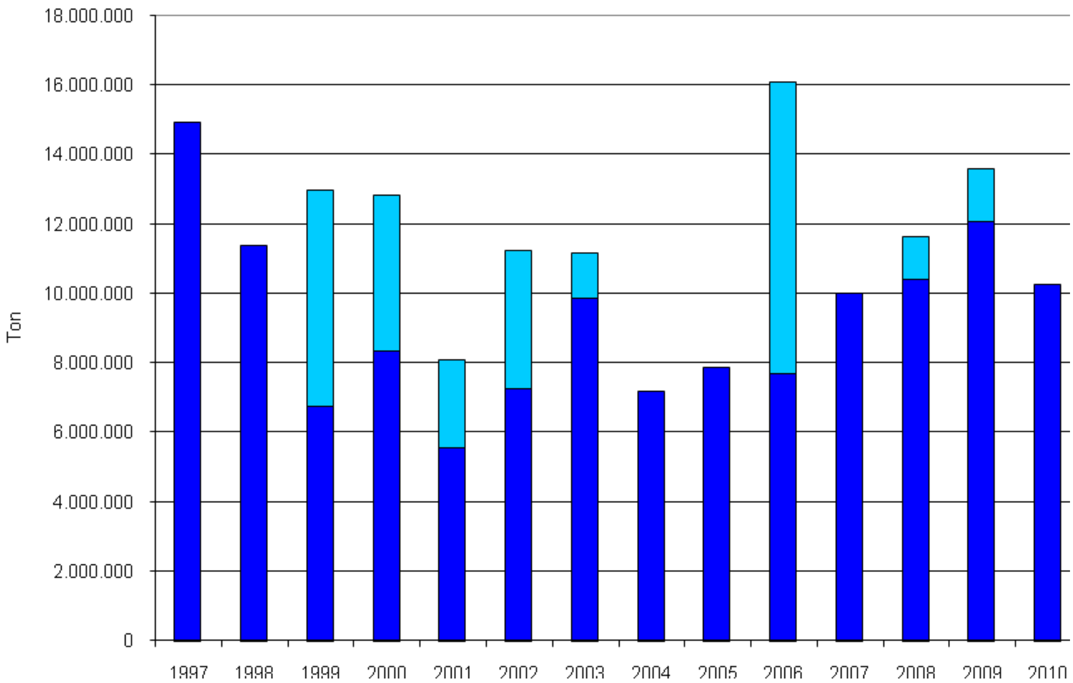


Figure 3.5: Overview of the amounts of dredged material dumped at sea since 1997, expressed in tonnes of solids. The statistical period runs from April to March of the next year. Dark blue: maintenance dredging works. Light blue: deepening dredging works. Source: BMM.

A vast part (76% in 1998-1999) of the dredged material consists of silt and clay (TVNK 1998; Fettweis and Van den Eynde 2003). These dredging and dumping activities damage the seabed at and around the disposal sites as it becomes submerged in sediments; in the channels as a result of continuous removal of sediments; and in a larger surrounding area due to a change in sediment composition.

The surface of the five disposal sites totals 16 km². The effect of disposal activities is not limited to the dumping zone, however, and can involve a far larger area around the zone (Du Four and Van Lancker 2008; Van Lancker *et al*. 2011). 60-70% of the dumped material is thus transported away and does not remain at the disposal site. A large part of this material consists of silt that, if suspended, can locally increase turbidity. A model study shows that the evenly distributed disposal, over a period of one year (1999), of 6.4 million TDS of silt on disposal site Br&W (Bridges and Roads) S1, increased turbidity by 50-100 mg/l on average in an area with a diameter of 20 to 40 km around the disposal site (Van den Eynde and Fettweis 2006). Another part consists of fine sand whose displacement changes the bathymetry and sediment composition around the disposal site. In this context, the disposal site S1 was moved to the north-west after regular dumping of dredged material had formed an artificial dune, making the site inaccessible to dredging ships. Gradual physical recovery of the seabed took place after discontinuation of the dumping activities (Du Four and Van Lancker 2008).

Cumulative effects

The dredging and dumping activities as well as the large infrastructural works in the coastal area have had a significant effect on the distribution of fine-grained sediments (Fettweis *et al*. 2009; Houziaux *et al*. 2011). It was established that sediments of freshly to softly consolidated silt layers today are concentrated in areas marking high human impact, whereas they used to be spread over a wider area about 100 years ago. Recent measurements further show that highly concentrated silt suspensions in the coastal area are also the result of the construction of fairways. Although these usually act as a silt trap, large amounts of silt can erode during storms that contribute significantly to the formation of highly concentrated silt suspensions, such as the ones measured near Zeebrugge after stormy weather (Fettweis *et al*. 2010). Highly concentrated suspension layers can also form as a result of the dumping itself. One specific experiment showed that the dumped material accumulated mainly in the bottom layer, thus creating a more or less constant presence of highly concentrated silt suspensions in a large area around the disposal site (Fettweis *et al.* 2011). These silt suspensions can be regarded as a temporary cover on the seabed.

3.2.4. Morphological changes (Bay of Heist, erosion Zeebrugge)

The morphological changes of recent decades in the eastern coastal zone directly or indirectly result from human interference: directly in the case of deepening works, harbour construction, dumping operations; indirectly in the case of changed erosion-sedimentation patterns due to disturbance of the hydrodynamics. These changes at beaches, foreshore and coastal zone were studied on the basis of bathymetric difference maps and trend analyses (Van Lancker *et al*. 2011; Janssens and Verwaest 2011). Erosion and sedimentation rates derived between 1997 and 2010 resulted in the following significant trends: (1) erosion of the channels at -0.02 to -0.03 m/year; (2) erosion of the foreshore at 0.03 to 0.06 m/year; (3) sedimentation in the dunes and at the foot of embankments up to 0.15 m/year; and (4) sedimentation due to human interference at 0.03 to 0.05 m/year. These trends manifest themselves evenly along the entire Belgian coast, but at the fastest rate near harbour constructions. Particularly the construction of the outer harbour of Zeebrugge initiated significant morphological changes. Erosion is prominent along the seaward part of the western breakwater. The interruption to littoral sediment transport caused by the breakwaters resulted in sedimentation alongside both jetties. The beach consequently expanded a few hundred metres seaward as a result (Van Lancker *et al*. 2011).

Due to local disturbance of the hydrodynamics caused by the harbour (eddy formation; shielding against waves), a sandbank formed east of the port, which falls dry at ebb tide (Van den Eynde *et al*. 2010 a).

Sedimentation of 21 million m³ occurred in the foreshore zone between 1976 and 1998, 18.5 million m³ of which occurred during the construction activities involved in the expansion of the harbour. Since the completion of the harbour expansion works in 1986, the foreshores east of the jetty and before Heist and Duinbergen show sedimentation of at least 0.05 m/year (Janssens *et al*. 2008).

