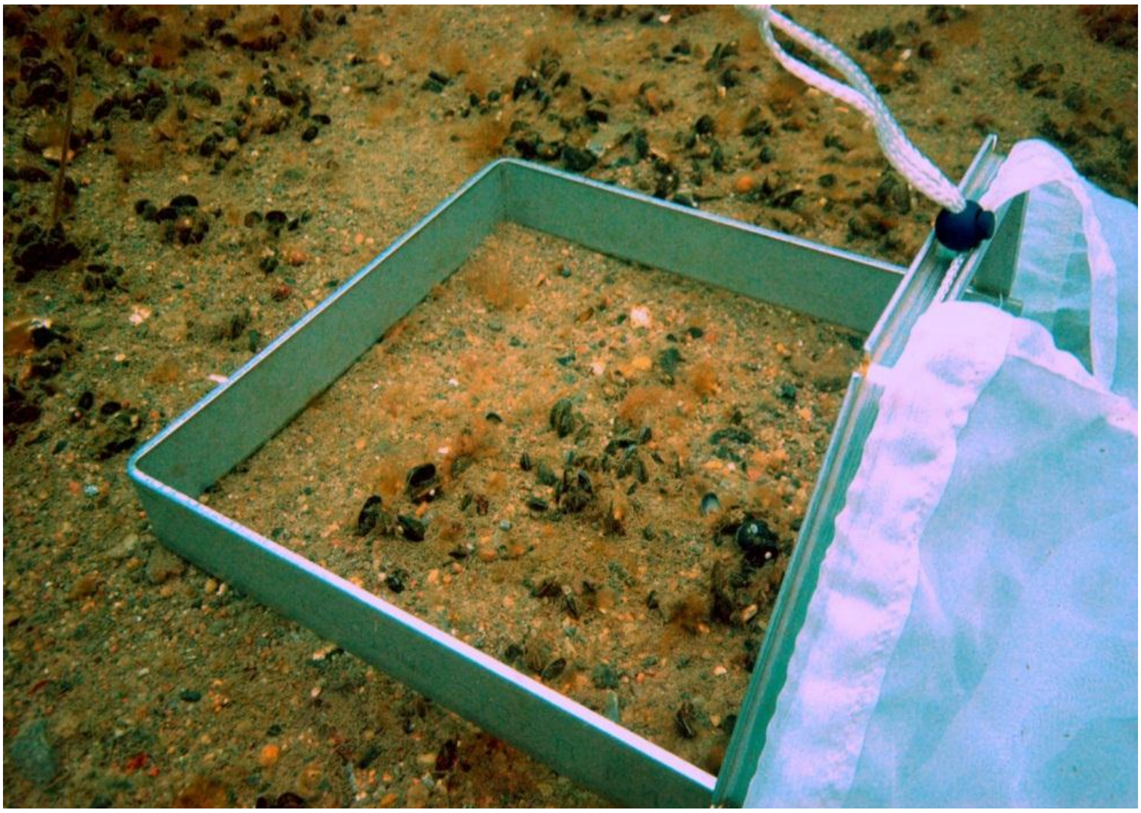
Final Report

FEHMARNBELT FIXED LINK
MARINE BIOLOGY SERVICES (FEMA)

Marine Fauna and Flora - Baseline

Benthic Fauna of the Fehmarnbelt Area

E2TR0020 - Volume II



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Note to the reader:
In this report the time for start of construction is artificially set to 1 October 2014 for the tunnel and 1 January 2015 for the bridge alternative. In the Danish EIA (VVM) and the German EIA (UVS/LBP) absolute year references are not used. Instead the time references are relative to start of construction works. In the VVM the same time reference is used for tunnel and bridge, i.e. year 0 corresponds to 2014/start of tunnel construction; year 1 corresponds to 2015/start of bridge construction etc. In the UVS/LBP individual time references are used for tunnel and bridge, i.e. for tunnel construction year 1 is equivalent to 2014 (construction starts 1 October in year 1) and for bridge construction year 1 is equivalent to 2015 (construction starts 1st January).

0 SUMMARY AND CONCLUSION

The main objective of this baseline study is to establish a well-founded description of the benthic macrofauna in the Fehmarnbelt, the sea strait between the German island of Fehmarn and the Danish island of Lolland. The Fehmarnbelt proper stretches from the southern end of the Langelandsbelt and the eastern end of the Kiel Bight in the west till the northern of the Mecklenburg Bight and Gedser Reef in the East. The study covers the potential alignment area of the proposed Fixed Link and adjacent waters, based on extensive data acquisition and including biological parameters like abundance, biomass, species diversity and community structure. Special emphasis was put on the Blue Mussel *Mytilus edulis* due to its key role in the coastal food web.

Present report
The present report provides the documentation of the baseline investigations on marine benthic fauna (here also referred to as benthic macrofauna), conducted as a part of the baseline investigations for the Fehmarnbelt Fixed Link.

The report is based on a two year field study conducted in the Fehmarnbelt and adjacent areas to provide recent data on benthic fauna communities. The results are compared and related to available historical information on the fauna of the investigation area where relevant. Furthermore, the ecological quality of the area is assessed in relation to the Water Framework Directive (WFD) and other legislative conservation objectives.

Finally, the importance of the benthic fauna communities is assessed, making use of a pre-defined classification procedure.

Purpose of the benthic fauna baseline investigation
The purpose of the benthic fauna baseline investigation is to describe the distribution and abundance of benthic fauna in Fehmarnbelt and adjacent waters before the Fehmarnbelt Fixed Link construction work starts. The specific objectives of the investigation are:

- To document and describe patterns in the distribution, abundance and biomass of marine benthic fauna in the proposed alignment area and in the adjacent waters, which may possibly become impacted by the construction or operation of a Fixed Link across the Fehmarnbelt;
- To provide baseline data for assessment of impacts from the proposed project; and
- To provide baseline data for a possible later monitoring of the development in benthic fauna during and during or after the establishment of the Fixed Link across Fehmarnbelt.

Field study 2009-2010
The Benthic Fauna Baseline Report describes the results of two years of extensive monitoring and mapping of the benthic fauna. Benthic epi- and infauna was sampled at 263 infauna stations and 123 epifauna stations (59 stations are indentical to deep water infauna stations), with locations as shown in Figure 0.1 using standardized methods (van Veen grabs operated from a ship at deep stations and frame samples operated by divers at shallower waters). The area covered the greater Fehmarnbelt including shallow and deep waters, and seven NATURA 2000 areas.

Because of their uneven distribution, Blue Mussels had their own sampling programme that encompassed video- or diver-observations of mussel cover (> 5000 observations), as well as frame sampling carried out by divers and supplemented by quantitative dredge sampling.

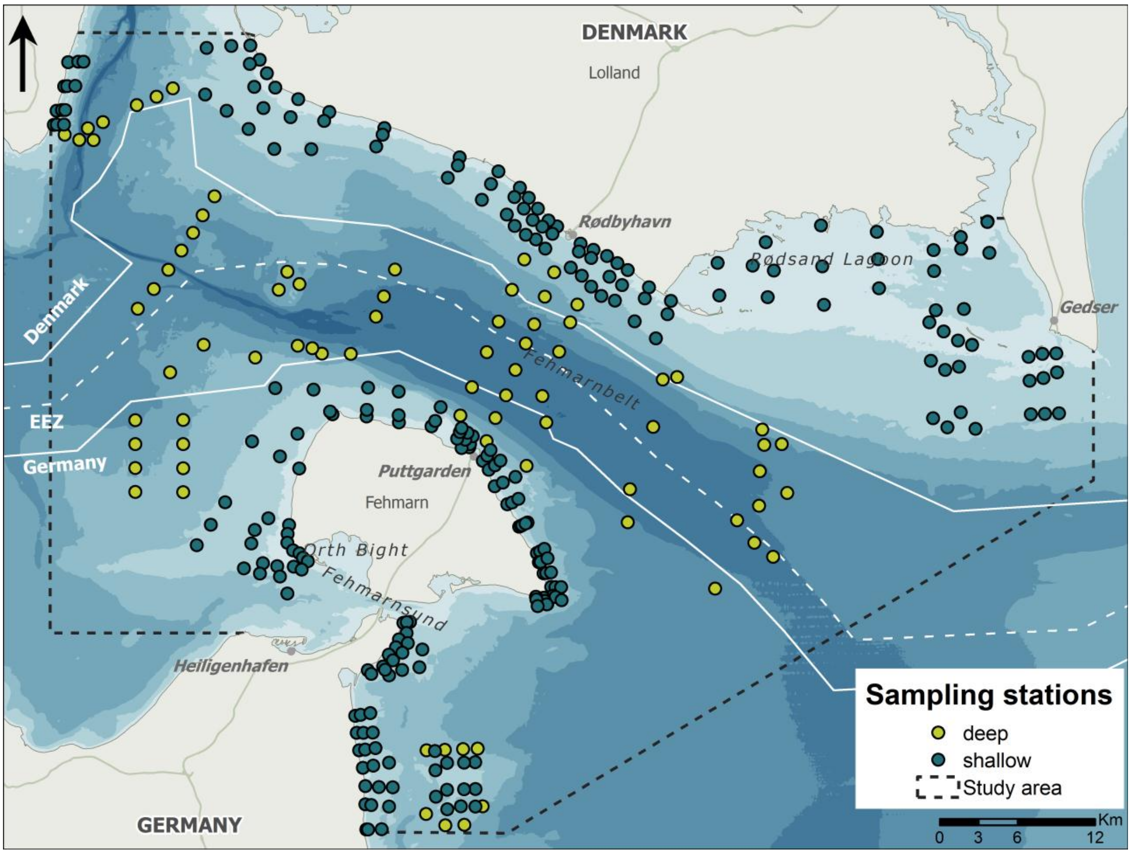

Figure 0-1 The geographical positions of the sampling stations for the benthic fauna baseline sampling campaign. The dark-coloured symbols denote shallow stations, whereas the light-coloured symbols denote deep stations.

The fauna was characterised by species distribution of abundance and biomass in terms of ash free dry weight (AFDW). For mussels that play an important role as food for winter-resting Eider ducks, also length distribution was quantified.

Species richness and biomass

There are two main spatial gradients in species richness in the Fehmarnbelt that both are linked to salinity. The most obvious gradient runs from shallow waters to the deeper parts. The other gradient in species number runs from west to east.

The areas with the highest species richness are notably the south-east reef offshore the Danish island of Langeland (Langeland Rev; 125-162 and 75-162 species, respectively) and areas north-west of Fehmarn. Areas with lowest species richness in the study area can be found especially on the south-west coast of Lolland (Albuen Bank), in the Lagoon of Rødsand and just south of the Lagoon of Rødsand (7-24, 7-49 and 7-49 species, respectively, see Figure 0-2).

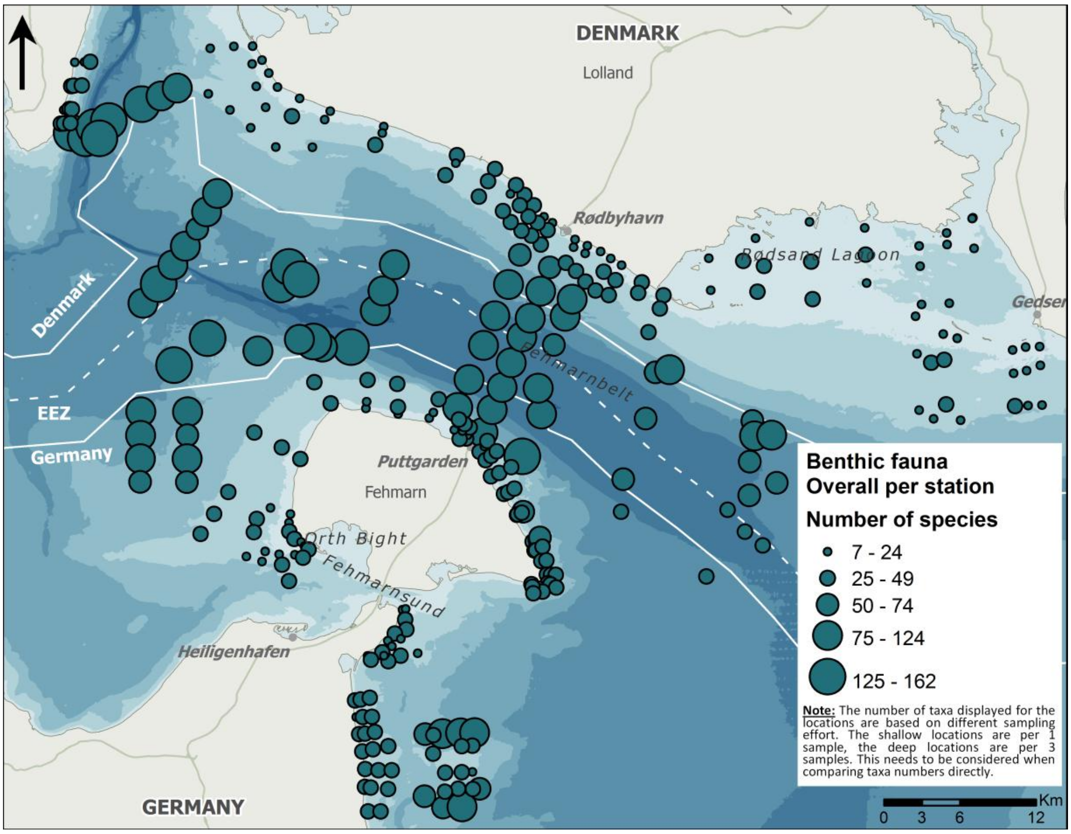

Figure 0-2 Species richness (total number of species observed) at each of the sampling sites within the study area.

The polychaetes (bristle worms) are the group with the highest number of species. This group consists of both infauna and epifauna species, including both highly specialised and opportunistic species which are able to thrive under nearly all conditions. The molluscs (bivalves and snails) and crustaceans (mainly amphipods, scuds) are groups with the second and third highest species number. In soft sediments without vegetation or other structuring elements like mussel assemblages, the molluscs (bivalves in particular) are more prominent. Such conditions prevail in large parts of the northern Fehmarn coast, but most notably in the deeper waters in general. In areas with vegetation or Blue Mussel assemblages, species richness of amphipods often exceeds mollusc species number. Such areas are mainly found in the western part of the Lagoon of Rødsand, along the east coast of Fehmarn, east of the German mainland around Großenbrode, around Staberhuk and at places off Lolland.

Blue Mussels by far dominate the biomass in the shallow waters of the Fehmarnbelt. Mussel biomass (see Figure 0-3) varied between 0 at deep waters below the pycnocline and a maximum of 120 g AFDW m^{-2} on the south-west coast of Lolland (Albuen Bank) at 8–12 m depth (averaged over areas of 750 $\times$ 750 m). At smaller scales (sample size) mussel biomass exceeded 1,000 g AFDW m^{-2} in few samples. Another area with an extended mussel population is the area west of Fehmarn that are known to support wintering Eider ducks.

Within the Fehmarnbelt area, the total mussel biomass was estimated to 27,000 tons AFDW, which is equivalent to 480,000 tons wet weight.

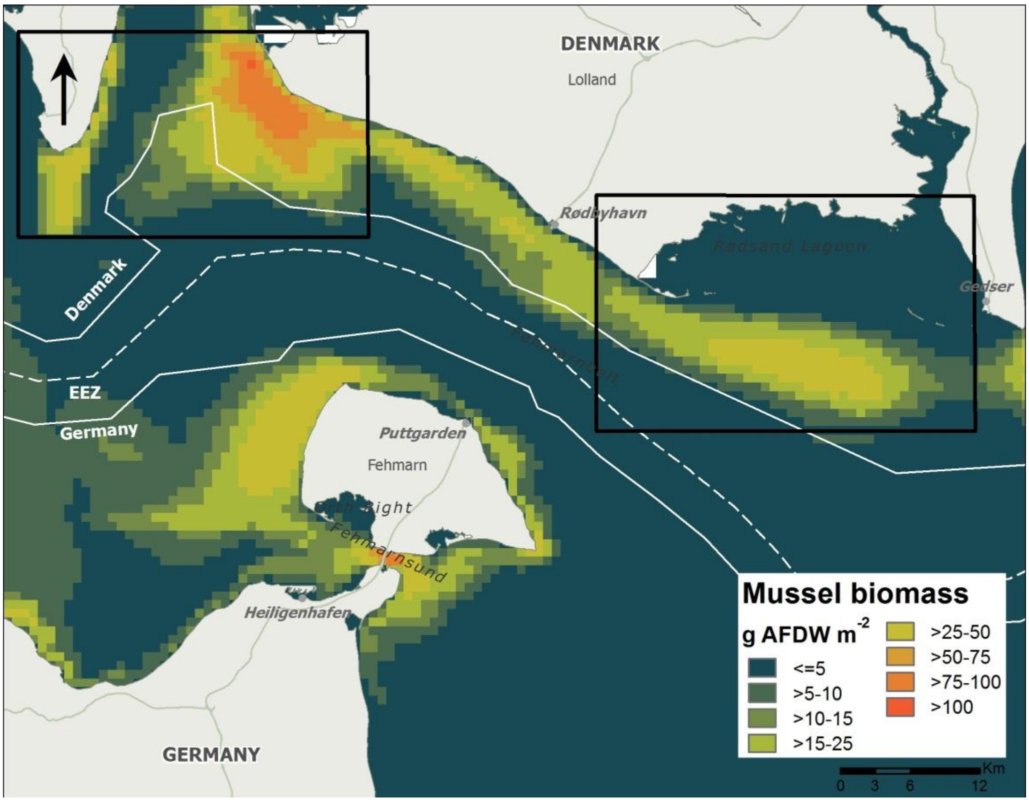

Figure 0-3 Map of mussel biomass (g AFDW m^{-2}) in the Fehmarnbelt region. Rectangles inserted delineate areas where biomass was corrected for mussel condition. The biomass values refer to averages over 750 x 750 m grid cells.

When Blue Mussels were excluded, the highest biomass was found in the deeper waters of the central Fehmarnbelt between the subtidal slopes of the Fehmarn and Lolland coasts, primarily due to presence of large, long-living bivalve *Arctica islandica*. *A. islandica* can reach a wet weight of 45 g (AFDW approx. 3 g) at a size of 65–70 mm. In comparison, most other species have wet weights below 1 g. A notable feature is a lower biomass along the Lolland coast compared to most of the Fehmarn coast (Figure 0-4). At the Fehmarn coast, the higher biomass is caused by the bivalves *Mya arenaria* and *Cerastoderma* spp. that are the largest bivalves (apart from Blue Mussels) in shallow waters. Thus, the biomass distribution to a large degree reflects the distribution and occurrence of large bivalves.

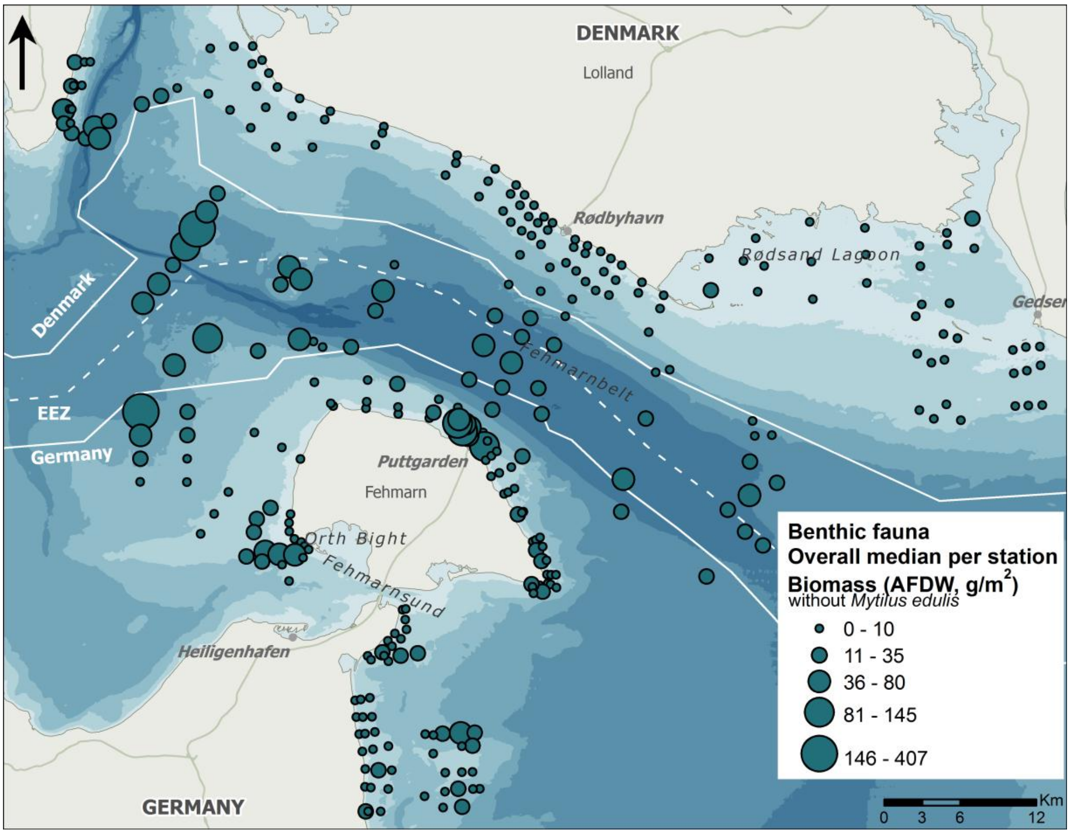

Figure 0-4 The median biomass (grams ash-free dry weight – AFDW - per square meter: gm^{-2}) at each of the sampling stations within the study area, over the entire field campaign between spring 2009 and autumn 2010. The biomass of the Blue Mussel Mytilus edulis *is not included.*

Fauna communities

Based on the co-existence of species and linked to environmental parameters, the fauna assemblages at each station were divided into specific species communities. Based on statistical analyses (combining fauna data with environmental data including depth, salinity, sediment grain size and organic content, substrate type, oxygen concentration and max sheer stress at seabed) these station data were expanded to a spatial prediction of the occurrence of the communities throughout the investigation area around the Fehmarnbelt.

Overall, nine in- and epifauna communities were derived (Table 0-1). Two of them were found in both deep (below pycnocline) and shallow waters (above pycnocline). Four communities were unique to deep waters and three communities were only found in shallow waters. The extent of communities in the Fehmarnbelt is shown in Figure 0-5. Each particular benthic fauna community has been named according to a prominent indicator species of that community.

Table 0-1 Summary characteristics of benthic fauna communities identified in the Fehmarnbelt. Except for the Mytilus community, mussels occuring in the communities are not included in biomass estimates.The biomass value of the Mytilus community stated between brackets is the mean total biomass without mussel biomass.

Community	Area (ha)	Depth zone	Total species number	Mean total biomass in g AFDW m^{-2}	Key features
Arctica	112,239	deep	261	47	infauna – muddy sediments
Bathyporeia	15,635	shallow	61	1	infauna – exposed sand
Cerastoderma	11,171	shallow	87	32	infauna – sheltered immobile soft bottom
Corbula	13,246	deep	180	12	in-/epifauna – transitional along pycnocline
Dendrodoa	21,251	deep	271	46	epifauna – hard substrate/algae
Gammarus	74,243	shallow/ deep	196	7	epifauna – hard substrate/algae
Mytilus	30,935	shallow/ deep	152	100 (8)	epifauna – hard substrate
Rissoa	11,635	Shallow	42	6	epifauna – eelgrass
Tanaissus	2,333	Deep	182	20	infauna – exposed sand and gravel
Total	292,739				

In terms of area extent the Arctica infauna community is by far the most important, and in terms of species richness and biomass the Arctica community is the second highest in the Fehmarnbelt. The community occurs in muddy and sandy muddy sediments in waters deeper than 25 m. The community features the second-largest number of species after the Dendrodoa community, with a very clear decreasing trend in species richness from west to east. The namesake species *Arctica islandica* is a long-living, large bivalve, commonly called Ocean Quahog and can get over 100 years old. The Arctica community strongly resembles the classical *Abra alba* community.

The Bathyporeia infauna community occurs in exposed shallow (< 5 m) sandy areas, where mobile sands are exposed to wave action and the dynamics of the sand motion does only allow deeply burrowing species such as the soft-shell clam *Mya arenaria* or fast-burrowing species such as the amphipod *Bathyporeia* to inhabit the environment. In the greater Fehmarnbelt the community is found south-east of the Rødsand Lagoon, at the north coast of Fehmarn and along the Flügge Sand spit off the Orth Bight. Overall, the community has low species richness and very low biomass underlining that mobile sand is a harsh environment.

The Cerastoderma infauna community is found predominantly in shallow waters above the seasonal separation between the brackish surface water and the more salty bottom water (the halocline). The Cerastoderma community is associated with soft bottom that is muddy to sandy. In the investigation area the community was mainly found in the eastern part of the Rødsand lagoon, off the north coast of Fehmarn, and on the Flügge Sand area off the south-western coast of Fehmarn. The community is rather species poor but with a high biomass (*Mytilus* excluded) dominated by the filter-feeding bivalves *Cerastoderma* and *Mya*, and *Macoma*.

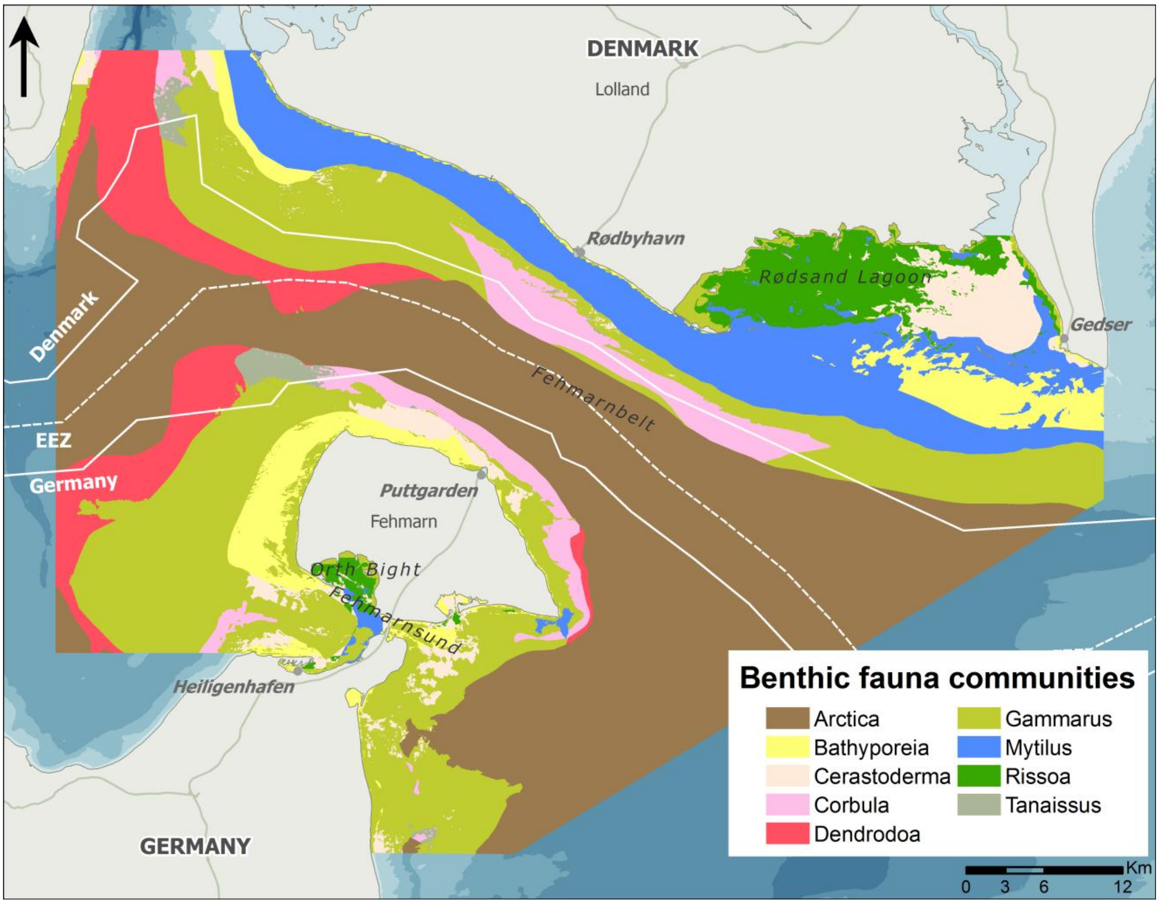

Figure 0-5 Predicted spatial distribution of the benthic fauna communities in the investigated area.

The Corbula community constitutes a transition community between shallow and deep water communities in waters of 10–20 m depth. The typical sediments are mixed and consist of sand, muddy sand, coarse sand, boulders and small mussel beds. The Corbula community is localised as two relatively narrow ribbons off the coast of both Fehmarn and Lolland and smaller in the Langeland Belt, offshore Lolland and southwest of Fehmarn, and offshore the German mainland. The biomass is dominated by several polychaetes and a few bivalves including and *Arctica islandica. Corbula gibba* giving name to the community is less important in terms of biomass.

The Dendrodoa epifauna community are characterised by hard substrate (sandy, partially coarse sediments, sometimes accompanied by boulders) in deeper waters (15–25 m). The community is named after the ascidian (sea squirt) *Dendrodoa grossularia* that lives as a filter-feeder attached to hard substrate. The Dendrodoa community is localised at the edges of the basin of the Kiel Bight offshore Fehmarn and Lolland. The Dendrodoa community has the highest species richness and high biomass due to many epibenthic species growing on the three-dimensional habitat.

The Gammarus epifauna community covers large areas in shallow waters where the seabed is dominated by benthic vegetation and areas with *Mytilus* assemblages. This habitat provides a 3 dimensional habitat and feeding environment for epifauna. Species richness is high and third largest among the 9 communities. Excluding Blue Mussels the biomass is low and is dominated by amphipods, isopods and gastropods. The species composition shows large overlap to the Mytilus community.

The Mytilus epifauna community is characterized by the occurrence of aggregations of the Blue Mussel *Mytilus edulis* together with an associated fauna. It is mainly found off the coast of Lolland where it occurs in water depths down to approximately 10 m. Around Fehmarn the most important areas are off Staberhuk and at the west coast. Mussels occur all over Fehmarnbelt and often dominate in terms of biomass, but to 'qualify' as a community *Mytilus edulis* should be the dominant species forming also the spatial structure of the habitat to a degree that enables the associated fauna to unfold. The associated fauna consists of species that utilize the hard substrate as settling and feeding ground (e.g. *Gammarus* spp., *Balanus* spp., *Corophium insidiosum*, *Littorina* spp.). Other species benefit from the presence of the mussels but are not dependent on it, like deposit feeders which are living on detritus and other remains of the Mytilus community (e.g. the polychaetes *Heteromastus filiformis*, *Marenzelleria viridis*, *Polydora cornuta*).

The Rissoa community is a shallow water epifauna community that is associated with eelgrass meadows (*Zostera marina*). The community has its largest extent in the western part of the Rødsand lagoon and in the Orth Bight, where dense eelgrass meadows occur. The community has the lowest species richness of the 9 communities and is also characterised by a low biomass of invertebrates. The namesake snail genus *Rissoa* belongs to the family Rissoidae which contains a number of snails represented in the community: *Pusillina sarsi*, *Rissoa membranacae*, *Rissoa parva*, and *Rissa violacea*. These snails typically sit on the leaves of eelgrass and feed on microalgae.

The Tanaissus infauna community named after the crustacean *Tanaissus lilljeborgi* has the least extent in the Fehmarnbelt. Habitats are characterised by sandy, partially coarse sediments in waters of around 15–22 m depth. The community features a moderate number of species that are most often present and a large proportion of infrequent species. Biomass is dominated by few filter feeding species and several large predators.

WFD assessment of Fehmarnbelt

The European Water Framework Directive (WFD) aims at establishing a good ecological status for European surface waters. Member states including Germany and Denmark have developed assessment methods for the classification of their coastal waters into five ecological quality classes (high, good, moderate, poor, bad), and benthic fauna is one of the biological quality elements included in assessments. Based on fauna data collected during the baseline study the ecological status was calculated for coastal waters in the Fehmarnbelt and adjacent waters.

The benthic indices used in Denmark and Germany differ in several aspects and they have not yet been intercalibrated. The assessment result shown in Figure 0.6 is based of application of the Danish index (DKI) in Danish waters and the German MarBIT in German waters. The assessment shows that the ecological status is moderate in Danish waters (along Lolland, in the Rødsand Lagoon, off Rødsand lagoon and west of Gedser) and also moderate in German waters (around Fehmarn, Fehmarnsund, and the assessed parts of German mainland).

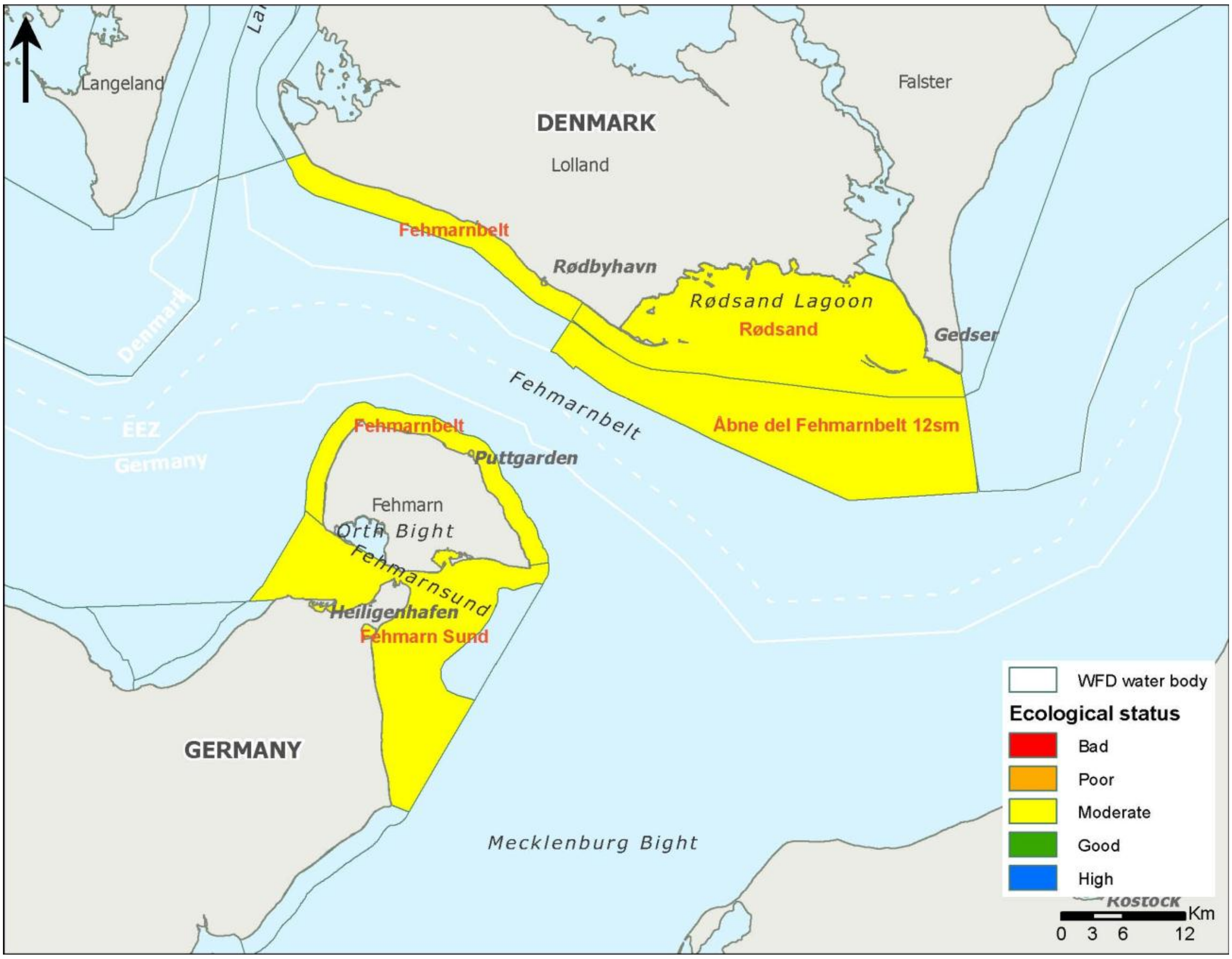

Figure 0-6 WFD assessments of the German and Danish water bodies on the basis of the baseline data for 2009–2010. All assessed water bodies were classified as having a 'moderate' ecological status. The colours used for the ecological status correspond to the ones defined in the Directive.

Importance

Within the framework of the Environmental Impact Assessment (EIA) of the Fehmarnbelt Fixed Link, the relevant environmental subcomponents including benthic fauna are classified according to a four-level Importance scale. The criteria are based upon legislative and on scientific and conservation arguments.

The following definitions of zones in the Fehmarnbelt area are used to describe the benthic fauna in context of their importance:

- Local: a geographically or ecologically separate part of the Fehmarnbelt area, such as Rødsand lagoon, the central Fehmarnbelt or the coasts of either Fehmarn or Lolland.
- Regional: the greater Fehmarnbelt area, including the eastern part of the Kiel Bight, the southern edge of the Langeland Belt, the Fehmarn Sound between the German mainland and Fehmarn, the Rødsand Lagoon and the western part of the Mecklenburg Bight.
- Pan-regional or between-regional: a scale which supersedes the regional scale, and applies to processes or fluxes that act between regions and therefore interconnects them. An example would be the larval recruitment of a species from a

source population in one region that settle in another, not necessarily neighbouring region. Pan-regional recruitment would make the latter (receptor) region's ecological integrity dependent on the ecological integrity of the former (donor) region.

The nine benthic fauna communities are classified into one of the four Importance levels (very high, high, medium and minor), according to specific criteria (Table 0-2). Characteristic species in this context are species that discriminate fauna communities from each other but also common typical species.

Table 0-2 Criteria for classification of the benthic fauna communities into one of the four Importance levels: Very high, High, Medium and Minor, and ranking of communities.

Importance level	Description
Very high	Benthic fauna communities that are determined by indicative or discriminate species which are protected under international conventions, like the FFH-guideline and/or HELCOM guidelines. The communities act on a between-regional scale with regard to ecosystem functioning. Community: Rissoa, Arctica
High	Benthic fauna communities that are determined by indicative or discriminate species which are protected under national legislation (BNatSchG and LNatSchG in Germany) and/or which appear on Red Lists. The communities act on a regional scale with regard to ecosystem functioning. Community: Mytilus, Dendrodoa, Tanaissus
Medium	Benthic fauna communities that are characteristic for the greater Fehmarnbelt area, and of importance for local ecosystem functioning. Community: Gammarus, Cerastoderma
Minor	Benthic fauna communities with a temporary character, e.g. subject to high environmental disturbance on short time-scales. Community: Corbula, Bathyporeia

The resulting benthic fauna community Importance map is shown in Figure 0-7.

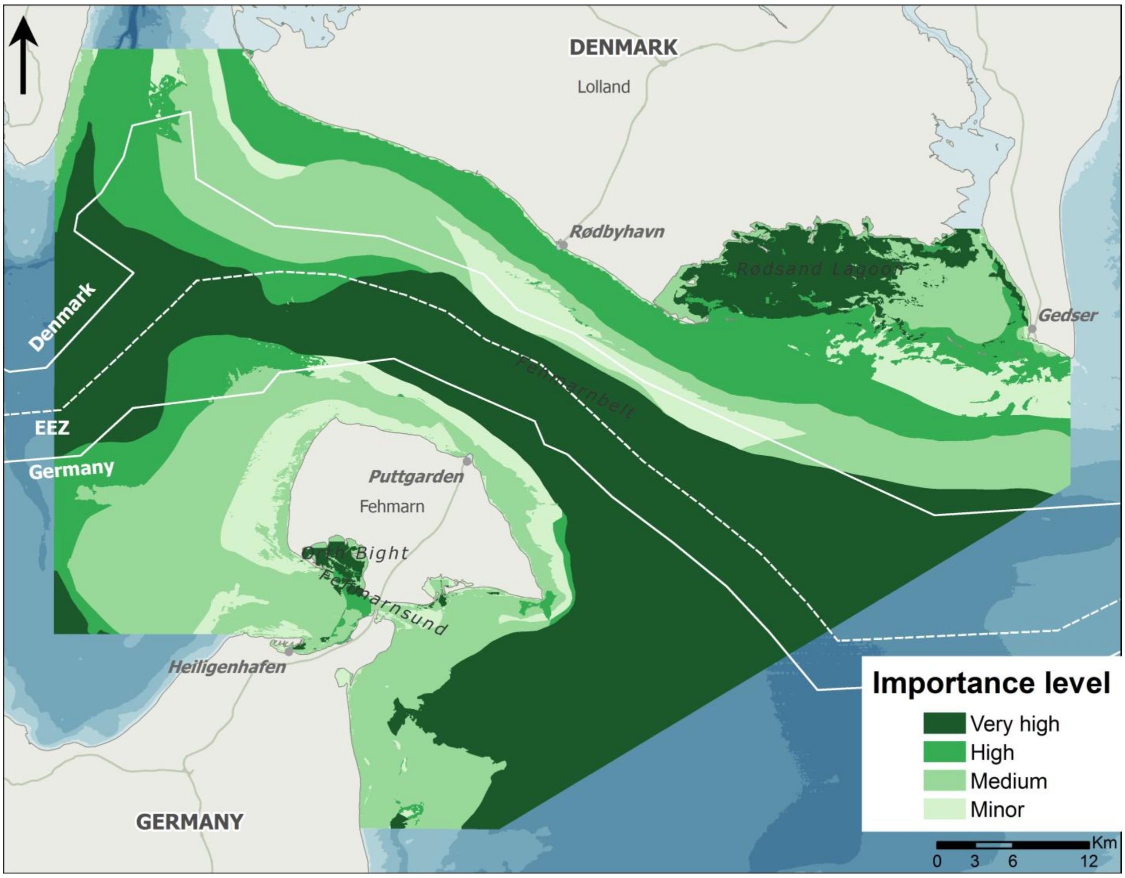

Figure 0-7 Benthic fauna community Importance map. In this map, the nine benthic communities have been classified according to the four-level Importance classification (very high, high, medium, minor).

