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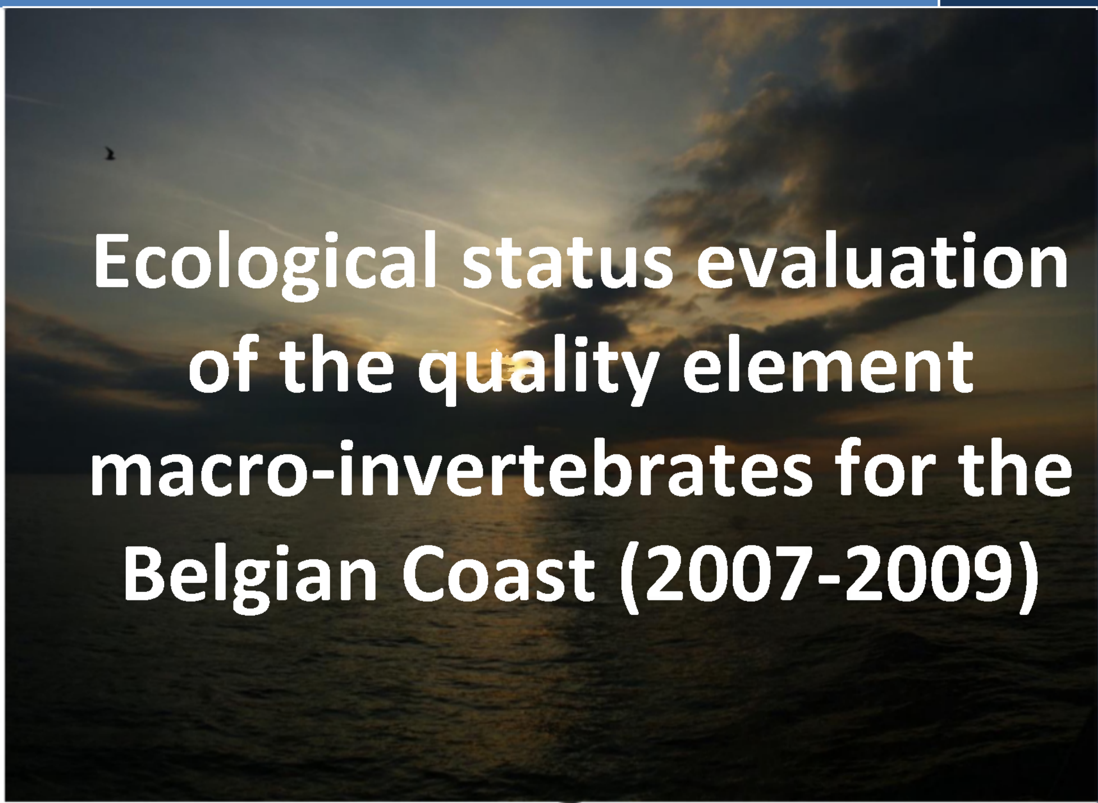
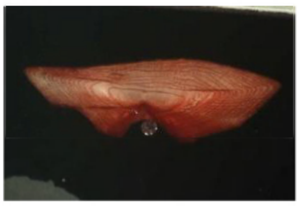
ANIMAL SCIENCES UNIT – RESEARCH AREA FISHERIES

REPORT ILVO-ANIMAL SCIENCES-FISHERIES N° 6



Ecological status evaluation of the quality element macro-invertebrates for the Belgian Coast (2007-2009)

Biological Environmental Research



Gert Van Hoey, Derweduwen Jozefien, Hillewaert Hans, Hostens Kris, Pecceu Ellen, Wittoeck Jan

Oktober 2010

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1 Summary

The Water Framework Directive (WFD; 2000/60/EG) aims to achieve a good ecological and chemical quality status of the European waters (Rivers, Lakes, coastal- and transitional waters). The quality status is determined based on the evaluation of different quality elements, e.g. macro-invertebrates. Macro-invertebrates are good indicators for detecting anthropogenic impacts and ecological degradation. The Belgian Coastal water body (< 1 nautical mile) is a small area, but this environment is highly influenced by the inputs from 4 harbors and 2 rivers (Ijzer, Scheldt), coastal defense works (dredging, sand suppletion) and fisheries. To evaluate the ecological quality status of this area, a WFD monitoring program was implemented in 2007 and the BEQI (Benthic Ecosystem Quality Index) (www.beqi.eu) is used as macro-invertebrate indicator tool. The ecological quality status has to be reported in the River Basin Management Plan of a water body, which is characterised by a reporting cycle of six years (2009-2015).

The current WFD monitoring program for macro-invertebrates is designed to evaluate its ecological quality status with a good confidence on an adequate spatial and temporal scale. A good spatial coverage of the samples per habitat in a water body is very important for a water basin assessment (habitat approach), due to the small scale spatial variation of the benthic characteristics. Therefore, samples were randomly taken at 9 or 11 locations, representative for one or more habitat types (*Abra alba, Nephtys cirrosa* and *Macoma balthica* habitat), in the water body Belgian Coast. A temporal coverage of the samples is important due to the fact that the benthic characteristics show strong year-to-year variations. Therefore, a yearly monitoring is executed instead of monitoring once over the evaluation period of 6 years. Currently, we are halfway of the first monitoring cycle (2007-2012). Finally to obtain a good confidence, a high number of samples has to be taken to reduce the chance of misclassification in the ecological quality status. Therefore, the number of samples is determined based on the observed variance in benthic characteristics in the reference dataset of each habitat type.

In this report, the monitoring results of the third year (2009) are outlined, together with an ecological quality status evaluation over the first part (2007-2009) of the first monitoring cycle. Beside it, a profound analysis on the habitat approach and a confidence analysis of the assessment of the macro-invertebrate monitoring program is made.

The most obvious pattern in the benthic data of the year 2009 is the massive recruitment of the bivalve *Ensis directus*, an invasive alien species, along the entire coastline. The linking of the samples to a certain habitat type is less obvious than in the previous years, partly due to the presence of *Ensis directus*. There are also more samples taken in sandy sediments (*Nephtys cirrosa* habitat). The BEQI level 3 shows that the *Abra alba* and *Nephtys cirrosa* habitat are in moderate status compared to the reference situation, which is mainly due to *Ensis directus* and a lower species richness. The *Macoma balthica* habitat is in a good status, mainly due to the high status of the parameter density.

The ecological quality status assessment over the period 2007-2009 shows an overall moderate status of the water body Belgian Coast for the quality element macro-invertebrates, due to the moderate status of all habitats. The *Abra alba* habitat shows a moderate status for most parameters, due to lower densities compared to the reference situation, mainly of the species *Spisula subtruncata*, *Magelona johnstoni* and *Lanice conchilega*. The poor to moderate status of the habitat

Nephtys cirrosa is due to the unusual high benthic densities (*Ensis directus*) in this sandy environment. The *Macoma balthica* habitat at the west coast is in a good status, but moderate in the central and eastern coast. This moderate status is mainly due to the nearly absence of *Petricola pholadiformis, Barnea candida* and *Polydora spp*. The number of species expected in this habitat type is also lower compared to the reference situation. It seems that the moderate benthic status of the Belgian Coastal waters is mainly caused by the lower densities and presence of certain key species in each habitat or the introduction and success of an alien species (*Ensis directus*). This ecological degradation of the macro-invertebrate fauna in the Belgian coastal area cannot directly be linked to one anthropogenic pressure, but is probably the result of the combined acting of the present anthropogenic impacts.

Two aspects, which are of importance in the benthic monitoring design, are the habitat approach and the confidence analysis on the assessment and this is investigated in more detail in this report. Currently, the determination of the habitat type of each sample is based on a biological analysis of the data, funded with sedimentological sample information. This approach may lead to the assignation of some poor benthic samples, qua diversity and density, to the wrong benthic habitat type. In other words, this approach can mask the real habitat potential of some locations. Secondly, the assigned habitat type of some parts of the locations does not correspond with the habitat suitability map. Therefore, it can be advisable to re-run the habitat suitability model in the Belgian Coastal area, based on the recent gathered monitoring information. A different procedure for habitat assignation of the samples has an effect on the EQR score's of the habitat, as tested in this report. Therefore, we concluded that one approach has to be selected, based on the visions of the benthic experts in Belgium.

The confidence of the ecological quality assessment, coupled to the sampling effort, is judged with a statistical power analysis in the BEQI approach. An estimate of the sampling effort depends on the wanted power, the effect size and the variance in the benthic habitat characteristics (number of species, density). Currently, confidence classes are defined based on the effect size that can be measured with a power of 75%. Setting the power on 75% should lead to an acceptable sample effort. For obtaining a good confidence, the sampling effort in the assessed habitat has to be of that size to detect an effect size of factor 2 (halving or double) with a power of 75%. Due to difference in variance in benthic parameters, the sampling effort needs to be much higher for the parameter density compared to number of species and varies also between the three habitat types. By this kind of analysis, the government and scientists can investigate the sampling effort to obtain a certain confidence over the effect size they want to judge.

There can be concluded that, regarding the quality element macro-invertebrates, the ecological status assessment over the period 2007-2009 assigns the Belgian coast as moderate. Therefore, the operational monitoring program needs to be continued. Adaptations or reductions in the program are possible, whereof some suggestions were tested and reported in this report, but the aspects regarding the habitat approach and confidence may not be neglected.

2 Introduction

The Water Framework Directive (WFD; 200/60/EG) is the umbrella legislation for addressing the ecological quality of water systems (rivers, lakes, transitional and coastal waters) in Europe (Box 1). The ecological quality status of a water body has to be determined based on different quality elements. For each of these elements, the member states shall ensure the establishment of programs for the monitoring of the water status in order to establish a coherent and comprehensive overview of the water status within each river basins district (Article 8 of the Directive). These programs should be operational six years after the date of entry into force of the WFD Directive (2000). Based on this program, the assessment of the ecological quality status of the water bodies has to be reported in its River Basin Management Plan. The first River Basins Management Plan has been accomplished in 2009 and should be revised in a periodic cycle of 6 years (next in 2015). The monitoring program for the Belgian Coastal waters is operational since 2007 (Artikel 8 rapport België), wherein the locations, the frequency and cycle of the monitoring of each element for surveillance and operational monitoring is defined (see appendix 1). The first River Basin Management Plan for the Belgian Coastal waters was accomplished in 2009.

Box 1: Water Framework Directive (WFD)

The European Water Framework Directive (WFD; 2000/60/EC) aims at achieving a 'good' ecological and chemical quality status for all water types, by 2015. The quality status of a water body can be determined based on the evaluation of biological quality elements, which are phytoplankton, macro-algae, macro-invertebrates and fish (the latter only in transitional waters), which are supported by chemical, physico-chemical (e.g. transparency, thermal and oxygen conditions, salinity and nutrients) and hydromorphological (e.g. depth variation, quantity structure and substrate of the sub-tidal and intertidal zone, tidal regime) quality elements. GES (Good environmental status) is defined as 'the values of the biological quality elements for the surface water body type show low levels of distortion resulting from human activity, but deviate only slightly from those normally associated with the surface water body type under undisturbed conditions'. The evaluation of the GES is based on the integration of well defined quality criteria per quality element. Each of these quality criteria supports a classification (bad, poor, moderate, good and high) to measure the 'health' of the system compared to reference conditions. For the biological quality element macro-invertebrates, the composition and abundance of the fauna has to be identified. Within a WFD context, a lot of benthic indicators were developed and intercalibrated, which combine some benthic variables such as abundance, biomass, diversity (e.g. Shannon Wiener, Margalef, Simpson indexes), Bray-Curtis similarity, species sensitivity/tolerance classifications (e.g. AMBI, $ES50_{0.05}$ species values) in a multivariate or multimetric way (Borja, Josefson et al. 2007).

Macro-invertebrates, one of the biological quality elements, is the focus in this report. The earlier attempts to assess the ecological quality status of benthic invertebrates in the Belgian Coastal waters showed some shortcomings (Van Damme, Meire et al. 2007); (Van Hoey, Ysebaert et al. 2007), such as (1) the low amount of reference samples to determine the reference values for the benthic parameters, and (2) almost no spatial coverage of the assessment samples within the 1 nautical mile zone of the Belgian coast. The first attempt was in 2007, where the reference conditions for benthic invertebrates for the Belgian coast were defined based on all available benthic data within the 6 nautical mile of the coast (Van Hoey, Wittoeck et al. 2008). The second attempt was fulfilled with the start of the WFD macro-invertebrate monitoring program. This monitoring program is constructed to allow a confident assessment incorporating the spatial and temporal variance of the benthos. This is necessary, because macro-invertebrates are characterised by natural year-to-year variations in their characteristics (Gray and Elliott ,2009). Also, a system based monitoring program (better spatial coverage) will be more optimal for an ecological quality status assessment than a station based program (de Jonge, Elliott et al. 2006), due to the small scale spatial variation of benthos. The number of samples, which has to be taken in each habitat, were determined based on the observed variance within the habitat characteristics. Therefore, samples were randomly taken in a few fixed locations (9 to 11) over the three years. They were representative for each habitat type in the different zones along the Belgian coast (see 2.1). This yearly operational monitoring of macro-invertebrates started in autumn 2007 and was repeated 2 times (2008 and 2009). The operational monitoring program was operational, due to the fact that the initial ecological quality status of macro-invertebrates was determined as 'moderate' for the Belgian Coastal waters (Van Damme, Meire, Gommers, Verbeeck, Van Cleemput, Derous, Degraer, and Vincx ,2007); (Van Hoey, Ysebaert, and Herman ,2007). Now, the first monitoring cycle of 3 years is ended and therefore this report can give an ecological quality status evaluation over this first WFD monitoring period.

The objectives of this report were to give:

- An assessment of the ecological status of macro-invertebrates, with the confidence level, within each habitat in each zone for monitoring year 2009. A basic description of the monitoring data of 2009 will also be outlined.
- An overall assessment of the first cycle (2007-2009) of the ecological status of macro-invertebrates, with the confidence level, within the water body 'Belgian Coastal waters', based on the three levels of the BEQI approach.
- An evaluation of the monitoring and assessment strategy (spatial and temporal design) and this in relation to the obtained statistical power, effect size and confidence of the assessments.

3 Material and Methods

3.1 Performed sampling strategy

The water body 'Belgian coast' was divided into three zones, in which the most important commercial ports and/or estuaries are situated: (1) a western zone, from the French border to Middelkerke, including the Ijzer estuary; (2) a central zone, from Middelkerke to De Haan, including the harbor of Ostend; and (3) an eastern zone, from De Haan towards the Scheldt estuary, including the harbors of Blankenberge and Zeebrugge. The deviation of the water body into three zones, makes it possible to evaluate the gradient in hydromorphological, physico-chemical and anthropogenic differences along the Belgian Coast.

The sampling locations were all situated within the 1 mile zone of the coast and their positions within the three zones were chosen in function of (1) the position of the Belgian harbors and the estuary of the Ijzer and Scheldt; (2) special zones for nature protection; (3) sedimentology; (4) benthic communities (Van Hoey et al., 2004; Degraer et al., 2008) and (5) accessibility of the sampling points in the light of long-term monitoring (Van Hoey et al., 2008). Based on these five criteria, sampling locations, representative for the occurring benthic communities, were determined within the 1 nautical mile zone of the BPNS,. The form and extent of each sampling location depended on the topology and the expected presence of the different habitats. The number of samples taken randomly at each location was based on the monitoring requirements of the BEQI within each habitat type (Table 1) (Van Hoey et al., 2007; Van Hoey et al., 2008).

Table 1. The sampling surfaces needed to reach a good assessment precision per habitat type, based on the methodology determined in (Van Hoey *et al.*, 2007).

	Sampling surface (m^2)		
Habitat	**minimal**	**OK**	**optimal**
Abra alba habitat	1.5	2	6
Macoma balthica habitat	1.2	1.8	5
Nephtys cirrosa habitat	1.2	1.8	4.9

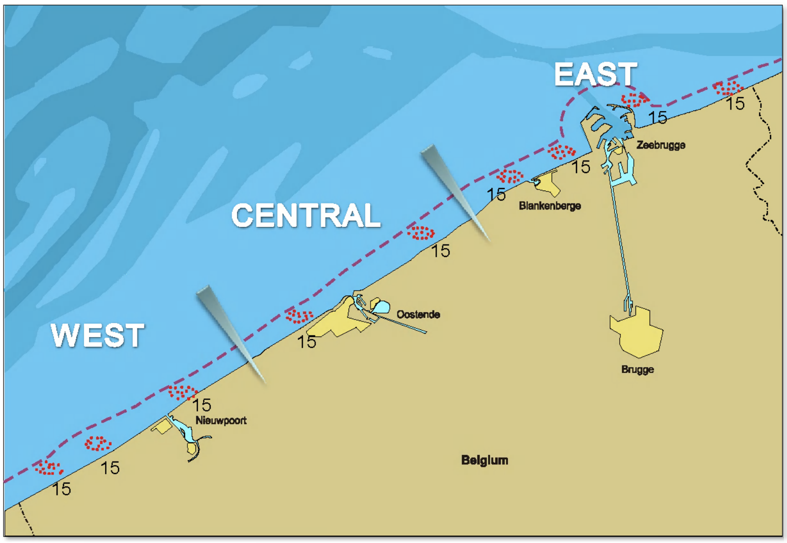

Figure 1: Position of the sampling locations (WGS84) in year 2007

For the KRW monitoring of 2007, 9 sampling locations were selected (Figure 1) with an extent of 0.6 km², in which 15 samples were randomly taken (Van Hoey et al., 2008). This design was adapted in 2008, to optimize the effort, by adding two extra locations (KRW10 and KRW11), and increase or decrease the number of samples for some habitats in certain zones (Van Hoey et al., 2009). These adaptations resulted in the selection of 11 sampling locations for the monitoring of 2008. At each location, a certain number of random samples was taken (see Table 2 or Figure 2 for more detail). At location KRW1 and KRW4 the location extent was increased to 1.2 km². This design was kept for the monitoring of 2009.

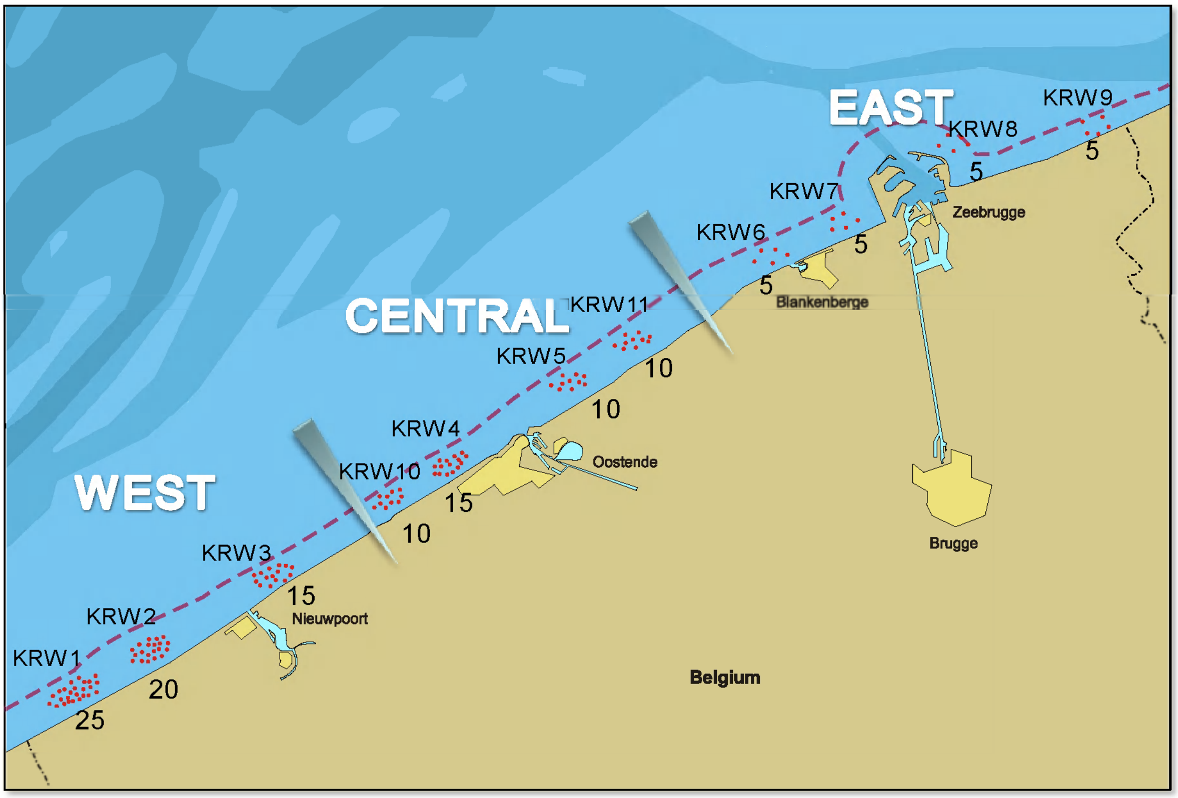

Figure 2. Position of the sampling locations (WGS84) in 2008 and 2009, indicating the number of samples taken at each station.

Table 2. Position of the different sampling locations with indication of the depth, distance to the coast, possible factors influencing these locations and the expected macrobenthic community.

Station	Latitude	Longitude	Depth	Location extent 2007	Location extent 2008-2009	# samples 2007	# samples 2008-2009	Influenced by	Expected community
KRW1	51°06.80 N	002°35.00 O	≈ 6.0 m	0.6 km²	1.2 km²	15	25	Port of Duinkerke (F)	Abra alba / Macoma baltica
KRW2	51°08.20 N	002°38.30 O	≈ 3.0 m	0.6 km²	0.6 km²	15	20	Port of Duinkerke (F) Mouth of the Yser Port of Nieuwpoort	Nephtys cirrosa
KRW3	51°10.00 N	002°43.50 O	≈ 5.5 m	0.6 km²	0.6 km²	15	15	Mouth of the Yser Port of Nieuwpoort	Macoma balthica
KRW10	51° 12.48 N	002°49.5 O	≈ 6.5m	0.6 km²	0.6 km²	0	10	Port of Oostende	*Abra alba/ Macoma baltica*
KRW4	51°13.10 N	002°51.40 O	≈ 6.5 m	0.6 km²	1.2 km²	15	15	Port of Oostende	*Abra alba/*

									Macoma baltica
KRW5	51°15.60 N	002°57.10 O	≈ 4.0 m	0.6 km²	0.6 km²	15	10	Port of Oostende Dump zone Oostende	*Macoma baltica*
KRW11	51°16.570 N	002°59.45 O	≈ 4 m	0.6 km²	0.6 km²	0	10	Port of Oostende Dump zone Oostende	*Macoma baltica*
KRW6	51°18.90 N	003°04.80 O	≈ 5.5 m	0.6 km²	0.6 km²	15	5	Port of Blankenberge Port of Zeebrugge	*Macoma baltica*
KRW7	51°19.90 N	003°08.60 O	≈ 3.0 m	0.6 km²	0.6 km²	15	5	Port of Zeebrugge	*Macoma baltica*
KRW8	51°22.10 N	003°13.80 O	≈ 8.0 m	0.6 km²	0.6 km²	15	5	Port of Zeebrugge	*Macoma baltica*
KRW9	51°22.30 N	003°20.00 O	≈ 6.5 m	0.6 km²	0.6 km²	15	5	Port of Zeebrugge Mouth of the Scheldt Dump zone Zeebrugge	*Macoma baltica*

During the monitoring campaign of 2007, 135 samples were taken with the RV Belgica (st0723, 8-10 October 2007) and with the vessel 'Stream' for the more shallow stations (12 and 15 October 2007). One of the samples (KRW2-15) was lost due to insufficient fixation. The benthic characteristics of those samples were in more detail described in [Van Hoey, 2008 4 /id].