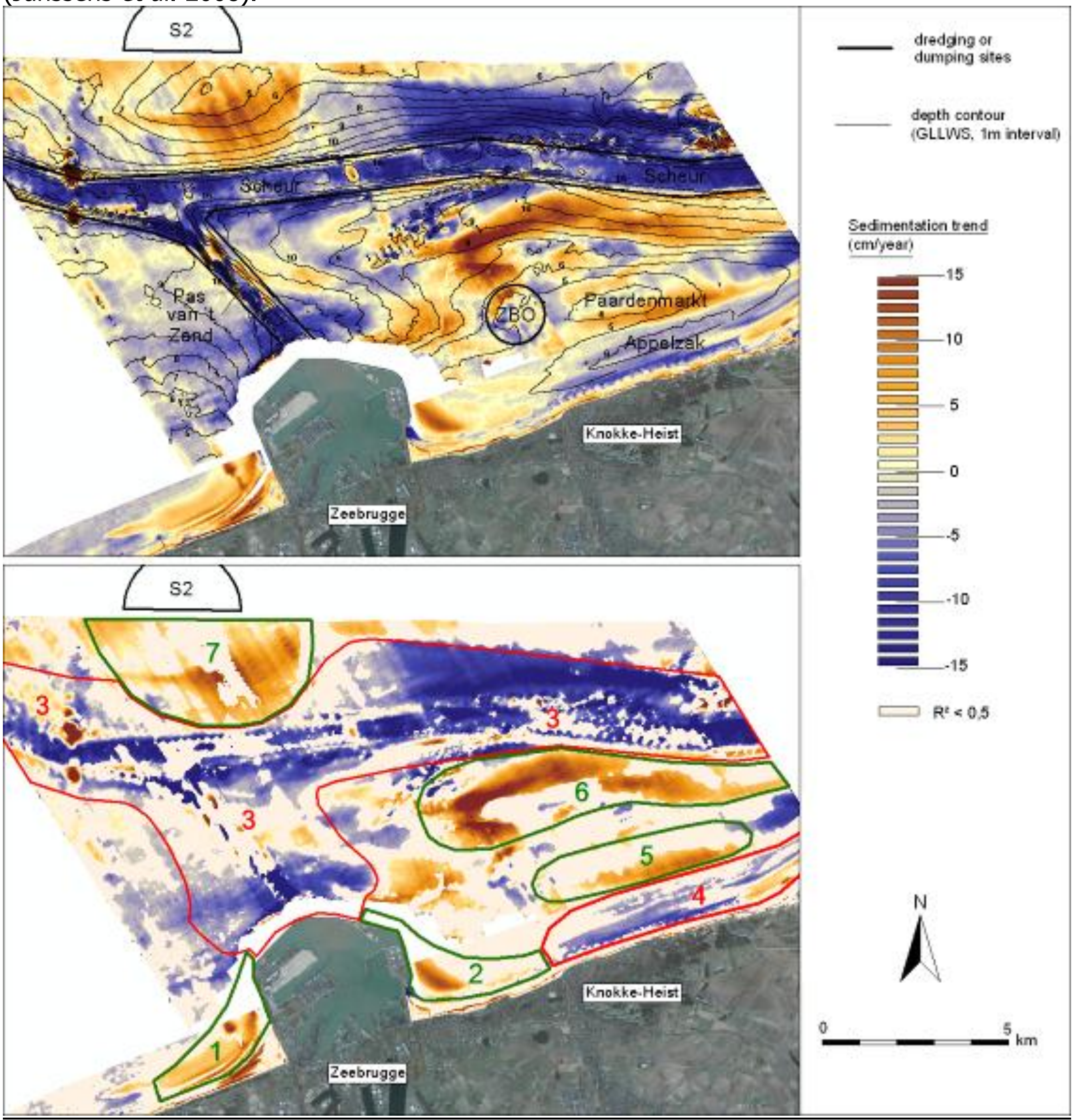


Figure 3.6: Erosion and sedimentation patterns around the Port of Zeebrugge (Van Lancker *et al*. 2011; Janssens and Verwaest 2011). The uppermost figure shows all the trends; the lowermost figure shows only the trends where $R^2>0.5$. Zones (1) (2) (3) and (7) are associated with the port infrastructure works and with dredging and dumping for the purpose of clearing and deepening the navigation channels. The trends in zone (4) (erosion in the ebb tide channel Appelzak), (5) and (6) (Paardenmarkt sandbank and Wielingen) clearly are not associated with human interference. The following cumulative effects on the environment are observed here: physical destruction, damage and disturbance.

3.3. Physical disturbance
3.3.1. Underwater noise

The underwater world is not a haven of silence. Sounds are produced by natural phenomena, such as rain, billows and tidal streams, and of course by numerous animal species: sea mammals communicating or searching for food; fish looking for a mate; clattering shellfish and teeth-grinding crustaceans. Sound is a wave travelling through a medium (e.g. air or water) and exerting variable pressure on surfaces (such as an eardrum). Under water, sound travels five times faster than in the air. The damping of sound under water, or the decrease of amplitude with distance, depends on the frequency: while the amplitude of high frequency sound decreases rapidly with the distance to the source, low frequency sound may still be measurable at a distance of many kilometres.

Data of underwater sound in the Belgian marine waters and its possible impact on underwater species are limited at present. Thorough monitoring and further scientific studies in the scope of the Marine Strategy therefore are necessary.

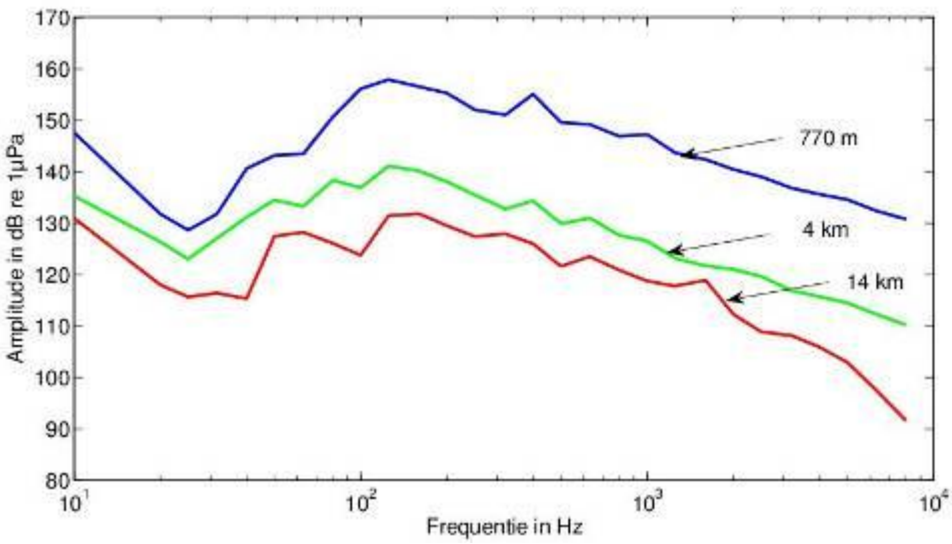


Figure 3.7: Peaks in underwater noise (1/3 octave band spectrum), measured at three separate distances from the Bligh bank during pile driving for a wind turbine foundation.

3.3.2. Marine litter

"Marine litter" is any not easily degradable, man-made or processed solid material that after intentional or accidental disposal, directly or via rivers or channels ends up in the coastal and marine environment. Marine litter hence originates from either land or sea. An estimated 20,000 tonnes of waste is dumped each year in the North Sea alone (Holm 2004). Approximately 75% of this volume consists of plastic (OSPAR 2007).

Litter on beaches has economic as well as ecological effects. The beaches lose their attraction for coastal tourism and a considerable number of species suffer adverse consequences from waste, particularly plastic. For instance, a Dutch study carried out in 2003 showed that 98% of stranded Northern Fulmars (*Fulmarus glacialis*) have plastic waste in their stomachs (Holm 2004). And during sampling campaigns held between 2002 and 2006 in Ostend and Koksijde, an average 1,000 foreign items were collected per kilometre (OSPAR 2007, 2010).

Although the origin of the waste varies a great deal, the shipping industry (both fishing and commercial shipping) appears to be a major contributor. Nylon nets were the most found item on Belgian beaches. But tourism is an important factor, too. New items surface as well, such as cardboard sleeves of fireworks, and new packaging. There is also a remarkably high quantity of balloon residues, and cigarette butts.