The zones which are classified particularly as of "Very high" Importance include the deepest central part of Fehmarnbelt, the western part of the Lagoon of Rødsand as well as an area in the Orth Bight. These areas are dominated by either Arctica or Rissoa communities, from which they derive their "Very high" classification.

The areas classified as of "High" importance include the coastal zones of Lolland, the slopes and the deeper parts in the Langeland Belt and a region in the eastern part of the Kiel Bight, as well as outer boundaries of the Lagoon of Rødsand and Albue Bank SW offshore Lolland, which are dominated by Mytilus, Dendrodoa or Tanaissus communities.

Areas where the Gammarus or Cerastoderma communities dominate, and are therefore classified as "Medium", are found in shallow waters around Fehmarn island, in Sagas Bank southeast of Fehmarn, in and around the Fehmarn Sound, in the near-shore parts of Orth Bight, Großenbrode and the Eastern part within the Lagoon of Rødsand, as well as in the region southeast offshore Gedser.

The coastal zones west of the island of Fehmarn, as well as highly dynamic areas southeast offshore Gedser, are the regions for the dynamic Bathyporeia and Corbula communities and of "Minor" importance. There are also regions in the central part of Fehmarnbelt, in which the transition zones are located between the shallow mesohaline and the deeper polyhaline waters that are classified of "Minor" importance.

1 INTRODUCTION

Marine benthic macrofauna (‘benthic fauna’) represents a conspicuous and important component of shallow coastal environments, being very productive and able to establish large biomasses. Their roles in the ecosystem include *biogeochemistry*; *cycling of nutrients* and *food for higher trophic levels, including commercially important ones*; *(de)stabilizing bottom sediment*.

Common or Blue Mussel (*Mytilus edulis*) are confined to areas of firm substrate such as stones, artificial substrates and other mussels. Mussels play an important role in the coupling between primary production in the water column and secondary production at the sea bed (benthic-pelagic coupling) and serve as three-dimensional habitat (biogenic reef) for macroalgae, other invertebrates and small fish.

The distribution of abundance, cover and biomass of benthic fauna are regulated by a complex of physical, chemical and biological factors. Salinity, temperature, substrate type and availability, and food availability, are important for the horizontal distribution and abundance of species. Physical disturbance (ice scouring, wave exposure current velocity) are important for the vertical distribution. Phytoplankton availability (primary production), predation and interspecific facilitation are biological interactions that determine the spatial distribution and composition of benthic macrofauna communities.

1.1 The Baseline Study

The overall objectives of the baseline surveys are to provide a detailed description of the benthic fauna communities necessary for a subsequent Environmental Impact Assessment (EIA), and to establish a basis for possible future monitoring of the benthic fauna.

The purpose of this report is to present the results obtained from the Fehmarnbelt Fixed Link - Marine Biology Services (FEMA) benthic fauna baseline sampling programme, carried out in 2009 and 2010 with the specific objectives:

- To collect existing and historical data on benthic fauna in the Fehmarnbelt area from local monitoring programmes and scientific studies;

- To document and describe patterns in the distribution and abundance of marine benthic fauna in the proposed alignment area and in the adjacent areas, possibly impacted by the construction and/or operation of a fixed link;
- To provide baseline data for assessment of impacts from the proposed project; and
- To provide baseline data for a possible later monitoring of the development in benthic fauna during and after the establishment of the fixed link across Fehmarnbelt.

Due to the nature of the marine benthic macrofauna, the field campaign for the benthic fauna included dedicated in- and epifauna sampling.

Specific mussel investigations to provide an extensive overview, in addition to the in- and epifauna sampling, was carried out due to the importance of mussels for the bird investigations.

The approach in this study has been firstly, to identify communities of generally co-occurring species in the area, and secondly, to describe the horizontal and vertical patterns in cover and biomasses of communities and/or key species.

1.2 Reporting

The reporting of the outcome of the benthic fauna baseline study consists of three main reports:

- FEMA Benthic Fauna, 1st Year Baseline, Draft Report, submitted in May 2010;
- FEMA Benthic Fauna, 1st Year Baseline, Draft Report Update, updated version of the report including further exploration of historical data and updated baseline maps, submitted in November 2010; and
- FEMA Benthic Fauna Baseline Report, final version including two years of baseline data (present document).

This report focuses on documenting and describing patterns in the data collected during the FEMA baseline sampling campaign conducted in 2009 and 2010. Other data from the area, e.g. support data for bird studies in winter 2008/2009 and historical data, are considered in the overall synthesis for the baseline conditions.

In this document, the use of the word "species" means in most cases the description of a single species of a genus *sensu strictu*. However, in few cases it also includes the description of higher taxa (singular: "taxon"). This is the case mostly for uncommon taxonomic groups, which comprise more than one single species of the same or even different genera, e.g. Oligochaeta, Nemertina and Insecta.

1.3 The Report

The present Baseline Report has been prepared in accordance with the scope of work and the various tasks defined during the scoping process for the study.

The Benthic Fauna Baseline Report describes the results of two years of monitoring conducted as a part of the present study, other recent data sets and the results of the benthic fauna analyses.

The Benthic Fauna Baseline Report is divided in the following sections plus references:

- Summary and Conclusion – an extended summary of the main findings
- Introduction (Section 1) – brief introduction to the investigation and the report
- Materials and Methods (Section 2) - outlines the study area, describes the field programme and methods and analyses used
- Environmental Conditions (Section 3) – brief description of main controlling environmental conditions for benthic fauna
- Macrozoobenthos in Fehmarnbelt (Section 4) – extensive description of observed benthic fauna communities
- Blue Mussels in Fehmarnbelt (Section 5) – extensive description of Blue Mussels

- WFD Assessment (Section 6) - Water Framework Directive assessment
- Law Protected Benthic Fauna (Section 7) – outlines the identified law protected species
- Importance (Section 8) - definition and mapping of importance of benthic fauna
- Existing Pressures (Section 9) – brief description of existing pressures on the benthic fauna communities in the Fehmarnbelt and neighbouring areas

2 MATERIALS AND METHODS

The Fehmarnbelt is the sea strait between the German island of Fehmarn and the Danish island of Lolland (Figure 2-1). The Fehmarnbelt proper stretches from the southern end of the Langelandsbelt and the eastern end of the Kiel Bight in the west till the northern of the Mecklenburg Bight and Gedser Reef in the East. The study covers the potential alignment area and adjacent waters, based on extensive data acquisition and including biological parameters like abundance, biomass, species diversity and community structure. Special emphasis was put on the Blue Mussel *Mytilus edulis* due to its key role in the coastal food web.

The baseline fauna programme and its coverage was designed to meet the objectives of the study. Furthermore, the programme was set up with the purpose to provide:

- benthic fauna data to support other Fehmarnbelt Marine Biology studies of, for example, marine benthic vegetation and marine habitats, as well as other biological components (fish and birds).
- identification and evaluation of potential reference areas for the key fauna communities, necessary as baseline data for a possible future monitoring programme where changes in the impact zone are compared with natural changes in a reference area.

This section presents the materials and methodology employed for the collection of the primary data sets of the Benthic Fauna Baseline sampling, performed during the years 2009 and 2010.

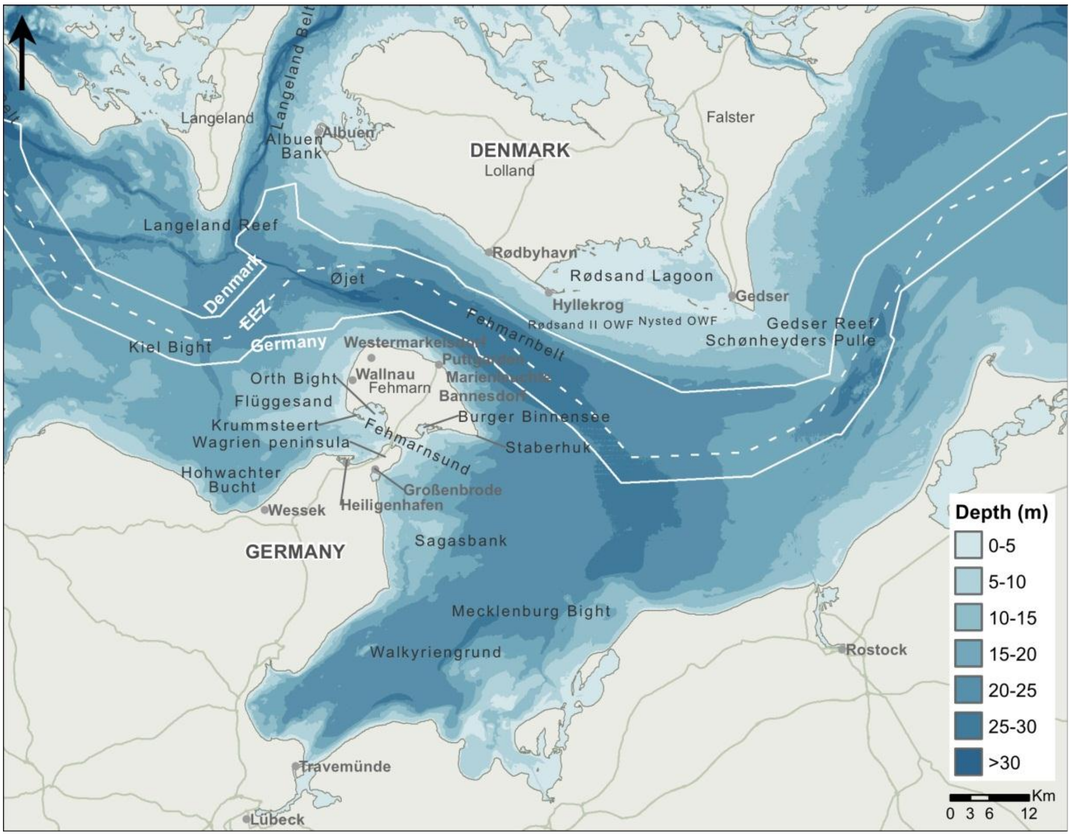

Figure 2-1 The names of geographical locations used within the baseline descriptions.

The Benthic Fauna Baseline sampling is composed of the following elements:

1. Shallow water in- and epifauna sampling (≤ 10m)

2. Deeper water in- and epifauna sampling (> 10m)

3. Blue Mussel (*Mytilus edulis*) – spatial distribution, coverage and quantitative sampling

4. Method harmonization and quality assurance

Supplementary data, forming part of the used material and methodologies for the performed data analyses, are also described in this section.

The following Natura 2000 areas have been included in the benthic fauna baseline investigations:

Natura 2000 areas	**Note**
DE 1533-301 (Staberhuk): 21 epifauna sites DE 1632-392 (Ostsee östlich Wagrien): 21 epifauna sites DE 1733-301 (Sagas Bank): 21 epifauna sites DK 00VA200[1] (Langeland): 20 epifauna sites DK 006X238 (Rødsand lagoon): 20 infauna sites	In these areas the sampling sites were at depths of 3, 6, and 9 m respectively (one sample per depth level).
DE 1332-301 (Fehmarnbelt):	In this area the two relevant habitat types (reefs and sandbanks) were sampled according to their extent. In the 2009 sampling, two reef areas and one sandbank area was defined. In each area, a station grid of 3 times 3 stations was sampled (9 stations altogether). In total 27 grab samples, 9 dredge hauls and 9 sediment samples were taken during the campaigns in 2009.
DE 1631-392 (Östliche Kieler Bucht):	Sampling in this area was not only for NATURA 2000 assessment but supported also the investigations of the bird group. 8 sites were chosen in 2 transects, each site comprised 3 quantitative Van Veen grab samples and one grab for sediment analysis.
DE 1733 301 (Sagas Bank):	In this area the relevant habitat types were sampled according to their extent. Altogether 8 sites (north and south of Sagas Bank) were chosen in 2 transects for infauna investigations. Each site comprised 3 quantitative Van Veen grab samples and one grab for sediment analysis.

[1] Anchoring is not permitted in this Natura 2000 area, sampling was therefore only conducted if it was possible under the given conditions

The location of the different Natura 2000 areas is illustrated in Figure 2-2.

It should be noted that results from surveys in Natura 2000 areas constitute an integral part of the descriptions and analyses provided in the following. A brief baseline description of the benthic fauna within each Natura 2000 area will be reported separately to Femern A/S.

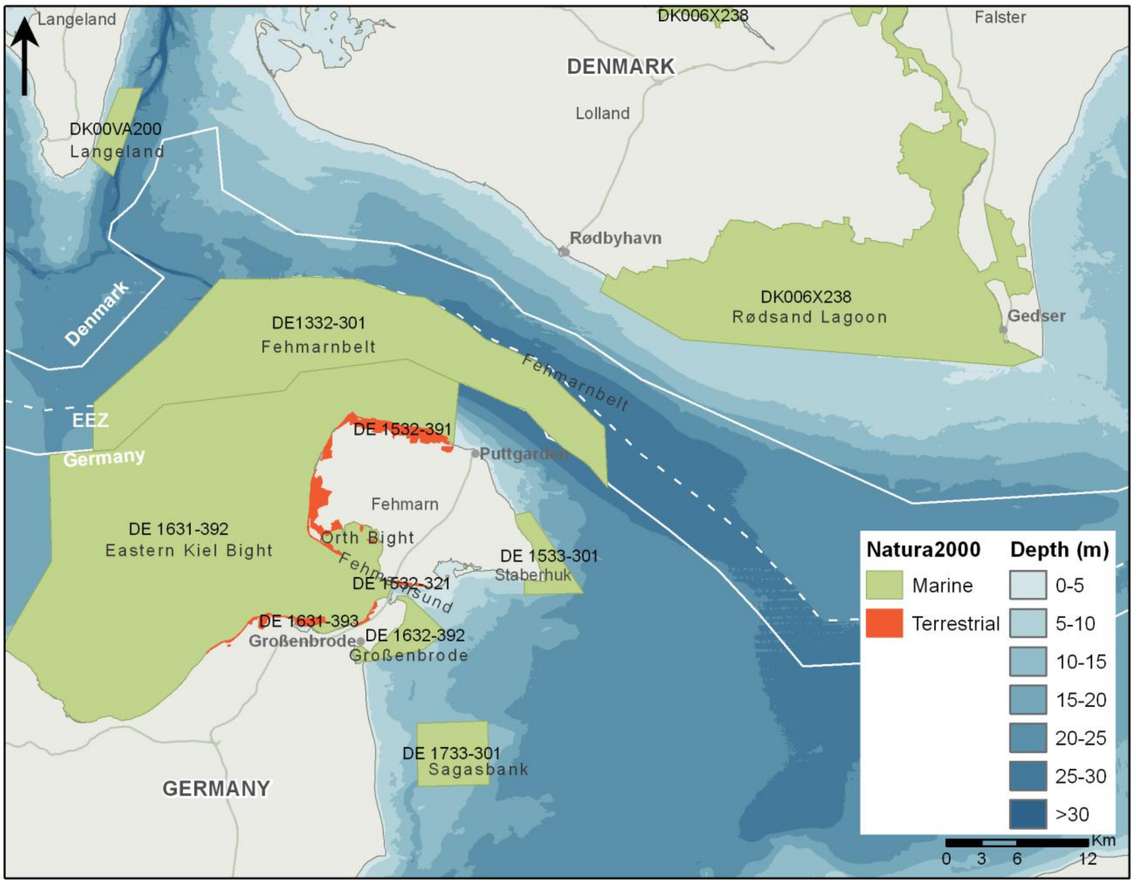

Figure 2-2 Investigation area with marine Natura 2000 areas included in the survey.

2.1 Field Campaign 2008–2010: in- and epifauna

The field campaign for the benthic fauna baseline sampling summarised in Table 2-1 was carried out in spring, summer and autumn in both survey years (2009 and 2010). The sampling was divided into "shallow" and "deep" waters campaigns because of two reasons:

1. The sampling in the shallow areas was done by SCUBA divers using a Kautsky sampling frame, since a larger vessel cannot take grab samples in very shallow waters and the propeller will disturb the sediment and thus make undisturbed samples impossible. The sampling in the deeper waters was done with a *Van Veen* grab sampler, operated from a ship. SCUBA diving is not advisable in deeper waters because of security reasons and restrictions for scientific divers.

2. From former experience (see Appendix 10), a clear separation was observed between marine and polyhaline species in the deeper part (below pycnocline) and mesohaline species in the shallow part (above pycnocline) of the Fehmarnbelt. The shallow waters typically fall under the scope of the Water Framework Di-

rective and have special requirements towards sampling design, which had to be taken into account.

Sampling was not possible in military areas (Hohwachter Bucht and smaller areas in the Fehmarnbelt) and in the area where the Rødsand II Offshore Wind Farm (OWF) was being constructed.

All infauna sampling was done twice per survey year, in spring and autumn. The spring sampling was conducted in the period from 1st May – 15th May to avoid a large "spring signal" (mass arrival of juvenile specimens) in the shallow water samples. Although this spring signal generally occurs later in deeper waters, the sampling periods were equal for shallow and deep water for maximum comparability. The autumn sampling was carried out in the period from 15th September – 15th October for both shallow and deep water infauna. Single samples were taken outside these time periods due to bad weather conditions.

Epifauna sampling was done once per survey year and was conducted in the beginning of summer in June/July.

Sediment sampling was done in conjunction with the infauna sampling in 2009 Table 2-2.

The software packages PRIMER, SPSS, R, and AquEco were used to analyse the structure of the benthic community and the importance of the measured environmental variables.

Table 2-1 Benthic infauna – summary of the baseline field surveys. Numbers in red indicate deviations where nominal counts were not reached. Deep epifauna samples have been taken at the same stations as the deep infauna samples..

Infauna	**nominal counts**			**actual sample counts per sampling campaign**						
Area	**station count**	**replicates**	**sample count**	**Spring 2009**	**Summer 2009**	**Autumn 2009**	**Spring 2010**	**Summer 2010**	**Autumn 2010**	**Surveyor**
Lolland/Falster	84	1	84	84		84	84		84	DHI
Rødsand	20	1	20	20		20				DHI
Sum Infauna – shallow waters Danish coast	**104**		**104**	**104**		**104**	**84**		**84**	
Fehmarn	84	1	84	84		84	84		83	MariLim
Sum Infauna – shallow waters German coast	**84**		**84**	**84**		**84**	**84**		**83**	
Fehmarnbelt	59	3	177	175		177	176		177	IOW
Hohwachter Bucht	8	3	24	24		24	24		24	MariLim
Sagasbank	8	3	24	24		24				MariLim
Sum Infauna – deep waters	**75**		**225**	**223**		**225**	**200**		**201**	
Total Infauna	**263**			**411**		**413**	**368**		**368**	

Table 2-2 Sediment – summary of the baseline field surveys.

Sediment	**nominal counts**			**actual sample counts per sampling campaign**						
Area	**station count**	**replicates**	**sample count**	**Spring 2009**	**Summer 2009**	**Autumn 2009**	**Spring 2010**	**Summer 2010**	**Autumn 2010**	**Surveyor**
Sediment – shallow waters Danish coast	104	1	104	104		104				DHI
Sediment – shallow waters German coast	84	1	84	84		84				MariLim
Sediment – deep waters	75	1	75	75		75				IOW
Total Sediment	**263**			**263**		**263**				

2.1.1 *Sampling stations*

Sampling stations are located throughout the entire Fehmarnbelt area, including the Lagoon of Rødsand, south-east Langeland, the eastern Kiel Bight, east off the Wagrien peninsula and the southern-most group of stations at the Sagasbank (Figure 2-3). The sample stations were arranged in transects perpendicular or parallel to the coast.

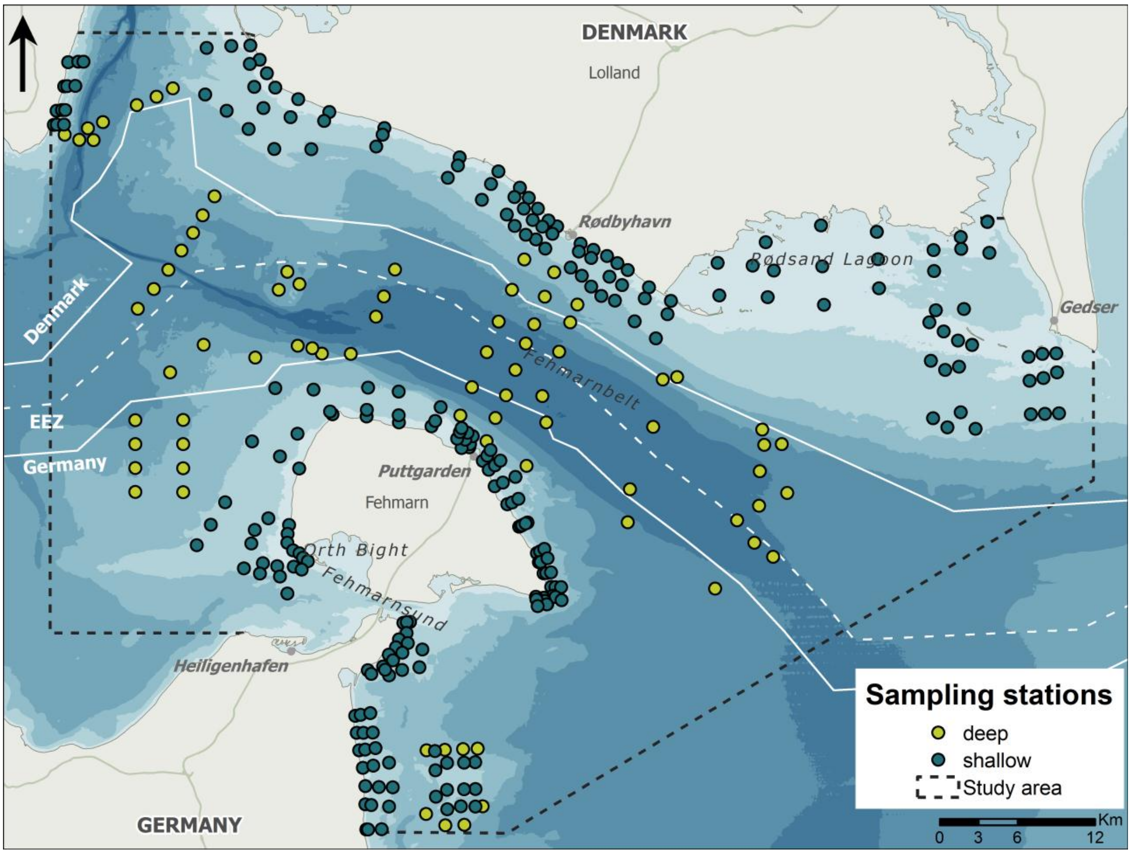

Figure 2-3 The geographical positions of the sampling stations for the benthic fauna baseline sampling campaign. The dark-coloured symbols denote shallow stations, whereas the light-coloured symbols denote deep stations. For more details see Appendix 2.

At each sampling station where epi- and infauna samples were taken, the following parameters were recorded:

1. Geographical position (WGS 1984)
2. Date and time
3. Weather and wind conditions (ICES codes)
4. Sediment type (macroscopic, visual description)

2.1.2 Shallow water sampling (≤ 10m)

Infauna samples were taken only in soft bottom, which was defined as sediment without plant communities and without rock or stones (according to the German WFD guideline). Sediment comprised all grain sizes from muddy sediments (< 20 µm) to gravel (5 mm). Abundance and biomass sampling was done at sampling stations at certain depths. The nominal depths for soft substrate sampling stations were 3 m, 6 m and 9 m.

Benthos samples (in- and epifauna) were taken by divers using a *Kautsky* sampling frame with a sample area of 0.1 m² and a fine mesh net on one side (Figure 2-4). The exact procedure is specified in the German Standard Operating Procedure (SOP), which is mandatory for all German certified laboratories. The obtained samples were fixated in 4 % buffered formaldehyde until further processing.

Sediment samples were taken with a diver-operated core with an inner diameter of 5 cm. The extracted core was supposed to contain the uppermost 5 cm of the sediment, or else to be rejected and taken again. The sediment samples were only taken during the 2009 campaign, and amounted to about 180 sediment stations in the shallow water sampling programme.

In addition to the common parameters recorded at each station mentioned above (Figure 2-3), the following parameters were collected or recorded:

- the presence of biogenic structures in the surrounding area
- faecal casts of *Arenicola marina* (lugworm)
- siphons of *Mya arenaria*
- presence of sea star *Asterias rubens*
- presence of shore crab *Carcinus maenas*
- presence of Anthozoans (sea anemones)
- Secchi depth (water transparency)
- 3-5 still photographs from each sampling station in order to illustrate the sampling habitat

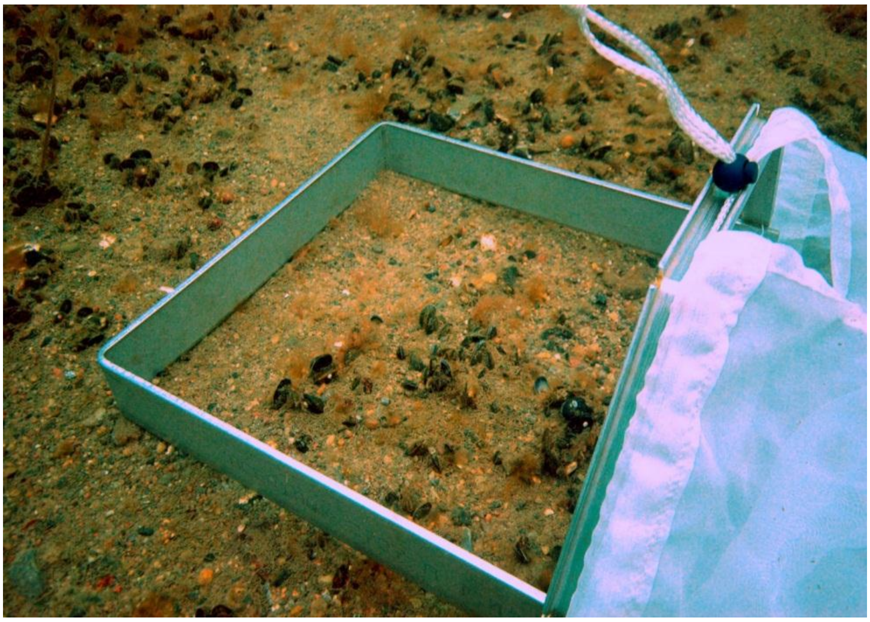

Figure 2-4 A Kautsky sampling frame used for benthic macrofauna sampling by SCUBA divers in the shallow waters above the pycnocline.

2.1.3 Deep water sampling (> 10m)

The deep water infauna sampling was performed from aboard a research vessel equipped with sampling facilities (winch, grabs, dredge, etc.). A total of about 70 sampling stations, organised in transects and clusters, were sampled during both the spring and autumn campaigns in 2009 and 2010, see Figure 2-3. Each station comprised 3 quantitative replicate grab samples for benthic fauna, one grab sample for sediment analysis and one qualitative dredge haul.

The sea bed sampling was done using a *Van Veen* grab (Figure 2-5) for infauna:

- *Van Veen* grab, weight 70–100 kg, 0.1 m² sampling surface, net covered lid, warp-rigged
- Sieve with 1000 µm mesh size; in case of large proportion of coarse and medium-grained sand or gravel, the sample should first be decanted through a sieve and rinsed at least five times. Fixation in 4 % buffered formalin.
- Sediment grab for analysis of sediment parameters (grain size, organic content)

Figure 2-5 A Van Veen grab sampler, operated with a large winch, from a ship. The grab sampler is used to sample sediment and benthic infauna in the deep waters below the pycnocline.

Additional dredge hauls were done for qualitative epifauna sampling, based on the German SOP:

- Dredge: width of 1 m, mesh size of 1 cm; duration of dredge hauls: ca. 5 minutes, trawling speed approx. 1 knot (= 1 nautical mile/hour), i.e. a length of approx. 150 m

2.2 Field Campaign 2008-2010: Blue Mussels

The Blue Mussel (*Mytilus edulis*) is especially abundant in the Danish coastal zone and is an important component of the benthic ecosystem. Moreover, it comprises a large part of the diet of many sea birds, like diving ducks (e.g. Eider ducks). Detailed knowledge of Blue Mussels is thus essential for the bird studies within the Fehmarnbelt baseline investigations.

In addition to the benthic in- and epifauna sampling campaigns, the spatial distribution, coverage, biomass, size distribution and condition of the mussels were determined with a separate, dedicated Blue Mussel campaign based on transect measurements and other sampling. The positions of transects are shown in Figure 2-6 and an overview of the mussel sampling programme is provided in Table 2-3.

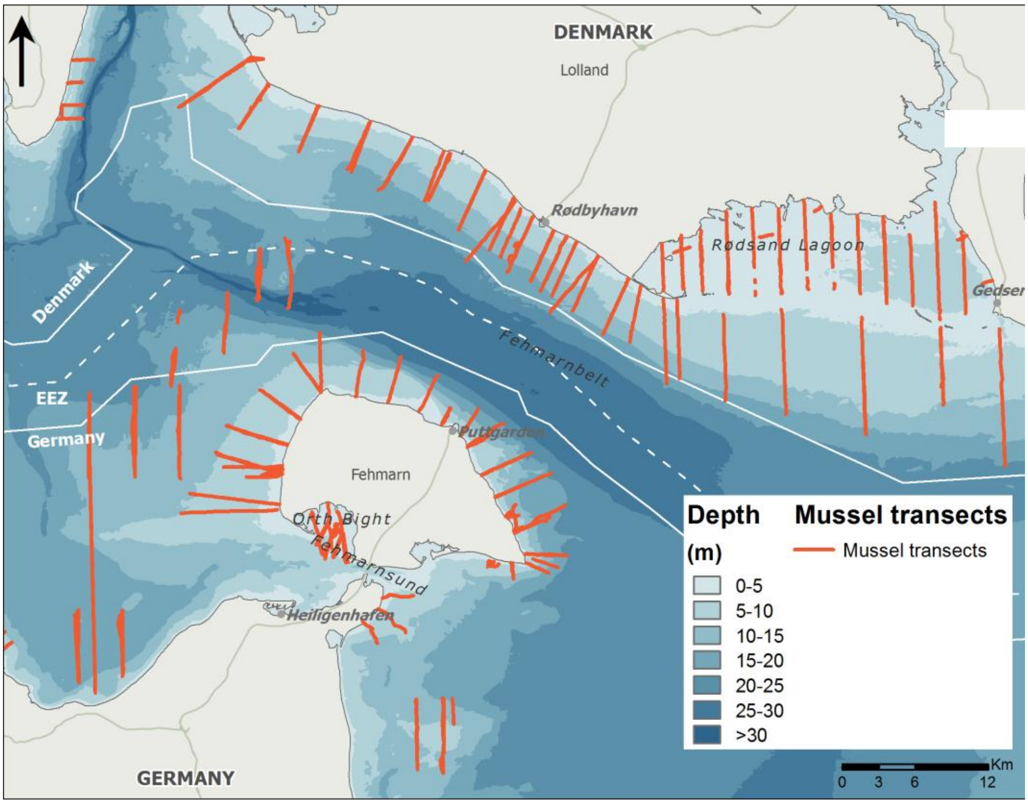

Figure 2-6 Sampling transects to determine the spatial distribution of mussels.

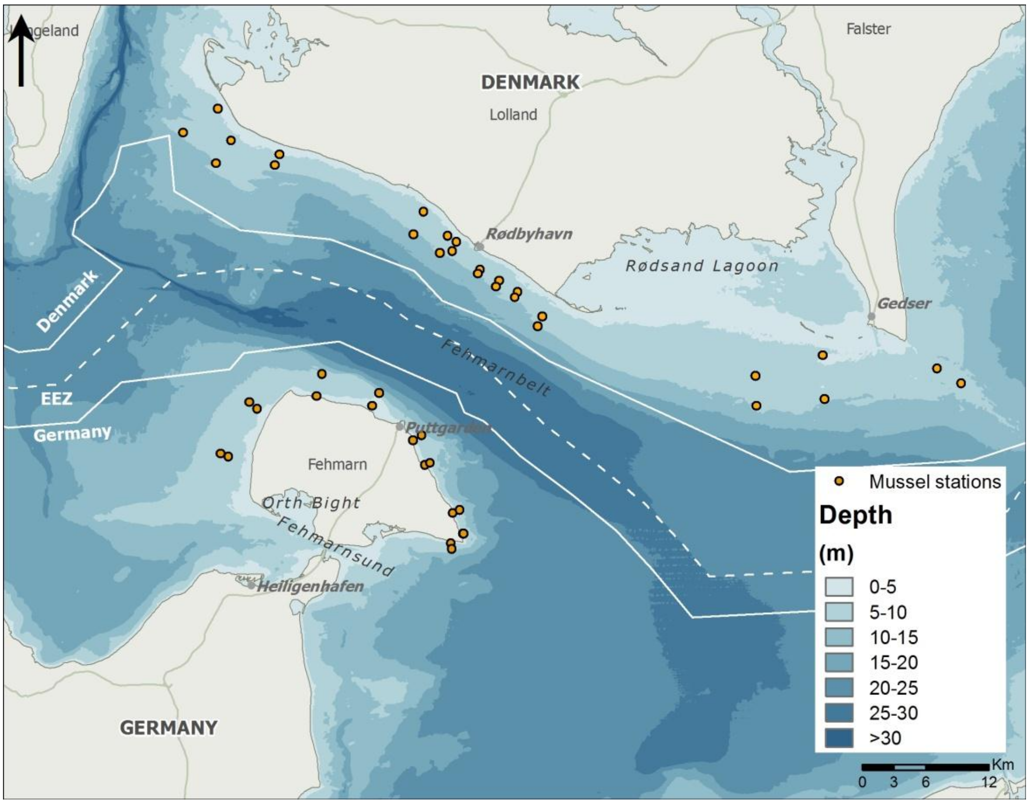

Figure 2-7 The geographic position of the dedicated mussel sampling stations in Fehmarnbelt.

Table 2-3 Summary of field surveys for mussels of the benthic fauna baseline investigations.

Survey component	**Stations in 2008**	**Stations in 2009**	**Stations in 2010**	**Replicates per station**	**Sampling Frequency**	**Surveyor**
Mussels - shallow water Danish coast		26	5 (monthly sampling)	5	Summer 2009, winter-spring 2010 (monthly)	DHI
Mussels - shallow water German coast		32	4 (monthly sampling)	5	Summer 2009, winter-spring 2010 (monthly)	Marilim
Mussels – support data for bird studies	25			5	Winter 2008/2009	DHI
Mussels – dredge samples Danish coast			3 hauls (280 m^2)		September 2010	DHI
Sum mussels	**25**	**58**	**9 + 3**			

2.2.1 *Mussel methodology*

The spatial distribution of *Mytilus edulis* was estimated based on continuous under water (UW) video recordings coupled with GPS- and depth-data recordings along predetermined transects (Figure 2-6). Along the transects, usually ranging between 2 m to 15 m water depths, the percentage coverage of mussels was estimated.

The video recordings were performed continuously within the WFD area (1 nautical mile [nm] zone). Outside the 1 nm zone, video transects were based on a "gap-wise" recording: A continuous stretch of 100 m was recorded, the next 200 m were skipped and then again 100 m were recorded and so on.

2.2.2 *Video transects*

Video recordings along transects perpendicular to the coast were carried out in both hard bottom and soft bottom areas. The purpose of the video recordings was to establish and document the area distribution of *Mytilus edulis* and to define biomass sampling sites.

Video transects were distributed on both sides of the proposed alignment area along the coasts of Lolland and Fehmarn and in the Natura 2000 areas: SCI DK 006X238 including Rødsand Lagoon, SCI DK 00VA200 Reef south-east of Langeland, SCI DE 1332-301 Fehmarnbelt, SCI DE 1533-301 Staberhuk, SCI DE 1631-392 eastern part of Kiel Bight, SCI DE 1632-392 Großenbrode and SCI DE 1733-301 Sagas-Bank.

2.2.3 *Quantitative sampling*

Quantitative data about *Mytilus edulis* (biomass, length distribution and condition) were obtained from diver-operated frame samplings (frame area: 25 × 25 cm = 625 cm^2). The sampling sites were selected on the basis of the results of the video surveys. Depending on the cover percentage of mussels (30 % or higher), sampling sites were selected along each video transect at approximately similar depths (around 6 m and 10 m). At each site the diver assessed the coverage of *Mytilus*, macroalgae, stones and sand. Each sample was placed in a net bag and transported to the surface. Representative still photos (approx. 3-5) were taken in order to characterise the sampling site. All replicate samples were unfixated (i.e. no ethanol or formaldehyde was added to the samples) and stored in a freezer until further processing.

The following parameters were recorded at each sampling site:

- Position (WGS84)
- Date and time
- Water depth
- Coverage of *Mytilus edulis*, macroalgae, stones and sand

In the laboratory, each replicate sample was processed separately. *Mytilus* individuals were sorted into 5 mm size classes starting with specimens >5 mm (5-10 mm, 10-15 mm, 15-20 mm, 20-25 mm, etc.).

From the collected mussels the following parameters were measured:

- Abundance (number of individuals) and size distribution frequency (see above)

- Biomass per sample: total wet weight (all classes), dry weight and ash free dry weight of each size class separately (all including shells)

For samples where there were too many mussels (>500 individuals), dry weight (DW) and ash free dry weight (AFDW) were determined for at least a minimum number of mussels within each size class, see Table 2-4.

Table 2-4 Size classes, mussel sampling

Size class	Minimum number of mussels
5-10 mm	50
10-15 mm	50
15-20 mm	30
20-25 mm	30
25-30 mm	20
30-35 mm	20
>35 mm	10

Video transects were taken along both the coasts of Fehmarn and Lolland and in some NATURA 2000 areas. These transects were distributed according the knowledge of spatial distribution of mussels obtained from the feasibility study and national monitoring programs (see Figure 2-6).

About 30 of the combined vegetation/mussel video transects were analysed for mussel coverage, 16 on the Danish side (excluding transects of the Rødsand lagoon) and 12 on the German side (excluding transects of the Orth Bight). These vegetation video transects were recorded in connection with summer sampling as part of the Benthic Vegetation Baseline work programme (FEMA 2013a), but analysis for mussel coverage was done in accordance with the fauna programme.

To ensure adequate data for the Baseline studies, it is necessary to obtain additional information about mussel coverage and biomass in these areas. Therefore, a total of 13 video transects were recorded during the yearly surveys on the Danish side and another 9 transects on the German side. In Germany, 5 transects were located in Hohwacht Bight (DE 1631-392; also as support for bird studies being the same transects as for the winter 2008/2009 studies), 1 within the NATURA 2000 site Staberhuk (DE 1533-301), and 3 within the NATURA 2000 site Großenbrode (DE 1632-392). In Denmark 7 transects were placed within a distance of 7 km west and east of the alignment. Another 6 reference transects were located further away along the Lolland coast: 3 transects as at 21-29 km west, and 3 transects at 29-46 km east of the alignment. The only NATURA 2000 area in the Danish part of the study area of Fehmarnbelt is the Lagoon of Rødsand. This lagoon is almost exclusively dominated by seagrass and soft sediment, and has virtually no mussels. Therefore, mussel transects have not been recorded in the Lagoon of Rødsand.

It should be noted that the exact extent of the quantitative sampling depended on the mussel abundance detected by the analysis of video recordings. About 60 sampling areas for mussel sampling were used in 2009, about 25 on Danish side and 35 on German side. In 2008 (winter 2008/2009) 25 sampling stations were used. Depending on the coverage of mussels, 2 sampling sites were selected per video transect as outlined above. At each sampling site, 5 replicates were collected.