During the monitoring campaign of 2008, 125 samples were taken; 45 samples during the Belgica campaign (2008/22c) on 30 September 2008 and 80 with the vessel 'Stream' on 9 and 10 October 2008 for the more shallow stations. The benthic characteristics of those samples are in detail described in [Van Hoey, 2009 5 /id]. The assignment of serial numbers to the 2008 samples at each location followed the numbering of 2007, except for the new locations, at which the numbering started at one (KRW10). The serial numbers at KRW11, which was also a new location, erroneously started at 16 but the number was kept for the sake of traceability of the data recording.

During the monitoring campaign of 2009, 125 samples were taken; 47 samples during the Belgica campaign ST0925B and ST0926 and 78 with the vessel 'Jacob Besage' on 19 and 22 Oktober for the more shallow stations. One of the samples (KRW9-16) was lost due to insufficient fixation, whereas samples (KRW11-22, KRW10-10, KRW10-6) were lost during the sampling processing. The labeling of the samples follows that of 2008.

3.2 Data gathering

The benthic samples were taken with a Van Veen grab (0.1 m²) and fixed with an 8 % formaldehyde solution. Afterwards the samples were sieved on a 1 mm sieve. The species in the samples were identified to species level when possible and the number of individuals was recorded. Quality control of the identifications was done by re-examination of some of the species/samples by different persons within the institute (no standardized recording of it). The biomass (Wet Weight and Ash Free Dry Weight) was determined per species following a standardized protocol (24 h drying at 110 °C for determining Dry Weight and 2 h incinerating at 450 °C for determining Ash Weight) on the data of 2007. For the biomass conversion (Wet Weight to Ash Free Dry Weight) of the data of 2008-2009, conversion factors were used, which were calculated based on the data of 2007 for the following taxonomic groups; Amphipoda, Anthozoa, Bivalvia, Diastylidae, Gastropoda, Mysida, Ophiuroidea, Paguridae, sedentairy Polychaeta, tube-building Polychaeta and mobile Polychaeta. The benthic lab of the biological environmental research groups follows the ISO16665 standard, "Water quality –

Guidelines for quantitative sampling and sample processing of marine soft-bottom macrofauna", for the sampling of marine soft-bottom macrofauna. External quality control for identification and enumeration of benthic macrofauna started from 2010 onwards by participation in the UK National Marine Biological Analytical Quality Control Scheme (NMBAQC).

From each Van Veen sample, a sediment sample was taken with a core. These samples were dried at 60 °C and analyzed with a Malvern Mastersizer 2000 following a standardized protocol. Depth and position of each sample were also registered during the campaigns.

All benthic data were delivered to the BMDC database of MUMM.

3.3 Standard data analysis

Different biological parameters were calculated using different tools, which were shortly outlined in this section.

First of all, the species dataset was standardized by lumping some species (Cirratulidae spp, *Spio* spp, Anthozoa spp) and removing other species from the dataset because they did not belong to the macrobenthos *sensu strictu* (eg. Mysida). Nematoda were excluded because of inadequate sampling techniques for quantifying meiofauna. Two samples at location KRW7 in 2008 were omitted since they lacked biota.

The calculated univariate variabels were: (1) density (ind./m²); (2) biomass (g AFDW); (3) number of species (N_0). The Hill diversity index N_2, which is the reciprocal of the Simpson's index (1/Simpson), was used in the analysis (Hill, 1973). This index is a measure of dominance.

Cluster analysis by group averaging sorting based on a Bray-Curtis similarity dataset was used as multivariate analysis. This cluster analysis was complemented with a SIMPROF test to define the significant different groups within the cluster analysis. The clustering was visualized using a non-metric Multi Dimensional Scaling analysis (MDS). A SIMPER analysis was performed to examine the contribution of each species to the average similarity within a cluster group. All multivariate analyses were performed with the PRIMER statistical program (version 6).

The samples per location were assigned to one of the macrobenthic habitats (*Abra alba* habitat, *Nephtys cirrosa* habitat and *Macoma balthica* habitat) in the Belgian Coastal zone based on the following procedure:

- A cluster analysis based on Bray-Curtis similarity was performed on a fourth root transformed density dataset, combined with a SIMPROF analysis to define significant cluster groups.
- Those SIMPROF defined cluster groups were, if necessary, combined into relevant clusters (e.g. combining the outliers in one cluster group) and visualized in a MDS plot.
- A SIMPER analysis was performed on the data to define the characteristic species per cluster group. Additionally, some biological parameters (average density, biomass, number of

species) and sedimentological parameters (median grain size, mud content) were calculated per cluster group.

- The cluster groups were linked to one of the three habitat types using the following criteria:
- Species composition, number of species and average density corresponding to the descriptions in Degraer *et al.* (2003) and Van Hoey *et al.* (2004).
- Sedimentological characteristics of the cluster according to the following classes:
    - *Macoma balthica* habitat: mud content more than 25 %, median grain size lower than 200 µm.
    - *Abra alba* habitat: mud content between 5-25 %, median grain size approximately 200 µm
    - *Nephtys cirrosa* habitat: mud content lower than 5 %, median grain size exceeding 225 µm.

Alternative approaches were tested and described in section 4.4.1.

3.4 BEQI (Benthic Ecosystem Quality Index)

The evaluation tool, which is selected to define the ecological quality status of benthic invertebrates in the Belgian coastal waters, is the Benthic Ecosystem Quality Index (BEQI). The BEQI is a multimetric method distinguishing three scale levels to assess the overall ecosystem functioning. The first level is the ecosystem level, which reflects the ecosystem functioning in the water body by evaluating the relation between macrobenthic biomass and system primary production. The second level is the habitat level, which attempts to evaluate changes in habitats due to anthropogenic pressures (land reclamation, dredging, hydrodynamic changes, …). The third level evaluates the changes in the benthos for a certain habitat compared to the reference situation of that habitat, based on four parameters: density, biomass, species richness and species composition. In other words, the BEQI multimetric integrates the information of the three levels and primarily aims to provide a signal that is capable of showing significant deviations from a defined reference state. For more information see Van Hoey *et al.* (2007a).

Box 2: Benthic Ecosystem Quality Index (BEQI)

The BEQI consists of three assessment levels, each of which consists of one or more parameters:

Level 1 – At the ecosystem level, the BEQI uses the relationship between macrobenthic biomass (B) and system productivity (P, sum of fytoplankton and microfytobenthos), as was demonstrated by Herman *et al.* (1999) based on a series of estuarine and coastal systems worldwide. This relation implies that for these shallow, well mixed systems, between 5 % and 25 % of the annual primary production (pelagic and benthic) is consumed by macrobenthos. The rest of the production is either consumed by pelagic grazers or directly incorporated into the microbial food web after decaying of the algal bloom. A B:P ratio of 1:10 is used as the reference ratio between the macrobenthic biomass and the system primary production (Escaravage *et al.* 2004). This ratio may represent a state of equilibrium where the sum of pelagic and benthic primary production is adequately matched by the biomass of grazers that are present in the system (i.e. macrobenthos and zooplankton). Deviations from this relation could indicate unbalanced ecosystem functioning (Ysebaert *et al.*, in prep) and were scaled according to the WFD definitions (see further).

Level 2 – At the second level the BEQI considers the spatial distribution of habitats within an ecosystem. At this level one addresses the diversity of habitat types, and compares the availability and spatial organisation of these types to an expected reference state, based on the physical and geomorphological constraints of the system. The term habitat refers to large, broad scale geomorphological structures in these ecosystems, easily quantified from remote sensing and sounding techniques, such as sand flats, mudflats, shallow subtidal, channel. When applying this indicator to the WFD, BEQI currently uses the surface area (spatial extent) of habitats as criterion at this level. The BEQI also includes eco-elements, which are habitats constituted of species that form conspicuous biogenic structures, in coastal and estuarine soft-sediment systems typically in the form of mussel beds and oyster reefs. The current status can be evaluated against a certain historical reference period, expert judgment or against the management objectives for a certain water body, evaluating as such the physical changes in the water body due to human activities: habitat loss due to land reclamation or infrastructural works, morphological changes due to dredging, etc. The deviations from the reference situation were scaled according to the WFD definitions (see further). Level 2 is not determined in the ecological status assessment for the macro-invertebrates of the Belgian Coast.

Level 3 – At the third level the BEQI analyses and evaluates the benthic macrofauna community per habitat or ecotope. The term ecotope is used from a landscape perspective. Ecotopes are ecologically distinct landscape features that are useful for stratifying estuarine landscapes for the measurement and mapping of landscape structure, function and for the measurement of spatial changes and the ecological potential of the system. In the Netherlands, a hierarchical ecotope classification has been worked out for brackish and marine waters. It uses salinity, depth or tidal elevation, hydrodynamics and sediment characteristics to define benthic ecotopes (Bouma *et al.* 2005, Ysebaert *et al.*, in prep). Threshold values defined for each parameter delimit condition classes wherein a characteristic benthic community is expected to occur. The BEQI level 3 uses four biological parameters: number of species, total density (ind.m^{-2}), total biomass (g AFDW.m^{-2}), and similarity (Bray-Curtis similarity based on 4^{th} root transformed density data). The similarity index compares the assessed species composition (species and their densities) with a reference species composition. Each parameter gives different information about the structure and functioning of the benthic community.

The BEQI evaluates the benthic community at the level of a habitat or ecotope, rather than the evaluation of a single sample. This requires a certain amount of reference and assessment samples and sampling area per habitat or ecotope, and allows the incorporation of natural variability (spatial and temporal).

The BEQI takes into account the total sampling surface within a certain habitat or ecotope, as the parameter results will strongly depend on the sediment surface sampled. Therefore, the expected reference values for the BEQI parameters are calculated per habitat or ecotope from permutations executed over increased sampling surfaces. An algorithm was used that computed rarefaction curves using a random resampling procedure with replacement (i.e. bootstrapping, using 2000 random samples). This allows to estimate, for any given sampling surface, the reference value that can be expected. Then this value can be compared with a similar sampling surface used to evaluate the current ecological status. For the parameters number of species and similarity, a one-sided evaluation approach (only values lower than the reference are evaluated in the high-bad gradient) is used, whereas for the parameters density and biomass a two-sided evaluation approach (values lower or higher than the reference are evaluated in the high-bad gradient) is used. Additionally, the BEQI also produces a list of species that are responsible for observed deviations from the reference state (a list of species which contributes mostly to the dissimilarity between reference and assessment: SIMPER analysis). This gives additional insight into how the current state has changed. This is done for the parameters density, biomass and similarity.

Ecological quality status classes – For each parameter at the three levels, reference values were determined for each ecological status class boundary of the WFD: high, > 0.8; good, 0.6-0.8, moderate, 0.4-0.6; poor, 0.2-0.4; bad, ≤ 0.2. For level 1 and 2, a reference value is determined for the high/good boundary and the values for the other WFD class boundaries were determined by equal scaling of this high/good reference value. At level 3, the reference value of the good/moderate boundary is determined based on the 5th percentile (number of species, similarity) or on the 2.5th and 97.5th percentile (density, biomass) out of the permutation distribution of each parameter (Ysebaert *et al.* subm.) (Figure 3). The moderate/poor and poor/bad reference value were determined by equal scaling (respectively 2/3 and 1/3 of the good/moderate reference value), whereas the median value (number of species, similarity) or the 25th and 75th percentile (density, biomass) out of the permutation distribution was used as the reference value of the high/good boundary.

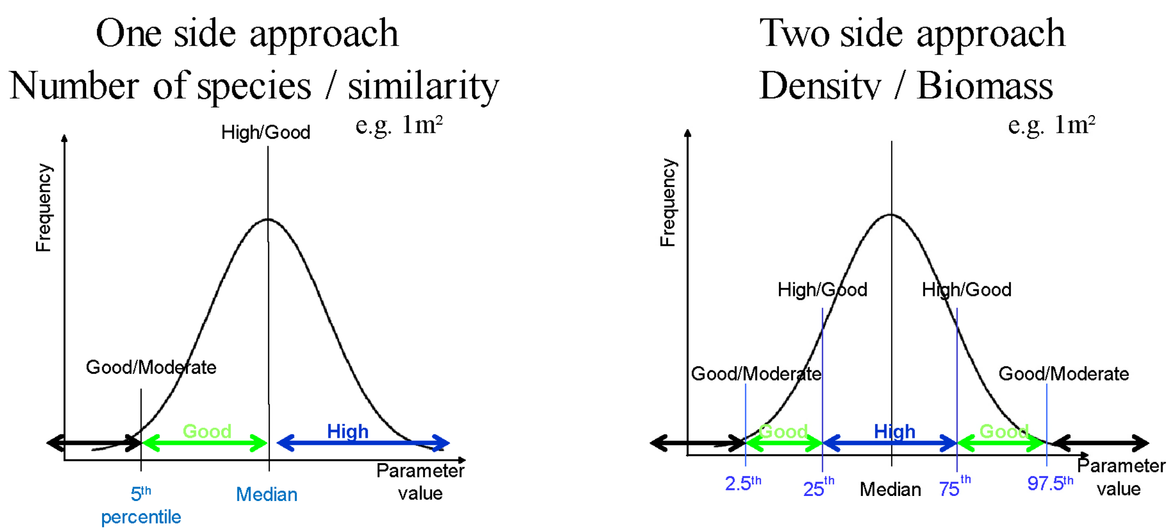

Figure 3. Outline of the reference boundary settings for the different benthic parameters.

Overall BEQI score – For the WFD, the different levels of the BEQI need to be summarized and integrated into one overall Ecological Quality ratio (EQR) and ecological status class. In the BEQI method priority is given to both transparency and simplicity. Each step of the integration remains visible and interpretable. At the level of the ecosystem, one parameter value is obtained, but at the other two levels more parameters are calculated and the overall EQR value of that level is obtained by averaging. Within level 3, first the ecotope is evaluated based on the average outcome of the four biological parameters, after which the outcomes of the different ecotopes are averaged to get an average estimate at level 3.

The BEQI index can be calculated with a web-application tool, developed by the Flanders Marine Institute (http://www.beqi.eu).

3.5 Confidence of the assessment results of the BEQI

It is advisable to determine the confidence of the assessment, which means to detect which is the chance to find a certain deviation from the reference value with a certain power. Therefore, a power analysis is used to determine the level of confidence of the assessment results with the BEQI (level 3) (Box 3).

The possibility to detect a certain deviation (effect size) from the median value for each evaluated parameter with a power of 75% and with the used sampling effort was evaluated. Four confidence classes were defined: (1) when it is possible to detect changes with a factor < 2, the power is evaluated as GOOD; (2) changes with a factor 2-5, the power is evaluated as MODERATE; (3) changes with a factor 5-10, the power is evaluated as LOW; (4) changes with a factor > 10, the power is evaluated as VERY POOR. Every assessment result of each parameter is judged with these confidence classes. A combined confidence result of the averaged assessment values of each parameter is determined by the lowest confidence class of one of the parameters.

Box 3: Confidence of an assessment

In a statistical test aiming at determining the significance of a difference between two populations, two different types of error can be committed. Type I error is concluding that there is a difference, while in fact there is none. As stated above, the probability of such errors depends on the significance level used. In this study, this probability level is 5 %. Type II error is the reverse: concluding that there is no difference, while in fact there is one. **The probability of a Type II error depends on the variance in the data, the effect size and the choice of the level of significance, the α which is set to 0.05**. The *power* of a test is defined as 1-β, where β is the probability of a Type II error. For type II errors, the criterion is in our case is set on 75% (or 75% certainty), usually 80%, since it has been found by practical experience that such a criterion gives a reasonable number of samples whereas a 90% criterion would mean taking an extremely large number of samples (Ferraro et al., 1994; Gray et al., 2009).

The BEQI method at level 3 describes the variance of the average reference conditions of the four parameters as a range of probability distributions along an axis of sampling effort. This distribution at every sampling surface is described by a median, quartiles and percentiles. This distribution is estimated with a permutation technique, by randomly drawing samples from the reference data set. Any average assessment value that falls outside the 95% of the random distribution around the median (which is outside the 2.5% and the 97.5% percentile borders) is defined to be significantly different from the reference conditions (at α=0.05). With a sample drawn from the same population as the reference population the chance is 5 % that it is rated significantly different and 95 % that is rated the same.

The power of the assessment is just the chance that the average of an assessment value falls outside the 2.5 and 97.5 borders of the distribution of the variance. When the assumption is made that the variance structure remains unaltered when the median of a population changes (in other words the average of the assessment may be different from the reference but the distribution of the quartiles around the median of the variance remains the same) it is easy to estimate the amount of overlap between the distribution of the reference and the distribution of the assessment (Figure 4).

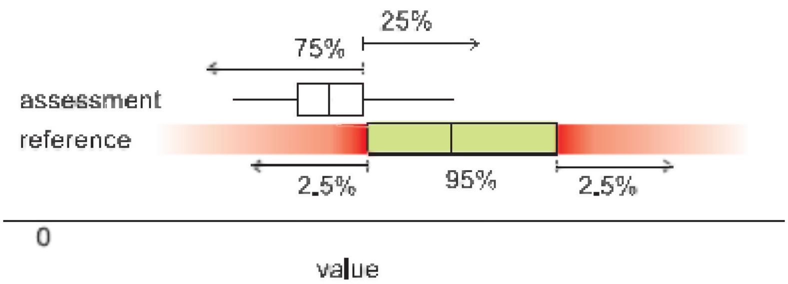

Figure 4. Example of the estimation of the statistical power to detect a significant difference between a reference sample and an assessment sample. The assessment box is like in a regular box plot, showing the median and the second and third quartile. The reference box shows the median with the 2.5 percentile and 97.5 percentile as the box edges. Any value falling in the red area is significantly different at the 5% level (α=0.05).

The reference condition for a certain sample surface is described along an axis by the median and the green box around the median. The range of the reference box is 95 % of the distribution running from the 2.5 percentile to the 97.5 percentile. Any average value from a sample drawn from a population that falls outside the range of the green box is from an (assessment) population with a median significantly different from the median of the reference.

The **power** is the chance to find a mean value outside the range of the green box. This is the same as the fraction of the distribution of the variance of the assessment sample (the white box) that falls outside the range of the green box. In the figure the white box shows the second and third quartiles of variance distribution around the median. There is still about 25% overlap with the reference box. The chance to find a significant difference in this particular case between the reference and the assessment is 75 %. It is assumed that the variance structure does not change with a change in the average of the population. This means that the quartile width of the assessment sample is the same as that of the reference.

The **effect size** in this case is the difference between the median of the assessment and the median of the reference. This is the sum of the difference between the median of the reference and the 2.5 percentile and the difference between the median and the 75 percentile of the assessment.

In Figure 5, it is explained what a sampling effort (in surface units) is required to detect a significant difference with a certain effect size with a chance of 75% for the *Macoma balthica* habitat of the Belgian Coastal zone. The green line is a median which is twice as small as the median of the reference (in other words an effect size 2). The purple line is the third quartile border derived from the reference distribution. At the sampling surface where the third quartile border crosses the border between good and moderate (at the black vertical line) 75% of the distribution of the "assessment" sample falls below the 2,5 percentile. This means that the chance is 75% to find a significant difference with an effect size of 2 (bisection), is at a sampling surface of about 9.3/m².

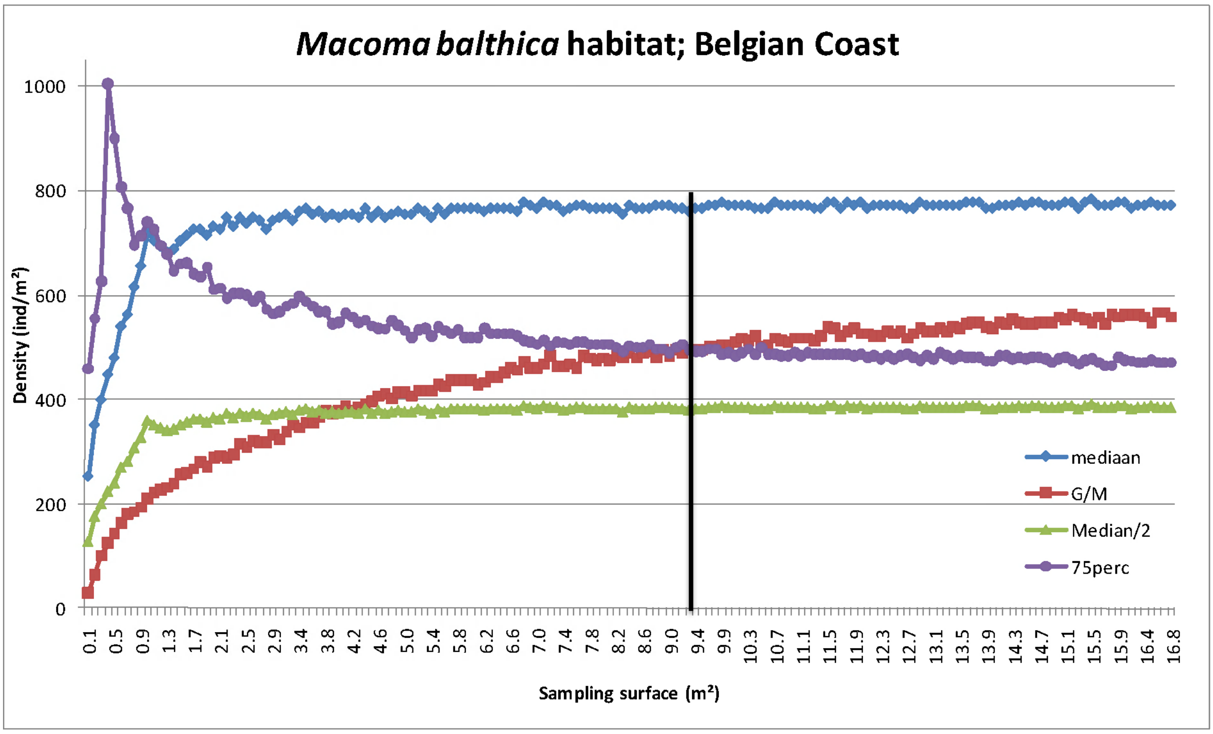

Figure 5. Example of the estimation of the sample size required to find an effect size of 2 (in this case a two times reduction) with a power of 75%.