Unintentionally released waste aside – for instance as a result of a lost load – the majority of the marine and coastal litter can be avoided through the implementation of simple procedures and a more responsible attitude from the people involved. Measures are taken to decrease the amount of litter at several levels, from banning plastic bags in supermarkets to international regulations on marine waste, and coastal municipalities launch all kinds of awareness projects and campaigns aimed at reducing litter.

In Belgium, the current Fishing for Litter project (until 2011) and Waste-free Ocean (from 2011 onwards) is a cooperation arrangement between the government and fishermen (Marine Environment Services 2011). The basic idea is that instead of throwing overboard any waste that ends up in their fishing nets, fishermen bring it ashore to ensure proper processing. In 2011 alone, 31 tonnes was caught this way and brought ashore. We also refer to the Belspo "AS-MADE" project that studies the distribution and origin of micro and macro plastic waste.

3.3.3. Climate change

Climate change creates physical and bio-geochemical disturbances that may affect the ecosystem of the southern North Sea. The consequences of climate change at the BCS include (Van den Eynde *et al.* 2011; Gypens *et al.* 2009; Borges and Gypens 2010):

1. The sea level in Ostend rose by 1.69 mm per year on average in the period from 1927 until 2006. After 1992 the increase accelerated and now amounts to 4.41 mm per year.
2. The water temperature of the North Sea increases by 0.023 °C to 0.053 °C per year.
3. Wind speed time series, significant wave height and frequency of storms on the Belgian coast don't seem to show a particular tendency. It must be noted, however, that because they were only initiated at the end of the 1970s, the series are too short to provide any conclusive information.
4. Some simulations indicate that the sea level increase will bring about a clear rise of the currents and the significant wave height on the Belgian coast.
5. The acidification of the seawater at the BCS is the result of an increase in atmospheric CO_2 and of changes in river nutrient supply. Changes in nutrient loads as a result of management measures have affected the carbon cycle to an extent that the changes in carbon chemistry are temporarily bigger than the ones caused by ocean acidification.

3.4. Pollution with hazardous substances

The main sources of hazardous substances in our coastal waters are industrial processes, agriculture, incineration of waste and fossil fuels, applications such as painting and asphalting, leaks and leaching during storage of waste and discharge or leaching from contaminated surfaces. In the form of dissolved substances and attached to particulate matter, the chemicals involved end up in streams and rivers and finally, in the sea. On a global scale, transport via the atmosphere is the main route by which pollutants end up in the sea, but on our coasts, it is overshadowed by transport via water.

The Belgian coast is affected mainly by the river basins of Seine-Somme, Scheldt and Meuse-Rhine, and by the Atlantic Ocean. Because each of the basins runs through highly industrialised and densely populated areas, they are usually heavily loaded with undesired components that cause both eutrophication and pollution from chemicals. The fact that the Atlantic seawater causes dilution of the components makes the situation even more complex.

The rivers and atmosphere are considered as diffuse sources, but in addition, the direct discharges into the sea must be considered also. Although accidental or intentional oil spills definitely are the best known examples, they don't necessarily have the biggest impact. Another important issue is that industrial discharge points have been closed since the late 1990s, and that purification stations no longer discharge in sea areas. In any case, during the time that these types of sources were active, the discharges were relatively insignificant and small as compared to the total Belgian waste load to the country's marine areas.

3.4.1. Introduction of synthetics and heavy metals

In the scope of the OSPAR programme "Riverine Inputs and Direct discharges", the input of synthetic materials via diffuse sources is calculated for cadmium, copper, lead, zinc, mercury, lindane and PCBs on an annual basis. Currently there is no annual sampling programme for other synthetic materials and metals.

The evaluations of the waste loads from sources in the coastal basin are approximate, because the area has an extremely diffuse hydrology and because the loads are calculated by multiplying concentrations by flow rates. In addition, measurements regularly returned concentrations below the detection limits for mercury, cadmium, lindane and PCBs, which added to the doubtfulness of the estimates. For this reason, loads are presented including a highest and lowest estimate. The Scheldt is the biggest source of waste loads from Belgium to the North Sea, accounting for more than 80% and as much as 99% of the synthetic materials and metals, respectively.

Figure 3.8 illustrates the development of waste loads in the last two decades. A statistic trend cannot be established for heavy metals, although a comparison of the earliest measurements to the current situation shows a clear difference for mercury. This is believed to be caused by the high variety of the loads, which is due to measurement-related problems. A significant downward trend can be seen for lindane - loads are now three times lower than at the start of the measurements. For PCBs, however, no statistically significant trend could be established, which is due partly to the measurements below the detection limits.

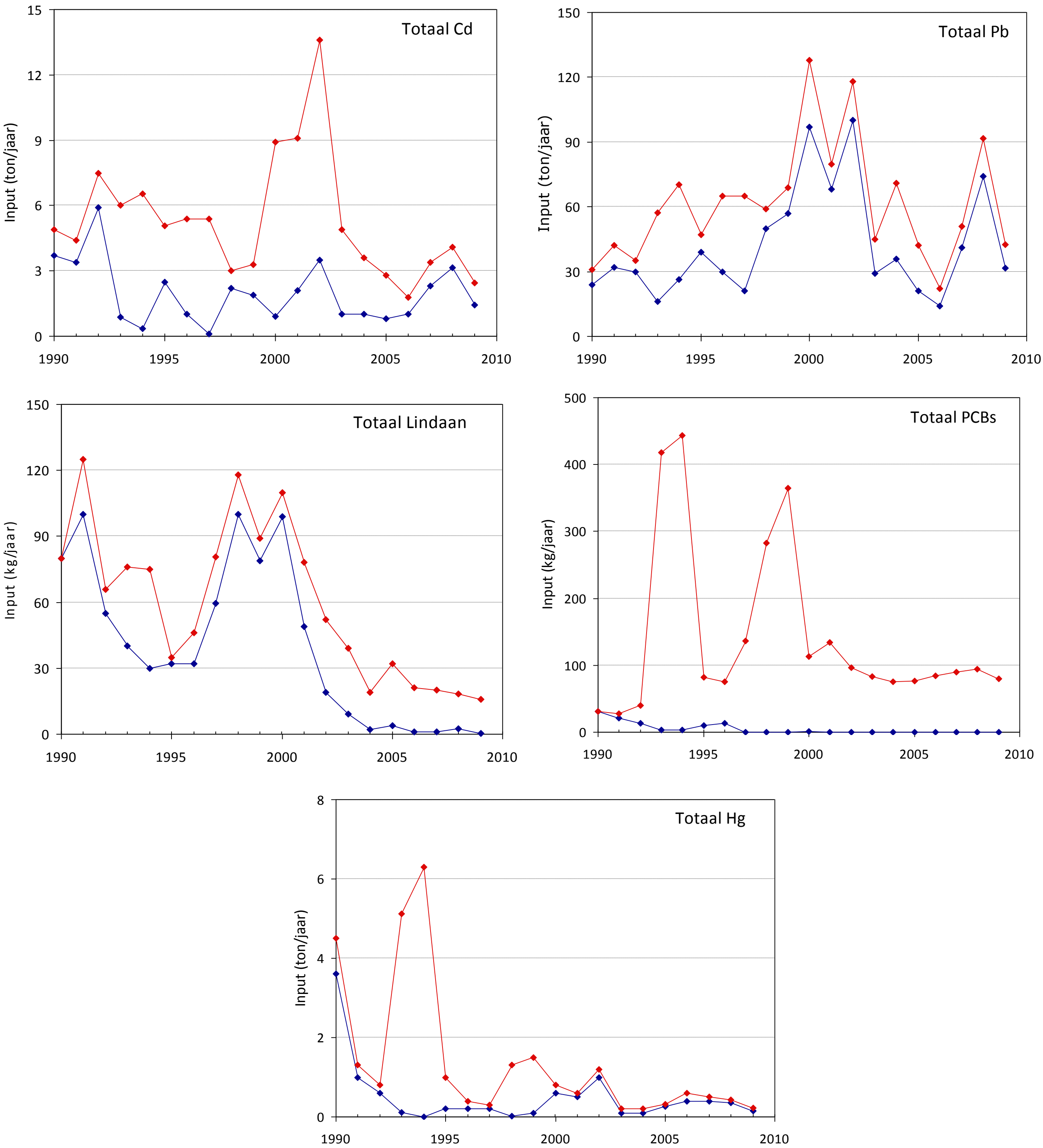


Figure 3.8. Development of the calculated waste loads of priority substances (red reflecting the highest estimate, blue the lowest) off the Belgian coast from 1991 to 2009.