During the winter and spring in 2010 mussels were sampled at monthly intervals (ice permitting) to follow development in biomass (AFDW) in the mussel population. These data was used in the calibration of the mussel model. Replicate frame samples (0.0625 m^2) were collected by divers at 5 stations along the Lolland coast and, at 4 stations along the Fehmarn coast. Both the sample locations (located at 6m and 9m depth) and sample workup procedures (i.e. abundances, wet weight, dry weight, ash free dry weight of size classes, followed by allometric regression between shell length and AFDW and calculating meat content as an index for condition)were identical to those used in the spring-summer-autumn campaigns..

In September 2010 dredge samples were collected to support the conversion of mussel coverage data to biomass per m^2. Eight transects perpendicular to the Lolland coast with a total length of 1500m were planned but presence of boulders and stones made it impossible to obtain samples around the alignment and eastwards. In contrast, parts of two transects Lo-W8 and Lo-W9 (Albuen Bank) could be sampled at depths ranging between 7.4 and 13.5m and covering a swept area of 280 m^2.

The dredge was a weighted 100 cm x 25 cm commercial oyster dredge towed at 1.5 knots. The dredge was fitted with a video camera recording entire dredge tracks to provide information on position, depth, mussel coverage, the catch efficiency of the dredge including presence of stones 'tipping' the dredge and the filling of the dredge (Figure 2-8).

Figure 2-8 Snapshots from video recording of dredge sampling of mussels in the Fehmarnbelt on 29 September 2010.

After bringing the dredge on deck empty shells, macroalgae, crabs etc, was sorted out of the sample and total wet biomass was measured using an electronic fish balance. Subsamples were subsequently analysed for wet weight – ash free dry weight relationships.

Like in any dredge sampling, the efficiency of the oyster dredge was not 100%. In this activity sampling efficiency was determined for each dredge track by quantifying the % of time the dredge was sampling with:

- 100% efficiency (i.e. lower frame part deeply submerged in sediment/substrate and no escapes),
- 0% efficiency (i.e. frame not touching the sediment)
- 66% efficiency (lower frame part touching but not fully embedded in substrate and minor escapes)
- 33% efficiency (lower frame part touching but not embedded in substrate and some escapes occurring)

Video was played at half speed during evaluation of efficiencies.

After correcting for dredge efficiency the accumulated biomass of mussels from each of the three dredge tracks was compared to the average of cover-percentages estimated from the same tracks covered by video-transects sampled in 2009 (Figure 2-9).

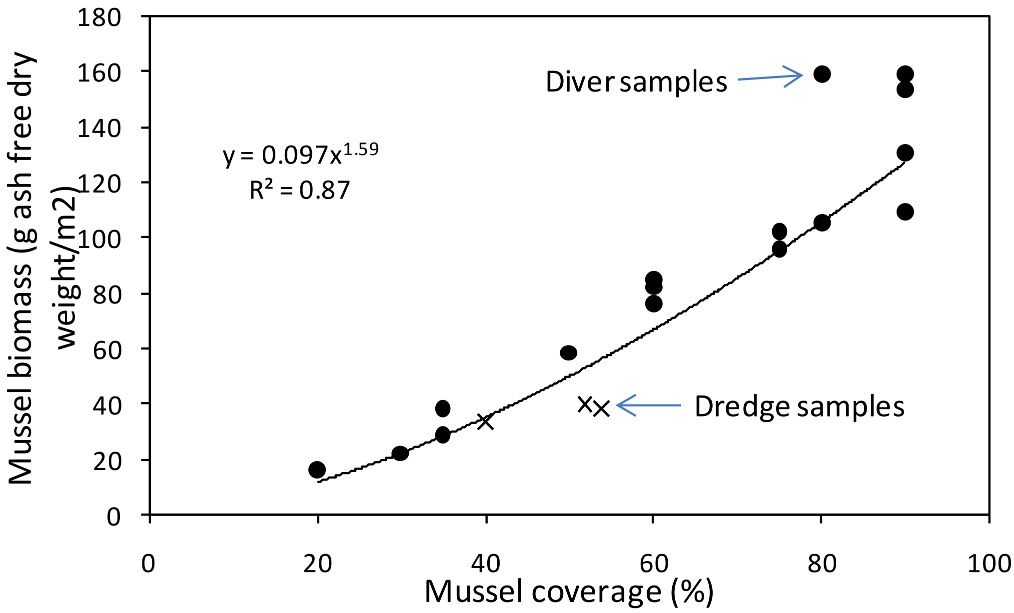

Figure 2-9 *Relation between mussel coverage and mussel biomass (AFDW). Data from divers samples where coverage was below 100 % and 3 dredge samples. Because of much larger sample size in dredge samples (81-151 m^2) compared to diver samples (1.25 m^2) they were weighted 5 times higher in calculation of trend line. The power function reflects that at increasing coverage mussels tend to occur in more than in one layer.*

Species distribution modelling (Guisan & Zimmermann 2000, Franklin 2009) of blue mussel *Mytilus edulis* cover was carried out using Generalised Additive Models (GAM, Hastie & Tibshirani 1990). GAMs are useful when dealing with complex and non-linear relationships between a response variable and different predictor (environmental) variables. GAMs are widely used (e.g. Guisan et al. 2002), and have been shown to perform well in comparisons with other methods (e.g. Moisen & Frescino 2002, Elith et al. 2006). The models were fitted with a quasi-binomial error distribution, which is suitable when the values of the response variable are restricted between 0 and 1 (Zuur et al. 2009).

The models were fitted in R version 2.9. (R Development Core Team, 2004) using the "mgcv" R package (Wood 2006). The GAM models were fitted using thin plate regression splines (which is the default in the "mgcv" package). In 'mgcv' the degree of smoothing (how closely the model follows the data) is chosen based on generalised cross-validation (Wood 2006). The default dimension (k = maximum degrees of freedom for each smooth function) is 10 for single covariate smooth functions. To reduce potential overfitting of the GAM models, smooth functions for each of the variables were limited to 5 (k=5). Granadeiro et al. (2004), for example, used a maximum of 4 degrees of freedom. The degree of smoothing was not limited for the interaction term of X and Y coordinates.

Cover of blue mussels obtained by transect surveys (see above) was used as response variable. Data on environmental factors, predictor variables, potentially important for the distribution and cover of blue mussels was obtained from FEHY water quality (WQ) and hydrodynamical (HD) modelling (FEHY 2013).

The predictors were chosen prior to the modelling based on expert opinion and the variables used were: depth, current speed (annual mean 2009), and an interaction term of X an Y coordinates (WGS 1984 UTM zone 32N). Coordinates were included to account for some of the spatial variation that could not be explained by the environmental variables.

2.3 Quality Assurance

As three different research teams and laboratories undertook the field work and data analyses, a thorough quality assurance is needed to ensure high quality and usability of the produced data. In general, all teams were following their national guidelines (e.g. German SOP) as well as international guidelines and standards (HELCOM, CEN, ISO) and thus already fulfilling an appropriate quality assurance. In addition, method harmonization, ring tests, and method comparisons were done, in order to document the quality and ensure that field sampling and data analysis were done the same way for the entire baseline study.

2.3.1 Method Harmonization Workshop

A workshop with the purpose to harmonize the different sampling and analysis methods took place in the beginning of 2009. The aim was to ensure identical data quality within the working groups, and, thus, highly comparable data for the baseline descriptions and the EIA. The benthic fauna workshop programme included different tasks of fieldwork and laboratory work.

Fieldwork - frame sampling
In a field exercise, all divers conducted the steps needed for sampling:

- site description
- frame sampling including guideline to positioning of the frame
- sample treatment: sieving and fixation
- sediment sampling

Differences in sampling between divers were discussed and harmonized.

Laboratory work – benthic fauna sample processing

All steps needed to process the samples from arrival in the laboratory until the determination of taxa and storage of the specimens were defined:

- documentation requirements for an accompanying sorting protocol
- sorting procedures (sieve mesh sizes, stereo microscope requirements, storing and labelling sorted specimens)
- procedure for handling taxa that occur in masses (more than 1000 specimens in a sample)
- handling of large amounts of Blue Mussels in infauna samples
- handling and processing of epifauna samples
- taxon determination (level of determination for different taxonomic groups and animal sizes within the groups, taxonomic groups to exclude)
- standardized species list (establishes singular valid names for species)
- counting of specimens (rules for counting of fragments of specimens, colonies)
- rules for measuring the length of bivalves into size classes
- exact procedure for biomass determination (wet weight, dry weight, ash free dry weight, use of conversion factors)
- procedure for establishing a project-specific reference and proof collection of all determined taxa for later referencing (securing of evidence)
- list of determination keys to use

In general, all these procedures follow the German SOP, which is a detailed superset of the more general HELCOM guidelines.

2.3.2 Ring Test

Three ring tests were carried out to document that the species identification methodology utilised by the three different laboratories is harmonized, the actual species identification by the laboratories is similar and comparable, and that the joint usage of the entire dataset is possible.

The first ring test consisted of sets of field samples from the study area and focused on the general performance of sorting and determination. The second ring test consisted of pre-determined specimens and focused on the determination of uncommon species. The third ring test consisted of artificial samples and focused on sorting efficiency.

The overall results indicate a good comparability of the data and the ring tests helped to further improve the quality of the sampled data.

The detailed description of the Ring Test is given in Appendix 11.

2.3.3 Method comparison

The baseline study was done with different sampling gear in the shallow and deep waters. The shallow water area down to a water depth of 10 m was sampled with a modified Kautsky sampling frame and the deeper areas from 10 m and down to the maximum depth of the investigation area was sampled using a Van Veen grab. Both sampling devices have the same sampling area of 0.1 m^2 and a comparable sediment penetration depth in soft bottom sediments. However, the frame was diver-operated and the sample transferred to a collection bag under water, whilst the grab was operated from a ship and the sample was transferred into tubs on board the ship. Once the sample was on board, the subsequent processing was identical.

In order to document the comparability of the data obtained with these two sample methods, a comparison test was conducted. The result showed that both methods are comparable in quality and result in the same assessment when used for the purpose of evaluation the ecological character with respect to health or community affiliation. Taxa counts and abundance varied between the two methods, showing a tendency to find more species in the grab, but a higher abundance in the frame. These differences were at least partly due to a difference in the underlying sampled community, not in the performance of the sampling method.

From the comparison analysis described in Appendix 12, it can be seen that no methodological differences exist that affect the outcome or comparability of the baseline analyses. It is rather the difference in the community composition of the samples causing different outcomes, and this is the desired effect.

2.4 Supplementary Data Used in the Report

Data on benthic fauna (e.g. spatial distribution, species composition, abundance and/or biomass) within the area also exist from other sources than the benthic fauna baseline investigations. This includes historical data and results from other projects.

2.4.1 Historical data

The historical data are used in the present baseline description where relevant. However, it should be noted that due to differences in sampling stations and methods, most of the historical data are not directly comparable to the data collected as part of the present benthic fauna baseline investigations. The historical benthic macrofauna data are thus only partly included in the present report, and only where it is relevant to provide a historical perspective to the analysis of the obtained baseline data.

In Appendix 10, a summarised overview of the historical data is provided. Detailed summaries are given of each of the projects from which the information of the summarised overview originated. Below, a synthesis of the available historical data is given, especially with regard to the obtained baseline data.

According to the information originating from historical time series, the bottom fauna in shallow waters of the Fehmarnbelt area is dominated by polychaetes, bivalves and crustaceans. Along the Danish coast the bottom fauna on the near-shore sandy zone is confined to a few and low-abundance species of polychaetes, gastropods and crustaceans, with an overall low biomass. Along the (partly hard bottom) coast of the German island of Fehmarn the bottom fauna is generally more diverse, more abundant and with a higher biomass.

The distribution of benthic macrofauna communities is primarily related to the water depth. However, environmental variables important for the structure of the bottom fauna such as temperature, salinity, sediment grain size, organic matter content, and dissolved oxygen (DO) concentration at the bottom are all highly correlated to water depth. The water column in Fehmarnbelt is stratified and the position and stability of the halocline determine the extent and duration of the exposure of the bottom fauna to ambient fluctuations of salinity, oxygen, and temperature. The depth of the boundary layer (pycnocline) between the lower-saline surface water and higher-saline bottom water is variable but lies typically in the 10-15 m range.

In most shallow water areas the soft bottom communities are dominated by few species, both in terms of abundance and biomass. The shallow, sandy beds in the coastal waters are mainly inhabited by benthic fauna assemblages, which are dominated by the gastropod *Hydrobia ulvae* and the bivalves *Mya arenaria, Cerastoderma edule* and *Macoma balthica*. Where present in higher densities, algae and eelgrass contribute to a higher species richness compared to bare soft bottom assemblages.

Between 5 and 15 m depth, the Blue Mussel *Mytilus edulis* is generally the dominant species, which facilitates a rich associated fauna assemblage. Both in the historical time series and in the baseline investigations, the areas where the highest mussel densities and biomass have been observed are consistently Albuen Bank (SW Lolland), Staberhuk (eastern tip of Fehmarn) and Großenbrode (east offshore the Wagrien peninsula, south of Fehmarn).

The transition zones between the shallow coastal waters and the deeper central Fehmarnbelt are characterised by species which have rather large tolerance ranges regarding abovementioned environmental variables. Because these transitional assemblages live under such variable conditions, they have a naturally disturbed character regarding species composition and biomass. Below 20 m, the deeper Fehmarnbelt is uniformly dominated by a community, which was named the Abra alba-community by Remane (Remane 1934). This community is a benthic macrofauna assemblage consisting mainly of the bivalves *Arctica islandica* and *Abra alba* and some characteristically associated species, like the small cumacean *Diastylis rathkei*.

Except that in the present Baseline Report, consisntently different names for the communities are used, the overall species distribution patterns are very similar as those that can be derived from the historical data sources. One of the reasons for the use of different naming for the benthic fauna communities, is that the area which is assessed is larger, and both the spatial and temporal resolution of the sampling campaigns were higher than in past campaigns. A second reason is that the mathematical methodology used in this Baseline Report to discern between different species assemblages is much more refined. An obvious consequence is that we observed both more and different species assemblages.

The historical data can serve as a good reference for the present baseline data, especially where large-scale and long-term patterns are concerned. The basic patterns of species distribution are consistent with historical data and information sources. However, because of the much lower spatial and temporal sampling resolution, the historical data do not add much value to the data obtained on a community level, as is done in detail, shown later in this Baseline Report.

2.4.2 Aerial Photos

Aerial photography was used as additional source of information for description of shallow water benthic fauna communities, for validation and adjustment of the results of community analysis and subsequent modelling and mapping for areas where the limited amount of background data was critical.

2.4.3 Environmental data

The Fehmarnbelt hydrographic group has been collecting data on the hydrographical and water quality conditions and has established models describing the existing environmental conditions. Data from those models are used to describe salinity, temperature, bathymetry, bed shear stress, and current speed in the area and at the sample sites. The models have been validated for a recent 12-month period (October 2008 – September 2009).

Environmental data are used for the description of physico-chemical and hydrographical conditions for benthic fauna, interpretation of the benthic fauna communities, and as input data for predictive mapping of benthic fauna communities.

2.5 Data Analysis

2.5.1 Abundance, biomass and species number

All sampling, preparation and species identification was conducted in accordance with national and international guidelines (German SOP, WFD, MSFD guidelines). This includes working with a standardized species list, the QA management handbook for laboratories, the monitoring handbook and standard operational procedures (SOP).

In the laboratory, the following parameters were determined:

1. Benthic fauna species (nomenclature according to World Register of Marine Species, WoRMS, date: 01.01.2010) and taxonomic group (polychaete, amphipod, bivalve, gastropod, etc.)

2. Number of individuals per species (abundance). All data were extracted from the joint database to avoid non-conformities. The database included a total of more than 46000 records for 1118 sampling events. All biomass and abundance values were recalculated to a surface area of 1 m^2 before further analysis and are presented based on this unit in the results sections.

3. Shell length of bivalves larger than 5 mm of the species *Arctica islandica*, *Macoma balthica*, *Cerastoderma edule*, and *Mya arenaria*)

4. Biomass: total wet weight per species. Dry weight and ash free dry weight were calculated by regression factors from wet weight (using existing conversion factors from IOW). For the bivalves *Arctica islandica*, *Macoma balthica*, *Cerastoderma edule,* and *Mya arenaria* dry weight and ash free dry weight was measured directly. This was done for all 5 mm size classes separately.

5. The qualitative dredge hauls were used as such. That is, the species that appeared in the dredge hauls, but not in the grab samples, were added to the total species number.

For the subsequent steps of analysis, the taxonomic information was partly condensed in order to avoid artefacts from higher taxonomic groups. This means, for taxa counts in general the total number of taxa was reported. In certain samples, however, it was not always possible to determine the taxon to species level. Then, the genus or family names were documented. When more than one species of the same genus occurred in a sample and additionally some specimens determined only to the genus level shared with the other species, this genus was not counted as an additional taxon for the species count. It is far too likely that the specimen belongs to the already recorded species and thus counting it would artificially increase the species counts.

Note: although mostly the term 'species' is used in the results sections, this also includes the higher level taxonomic groups. The correct terms would be 'taxon' ('taxa' in plural) instead of 'species', but since the species represent by far the major part of the data, the term 'species' was used.

2.5.2 Data presentation

In Section 5, the analysed data are presented partly in form of box plots. The box plots focus on the presentation of the data and their main variability. The boxes always represent the range from the 25th to the 75th percentile of the data and the median as a line within the box. As such, the box plots capture 50% of the data. 25% of the data lie above and below the boxes respectively. These are regarded as mainly extreme values and outliers that have only a minor relevance for the overall results and. Therefore, they are not shown as whiskers in the box plots. Also, most boxes start at a value of 0 and there will be no values below this, making whiskers needless.

Box plots that present a range of species and their associated values (counts, abundance and biomass) are always ordered in the same way: First annelids, then molluscs, then crustaceans, and finally others (summarised). Within the groups, the species are arranged alphabetically.

Biomass values are always given as ash free dry weight (AFDW), unless stated otherwise.

2.5.3 Benthic fauna community analysis

Pre-treatment and data selection
In preparation of the community analysis, a thorough data quality control was performed to reduce the influence of random noise and inaccuracy mainly following the guidelines given by Clarke and Warwick (2001). It was targeted to exclude or summarize non-representatively sampled taxa. Thus, data on rare species and species, which have not been identified by all laboratories, have been excluded from the community analysis. The overall descriptions of the communities in the following sections do include all available information from the sample analyses.

The pre-treatment procedure for the community analysis included the following steps:

- Exclusion of all qualitative data (dredge samples, uncountable species such as Bryozoa, etc.) as they are not applicable in quantitative analyses.

- Removal of all stations without a full species data set (i.e. supplementary investigation in late winter of 2008/2009 and exclusive Blue Mussel sampling in summer of 2009).

- Exclusion of all taxa that occurred in < 3% of the samples (= frequency of occurrence < 3%). There are different studies stressing the importance of rare species for habitat ecology (e.g. Cao et al. 1998). In the present study, species reduction (exclusion of rare species and extraction of the dominant ones) was done in order to allow the employment of various statistical methods and the interpretation of results (Legendre and Gallagher, 2001; Lozán and Kausch, 2004). The aim is to extract general patterns, which would become confusing by the occurrence of rare species across the sites.

- Exclusion of all taxa identified to a higher taxonomic level than genus, because a mixture of several species summarized in one taxon may cover existing ecological differences between the summarized species (e.g. Oligochaeta) and therefore smooth down existing differences between communities. Exceptions were: *Phoronis* spp., chironomids and Turbellaria (no taxon of the latter two groups was identified down to genus/species level and all species of both taxa were expected to show similar ecological demands in the study area).

  All anthozoan species have been summarized in the taxon "Anthozoa" as they have not been identified by all of the laboratories (not required following international guidelines), but were regarded as important indicator group for hard substrates, featuring comparable ecological demands.

- Exclusion of all Nemertea species as they have not been identified by all of the laboratories (not required following international guidelines).

- Exclusion of the Blue Mussel (*Mytilus edulis*) from all analyses. The coverage of *M. edulis* is to be included as an environmental predictor in the following benthic fauna community analysis.

The final adjusted species list used in the community analysis comprised 161 species (see Appendix 5).

Overall 325 sample sites were included in the analysis, subdivided in 79 deep-water stations sampled with *Van Veen* grab and 246 sites in shallow waters (sampled with a Kautsky sampling frame).

Due to the different sampling strategies and particularly different sampling effort, the shallow and deep water data sets were *a priori* treated separately. While the deep water set is very constant in terms of sampling effort and seasonal distribution of sampling, the shallow water data set is rather heterogeneous. Whereas the majority of sites have been sampled in four campaigns with comparable effort, some stations were sampled only once or twice and/or during different seasons. As the summer campaigns were especially dedicated to epifauna sampling, they had to be included in the analysis in order to obtain the overall picture of different macrofauna communities. Nevertheless, this difference has to be kept in mind when interpreting the outcome of the analysis.

Abundance has been chosen as response variable in community analysis. Usually, biomass is regarded as the more robust parameter due to its lower seasonal and inter-annual variability. In the study area, biomass was overly dominated by a few widespread bivalve species, thus differences between communities which may be based on a variety of smaller species were hard to detect (even using strong data transformation). To down-weigh the influence of dominant species and to stress the importance of rare species, abundance data were fourth-root transformed a method commonly used for communities with very high dominance values of single species (e.g. Gogina et al 2010) has been applied.

The community analysis was initiated by averaging the species abundance values over all replicates taken in all available campaigns. This procedure was used to stress the stable characteristic features within the communities and to down-weigh temporal or random effects from the different sampling strategies or from local habitat variability.

Grouping of sampling stations

An appropriate method for discerning groups in (large) community data sets is hierarchical clustering based on Bray–Curtis similarities (Clarke and Warwick 2001, Gogina et al 2010, van Hoey et al 2004). In order to stimulate grouping, so-called "complete linkage" has been used as a cluster mode for both the shallow and the deep water data sets (Clarke and Warwick 2001). Initially, a number of cut-offs were set resulting in a reasonable number of groups (2–10 groups per data set). The optimal number of groups per analysis was found using a combination of SIMPROF- and IV-Analysis (Dufrène and Légèndre 1997, van Hoey et al 2004) and expert judgement[2]. The IV-Analysis was conducted using the duleg-function within the LABDSV-package (Roberts 2008) written for the open source software R (R Development Core Team 2009). PRIMER (v6) software was used for all other above mentioned analysis (Clarke and Gorley 2006). Also, species responsible for classification were determined applying SIMPER exploratory analysis and Indicator-Species-Analysis (Dufrène and Légèndre 1997).

The relevance of the resulting clusters was verified on a non-metric multidimensional scaling (nMDS) surface (Gogina et al. 2010).

Definition of assemblages - Linkage with environmental parameters

Correlations between biological and environmental variables were examined via BIO-ENV procedure of PRIMER software (Clarke and Ainsworth 1993) and principal component analysis (PCA), applying the necessary data transformations (Légèndre and Gallagher 2001). Additionally, the significance of separation between the biological clusters based on the abiotic variables was tested using the ANOSIM-function (Clarke 1993).

For analysing the linkage between biological and environmental variables, a collection of both measured and modelled variables was used (Table 2-5). Modelled variables were those available in October 2010, which for this purpose has the same quality as later updated versions.

All explanatory variables were tested for mutual linear relationships (co linearity) before the analysis. In the case two or more explanatory variables are collinear (i.e. display strong mutual linear relationships), there is a risk of including redundant information in the analysis, due to some degree of overlap between the variables.

[2] No commonly used road map for this procedure has been published and accepted by the scientific community. Thus the steps of this procedure follow the analysis approach found in the cited literature and are also based on own experience.

Table 2-5 List of environmental variables available for community analysis.

Variable	Method
Water depth (m)	Measured
Loss on ignition (mass %)	Measured
Sediment fractions (%)	Measured
Median grain size (mm)	Calculated
Mussel coverage (%)	Modelled
Oxygen content (mgl^{-1})	Modelled
Temperature (°C)	Modelled
Current speed (m/s^{-1})	Modelled
Bed shear stress (Nm^{-2})	Modelled
Salinity (psu)	Modelled
Vegetation coverage (%)	Modelled

Predictive community distribution modelling (ordination and mapping)
The information on spatial distribution of benthic macrofauna was merely restricted to the point observations (sampling stations), even in the most well-studied locations. In order to obtain the full distribution coverage, usually two strategies were followed:

1) Spatial interpolation based on sampling point information.

2) Development of habitat suitability models that predict the presence of benthic fauna based on the suitability of the physical habitat (Degraer et al. 2008).

The first strategy provides a static picture, and is highly dependent on not only the number of samples, but also their position. Spatial interpolation disregards significant spatial information and variability (patchiness), and is therefore not recommended.

The applied ordination methods contributed to the detection of systematic patterns in the community data and may reveal transitional zones. For mapping purposes, methods of gradient analysis were complemented by numerical classification methods that allowed for cutting a continuous range of values (e.g. depth, temperature, salinity) even if there were no distinctive boundaries (Leps and Smilauer 2003).

According to Ysebaert et al. (2002), the usage of modelled estimates of environmental variables is favoured over the data which is measured directly and simultaneously with benthic sampling. Modelled estimates of environmental variables are highlighted by its advantages, like the availability of a high spatial resolution and a sort of smoothing caused by the simulation (i.e. elimination of outliers). However, taking into account the complexity of the functioning of ecosystems, the uncertainty of model simulations may increase the complexity of the interpretation of derived (empirical) relationships between environment and biota.

The preliminary analysis of the environmental conditions (abiotic parameters such as temperature, dissolved oxygen concentration, salinity etc.) should exclusively be based on direct *in situ* measurements. Therefore, to enable the investigation of relationships between environment and biota, the model calibration should rely on directly observed data to the highest extent possible. Transformation of observed data should be applied only when necessary, to reduce the loss of information which is contained in the data. However, the community prediction was mainly based on modelled data of sufficient resolution available for the study area, thus allowing some sort of validation of modelling success. The use of simulated data for the model estimation is forced merely by the necessity and absence of alternatives. The usefulness of environmental variables as predictors for the distribution of benthic communities is restricted by the spatial resolution in which they are available. Thus, only biological and environmental variables for which the data were widely and readily available were used in the modelling exercise. These variables are summarised in Table 2-6.

Other parameters (e.g. water temperature, current speed and directions, water quality parameters) were initially also checked and included, but did not improve the model accuracy.

The classification method “Classification and Regression Trees” (CART) was chosen for modelling. This technique has proven to be a robust tool for modelling marine benthic communities (Pesch et al. 2008). The strengths of CART are its capacity to deal with interactions between variables, its applicability on categorical variables, the robustness when dealing with heterogeneous distributed data and the simplicity of displaying results, and therefore the easy-to-understand outcome. The classification trees were calculated using the package “tree” (Ripley 2009) within the open source software R (R Core Development Team 2009). The optimal size of the tree was determined using the overall deviance. In order to estimate the goodness of the resulting tree, cross-validation techniques were used.

Table 2-6 Final list of the biological/environmental variables which were used for the predictive modelling of benthic fauna communities.

Variable	Method	Remark
Water depth (m)	Measured	
Temperature (°C)	Modelled	
Salinity (psu)	Modelled	Annual and Summer minimum and mean
Oxygen content (mgl^{-1})	Modelled	Winter and Summer minimum and mean
Bed shear stress	Modelled	Maximum values
Substrate	Measured	Habitat map classification
Mud content (%)	Modelled	Using regression kriging
Blue Mussel coverage (%)	Modelled	
Vegetation coverage (%) and community types	Modelled	

3 ENVIRONMENTAL CONDITIONS

Data on the hydrographic conditions are collected as part of the baseline investigations. In connection with this a hydrodynamic model describing the existing environmental conditions was established. The model has been validated for a recent 12 months period (October 2008 – September 2009).

Some of the hydrographic data are important for the interpretation of the benthic fauna community. Therefore, summary maps of key parameters for the benthic fauna community analysis are presented in the following.

3.1 Bathymetry

Fehmarnbelt is a rectangular sea strait with a maximum depth of about 30 m and a width varying between 18 km and 25 km (Figure 3-1).

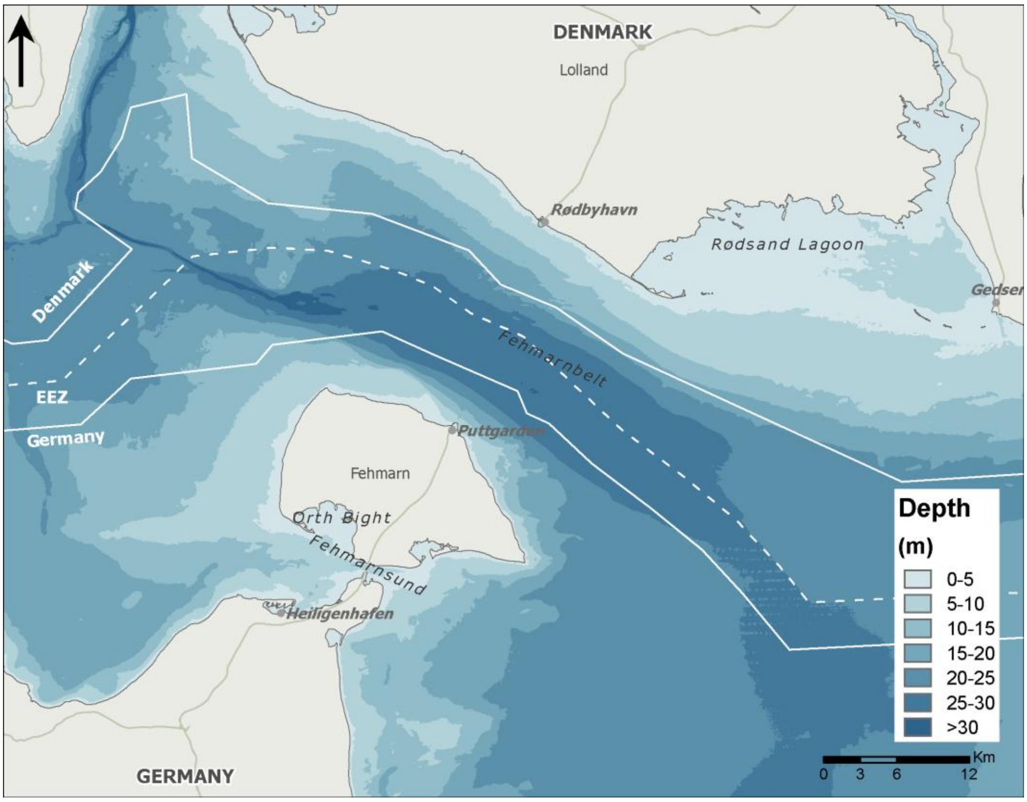

Figure 3-1 Bathymetry map of the greater Fehmarnbelt area; included are the Kiel Bight to the West, the Langeland Belt to the North-West and the Mecklenburg Bight to the South-East.

3.2 Sediment Grain Size Distribution

A large number of sediment samples have been collected. The median grain size, D_{50}, in sediment samples collected (upper layer of geotechnical sediment cores) during 2009 confirms that the seabed material in Fehmarnbelt primarily consist of sand/sandy mud. Medium to coarse sand (D_{50} = approx. 0.25-1 mm) is mainly found along the Danish coast and along the shoreline South-East of Puttgarden on the German side. Very fine sand to fine sand (D_{50} = approx. 0.1-0.25 mm) is found West of Puttgarden and in the deeper areas with a water depth of >12 m. These sedimentology data were used to compose a substrate map.

3.3 Substrate Characteristics

A substrate map (Figure 3-2) was developed for the wider Fehmarnbelt area - encompassing parts of Kiel and Mecklenburg Bays - of which the interpretation is based on different data sources. In the Fehmarnbelt area, including Rødsand Lagoon and the coastline around Fehmarn Island, a high resolution was achieved through the use of aerial photography (in shallow waters) and multibeam data (in deeper waters), classified with Definiens image analysis software and ground-truthed with sedimentological data from the baseline sampling. For more details on recording, substrate classification and mapping methodology, the reader is referred to the Habitat Mapping report (E2TR0020, Volume III).

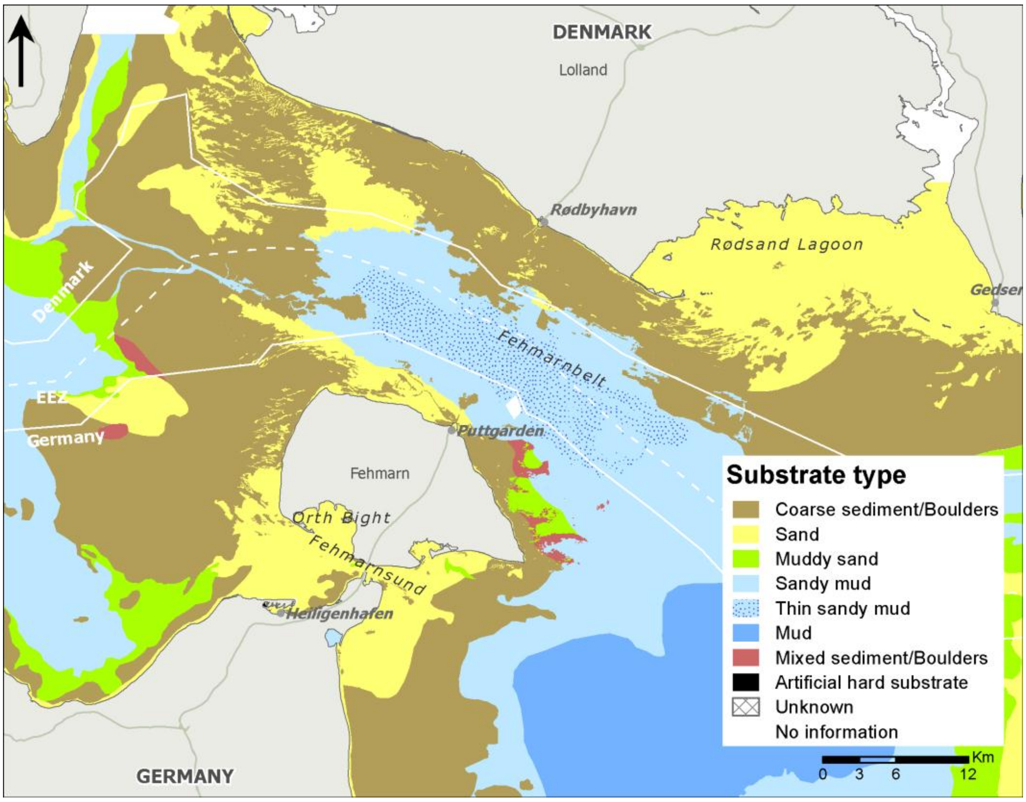

Figure 3-2 Substrate map for the greater Fehmarnbelt area.

In the wider area of the SW Belt Sea (Kiel Bight and Mecklenburg Bight), interpretation was based on a 50 m bathymetric grid and grain-size data from archives (MUDAB, IOW). Hence, the map is less detailed and potentially less accurate in these areas. Eight substrate classes are mapped: Coarse sediment/boulders, sand, muddy sand, sandy mud, thin sandy mud, mud, mixed sediment/boulders and artificial hard substrate. These substrate classes were chosen in line with definitions of the EUNIS habitat classification system, but have been expanded by "artificial hard substrate" and "thin sandy mud", where a layer of sandy mud of only a few cm thick exists on top of another, harder substrate.

3.4 Salinity

Fehmarnbelt is part of the transition area between the brackish waters of the Baltic Sea and the saline North Sea. The connection from the Baltic Sea (salinity 5-15 psu) goes via Fehmarnbelt to the Great Belt and Little Belt, and futher on to the Kattegat, the Skagerrak and into the North Sea where salinity of about 34 psu.

The annual mean and summer bottom salinity, as simulated by the hydrographic model, are presented in Figure 3-3 and Figure 3-4, respectively. It appears that the depth gradient of summer mean salinity (Figure 3-4) is slightly stronger than is the case for the annual mean salinity (Figure 3-3).

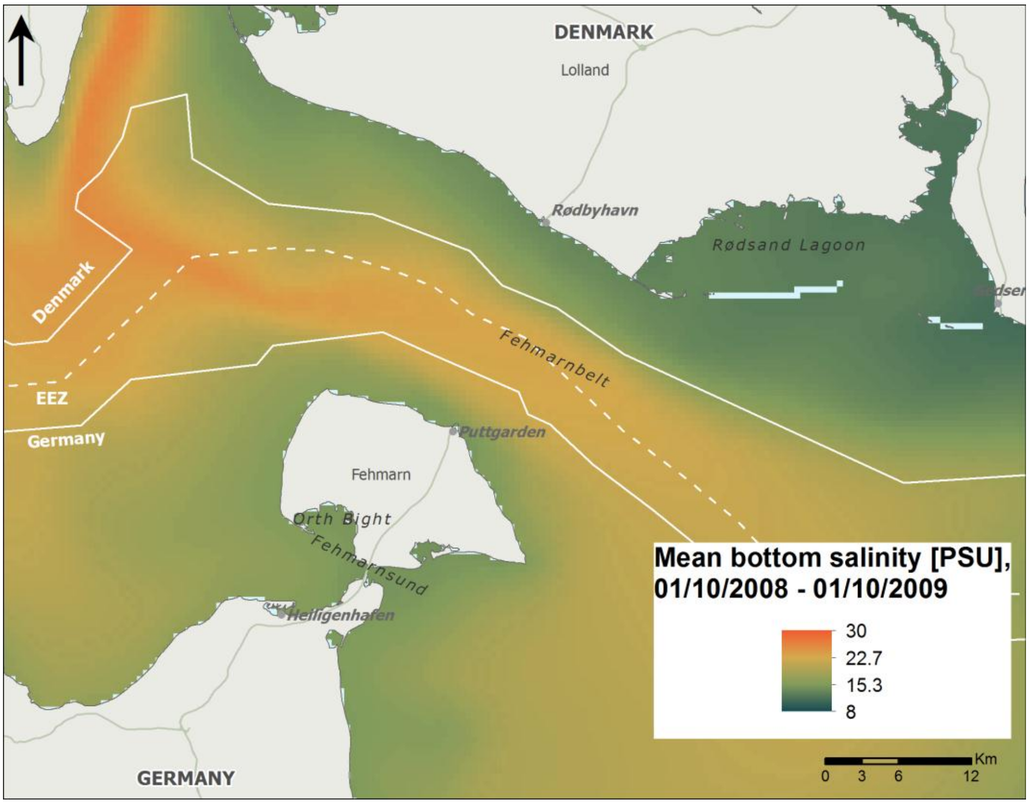

Figure 3-3 *Salinity map in the bottom layer showing annual mean (based on model output from simulated period from October 2008 to September 2009)*

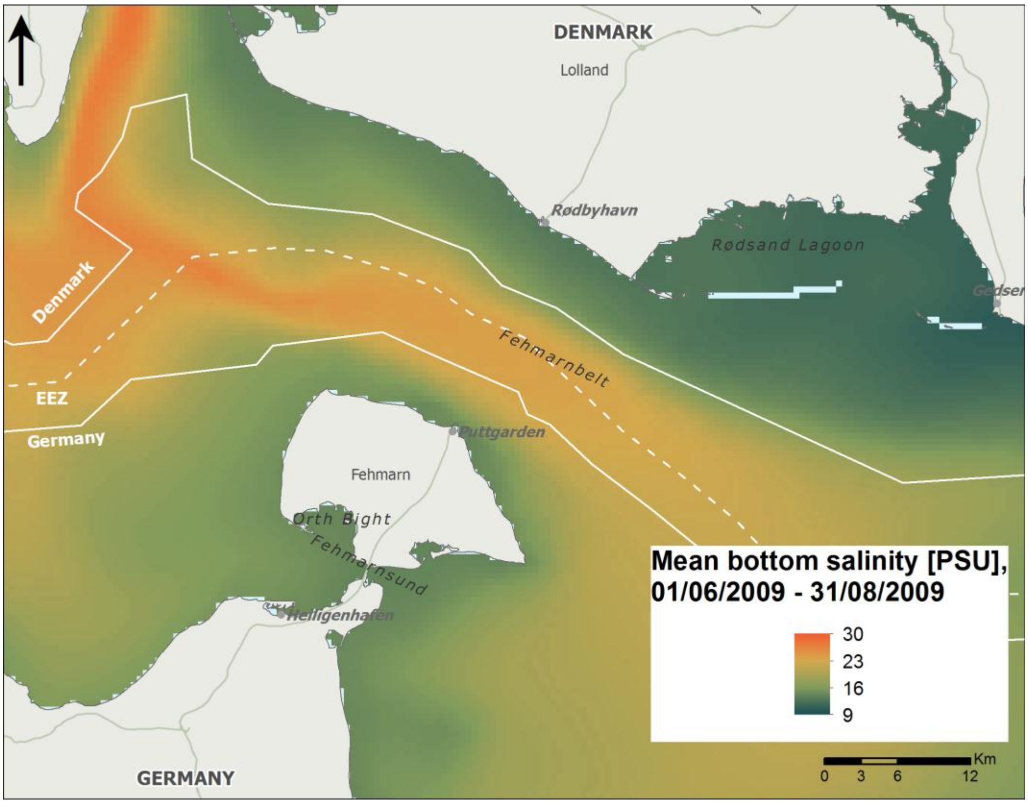

Figure 3-4 Salinity map in the bottom layer showing summer mean (based on model output from a simulated period from June 2009 to August 2009)

3.5 Temperature

As a result of the currents flowing through the Fehmarnbelt and its characteristic bathymetry and stratification conditions, a spatially varying temperature profile exists.