The other way around, it is also possible to calculate the detectable effect size with a power of 75% at any given sampling surface. This is done by summing the difference between the median and the 2.5 percentile or 97.5 percentile and the difference between the median and the 25 or 75 percentile. This makes it possible to estimate the sample effort needed to detect a certain effect size with a power of 75% for each habitat type, which is outlined in section 4.4.2. This issue needs further attention and investigations during the development of monitoring strategies.

4 Results

4.1 Results of macrobenthos monitoring 2009

4.1.1 Density, biomass and diversity

The density, biomass (gAFDW) and the diversity (number of species and N_2) distribution is analyzed for each sample at each location (Figure 6; Figure 7; Figure 8; Figure 9).

The density is quite variable between the samples and locations, but considerably higher in 2009, compared to 2007-2008, especially for the samples at locations KRW2, KRW3, KRW10, KRW11, KRW6 and KRW7 (Figure 6). This is due to the high contribution of the density of *Ensis directus* (juveniles=year-0 class) to the total density at those locations. Almost at every location, a mass recruitment of *Ensis directus* is found, which is most pronounced at locations KRW2, KRW3 (around the harbor of Nieuwpoort) and KRW10. Another hot spot of recruitment is at location KRW 11. Even at the east coast, where previously no *Ensis* species were found, recruitment has taken place. The highest density was observed at station KRW10-1 (20110 ind/m²), due to high densities of *Ensis* species, *Lanice conchilega*, *Microprotopus maculatus* and *Phyllodoce mucosa*.

Table 3. The average density of *Ensis directus* (ind/m²) at each location in each monitoring year.

Average density	2007	2008	2009
KRW1	31	34	296
KRW2	18	11	2967
KRW3	4	1	1337
KRW10	-	17	3924
KRW4	29	42	478
KRW5	1	0	218
KRW11	-	12	2291
KRW6	0	2	430
KRW7	0	0	142
KRW8	0	0	0
KRW9	0	0	128

The pattern in the number of species is quite comparable between the samples at each locations, but variable between the locations (Figure 7). The lowest values are observed at the locations (KRW6, KRW7, KRW8, KRW9) at the eastern Belgian coast. The highest number of species is found at location KRW 1. The variability is highest between the samples at location KRW 4.

The N_2- index shows clearly the highest values at location KRW1 (Figure 8), indicating the highest biodiversity. Another rather divers location is KRW4. In contrast, the diversity is much lower at location KRW2 en KRW11, due to the dominance of one species, *Ensis directus*.

The biomass is quite variable between the samples at each location (Figure 9). The samples at location KRW5, KRW8 and KRW9 wer ethe lowest, whereas the highest biomass values were found at location KRW1 and some samples at location KRW 4, KRW10 and KRW11.

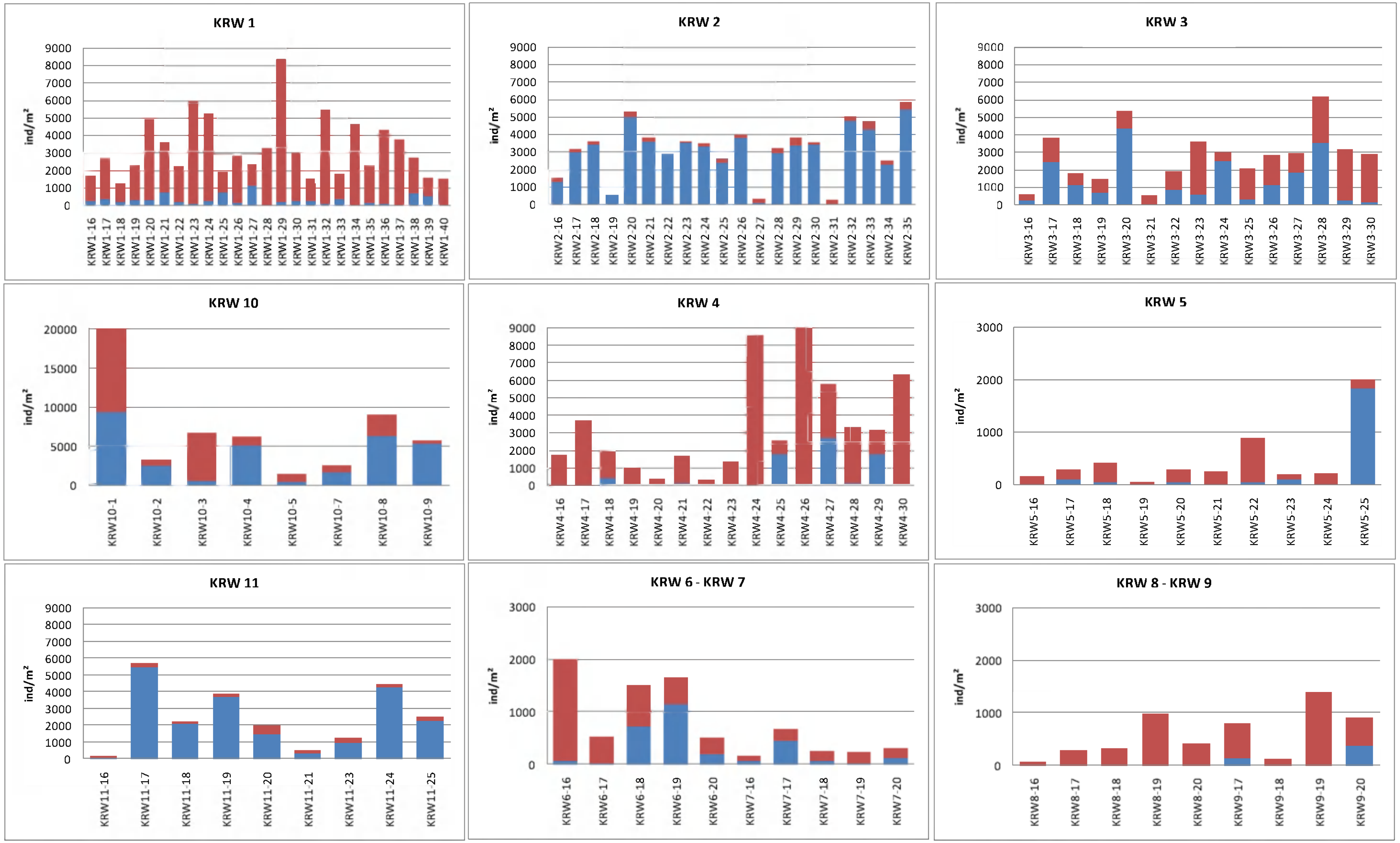

Figure 6. Density distribution (ind./m²) for the different samples at each location (ordered according to their position along the Belgian Coastline [west-east]). Blue bars indicates the density of Ensis spp.; Red bars indicates the density of the other benthic species.

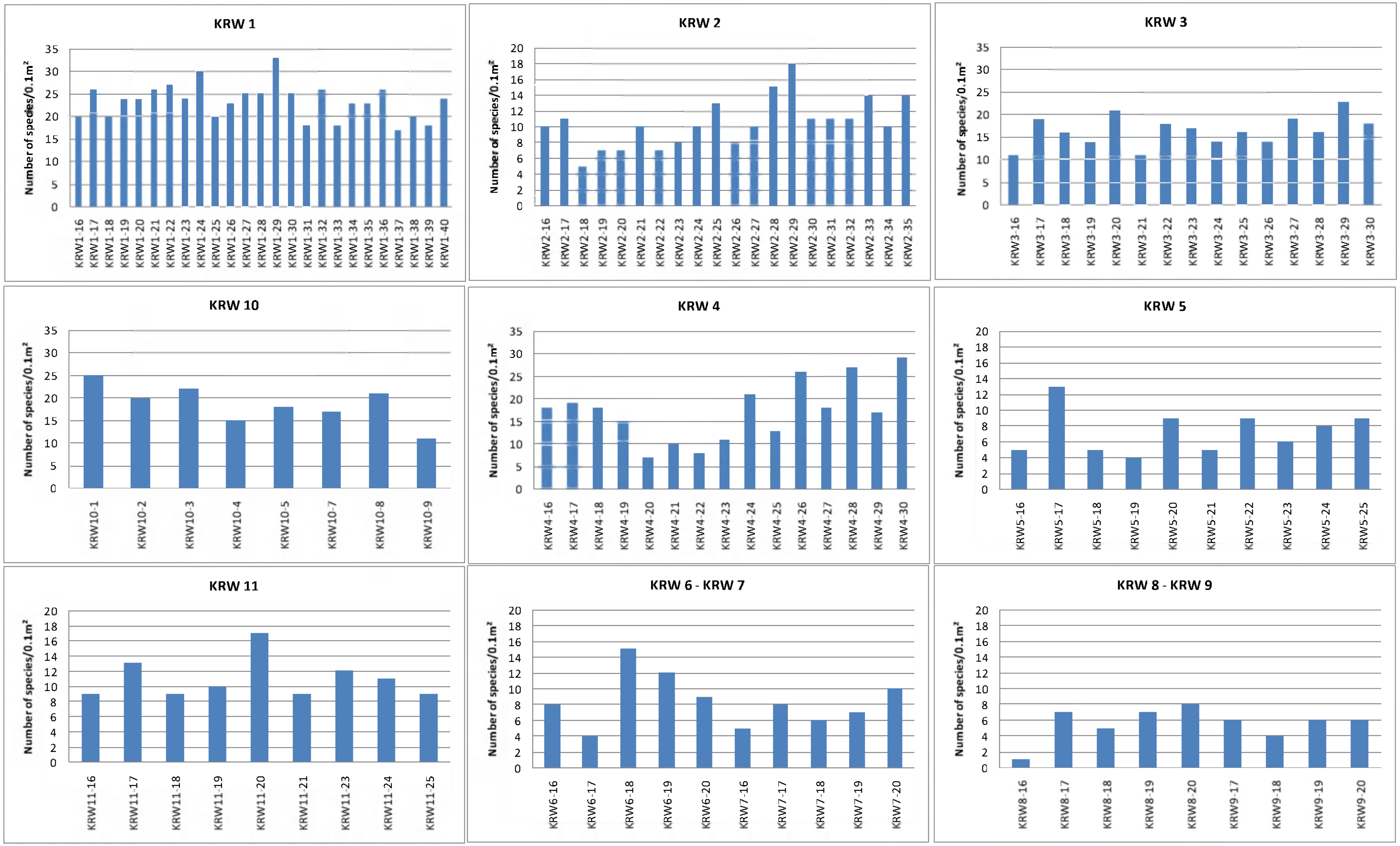

Figure 7. Distribution of number of species/0.1m² for the different samples at each location (ordered according to their position along the Belgian Coastline [west-east]).

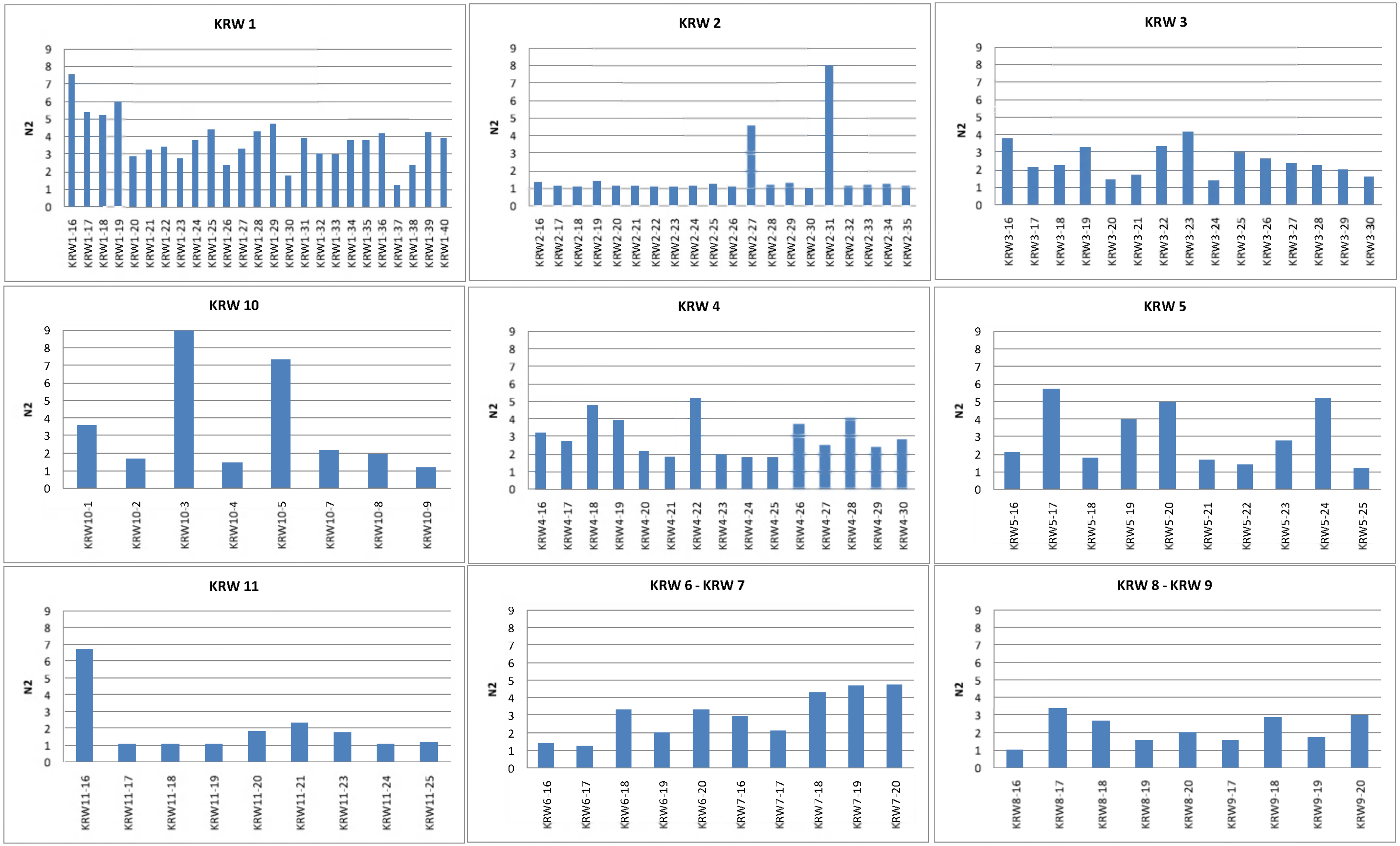

Figure 8. Distribution of N_2 (Hill index) for the different samples at each location (ordered according to their position along the Belgian Coastline [west-east]).

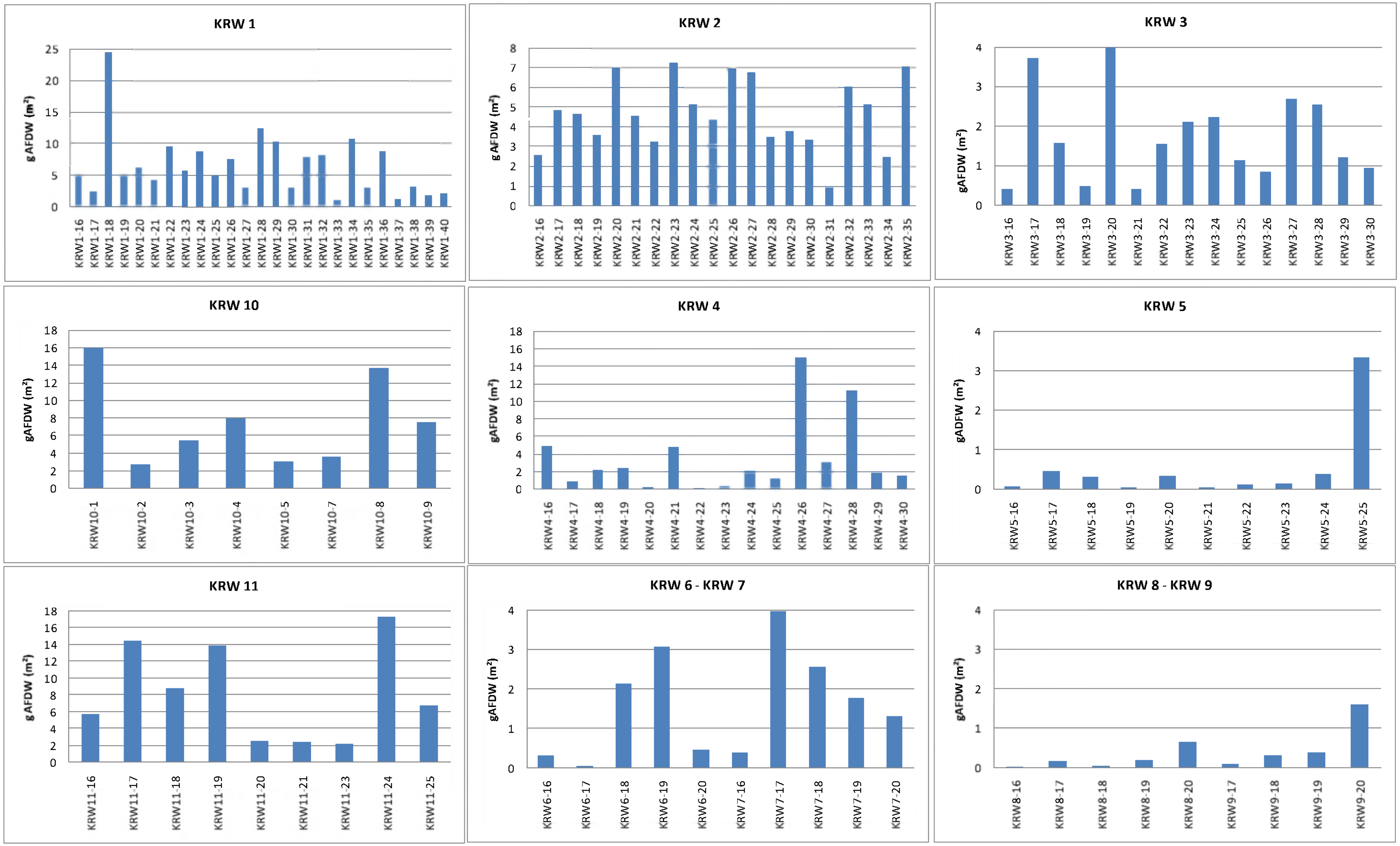

Figure 9. Distribution of biomass (g AFDW/m²) for the different samples at each location (ordered according to their position along the Belgian Coastline [west-east]).

4.1.2 Sedimentology

The median grain size and sediment fractions of each sample at each location are visualized in Figure 10 and Figure 11.

The median grain size varies around 200µm for the samples at location KRW1, with only sample KRW1-32 and KRW1-39 with some coarser material (Figure 10; Figure 11). The mud content (<64µm) is rather low and the fine sand fraction dominates (Figure 11).

At location KRW2, the median grain size varies around 250µm, with the dominance of the median sand fraction at most locations and a very low mud content.

The samples at location KRW3 are characterised by a median grain size range between 170 and 200 µm. The fine sand fraction is the dominant sediment fraction and the mud content is rather low (<10%).

The median grain size of all samples at location KRW10 varies between 190-200 µm. The samples are strongly dominated by the fine sand fraction.

The sedimentological characteristics at location KRW4 is more variable, but most samples are characterised by a median grain size between 150-200µm. Of two samples (KRW4-20 and KRW4-22), the median grain size is low (50µm) and the mud fraction is high (>30%).

The samples at location KRW5 have a median grain size of 250µm and are characterised by an equal dominance of fine and medium sand fractions.

The sedimentological characteristics of the samples at location KRW11 are similar to those of KRW5, with a median grain size varying between 200-240 µm, but a higher dominance of the fine sand fraction in comparison to the medium sand fraction.

The samples at location KRW 6 are dominated by mud, except KRW6-17, resulting in a low median grain size for most samples.

The median grain size of the samples at location KRW7 is around 200µm, with a very low mud content and the dominance of the fine sand fraction.

The sedimentological characteristics of the samples at location KRW8 are very similar to those of KRW 6, with the dominance of mud, resulting in a very low median grain size for all samples.

The samples at location KRW9 are characterised by a rather low mud content (<10%), and a rather high coarse sand fraction, resulting in a high median grain size for some samples (e.g. KRW9-18 and KRW9-19).

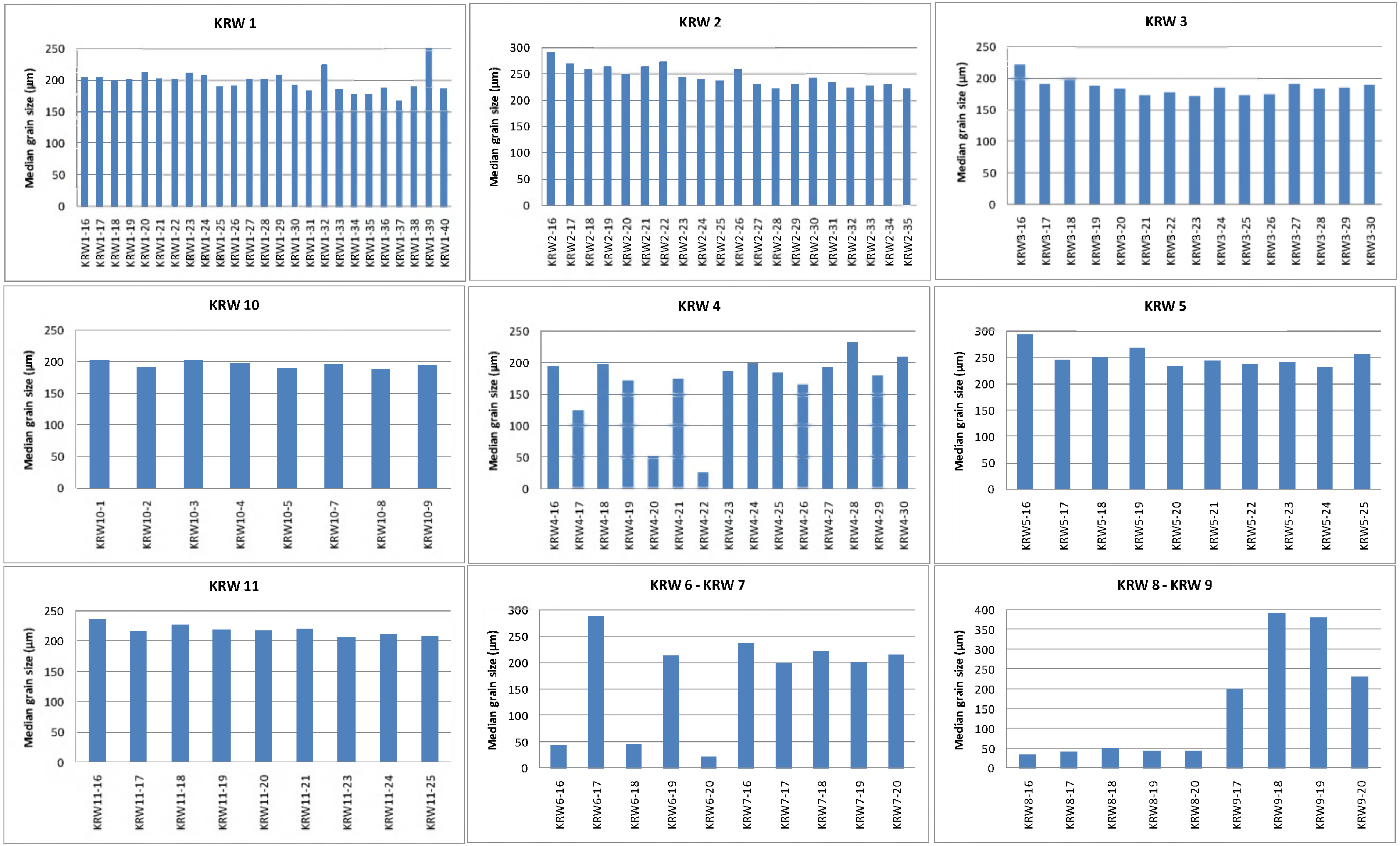

Figure 10. Distribution of the median grain size (µm) for the different samples at each location (ordered according to their position along the Belgian Coastline [west-east]).