Measures to stop the inflow towards the marine environment were taken for all the above-mentioned substances. Although initially indicating a strong and clearly demonstrable decrease, the results show that the effects must be viewed on a broader time scale. The clear fall observed for lindane is a result of the product's previous application as a pesticide. The effect of its discontinuation shows quite rapidly. The lack of trends in heavy metals and PCBs is probably due to the varied historical pollution, which creates various diffuse sources – such as the leaching of contaminated seabeds – as a result of which the situation will improve but gradually.

3.4.2. Pollution caused by ships (carbon dioxide)

The BCS is one of the busiest waters in the world. In contains two crucial shipping routes: the central route Noordhinder TSS (Traffic Separation Scheme), which forms the main connection between the Channel and Dover Strait and the large North Sea ports; and the Westhinder TSS, which in French waters forms a branch of the Noordhinder TSS in the direction of the Westerscheldt. In addition there are several transversal routes from and to the United Kingdom, as well as a number of coastal routes.

Each year a total of approximately 150,000 ships sail the Belgian sea areas, including the Noordhinder TSS; about 15% are tankers (oil, chemicals and gas tankers); approximately 50% are container ships and RoRos (Roll-on/Roll-off ships). Oil and other (environmentally) hazardous substances are usually carried by tankers, container ships and RoRos. As a general tendency, maritime transport has been on the rise over the years; remarkably enough, however, this has not so much translated into an increase in the number of ships off our coast, but rather in an increase in the average size of the ships.

This increased ship movement holds an increased risk of oil spills. Oil spills can occur after an accident, but they can also be the result of intentionally pumping overboard oil residues, which, albeit in little amounts, happens frequently; these are the so-called operational discharges of oil. The Belgian programme for aerial surveillance gives a clear indication of the magnitude of oil spills.

Despite the increase in maritime transport, the results from the aerial surveillance from mid 1991 through 2010 show a clearly decreasing trend in the number of detected illegal oil discharges per year in the Belgian zone of responsibility. In the 1990s, about 50 oil discharges were detected each year - roughly one detection in every 4.5 flight hours. Since the year 2000, the number of detected oil spills has decreased considerably (and keeps falling) to approximately 25 oil patches per year, which roughly corresponds to one detection per 10 flight hours. The total volume of illegal oil spills also has fallen drastically.

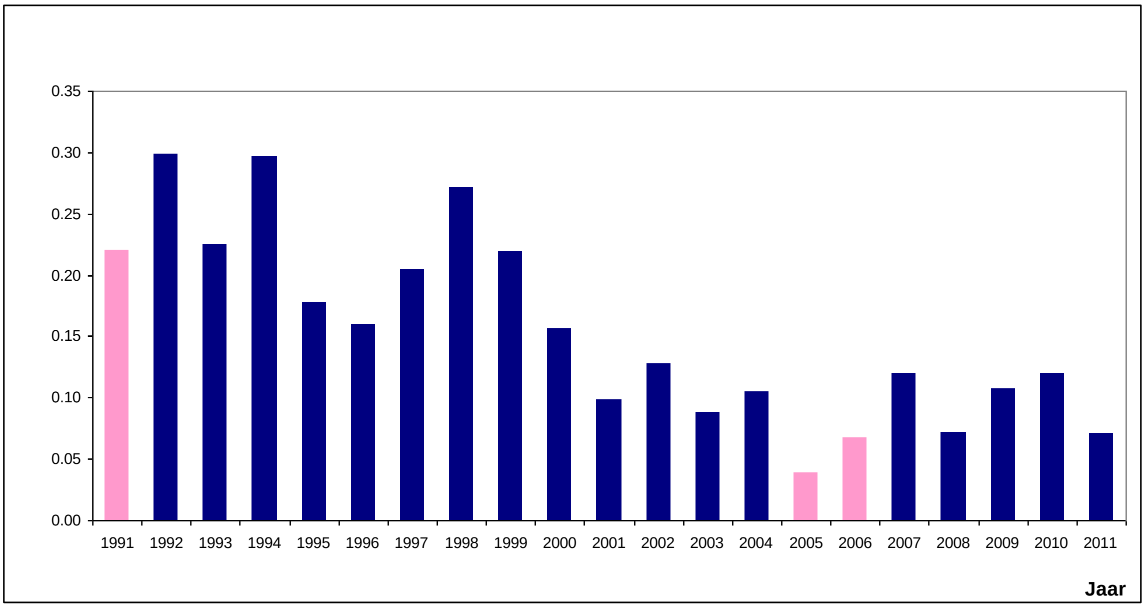


Figure 3.9: Number of detected cases of pollution by hydrocarbons per flight hour (in pink: year of reduced surveillance). Source: BMM.

There is little doubt that the generally decreasing trend is a result of the aggregate of policy measures taken at a national, European and global level, such as the designation of the North Sea as a "Special area" under the Marpol Convention in 1999; the improved port reception installations in EU harbours, created in accordance with the 2002 European Directive on port reception facilities; and the preventive effect of the current surveillance tools.

3.4.3. Introduction of radionuclides

The North Sea is subject to direct discharges from radioactive facilities. Besides the effluents from the nuclear facilities in France (including the Gravelines nuclear power plant; the Paluel and Flamanville power plants whose waste water arrives via the Channel; and the La Hague reprocessing facility) and the UK (the Dungeness, Bradwell and Sizewell facilities), several rivers flowing into the North Sea also contain slightly radioactive waste water, for instance the Meuse and the Scheldt. For this reason, the North Sea is watched closely by all the surrounding countries that have signed the OSPAR convention.

From the Belgica, samples are taken of the water, sediment and bottom fish four times a year and at several locations on the BCS. 16 samples are taken in the zone 5 to 37 km off the coast near Koksijde, Nieuwpoort, Ostend and Blankenberge. Measurements include alpha, beta and gamma radiation as well as the element ^{40}K for natural radioactivity.

Each year 450 samples are taken along the coast that are then subjected to 1700 measurements for radioactivity. The results show that radioactivity is not a problem in the marine environment. The main radioactivity comes from the naturally occurring ^{40}K which is observed in the various compartments of the marine environment.

Furthermore, only traces of artificial radioactivity are found – ^{137}Cs, ^{60}Co, $^{238,(239+240)}Pu$ – namely in sediment and in fish. Fish contain traces of ^{137}Cs. The artificial transuranium elements $^{238,(239+240)}Pu$ - ^{241}Am cannot be traced: all concentrations are below the detection limit.