The annual mean and summer bottom temperature as simulated by the hydrographic model are presented in Figure 3-5 and Figure 3-6, respectively. There is a steep temperature gradient between shallow and deeper waters in summer, whereas this gradient becomes much less steep using the annual mean values. However, the deeper waters remain consistently colder than the shallower waters.

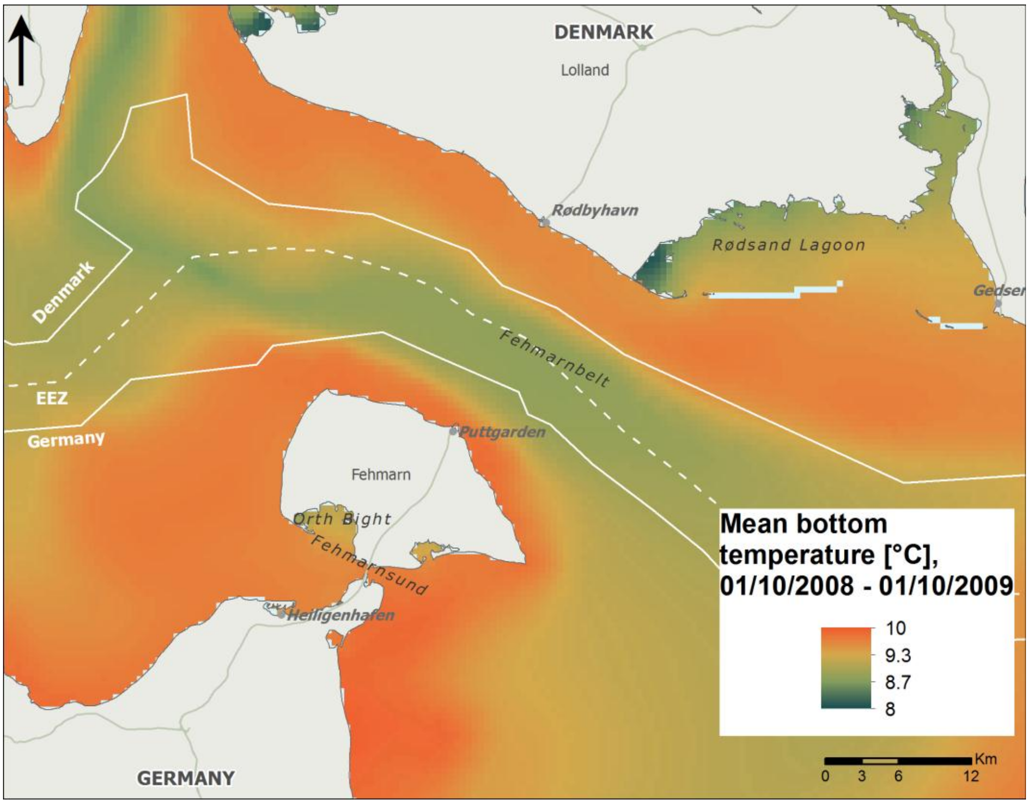

Figure 3-5 Temperature map in bottom layer showing annual mean (based on model output from a simulated period from October 2008 to September 2009)

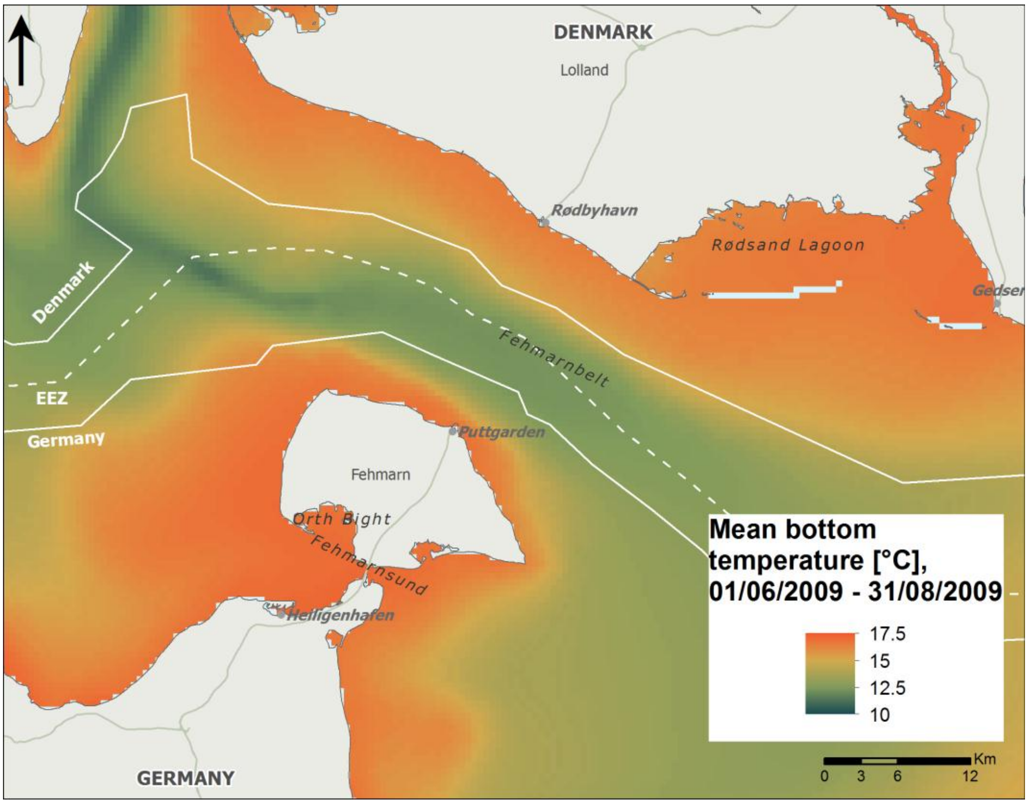

Figure 3-6 Temperature map in bottom layer showing summer mean (based on model output from a simulated period from June 2009 to August 2009)

4 MACROZOOBENTHOS IN FEHMARNBELT

This section presents the results of the benthic macrofauna baseline study. The first sub-section (5.1) gives an overview of the main spatial trends in the investigation area. The described structural differences and similarities are analysed, linked to environmental factors and used to identify distinct assemblages (5.2). The occurrence of the resulting communities is predicted (mapped) for the whole investigation area. Finally, each benthic fauna community is treated in a separate section, describing the main characteristics and both temporal and spatial trends (5.3).

4.1 Inventory and Main trends

Differences and trends in the composition of the benthic fauna are shown by using descriptive parameters like overall species richness, abundance and biomass. Distinct trends from western to eastern and from shallow to deep section of the investigation area are highlighted.

4.1.1 Species richness and taxonomic composition

There are two main spatial gradients in Fehmarnbelt in species richness (Figure 4-1). The most obvious gradient runs from shallow waters to the deeper parts. The other gradient in species number runs from west to east.

The areas with the highest species richness are notably the south-east reef offshore the Danish island of Langeland (Langeland Rev; 125-162 and 75-162 species, respectively) and areas north-west of Fehmarn (Figure 4-1). Areas with lowest species richness in the study area (Figure 4-1) can be found especially on the south-west coast of Lolland (Albuen Bank), in the Lagoon of Rødsand and just south of the Lagoon of Rødsand (7-24, 7-49 and 7-49 species, respectively).

In general, sampling stations close to shore consistently have lower number of species than stations located further offshore. The deeper waters of the central Fehmarnbelt are polyhaline (salinity 18–30 psu) in nature; the shallow parts are α-mesohaline (salinity 10–18 psu) most of the time. This is caused by the positions of the seasonal pycnocline and the general inflow of marine water in the bottom layer. Approximately 70% of the marine water inflow into the Baltic Sea is running through the Fehmarnbelt. These conditions are determinant for the difference in species richness between shallow and deeper waters.

Due to the generally lower diversity in shallower areas, almost all species were captured by the frame sampling method. To our knowledge, even with a higher effort, the species richness would not increase dramatically. The high diversity of the deep stations (due to the higher salinity) is reflected by the graphs shown in this report. The table in Appendix 2, based on all stations (high number of replicates and seasons), clearly shows the difference in species richness between shallow and deep water benthic communities.

The gradient found from west to east is also linked with salinity. The eastern-most part of the study area has generally a lower salinity than the western-most part, especially in the shallow waters above the halocline. Thus, similar environmental conditions causing the change from shallow to deep also apply from west to east. Some species found in the study area are restricted to either the shallow or the deep part (above/below the halocline). E.g. the bivalves *Arctica islandica* and *Astarte* spp. or the polychaete *Terebellides stroemi* were almost exclusively found in deeper waters. They are all marine species that are not able to tolerate full mesohaline conditions. On the other hand the bivalves *Parvicardium hauniense* and *Cerastoderma glaucum* or the polychaete *Marenzelleria viridis* are adapted to lower salinities.

The polychaetes (bristle worms) are the group that contained the highest number of species. This group consists of both infauna and epifauna species. Among them, both highly specialised species and opportunistic species are found, which thrive under nearly all conditions. The second-largest groups are typically the molluscs (shells/bivalves and snails/gastropods) or the crustaceans (mainly amphipods, scuds), depending on the habitat of the area. In soft bottom sediments without vegetation or other structuring elements like mussel assemblages, the molluscs are more prominent, mostly by a larger number of bivalve species. This is true for large parts of the northern Fehmarn coast, but most notably for the deeper waters in general. Areas with vegetation or mussel assemblages often share higher numbers of amphipods compared to molluscs, but also more gastropods compared to bivalves. Such areas were mainly found in the western part of the Lagoon of Rødsand, along the east coast of Fehmarn and east of the German mainland around Großenbrode. Also areas with a high coverage of mussels, around Staberhuk and at places off the south coast of Lolland, showed these characteristics.

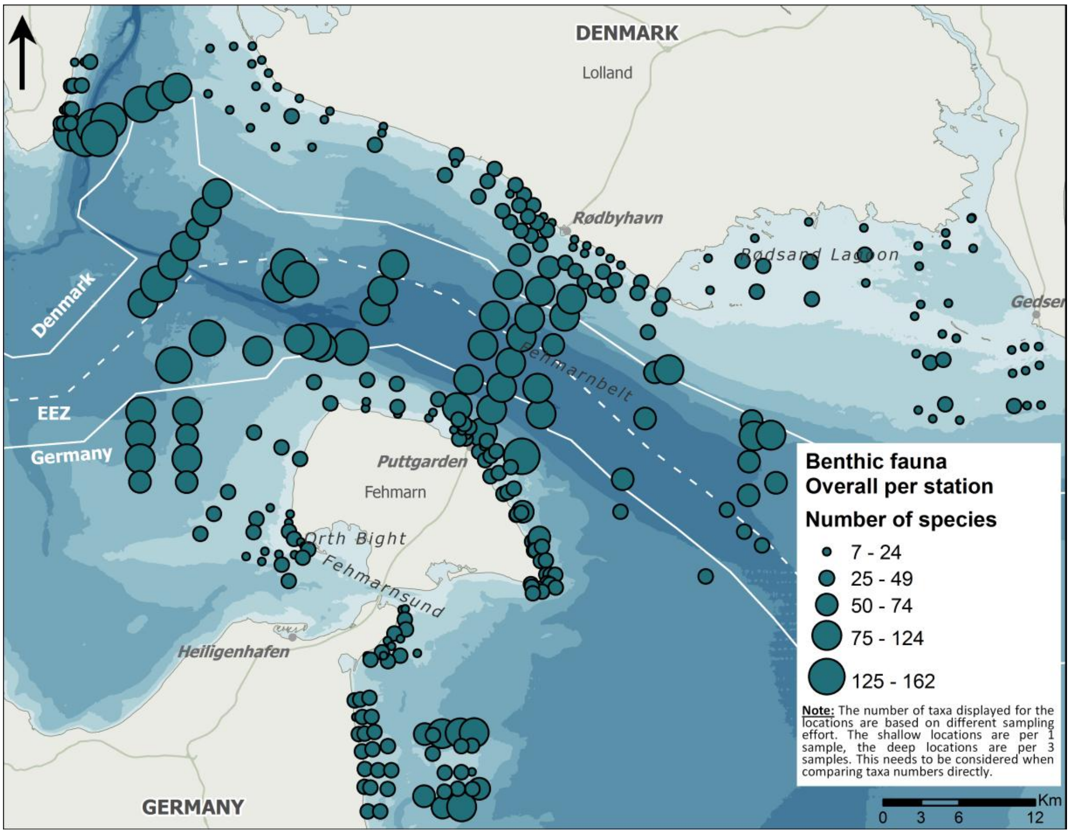

Figure 4-1 The species richness (total number of species observed) at each of the sampling sites within the study area over the entire field campaign between spring 2009 and autumn 2010.

As a summary, the mean, minimum and maximum number of species in each administrative area of the Fehmarnbelt is stated in Table 4-1.

Table 4-1 Summary of the total number of species observed per administrative area in the study area around Fehmarnbelt.

Administrative area	Stations	Number of species		
		mean	minimum	maximum
Overall	325	43	7	162
Danish waters	151	40	7	155
German Waters	174	45	10	162
German coastal zone	154	37	10	126
German EEZ	20	108	41	162
DE 1332-301 (Fehmarnbelt)	16	123	88	162
DE 1533-301 (Staberhuk)	27	33	14	62
DE 1631-392 (Östliche Kieler Bucht)	43	37	10	112
DE 1632-392 (Ostsee östlich Wagrien)	15	24	14	35
DE 1733-301 (Sagas Bank)	11	34	24	63
DK 006X238 (Rødsand lagoon)	33	20	7	32
DK00VA200 (Langeland)	8	60	28	155

4.1.2 *Abundance*

The median number of individuals per square meter, the median abundance, is observed to be highest mainly at Langeland Rev, along the north-east coast of Fehmarn and at Großenbrode (east offshore the Wagrien peninsula; Figure 4-2). There are some high-abundance stations in the Lagoon of Rødsand and both north-west and south-west offshore Fehmarn as well.

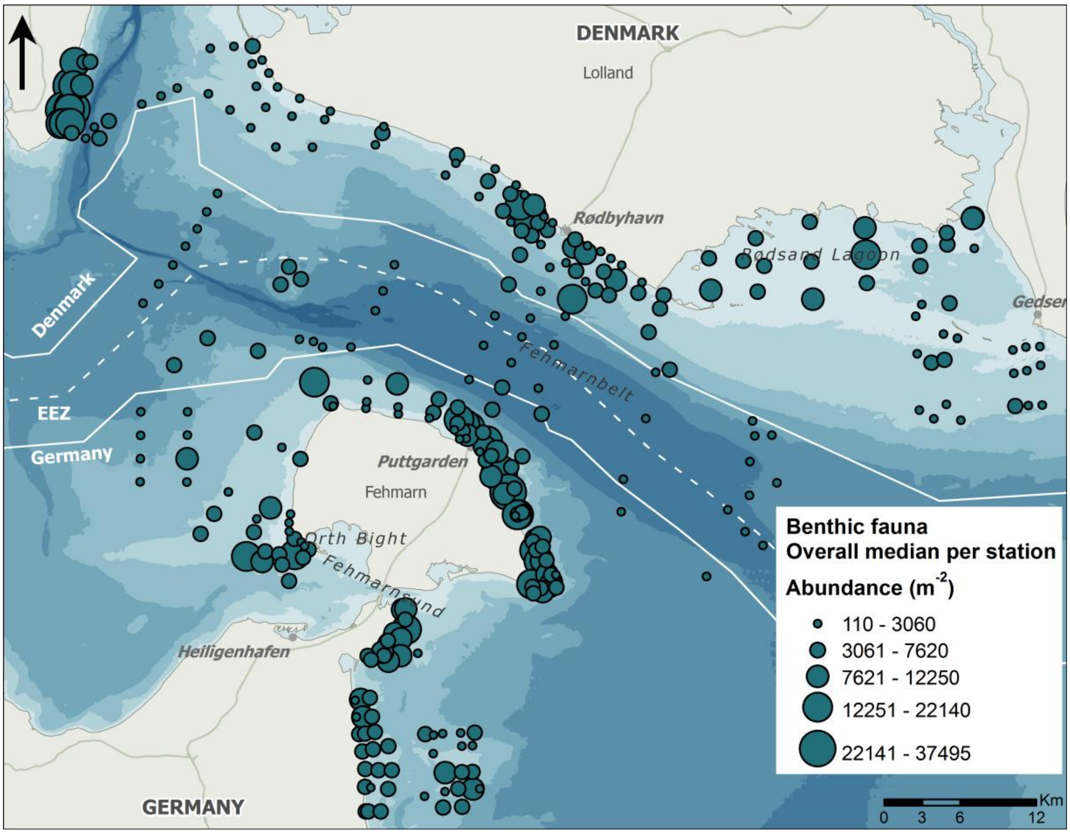

Figure 4-2 The median abundance (number of individuals per square meter: m^{-2}) at each of the sampling stations within the study area, over the entire field campaign between spring 2009 and autumn 2010.

The distribution of the abundance is roughly contrary to the distribution of species richness: there are generally higher abundances recorded close to shore than in the deeper parts. The species-rich areas in the central western part of the Fehmarnbelt are characterised by relatively low abundances, whereas the stations in the Lagoon of Rødsand, which were low in species, were observed to have intermediate to high abundances (Figure 4-2). Exceptions are the stone reef south-east offshore Langeland (Langeland Rev) and the south-west coast of Lolland (Albuen Bank), where the high resp. low species richness (Figure 4-1) was accompanied by high resp. low abundances (Figure 4-2).

The general pattern in species richness is coupled to the complexity and three-dimensional structure of the different habitats. The high-abundance areas at Langeland, Fehmarn, around Rødby, and off Großenbrode have high vegetation coverage, attracting many epifauna species in addition to the soft bottom infauna species and mussels. The low-abundance areas are soft bottoms with only minor or no vegetation and this is notably the case in the major part of the deeper waters, where species richness is higher. Only reef-like regions like Øjet in the western central Fehmarnbelt show higher abundance, again due to a richer habitat structure and additional epifauna species.

As a summary, the mean, minimum and maximum number of species in each administrative area of the Fehmarnbelt is presented in Table 4-2.

Table 4-2 Summary of the total abundance (m^{-2}) observed per administrative area in the study area around Fehmarnbelt.

Administrative area	**Stations**	**Abundance**		
		mean	**minimum**	**maximum**
Overall	325	5754	105	36760
Danish waters	151	4992	105	36760
German Waters	174	6414	448	36470
German coastal zone	154	6802	448	36470
German EEZ	20	3429	1162	11787
DE 1332-301 (Fehmarnbelt)	16	3907	1494	11787
DE 1533-301 (Staberhuk)	27	8407	1130	18390
DE 1631-392 (Östliche Kieler Bucht)	43	5753	448	19400
DE 1632-392 (Ostsee östlich Wagri-en)	15	8567	2240	13680
DE 1733-301 (Sagas Bank)	11	3944	1455	9160
DK 006X238 (Rødsand lagoon)	33	4407	198	12475
DK00VA200 (Langeland)	8	14455	1544	35760

4.1.3 Biomass

The areas with highest median biomass values are notably the western part of the deeper central Fehmarnbelt and the coastal area of Fehmarn around Puttgarden (Figure 4-3). Several stations west offshore Fehmarn display high median biomass values as well.

In determining the median biomass throughout the study area, the Blue Mussel *Mytilus edulis* was excluded from the analyses. *Mytilus* generally attained such high biomass values that other, smaller differences between stations could not be discerned.

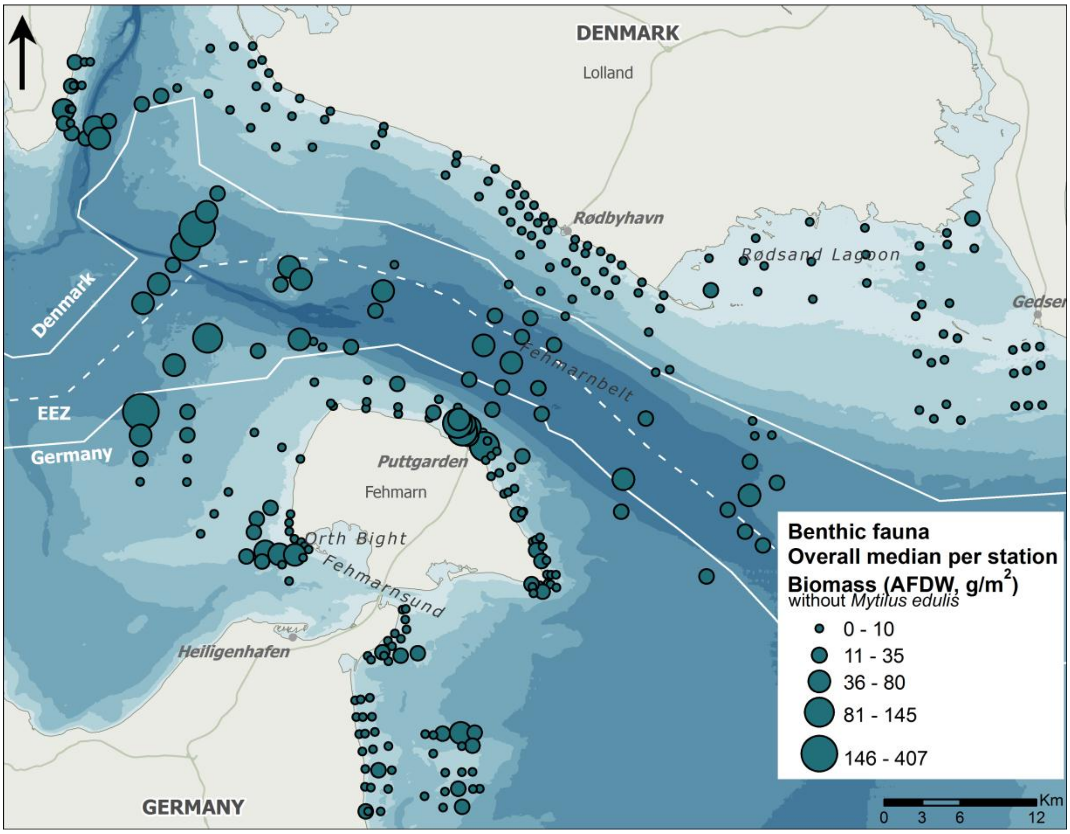

Figure 4-3 The median biomass (grams ash-free dry weight (AFDW) per square meter: gm^{-2}) at each of the sampling stations within the study area, over the entire field campaign between spring 2009 and autumn 2010. The biomass of the Blue Mussel Mytilus edulis *is disregarded.*

The deeper central Fehmarnbelt is consistently higher in biomass than most shallow coastal areas. This is caused by the large, long-living bivalve *Arctica islandica* that can reach a wet weight of 45 g (AFDW approx. 3 g) at a size of 65–70 mm. Compared to this, typical other species have wet weights below 1 g. When the biomass of *Mytilus* was excluded, the Lolland coast was shown to be low in biomass compared to most of the Fehmarn coast (Figure 4-3). The majority of the biomass on the Lolland coast is thus made up by blue mussels. At the Fehmarn coast, the higher biomass is made up by mainly the bivalves *Mya arenaria* and *Cerastoderma* spp. that are the largest bivalves in shallow waters.

Thus, the biomass distribution to a large degree reflects the distribution and occurrence of large bivalves, whereas the abundance distribution rather reflects habitat structure.

As a summary, the mean, minimum and maximum number of species in each administrative area of the Fehmarnbelt is stated in Table 4-3.

Table 4-3 Summary of the total biomass (AFDW as gm^{-2}) observed per administrative area in the study area around Fehmarnbelt.

Administrative area	stations	Biomass mean	minimum	maximum
Overall	325	15.62	0.13	381.22
Danish waters	151	11.96	0.13	145.37
German Waters	174	18.79	0.5	381.22
German coastal zone	154	16	0.5	381.22
German EEZ	20	40.3	8.53	98.98
DE 1332-301 (Fehmarnbelt)	16	41.81	8.53	98.98
DE 1533-301 (Staberhuk)	27	7.36	0.84	20.11
DE 1631-392 (Östliche Kieler Bucht)	43	24.24	0.5	381.22
DE 1632-392 (Ostsee östlich Wagri-en)	15	7.95	0.9	18.78
DE 1733-301 (Sagas Bank)	11	7.64	2.49	13.43
DK 006X238 (Rødsand lagoon)	33	3.88	0.13	13.57
DK00VA200 (Langeland)	8	8.7	2.84	19.08

4.2 Community analysis

In the previous section, differences and trends in the composition of the benthic fauna were shown by using descriptive parameters like overall species richness, abundance and biomass. Distinct trends from west to east and from the shallower to deeper parts of the investigation area were highlighted.

The benthic assemblages are well known to show clear structural and compositional changes along environmental gradients. A thorough analysis of the resulting "com-munities" is therefore an essential part of description of baseline conditions.

The following section gives the results of the community analyses for the benthic fauna of the Fehmarnbelt area. The first sub-section summarizes the main outcome of the community analysis itself. Based on the co-existence of abundant species, the sampled fauna at each station is divided into specific species assemblages or benthic fauna communities. These communities were subsequently linked to (com-binations of) environmental conditions, which were then used as parameters to predict the occurrence of these communities in other localities. In the following step the results are expanded from point data to a spatial prediction of the occurrence of these communities throughout the investigation area around the Fehmarnbelt (summarized in Section 4.2.2).The entire analysis procedure is explained in detail in Appendix 6.

4.2.1 *Community Classification*

The most important factor dividing the benthic fauna communities into two main clusters is the rather stable seasonal pycnocline dividing the Fehmarnbelt area into two distinct horizontal water bodies. Additional environmental factors which were responsible for further differentiation of the communities were: further salinity gradients (horizontal and vertical), sediment characteristics (grain size distribution and organic content), epibenthic structures (hard substrate and algae), dissolved oxygen concentration, exposure (measured as bed shear stress or current speed), and water depth as a proxy integrating several gradients of (partly unmeasured) parameters.

Overall, nine in- and epifauna communities were derived (Table 4-4). Two of them comprise clusters from both deep (below pycnocline) and shallow water (above pycnocline). Four communities were unique for deep waters and three communities were only found in shallow waters. The classification of the sampling stations to each of the benthic fauna communities is shown in Figure 4-4.

Table 4-4 The nine benthic fauna communities with information on their respective depth zones and some key features.

Community name	Depth zone	Key features
Arctica	deep	infauna – muddy sediments
Bathyporeia	shallow	infauna – exposed sand
Cerastoderma	shallow	infauna – sheltered immobile soft bottom
Corbula	deep	in-/epifauna – transitional along pycnocline
Dendrodoa	deep	epifauna – hard substrate/algae
Gammarus	shallow/deep	epifauna – hard substrate/algae
Mytilus	shallow/deep	epifauna – hard substrate
Rissoa	shallow	epifauna – eelgrass
Tanaissus	deep	infauna – exposed sand and gravel

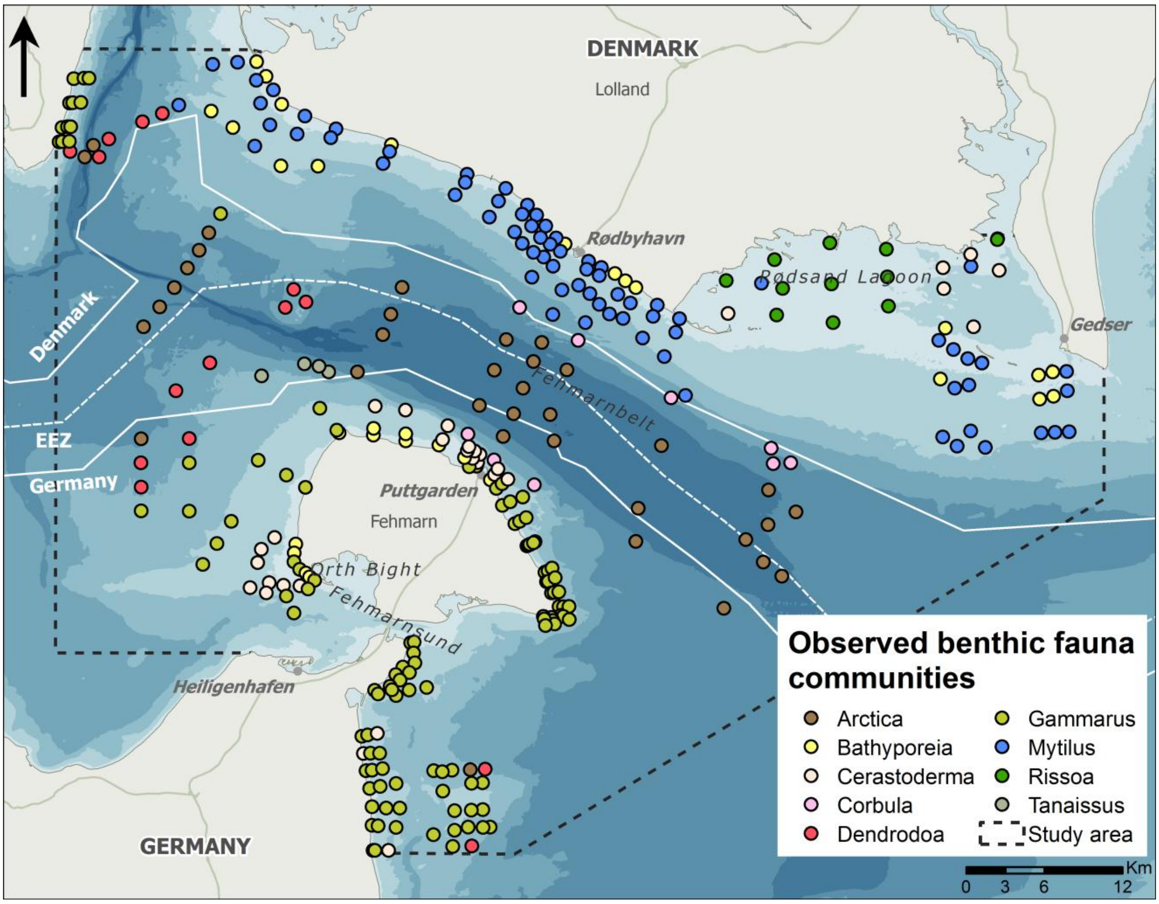

Figure 4-4 Attribution of the sampling stations to the derived benthic fauna communities.

The epifauna and infauna are represented in four communities each. The Corbula community is found to be a mixture of epibenthic and infauna species. It is mainly present on the slopes of Fehmarnbelt along the pycnocline, also forming the transition between the mostly mesohaline shallow water communities and the polyhaline deep water communities.

Typical epifauna communities are the Dendrodoa, Gammarus, Mytilus and Rissoa communities. While the Gammarus and Mytilus communities are to be found on the shallower parts of the slope, characterised by hard substrates, boulders, cobbles, and partly by macroalgae, the Dendrodoa community is found on hard substrates in deeper waters, typically below the halocline. The Rissoa community is associated with eelgrass (*Zostera marina*) meadows.

Also the infauna communities show a depth zonation with two communities being present above and two below the pycnocline.

The Bathyporeia community, although a loose agglomeration of species and transient in character, is linked with high hydrodynamic energy conditions and thus very mobile sandy substrates, mainly found near shore in the shallowest parts of the Fehmarnbelt. Contrary, the Cerastoderma community is found in low hydrodynamic energy conditions ("sheltered") and, consequently, in areas with accumulation of fine (muddy) sediments.

The Arctica community is confined to the deepest waters in the Kiel Bight, the central Fehmarnbelt, and the Mecklenburg Bight, with muddy sand or mud. Finally, the

Tanaissus community is a typical infauna community and, like the Bathyporeia community, associated with sandy substrates and increased hydrodynamic energy conditions. As the Tanaissus community is typically located in deeper waters, it is intrinsically characterised by a higher species number than the Bathyporeia community.

4.2.2 Predicted Community Distribution

After having classified all sampling stations to specific communities, their distribution needs to be expanded to the entire Fehmarnbelt area. Based on the characteristic environmental factors (observed and modelled), the spatial distribution of the nine benthic fauna communities is predicted (Figure 4-5).

The final distribution map reflects the described characteristics of the nine benthic fauna communities quite well. The Arctica community is by far the most widespread community in the study area, covering large areas in the deep water part. The Corbula community displays its transitional characteristics along the subtidal slopes of Fehmarn and parts of the Danish coasts. It is displaced in shallow waters by the Cerastoderma community, if soft sediments dominate and by the Gammarus community on more structured substrates with hard bottom. The Gammarus community covers the second largest part within the study area (Figure 4-5). The Mytilus community is widespread along the Danish coast, whereas it is relatively rare along the German side. The Tanaissus and Rissoa communities show, as expected, very limited extents as both are linked to specific environmental conditions. Finally, the Dendrodoa community is mainly found substituting the Gammarus community below the pycnocline as a deep water epifauna community.

Table 4-5 Predicted areas (km^2) for the nine communities. The total size of the investigation area is 2926.1 km^2.

Community	Predicted area (km^2)	Fraction of the total investigation area (%)
Arctica	1122.4	38.4
Bathyporeia	155.6	5.3
Cerastoderma	111.9	3.8
Corbula	132.5	4.5
Dendrodoa	212.5	7.3
Gammarus	742.3	25.4
Mytilus	309.2	10.6
Rissoa	116.4	4.0
Tanaissus	23.3	0.8

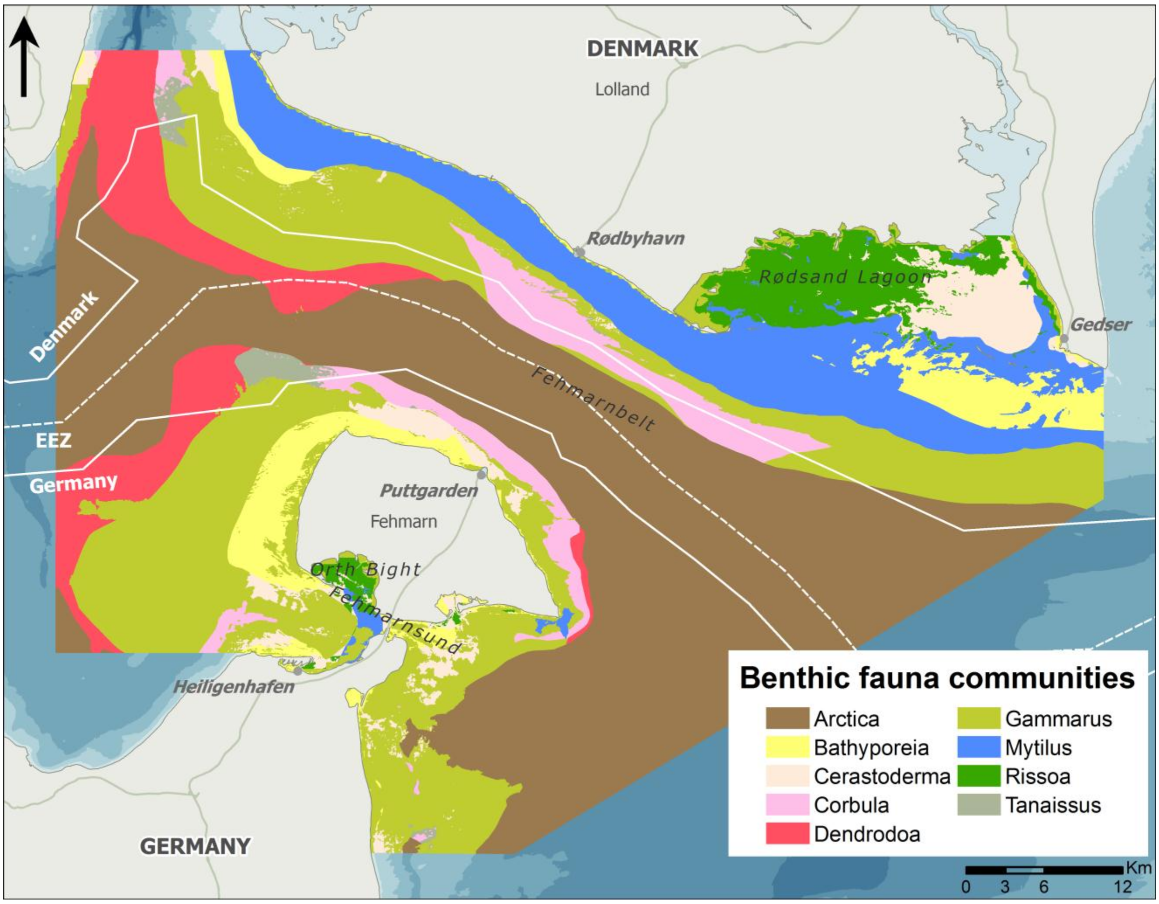

Figure 4-5 Predicted spatial distribution of the benthic fauna communities in the investigated area.

4.3 Benthic Fauna Communities

The following sections describe in details the observed fauna communities and their characteristic features in terms of species composition, abundance, and biomass. It should be noted that none of these communities are isolated from each other by sharp boundaries. They are interrelated and overlap to a certain degree and many kinds of hybrid combinations are possible. This is especially sofor the shallow water communities.

As an example, Figure 4-6 shows a location off the west coast of Fehmarn in approx.6 m water depth (sample location Fe-W08-02) in spring 2009. There is soft bottom clearly visible in between patches of hard substrate and algal growth. The soft bottom is inhabited by an infauna community largely resembling the Cerastoderma community, whereas the algal patches are characteristic spring algae (mostly *Halosiphon tomentosa*), attracting a typical epifauna Gammarus community. This is a temporary community here, since *Halosiphon* disappears in summer and autumn. On the small cobbles and pebbles covering the substrate in small patches, the Mytilus epifauna community lives, which in itself already has an overlap with the Gammarus community, but is more driven by the presence of the Blue Mussel *Mytilus edulis* than the algae. However, the algae also utilize *Mytilus* to attach themselves to a surface, especially when other hard substrate is scarce. Thus, there are manifold interactions and mixtures of communities in one place. This is particularly the case in the shallow waters, where vegetation communities add additional habitat complexity. The deeper water communities are more homogeneous in this respect.

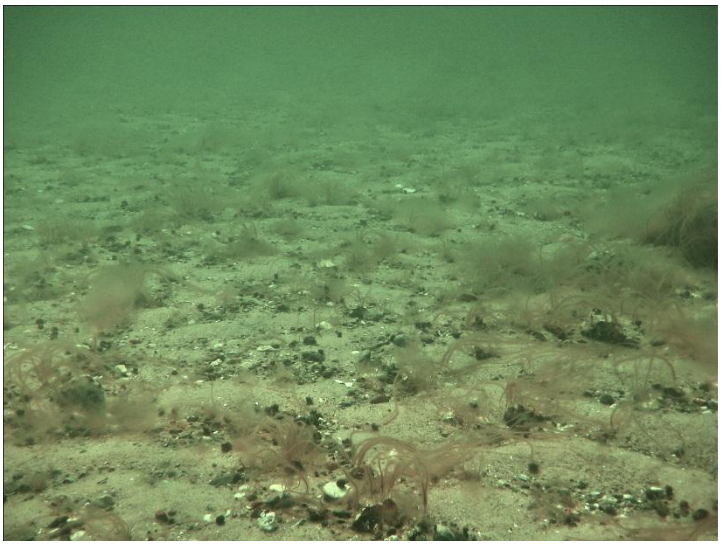

Figure 4-6 *Example of the mixture of different communities at one place. The image shows both soft bottom containing infauna, mussels and snails as epifauna hard bottom components, and algae with associated mobile epifauna species.*

A general pattern differentiates the shallow from the deep communities. In the shallow waters above the pycnocline, the mud snail *Hydrobia ulvae* is by far the most abundant species. It can often be seen in masses on the soft bottom (Figure 4-7) and reach up to approx. 85% relative abundance.

Figure 4-7 *Example of shallow water soft bottom in approx. 6 m water depth off the north coast of Fehmarn. The small spots on the images are the mud snail* Hydrobia ulvae *(around 2–3 mm in size) that dominates nearly all shallow water locations in terms of abundance.*

This is not the case in deeper waters below the pycnocline, where polychaetes or the namesake community species dominate. Therefore, although *Hydrobia ulvae* is very dominant, it has often been left out in the descriptions and especially the figures below, since it is no special component of one single shallow water community. It rather is a generic, dominant species in all shallow water communities.

In addition, the following general patterns can be observed:

- the polychaetes always are the taxonomic group with most species in the communities, regardless of depth zonation

- shallow water communities are in general composed of less species than deep water communities due to lower salinity and inflow of marine water from the North Sea in the deep regions

- the taxonomic groups discussed in the community descriptions can to a certain degree be regarded as groups in terms of ecological functioning (functional groups). They often reflect the habitat on/in which they settle and thus he ecological niche in which they live

In the following, a comprehensive description is provided for each of the benthic fauna communities in combination with their respective environmental characteristics. The benthic fauna communities will hereafter be discussed in alphabetical order.