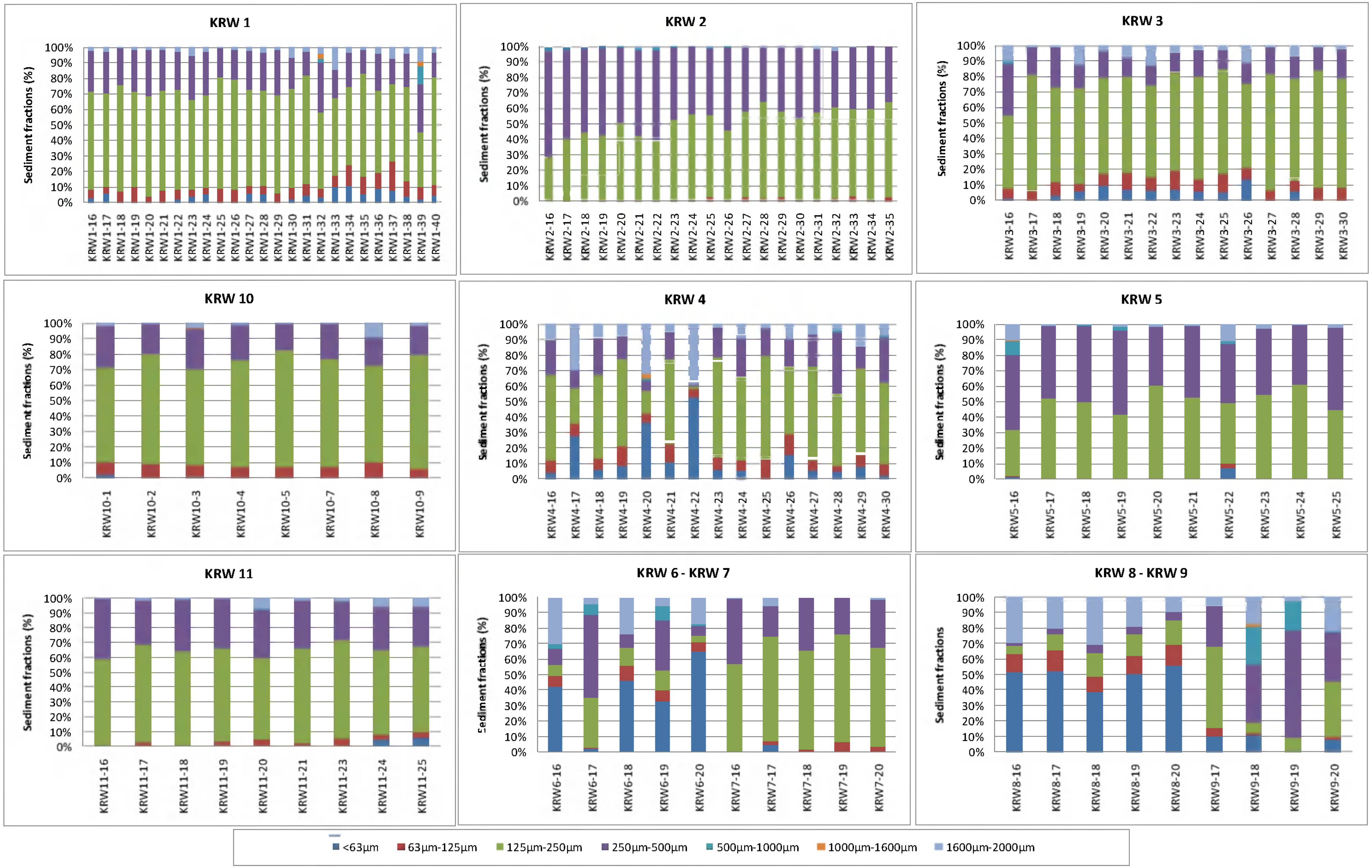

Figure 11. Distribution of the sediment fractions for the different samples at each location (ordered according to their position along the Belgian Coastline [west-east]).

4.1.3 Benthic community structure

The samples of each location are assigned to one of the macrobenthic habitat types in the Belgian Coast based on the procedure described in section 2.3.

STEP 1-2: Selection of relevant cluster groups

The 37% similarity level reveals 5 main clusters and one sample (KRW5-19) as outlier (Figure 12). Cluster 2 is split in 3 sub-groups at the 47% similarity level. These seven cluster groups are relevant and visualized in the MDS plot (Figure 13).

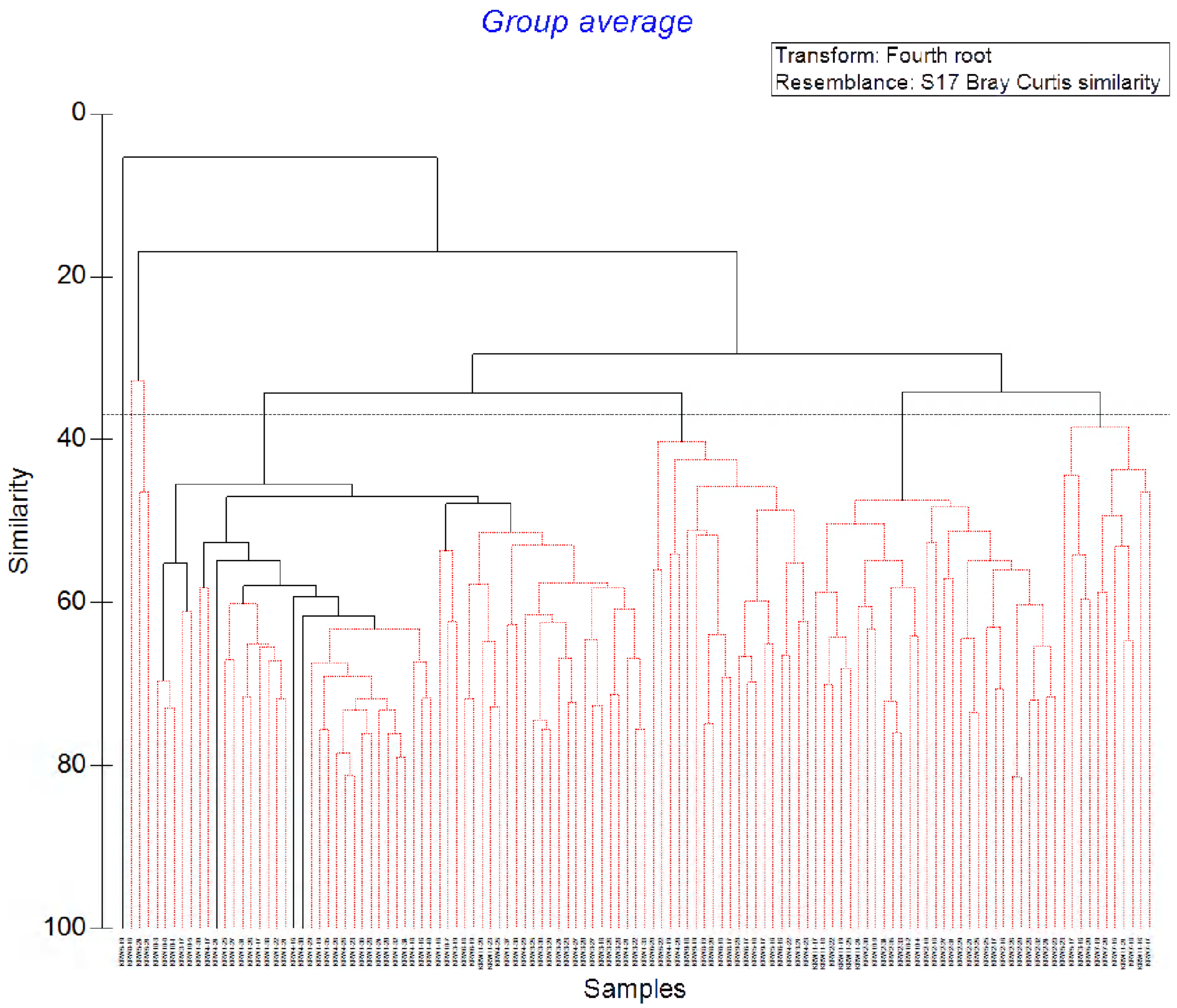

Figure 12. Cluster analysis (Group average) based on Bray Curtis similarity, accompanied with SIMPROF analysis. The 37% similarity level is indicated with a dotted line.

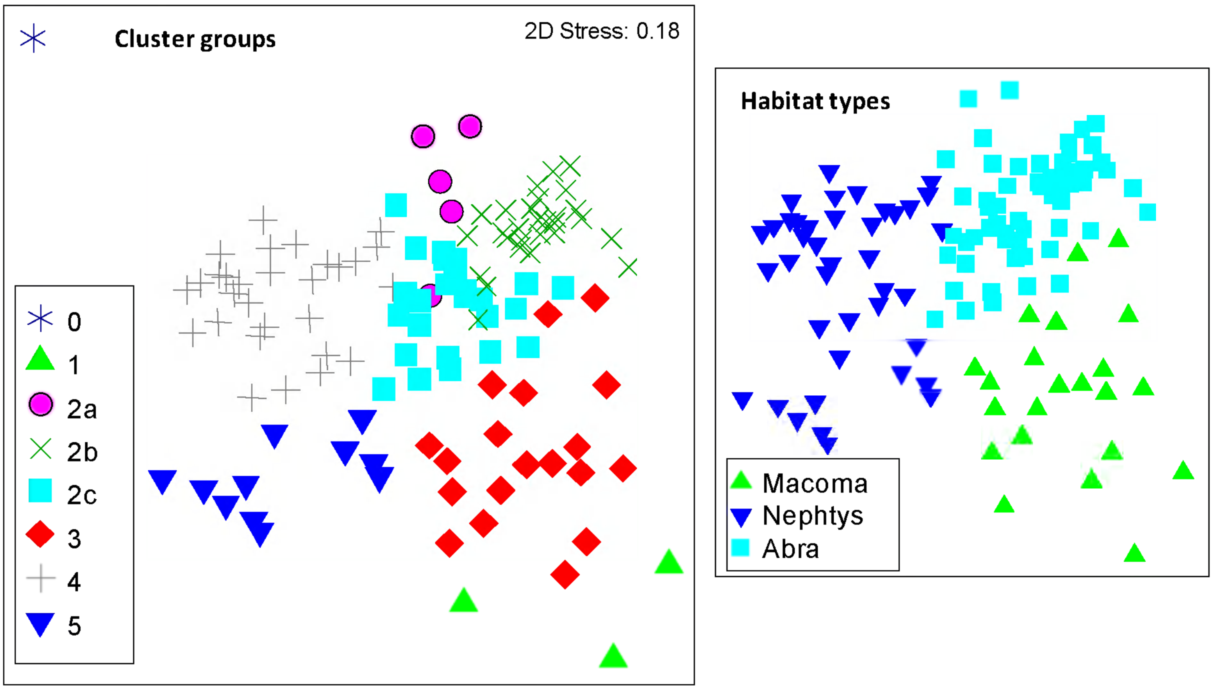

Figure 13. MDS plot of the monitoring data of 2009, with indication of the cluster groups and the habitat types.

STEP 3: Characterization of the cluster groups

The biological and sedimentological characteristics per cluster group are described in Table 4.

- Cluster 1, considered as outlier group, is characterised by a low number of species (5 species/0.1m²) and density (177 ind./m²) and a relatively high mud content. The characteristic species are Cirratulidae spp, *Spio* spp and *Glycera alba*. 2 samples of location KRW5 and one of KRW8 are part of this cluster.
- Cluster 2a groups a few samples of location KRW3 and KRW10 and is characterised by very high densities (8236 ind./m²) and a relative high species richness (21 species/0.1m²). The sedimentological characteristics are a low mud content and a average median grain size of 194µm (fine sand).
- The samples in cluster 2b are characterised by high densities (3783 ind./m²) and the highest species richness (24 species/0.1m²). The samples of these cluster are taken at location KRW1 and KRW4 and the sediment is characterised as fine sand (197 µm), with a relatively low mud content (5%). The main characteristic species are Cirratulidae spp and Oligochaeta spp.
- Cluster 2c groups samples of many locations (KRW1, KRW3, KRW4, KRW10, KRW11, KRW6) and is characterised by a high average density of 2758 ind./m² and a relative high species richness (17 species/0.1m²). The main species are *Ensis* spp, Cirratulidae spp, Oligochaeta spp, *Abra alba* and *Nephtys* juveniles. The sediment is characterised as fine sand (182 µm), with a relative low mud content (7%).

Table 4. Overview of the average values for some biological and sedimentological characteristics per cluster group with standard error values for data of the year 2009. The number of samples belonging to each cluster per sampling location is also added. Explanation abbreviations: Spp (species) and juv (juveniles)

	Macoma	**Abra**	**Abra**	**Abra**	**Macoma**	**Nephtys**	**Nephtys- (Macoma)**
Cluster groups (38% similiarity)	1	2a	2b	2c	3	4	5
Total number of samples	3	5	28	25	19	29	11
KRW1			21	4			
KRW2						20	
KRW3		1		12	1		1
KRW10		4		1		3	
KRW4			7	4	4		
KRW5	2				3	1	3
KRW11				2		5	2
KRW6				2	3		
KRW7							5
KRW8	1				4		
KRW9					4		
Median grain size (µm)	170 ± 68	194 ± 3	197 ± 4	182 ± 6	164 ± 28	236 ± 5	224 ± 5
Mud content (%)	17 ± 17	1 ± 0.5	5 ± 1	7 ± 2	24 ± 5	0.3 ± 0.2	1 ± 0.4
Average number of species/0.1m²	5 ± 2	21 ± 1	24 ± 1	17 ± 1	7 ± 1	11 ± 1	8 ± 1
Average density (ind/m²)	177 ± 55	8236 ± 3237	3783 ± 421	2758 ± 270	693 ± 112	3438 ± 298	334 ± 54
SIMPER species (> 8%)	Cirratulidae spp (74%)	*Ensis directus* (14%)	Cirratulidae spp (13%)	*Ensis directus* (20%)	Cirratulidae spp (44%)	*Ensis directus* (46%)	*Ensis directus* (34%)
	Spio spp (15%)	Cirratulidae spp (11%)	Oligochaeta spp (12%)	Cirratulidae spp (19%)	Oligochaeta spp (21%)	*Nephtys* juv (13%)	*Nephtys cirrosa* (23%)
	Glycera alba (11%)	*Phyllodoce mucosa* (8%)		Oligochaeta spp (8%)	*Macoma balthica* (11%)	*Nephtys cirrosa* (10%)	*Macoma balthica* (16%)
		Lanice conchilega (8%)		*Abra alba* (8%)	*Ensis directus* (9%)		*Magelona johnstoni* (9%)
		Notomastus latericeus (8%)		*Nephtys* juv (8%)			

- The samples of cluster 3 are characterised by Cirratulidae spp, Oligochaeta spp and *Macoma balthica*. The samples contain a relative high mud content (24%) and a low median grain size (164µm). The densities are relatively low (693 ind./m²), whereas the species richness is low (7 species/0.1m²). The samples of this cluster are taken at locations KRW9, KRW8, KRW6, KRW5, KRW4 and KRW3.
- The samples of cluster 4 are characterised by the highest median grain size (236µm) and the lowest mud content (0.3%). The densities are high (3438 ind./m²) and the species richness relatively low (11 species/0.1m²). The characteristic species are *Ensis* spp, *Nephtys* juveniles and *Nephtys cirrosa*. The samples of this cluster are mainly taken at location KRW2, but also at location KRW5, KRW10 and KRW11.
- Cluster 5 is characterised by samples with high densities of *Ensis* spp., together with *Nephtys cirrosa* or *Macoma balthica*. The sediment is characterised as clean sand (low mud content). The density (334 ind./m²) and number of species (8 ind./m²) are relatively low.

STEP 4: Assignation of the cluster groups to one of the three habitat types.

Each cluster is assigned to one of the benthic habitats, based on the typical species per cluster, average density, species richness and sedimentological characteristics (Figure 13, Table 4). Classification of the samples and cluster to one of the macrobenthic habitats is obvious in most cases, but is less straightforward in others. This is due to the fact that benthic habitats do not form clearly defined units and that gradients between habitats exist. On top of it, the mass recruitment of the bivalve *Ensis directus* in 2009 partly masks the boundaries between the different habitats, due to its recruitment in the three habitats. A reference of it is cluster 5, which contains samples characterised by *Macoma balthica* and/or *Nephtys cirrosa*, together with *Ensis directus*. Furthermore, not all the locations could be assigned to one habitat type due to local heterogeneity at those locations.

The *Abra alba* habitat, assigned to clusters 2a, 2b and 2c, is mainly situated in the Western and Central coastal zone, as expected, scattered over different locations. The locations KRW1, KRW3, KRW4 and KRW10 could mainly be assigned as *Abra alba* habitat. The *Nephtys cirrosa* habitat, assigned to clusters 4 and 5 is mainly found at location KRW2, with a few samples assigned to this habitat at locations KRW5, KRW10, KRW11 and KRW7. The assignation of cluster 5, situated in the MDS plot between cluster 4, characterised as *Nephtys cirrosa*, and cluster 3, characterised as *Macoma balthica* habitat is not obvious (Figure 13), but is defined as *Nephtys cirrosa* habitat, due to its sedimentological characteristics (clean sand). The *Macoma balthica* habitat, assigned to clusters 1 and 3, is mainly situated in the eastern and central coastal zone, respectively at locations KRW9, KRW8, KRW6 and KRW5 and KRW4. There was no *Macoma balthica* habitat defined in the Western coastal zone.

Because the BEQI approach evaluates on habitat level instead of sample level, the samples at the different zones along the Belgian coast are grouped according to their habitat characteristics for the ecological status assessment (Table 5).

Table 5. The Total number of samples and sampling surface collected per habitat type at each zone of the Belgian Coast.

zone	Abra	Macoma	Nephtys
Western	38	1	21
Central	18	9	14
Eastern	2	12	5

The habitat determination of the samples at the different locations and zones of the Belgian Coast shows that in 2009 some habitat types are more intensely sampled than others in comparison with the two previous years. The *Macoma balthica* habitat in the Western coastal zone is not sampled (one sample). In the Central coastal zone, the *Nephtys cirrosa* habitat, not taken into account in previous years due to too low number of samples, is adequately sampled in 2009. In the Eastern coastal zone, the samples of location KRW7 are attributed to the *Nephtys cirrosa* habitat, whereas in previous years the samples at these locations were attributed to the *Macoma balthica* habitat. This means that for the assessment year 2009, the following habitats in each zone are confidently assessed: the *Abra alba* and *Nephtys cirrosa* habitat in the Western coastal zone, the *Abra alba* and *Nephtys cirrosa* habitat in the Central coastal zone and the *Macoma balthica* and *Nephtys cirrosa* habitat in the Eastern coastal zone.

4.2 Ecological quality status of benthos in 2009 in the Belgian Coastal waters

The ecological quality status assessment of the benthos of the Belgian Coast for the year 2009 is mainly based on level 3 of the BEQI. Level 1, is evaluated based on expert judgment, due to the lack of primary production data. Level 2, which evaluates changes in habitat area is not included, because no information of past and current habitat area surfaces is available.

Level 1 – Based on the precautionary principle, the EQR is set on 0.6 (good-moderate boundary) by expert judgment (Van Hoey et al., 2009). It is obvious that there were problems in the Belgian Coastal waters regarding the primary production, due to the massive blooms of *Phaeocystis* (Lancelot et al., 2007), but recent estimates of primary production in the Belgian coastal waters is lacking. The response to it in benthic biomass for the coastal zone is also not clear, due to the restriction of the biomass estimates within the 1 nautical mile zone. Therefore, this level is evaluated by expert judgment.

Level 3 – At level 3, only the parameters density, number of species and species composition (similarity) is taken into account. The parameter biomass is not evaluated due to the lack of biomass reference data.

At the **Western coastal zon**e, the *Abra alba* habitat is in moderate status (EQR=0.480), due to the moderate status of the three parameters. The density and number of species are lower than expected from the reference data. The density difference can mostly be attributed to the absence of *Spisula subtruncata*, which is present in high densities in the reference. Contrary, the density of Cirratulidae spp is much higher in the assessment compared to the reference. The moderate status of the parameter similarity can be attributed to the species *Spisula subtruncata, Lanice conchilega, Eumida* spp and Cirratulidae spp. The poor status of the *Nephtys cirrosa* habitat is caused by the mass recruitment of *Ensis directus* in the coastal area, leading to unnatural high densities for this habitat type and changes in the species composition (moderate status for parameter similarity). An evaluation of the habitat *Macoma balthica* by one sample, leads to a very poor confidence and therefore it is ignored.

In the **Central coastal zone**, the *Abra alba* habitat is evaluated as moderate (EQR=0.595), due to the moderate status of the parameters number of species and similarity, caused by the species *Spisula subtruncata* and *Ensis directus*. The density is evaluated as high, due to the higher densities of *Ensis directus* and Cirratulidae spp in the assessment compared to the reference. The moderate status (EQR=0.452) of the *Nephtys cirrosa* habitat is caused by the mass recruitment of *Ensis directus* in the coastal area, leading to unnatural high densities for this habitat type and changes in the species composition (moderate status for parameter similarity). An evaluation of the habitat *Macoma balthica* by nine samples, leads to a low confidence and is therefore ignored.