Table 3.1: Monitoring programme for radioactive elements in the marine zone

Compartment		Venue	Measurement type	Sampling frequency
Air	dust particles	Koksijde	Spectrometry · · · · ·Be, $^{134\text{-}137}Cs$, $^{141\text{-}144}Ce$, $^{103\text{-}106}Ru$, ^{95}Zr, ^{95}Nb	every 4 weeks
			Spectrometry · total	daily
			Spectrometry · ·total	daily
Soil	permanent prairie (bottom and grass)	Koksijde	Spectrometry · · · · ·Be, $^{134\text{-}137}Cs$, $^{(57)\text{-}58\text{-}60}Co$, ^{54}Mn, ^{65}Zn, ^{110m}Ag, ^{40}K, $^{226\text{-}228}Ra$, ^{228}Th	Annually
SEA	water	at sea (Belgica campaign), 16 locations	Spectrometry · · $^{134\text{-}137}Cs$, $^{57\text{-}58\text{-}60}Co$, ^{54}Mn, ^{40}K Spectrometry · · total Spectrometry ·: $^{238\text{-}(239+240)}Pu$	every trimester
	sediment	at sea (Belgica campaign), 16 locations	Spectrometry · · · ·Be, $^{134\text{-}137}Cs$, $^{(57)\text{-}58\text{-}60}Co$, ^{54}Mn, ^{65}Zn, ^{110m}Ag, ^{40}K, $^{226\text{-}228}Ra$, ^{228}Th Spectrometry · : $^{238\text{-}(239+240)}Pu$	every trimester
	algae	Ostend - coast	Spectrometry · · · ·Be, $^{134\text{-}137}Cs$, $^{(57)\text{-}58\text{-}60}Co$, ^{54}Mn, ^{65}Zn, ^{110m}Ag, ^{40}K, $^{226\text{-}228}Ra$, ^{228}Th	every trimester

		^{90}Sr, $^{238-(239+240)}$Pu, ^{241}Am,	
mussels and prawns	Ostend - coast	Spectrometry · ·· ·Be, $^{134-137}$Cs, $^{(57)-58-60}$Co, ^{54}Mn, ^{65}Zn, ^{110m}Ag, ^{40}K, $^{226-228}$Ra, ^{228}Th ^{90}Sr, $^{238-(239+240)}$Pu, ^{241}Am,	every trimester
fish	at sea (Belgica campaign), 16 locations	Spectrometry · ·· ·Be, $^{134-137}$Cs, $^{(57)-58-60}$Co, ^{54}Mn, ^{65}Zn, ^{110m}Ag, ^{40}K, $^{226-228}$Ra, ^{228}Th ^{90}Sr, $^{238-(239+240)}$Pu, ^{241}Am,	every trimester

Table 3.2: Radioactivity measurements in the marine environment: water and sediment

	Water (Bq/l)		Sediment (Bq/kg sec)	
	measurement	*DL*	measurement	*DL*
·	NM	~ 0.1	NM	0.4 to 6.0
^{137}Cs	NM	0.1	0.8 to 1.3	~ 0.8
^{60}Co	NM	0.1	NM	~ 0.7
·· total	10 to 11			
···	~ 12		200 to 350	
$^{226.228}$Ra			7 to 10	
$^{238,(239+240)}$Pu	NM	~ 1.0 10^{-4}	traces	~ 0.43

NM: not measurable; measurement equal to or under the detection limit (DL)

Table 3.3: Radioactivity measurements in the marine environment: fauna and flora

	Flora (Algae) (Bq/kg fresh)		Fauna (mussels and prawns) (Bq/kg fresh)		Fauna (flatfish) (Bq/kg fresh)	
	measurement	DL	measurement	DL	measurement	DL
·	NM	~ 0.2	NM	0.1 to 0.2	NM	0.3 to 0.6
^{137}Cs	NM	~ 0.2	NM	~ 0.11	traces	~ 0.4
^{60}Co	NM	~ 0.2	NM	~ 0.13	NM	~ 0.4
^{131}I	0.6 to 6.1		NM	~ 0.13	NM	~ 300
^{90}Sr	NM	~ 1.6	NM	~ 1.0	NM	~ 1.1
···	200 to 300		40 to 100		110 to 130	
^{99}Tc	NM	~ 75				
^{228}Ra	1.0 to 3.0	~ 0.5	NM	0.5 to 0.6	NM	~ 1.7

$^{238,(239+240)}Pu$	NM	~ 0.12	NM	0.05 to 0.09	NM	~ 0.09
^{241}Am	NM	~ 0.15	NM	0.05 to 0.09	NM	~ 0.09

NM: not measurable; measurement equal to or under the detection limit (DL)

3.4.4. Chemical effects from the dumping of dredged material

The sediments of the impact zone (dumping location) and the control zone for heavy metals, PCBs and pesticides showed but limited differences (Lauwaert *et al.* 2011). The dumping area Br&W Zeebrugge East forms an exception: pollution levels are higher here than in the control zone. The other measured heavy metals and persistent organic connections do not come near the limits (Environmental Assessment Criteria, OSPAR, MSFD Task Group 8 Contaminants and pollution effects, Belgian Official Journal).

Chemical analysis was carried out mainly on starfish and shrimp for determining the (bio)accumulation level of persistent organic substances and heavy metals (Lauwaert *et al*. 2011). No significant trends were observed for 2009-2010 between the control zone and the impact zone. Compared to the control zones, higher PAH levels were observed in marine species in the impact area of the disposal sites Br&W Zeebrugge East, Br&W Ostend and Br&W S1. An increased level of CU was found in marine species at the disposal sites Br&W S2 and Br&W Ostend. At the Br&W Ostend a remarkably high level of PCB was found as well. The measured levels of PCBs, PAHs and heavy metals are lowest at disposal sites Br&W S1 and Nieuwpoort.

3.5. Enrichment with nutrients and organic substances

Human activities are the cause of the introduction of nutrients via direct sources (e.g. companies, purification stations) and via diffuse sources (e.g. agriculture, households, water excess, nitrogen supply via the atmosphere). As a result, during the 1960s to 1980s the levels of N and P have increased considerably both in the Belgian rivers and in the Belgian coastal waters. Eutrophication of the Scheldt reached a peak in the 1970s, after which followed a period of de-eutrophication as a result of efforts to reduce nitrogen and phosphorus discharges. It is important to note that the combined efforts translated into a faster reduction of phosphorus concentrations than of nitrogen concentrations, leading to an uneven N:P ratio (Brion *et al*. 2008).

Before reaching the coastal zone, the nutrients released by diffuse sources or point sources can be converted, removed or held. The estuaries, and more generally the transition zones, play a key role in this process as they harbour countless biogeochemical transformations (Soetaert en Herman 1995). The combined effect of all the processes influencing the passing components is called "filtering" and the efficacy of these filters increases with the period the waters remain in the relevant system (Soetaert *et al.* 2006). For this reason, there is not necessarily a direct connection between the nutrient emissions in the rivers and the nutrient load released by the estuary in the coastal area.