Each community will be discussed in terms of its spatial distribution, typical depth range, fauna species composition and ecological functioning. For each community, the general, temporal and spatial trends and variability will be presented for the number of taxa (species), the most abundant species and most dominant species in terms of biomass.

Also for each community, there is a summary table, much like the summary tables in section 4.1, where the following information is given per administrative area:

- the number of stations where the particular community is observed

- the predicted surface area (per administrative nautical area) of the particular community

- the mean number of species observed

- the mean abundance (ind. m^{-2}) observed

- the mean biomass (g AFDW m^{-2}) observed

Naturally, when the number of stations where the particular community is observed is zero, the values for number of species, abundance and biomass are also zero. To increase the readability of the tables, these zero values are therefore not shown.

4.3.1 Arctica community

A large area in the Fehmarnbelt is occupied by the Arctica community. It is observed in the characteristically muddy and sandy muddy sediments in waters deeper than 25 m (Figure 4-8 and Figure 4-9). The community is therefore confined to waters that are of higher salinity than the surface waters, and live under conditions of 25-30 PSU. The community features the second-largest number of species (Figure 4-10 and Figure 4-11, Table 4-1) after the Dendrodoa community, with a very clear decreasing trend in species richness from west to east (Figure 4-12). The Arctica community strongly resembles the classical *Abra alba* community, which is mentioned in older literature (Remane 1934).

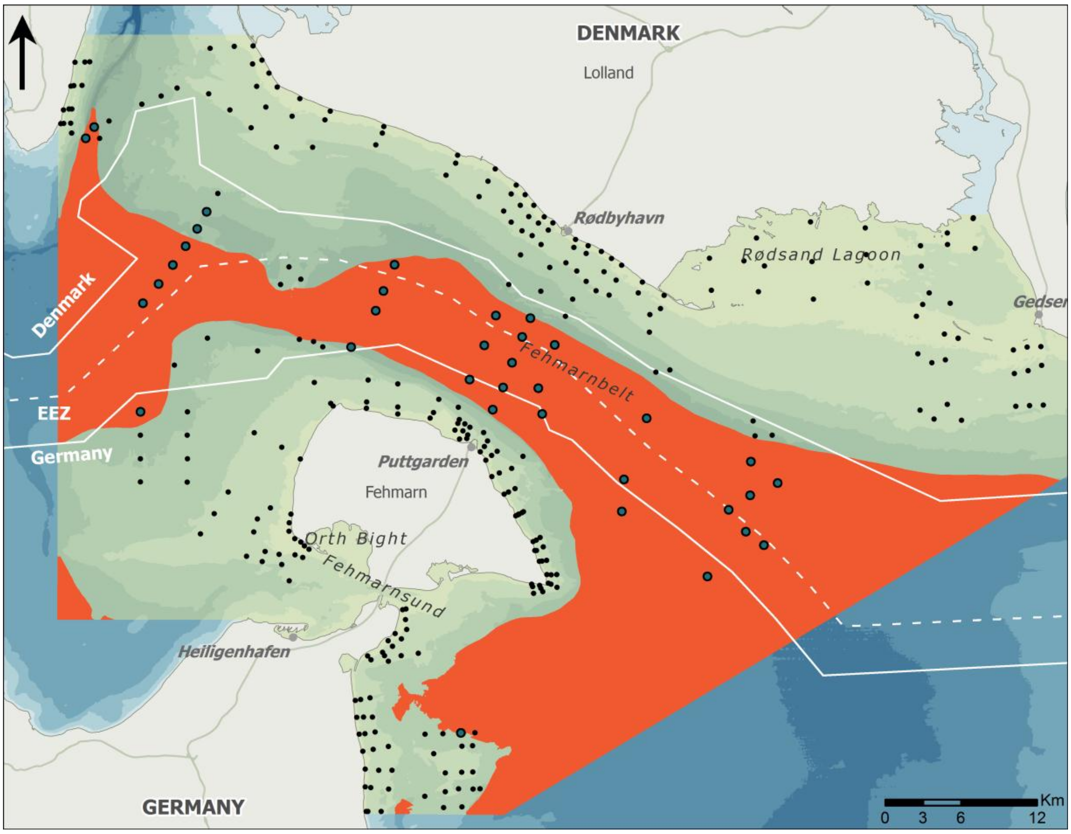

Figure 4-8 Overview of the spatial distribution of the Arctica community in the Fehmarnbelt region. Green area = study area. Large, blue circles = sampled stations. Red polygon = predicted areas.

Figure 4-9 Typical sediment appearance (left) of the Arctica community and an adult specimen of the namesake key species Arctica islandica *(right).*

Table 4-6 Summary of sampled stations, predicted surface area, mean number of species, mean abundance (m^{-2}) and mean biomass (g AFDW m^{-2}) in each administrative area for the Arctica community.

Administrative area	No. of stations	Predicted area (km^2)	No. of species	Abundance	Biomass
Overall	35	1122.	86	1957	46.64
Danish waters	17	406	91	1862	42.77
German Waters	18	716	81	2047	50.3
German coastal zone	7	418	74	2035	73.21
German EEZ	11	298	85	2054	35.72
DE 1332-301 (Fehmarnbelt)	7	220	107	2360	36.57
DE 1533-301 (Staberhuk)	0	0.5			
DE 1631-392 (Östliche Kieler Bucht)	1	24	84	2175	381.22
DE 1632-392 (Ostsee östlich Wagrien)	0	0			
DE 1733-301 (Sagas Bank)	0	1			
DK 006X238 (Rødsand lagoon)	0	0			
DK00VA200 (Langeland)	1	1	131	1544	12.33

The community consists of typical marine species. The namesake species *Arctica islandica* is a long-living, large bivalve, commonly called Ocean Quahog, can live over 100 years old (Witbaard et al., 1994). *A. islandica* is a facultative suspension-feeding bivalve, adapted to conditions of low oxygen levels. Rather than being the most numerous species, it is a large species that makes up some 65 % of the biomass of the Arctica community. The size and the fact that it is a motile species means that it is the dominant species in determining the biota-induced sediment processes, such as bioturbation and related geochemistry (Montserrat et al., 2009). The sizes of the areas where the community is found are listed in Table 4-6.

Taxonomic compositionThe filter-feeding bivalve *Arctica islandica* is clearly dominant in terms of biomass. The highest abundances were reached by several bivalve and polychaete species and the abundant cumacean *Diastylis rathkei*.

In total, 261 species of 27 different groups were found in the Arctica community (Figure 4-10). The Polychaetes (bristle worms, a subgroup of the Annelida, the ringworms) was the group with most species. The polychaetes dominated the Arctica community, with 92 different species. Further prominent groups within the Arctica community were amphipods (small crustaceans: 28 species), bivalves (26 species), gastropods (snails: 23 species) and bryozoans with 15 species.

The species richness of other groups within the Arctica community was clearly lower, and almost all species of this community were observed during the campaigns in 2009. In 2010, an additional 20 species were found, indicating a low variability in this community with respect to species composition.

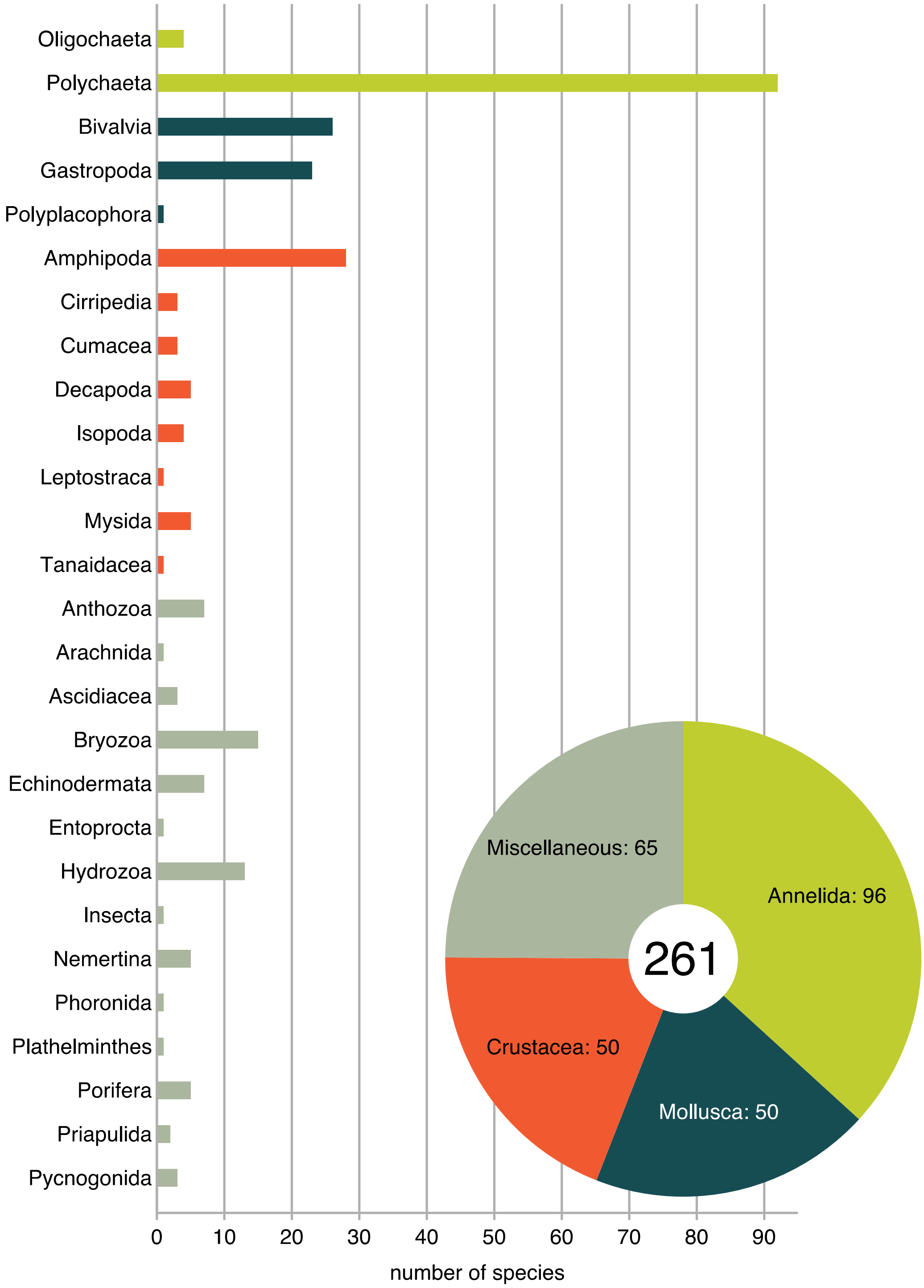

Figure 4-10 *Macrozoobenthos species composition of the Arctica community during the baseline investigation campaigns in 2009–2010.*

The absolute number of species showed small variations between sampling campaigns (Figure 4-10). The median species number per station ranged between 37-55 in the Arctica community, and was thus distinctly lower than the maximum of 261. However, the variability of species richness was relatively low: 19% (49 species) were found only once and another 16% of the species occurred only up to three times during the investigation period. Only the main constituent, *Arctica islandica*, was nearly always present. Furthermore, 12 species (4.6%) were found at least with a frequency higher than 80%. In addition to the most abundant species, the polychaete *Bylgides sarsi*, the ophiurid *Ophiura albida* and tubificid oligochaetes were observed very frequently.

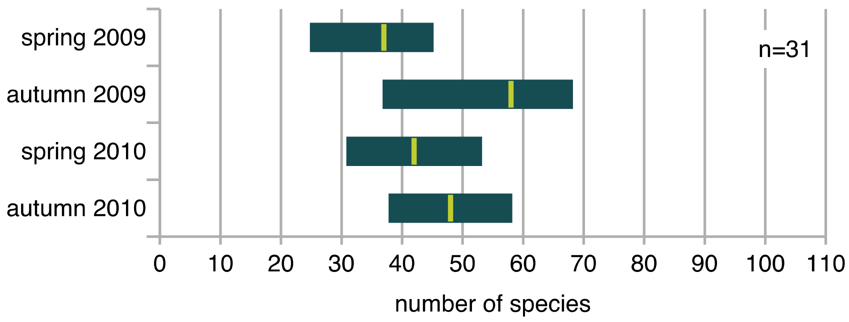

Figure 4-11 *Number of species per station found in the Arctica community during the four investigation campaigns in 2009 and 2010. Box: 25-75th percentile, Line in box: median.*

The median number of species throughout the Fehmarnbelt (Figure 4-12) decreased clearly from around 60 species in the western area (13 stations) to about 45 in the central region (11 stations) and dropped to around 30 species in the east of the Fehmarnbelt area (10 stations). In the central and eastern part of this community the median values increased during the investigation period (Figure 4-12).There is a tendency to a higher species number during autumn 2010 (compared with the autumn of 2009) in the western area, which could be related to an increase in dissolved oxygen in the bottom waters during 2010 (FEHY 2013).

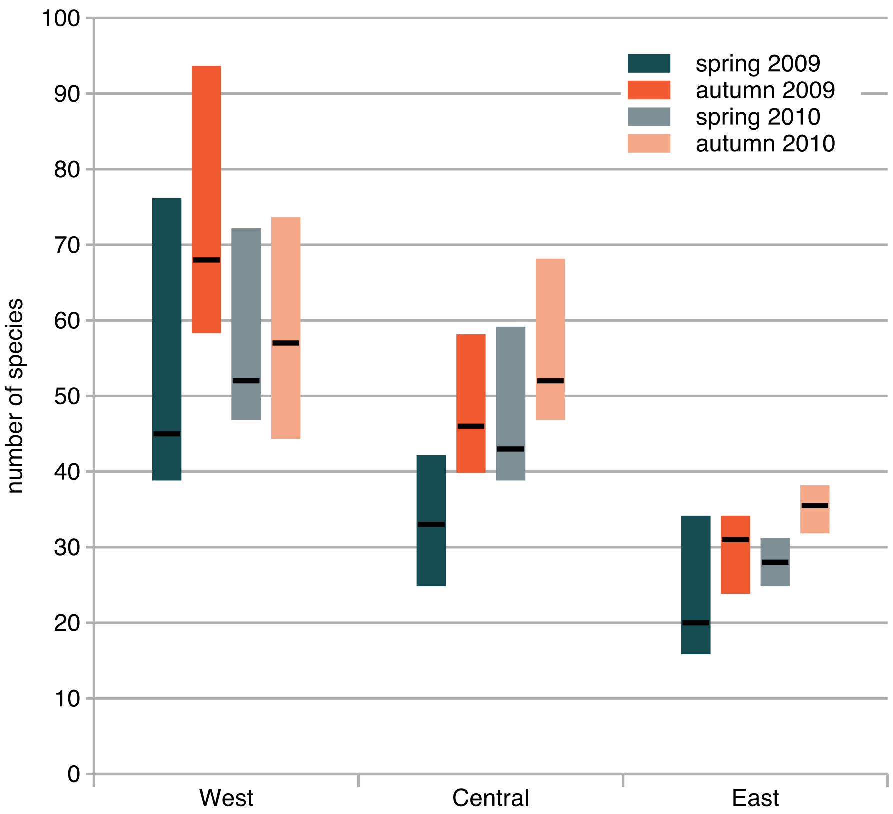

Figure 4-12 *Number of species in the Arctica community for three different regions during the four investigation campaigns in 2009 and 2010. Box: 25-75th percentile, Line in box: median.*

Abundance and biomass

The Arctica community is characterised by a distinctive species assemblage of several highly frequent key species. Several of the abundant key species of the Arctica community belong to the polychaetes (Figure 4-13). Furthermore, several bivalves and the cumacean *Diastylis rathkei* are abundant species of this community. The summarised abundances of these species were more than twice as high as the abundances of the other community members. The median abundances for the polychaetes *Terebellides stroemi*, *Lagis koreni* and *Scoloplos armiger* were clearly highest. *Abra alba* was clearly the most abundant bivalve.

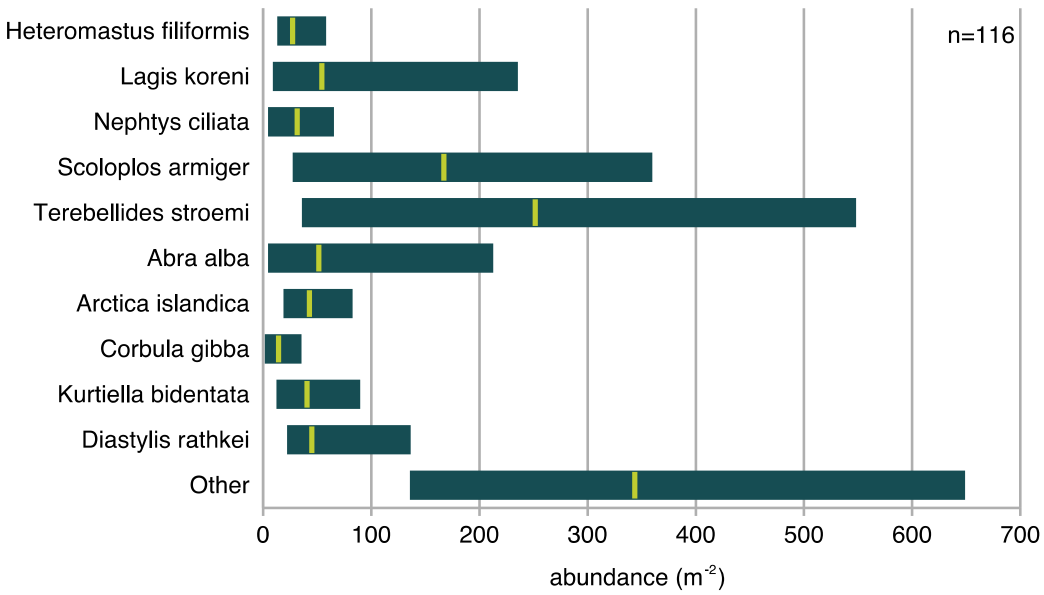

Figure 4-13 Abundances (m^{-2}) of the main representatives of the Arctica community during the baseline investigation 2009–2010. Box: 25-75th percentile, Line in box: median.

The ten most dominant species of the Arctica community each revealed a certain degree of temporal variability (Figure 4-14). For example: the median abundances of *Kurtiella bidentata*, *Scoloplos armiger* and *Nephtys ciliata* increased over the investigation period. In contrast, the median abundances of *Arctica islandica* and *Corbula gibba* were constant through time.

Only low abundances for *Terebellides stroemi* were observed in spring 2009. *Abra alba* showed a rather consistent annual trend with higher median abundances in spring, whereas *Diastylis rathkei* and *Heteromastus filiformis* revealed higher abundances in autumn. For the polychaete *Lagis koreni*, very high abundances were found only in autumn 2009.

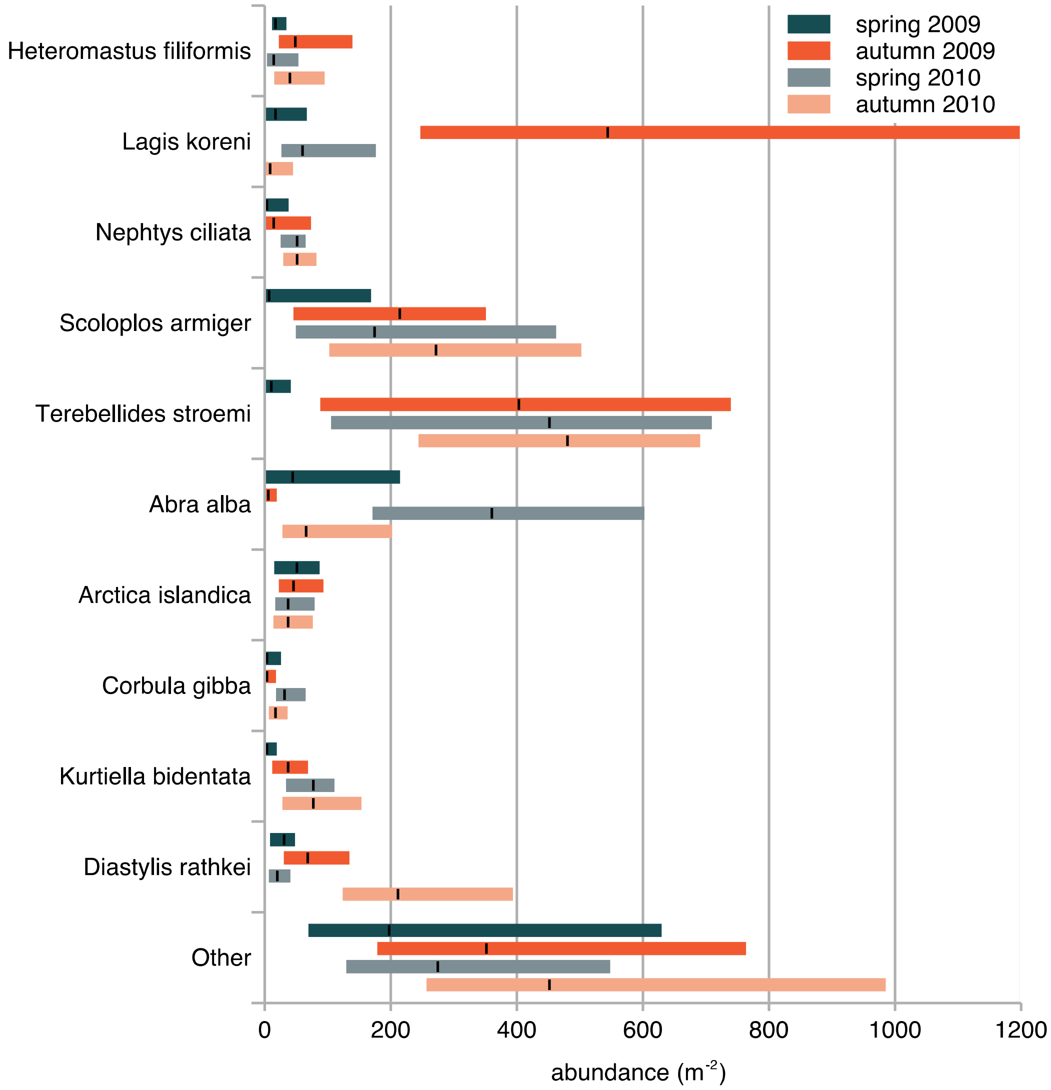

Figure 4-14 Abundances (m^{-2}) of the main representatives of the Arctica community during the four investigation campaigns in 2009 and 2010. Box: 25-75th percentile, Line in box: median.

The spatial distribution of the ten most dominant species varied per species. For several species the abundances decreased from West to East (Figure 4-15): *Abra alba*, *Corbula gibba*, *Nephtys ciliata*, *Scoloplos armiger*, and the category "Other". In contrast, the polychaetes *Lagis koreni* and *Terebellides stroemi* reached higher values in the eastern part of the spatial distribution of the Arctica community.

For the species *Arctica islandica*, *Diastylis rathkei* and *Kurtiella bidentata*, the abundances were observed to be constant between the western, central and eastern part of the Fehmarnbelt.

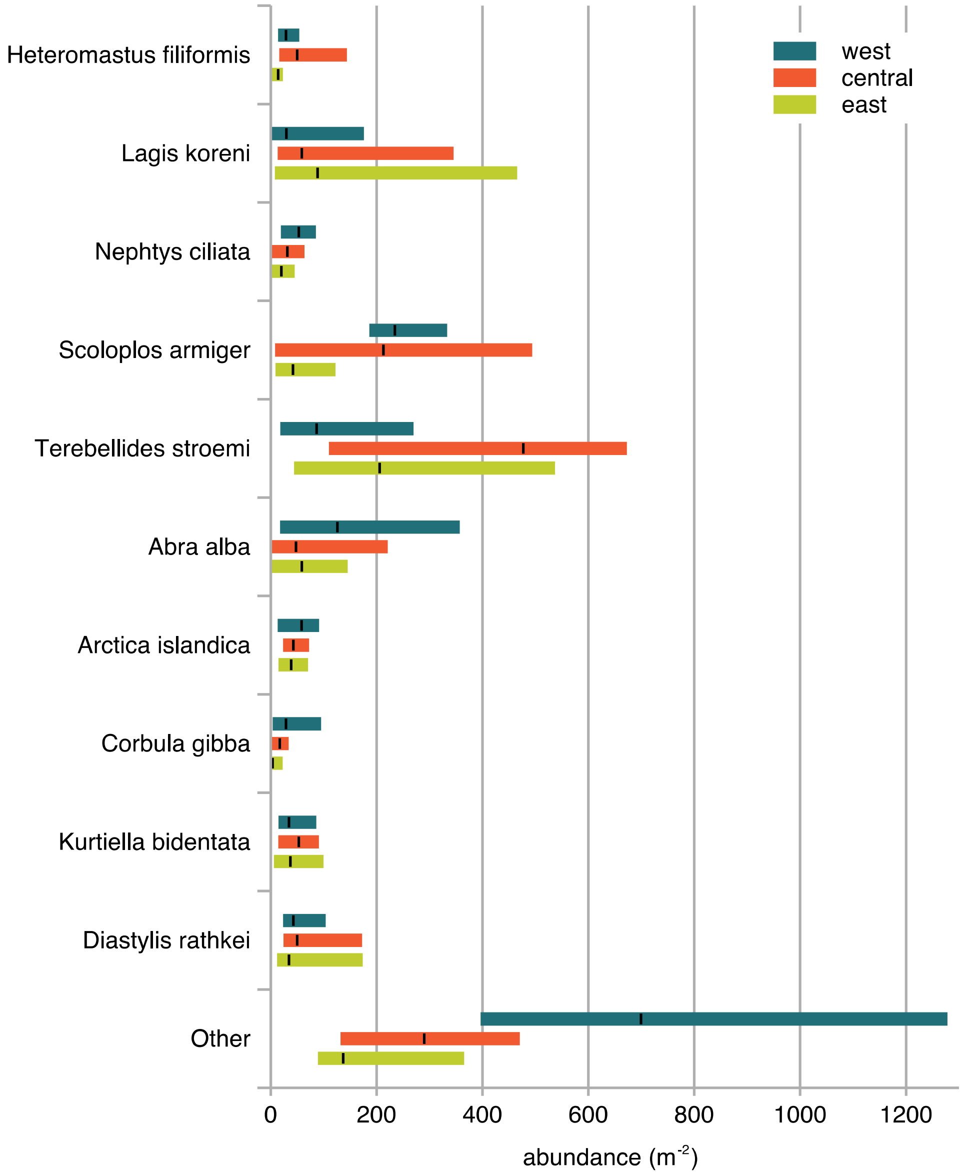

Figure 4-15 Abundances (m^{-2}) of the main representatives of the Arctica community for three different regions during the investigation period 2009–2010. Box: 25-75th percentile, Line in box: median.

The biomass in the Arctica community was clearly dominated by the bivalve *Arctica islandica* (Figure 4-16). Because of the occurrence of large-sized individuals, the polychaetes *Nephtys ciliata* and *Terebellides stroemi* attained considerable biomasses. All other observed species ("Other") attained a combined biomass comparable to that of *T. stroemi*.

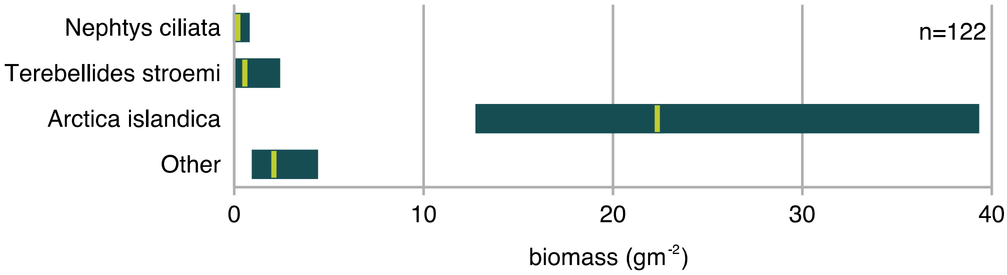

Figure 4-16 Biomass (AFDW gm^{-2}) of the main representatives of the Arctica community during the investigation period 2009–2010. Box: Box: 25–75th percentile, Line in box: median.

The observed biomasses of *Arctica islandica* showed low temporal variation (Figure 4-17). The median biomass of these big bivalves did not differ significantly between the four sampling campaigns. This was also the case for *Nephtys ciliata*. Hence, an effect of the low dissolved oxygen concentration observed during late summer-autumn of 2010 (FEHY 2013) could not be seen.

The biomass of the polychaete *Terebellides stroemi* increased consistently during the four sampling campaigns. The trend of increasing abundances of *T. stroemi* was accompanied by a clear increase in biomass during the entire investigation period.

All other combined infauna displayed a rather constant combined biomass through time.

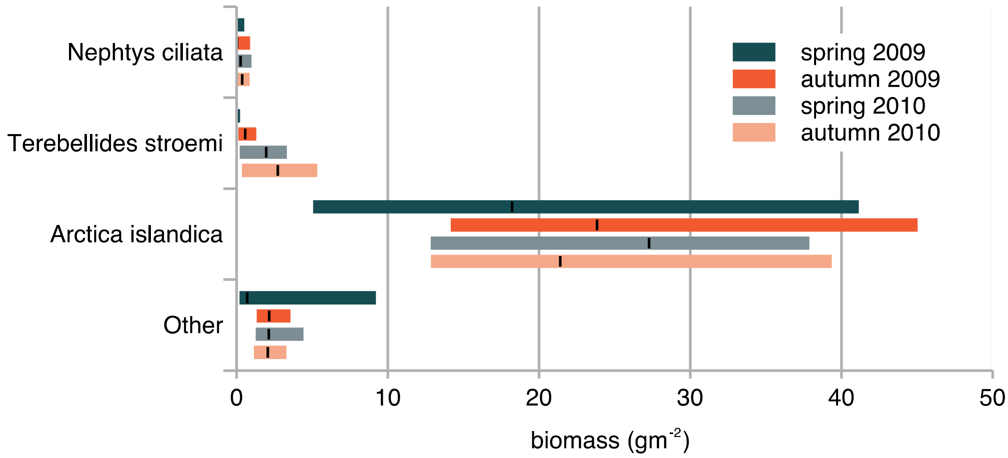

Figure 4-17 Biomass (AFDW gm-2) of the main representatives of the Arctica community during the four investigation campaigns in 2009 and 2010. Box: 25-75th percentile, Line in box: median.

The spatial biomass distribution of 3 of the 6 most dominant species showed a decreasing tendency from west to east (*Alitta virens*, *Astarte borealis*, *A. elliptica*; Figure 4-18). Also the remaining 'Other' species showed this pattern. *Arctica islandica*, *Nephtys ciliata* and *Terebellides stroemi* were invariable.

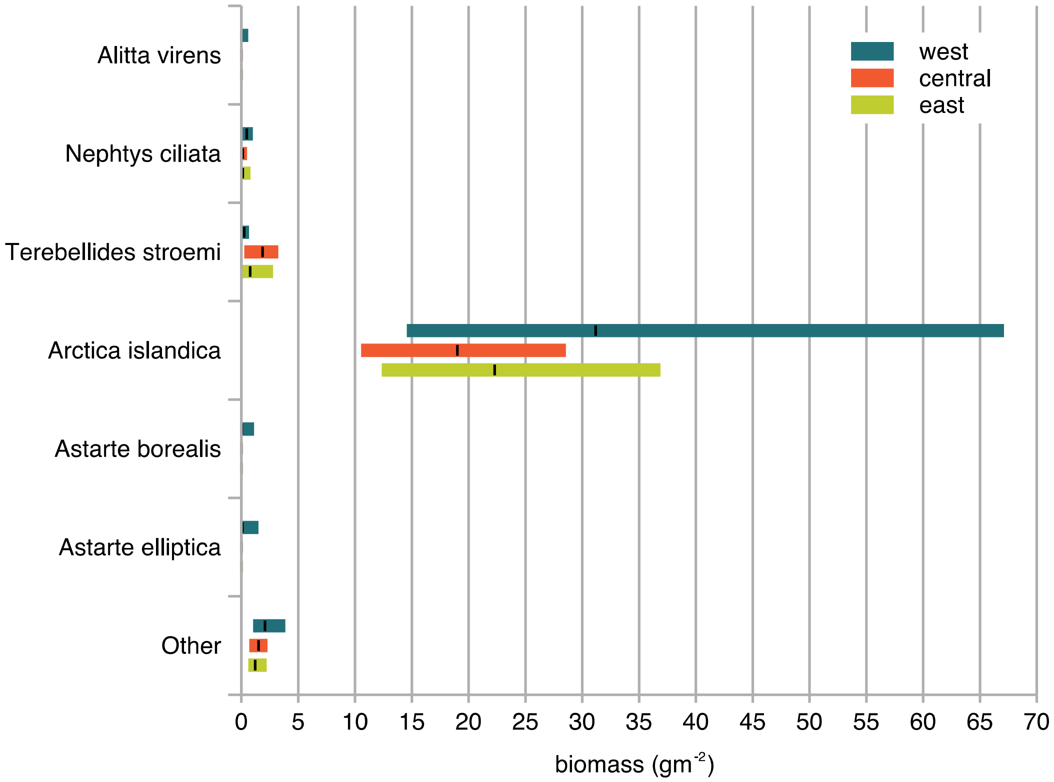

Figure 4-18 Biomass (AFDW gm-2) of the main representatives of the Arctica community for three different regions during the investigation period 2009–2010. Box: 25–75th percentile, Line in box: median.

4.3.2 Bathyporeia community

The Bathyporeia community is an infauna community of very shallow sandy areas, typically in less than 5 m water depth. In very exposed localities the community can also occur deeper.

In the investigation area, the community was found where mobile sands are exposed to wave action and the dynamics of the sand motion does not allow other communities to settle on the sediment. This is observed for example south-east of the Rødsand Lagoon, at the north coast of Fehmarn and along the Flügge Sand spit off the Orth Bight (Figure 4-19). The community mapping predicts this community also in front of the Graswarder sand spit at Heiligenhafen and offshore the Burger Binnensee. All these areas are characterized by mobile sands that are transported by along-shore currents. The sizes of the areas are listed in Table 4-7.

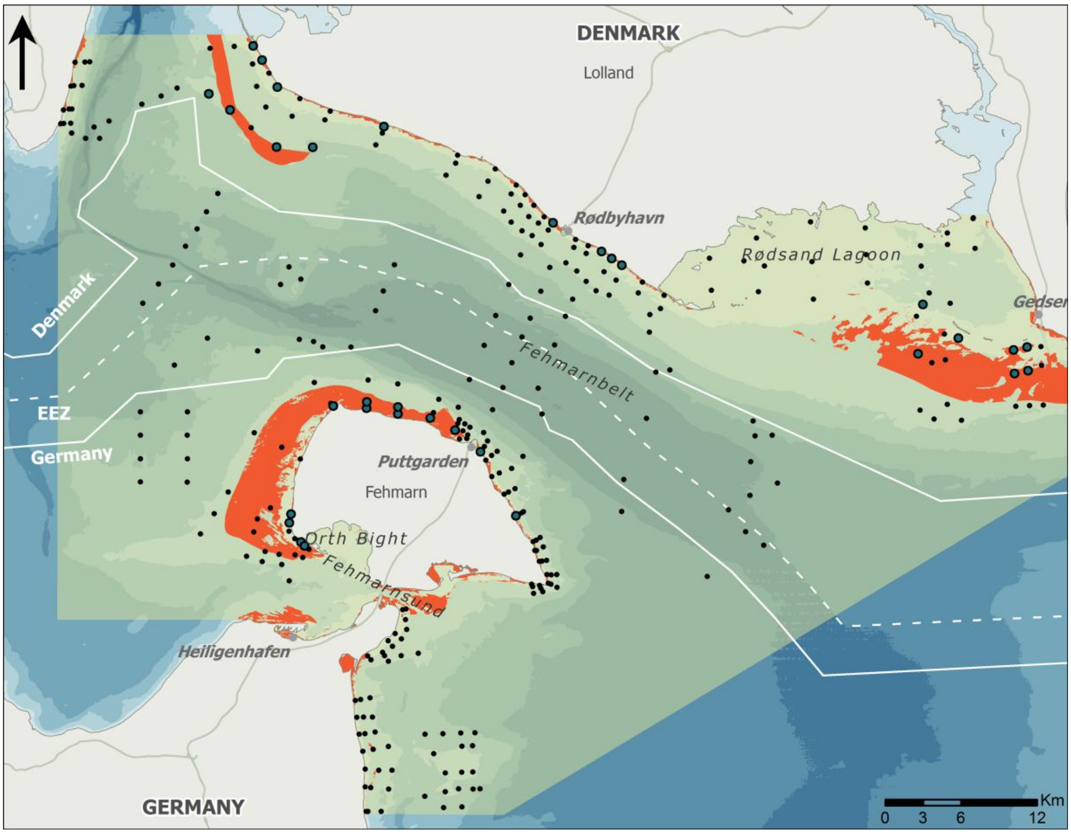

Figure 4-19 Overview of the spatial distribution of the Bathyporeia community in the Fehmarnbelt region. Green area = study area. Large, blue circles = sampled stations. Red polygons = predicted areas.

The namesake amphipod genus *Bathyporeia* is specialized to live under the dynamic conditions that form this community (Figure 4-20). The most abundant species in this genus is *Bathyporeia pilosa*. It lives burrowed in the sand but is also a good swimmer and grazes on microscopic algae by scraping them from the surface of sand particles (Remane 1940; Schellenberg 1942; Köhn and Gosselck 1989). The community resembles the Bathyporeia community of Remane (1940).

Figure 4-20 Typical sediment appearance of the Bathyporeia community (left) and a specimen of the namesake genus Bathyporeia *(right).*

Table 4-7 *Summary of sampled stations, predicted surface area, mean number of species, mean abundance (m^{-2}) and mean biomass (AFDW gm^{-2}) in each administrative area for the Bathyporeia community.*

Administrative area	No. of stations	Predicted area (km^2)	No. of Species	Abun-dance	Biomass
Overall	32	156	16	1243	1.33
Danish waters	19	81	15	751	0.97
German waters	13	76	17	1963	1.85
German coastal zone	13	76	17	1963	1.85
German EEZ	0	0			
DE 1332-301 (Fehmarnbelt)	0	0			
DE 1533-301 (Staberhuk)	1	1	14	1130	0.84
DE 1631-392 (Östliche Kieler Bucht)	10	62	16	2036	1.41
DE 1632-392 (Ostsee östlich Wagri-en)	0	2			
DE 1733-301 (Sagas Bank)	0	0			
DK 006X238 (Rødsand lagoon)	6	11	13	411	0.87
DK00VA200 (Langeland)	0	0			

Taxonomic composition

In general, the community is rather poor in terms of number of species. A total of 61 species were found (Figure 4-19) and only the Rissoa community (see section 4.3.8) has less (42) species. The main explanation for the low species number is the dynamic nature of the sandy environment. It prevents many species from settling permanently and building up high biomass populations.

The most characteristic species found in this community are the amphipods of the family Haustoriidae, like *Bathyporeia* spp. and *Haustorius arenarius*. *Haustorius* is also specialized on fine dynamic sands (Köhn and Gosselck 1989). Additional characteristic species are the mud snail *Hydrobia ulvae*, the clam *Mya arenaria*, the cockle *Cerastoderma edule*, and *Macoma balthica*. They can settle but do not reach the stage of self-sustainable high-density, high-biomass populations, because the sediment is constantly being disturbed. This can be seen in the phenomenon that winter storms severely disturb the sediment, causing the abundance of abovementioned bivalves to be lower in the following spring.

In terms of the number of species, the Annelida (ringworms) are the taxonomic group with most species. This is true for all communities in the investigation area, but in this community the polychaetes do not play a role. Although *Ophelia rathkei*, *Pygospio elegans*, *Marenzelleria viridis*, and *Alitta succinea* are among the 20% most abundant species in total, they do not occur frequently (found in 12–37% of the samples) and are mainly present in the westernmost region around Flügge on Fehmarn. Also species like the Blue Mussel *Mytilus edulis* can be frequently found, often in aggregations lying loose on the sea floor and with associated fauna. These assemblages are however temporary parts of the community as the sediment is under constant change. Thus, only a few of the species in the respective 3 main groups shown in Figure 4-21 (Annelida, Crustaceans, Mollusca) are characteristic and have a relatively high frequency. A total of 13 species (21%) occurred once and 6 species (10%) occurred twice during the four sampling occasions. This is also reflected on a sample level (Figure 4-22). Thus, about a third of the species assemblage of the Bathyporeia community only occurs temporarily. The observed median number of species per sample is 7, which does not show a seasonal variation. This median number of species is a low number compared to the other communities and again shows the transient nature of the community and the fact that only few species are able to attain high density-high biomass populations in these types of habitats.