At the **Eastern coastal zone**, the *Macoma balthica* habitat is evaluated as good (EQR=0.667), due to the high status for density. The parameter number of species is evaluated as moderate, as also similarity. The difference in species composition between assessment and reference can mainly be attributed to the nearly absence of *Petricola pholadiformis, Barnea Candida* and *Polydora spp* in the assessment. The dominant species in the assessment are *Cirratulidae spp* and *Ensis directus*. A confident assessment of the habitat *Nephtys cirrosa* could be done in the Eastern zone, leading to a good status evaluation. This good status can be attributed to the high status of density and good status of number of species. The moderate status in similarity is caused by the higher densities of *Ensis directus* and *Macoma balthica* species in the assessment compared to the reference. An evaluation of the habitat *Abra alba* by two samples, leads to a very poor confidence and is therefore ignored.

The average score at level 3 for the benthos at the Belgian Coast, by averaging the scores per habitat (*Abra alba*: 0.538, moderate status; *Macoma balthica*: 0.667, good status; *Nephtys cirrosa,* 0.526) was 0.577, which means a moderate status.

Overall score - When combining the different levels, the EQR score for the Belgian Coast was 0.589, which means a moderate status for the Belgian Coast for the year 2009. However, a lower or higher ecological status was found when looking at certain habitats. This indicates that there were difference in the impact degree of certain pressures at certain habitats in the coastal area.

Table 6. The assessment values, reference boundary values and EQR scores for each parameter of level 3 of the BEQI for the different habitats in each zone for 2009. The confidence of the assessment of each parameter is assigned. Parameters: Density (ind/m²), similarity (Bray-curtis) and species (number of species/sample surface).

2009	Habitats	parameter	Assessment surface	Assessment value	Reference boundary values Poor min	Mod min	Good min	High min	Reference	High max	Good max	Mod max	Poor max	EQR score	EQR status	Confidence Effect size class
Zone 1	*Abra alba*	density	3.80	3206	1348	2696	4043	5309	6180	7135	9308	12411	15514	0.476	Moderate	Good
		similarity	3.80	0.61	0.28	0.56	0.84	0.87						0.439	Moderate	Good
		species	3.80	78	30	59	89	97	147					0.526	Moderate	Good
		average of parameters												0.480	Moderate	Good
	Nephtys cirrosa	density	2.10	3061	69	137	206	275	328	391	533	711	888	0.000	Bad	Good
		similarity	2.10	0.53	0.22	0.45	0.67	0.74						0.479	Moderate	Good
		species	2.10	45	14	27	41	49	92					0.700	Good	Good
		average of parameters												0.393	Poor	Good
	Macoma balthica	density	0.10	530	10	20	29	140	275	690	5380	7173	8967	0.877	High	Very Poor
		similarity	0.10	0.29	0.03	0.05	0.08	0.2						0.821	High	Moderate
		species	0.10	11	1	1	2	7	89					0.810	High	Moderate
		average of parameters												0.836	High	Very Poor
Zone 2	*Abra alba*	density	1.80	5059	1128	2257	3385	4818	6003	7569	11224	14966	18707	0.841	High	Moderate
		similarity	1.80	0.58	0.25	0.51	0.76	0.82						0.459	Moderate	Good
		species	1.80	59	24	49	73	82	147					0.485	Moderate	Good
		average of parameters												0.595	Moderate	Moderate
	Nephtys cirrosa	density	1.40	2677.1	60.6	121.3	181.9	260.6	322	395	592.4	789.9	987.3	0.000	Bad	Moderate
		similarity	1.40	0.53	0.2	0.4	0.59	0.68						0.535	Moderate	Good
		species	1.40	47	11	22	33	42	92					0.820	High	Good
		average of parameters												0.452	Moderate	Moderate
	Macoma balthica	density	0.90	537	66	132	198	372	681	1014	2043	2724	3405	0.907	High	Low
		similarity	0.90	0.54	0.16	0.33	0.49	0.61						0.678	Good	Good
		species	0.90	32	8	17	25	34	89					0.756	Good	Good
		average of parameters												0.780	Good	Low
Zone 3	*Abra alba*	density	0.20	1580	221	441	662	2586	4311	8570	25662	34216	42770	0.695	Good	Very Poor
		similarity	0.20	0.25	0.12	0.23	0.35	0.53						0.422	Moderate	Good
		species	0.20	17	7	14	21	37	147					0.486	Moderate	Moderate
		average of parameters												0.534	Moderate	Very Poor
	Nephtys cirrosa	density	0.50	322	44.2	88.4	132.6	222.7	301.7	429.1	830.7	1107.6	1384.5	0.968	High	Moderate
		similarity	0.50	0.34	0.13	0.25	0.38	0.51						0.542	Moderate	Good
		species	0.50	20	5.3	10.7	16	25						0.689	Good	Good
		average of parameters												0.733	Good	Moderate
	Macoma balthica	density	1.20	695	76	153	229	428	698	1063	1888	2517	3146	0.998	High	Moderate
		similarity	1.20	0.45	0.18	0.37	0.55	0.66						0.487	Moderate	Good
		species	1.20	25	10	19	29	39						0.517	Moderate	Good
		average of parameters												0.667	Good	Moderate

4.3 Ecological quality status evaluation of benthos over the period 2007-2009 in the Belgian Coastal waters

To do a proper, confident assessment of the ecological quality status of macro-invertebrates, it is important to do this on a spatial and temporal time scale. Firstly, because benthic characteristics shows natural variance over the years. Secondly, because the reference data where it is compared to is a reflection of the natural spatial and temporal variation in the benthic community characteristics. The sampling at different locations, representing one or more habitat types in the three zones along the Belgian coast provide benthic data on a good spatial scale. Pooling of the data over the three monitoring years provide a good temporal scale. The sampling effort behind the yearly evaluation scores leads mainly to a moderate or lower confidence class for the ecological quality status assessment. Therefore, the evaluation over the entire period 2007-2009 will lead to a more confident assessment of the ecological quality status of macro-invertebrates for the water body Belgian Coast.

4.3.1 Habitat characterization

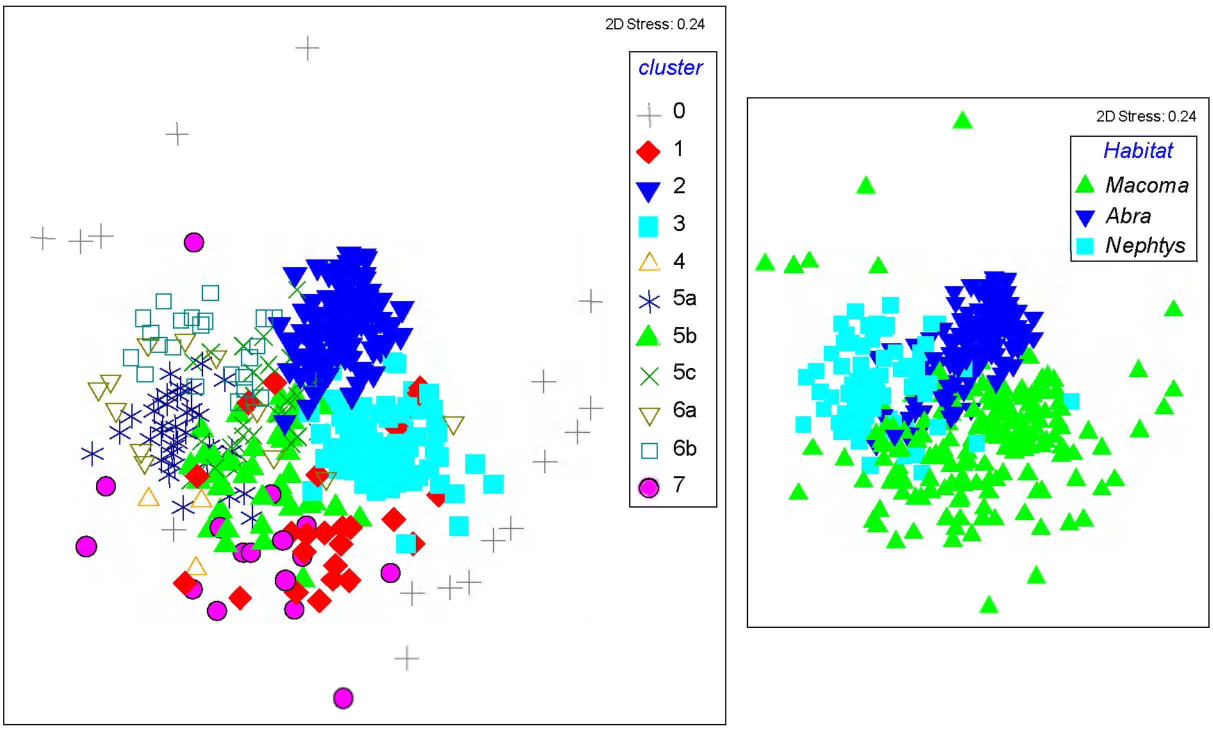

Figure 14. MDS plot of the monitoring data of 2007-2009, with indication of the cluster groups and the habitat types

The habitat characterization of the samples at each location is done for the data of each year separately, following the procedure described in 2.3. In this section, is looked if the samples were assigned to the same habitat type, based on a combined analysis of all data over the three years (temporal and spatial variability).

Table 7. Overview of the average values for some biological and sedimentological characteristics per cluster group with standard error values. The number of samples belonging to each cluster per sampling location is also added. Explanation abbreviations: Spp (species) and juv (juveniles)

	Macoma	Macoma- (Abra)	Abra	Macoma	Macoma	Nephtys	Macoma	Abra	Nephtys- (Macoma)	Nephtys	Macoma
Cluster groups	0	1	2	3	4	5a	5b	5c	6a	6b	7
Total number of samples	18	25	102	69	3	35	41	34	12	23	16
KRW1			50	10			1	4			
KRW2						31		8		15	
KRW3		8	13	3			16	4	1		
KRW10			5					11		2	
KRW4		4	29	7			6				
KRW5	4	8		2	3	2	3	3	3	1	5
KRW11	1	1	3	1		2		4	2	5	
KRW6	2	2	2	8					1		10
KRW7	2						15		5		1
KRW8	1			24							
KRW9	8	2		14							
Median grain size (µm)	159 ± 30	201 ± 11	187 ± 3	116 ± 13	199 ± 33	247 ± 4	155 ± 6	202 ± 7	207 ± 17	237 ± 5	135 ± 23
Mud content (%)	36 ± 7	13± 3	8 ± 1	45 ± 4	23 ± 13	1 ± 1	23 ± 3	4 ± 2	7 ± 5	0.4 ± 0.3	47 ± 7
Average number of species (0.1m²)	2 ± 0.3	8 ± 0.6	23 ± 0.7	9 ± 0.4	7 ± 1.3	11 ± 0.5	9 ± 0.5	16 ± 0.7	9 ± 0.6	10 ± 0.6	6 ± 0.8
Average density (ind/m²)	32 ± 4	240 ± 41	4192 ± 386	552 ± 52	150 ± 26	602 ± 152	378 ± 38	966 ± 120	404 ± 66	3726 ± 312	183 ± 30
SIMPER SPECIES (>7%)	Oligochaeta spp (32%) Cirratulidae spp (25%) *Magelona johnstoni* (15%) *Capitella* spp (8%) *Pariambus typicus* (8%)	*Spio* spp (18%) *Glycera alba* (18%) Cirratulidae spp (16%) Capitella spp (14%) *Nephtys* juv (11%) Diastylis bradyi (9%)	Cirratulidae spp(16%) Oligochaeta spp (11%) *Ensis directus* (8%) *Abra alba* (7%) *Nephtys* juv (7%)	Cirratulidae spp (31%) Oligochaeta spp (25%) *Nephtys* juv (17%) *Macoma balthica* (8%)	*Nephtys cirrosa* (31%) *Magelona johnstoni* (26%) *Glycera alba* (24%) *Nephtys* juv (11%)	*Nephtys* juv (20%) *Nephtys cirrosa* (20%) *Spio* spp(17%) *Donax vittatus* (10%) *Ensis directus* (9%)	*Nephtys* juv (20%) *Nephtys hombergii* (17%) *Macoma balthica* (16%) *Magelona johnstoni* (13%) *Donax vittatus* (9%)	*Spio* spp (16%) *Nephtys* juv (11%) *Magelona johnstoni* (9%) *Pariambus typicus* (8%) Cirratulidae spp (7%) *Capitella* spp (7%) *Donax vittatus* (7%) *Nephtys hombergii* (7%)	*Ensis directus* (33%) *Nephtys cirrosa* (22%) *Macoma balthica* (21%) *Magelona johnstoni* (8%)	*Ensis directus* (51%) *Nephtys* juv (12%) *Nephtys cirrosa* (9%)	*Spio* spp (32%) Bathyporeia elegans (19%) *Nephtys hombergii* (18%) *Macoma balthica* (15%)

Cluster 0, groups the outlier samples at a similarity level of 18%. The 32% similarity level reveal 7 main clusters. Cluster 5 is split in 3 sub-groups at the 40% similarity level, cluster 6 is split in 2 sub-clusters at the 34% similarity level. These 11 cluster groups are relevant and visualized in the MDS plot (Figure 14).

The biological and sedimentological characteristics per cluster group are described in Table 7. Each cluster is assigned to one of the benthic habitats, based on the typical species per cluster, average density, species richness and sedimentological characteristics (Table 7, Figure 14). Classification of the samples and cluster to one of the macrobenthic habitats is obvious in most cases, but is less straightforward in others. For example, cluster 1, assigned as *Macoma balthica* habitat, based on the biological characteristics and position on the MDS, shows qua sedimentology similarity with *Abra alba* habitat. Cluster 6a shows from biological view point similarity with the *Macoma balthica* habitat, but also with *Nephtys cirrosa* habitat. The samples of cluster 6b, assigned as *Nephtys cirrosa* habitat, contain high densities of *Ensis directus*. The habitat assignation of the other clusters is more obvious.

When the habitat characterization of the samples, based on the complete dataset (2007-2009) is compared with the habitat characterization per year, only 5.8% of the samples is assigned to another habitat type and some previously not classified samples are now assigned to a certain habitat. Therefore, it seems that the procedure used for habitat determination of the samples, is not temporally influenced. For this reason, the habitat determination of the samples of the separate years is used, except for the not classified samples, to do the ecological quality status assessment over the period 2007-2009 of each habitat in each zone.

4.3.2 Ecological quality status: 2007-2009

The ecological quality status assessment of the benthos of the Belgian Coast for the period 2007-2009 is mainly based on level 3 of the BEQI. Level 1, is evaluated based on expert judgment, due to the lack of primary production data. Level 2, which evaluates changes in habitat area is not included, because no information of past and current habitat areas is available.

Level 1 – Based on the precautionary principle, the EQR is set on 0.6 (good-moderate boundary) by expert judgment, as was done for the individual year evaluations (Van Hoey et al., 2009). It is obvious that there were problems in the Belgian Coastal waters regarding the primary production, due to the massive blooms of *Phaeocystis* (Lancelot et al., 2007), but recent estimates of primary production in the Belgian coastal waters is lacking. The response to it in benthic biomass for the coastal zone is also not clear, due to the restriction of biomass estimates within the 1 nautical mile zone only. Therefore, this level is evaluated by expert judgment.

Level 3 – At level 3, only the parameters density, number of species and species composition (similarity) is taken into account. The parameter biomass was not evaluated due to the lack of biomass reference data.

In the **Western Coastal zone**, the three main habitats are assessed with good confidence for all parameters, except the parameter density for the *Macoma balthica* habitat.

- The *Abra alba* habitat is evaluated as moderate (EQR= 0.479), due to the moderate status of the parameters number of taxa and similarity and the poor status for density. The density is much lower (half) (3012 ind/m²) than expected from the reference (6258 ind/m²), leading to a poor EQR score (0.396). The species mostly contributing to this difference are *Spisula subtruncata* (-2730 ind/m²), *Magelona johstoni* (-408 ind/m²), *Lanice conchilega* (-334 ind/m²), *Abra alba* (-202 ind/m²), which are more abundant in the reference compared to the assessment. Contrary, Cirratulidae spp (+927 ind/m²), *Ensis directus* (+348 ind/m²) and Oligochaeta spp (+261 ind/m²) are more abundant in the assessment compared to the reference. The species contributing to the dissimilarity between assessment and reference are *Spisula subtruncata,* Cirratulidae spp*, Magelona johnstoni, Spisula* juv, *Phyllodoce spp* and *Ensis directus*. The number of taxa found by a total sampling surface of 7.4m² is a little bit lower than expected from the reference data to get a good status (104 spp/7.4m²). Some taxa (11) were newly found in the assessment period, compared to the reference period, but none of them has a major influence on the ecological quality status assessment.
- The *Macoma balthica* habitat is evaluated as good (EQR=0.607), due to the good status of the parameters density and number of species, whereas the similarity is moderate. The difference in similarity between assessment and reference can be attributed to the species *Barnea candida, Petricola pholadiformis*, both not found in the assessment data and *Polydora spp*. The density is lower than expected from the reference, but still within the good status class. Only 7 other taxa are found in the assessment compared to the reference list.
- The *Nephtys cirrosa* habitat is evaluated as poor (EQR=0.39), due to the bad status of the parameter density, whereas the similarity is moderate and the number of species is good. The high difference between the density in the assessment compared to the reference can mainly be attributed to *Ensis directus* (+1131 ind/m²), other positively contributing species are *Spio spp* (+57 ind/m²) and *Nephtys* juv (+42 ind/m²). Negatively contributing species for the parameter density are *Nephtys cirrosa* (-40 ind/m²) and *Magelona johnstoni* (-36 ind/m²). The dissimilarity between assessment and reference can be attributed to the species *Ensis directus, Microphthalmus spp, Ophelia limacina* and *Phyllodoce spp*. Thirteen taxa are encountered in the assessment data and not in the reference data, whereof no taxa has a major influence on the ecological quality status assessment.

In the **Central coastal zone**, the three main habitats are assessed with good confidence for all parameters, except the parameter density for the *Macoma balthica* habitat.

- The *Abra alba* habitat is evaluated as moderate (EQR=0.563), due to the moderate status of the parameters similarity and number of species, whereas the parameter density is good. The species mostly contributing to the difference in the parameter density are *Spisula subtruncata* (-2730 ind/m²), *Magelona johstoni* (-398 ind/m²), *Mysella bidentata* (-175 ind/m²), *Spiophanes bombyx* (-174 ind/m²), which are more abundant in the reference compared to the assessment. Contrary, Cirratulidae spp (+1077 ind/m²) , *Ensis directus* (+583 ind/m²), Oligochaeta spp (+539 ind/m²) are more abundant in the assessment compared to the reference. The species responsible for the moderate score for similarity are *Spisula subtruncata, Phyllodoce* spp, Cirratulidae spp and *Ensis directus*. The number of species is a little bit lower than what is expected for obtaining a good status.

Table 8. The assessment values, reference boundary values and EQR scores for each parameter of level 3 of the BEQI for the different habitats in each zone for 2007-2009. The confidence of the assessment of each parameter is assigned. Parameters: Density (ind/m²), similarity (Bray-curtis) and species (number of species/sample surface).

2007-2009		parameter	Assessment		Reference boundary values									EQR		Confidence
	Habitats		surface	value	Poor min	Mod min	Good min	High min	Reference	High max	Good max	Mod max	Poor max	score	status	Effect size class
Zone 1	*Abra alba*	density	7.40	3013	1521	3042	4563	5615	6258	6909	8447	11262	14078	0.396	Moderate	Good
		similarity	7.40	0.70	0.30	0.59	0.89	0.91						0.477	Moderate	Good
		species	7.40	98	35	69	104	111	147					0.565	Moderate	Good
		average of parameters												0.479	Moderate	Good
	Nephtys cirrosa	density	5.30	1463	82	165	247	301	334	369	455	607	758	0.014	Bad	Good
		similarity	5.30	0.59	0.27	0.54	0.81	0.85						0.442	Moderate	Good
		species	5.30	62	19	39	58	65	92					0.714	Good	Good
		average of parameters												0.390	Poor	Good
	Macoma balthica	density	3.70	420	121	242	363	601	756	934	1380	1840	2300	0.648	Good	Moderate
		similarity	3.70	0.63	0.25	0.50	0.75	0.81						0.499	Moderate	Good
		species	3.70	54	17	34	51	59	89					0.675	Good	Good
		average of parameters												0.607	Good	Moderate
Zone 2	*Abra alba*	density	4.70	4685	1408	2817	4225	5408	6225	7091	9148	12197	15246	0.678	Good	Good
		similarity	4.70	0.67	0.28	0.57	0.85	0.88						0.468	Moderate	Good
		species	4.70	85	31	63	94	102	147					0.543	Moderate	Good
		average of parameters												0.563	Moderate	Good
	Nephtys cirrosa	density	2.10	1924.8	68.6	137.3	205.9	275.4	327.7	391.4	533	710.7	888.3	0.000	Bad	Good
		similarity	2.10	0.56	0.22	0.45	0.67	0.74						0.501	Moderate	Good
		species	2.10	53	13.7	27.3	41	49	92					0.819	High	Good
		average of parameters												0.440	Moderate	Good
	Macoma balthica	density	4.80	321	139	278	417	623	760	925	1299	1732	2165	0.461	Moderate	Moderate
		similarity	4.80	0.68	0.26	0.53	0.79	0.84						0.518	Moderate	Good
		species	4.80	61	19	37	56	63	89					0.743	Good	Good
		average of parameters												0.574	Moderate	Moderate
Zone 3	*Macoma balthica*	density	9.20	390	163	326	489	663	770	884	1129	1505	1882	0.479	Moderate	Good
		similarity	9.20	0.65	0.29	0.57	0.86	0.89						0.454	Moderate	Good
		species	9.20	59	22	45	67	73	89					0.528	Moderate	Good
		average of parameters												0.487	Moderate	Good

- The *Macoma balthica* habitat is evaluated as moderate (EQR=0.574), due to the moderate status of the parameters similarity and density, whereas the number of species is evaluated as good. The density is lower than expected from the reference data, which can be attributed to the lower density of mainly *Cirratulidae spp* (-117 ind/m²), *Polydora spp* (-105 ind/m²) in the assessment compared to the reference. The three main species contributing to the dissimilarity between assessment and reference are the same as for the *Macoma balthica* habitat in the Western coastal zone.
- The *Nephtys cirrosa* habitat is evaluated as moderate (EQR=0.440), due to the bad status of the parameter density, whereas the parameter similarity is moderate and the number of species high. The difference between assessment and reference for the parameter density can mainly be attributed to the mass recruitment of *Ensis directus* (+1583 ind/m²), causing unnaturally high densities for this habitat type. The species contributing to the dissimilarity between assessment and reference are *Ensis directus, Microphthalmus spp, Ophelia limacina* and *Phyllodoce spp*. From the 13 new taxa, in comparison to the reference list, no taxa influence the scores of the other parameters.

In the **Eastern coastal zone**, the main habitat type is the *Macoma balthica* habitat, whereof all parameters are assessed with good confidence. The assignation of some samples of the monitoring year 2009 to other habitat types, leads to the occurrence of those habitats in the eastern coastal zone. Those are not taken into account, due to their minor importance over the evaluation period.