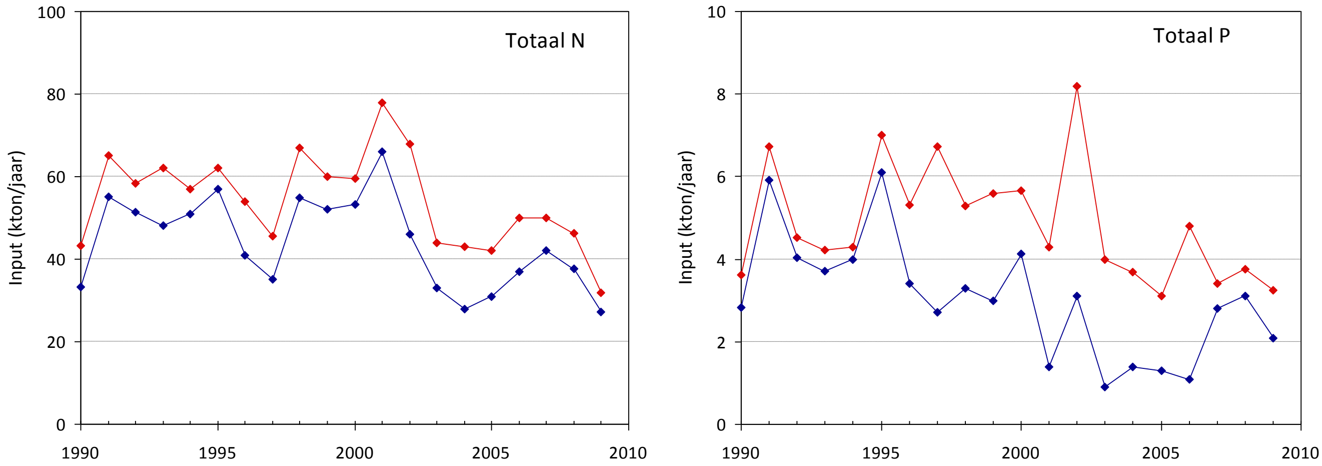
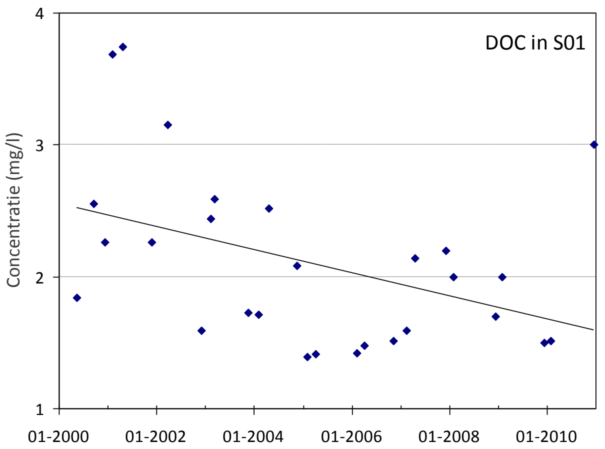
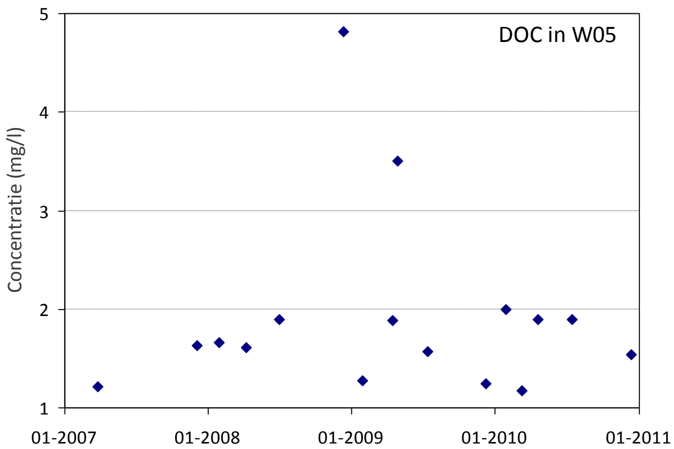


Figure 3.10: Development of the total introduction of nitrogen en phosphorus to the coastal waters in the period 1990-2009 (red: highest estimate; blue: lowest estimate).

As regards the Belgian coastal area, the Scheldt estuary is the main contributor of nitrogen and phosphorus introduction via rivers. For 2009, the Scheldt's delivery of nutrients to the sea is estimated at 39.94 kton for N and 2.87 kton for P. These values equal 70% and 65%, respectively, of the Belgian delivery to the coastal waters (Brion *et al*. 2008). Just like for heavy metals and organic substances, the evaluations of the waste loads of the sources in the coastal basin are approximate for reasons of the zone's extremely diffuse hydrology. Because the nutrient inflow in the form of these substances was considerably lower in an undisturbed condition, the region can still be regarded as affected. However, trends show a positive development. For nitrogen we see a constant and significant downward trend of about 780 tonnes/year. For phosphorus this figure is around 125 tonnes/year. It should be noted that the waste load decreases are of a similar magnitude as the flow rate increases derived above, meaning that the dilution effect can be assumed to play a key role.

The above-mentioned downward trend is also found for the development of the organic material reaching the sea via the Scheldt. Figure 3.11a illustrates the development of the total organic carbon level (used here as a proxy for the organic material) in the Scheldt estuary at decreasing tide. Both can be linked to the efforts towards water purification of the past decades. For comparison: the trend is not observed in locations further from the coast that are subject to several actors (figure 3.11b).





Figures 3.11 a and b: Development of the level of dissolved organic carbon between 1999 and 2010 in the Scheldt estuary (S01) and off the Belgian coast (W05).

3.6. Biological disturbance

3.6.1. Introduction of microbial pathogens

One of the places where microbial pathogens can be found is in water contaminated by faecal matter. There are no direct sewage discharges into the North Sea. Water is only released to the sea via the four port channels (Nieuwpoort, Ostend, Blankenberge and Zeebrugge), which in turn are connected to channels and currents in the hinterland. Overflows can become operational during heavy rainfall and as a result, faecally contaminated water will enter the waterways and the harbours. At low tide, these will discharge to the sea. Depending on parameters such as wind, the contamination will spread along the coast. In the scope of the European Bathing Water Directive 2006/7/EC, the risk of gastrointestinal disorders is estimated based on the concentration of *E. coli* bacteria and intestinal enterococci, which serve as indicator organisms. The measuring results show the highest average concentrations around the port channels of Ostend and Blankenberge. The highest concentrations were measured west of these channels, because at low tide, the current (outflow) flows in this direction. Higher concentrations are also observed west of Zeebrugge and Nieuwpoort.

If concentrations are too high, bathing is discouraged for certain groups or completely prohibited. In recent years all the beaches met the European imperative standards. This is an improvement compared to previous years.

3.6.2. Non-indigenous species introduced through human activities

Four of the introduced species, i.e. the American jackknife *Ensis directus*, the Japanese oyster*Crassostrea gigas*, the New Zealand barnacle *Elminius modestus* and the common slipper shell *Crepidula fornicata* currently have a dominant presence in the marine coastal habitats. These are opportunistic species that, given their considerable adaptability and quick propagation cycles, form a significant threat to the indigenous flora and fauna. Introduced species can also have a negative effect on plankton. Large numbers of *C. wailesii* can produce harmful amounts of mucus.

When introduced species – like the above examples – drive out the indigenous species and consequently change biodiversity and biomass, modify the original habitats and have a clear impact on the ecosystem in the coastal areas, we speak of invasive species.

3.6.3. Selective extraction of species and bycatch

Every year, upon request of, among others, the European Commission (EC) and the East Atlantic Fisheries Commission (NEAFC), ICES provides estimates of the volume of the fish stocks in view of advice for future fishing efforts (ICES, 2007). Based on these assessments, emergency measures and recovery plans were formulated for fish stocks that were under heavy pressure (e.g. cod). The status of the fish stocks in the North Sea is comparable to that in adjoining areas. In the Baltic Sea, the Irish Sea, the Celtic Sea and the Bay of Biscay, the vast majority of fish stocks show signs of overfishing too (ICES, 2005, 2007). Symptomatic of this is the large number of fish stocks for which management and recovery plans were introduced in the past few years (ICES, 2007).

Beam trawl fishing, the most commonly practiced fishing technique at the BCS (Depestele *et al*. 2012) is typically a mixed fishery, initially aimed at catching plaice, sole, dab, turbot and brill (unpublished data from the Sea Fishery Services). In addition, it typically involves large bycatch of both commercial and non-commercial species. The total number of commercial species caught by the Belgian beam trawler fleet is about 40, including plaice *Pleuronectes platessa* (landings from the North Sea in 2010: 60,674 tonnes), cod *Gadus morhua* (31,300 tonnes), sole *Solea solea* (12,603 tonnes) and whiting *Merlangius merlangus* (21,884 ton), but also ray Rajidae spp., gurnard Triglidae spp., surmullet *Mullus surmuletus*, monkfish *Lophius piscatorius*, lemon sole *Microstomus kitt*, Norway lobster *Nephrops norvegicus* and brown crab *Cancer pagurus*.