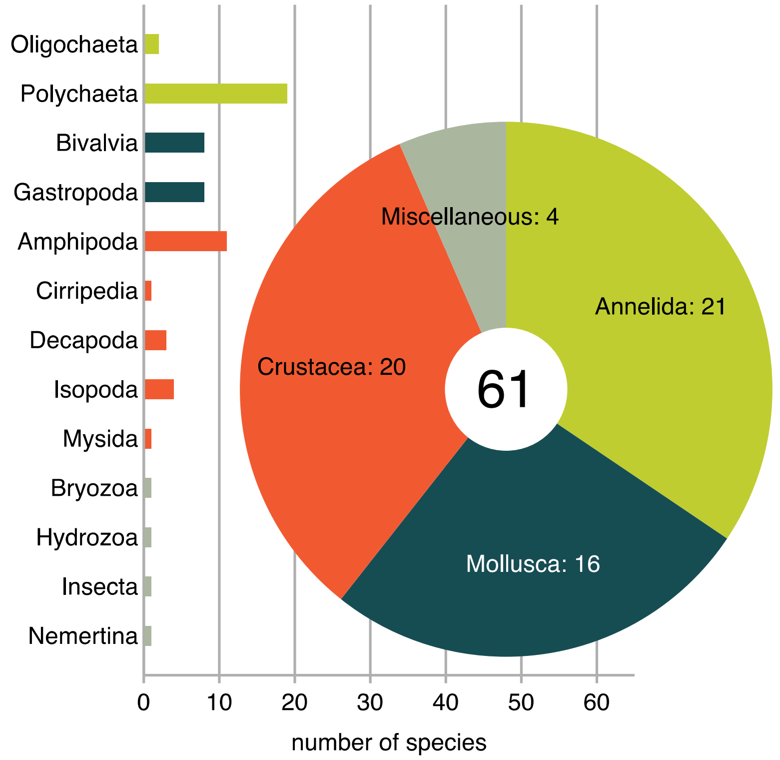

Figure 4-21 Macrozoobenthos species composition of the Bathyporeia community during the baseline investigation campaigns 2009–2010.

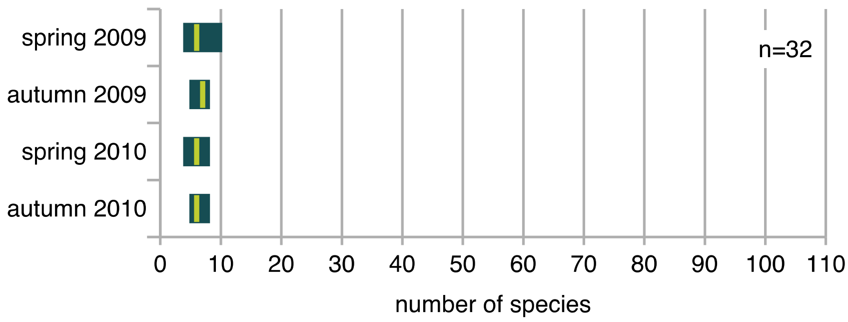

Figure 4-22 Number of species per sample (0.1 m^2) found in the Bathyporeia community during the baseline investigation campaigns 2009–2010. Box: 25–75th percentile, Line in box: median.

Abundance and biomass

Hydrobia ulvae is the most abundant species (median value: 200 m^{-2}) in the Bathyporeia community, as it is in all shallow water communities above the seasonal halocline of 10–15 m water depth. All other species, including the characteristic species *Bathyoreia pilosa*, have median abundances that are less than 25% of that value (around 25 individuals m^{-2}, see Figure 4-23). The medians tend to lie towards the 25th percentile showing that higher abundances do occur and can reach values over 100 m^{-2} in single cases, but are not the typical case.

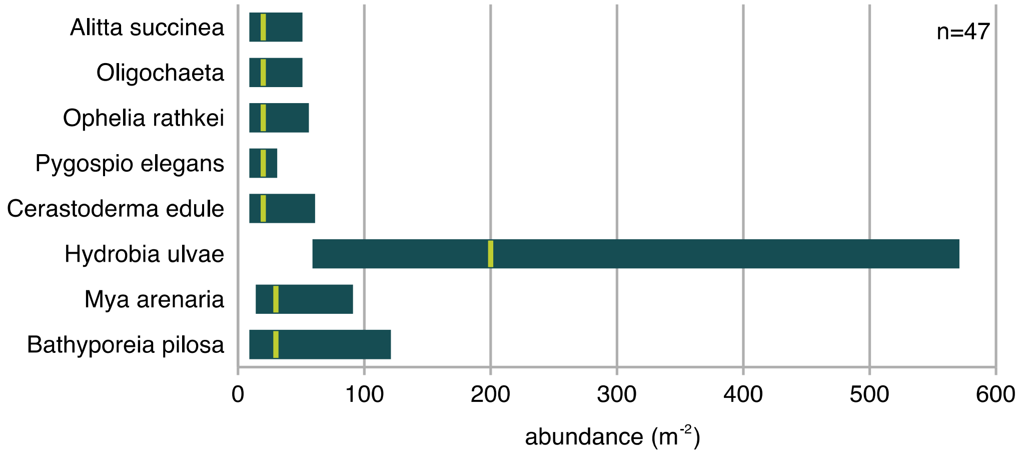

Figure 4-23 Abundance (m^{-2}) of the main representatives of the Bathyporeia community during the baseline investigations 2009–2010. The median abundance of the samples (all species) is 455 m^{-2}. Box: 25–75th percentile, Line in box: median.

Some of these most abundant species show a seasonal pattern in abundance. The abundances of *Hydrobia ulvae* and the bivalves *Cerastoderma edule* and *Mya arenaria* are lower in spring and higher in autumn. This could indicate that the bivalves need to regenerate a population each summer that is partly destroyed again during winter. In contrast, the abundances of *Alitta succinea* and the oligochaetes are higher in spring and lower in autumn (Figure 4-24). These species are feeding on detritus and deposited material and benefit from higher amounts of detritus (phytodetritus – dead algal material) in spring (Theede et al. 1973; Giere and Pfannkuche 1982).

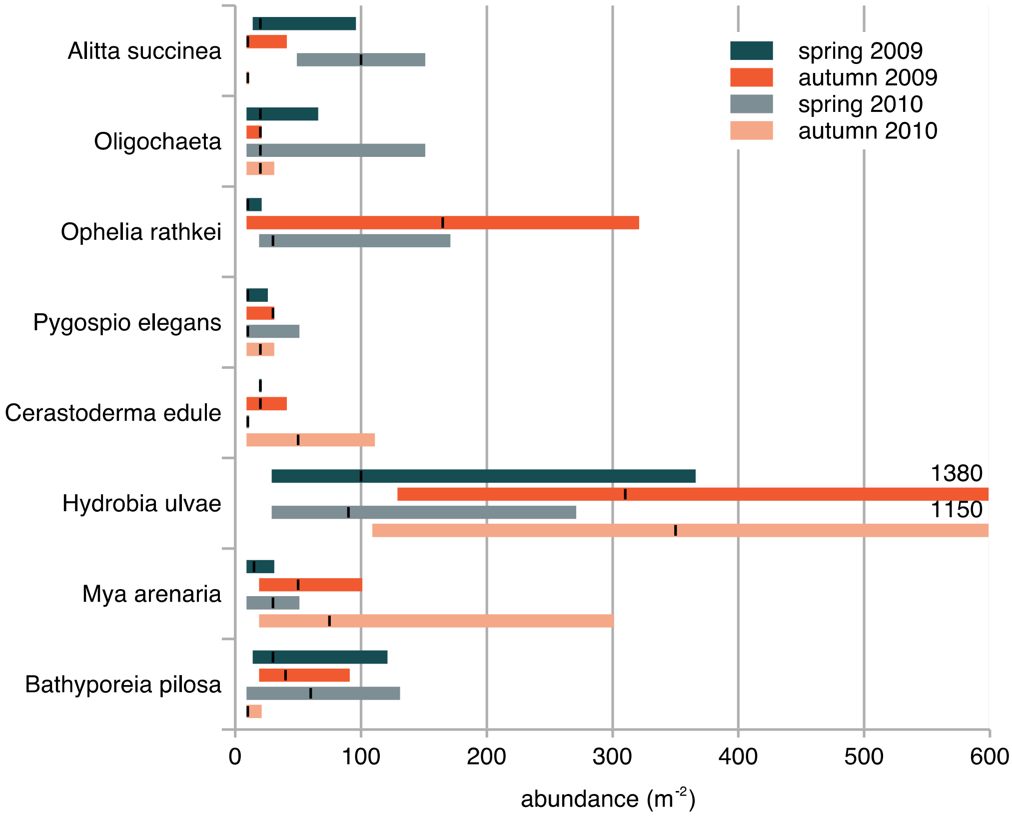

Figure 4-24 Seasonal variation of abundances (m^{-2}) of the main representatives of the Bathyporeia community during the baseline investigations 2009–2010. Box: 25–75th percentile, Line in box: median. Numbers in plot mean values of upper box boundaries.

In terms of biomass, the larger bivalves are dominating (Figure 4-25). *Cerastoderma edule* and *Mya arenaria* together make up more than half the median biomass of the community, which is a typical situation when bivalves are part of an infauna community. The size of the bivalves causes the total biomass to rapidly amount to high values, although the particular species are not the most abundant ones. The seasonal pattern for biomass is similar to that of abundance. Only the bivalves *Cerastoderma edule* show an opposite pattern here: the median biomass is around 10 times higher in spring than in autumn (Figure 4-26).

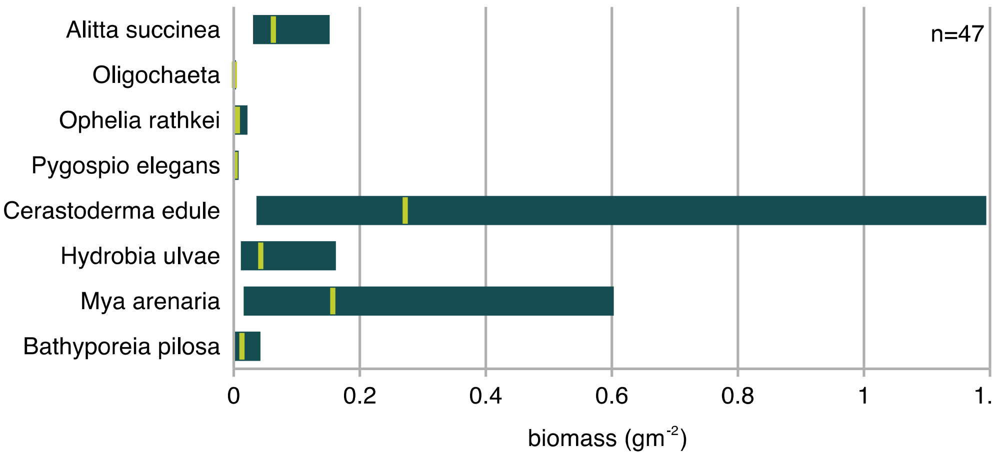

Figure 4-25 Biomass (AFDW gm^{-2}) of main representatives of the Bathyporeia community during the baseline investigations 2009–2010. Box: 25–75th percentile, Line in box: median.

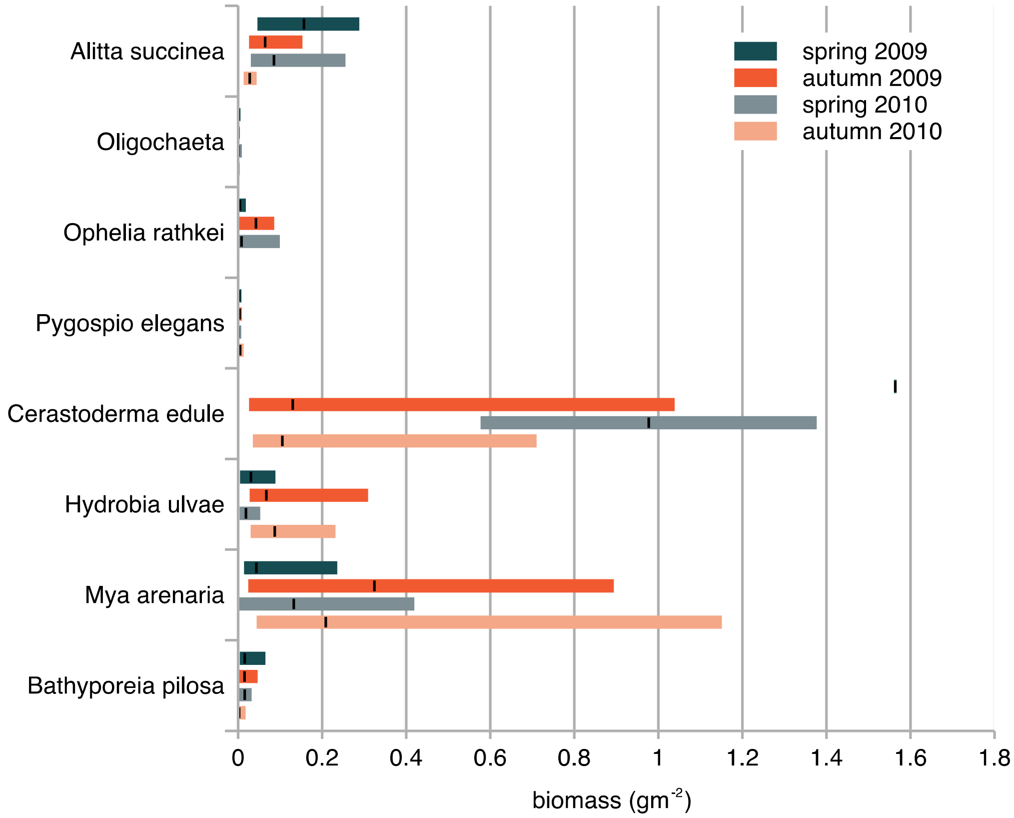

Figure 4-26 Seasonal variation of biomass (AFDW gm^{-2}) of the main representatives of the Bathyporeia community during the baseline investigations 2009–2010. Box: 25–75th percentile, Line in box: median.

4.3.3 Cerastoderma community

The Cerastoderma community is an infauna community found predominantly in shallow waters above the seasonal halocline. It is associated with soft bottom that is muddy to sandy. In the investigation area the community was mainly found in the eastern part of the Rødsand lagoon, off the north coast of Fehmarn, and on the Flügge Sand area off the south-western coast of Fehmarn (Figure 4-27 and Table 4-8).

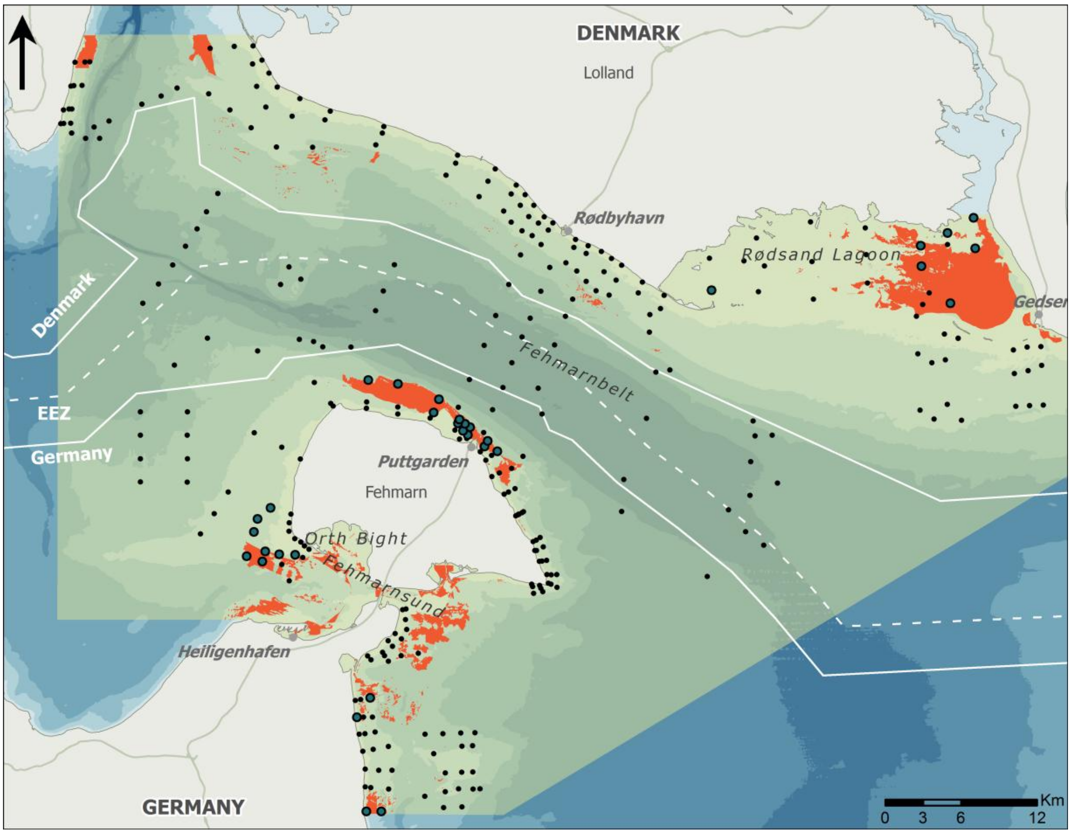

Figure 4-27 *Overview of the spatial distribution of the Cerastoderma community in the Fehmarnbelt region. Green area = study area. Large, blue circles = sampled stations. Red polygons = predicted areas.*

Figure 4-28 *Typical sediment appearance of the Cerastoderma community (left) and a specimen of the namesake genus* Cerastoderma *(right).*

The characteristic species of this community are the bivalves *Cerastoderma edule*, *Mya arenaria*, and *Macoma balthica*. These species are widely spread throughout the investigation area but have their main distribution in terms of abundance within the Cerastoderma community (Figure 4-28). *Cerastoderma edule* is not present in the Arctica and Tanaissus community, both associated with deeper waters below the halocline. In the Corbula community it is found with 1 specimen per 5 samples (on average over all samplings) compared to 17 specimens per sample in total for the Cerastoderma community. *Mya arenaria* is most abundant in the shallow communities (mainly in this and the Gammarus community), but it is also regularly found in all other communities. *Macoma balthica* is the only of the 3 species that can also reach higher abundances in the deeper water communities (on average between 1 and 10 specimens per sample).

No other of the species occurring in this community has a similar level of association to the Cerastoderma community. They occur in the other communities as well but do not form a characteristic part of this community.

Historically, this community was also called *Macoma*-community as opposed to deeper water *Abra*-community (Remane 1934). But already at that time, it was not considered to be good naming. Its namesake species, *Macoma balthica*, is so widely spread and can adapt to many environmental conditions making it unsuited to serve as indicator species.

Table 4-8 Summary of sampled stations, predicted surface area, mean number of species, mean abundance (m^{-2}) and mean biomass (g AFDW m^{-2}) in each administrative area for the Cerastoderma community.

Administrative area	No. of stations	Predicted area (km^2)	No. of Species	Abundance	Biomass
Overall	32	112	23	8776	32.51
Danish waters	7	65	18	4956	4.64
German waters	25	47	24	9845	40.32
German coastal zone	25	47	24	9845	40.32
German EEZ		0			
DE 1332-301 (Fehmarnbelt)	0	0			
DE 1533-301 (Staberhuk)	0	0.1			
DE 1631-392 (Östliche Kieler Bucht)	12	24	23	10134	31.03
DE 1632-392 (Ostsee östlich Wagrien)	0	3			
DE 1733-301 (Sagas Bank)	0	0.1			
DK 006X238 (Rødsand lagoon)	7	57	18	4956	4.64
DK00VA200 (Langeland)	0	0.4			

Taxonomic composition

The taxonomic group with most species is, as in all other communities, the polychaetes (Figure 4-29). The most abundant and therefore important species are *Scoloplos armiger* and *Pygospio elegans*. They inhabit sandy to muddy sediments and are typical for the shallow water communities.

The bivalves are the second-most abundant group in terms of number of species with the 3 species *Cerastoderma edule*, *Mya arenaria*, and *Macoma balthica* being the most important. In the Rødsand lagoon where the salinity is minimal compared to the complete investigation area, *Cerastoderma edule* is replaced by *Cerastoderma glaucum*. Both species share many ecological characteristics and have nearly identically looking shells. However, *Cerastoderma glaucum* is adapted to salinities lower than 16 psu (Stotz 1986), whereas *Cerastoderma edule* needs salinities above 12 psu (Brock 1980). Thus, in the investigation area and especially within the Cerastoderma community, these two species both occur in varying ratios. Despite this fact, the associated benthic community and thus the ecological functioning of the communities at different localities is very similar.

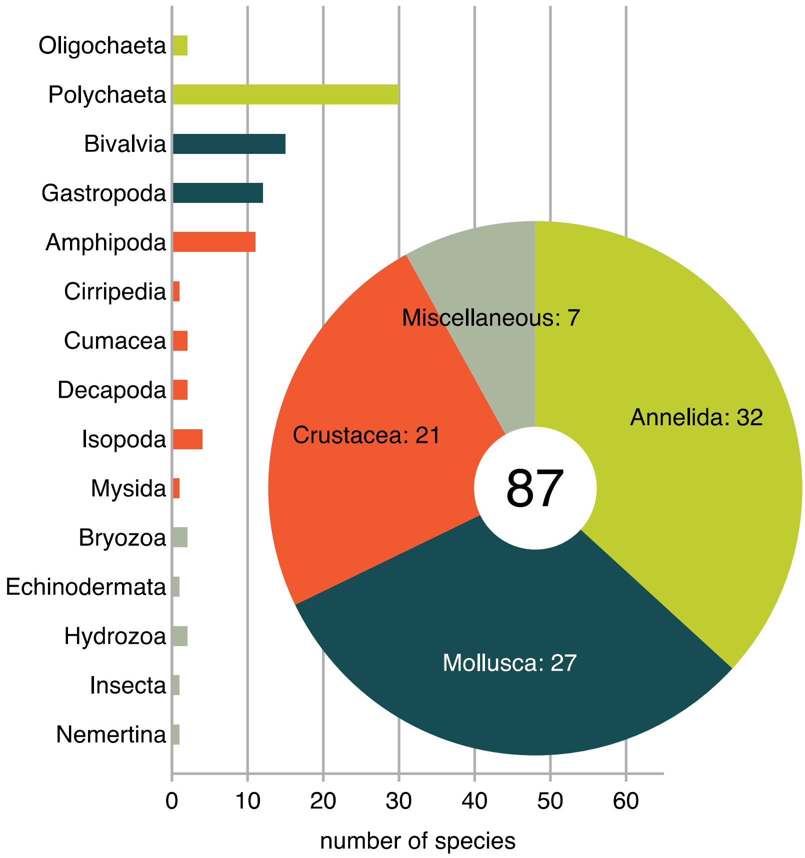

Figure 4-29 Macrozoobenthos species composition of the Cerastoderma community during the baseline investigations 2009–2010.

Also bivalves like the Blue Mussel *Mytilus edulis* or the small cockle *Parvicardium ovale* occur frequently. *Mytilus* usually does not form mussel beds in this community, but the area in which the Cerastoderma community lives is a typical settlement area for the mussel. It forms aggregates of individuals that attach to each other and drift around without being fastened to the sediment. *Parvicardium ovale* is more frequent and abundant in the deeper water communities, but is the 3rd most abundant bivalve on the same level as *Mytilus edulis*.

Only the gastropods and amphipods are represented with species numbers similar to the bivalves. Besides the dominating mud snail *Hydrobia ulvae* the next species (also in terms of the abundance) is the snail *Retusa truncatula*. It is a predator and feeds on *Hydrobia* spp. (Rasmussen 1973) and thus can be found where *Hydrobia* is living. The other snails are mainly associated to phytal biotopes and thus do not strictly belong to the Cerastoderma community. They are present since the area of the Cerastoderma community is not a homogeneous habitat but also consists of patches with algae (e.g. on mussels).

Seasonally, there is no pattern in the species richness of the Cerastoderma community. The number of species is typically around 10 per sample (Figure 4-30).

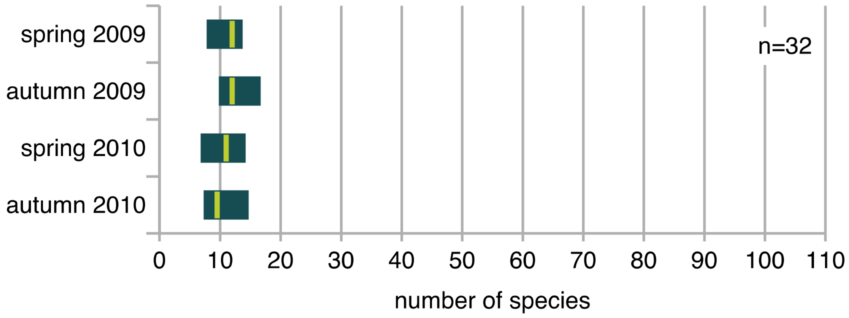

Figure 4-30 *Seasonal variation of the number of species per sample in the Cerastoderma community during the baseline investigations 2009–2010. Box: 25–75th percentile, Line in box: median.*

Abundance and biomass

In terms of abundance, the mud snail *Hydrobia ulvae* is dominating. Its median abundance is 5655 m^{-2} and thus one order of magnitude higher than the second-most abundant species *Mya arenaria* (Figure 4-31). Within the community-specific species, however, the three bivalves *Mya arenaria*, *Cerastoderma edule*, and *Macoma balthica* are the most abundant ones, not only in terms of abundance but also in terms of biomass (Figure 4-33). Because of their size, the biomasses of these bivalves are up to an order of magnitude higher than the biomass of *Hydrobia ulvae*, showing how important these species are in comparison, e.g. as a food source for fish (Stotz 1986). *Macoma balthica* as the species with the weakest association to this community shows the smallest abundance and biomass of the three species. Next to the molluscs, the polychaetes *Scoloplos armiger* and *Pygospio elegans* are most abundant species. The Cerastoderma community is their main distribution area in the shallow waters, where they can build up comparatively high biomass.

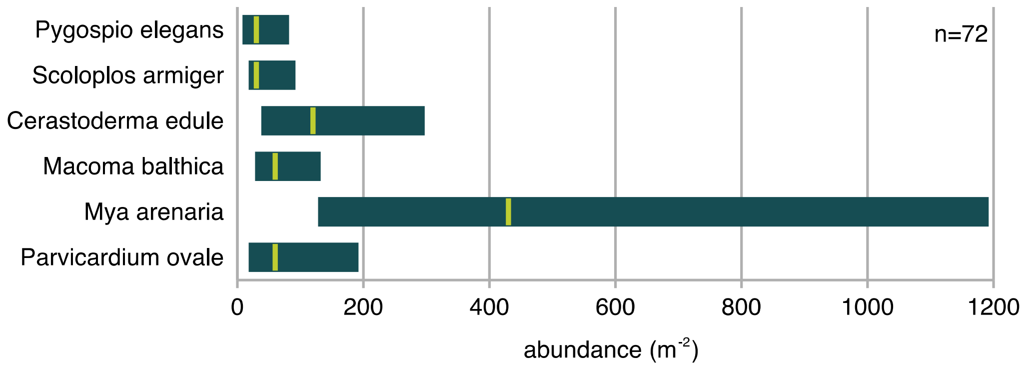

Figure 4-31 *Abundances (m^{-2}) of the main representatives of the Cerastoderma community during the baseline investigations 2009–2010.The small gastropod* Hydrobia *sp. attained median densities of 5655 ind. m^{-2} (see text). For readability, these values are not shown. Box: 25–75th percentile, Line in box: median.*

The seasonal variation within the abundance of the Cerastoderma community is not large (Figure 4-32). Only *Mya arenaria* and to a lesser degree also *Cerastoderma edule* and *Parvicardium ovale* reached the highest abundances in autumn 2010. These peaks are due to the settlement of juvenile bivalves during 2010 (most specimens under 5 mm in size) and show the successful recruitment within this community. This shows that the community has a stable bivalve population that is not as dynamic as e.g. the Bathyporeia community.

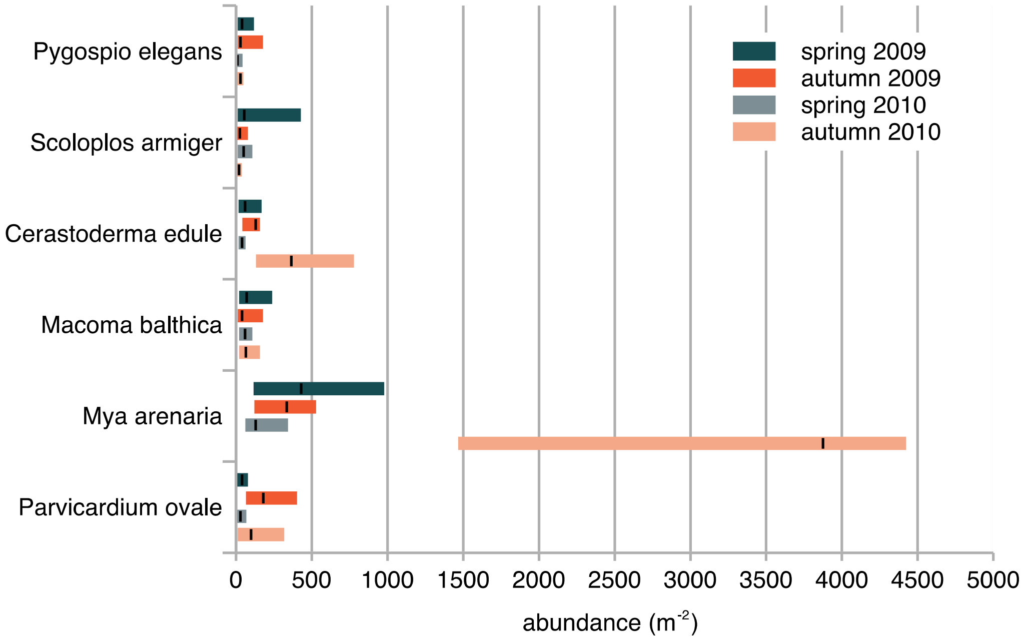

Figure 4-32 Seasonal variation of abundance (m^{-2}) of the main representatives of the Cerastoderma community during the baseline investigations 2009–2010. Box: 25–75th percentile, Line in box: median.

The biomass distribution within the community shows the dominance of the bivalves (Figure 4-33). The namesake species *Cerastoderma edule* builds up median biomasses which are three times as high as the next species *Mya arenaria*. The minor role of *Macoma balthica* in this community is also visible here. Its median biomass amounts to less than 3 g AFDW m^{-2}. The biomass of the main polychaetes, however, is very small.

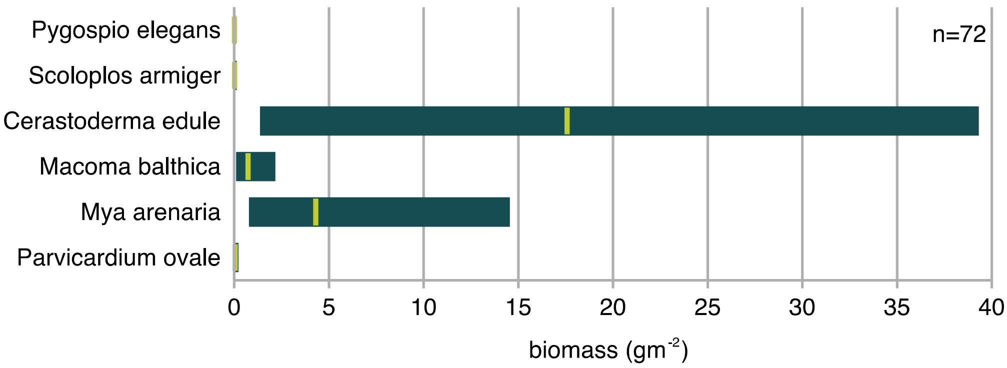

Figure 4-33 Biomass (AFDW gm^{-2}) of the main representatives of the Cerastoderma community. Box: 25–75th percentile, Line in box: median.

The seasonal variation of biomass clearly shows the recruitment success of the Cerastoderma community. The median values in autumn 2010 are in the lower end of the data, meaning that most specimens were small juveniles (Figure 4-34). This can be seen for *Mya arenaria* and *Cerastoderma edule* with the latter species having the largest contribution to the total biomass.

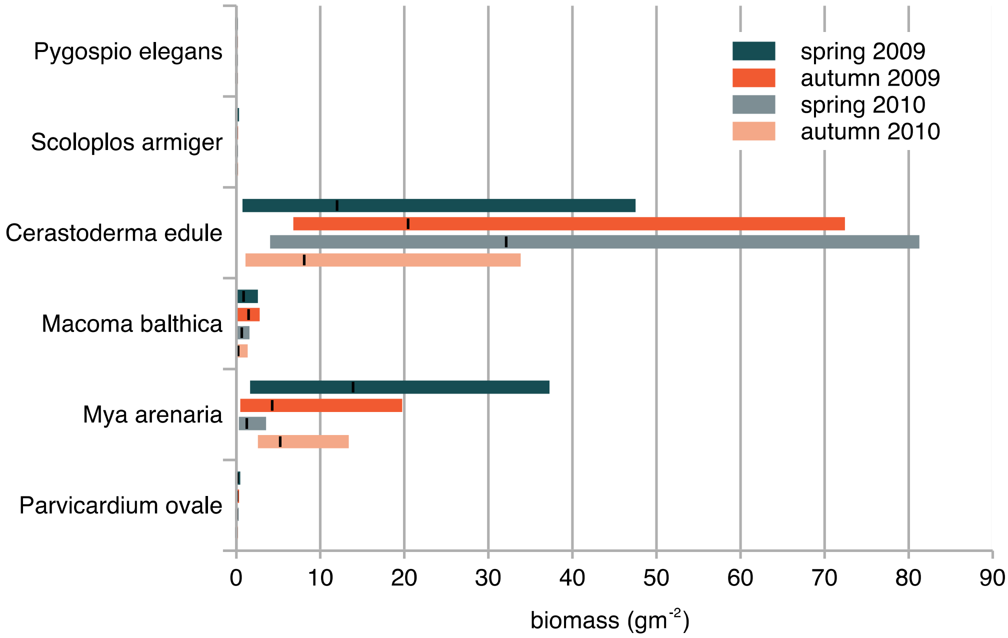

Figure 4-34 Seasonal variations in biomass (AFDW gm^{-2}) of the main representatives of the Cerastoderma community. Box: 25–75th percentile, Line in box: median.

4.3.4 Corbula community

The *Corbula* community occurs typically as a transition community between shallow and deep water communities in waters of 10–20 m depth. The typical sediments are mixed and consist of sand, muddy sand, coarse sand, boulders and small mussel beds (Figure 4-36).

In the Fehmarnbelt, the Corbula community is localised according the depth gradients as two relatively narrow ribbons off the coast of both Fehmarn and Lolland, which were actually sampled (Figure 4-35). Several other small areas were predicted (Figure 4-35), for instance in the southern part of the Langeland Belt, offshore Lolland and southwest of Fehmarn, offshore the German mainland. The sizes of the areas are listed in Table 4-9.

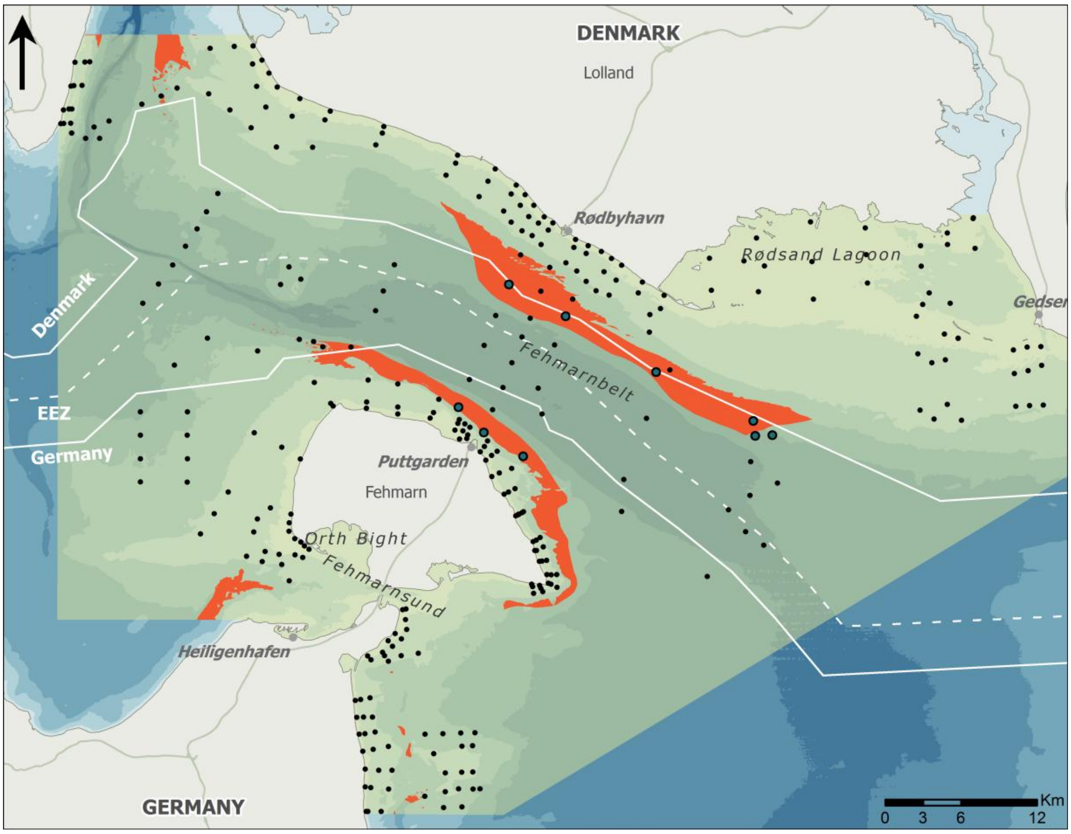

Figure 4-35 Overview of the spatial distribution of the Corbula community in the Fehmarnbelt region. Green area = study area. Large, blue circles = sampled stations. Red polygons = predicted areas.

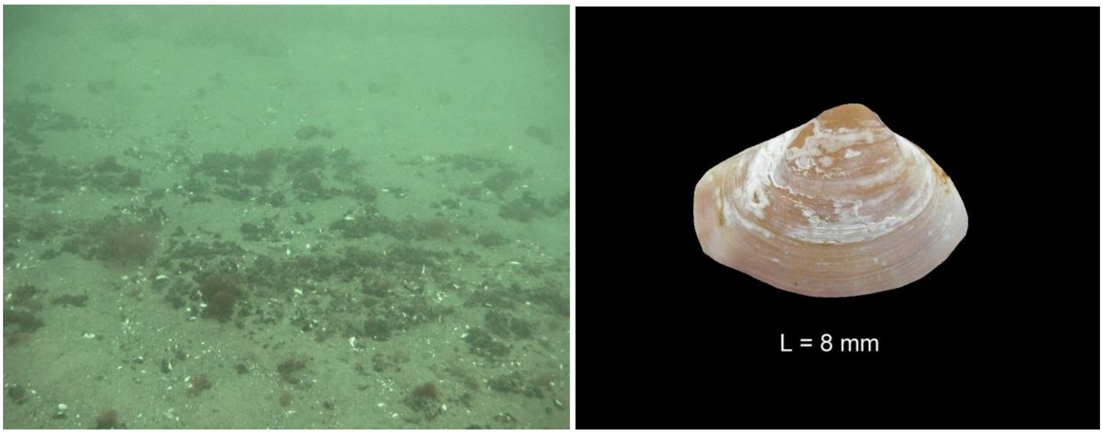

Figure 4-36 Typical sediment appearance of the Corbula community (left) and a specimen of the namesake species Corbula gibba *(right).*

Table 4-9 Summary of sampled stations, predicted surface area, mean number of species, mean abundance (m^{-2}) and mean biomass (g AFDW m^{-2}) in each administrative area for the Corbula community

Administrative area	No. of stations	Predicted area (km^2)	No. of Species	Abundance	Biomass
Overall	9	132	82	3630	11.65
Danish waters	6	83	76	2198	11.45
German waters	3	50	95	6494	12.06
German coastal zone	3	50	95	6494	12.06
German EEZ	0	0			
DE 1332-301 (Fehmarnbelt)	0	2			
DE 1533-301 (Staberhuk)	0	3			
DE 1631-392 (Östliche Kieler Bucht)	0	18			
DE 1632-392 (Ostsee östlich Wagrien)	0	0			
DE 1733-301 (Sagas Bank)	0	0.6			
DK 006X238 (Rødsand lagoon)	0	0			
DK00VA200 (Langeland)	0	0			

Taxonomic composition

In total, 180 species of 24 different groups were found in the Corbula community (Figure 4-37). The Annelida was the most species-rich group, illustrated by the dominance of polychaetes in this community, of which 63 different species were determined. Further prominent groups were bivalves (24 species), gastropods (17 species), amphipods (15 species) and bryozoans with 12 species (Figure 4-37). The species richness of other taxonomic groups was clearly lower.