- The *Macoma balthica* habitat is evaluated as moderate (EQR= 0.487), due to the moderate status of the three parameters (density, similarity and number of species). The dissimilarity between assessment and reference can be attributed to *Barnea candida*, *Polydora spp*, *Alitta succinea* and *Petricola pholadiformis*. The difference in density can also mainly be attributed to the above mentioned species, which were present in lower densities in the assessment compared to the reference. No one of the 8 new taxa, is responsible for changes in the other parameters

The average score at level 3 for the benthos at the Belgian Coast, by averaging the scores per habitat (*Abra alba*: 0.521, moderate status; *Macoma balthica*: 0.556, moderate status; *Nephtys cirrosa*: 0.415, moderate status) is 0.497, which means a moderate status.

Overall score - When combining the different levels, the EQR score for the Belgian Coast was 0.549, which means a moderate status for the Belgian Coast for the period 2007-2009. However, a lower or higher ecological status was found when looking at certain habitats. This indicates that there were difference in the impact degree of certain pressures at certain habitats in the coastal area.

4.4 Evaluation of the monitoring and assessment strategy

Three years of intensive sampling in the Belgian Coastal zone (<1 nautical mile) reveals valuable information on how to assess the benthic quality status within a water body, knowing that benthic community characteristics are very variable on a temporal and spatial time scale. Two topics are essential for monitoring and assessing benthos in a water body:

- **The habitat approach**. The benthic community characteristics (density, number of species, species composition) are typical for a certain habitat (strongly determined by sedimentology) (Van Hoey et al., 2004; Degraer et al., 2008), but it is not easy to track deviation lines between the benthic communities (See 3.4.1). Secondly, the habitat characteristics along the Belgian Coast can change on a short distance (within 100 meters). Therefore, it is not easy to localize the samples in advance to a certain habitat type in the monitoring program and were they assigned afterwards based on a certain procedure to a certain habitat type. This procedure needs to be standardized to make repeating assessments possible, without major changes in assessed surface area per habitat. A different assignation of samples to a certain habitat type can have an influence on the ecological status scores. Therefore, the application of the habitat approach (location of the samples at each location in the 1 nautical mile zone of the Belgian Coast) is in detail investigated in section 3.4.1 and the methodologies for assignation of sample to a certain habitat were discussed.
- **The confidence of the assessment**. There is a need for taking enough samples in each habitat type to get a confident assessment of the ecological status to minimize the chance of misclassification. Taking one benthic sample in an area is not enough due to the fact that there is a high variance between benthic samples within a location or habitat type. And secondly, a basin oriented monitoring (spatial coverage) is more appropriate than a station oriented monitoring for quality status assessments of water bodies. Therefore, there is the need to take such amount of samples to include the natural variance of the benthos in the ecological quality status assessment of a habitat. This can be obtained by power analysis, whereby the relation between the sampling effort and the effect size by a certain power is investigated (see 3.4.2).

4.4.1 Habitat approach

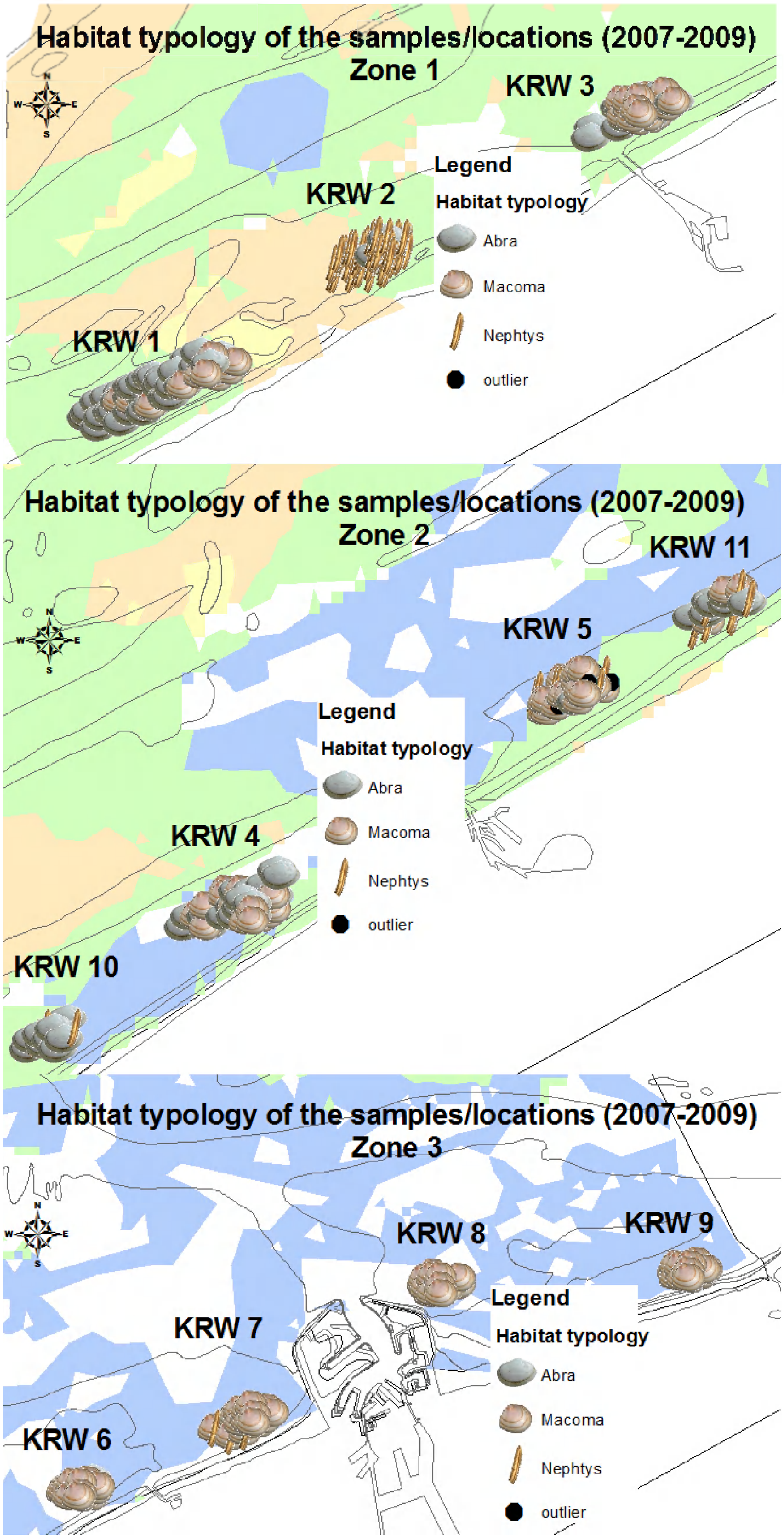

Figure 15. Habitat overview of the samples taken over the period 2007-2009 at the different locations at the different zones. The habitat type of the samples is plotted on the habitat suitability map (Degraer et al., 2008).

4.4.1.1 Habitat characterisation of locations

The samples at each location are assigned to a habitat type, based on the procedure described in 2.3 and visualized in Figure 15. The samples are plotted on the habitat suitability map (Degraer et al., 2008), which is constructed by modeling and which gives a view on which habitat type to expect in these areas. The confidence of the prediction of the habitat suitability within the 1 mile zone will be lower in comparison to further offshore, due to the nearly absence sedimentological data in this area. Based on the WFD monitoring data of 2007-2009 at different locations within the 1 mile zone, some conclusions about the habitat heterogeneity or homogeneity at those locations can be made. This helps us to optimize the position of the sample locations for the ecological quality status evaluation of certain habitats within the water body 'Belgian Coast'.

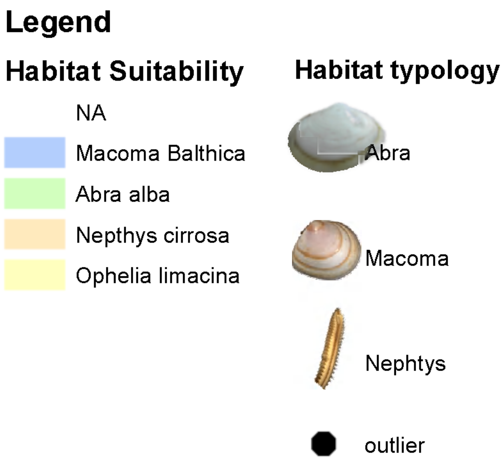

Figure 16. The common legend for the figures under topic 4.4.1.1, concerning habitat suitability and the sample habitat typology.

1) At some locations, the biological and sedimentological habitat characteristics seem to be homogeneous over time and the entire location could be assigned to one habitat type.

- The samples at location KRW6, KRW8 and KRW9, which are characterised by high mud contents and low densities and species richness, where mostly assigned to the *Macoma balthica* habitat type. The habitat assignation of the area corresponds with the predicted one on the habitat suitability map.
- The samples at location KRW2 are situated in clean sand (no mud content; median grain size between 200-300µ) and are mostly assigned to the *Nephtys cirrosa* habitat (Figure 17). The habitat suitability map assigns this area mainly as *Abra alba* habitat type, but this study shows that the biological and sedimentological (no mud content) characteristics of this area corresponds better with the *Nephtys cirrosa* habitat type. The only natural gradient in this area is a small decreasing trend in median grain size along the slope of the Broersbank (from Southwest over Northeast).

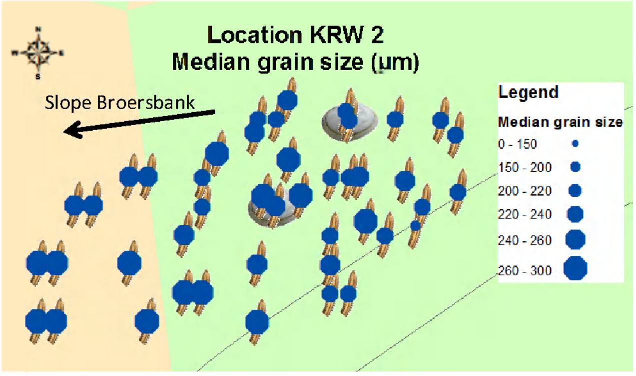

Figure 17. Median grain size (µm) distribution of the samples at location KRW 2.

- The samples at location KRW1, are mainly assigned to the *Abra alba* habitat, as expected from the habitat suitability map (Figure 15). A few samples over the years are assigned to the *Macoma balthica* habitat, mainly due to the higher mud content and the lower species richness of those samples compared to the others (Figure 18). It seems that the 'Potje' area at the east side, before the slope of the Broersbank is more muddy. This can be attributed to the fact that mud is more accumulated in this small area due to the residual streaming and the closeness of this area. Therefore, this part of the area seems to be naturally impoverished, due to the high mud content. We can conclude that the location KRW1 has the habitat potential of an *Abra alba* habitat.

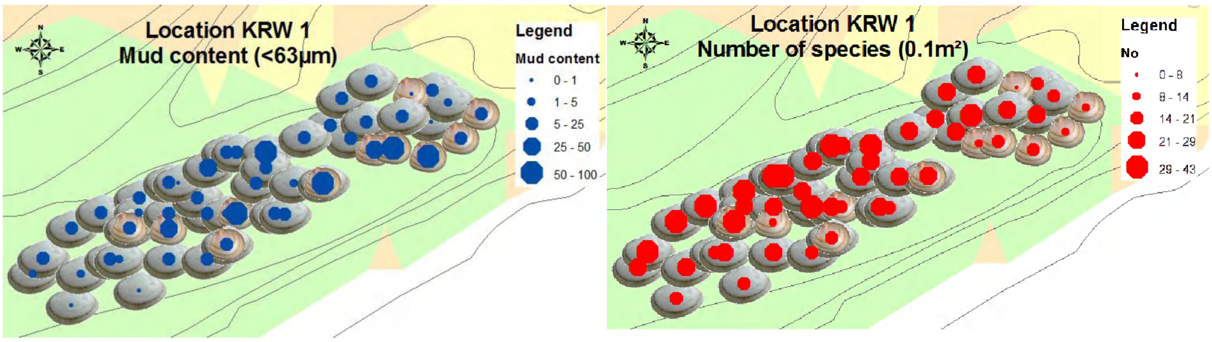

Figure 18. The distribution of the mud content (top figure) and the number of species for the samples at location KRW 1.

- Most samples at location KRW10 are assigned as *Abra alba* habitat, whereas a few as *Nephtys cirrosa* habitat. At this location, the habitat suitability map indicates a transition between *Abra alba* and *Macoma balthica* habitat (Figure 15). Despite the low mud content and based on the biological and sedimentological (very fine sand) data collected in 2008-2009, this area has the potential of an *Abra alba* habitat.

2) For some locations, the habitat heterogeneity is high, but a certain gradient can be observed within the area
    - The samples at location KRW 5 could not be uniformly assigned to one community. The majority of the samples can be linked to the *Macoma balthica* or *Nepthys cirrosa* habitat. A few samples are assigned as outliers in the benthic community analysis, but show most affinity with the *Macoma balthica* habitat. The sedimentological characteristics of the samples show high mud concentrations and lower median grain sizes towards the northeast,

whereas the southwest part is more sandy (lower mud content, higher median grain size). The area encircled on the map is very heterogeneous, so the samples could mostly not be assigned to a certain habitat type (Figure 19). The habitat suitability map assigns this area partly as *Abra alba* habitat and *Macoma* balthica habitat. Nevertheless, some samples without mud content were assigned to the *Macoma balthica* habitat. The species diversity of the samples in this area is low. Based on this information it is clear that this area is heterogenic in its sedimentology, and the benthic fauna is impoverished. Therefore, the habitat suitability of this area is not clear.

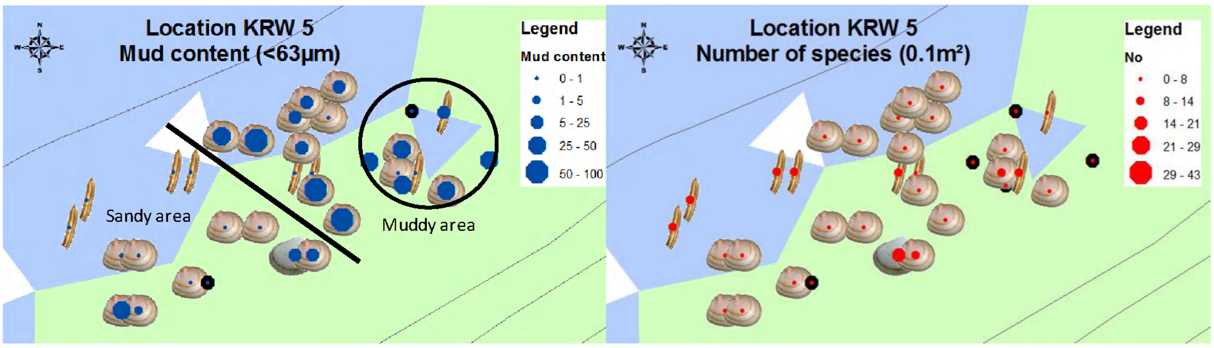

Figure 19. The distribution of the mud content (left panel) and the species richness (right panel) of the samples at location KRW 5, with indication of the habitat type per sample.

- The samples at KRW11 are linked to the three habitat types coinciding with a gradient in increasing mud content from the southwest to the northeast (Figure 20). Samples in the southwest are assigned to the *Nephtys cirrosa* habitat, central samples to the *Abra alba* habitat and samples in the northeast are catalogued as *Macoma balthica* or *Nephtys cirrosa* habitat. The species richness is also highest in the central part, coinciding with the *Abra alba* habitat typology. Therefore, it seems that this location is characterised by a change in sedimentology from clean sand towards muddy sand over a small distance.

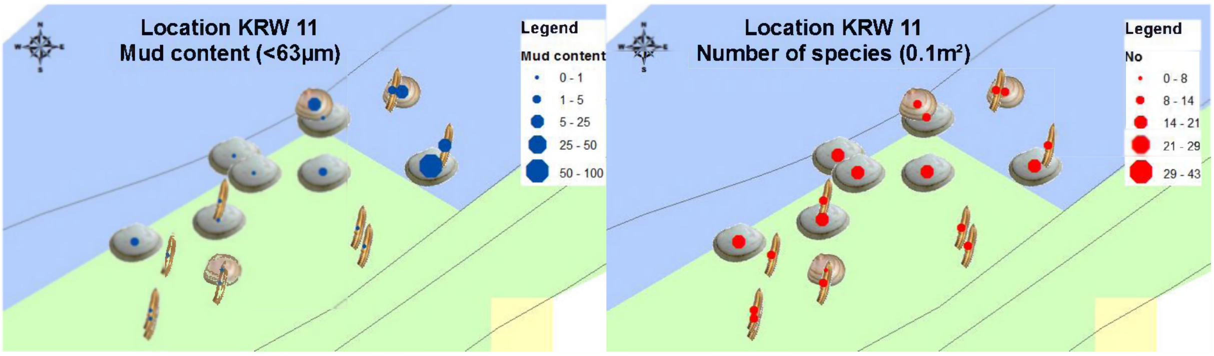

Figure 20. The distribution of the mud content (left panel) and the species richness (right panel) of the samples at location KRW 11, with indication of the habitat type per sample.

- The 15 samples of 2007 and the 5 of 2008 at location KRW7 are linked to *Macoma balthica* habitat, whereas the 5 samples in 2009 are linked to the *Nephtys cirrosa* habitat. There seems also a trend of more sandy sediment in the southwest, with increasing mud towards the northeast and the 1 nautical mile line. The species richness at this location is poor. The assignation of the samples of 2009 to the *Nephtys cirrosa* habitat is mainly due to the successful recruitment of *Ensis directus.*

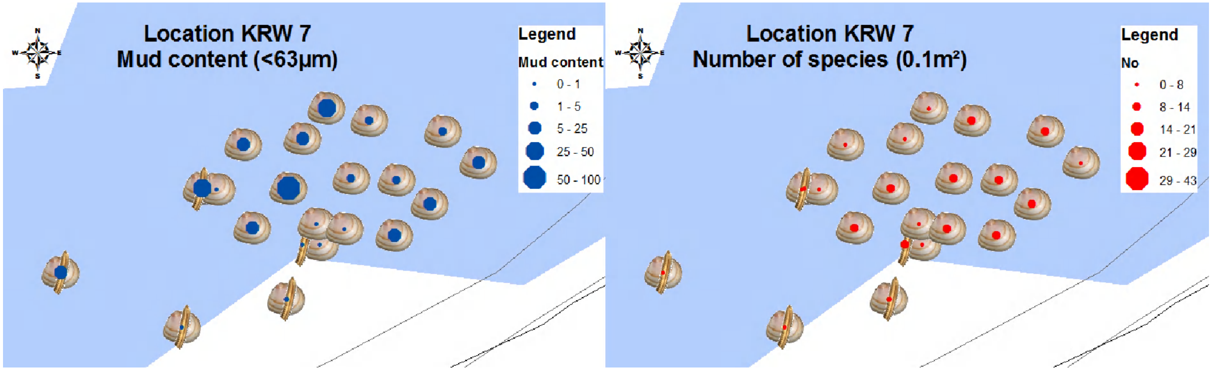

Figure 21. The distribution of the mud content (left panel) and the species richness (right panel) of the samples at location KRW7, with indication of the habitat type per sample.

3) At some locations, two habitat types dominate in a scattered distribution, which can probably be attributed to a wrong linking of the samples to a certain habitat type. The samples can have another habitat potential in this areas, than what the biological cluster analysis gives.
   - The samples at location KRW 3 are mainly characterised as *Macoma balthica* habitat and some as *Abra alba* habitat (especially those of 2009). The sedimentology of this area is mainly characterised by muddy sediments, which is indicative for the *Macoma balthica* habitat. The samples assigned as *Abra alba* habitat are characterised by the lowest mud contents in the area and by a higher species richness than the other samples (Figure 22). The habitat potential of this area, based on the modeling, is an *Abra alba* habitat. Based on this information, it can be possible that this area is an *Abra alba* habitat, but currently impoverished. The reason for this can be linked to the dredging and sand suppletion activities in the neighborhood.

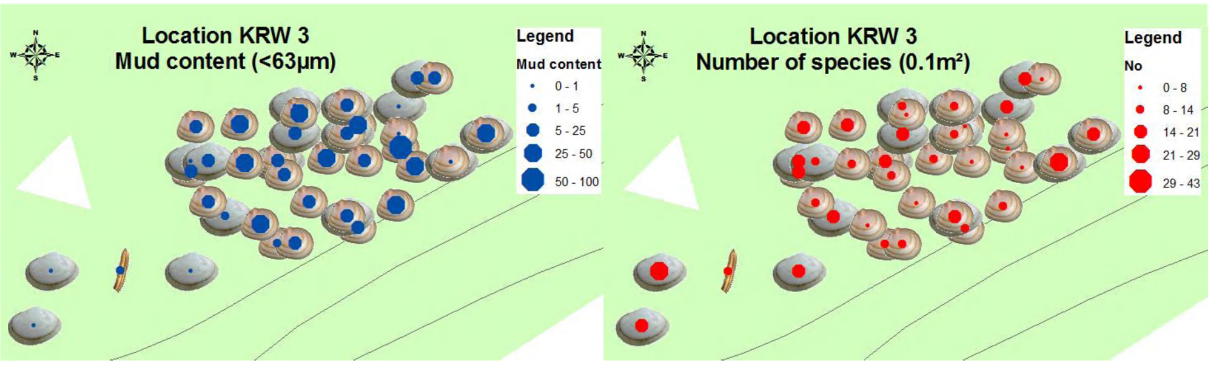

Figure 22. The distribution of the mud content (left panel) and the species richness (right panel) of the samples at location KRW3, with indication of the habitat type per sample.

   - The samples at location KRW 4 are assigned as *Abra alba* habitat or *Macoma balthica* habitat, whereas the habitat potential, based on the modeling, gives a *Macoma balthica* habitat. The samples assigned as *Abra alba* are mainly situated in the central part of the location, whereas the samples of the *Macoma* balthica habitat are more located towards the coastline and towards the slope of the Stroombank. The sedimentology in this area is muddy, corresponding with the characteristics of a *Macoma balthica* habitat. The samples characterised as *Abra alba* habitat, mostly show a higher species richness and a lower mud content than the other samples. Based on this information, is it not clear if this area has the potential of an *Abra alba* habitat and is impoverished by anthropogenic pressures or that this is a *Macoma balthica* habitat in a good status. Probably, the central part of the area is a *Abra alba* habitat and the boundaries a *Macoma balthica* habitat.