The common shrimp *Crangon crangon* is also intensively fished at the BCS. In 2010, Belgian fishermen landed 1649 tonnes, half of which is believed to have been fished in the Belgian coastal area. A 'catch per unit of effort' figure is used to monitor the development of the biomass of the common shrimp. The data indicate a downward trend from the late 1970s until the late 1990s. The downfall stabilised at the beginning of 2000 and the population even started showing growth. The reason for this long-term variation is unclear. The common shrimp stock is affected by technical measures. There are no TACs for common shrimp.

Besides the landed fish, fishermen also catch considerable amounts of non-marketable living organisms and waste. This bycatch includes:

- undersized commercial fish species (e.g. small plaice and cod in beam trawling);
- commercial fish that may not be landed in view of quota restrictions (e.g. cod after having fished the cod quota);
- commercial species with low economic value (e.g. haddock, hake, whiting);
- non-commercial fish species (e.g. gobies Gobiidae spp.) and invertebrates (e.g. starfish *Asterias rubens* and swimming crab *Liocarcinus holsatus*);
- sea mammals (e.g. harbour porpoise *Phocaena phocaena*) and seabirds (e.g. cormorant *Phalacrocorax carbo*);
- waste.

Undesired bycatch constitute a burden, both for fishermen and for the natural environment. It prolongs the processing time of the catch and in addition, bycatch such as starfish or stones can damage the catch. More importantly, bycatch of undersized fish contributes to overfishing and can affect the benthos.

Flatfish beam trawlers in Belgium only use nets with a mesh size of 80 mm. Although highly suitable for sole, this mesh size is too small for plaice and promotes the bycatch of a considerable amount of undersized plaice – less than 27 cm, 1-2 years old – most of which subsequently dies from injuries inflicted by the net or during sorting on board. Plaice fishery outside the Belgian waters using 100 and 120 mm mesh nets shows considerably less bycatch.

Sea mammals are not or hardly affected by beam trawling. In trammel net fishery, bycatch of sea mammals strongly depends on the type of fishery. Recreational beach fishery targeted at sole constitutes a problem in spring (Depestele *et al*. 2012). A substantial side effect of beam trawling (both for flatfish and shrimp) is the effect on the seabird population as a result of the high discards, which serve as an additional and easily attainable food source for particularly gulls, such as herring gull *Larus argentatus* and lesser black-backed gull *Larus fuscus* (Depestele *et al*. 2012). The effect is considerably less in trammel net fishing due to smaller discards. However, these nets could involve considerable bycatch of diving species, such as razorbill *Alca torda* and common murre *Uria aalge*, but there are no quantitative figures to support this assumption.

3.6.4. Wind farms

In 2011, there are four Belgian consortiums with an environmental licence to build and operate wind farms: C-Power (Thornton bank: 6 active wind turbines, a total of 54 turbines planned, 318 MW); Belwind (Bligh bank: 55 active wind turbines, 110 turbines planned, 330 MW); Northwind (Lodewijk bank: 72 wind turbines planned, 216 MW); and Norther (84 wind turbines planned, 470 MW). Environmental licences include the obligation to study the effects of wind farms (Degraer and Brabant 2009, Degraer *et al*. 2010, Degraer *et al.* 2011).

The introduction of wind turbines created a new habitat in a mainly sandy environment: the hard substrates of the foundations. This new habitat was quickly colonised by several plants and animals and in as little as 3.5 months a surprisingly extensive species richness – 49 species – appeared to have developed, covered by a dense blanket of the sea mat (*Electra pilosa*), which creates a habitat for numerous other species, including small shellfish (Crustacea), bristle worms (Polychaeta), mussels (*Mytilus edulis*) and queen scallops (*Aequipecten opercularis*).

Depending on the depth, several communities emerged that can be divided into three vertical zones: (1) an intertidal and splash zone, characterised by the dominance of larvae of the marine splash midge *Telmatogeton japonicus* and the presence of four hair algae; (2) a shallow subtidal to low intertidal zone dominated by barnacles and the scud *Jassa falcata*; and (3) a deeper subtidal zone with a dense layer of *E. pilosa*.

Meanwhile, the foundations are completely overgrown by mussels, barnacles, etc., and numbers run as high as 20,000 organisms per square meter of no less than 74 species. Three years after the installation of the first wind turbines it can now be demonstrated that these new artificial hard substrates are very important for the species inhabiting intertidal hard substrates, who have limited or no natural offshore habitat in the southern North Sea. For 17 species, eight of which are non-indigenous, the wind farms will help their introduction into the southern North Sea. This possible 'stepping stone' effect, enabling species to spread over large distances via a range of closely spaced colonisation islands, is particularly relevant for species that do not have a planktonic larval stage, such as the *Jassa spp*. and *T. japonicus*.

Figure 3.12: Encounter with a spider crab on the erosion-resistant protection (-25 m) of a C-Power wind turbine.

Prohibiting bottom fishing at the wind farms also will have a (positive) effect on the benthic fauna. However, evaluating the impact on that fauna is currently difficult as a result of a strong natural, seasonal and annual variability and consequently, the study focused mainly on getting to understand this natural variability. It was demonstrated, however, that the growth of organisms on the hard substrates creates a local rise of organic substances in the water column. Because the wind turbines are located far from the coast, in an area that is naturally poor in organic matter, this organic enrichment will still have an impact on the environment. The mix of fine particles with the naturally existing purely sandy sediment and the high macrobenthic densities found here seem to confirm that statement.

The growth on the foundations and the rich macrobenthic communities of the sandy sediment in turn provide an additional source of food for several predators, including cod *Gadus morhua* and pout *Trisopterus luscus*. Both species can have a high seasonal presence around the foundations of wind turbines (up to 30,000 pouts around one single turbine!). At sandy sediments the increased availability of food could benefit fish and epibenthos. The fact that swimming crabs and grey shrimps living at wind farms are larger, on average, than specimen outside this area seems to confirm this.

Also, the number of great terns and common terns increased considerably since the first wind turbines arose on the Thornton bank and the same goes for the common gull (*Larus canus)* and the herring gull on the Bligh bank. The increase in numbers of birds could be caused by their attraction to artificial structures as a resting place, or as some kind of point of recognition in open sea. But the higher seabird densities could also be the result of the organic enrichment and its snowball effect on the entire marine food chain. The increase contradicts the fear of seabirds avoiding the area (which indeed is the case for the northern gannet *Morus bassanus*) and of the consequential habitat loss. However: the larger the amount of birds, the higher the risk of collisions with turbines. An initial evaluation based on a worst-case estimate of the expected species-related collision risk indicates a relatively small collision risk for razorbills, terns and small gulls (<0,02 %), but shows a higher collision risk for gulls, great skuas and northern gannets (0,05-0,22 %). Radar studies will put more realistic figures on these estimates in the future.

3.6.5. Biological disturbance from sand extraction

Long-term research into the biological impact of sand extraction did not show any significant effects thereof on the macrobenthos ((De Backer *et al.* 2011). This conclusion is based on results of sampling in areas where intensive extraction led to seabed depressions. Similar depressions were observed at the BCS at three locations, namely at the central and northern part of the Kwinte bank and at the Buiten Ratel sandbank. In the meantime, the zones at the Kwinte bank have been excluded from extraction. Recolonisation of the macrobenthos took no more than 1 to 2 years, the biomass recovering in a period between 2 to 5 years. The Kwinte bank showed a degradation of the benthic community, whereas intensive extraction on the Buiten Ratel led to a more diverse benthic community. The increased diversity is due to an introduction of typical fine-sanded species in an area that is coarse-grained by nature. The presence of a low percentage of very fine sand, probably caused by a surplus of fine material during extraction and/or better availability of this fraction as a result of regular reworkings of the seabed, attracts these species to the area. The contrasting results indicate that the biological impact on the macrobenthos of intensive sand extraction highly depends on the natural circumstances in the sand reclamation area (De Backer *et al*. 2011).