In each sampling campaign, some species were sampled regularly while a large number of uncommon species were found in each campaign. The numbers of totally observed species thus increased from 124 to 152 in 2009 (Figure 4-38) and then again from 164 to the overall total of 180 species at the end of 2010. This indicates a high variability mainly for uncommon species within the Corbula community. The namesake species *Corbula gibba*, displays a strong transient distribution pattern and is a characteristic bivalve for this community.

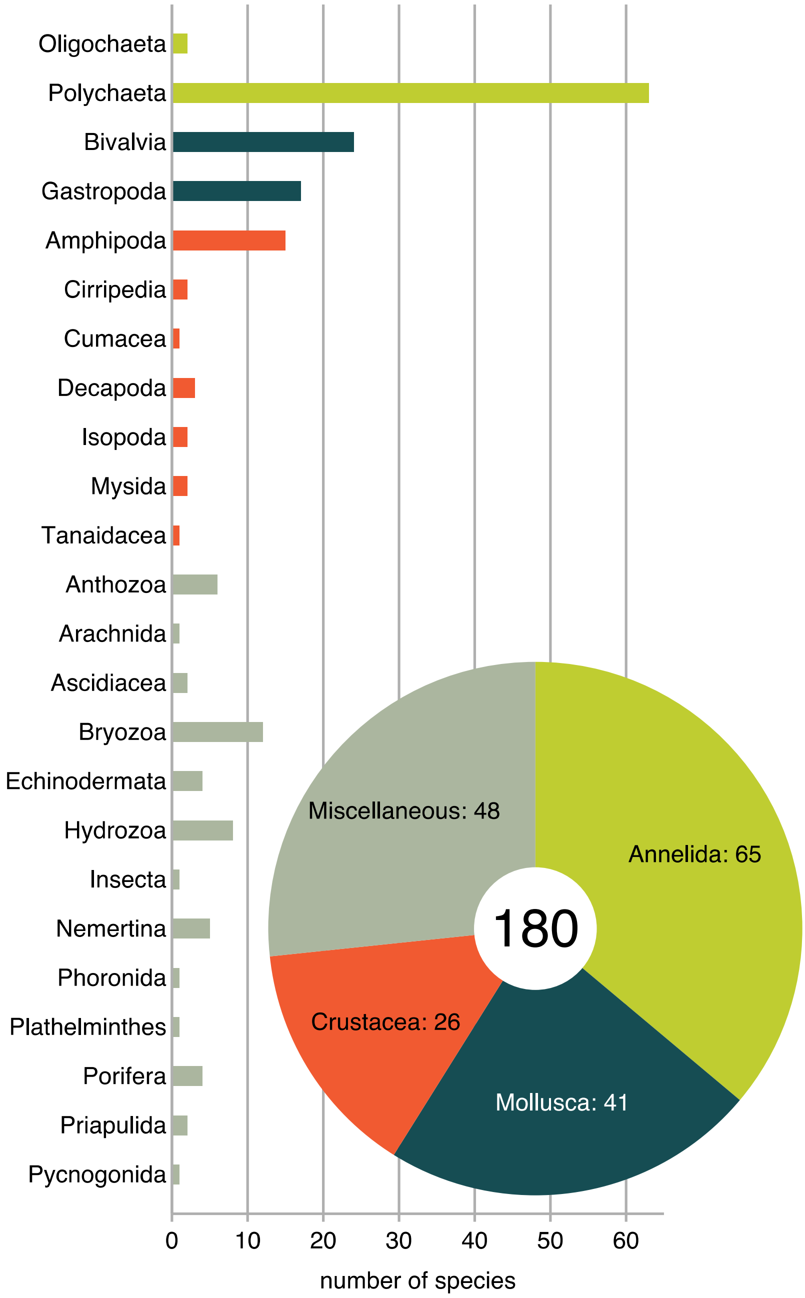

Figure 4-37 Macrozoobenthos species composition of the Corbula community during the baseline investigation campaigns in 2009–2010.

The median number of species in the Corbula community increased over the investigation period (from 36 to 50), but was always much lower than maximum of 180. The high variability of species richness in this area was reflected in different frequencies of occurrence of many species. Of all observed species, 25% (45 species) were found only once and another 17% occurred only up to three times during the investigation period. The bivalve, after which the community is named, *Corbula gibba*, was present in all samples. Furthermore, 16 species were found at least with a frequency higher than 80%. Examples of these frequently occurring species are: *Diastylis rathkei*, *Scoloplos armiger*, *Hydrobia ulvae* and the bivalves *Kurtiella bidentata*, *Mytilus edulis* and *Macoma balthica*.

The high values (25% + 17%) of rare species were noticeably reflected in spatial and seasonal variations in species composition of the Corbula community. The spatial variation between the community in Danish and German areas was minor and concerned mostly uncommon species. Some low frequent species were found only on the Danish side, for instance *Spio goniocephala* and *Balanus improvisus*, whereas the species *Arenicola marina*, *Callopora lineata* and *Nassarius reticulates* were recorded only on the German side.

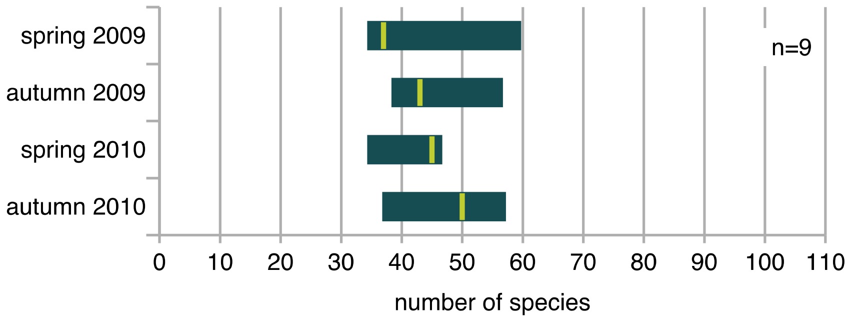

Figure 4-38 Number of species per station in the Corbula community during the four investigation campaigns in 2009 and 2010. Box: 25–75th percentile, Line in box: median.

Abundance and biomass

The Corbula community was characterised by high abundance of several key species, which belong to the molluscs and polychaetes (Figure 4-39). The combined abundances of the key species were in the same range as the abundances of the remaining community members. However, the individual species from the group "Other" did not reach mean abundances higher than 100 m^{-2}.

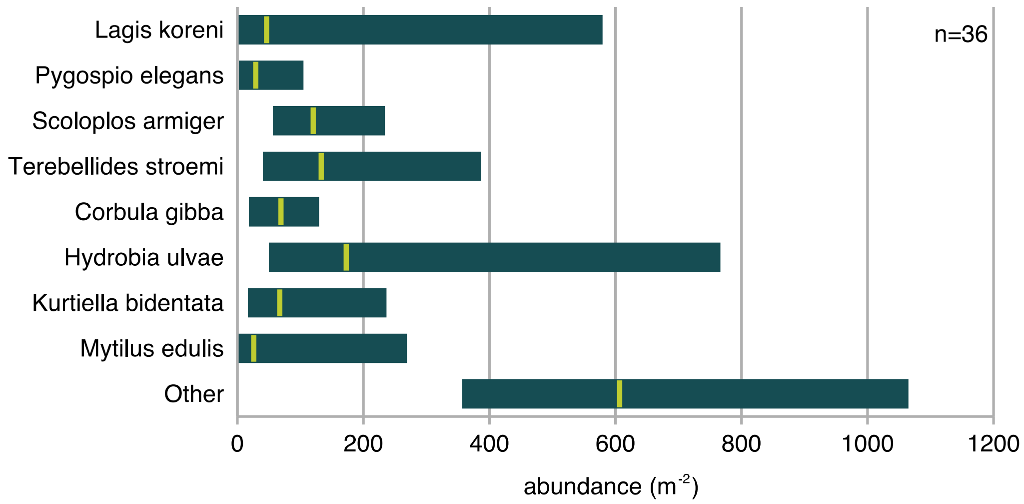

Figure 4-39 Abundances (m^{-2}) of the main representatives of the Corbula community during the investigation period 2009–2010. Box: 25–75th percentile, Line in box: median.

Seasonal variability was low only for *Corbula gibba* (Figure 4-40), whereas the other species of this community revealed individual seasonal variations.

The highest variations were found for the small polychaetes *Lagis koreni* and *Pygospio elegans*. Of these species, very high abundances were observed in autumn 2009, while in contrast only few individuals were found one year later. The median abundance of *Mytilus edulis* was clearly higher in 2009 than in 2010. The median abundances of *Kurtiella bidentata* and *Scoloplos armiger* showed an annual trend with low median abundances in spring and higher abundance in autumn.

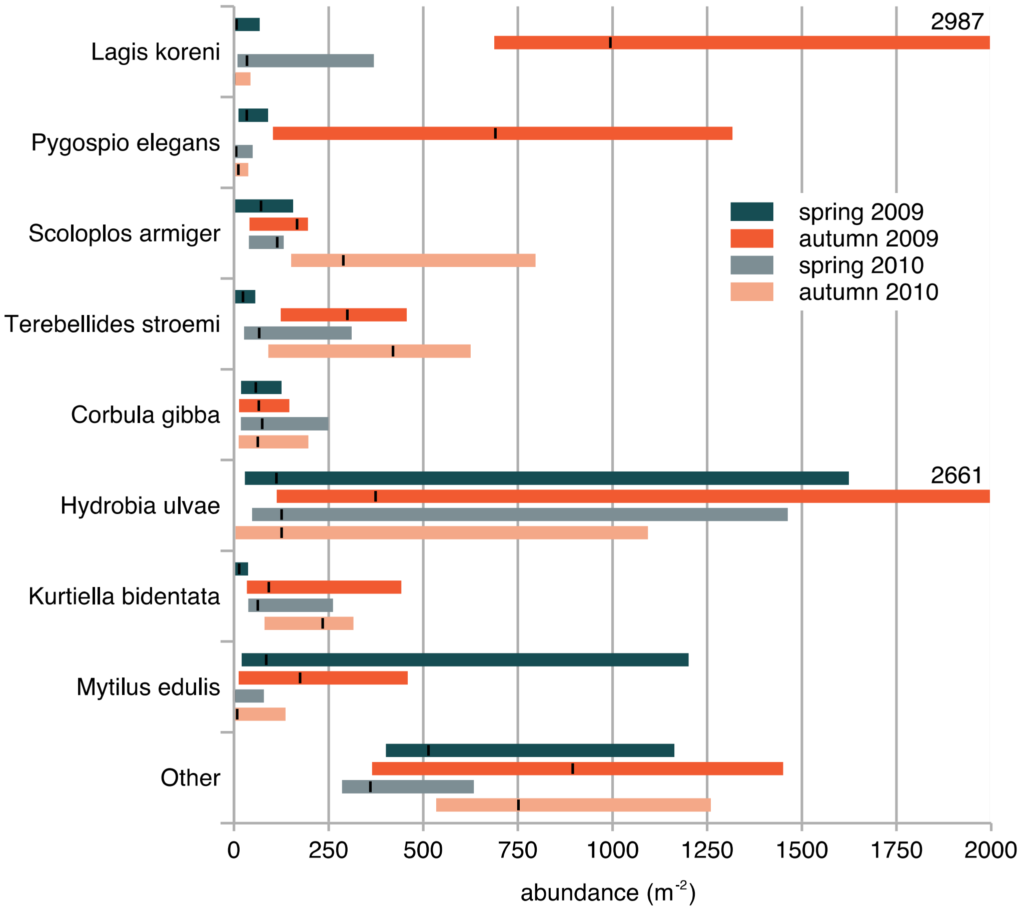

Figure 4-40 Abundances (m^{-2}) of the main representatives of the Corbula community during the four investigation campaigns in 2009 and 2010 Box: 25–75th percentile, Line in box: median. Numbers in plot mean values of upper box boundaries.

With the exception of the polychaete *Lagis koreni*, there was a clear spatial variation within the *Corbula* community (Table 4-10). Most of the dominant species reached higher abundances on the German side, whereas the abundances of *Mytilus edulis* and *Terebellides stroemi* were higher on the Danish side.

Table 4-10 Mean abundances (m^{-2}) of the main representatives of the Corbula community separated for Danish and German side during the four investigation campaigns in 2009 and 2010.

Species	German side	Danish side
Corbula gibba	663	58
Hydrobia ulvae	2846	171
Kurtiella bidentata	366	93
Lagis koreni	703	617
Mytilus edulis	149	419
Pygospio elegans	347	171
Scoloplos armiger	450	122
Terebellides stroemi	117	368

The biomass of the Corbula community was dominated by several polychaetes and a few bivalves (Figure 4-41). *Arctica islandica* and *Alitta virens* showed higher variations than the other species. Among the remaining species considerable biomass values were observed for the highly frequent gastropod *Hydrobia ulvae* and for the less frequently occurring bivalves and polychaetes *Cerastoderma edule*, *Astarte borealis*, *Astarte elliptica* and *Nephtys caeca*.

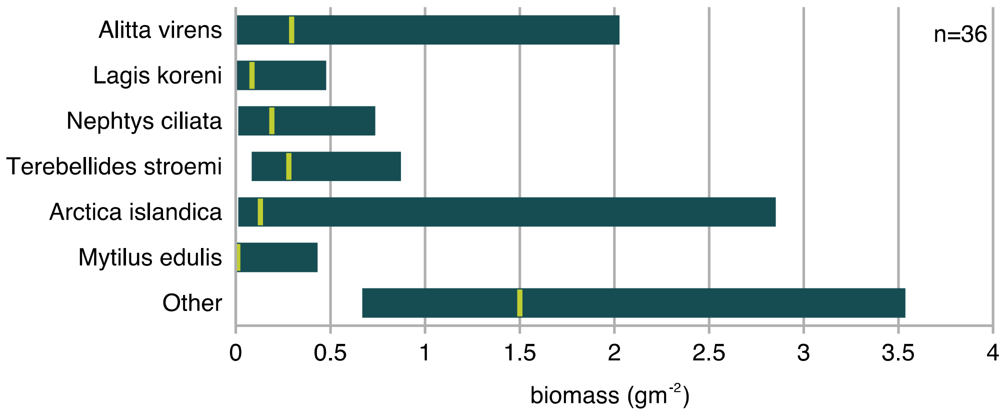

Figure 4-41 Biomass (AFDW gm^{-2}) of the main representatives of the Corbula community during the investigation period 2009–2010 Box: 25–75th percentile, Line in box: median.

The biomasses of the main species and the remaining "Other" species showed seasonal variations (Figure 4-42). The median values for *Mytilus edulis* were higher in 2009 than in 2010. The contrary was the case for the polychaete *Nephtys ciliata*. The bivalve *Astarte borealis* was only found in spring 2009 with high biomass values. For all other species no distinct trend was visible.

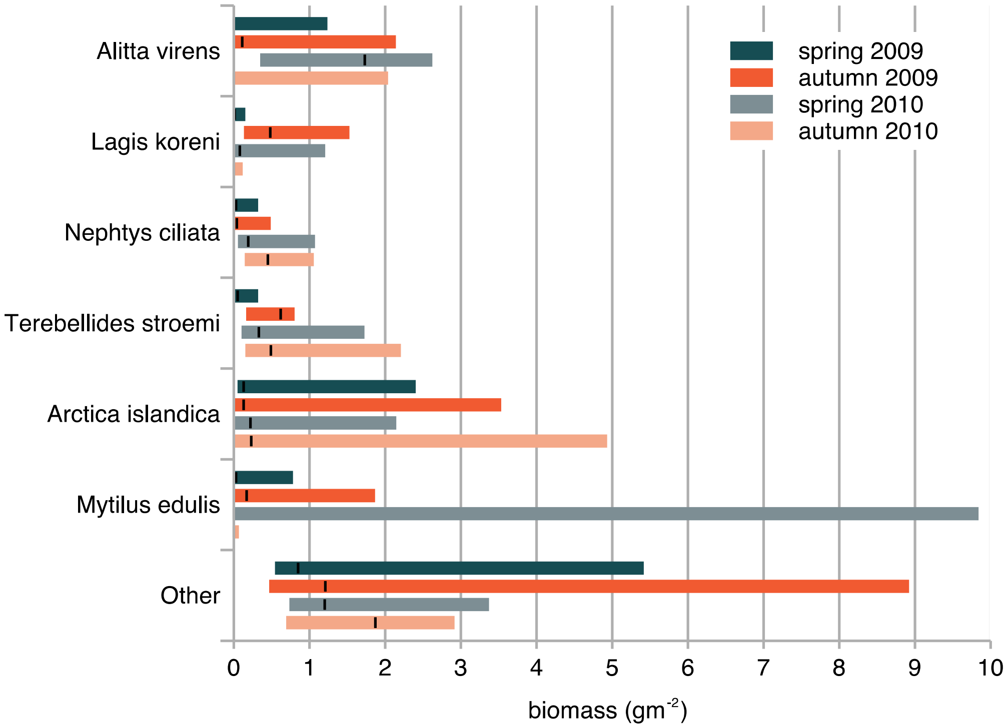

Figure 4-42 *Biomass (AFDW gm^{-2}) of the main representatives of the Corbula community during the four investigation campaigns in 2009 and 2010. Box: 25–75th percentile, Line in box: median.*

With the exception of *Lagis koreni* and *Nephtys ciliata*, which displayed a rather constant spatial distribution pattern, there was a slight spatial variation of biomass within the *Corbula* community (Table 4-11). Several dominant species reached slightly higher biomasses on the German side, whereas the values of *Mytilus edulis* and *Terebellides stroemi* were clearly higher on Danish side due to the higher abundances.

Table 4-11 *Mean biomass (AFDW gm^{-2}) of the main representatives of the Corbula community separated for Danish and German side during the four investigation campaigns in 2009 and 2010.*

Species	German side	Danish side
Alitta virens	2.481	1.842
Arctica islandica	5.358	1.955
Astarte borealis	2.358	0.615
Lagis koreni	0.487	0.507
Mytilus edulis	0.103	7.874
Nephtys ciliata	0.482	0.485
Terebellides stroemi	0.338	1.094

4.3.5 *Dendrodoa community*

Large areas in the western part of the Fehmarnbelt are occupied by the Dendrodoa community. The community is characterised by sandy, partially coarse sediments, sometimes accompanied by boulders in deeper waters of around 15–25 m depth (Figure 4-44).

In the Fehmarnbelt, the Dendrodoa community is localised at the edges of the basin of the Kiel Bight offshore Fehmarn and Lolland. In these areas, the Dendrodoa community was actually observed (Figure 4-43), whereas it was predicted in also a small area east offshore Fehmarn (Figure 4-43). The sizes of the areas are listed in Table 4-12.

The Dendrodoa community is a typical solid-substrate community. It contains many sessile species or semi-sessile, which are obligate or facultative suspension feeders, such as bivalves, sea squirts, anemones and sponges.

Table 4-12 Summary of sampled stations, predicted surface area, mean number of species, mean abundance (m^{-2}) and mean biomass (g AFDW m^{-2}) in each administrative area for the Dendrodoa community.

Administrative area	**No. of stations**	**Predicted area (km^2)**	**No. of species**	**Abundance**	**Biomass**
Overall	15	213	132	4770	46.02
Danish waters	5	112	142	4205	28.35
German waters	10	100	127	5053	54.86
German coastal zone	5	61	105	3244	43.34
German EEZ	5	39	149	6861	66.38
DE 1332-301 (Fehmarnbelt)	5	39	149	6861	66.38
DE 1533-301 (Staberhuk)	0	0.3			
DE 1631-392 (Östliche Kieler Bucht)	3	56	110	3539	55.15
DE 1632-392 (Ostsee östlich Wagrien)	0	0			
DE 1733-301 (Sagas Bank)	0	0			
DK 006X238 (Rødsand lagoon)	0	0			
DK00VA200 (Langeland)	1	9	155	8076	19.08

Taxonomic composition
The community is featured by a large number of species, with numerous common ones and a large proportion of infrequently observed species. Filter feeding bivalves dominate the biomass and also reach high abundances. Single species of amphipods, ascidians, anthozoans and polychaetes dominated from other groups.

The namesake genus Dendrodoa is represented by the ascidian (sea squirt) *Dendrodoa grossularia*. It lives attached to hard substrate (cobbles, boulders) but also on red algae that populate the boulders and coarse sediments in the infralittoral part of the community area and can sometimes cover large parts of the thalli of these algae. This gives rise to a number of associated taxa that also use this habitat: the Blue Mussel (*Mytilus edulis*) as the most abundant species in this community and the snails *Bittium reticulatum* and *Onoba semicostata*.

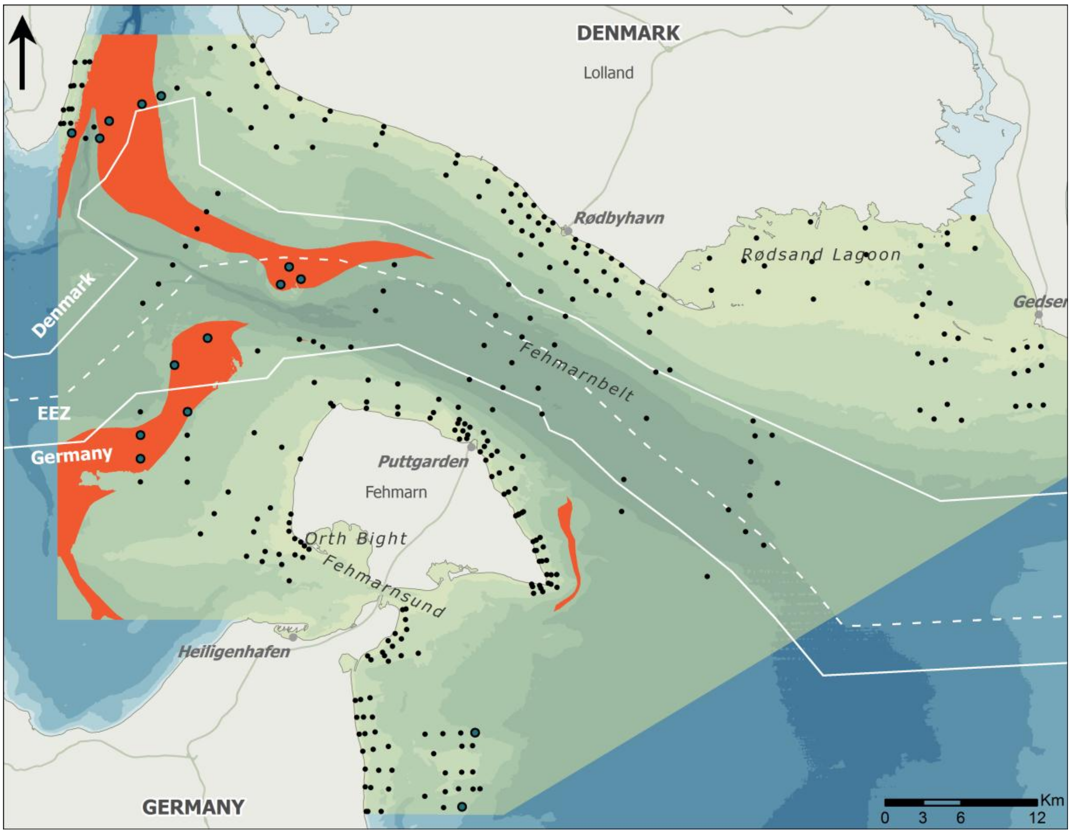

Figure 4-43 Overview of the spatial distribution of the Dendrodoa community in the Fehmarnbelt region. Green area = study area. Large, blue circles = sampled stations. Red polygons = predicted areas.

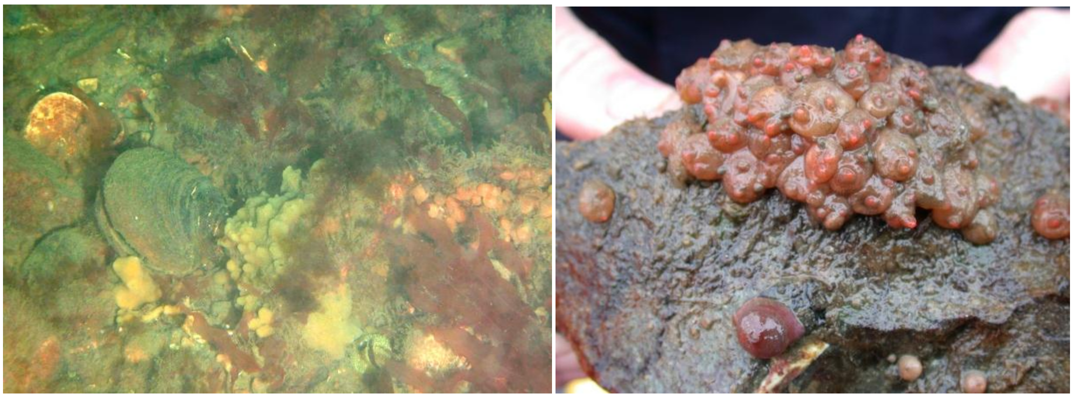

Figure 4-44 Typical seabed appearance of Dendrodoa community (left) and a colony of specimen of the namesake species Dendrodoa grossularia *(right).*

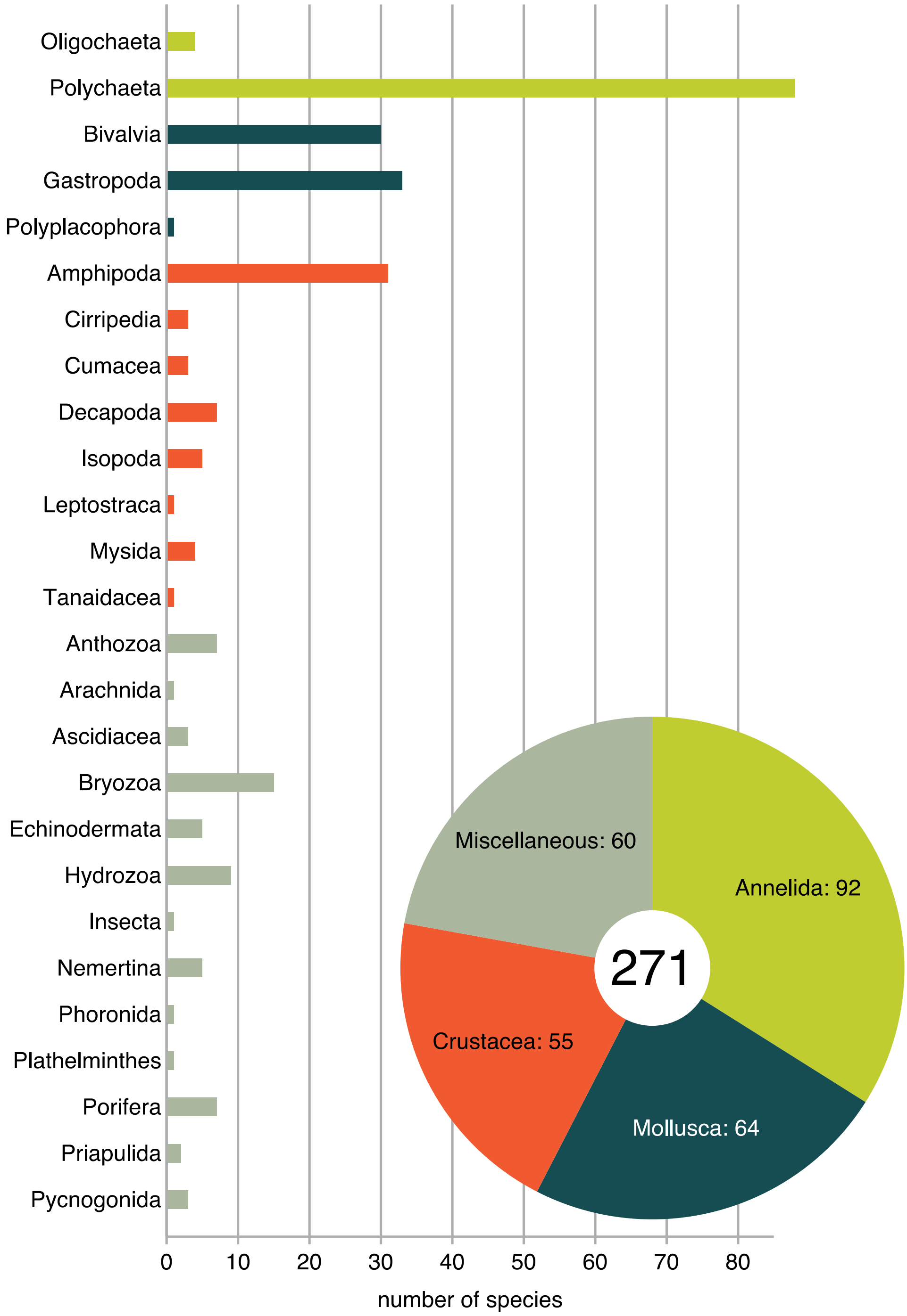

Figure 4-45 Macrozoobenthos species composition of the Dendrodoa community during the baseline investigations campaign in 2009–2010.

In total, 271 species of 26 different groups were found in the Dendrodoa community (Figure 4-45). The polychaetes was the most species-rich group in this community, with 88 different species determined. Further prominent groups were gastropods (33 species), amphipods (30 species), bivalves (30 species) and bryozoans (15 species). The species richness of other taxonomic groups was clearly lower.

During each sampling campaign, some species were observed regularly, while a large number of uncommon species were found. Thus, the numbers of totally observed species increased from 186 to 221 during the campaigns of 2009 and subsequently to 242 and finally to the overall total of 271 species at the end of the 2010 campaign. This pattern indicates a high variability within this community, mainly for uncommon species.

The absolute numbers of species increased slightly from the spring 2009 until the autumn campaign of 2010. Median species numbers in the Dendrodoa community were around 90–100 (Figure 4-46), which is lower than the observed total of 271.

The variability of the species richness was relatively low: 16% (44 species) were found only once and another 12% occurred only up to three times during the investigation periods. Only 3 species were always present in the samples, namely *Kurtiella bidentata*, *Parvicardium ovale* and *Scoloplos armiger*. Furthermore, a total of 42 species were found with a frequency of at least 80%.

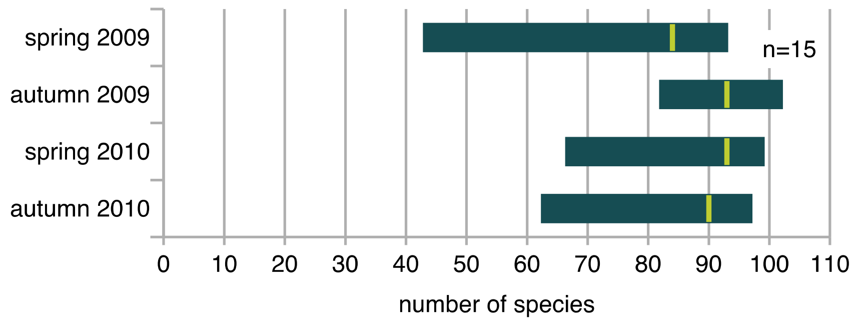

Figure 4-46 Number of species per station in the Dendrodoa community during the four investigation campaigns in 2009 and 2010. Box: 25–75th percentile, Line in box: median.

Abundance and biomass

The Dendrodoa community was characterised by the abundant appearance of several highly frequent key species, which belong mainly to the bivalves (Figure 4-47). Single species of several other groups (amphipods, ascidians, anthozoans, polychaetes) were also dominant. The combined abundances of the key species were in the same range as the abundances of the remaining "Other" community members. Furthermore, 32 species of different groups belonging to the polychaetes, oligochaetes, bivalves, amphipods, gastropods, nemerteans, echinodermates, cumaceans and cirripeds reached mean abundances of higher than 100 m^{-2}.

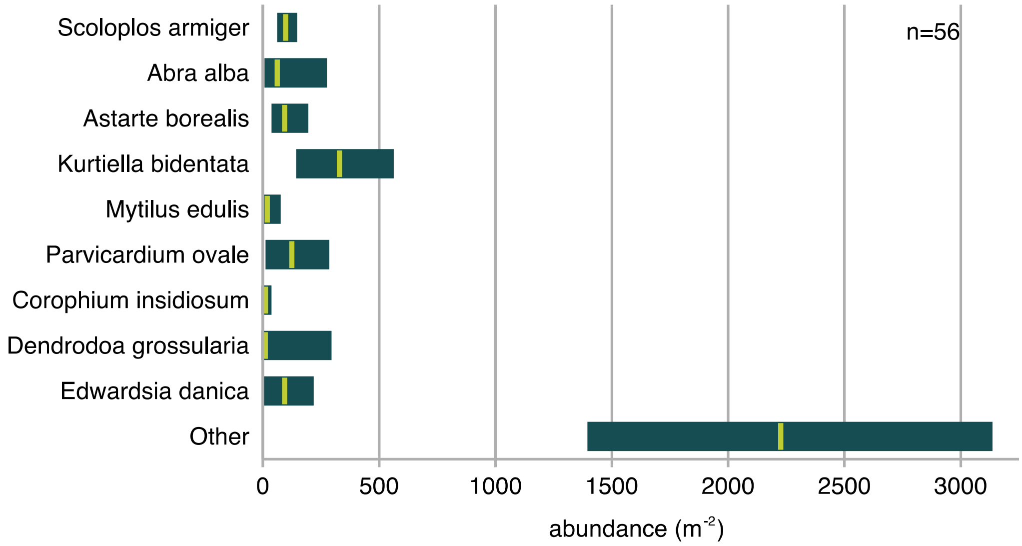

Figure 4-47 Abundances (m^{-2}) of the main representatives of the Dendrodoa community during the investigation period 2009–2010. Box: 25–75th percentile, Line in box: median.

The dominant species of the Dendrodoa community each revealed a seasonal variation (Figure 4-48). The median abundances of *Kurtiella bidentata* increased over the investigation period, whereas abundance of *Corophium insidiosum* and *Mytilus edulis* decreased. The abundances of *Parvicardium ovale* were much higher in 2009 than in 2010 and the species *Abra alba* and *Edwardsia danica* showed a seasonal trend with higher median abundances in spring. In contrast, the median abundances of *Astarte borealis*, *Dendrodoa grossularia* and *Scoloplos armiger* were more stable through time.

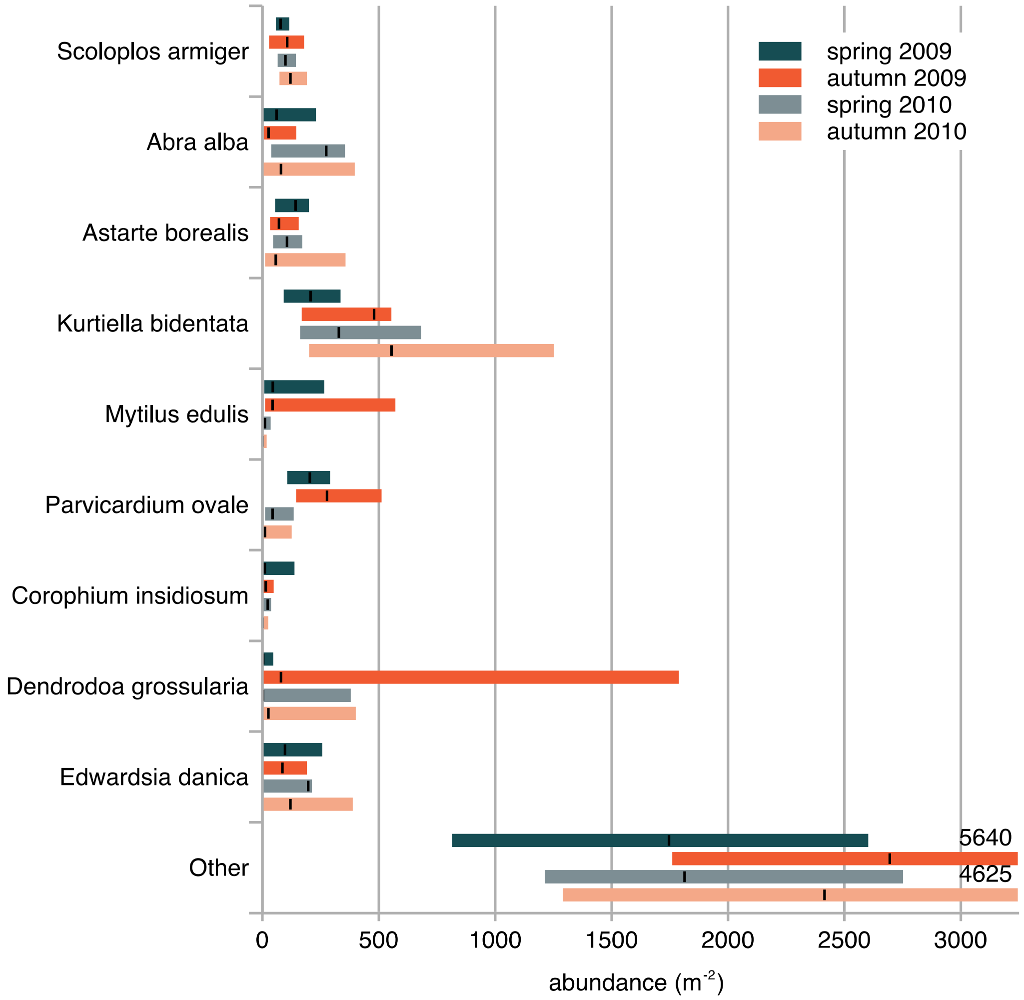

Figure 4-48 Abundances (m^{-2}) of the main representatives of the Dendrodoa community during the four investigation campaigns in 2009 and 2010. Box: 25–75th percentile, Line in box: median. Numbers in plot mean values of upper box boundaries.

The biomass of the Dendrodoa community was dominated by several bivalve species and its namesake, the ascidian *Dendrodoa grossularia* (Figure 4-49). The three bivalve species *Arctica islandica*, *Astarte borealis* and *Astarte elliptica* have biomasses clearly higher than all other species. In addition, but not shown, the gastropod *Neptunea antiqua*, *Mytilus edulis* and the sea star *Asterias rubens* also had high biomasses.

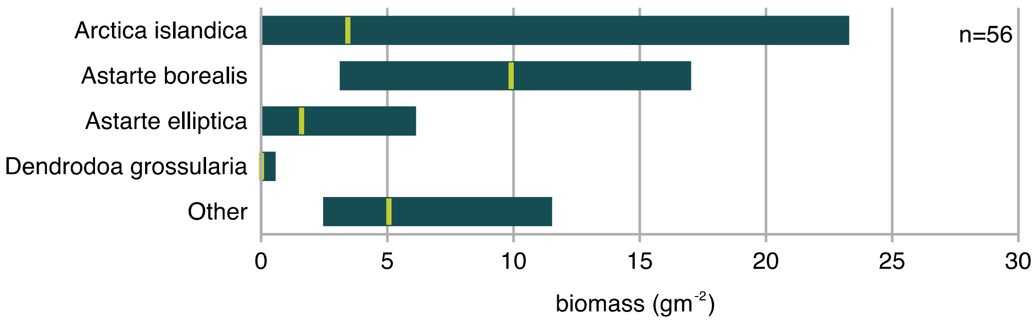

Figure 4-49 Biomass (AFDW gm^{-2}) of the main representatives of the Dendrodoa community during the investigation period 2009–2010. Box: 25–75th percentile, Line in box: median.

The biomasses of the main species and the remaining "Other" species showed no remarkable changes, other than the natural seasonal variation (Figure 4-50). This is a strong indication that the Dendrodoa community is a stable community in the Fehmarnbelt area.

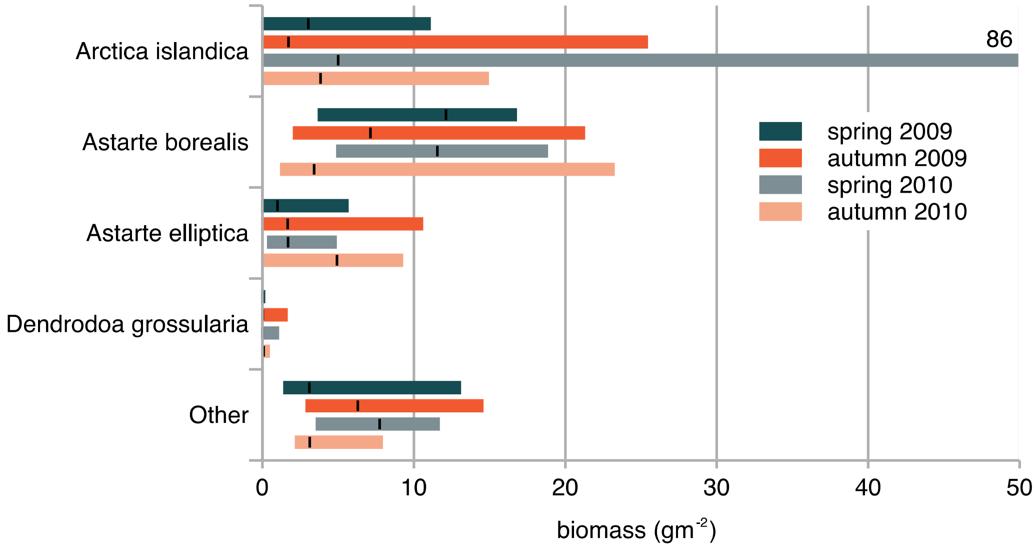

Figure 4-50 Biomass (AFDW gm^{-2}) of the main representatives of the Dendrodoa community observed in each of the four investigation campaigns in 2009 and 2010. Box: 25–75th percentile, Line in box: median. Number in plot means value of upper box boundary.