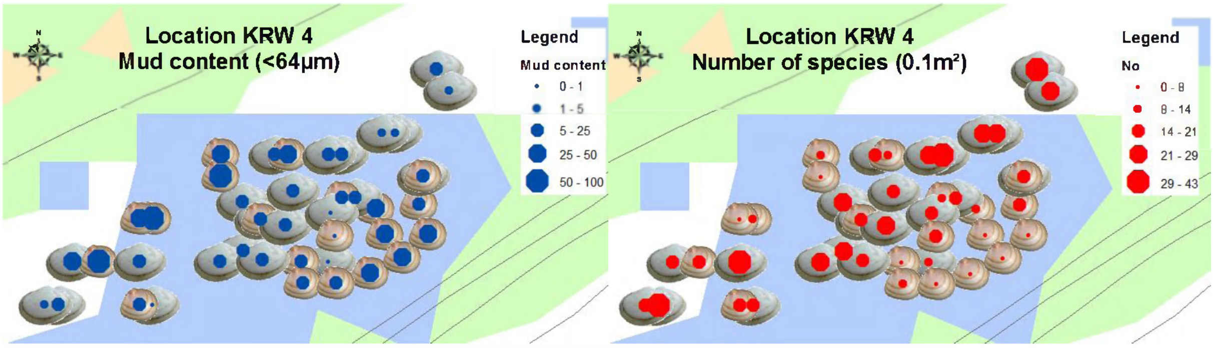

Figure 23. The distribution of the mud content (left panel) and the species richness (right panel) of the samples at location KRW4, with indication of the habitat type per sample.

There can be concluded that it is difficult to monitor in one habitat type only, due to the small scale variation in sedimentological and biological characteristics at the sample locations and due to the continuous gradient in the benthic community characteristics between the habitat types. The samples assigned to a certain habitat fits mainly with the sediment and number of species observed at those locations.

4.4.1.2 Sample assignation procedure

The current methodology for the assignation of the samples to a habitat type used biological and sedimentological information to classify the samples. This methodology, classifies the major part of the samples very well, but samples which were sometimes characterised by a poor species richness were definitely classified as *Macoma balthica* or *Nephtys cirrosa* habitat. Muddy samples with a higher species richness were characterised as *Abra alba.* This problem in the assignation procedure sometimes masks the real habitat potential characteristics of these areas or the effects of anthropogenic pressures.

An alternative methodology could assign the habitat type of the samples based on sedimentological information only, as done for the habitat suitability modeling (Degraer et al., 2008). In this case, an alternative monitoring strategy could be to collect more samples at each location and run a sediment analysis for selecting those samples which perfectly fit the habitat characteristics. The characteristics of the benthic communities and the occurrence of certain species seems to be roughly determined by the following classes (Van Hoey et al., 2004):

- *Macoma balthica* habitat: mud content more than 25 %, median grain size lower than 150 µm.

- *Abra alba* habitat: mud content between 1-25 %, median grain size between 150-220 µm
- *Nephtys cirrosa* habitat: mud content lower than 1 %, median grain size exceeding 220 µm.

Therefore, it could be worthwhile to run the habitat suitability model on the sedimentological data, collected in the 1 nautical mile zone to improve the habitat suitability estimate for benthos in this area, based on Degraer et al. (2008). The disadvantage of this method is that the benthic characteristics do not respond that sharply to the sediment boundary characteristics in an area (e.g. the mass recruitment of *Ensis directus*, regardless the sedimentology). Secondly, mud content can be variable on a very small scale and can sometimes be temporary higher or lower (storms, currents, …). Therefore, the point sediment measures do not cover this aspect with high confidence.

Currently, we can judge the habitat type potential by expert judgment, based on the knowledge of the biological and sedimentological characteristics of each location, as described higher. Maybe we have to conclude that at some locations the habitat heterogeneity, mainly observed in the biological characteristics, is less variable and is more or less structured. This is a first attempt to scope better the real habitat potential of a location, which ideally has to be tested by the habitat suitability models (Degraer et al., 2008).

4.4.1.3 Conclusion

Therefore, the following conclusion can be made, regarding the habitat potential of each location and the future monitoring, based on the current knowledge of these areas:

- KRW 1: The 'Potje area' has the potential to accommodate *Abra alba* habitat, despite the sometimes muddy patches. This closed area (surrounded by the Trapegeer-Broersbank sandbank complex) is characterised by more muddy sediments in the tip towards the Broersbank area, due to natural factors (hydro- and geomorphology of the area). Therefore it is advisable to monitor in the Southwest part of the 'Potje area' to assess the ecological quality of the *Abra alba* habitat at this location.
- KRW 2: The slope of the Broersbank is clearly characterised as *Nephtys cirrosa* habitat, due to the clean sandy sediments (no mud; median grain size of 220-300 µm). The sediment becomes more sandy further on the slope, which indicates a natural gradient in physical characteristics of this area. To ideally monitor the *Nephtys cirrosa* habitat, it is advisable to keep the monitoring of this habitat towards the top if this area.
- KRW 3: This location is mainly assigned as *Macoma balthica* habitat, but seems to have the potential characteristics of an *Abra alba* habitat. Extern benthic experts needs to be consulted for advice.
- KRW 10: This area can clearly be assigned as *Abra alba* habitat.
- KRW 4: This location seems to show a gradient in sedimentology, where the central part can be assigned as *Abra alba* habitat, and the borders as *Macoma balthica* habitat. The habitat patchiness at this location has to be taken into account when collecting the samples for both habitats in the Central coastal zone.
- KRW 5: This locations seems to be a sandy area (especially western part and towards the coast line), but with some spots with higher mud content towards the 1 nautical mile. This

area can have the potential of *Nephtys cirrosa* habitat. Therefore, taking samples towards the muddy area has to be avoided.

- KRW 11: A clear habitat gradient is observed at this location, with a change from sandy sediment to muddy sand at a small distance. For future monitoring, when samples need to be taken at this location, the ones which has to be representative for *Nephtys* cirrosa needs to be located in the southwest part, whereas those representative for *Abra* alba habitat has to be taken towards the northeast.
- KRW 6: This location is clearly representative for *Macoma balthica* habitat.
- KRW 7: This location is characterised by *Macoma balthica* habitat, despite the fact that this area is fine sandy. The mud content increases towards the harbor of Zeebrugge. For future monitoring, it is advisable to take samples, which has to be representative for *Macoma balthica* habitat, more to the east and the 1 nautical mile line at this location.
- KRW 8: This location is clearly representative for *Macoma balthica* habitat.
- KRW 9: This location is clearly representative for *Macoma balthica* habitat.

4.4.2 Confidence of the assessment

It is very important to take a certain amount of samples within a habitat or water body to get a confident ecological status assessment and reduce misclassification. There were two types of statistical errors: a type I error is rejecting a null hypothesis when it is true (false negative) and a type II error is accepting a null hypothesis when it is false (false positive) (Box 3). In our case, there is guard against making a type I error by allowing 5% error due to chance (probability level for G/M boundary). For type II errors, the criterion in our case is set on 75% (or 75% certainty, power). An estimate of the sampling effort depends on the wanted power, the effect size and the variance in the benthic habitat characteristics. Currently, a calculation is made, which sampling effort is needed to get a confident assessment with a certain effect size by a power of 75%. It is obvious that the sampling effort increased strongly when a smaller effect size needed to be assessed with a power of 75% (Figure 24). This pattern differs with the type of parameter. Due to the fact that the variability in density by the same sampling efforts is larger than for the parameter number of species, more samples are needed to evaluate the same effect size for density as for number of species with the same power.

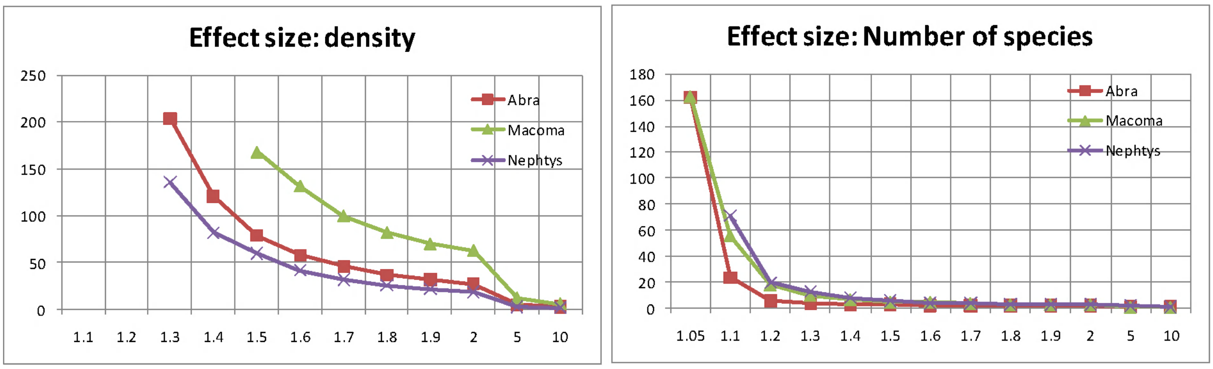

Figure 24. Relation between effect size and sampling effort for the parameters density and number of species

From management perspective, it could be logical that changes in density has not been assessed that strongly as changes in number of species. An adequate judging of the decline in diversity is more necessary than for density. In other words, a loss of half of the species is worse than a loss of half of the density. Therefore, the effect size or change you want to be sure of in the case of number of species is smaller than that of density. Secondly, the community parameters vary greatly with the degree of heterogeneity of the habitat. It seems that the *Macoma balthica* habitat is more heterogeneous than the *Abra alba* and *Nephtys cirrosa* habitat, especially for the parameter density.

Based on this information, there can be concluded that the following sampling efforts were needed, for the assessment for the benthic parameters, to fall in the effect size classes currently defined in the BEQI approach.

Table 9. The number of samples ($0.1m^2$) needed per habitat type to fall in a certain confidence class with a power of 75%.

	# samples	Good	Moderate	Low	Very Poor
Abra alba	# species	>2	2	1	1
	Density	>27	27-5	5-3	<3
Nephtys cirrosa	# species	>3	3	2	1
	Density	>19	19-3	3-2	<2
Macoma balthica	# species	>3	3	1	1
	Density	>63	63-12	12-6	<6

4.4.3 Testing of effect of alternative approaches on the ecological quality assessment results

1) An Alternative habitat approach (expert judgment)

The assignation of the samples, based on the habitat suitability of the locations by expert judgment, shall have its effect on the ecological quality status assessment, which is described in this section.

For the Western coastal zone, locations KRW1 and KRW3 were assigned as *Abra alba* habitat and KRW2 as *Nephtys cirrosa* habitat. The EQR values are not changed substantially for the *Nephtys cirrosa* habitat (Table 10), due to the fact that it contains mainly the same samples as in the normal assessment (Table 8). The EQR values of the *Abra alba* habitat were decreased, especially density, due to the incorporation of the samples in this zone previously assigned to the *Macoma balthica* community. Those samples were characterised by lower densities and species richness.

For the central coastal zone, most of the locations, except KRW10 (*Abra alba* habitat) cannot be assigned to one habitat type. The samples taken in the central part of location KRW 4 are assigned as *Abra alba* habitat, whereas the border samples as *Macoma balthica* habitat. Location KRW5 is partly assigned as *Nephtys cirrosa* (southwestern part) and *Macoma balthica* habitat (northeastern part), whereas KRW 11 is partly assigned as *Nephtys cirrosa* (southwestern part) and *Abra alba* habitat (northeastern part). The EQR values of the *Abra alba* habitat are only changed for the parameter density. The EQR values of the *Nephtys cirrosa* habitat were slightly increased, except for number of species. The main changes were observed in the assessment of the *Macoma balthica*

Table 10. The assessment values, reference boundary values and EQR scores for each parameter of level 3 of the BEQI for the different habitats in each zone for 2007-2009. The confidence of the assessment of each parameter is assigned. Parameters: Density (ind/m²), similarity (Bray-curtis) and species (number of species/sample surface).

2009	Habitats	parameter	Assessment surface	Assessment value	Reference boundary values: Poor min	Mod min	Good min	High min	Reference	High max	Good max	Mod max	Poor max	EQR score	EQR status	Confidence Effect size class
Zone 1	*Abra alba*	density	11.00	2161	1611	3222	4833	5748	6257	6799	7993	10657	13322	0.268	poor	Good
		similarity	11.00	0.69	0.30	0.60	0.91	0.92						0.459	moderate	Good
		species	11.00	98	37	75	112	119						0.525	moderate	Good
		average of parameters												0.417	moderate	Good
	Nephtys cirrosa	density	5.40	1450	83	166	249	302	335	373	461	615	769	0.023	bad	Good
		similarity	5.40	0.59	0.27	0.54	0.81	0.85						0.437	moderate	Good
		species	5.40	64	19	39	58	66						0.750	good	Good
		average of parameters												0.403	moderate	Good
Zone 2	*Abra alba*	density	5.80	4008	1459	2918	4378	5496	6213	6996	8649	11531	14414	0.549	moderate	Good
		similarity	5.80	0.67	0.29	0.58	0.87	0.89						0.459	moderate	Good
		species	5.80	87	33	65	98	106						0.533	moderate	Good
		average of parameters												0.514	moderate	Good
	Nephtys cirrosa	density	2.40	894.6	71.4	142.9	214.3	283	332.1	390.7	528.1	704.1	880.2	0.197	bad	Good
		similarity	2.40	0.5	0.23	0.46	0.7	0.76						0.432	moderate	Good
		species	2.40	50	14.3	28.7	43	51.5						0.765	good	Good
		average of parameters												0.465	moderate	Good
	Macoma balthica	density	3.40	651	116	231	347	592	758	944	1409	1879	2349	0.816	high	Moderate
		similarity	3.40	0.68	0.25	0.49	0.74	0.8						0.548	moderate	Good
		species	3.40	56	17	33	50	57						0.771	good	Good
		average of parameters												0.712	good	Moderate
zone 3	*Macoma balthica*	density	9.90	411	169	338	507	659	763	877	1108	1477	1846	0.486	moderate	Good
		similarity	9.90	0.66	0.29	0.58	0.87	0.9						0.456	moderate	Good
		species	9.90	60	23	45	68	74						0.529	moderate	Good
		average of parameters												0.490	moderate	Good

habitat, with a change from moderate to good status, especially due to the high status of the parameter density.

For the eastern coastal zone, all locations were assigned as *Macoma balthica* habitat and the ecological status evaluation revealed no changes in the EQR values, despite the fact that the 5 samples of KRW7, taken in 2009 and assigned as *Nephtys cirrosa*, were taken into account.

The average score at level 3 for the benthos at the Belgian Coast with the alternative assignation of the samples to the habitats, by averaging the scores per habitat (*Abra alba*: 0.466, moderate status; *Macoma balthica*: 0.601, good status; *Nephtys cirrosa*: 0.434, moderate status) is 0.500, which means a moderate status. This average score does not differ from the previous assessment, which was 0.497. The only difference was the good status of the *Macoma balthica* habitat.

2) Yearly evaluation without considering the 3 zones

In this part, the ecological quality status of the benthic habitats is tested, without analyzing the habitats per zone. The assignation of the samples to a habitat type is based on the methodology described in section 3.3.

In Table 12 the detailed assessment values of each parameter in each habitat along the Belgian Coast is described. The EQR value is compared with the EQR value obtained from the average of each assessed habitat in each zone in Table 11.

Table 11. Average EQR value of each habitat along the Belgian Coast for the years 2009, 2008 and 2007. EQR is the value of the habitat assessment, regardless the different zones. EQR* is the average values of the individual habitat assessments in the three zones along the Belgian Coast.

	Habitat	EQR	EQR*
2009	*Abra alba*	0.49	0.538
	Nephtys cirrosa	0.415	0.526
	Macoma balthica	0.646	0.667
	Average Belgian Coast	0.517	0.577
2008	*Abra alba*	0.525	0.573
	Nephtys cirrosa	0.655	0.668
	Macoma balthica	0.571	0.592
	Average Belgian Coast	0.584	0.611
2007	*Abra alba*	0.534	0.604
	Nephtys cirrosa	0.754	0.757
	Macoma balthica	0.484	0.532
	Average Belgian Coast	0.591	0.631

The EQR values of the analyses of the habitats, without taking into account the different zones, reveals lower EQR values, than averaging the EQR values of the separate habitats. This is due to the fact that taking the average approach can lead to the averaging out of indicators in low or high status. Secondly, an overall assessment of the habitats instead of averaging leads to a more

Table 12. The assessment values, reference boundary values and EQR scores for each parameter of level 3 of the BEQI for the different habitats in each zone for the years 2009, 2008 and 2007 separately, independent of the zonation of the Belgian Coast. The confidence of the assessment of each parameter is assigned. Parameters: Density (ind/m²), similarity (Bray-curtis) and species (number of species/sample surface).

2009			Assessment		Reference boundary values									EQR		Confidence
	Habitats	parameter	surface	value	Poor min	Mod min	Good min	High min	Reference	High max	Good max	Mod max	Poor max	score	status	Effect size class
Zone 2	*Abra alba*	density	5.80	3725	1459	2918	4378	5496	6213	6996	8649	11531	14414	0.511	moderate	Good
		similarity	5.80	0.65	0.29	0.58	0.87	0.89						0.445	moderate	Good
		species	5.80	84	33	65	98	106						0.514	moderate	Good
		average of parameters												0.490	moderate	Good
	Nephtys cirrosa	density	4.00	2584	80.2	160.4	240.6	296.5	335	377.3	483.1	644.1	805.2	0.000	bad	Good
		similarity	4.00	0.56	0.26	0.51	0.77	0.82						0.439	moderate	Good
		species	4.00	61	17.7	35.3	53	60						0.806	high	Good
		average of parameters												0.415	moderate	Good
	Macoma balthica	density	2.30	597	100	201	301	545	724	982	1540	2053	2566	0.814	high	Moderate
		similarity	2.30	0.59	0.23	0.45	0.68	0.76						0.524	moderate	Good
		species	2.30	42	14	28	42	51						0.600	good	Good
		average of parameters												0.646	good	Moderate
2008			Assessment		Reference boundary values									EQR		Confidence
	Habitats	parameter	surface	value	Poor min	Mod min	Good min	High min	Reference	High max	Good max	Mod max	Poor max	score	status	Effect size class
Zone 2	*Abra alba*	density	5.00	3524	1437	2873	4310	5425	6224	7067	9043	12058	15072	0.491	moderate	Good
		similarity	5.00	0.70	0.29	0.57	0.86	0.88						0.489	moderate	Good
		species	5.00	94	32	63	95	103						0.594	moderate	Good
		average of parameters												0.525	moderate	Good
	Nephtys cirrosa	density	2.40	475.4	71.4	142.9	214.3	283	332.1	390.7	528.1	704.1	880.2	0.677	good	Good
		similarity	2.40	0.58	0.23	0.46	0.7	0.76						0.501	moderate	Good
		species	2.40	51	14.3	28.7	43	51.5						0.788	good	Good
		average of parameters												0.655	good	Good
	Macoma balthica	density	5.10	295	139	279	418	633	765	924	1299	1733	2166	0.423	moderate	Moderate
		similarity	5.10	0.64	0.27	0.53	0.8	0.84						0.481	moderate	Good
		species	5.10	65	19	38	57	64						0.808	high	Good
		average of parameters												0.571	moderate	Moderate
2007			Assessment		Reference boundary values									EQR		Confidence
	Habitats	parameter	surface	value	Poor min	Mod min	Good min	High min	Reference	High max	Good max	Mod max	Poor max	score	status	Effect size class
Zone 2	*Abra alba*	density	1.50	3605	1065	2130	3195	4692	5924	7603	11639	15519	19399	0.655	good	Good
		similarity	1.50	0.57	0.25	0.49	0.74	0.8						0.460	moderate	Good
		species	1.50	56	23	46	69	79						0.487	moderate	Good
		average of parameters												0.534	moderate	Good
	Nephtys cirrosa	density	1.50	319.3	62.4	124.8	187.2	264.4	322.3	397.2	580.2	773.6	967	0.990	high	Good
		similarity	1.50	0.55	0.2	0.4	0.61	0.69						0.540	moderate	Good
		species	1.50	40	11.3	22.7	34	43						0.733	good	Good
		average of parameters												0.754	good	Good
	Macoma balthica	density	10.30	370	169	338	507	673	769	880	1109	1478	1848	0.438	moderate	Good
		similarity	10.30	0.68	0.29	0.58	0.87	0.9						0.468	moderate	Good
		species	10.30	62	23	45	68	75						0.547	moderate	Good
		average of parameters												0.484	moderate	Good

confident assessment, because more parameters in the assessment per habitat per zone were assessed with a moderate confidence than in the other case.

5 Discussion

5.1 Ecological quality status of benthos over the period 2007-2009.

Three years of detailed monitoring in the water body ' Belgian coast' resulted in a confident assessment and indicated a moderate status for the quality element macro-invertebrates (EQR: 0.549). The yearly assessments indicated a good status for the first two tears, although at the boundary of good-moderate (EQR: 0.63 and 0.61), whereas 2009 showed a moderate status (EQR: 0.589). The yearly ecological status analysis showed a decreasing trend in ecological status, which is confirmed by the overall assessment over the 3 year period. An assessment over a 'longer' time period should have a higher confidence, due to the fact that:

- benthos shows strong year-to-year variations in its characteristics, by which a 'bad' year (naturally lower or higher densities) or a 'good' year can be erroneously interpreted.
- Secondly, the reference conditions for each habitat in the Belgian Coastal area are determined based on data over a longer time period to scope the year-to-year variance.
- Thirdly, the confidence of a water body assessment increases when taking into account more samples, which are spatially and temporally spread.

From the yearly and the overall assessments, it is clear that some parameters or habitats were in a good or even high status, whereas others were in poor or bad status. By taking the average approach for determining the overall status over a certain period, degraded conditions of certain habitats were obscured. Therefore, it is important to consider and discuss the scores for the parameters and locations separately (see 4.2; 4.3.2).

Generally, it can be concluded, based on the results of the different assessments, that the ecological quality status of macro-invertebrates along the Belgian Coast is degraded. Despite the fact that some zones and habitats showed a better status than others (e.g. west coast versus east coast), the most obvious effect is that some key species in certain habitats (e.g. *Spisula subtruncata* in the *Abra alba* habitat or *Petricola pholadiformis* in the *Macoma balthica* habitat) were nearly absent in the assessment in contrast to the reference. This explains the moderate status of the parameter similarity in most cases. In 2009, the differences in the species composition between assessment and reference were strengthened by the high densities of *Ensis directus* (very successful recruitment in 2009). The diversity (number of species) did not seem to be changed (for most habitats in good status), except for the *Abra alba* habitat at the west coast and the *Macoma balthica* at the east coast. In most cases, the parameter density showed a moderate status, with lower densities in the assessment period compared to the reference, except for the habitat *Nephtys cirrosa* (unexpected higher densities of *Ensis directus*).

This ecological degradation of the macro-invertebrate fauna in the Belgian coastal area cannot directly be linked to a single anthropogenic pressure, but is probably the result of the combined acting of a number of anthropogenic pressures, such as the occurrence of alien species, fisheries, pollution, harbors and eutrophication. Currently, there is no classification concerning the degree of impact in the various regions of the Belgian Coastal area.

In this paragraph, I only describe which effect those pressures could have on the ecological status classification, due to the lack of clear stressor-response data in the Belgian coastal area.