Effects of sand extraction were also studied in nematode communities (Vanaverbeke and Vincx, 2008). Two years after discontinuation of the activities there was no change in densities, diversities or biomass, however the composition and stability of the nematode community as compared to the extraction areas did change.

3.6.6. Biological effects from the dumping of dredged materials

Changes in the benthic habitats as a result of the dumping of dredged materials have been monitored for the five existing deposit sites since 2004 (see figure 3.4); for the Br&W S2 site, data is available from 1978 (Lauwaert *et al.* 2011). The observed effects are related to the nature of the sediments and dumping intensity and can be ascribed mainly to submergence of organisms or changes in sediment composition (enrichment of fine-grained sediments in sand); both result in habitat modification. The benthic characteristics of the deposit sites in the *Macoma balthica* habitat (Br&W Zeebrugge East and Br&W Ostend) remained unchanged. Changes occurred mainly at the deposit sites located in the more vulnerable benthic habitats such as the *Abra alba* habitat (Br&W S1) and sandy environments (Br&W S2). The high dumping intensity at Br&W S1 led to a gradual loss of *Abra alba* habitat, whereas in the surrounding area the density of the tube-building polychaete *Owenia fusiformis* increased considerably over the last few years. At Br&W S2 an enrichment with silt-preferring species occurred, whereas the western part showed a lower diversity. These changes cannot be attributed specifically to changes in dumping intensity. Due to the low dumping intensity at the Nieuwpoort deposit site, the observed variability in benthic characteristics may not have been caused by dumping. As for the epibenthic and demersal fish fauna, no clear impact from dumping was observed.

4. CONCLUSIONS

The Belgian Continental Shelf forms part of a greater aggregate: the oceans. It cannot escape worldwide influences such as the effects of climate change, or the degradation of biodiversity due to the internationalisation of traffic. Also, it is an open area and anything happening outside its boundaries may have more impact that what occurs within. A dynamic sea section, it is exposed to strong fluctuations that make it hard to distinguish between natural and anthropogenic actors. Observations don't have much value unless they are embedded in larger series of data. For this reason the monitoring activities are of strategic importance and must remain linked to the fundamental research.

This report shows the extent to which our part of the North Sea, despite its limited size, is exposed to human pressure. How does it withstand all that? Several elements give us at least some hope: the observed introduction of pollutants from land shows a clearly decreasing trend. In the specific case of nitrogen, reduction of eutrophication of the coastal waters can become manifest as soon as the agreements on reducing the inflow from land are being complied with. Illegal hydrocarbon discharges by ships have reduced by half in the last ten years. Harbour porpoises have again become a familiar sight.

Defining the quality of the marine environment is a delicate affair and must transcend the opinion of individual experts. Quantified criteria are required to establish what is acceptable and what is not. This must be based on scientifically founded arguments, societal acceptability and political willingness – both to establish the required criteria and to come to agreement on methods and resources to realise them within the agreed terms.

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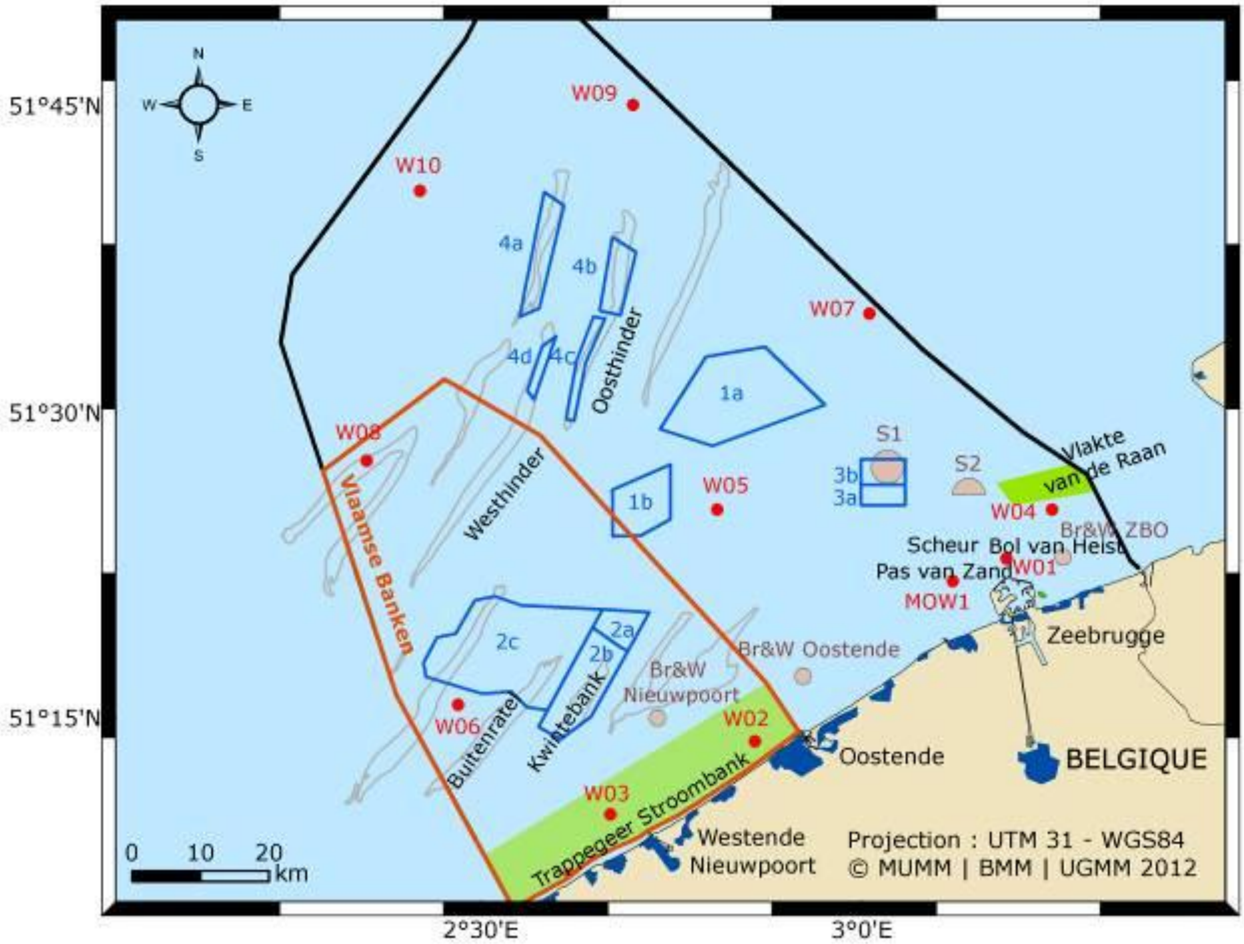
6. MAP WITH PLACE NAMES



7. COLOPHON

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Dutch version:

Belgische Staat, 2012. Initiële Beoordeling voor de Belgische mariene wateren. Kaderrichtlijn Mariene Strategie – Art 8 lid 1a & 1b. BMM, Federale Overheidsdienst Volksgezondheid, Veiligheid van de Voedselketen en Leefmilieu, Brussel, België, 81 pp.

Contact:

If you have questions, or if you wish to receive a digital copy of this report, please send an email to michael.kyramarios@environnement.belgique.be (Director Marine Affairs) or saskia.vangaever@milieu.belgie.be (Expert Marine Affairs).

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