- Firstly, there is the impact of the dominance of *Ensis directus*, an invasive alien species, on the benthic communities. This species can be very dominant, thereby probably impoverishing the local benthic communities (currently under investigation in the BELSPO project "*Ensis*"). This species had a very successful recruitment in 2009, during which a lot of settled individuals survived in the three habitat types. Investigation and monitoring is needed to evaluate the scale of the impact and the time scale of the effect. It is very difficult to take measures to reduce the impact of this invasive alien species, but further investigation has to evaluate if *Ensis directus* has to be dealt with as a real pressure or if it can be considered as a common, accepted species in our waters.
- Secondly, coastal fishery (mainly for shrimp), can also impoverish the benthic community in coastal areas by increasing bottom disturbance, and by reducing the abundance of longer living or habitat structuring species. Therefore, a quantification of this pressure and its effect on the benthic community is of great importance. A solution (measure) is the delineation of areas without or with reduced fishery activities, by preference in Marine protected area's (cf Natura 2000 areas).
- Thirdly, the presence of the harbors caused changes in the hydromorphological and geomorphological structure of the coastline and indirectly changed the local benthic communities. For example, the presence of the harbor of Zeebrugge and the continuous maintenance dredging works are responsible for changes in the sediment stability of the eastern Belgian coastal area (more fluid mud, increased sand transport). This increasing instability could be the main reason for the observed decline of characteristic species (*Barnea candida, Petricola pholadiformis, Polydora spp*) (Lauwaert et al., 2009; Van Hoey et al., 2010), and for the moderate status of the *Macoma balthica* habitat. The same pattern can be observed around the harbor of Ostend.
- Fourthly, eutrophication caused by the inputs from the rivers Scheldt and Ijzer and from the harbors will favor the occurrence of opportunistic species and increase their densities (Van Hoey et al., 2009). Therefore, a further reduction in nutrient inputs from the rivers will be an appropriate and necessary measure to improve the habitat quality of the benthic communities.
- Fifthly, some types of chemical pollution in the coastal area have an impact on the reproduction of some gastropods (e.g. TBT).
- Finally, sand suppletion activities on certain beaches in the light of coastal defense works can be considered as an additional pressure.

Currently, there are no signals that the anthropogenic pressures in our coastal area decreased in the last decades, except for some aspects of chemical pollution and eutrophication (nutrient input).

When discussing the interpretation of the assessments, it should be kept in mind that we do not know what the real reference potential is for the benthic habitats at the Belgian coast, due the lack of ‘pristine’ reference conditions. Currently, the reference characteristics of the benthic habitats were defined based on the variability in benthic community characteristics of the period 1994-2004. Despite the exclusion of benthic samples in known impact areas (e.g. dumping sites), anthropogenic effects on the reference data could not entirely be excluded, since some pressures have not yet sufficiently been quantified. The current definition of reference condition reflects more or less what we currently expect of species composition in the habitats in the dynamic, impacted coastal system. This ‘reference’ reflects the minimal expectations for a good condition under the pressure degree of the current time period. To improve the current notion of “reference”, it is recommended to analyze the current reference and assessment data in relation to changes in anthropogenic pressures (at least semi-quantitatively) over time. Secondly, it is advisable to check the current reference data with some criteria (e.g. which dominant species are expected, excluding ‘rare’ samples) to their ‘real’ reference potential. Thirdly, modeling or regression analysis could possibly provide an idea of how far the current reference status deviates from the ‘real’ reference (benthos characteristics under minimal anthropogenic pressure).

5.2 Monitoring strategy

This section elaborates on the importance of aspects such as spatial and temporal coverage and number of samples in the design of a benthic monitoring program.

A good spatial coverage of the samples per habitat in a water body is very important for a water basin assessment (habitat approach), due to the fact that the ecological status of one sample location cannot be representative for the ecological status of an entire habitat and due to the small scale spatial variation of the benthic characteristics. Therefore, it is important to spatially distribute samples within a habitat, instead of taking samples at one station in a habitat. A disadvantage of this stratified random sampling design is that the *a posteriori* assignment of the samples to a habitat type is not always obvious, as described in 4.4.1. The habitat heterogeneity at the currently used monitoring locations is well-known after 3 years of detailed monitoring. Consequently, the sampling locations in the coastal area can be positioned in function of the targeted habitat types based on expert judgment (see 4.4.1). Additionally, the existing habitat suitability model of the Belgian coastal area can be optimized by adding the most recent information on sediment characteristics.

To ensure an adequate temporal coverage, it is advised to take samples every year instead of tri-annually given the year-to-year variation in benthic characteristics. The recruitment patterns of benthic organisms are very variable, but they sometimes show a cyclic pattern (Van Hoey et al., 2007 and references therein). Therefore, the presence, absence or dominance of certain species differs interannually, especially in dynamic coastal systems, which are usually characterised by benthic communities with high turn-over rates. This temporal variance aspect was also included in the selection of the reference conditions of the macro-invertebrate fauna at the Belgian coast. Logically, this temporal aspect should also be included in the assessment. The distribution in time of the monitoring activities for an ecological quality assessment will reduce the chance of misclassification due to one ‘bad’ or ‘good’ year.

The minimization of the chance of misclassification is of major importance and depends on the sampling effort needed per habitat type to get a confident ecological quality status assessment. Power analyses are necessary to determine the sampling intensity once the level of required and/or anticipated change (effect size) has been defined (Gray, 2009). Currently, confidence classes are defined based on the effect size that can be measured with a power of 75%. Setting the power on 75% should lead to an acceptable sample effort (Gray, 2009). Currently a good confidence is reached when the sampling effort in the assessed habitat is of that size to detect an effect size of factor 2 (halving or doubling) with a confidence of 75%. The sampling effort needed under this confidence is much higher for the parameter density compared to number of species and also varies between the three habitat types. Regarding this aspect it is advisable to refine the level of confidence, the effect size and the sampling effort for the different parameters and habitats in dialogue with the government.

Finally, the results (see 4.4.3) showed that a different approach in the monitoring and assessment strategy (amount of samples, habitat type, pooling approach) has an effect on the ecological status scores. Therefore, an optimal approach has to be selected for future assessments.

The previous three years, there was an operational monitoring program for macro-invertebrate fauna (appendix 1) due to the fact that benthos was initially assigned to be in moderate conditions. This seems to be confirmed by the ecological status assessment over the period 2007-2009. Therefore, the operational monitoring program needs to be continued. Adaptations or reductions in the program are possible in dialogue with the government, but the aspects regarding the habitat approach and confidence should be dealt with. Following aspects can be reconsidered or adapted:

- Currently, the Belgian coastal water body is split up in three zones to make it possible to assess the natural and anthropogenic gradient in its characteristics from southwest to northeast. This may not be necessary, because it seems that the observed differences in species composition between the assessment and reference are more or less the same for each habitat in each zone. This leads to a more confident assessment than averaging the habitat scores of the three zones.
- A redefinition is needed of the confidence desired by the government regarding the aspects power and effect size.
- The habitats or locations in a good status over the 3 years can be monitored following the surveillance monitoring program (appendix 1).

An adaptation of the current operational and surveillance monitoring programs of the Belgian coastal waters can be submitted to the European Commission, taking into account the minimal requirements defined in the text (Box 4).

Box 4: Frequency of monitoring (WFD Directive)

For the surveillance monitoring period, the frequencies for monitoring parameters indicative of physico-chemical quality elements given below should be applied unless greater intervals would be justified on the basis of technical knowledge and expert judgment. For biological or hydromorphological quality elements monitoring shall be carried out at least once during the surveillance monitoring period.

For operational monitoring, the frequency of monitoring required for any parameter shall be determined by Member States so as to provide sufficient data for a reliable assessment of the status of the relevant quality element. As a guideline, monitoring for macro-invertebrates should take place at intervals of maximal three years (surveillance) unless greater intervals would be justified on the basis of technical knowledge and expert judgment.

Frequencies shall be chosen so as to achieve an acceptable level of confidence and precision. Estimates of the confidence and precision attained by the monitoring system used shall be stated in the river basin management plan.

Monitoring frequencies shall be selected which take account of the variability in parameters resulting from both natural and anthropogenic conditions. The times at which monitoring is undertaken shall be selected so as to minimize the impact of seasonal variation on the results, and thus ensure that the results reflect changes in the water body as a result of changes due to anthropogenic pressure. Additional monitoring during different seasons of the same year shall be carried out, where necessary, to achieve this objective.

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7 Appendix 1. WFD monitoring program

In this appendix, a summary of the WFD monitoring program for the Belgian Coastal waters for operational (Table 13) and surveillance monitoring (Table 14) is given, with indication of the sampling locations, frequency and cycle.

COASTAL MONITORING SITES (Figure 25**):**

The coastal monitoring stations of Belgium, used in previous years for the OSPAR monitoring, are re-organized to fulfill the monitoring requirements of the WFD and OSPAR at the same time. This means that the 3 monitoring sites for biological quality elements under the WFD are located in such a way that:

- they are located within the zone of 1 nautical mile (only site WO3 had to be adjusted a little bit further in order to make it possible to navigate to this place with an oceanographic vessel).

- their location is representative to follow up the impacts of possible pressures in the coastal zone. Each of the stations is located in the neighbourhood of a harbour, from east to west Zeebrugge, Oostende and Nieuwpoort. By comparing the three sites from east to west, a frequent assessment can also be made of the impact of the effluents from the Scheldt in the coastal waters.

- the use of sub-sites and area sampling for the macrobenthos allows detecting impacts of a series of pressures such as eutrophication, fisheries and hazardous substances near the harbours. Sampling west and east from harbours is also evaluated.

The coastal area is split up in 3 sub-areas or zones (each represented by a monitoring site) to reflect the anthropogenic gradient in the coastal area caused by the estuary of the Scheldt and to improve the quantitative follow-up of the ecological status. For the quality element macrobenthos, sub-sites have been defined within the three coastal zones, because of the variation in soft-bottom habitats within the zones. Macrobenthos assessment and classification of the Belgian coastal zone, based on habitat types within the coastal zones, is ecologically more meaningful than a classification of the whole zone as one type. The reported coordinates of the monitoring site per coastal zone is used as the centroid for the macrobenthos monitoring sub-sites, for the sake of simplicity. At every sub-site several stations are sampled, which are selected by a randomly stratified sampling design at every campaign.

Operational monitoring:

Five monitoring sites are defined for the operational monitoring program for the coastal waters. At three sites all biological quality elements are measured. Priority substances are measured at three sites, one in common with the biological quality elements and two other sites. Non-priority substances are measured in the sediment at 6 sites in the territorial waters within the framework of the OSPAR monitoring, including the three sites for biological quality elements under the WFD, the sites for operational monitoring of priority substances under the WFD and an additional station near the area “Vlakte van de Raan” closer to the mouth of the Scheldt.

Table 13. Operational monitoring

	sites	QE	sub-sites	parameter	frequency	cycle	Ass_WB	start
BEFED_Schelde_SWP_OPP_C	BEFED_WO1	QE1-1	no	phytoplankton	12	1	BENZ	end 2007
BEFED_Schelde_SWP_OPP_C	BEFED_WO1	QE1-3	area	benthos	1	1	BENZ	2007
BEFED_Schelde_SWP_OPP_C	BEFED_WO1	QE2-6-1	no	depth variation	4	1	BENZ	2007
BEFED_Schelde_SWP_OPP_C	BEFED_WO1	QE2-6-2	area	structure substrate	1	1	BENZ	2007
BEFED_Schelde_SWP_OPP_C	BEFED_WO1	QE2-8-1	no	direction currents	4	1	BENZ	2007
BEFED_Schelde_SWP_OPP_C	BEFED_WO1	QE2-8-2	no	wave exposure	4	1	BENZ	2007
BEFED_Schelde_SWP_OPP_C	BEFED_WO1	QE3-1-1	no	transparancy	4	1	BENZ	2007
BEFED_Schelde_SWP_OPP_C	BEFED_WO1	QE3-1-2	no	thermal conditions	4	1	BENZ	2007
BEFED_Schelde_SWP_OPP_C	BEFED_WO1	QE3-1-3	no	oxygenation	4	1	BENZ	2007
BEFED_Schelde_SWP_OPP_C	BEFED_WO1	QE3-1-4	no	salinity	4	1	BENZ	2007
BEFED_Schelde_SWP_OPP_C	BEFED_WO1	QE3-1-6	no	nutrient conditions	4	1	BENZ	2007
BEFED_Schelde_SWP_OPP_C	BEFED_WO1	QE3-2	no	priority substances	12	1	BENZ	2007
BEFED_Schelde_SWP_OPP_C	BEFED_WO1	QE3-3	no	non-priority substances	1	1	BENZ	2007
BEFED_Schelde_SWP_OPP_C	BEFED_WO2	QE1-1	no	phytoplankton	12	1	BENZ	end 2007
BEFED_Schelde_SWP_OPP_C	BEFED_WO2	QE1-3	area	benthos	1	1	BENZ	2007
BEFED_Schelde_SWP_OPP_C	BEFED_WO2	QE2-6-1	no	depth variation	4	1	BENZ	2007
BEFED_Schelde_SWP_OPP_C	BEFED_WO2	QE2-6-2	area	structure substrate	1	1	BENZ	2007
BEFED_Schelde_SWP_OPP_C	BEFED_WO2	QE2-8-1	no	direction currents	4	1	BENZ	2007
BEFED_Schelde_SWP_OPP_C	BEFED_WO2	QE2-8-2	no	wave exposure	4	1	BENZ	2007
BEFED_Schelde_SWP_OPP_C	BEFED_WO2	QE3-1-1	no	transparancy	4	1	BENZ	2007
BEFED_Schelde_SWP_OPP_C	BEFED_WO2	QE3-1-2	no	thermal conditions	4	1	BENZ	2007
BEFED_Schelde_SWP_OPP_C	BEFED_WO2	QE3-1-3	no	oxygenation	4	1	BENZ	2007
BEFED_Schelde_SWP_OPP_C	BEFED_WO2	QE3-1-4	no	salinity	4	1	BENZ	2007
BEFED_Schelde_SWP_OPP_C	BEFED_WO2	QE3-1-6	no	nutrient conditions	4	1	BENZ	2007
BEFED_Schelde_SWP_OPP_C	BEFED_WO3	QE1-1	no	phytoplankton	12	1	BENZ	end 2007
BEFED_Schelde_SWP_OPP_C	BEFED_WO3	QE1-3	area	benthos	1	1	BENZ	2007
BEFED_Schelde_SWP_OPP_C	BEFED_WO3	QE2-6-1	no	depth variation	4	1	BENZ	2007
BEFED_Schelde_SWP_OPP_C	BEFED_WO3	QE2-6-2	area	structure substrate	1	1	BENZ	2007
BEFED_Schelde_SWP_OPP_C	BEFED_WO3	QE2-8-1	no	direction currents	4	1	BENZ	2007
BEFED_Schelde_SWP_OPP_C	BEFED_WO3	QE2-8-2	no	wave exposure	4	1	BENZ	2007
BEFED_Schelde_SWP_OPP_C	BEFED_WO3	QE3-1-1	no	transparancy	4	1	BENZ	2007
BEFED_Schelde_SWP_OPP_C	BEFED_WO3	QE3-1-2	no	thermal conditions	4	1	BENZ	2007
BEFED_Schelde_SWP_OPP_C	BEFED_WO3	QE3-1-3	no	oxygenation	4	1	BENZ	2007
BEFED_Schelde_SWP_OPP_C	BEFED_WO3	QE3-1-4	no	salinity	4	1	BENZ	2007
BEFED_Schelde_SWP_OPP_C	BEFED_WO3	QE3-1-6	no	nutrient conditions	4	1	BENZ	2007
BEFED_Schelde_SWP_OPP_C	BEFED_WO5	QE3-2	no	priority substances	12	1	BENZ	2007
BEFED_Schelde_SWP_OPP_C	BEFED_WO5	QE3-3	no	non-priority substances	1	1	BENZ	2007
BEFED_Schelde_SWP_OPP_C	BEFED_WO6	QE3-2	no	priority substances	12	1	BENZ	2007
BEFED_Schelde_SWP_OPP_C	BEFED_WO6	QE3-3	no	non-priority substances	1	1	BENZ	2007

Surveillance monitoring:

Four monitoring sites are defined for the surveillance monitoring programe for the coastal waters. At three sites all biological quality elements are measured. Priority and non-priority substances are measured at one station.

Table 14. Surveillance monitoring

	sites	QE	sub-sites	parameter	frequency	cycle	Ass_WB	start
BEFED_Schelde_SWP_SUP_C	BEFED_WO1	QE1-1	no	phytoplankton	12	1	BENZ	end 2007
		QE1-3	area	benthos	1	3	BENZ	2007
		QE2-6-1	no	depth variation	4	1	BENZ	2007
		QE2-6-2	area	structure substrate	1	3	BENZ	2007
		QE2-8-1	no	direction currents	4	1	BENZ	2007
		QE2-8-2	no	wave exposure	4	1	BENZ	2007
		QE3-1-1	no	transparancy	4	1	BENZ	2007
		QE3-1-2	no	thermal conditions	4	1	BENZ	2007
		QE3-1-3	no	oxygenation	4	1	BENZ	2007
		QE3-1-4	no	salinity	4	1	BENZ	2007
		QE3-1-6	no	nutrient conditions	4	1	BENZ	2007
	BEFED_WO2	QE1-1	no	phytoplankton	12	1	BENZ	end 2007
		QE1-3	area	benthos	1	3	BENZ	2007
		QE2-6-1	no	depth variation	4	1	BENZ	2007
		QE2-6-2	area	structure substrate	1	3	BENZ	2007
		QE2-8-1	no	direction currents	4	1	BENZ	2007
		QE2-8-2	no	wave exposure	4	1	BENZ	2007
		QE3-1-1	no	transparancy	4	1	BENZ	2007
		QE3-1-2	no	thermal conditions	4	1	BENZ	2007
		QE3-1-3	no	oxygenation	4	1	BENZ	2007
		QE3-1-4	no	salinity	4	1	BENZ	2007
		QE3-1-6	no	nutrient conditions	4	1	BENZ	2007
	BEFED_WO3	QE1-1	no	phytoplankton	12	1	BENZ	end 2007
		QE1-3	area	benthos	1	3	BENZ	2007
		QE2-6-1	no	depth variation	4	1	BENZ	2007
		QE2-6-2	area	structure substrate	1	3	BENZ	2007
		QE2-8-1	no	direction currents	4	1	BENZ	2007
		QE2-8-2	no	wave exposure	4	1	BENZ	2007
		QE3-1-1	no	transparancy	4	1	BENZ	2007
		QE3-1-2	no	thermal conditions	4	1	BENZ	2007
		QE3-1-3	no	oxygenation	4	1	BENZ	2007
		QE3-1-4	no	salinity	4	1	BENZ	2007
		QE3-1-6	no	nutrient conditions	4	1	BENZ	2007
	BEFED_WO5	QE3-2	no	priority substances	12	6	BENZ	2007
		QE3-3	no	non-priority substances	1	1	BENZ	2007

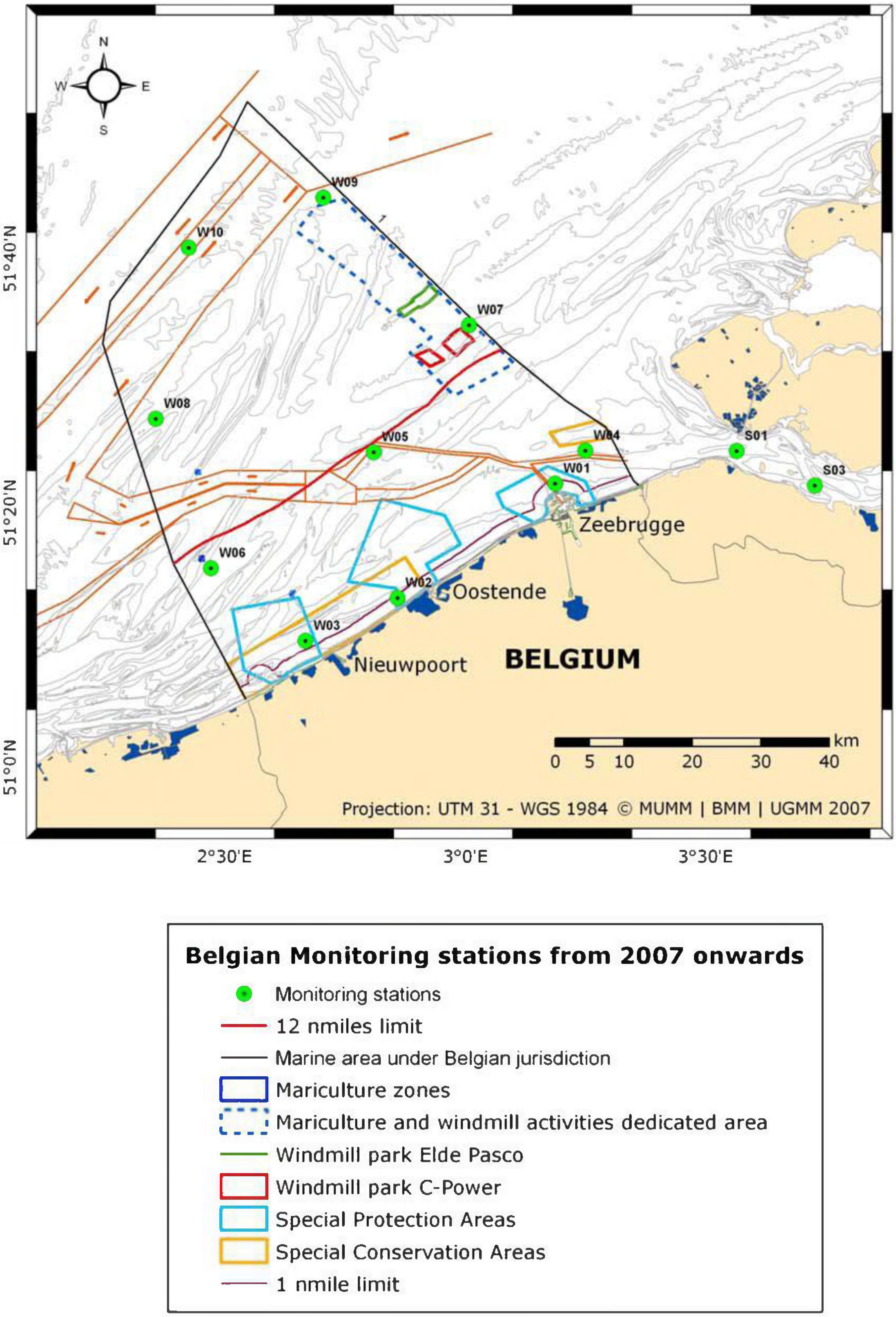

Figure 25. Location of the monitoring locations in the Belgian Coastal waters for WFD and OSPAR perspective.