4.3.6 *Gammarus community*

The Gammarus community is a predominantly shallow water epifauna community that is found in all places where benthic vegetation or mussels are covering the sea floor to a varying degree, since stable mussel aggregations typically are partly covered by filamentous algae and provide a hiding and living space for the epifauna (Figure 4-51 and Table 4-13).

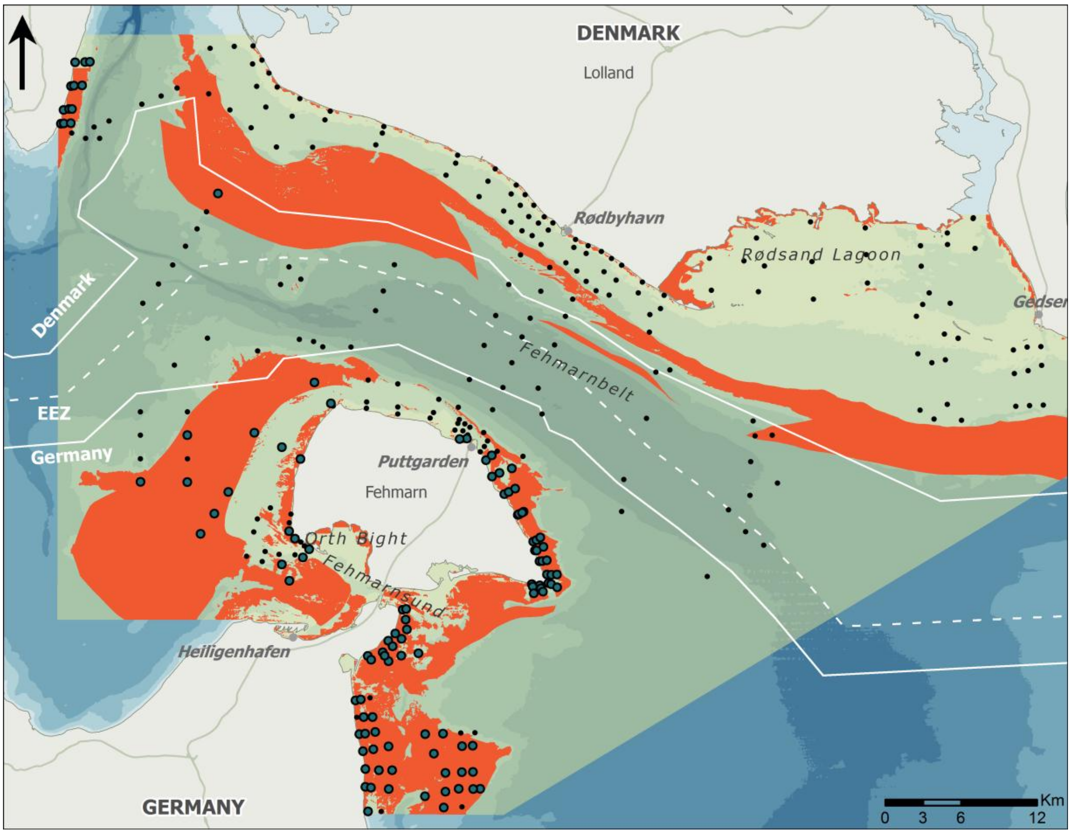

Figure 4-51 Overview of the spatial distribution of the Gammarus community in the Fehmarnbelt region. Green area = study area. Large, blue circles = sampled stations. Red polygons = predicted areas.The large area offshore south-western Lolland is predicted to be largely a Gammarus community, although there are no observation there. This area is a ammunition dump site and therefore prohibited from fishing / sampling.

The namesake genus *Gammarus* is an amphipod (commonly called scud) genus that is represented in the investigation area with two dominating (*Gammarus oceanicus* and *Gammarus salinus*) and two rarer species (*G. locusta*, *G. zaddachi*) (Figure 4-52). They all live associated to algae and mussel communities where they feed on anything from algae and seaweeds to detritus. They hide in the algae plants but can also swim freely in the water column to migrate to other localities.

Figure 4-52 Typical appearance of the sediment and habitat of the Gammarus community (left) and a specimen of the namesake genus Gammarus *(left).*

The association with algae is also typical for all the other characteristic species of this community. E.g. the amphipod *Microdeutopus gryllotalpa* occurs frequently and lives in tubes built from algae branches. The isopod species *Idotea balthica, Idotea chelipes,* and *Jaera* albifrons also belong to the characteristic fauna of the Gammarus community. They feed on algae and are an important part of the grazing species because they are able to limit algae biomass if they occur in large numbers, especially in winter when the perennial algae do not grow.

There is a similarity between the Gammarus and the Mytilus community in terms of species composition. The Gammarus community mainly lives on algae communities, which on the other hand depend on hard substrate and often are in competition with mussel communities that also need hard substrate as settling ground. Thus, the Gammarus community can be found in different configurations with hard substrate, mussels, and algae having varying density and species composition. The overlap to the Mytilus community is high and the different hybrids of these communities cannot be separated from each other.

Table 4-13 Summary of sampled stations, predicted surface area, mean number of species, mean abundance (m^{-2}) and mean biomass (g AFDW m^{-2}) in each administrative area for the Gammarus community.

Administrative area	No. of stations	Predicted area (km^2)	No. of species	Abundance	Biomass
Overall	113	742	35	8401	7.1
Danish waters	13	341	33	17580	11
German waters	100	401	35	7208	6.59
German coastal zone	100	394	35	7208	6.59
German EEZ	0	6.5			
DE 1332-301 (Fehmarnbelt)	0	6.5			
DE 1533-301 (Staberhuk)	26	10	34	8687	7.61
DE 1631-392 (Östliche Kieler Bucht)	16	241	41	5469	6.36
DE 1632-392 (Ostsee östlich Wagrien)	15	11	24	8567	7.95
DE 1733-301 (Sagas Bank)	11	30	34	3944	7.64
DK 006X238 (Rødsand lagoon)	0	17			
DK00VA200 (Langeland)	6	4.5	32	17670	6.37

Taxonomic composition

The taxonomic composition of this community is in general very similar to the Mytilus community. The largest group in terms of species is the polychaetes (Figure 4-53). In contrast to most other communities, the most typical species in this community are epifauna polychaetes that benefit from the three-dimensional structures (algae and mussels) that form the habitat. These most abundant species (listed in descending order with respect to abundance) are *Harmothoe imbricata*, *Eteone longa*, *Polydora cornuta*, *Harmothoe impar*, *Bylgides sarsi*, *Streptosyllis websteri*, and *Spirorbis spirorbis*. Some of these species also live as infauna and thus exploit both living forms. *Spirorbis spirorbis* is special in that it builds calcareous coiled shells that are fastened to hard substrate. This can be a stone but also the thallus of larger algae like *Fucus*.

The second largest group are the crustaceans and mainly represented by amphipods, isopods, and decapods. The amphipods are the second group in terms of number of species, after the polychaetes. Other amphipods besides the namesake *Gammarus* spp. (i.e. *Gammarus salinus* and *G. oceanicus*), are characteristic for this community, e.g. *Microdeutopus gryllotalpa*, *Calliopius laeviusculus*, *Ampithoe rubricata*, or *Ericthonius brasiliensis*. All are associated to either the mussels or the algae that shape this community and (apart from *Calliopius laeviusculus*) live in tubes attached to these. The isopods occur with five species, the three *Idotea* species *Idotea balthica*, *Idotea chelipes*, and *Idotea granulosa*, and the two other species *Jaera albifrons* and *Cyathura carinata*. Apart from the latter, they are all herbivores feeding on the algae. The four decapod species are mainly represented by *Carcinus maenas* and *Crangon crangon*. All the above-mentioned crustaceans also occur in the Mytilus community showing the overlap between these two communities.

The Mytilus community was initially restricted to "clean" mussel beds or drifting clumps of blue mussels without or with low coverage of red algae. Contrary, the Gammarus community was found in areas where blue mussels were present, but not dominant. In the Gammarus community, macroalgae dominate the coverage, instead of blue mussels. The transition of these two habitats is of course very smooth, making the objective separation difficult. However, the function of the epibenthic community with and without algae is very distinct, and from this point of view, the separation becomes valid. The MDS-plot in Appendix 6 shows large parts of the data points from the Gammarus community that were fully separated from the Mytilus data points, although there was some small overlap. This is of course quite normal as both the communities are strongly related to each other.

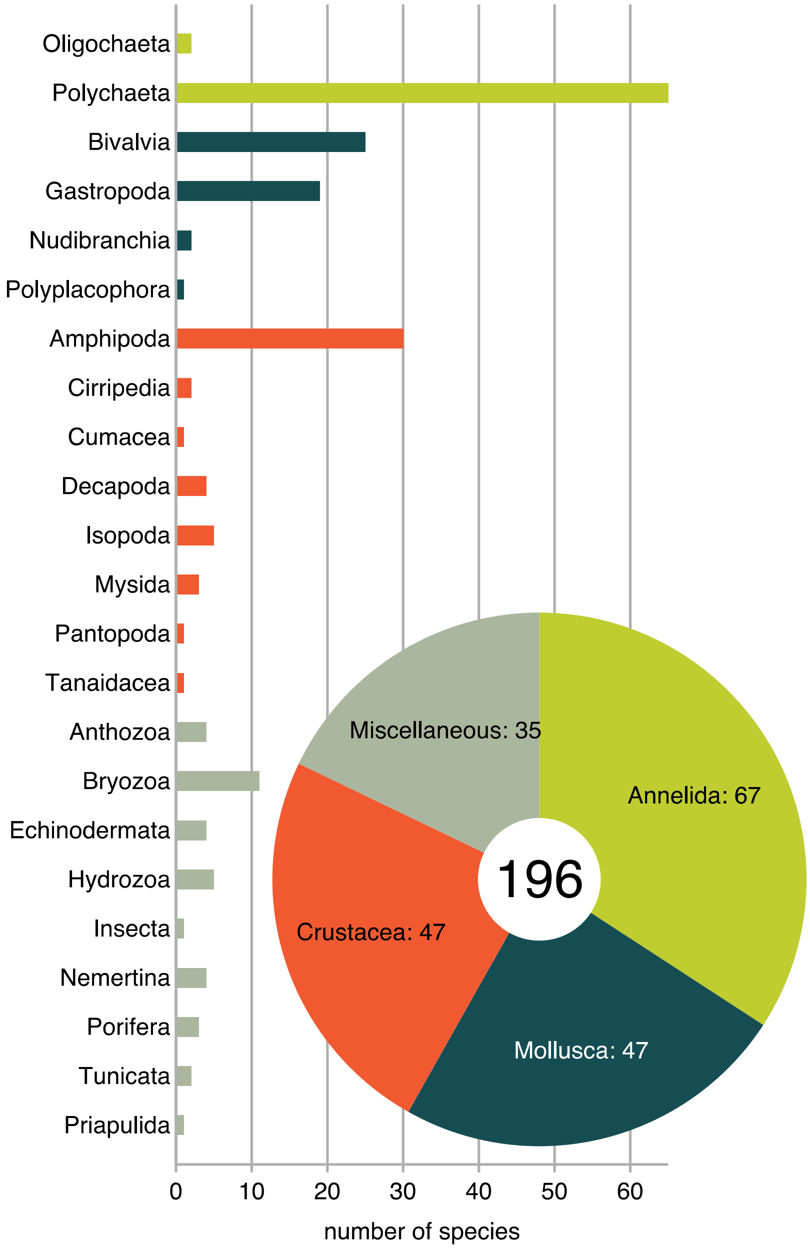

Figure 4-53 Macrozoobenthos species composition of the Gammarus community during the baseline investigations 2009–2010.

Within bivalves only a few species are associated with the habitat, most of them just inhabit the soft bottom sediment between the algae/mussel patches and also are abundant in the infauna communities. Only *Musculus discors*, *Modiolarca subpicta*, *Musculus niger*, and *Parvicardium hauniense* are epifauna species that can be regarded as typical for this community. The gastropods however, as typical epifauna species, are associated to a large degree with the Gammarus community. The most abundant are *Bittium reticulatum*, *Pusillina inconspicua*, *Littorina saxatilis*, *Odostomia scalaris*, and *Littorina littorea*. The two *Littorina* species are shallow water species that are not found in the deeper water communities and have a strong association to mussels and other hard substrates.

Seasonally, there is no clear seasonal variation in the species richness of the Gammarus community (Figure 4-54). Around 15-20 species were found per sample, which is a typical value for shallow water fauna and comparable to e.g. the Cerastoderma community.

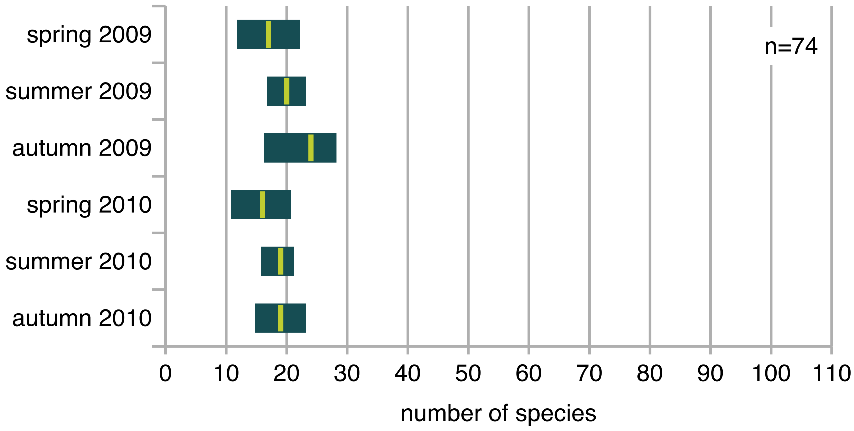

Figure 4-54 Seasonal variation of the number of species per sample in the Gammarus community during the baseline investigations 2009–2010. Box: 25–75th percentile, Line in box: median.

Abundance and biomass

In terms of abundance the isopod *Idotea chelipes* is on average the most abundant one with a medium value of 1560 m^{-2} (Figure 4-55). The characteristic *Gammarus* species do not reach these high numbers, being approximately an order of magnitude lower. This can be explained by the regionally very high numbers of *Idotea chelipes* (only found at Langeland within this community) while the *Gammarus* species are distributed everywhere in the area. Although very abundant, the mud snail *Hydrobia ulvae* is not as abundant in the Gammarus community as it is in the other communities. *Hydrobia* prefers open, soft (muddy) bottom without either much vegetation or coarser sediment.

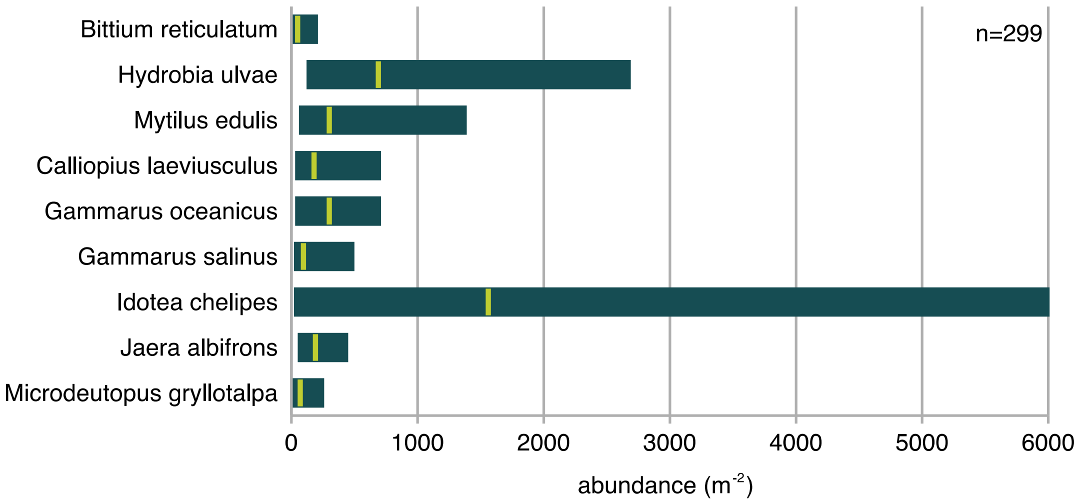

Figure 4-55 Abundances (m^{-2}) of the main representative of the Gammarus community during the baseline investigations 2009–2010. Box: 25–75th percentile, Line in box: median.

The seasonal patterns in the abundance distribution clearly show the different effect of sampling. The spring and autumn values are from sampling the soft bottom infauna while the summer samples are from epifauna sampling (Figure 4-56). Thus, the summer values show much higher abundances for the species characteristic of the community, such as the amphipods and isopods. It also shows that the high amount of *Idotea chelipes* from the Langeland population only was an event in summer 2009 and is thus attributable to the epifauna only.

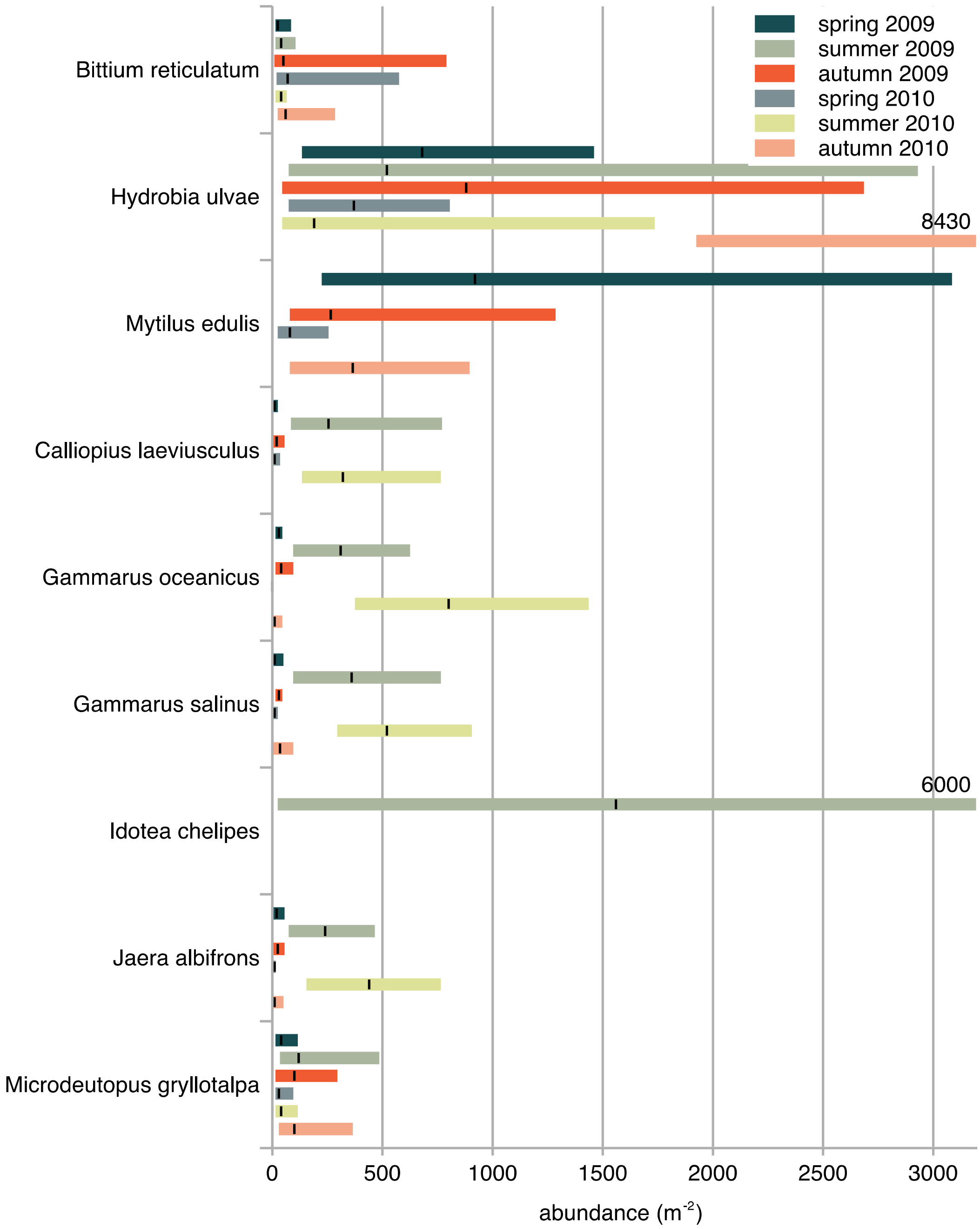

Figure 4-56 Seasonal variation of abundances (m^{-2}) of the main representative of the Gammarus community during the baseline investigations 2009–2010. Box: 25–75th percentile, Line in box: median. Numbers in plot mean values of upper box boundaries.

Similar to the abundance, the overall biomass shows that the *Gammarus* species play a major role in the community (Figure 4-57). Only *Idotea chelipes* reaches higher values because of the abovementioned reasons. The biomass of the indicative species is not very different, so the pattern seen in the abundance also is reflected in the biomass data.

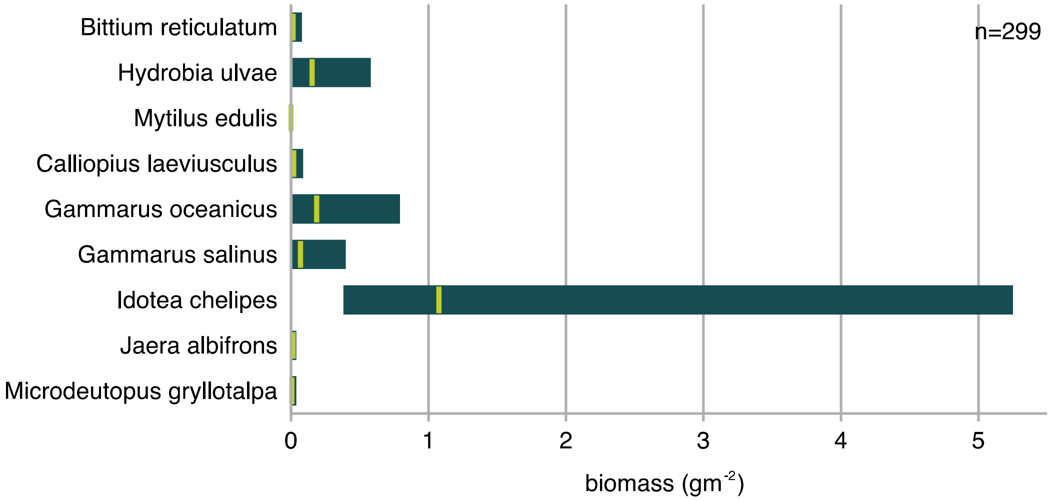

Figure 4-57 Biomass (AFDW gm^{-2}) of the main representative of the Gammarus community during the baseline investigations 2009–2010. Box: 25–75th percentile, Line in box: median.

The seasonal variation also shows the same pattern (Figure 4-58). The summer data show the major contribution from amphipods and isopods, mainly Gammarus spp. and to a lesser degree the other amphipods *Calliopius laeviusculus* and *Microdeutopus gryllotalpa*. The numbers reflect the status of the Gammarus community as a stable and productive community.

Local conditions, like in the case of Langeland Reef, can have a great influence on the composition and biomass of the community and shows that the underlying habitat structures and the amount of hard substrate or algae is paramount for the specific local occurrence of the Gammarus community.

Figure 4-58 Seasonal variation of biomass (AFDW gm^{-2}) of the main representative of the Gammarus community during the baseline investigations 2009–2010. Box: 25–75th percentile, Line in box: median. Numbers in plot mean values of upper box boundaries.

4.3.7 *Mytilus community*

The Mytilus community is an epifauna community characterized by the occurrence of aggregations of the Blue Mussel *Mytilus edulis* in varying size and density together with an associated fauna. It is mainly found off the coast of Lolland where it occurs in water depths down to approximately 10 m. Around Fehmarn the most important areas are off Staberhuk and at the west coast (Figure 4-59 and Table 4-14).

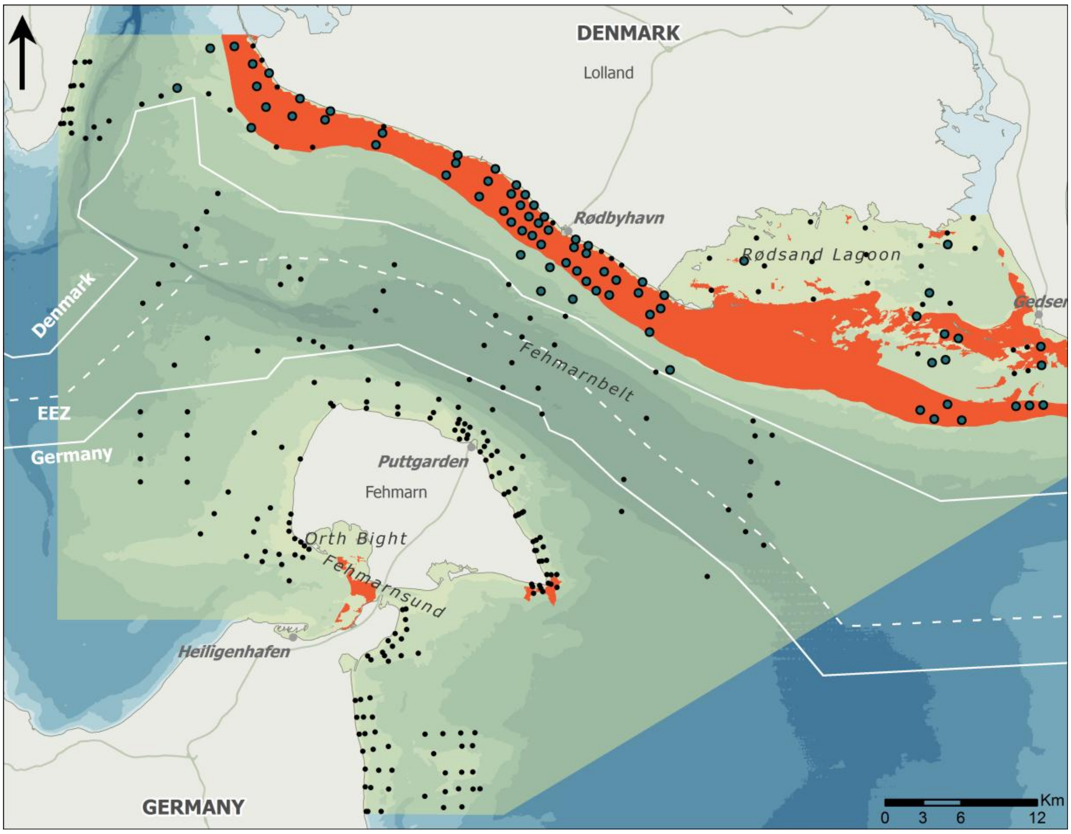

Figure 4-59 Overview of the spatial distribution of the Mytilus community in the Fehmarnbelt region. Green area = study area. Large, blue circles = sampled stations. Red polygons = predicted areas.

Despite the fact that the Mytilus community is restricted to certain parts of the investigation area, the species *Mytilus edulis* is essentially present at all locations where there is enough hard substrate to settle on or where loose lying aggregates ("clusters" of a few to some 50 specimens) can form on the sea floor (Figure 4-60) (see also Section 5 for a comprehensive description of the distribution and status of mussels). However, in order to be regarded as a community in the strict sense, *Mytilus edulis* should be the dominant species forming also the spatial structure of the habitat to a degree that enables the associated fauna to unfold (Figure 4-61).

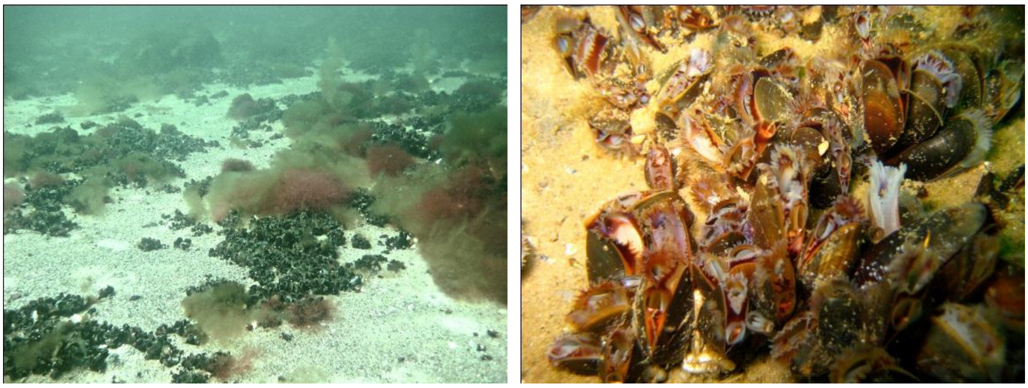

Figure 4-60 Typical sediment appearance of the Mytilus community (left) and specimens of the namesake species Mytilus edulis *(right).*

This associated fauna consists mainly of species that utilize the hard substrate (also the one formed by the mussels themselves) as settling and feeding ground (e.g. *Gammarus* spp., *Balanus* spp., *Corophium insidiosum*, *Littorina* spp.). Other species benefit from the presence of the mussels but are not dependent on it, like deposit feeders which are living on detritus and other remains of the Mytilus community (e.g. *Heteromastus filiformis*, *Marenzelleria viridis*, *Polydora cornuta*).

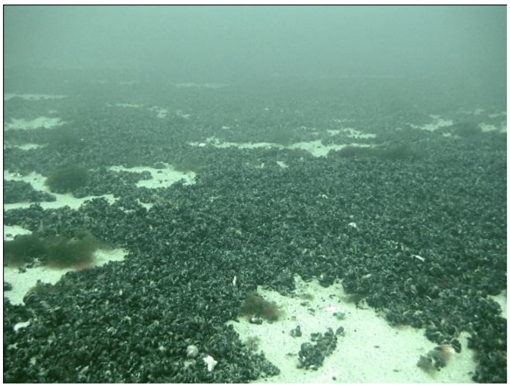

Figure 4-61 Example of a dense Mytilus bed in the investigation area around Staberhuk in summer 2009.

There is a similarity between the Mytilus and the Gammarus community in terms of species composition. The Mytilus community forms mainly on hard substrate and often is in competition with algae communities that also need hard substrate as settling ground (Figure 4-60). The algae communities, however, are a living space for the Gammarus community. Thus, hard substrate, mussels, and algae together with an associated epifauna resembling the Gammarus or the Mytilus community are typically found in different configurations with varying density and species composition. The overlap is high and the different hybrids of these communities cannot be separated from each other. The percentage coverage of macroalgae was determinant for the separation between the Gammarus community (macroalgal cover dominant) and the Mytilus community (“clean” mussel beds, macroalgae present, but not dominant), as was also pointed out in section 4.3.7.

Table 4-14 Summary of sampled stations, predicted surface area, mean number of species, mean abundance (m^{-2}) and mean biomass (g AFDW m^{-2}) in each administrative area for the Mytilus community.

Administrative area	No. of stations	Predicted area (km^2)	No. of species	Abun-dance	Biomass
Overall	73	309	31	4450	8.37
Danish waters	73	302	31	4450	8.37
German waters	0	7			
German coastal zone	0	7			
German EEZ	0	0			
DE 1332-301 (Fehmarnbelt)	0				
DE 1533-301 (Staberhuk)	0	2			
DE 1631-392 (Östliche Kieler Bucht)	0	4			
DE 1632-392 (Ostsee östlich Wagri-en)	0				
DE 1733-301 (Sagas Bank)	0				
DK 006X238 (Rødsand lagoon)	9	72	22	2519	2.99
DK00VA200 (Langeland)	0				

Taxonomic composition

The taxonomic composition of the Mytilus community (Figure 4-62) is in general very similar to the composition of the Gammarus community. The Polychaetes are the largest group in terms of the number of species. This is the same as for all communities. Only around 5 to 10 (out of 50) of the polychaete species are however abundant enough to play an ecological role for the community. The most abundant are *Pygospio elegans*, *Alitta succinea*, *Heteromastus filiformis*, *Marenzelleria viridis*, and *Polydora cornuta*. They are all mobile or semi-sessile deposit-feeding polychaetes utilizing the heterogeneity of the habitat structure to find their food. *Polydora cornuta* lives in tubes that are attached onto the mussel shells.

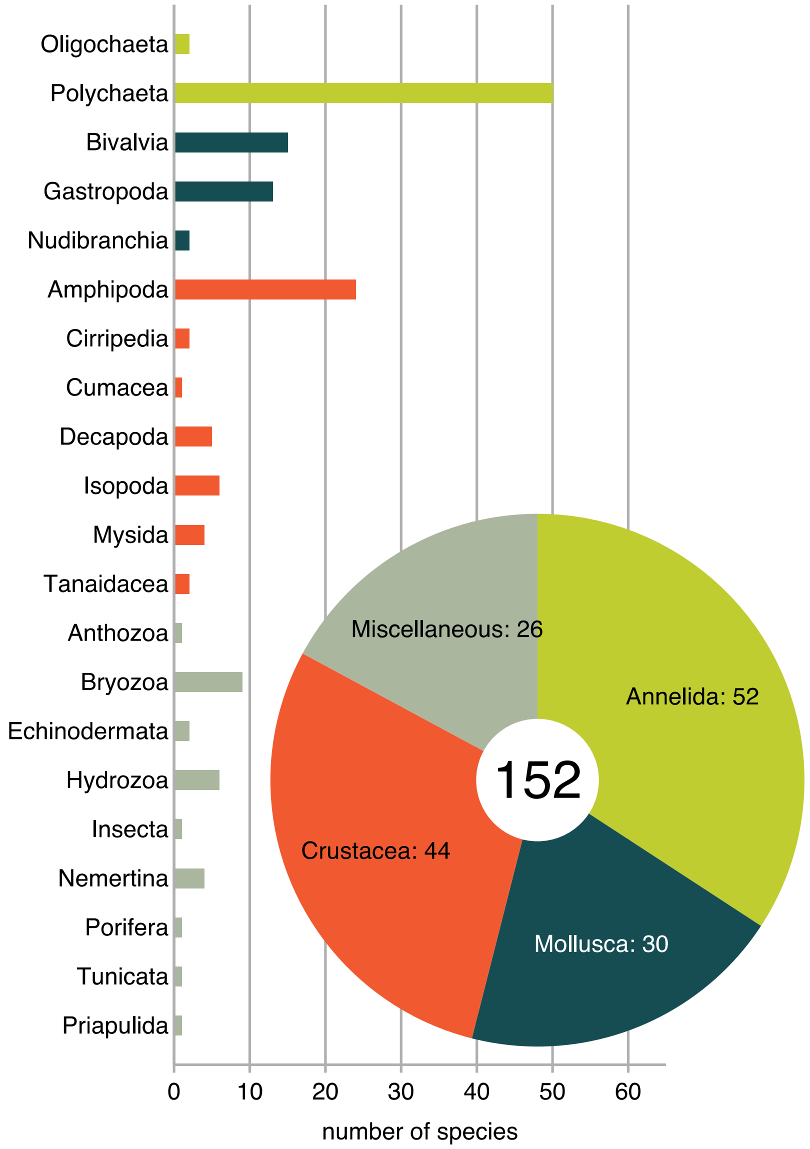

Figure 4-62 Macrozoobenthos species composition of the Mytilus community during the baseline investigations 2009–2010.

Crustaceans are the second-most important group and mainly consist of amphipods, isopods, and decapods. The species of this group are very similar to the ones found in a Gammarus community, e.g. Gammarus spp., *Microdeutopus gryllotalpa*, *Corophium* spp., *Melita palmata*, or *Calliopius laeviusculus*. All these species are associated to algae or mussels as living or feeding space. Also the isopod species are the same as for the Gammarus community (*Cyathura carinata*, *Idotea* spp., *and Jaera albifrons*). The decapods are mainly represented with *Crangon crangon* and *Carcinus maenas*.

The molluscs are represented with 15 bivalves, 13 gastropods, and 2 nudibranchs. Despite the similar number of species, the gastropods play a more important role for the community than the bivalves since many of the bivalves are infauna species that benefit from the presence of the Mytilus community but are not an intrinsic part of the habitat structuring elements as the mussel are. Besides *Mytilus edulis*, only *Parvicardium hauniense*, *Hiatella arctica*, and *Modiolarca subpicta* are epibenthic and associated with hard substrate or algae. The other 11 species are typical infauna species like *Mya arenaria* and *Macoma balthica*. They inhabit the soft sediment in between the mussel patches, but e.g. young *Mya arenaria* are often also found within the patches. The gastropod species are all epifaunal species and truly utilise the reef substrate. The most abundant species are *Hydrobia ulvae*, *Littorina littorea*, *Pusillina inconspicua*, and *Odostomia scalaris*. *Littorina littorea* and the also occurring sibling species *Littorina saxatilis* are shallow water species not found in the deeper water communities and have a strong association to mussels and other hard substrates on which they feed on diatoms and other microalgae. Also *Pusillina inconspicua* and *Odostomia scalaris* feed on microalgae and typically live on their thalli, while *Hydrobia ulvae* is a species grazing on the surface of the soft bottom but also in the mussel patches.

In terms of the seasonal variations in species richness, the Mytilus community shows only little variation (Figure 4-63). The number of infaunal species found per sample is a little higher than for the Gammarus community, which is the other shallow water epifauna community.

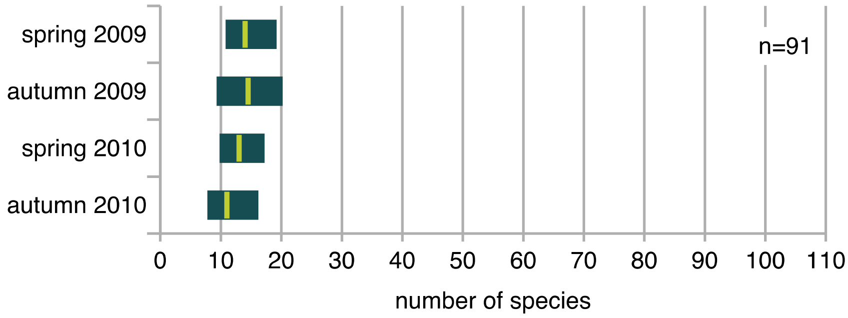

Figure 4-63 Seasonal variation of the number of species per sample in the Mytilus community during the baseline investigations 2009–2010. Box: 25–75th percentile, Line in box: median.

Abundance and biomass

In terms of abundance *Mytilus edulis* is the dominant specis (median abundance 800 m^{-2}) directly followed by *Hydrobia ulvae* (Figure 4-64). Thus, the Mytilus community is the only shallow water community that is not numerically dominated by the mud snail *Hydrobia ulvae*. The most important role is here for the mussel as habitat forming species and as the foundation of the community. None of the associated species reach such high abundances, many of them lay an order of magnitude lower than the abundance of *Mytilus* or *Hydrobia*.

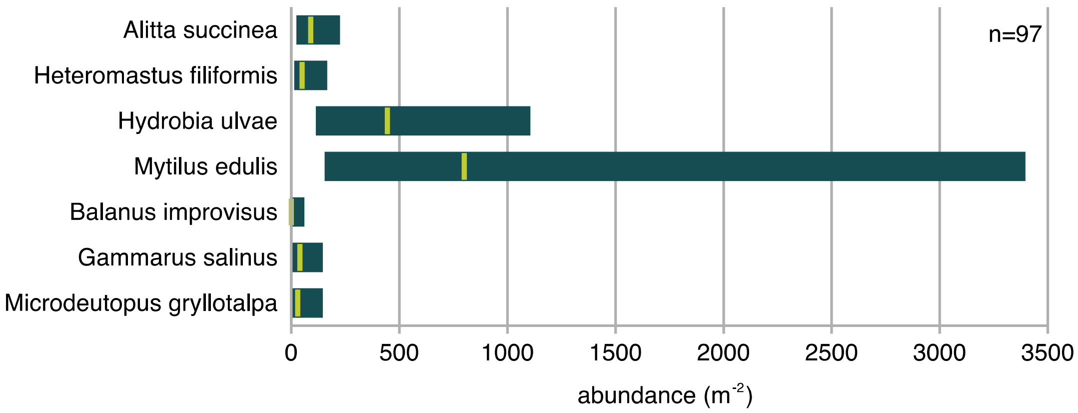

Figure 4-64 Abundances (m^{-2}) of the main representatives of the Mytilus community during the baseline investigations 2009–2010. Box: 25–75th percentile, Line in box: median.

There is no seasonal pattern in the abundances of the main species (Figure 4-65), except for *Hydrobia* sp.. All of them are present in similar numbers throughout the seasons. For *Mytilus edulis*, the data show that the median values lie in the lower end of the abundance data. This means that mainly lower abundances are found and the highest density values are not observed often. This again stresses the fact that the Mytilus community often has a patchy character, rather than dense mussel beds.

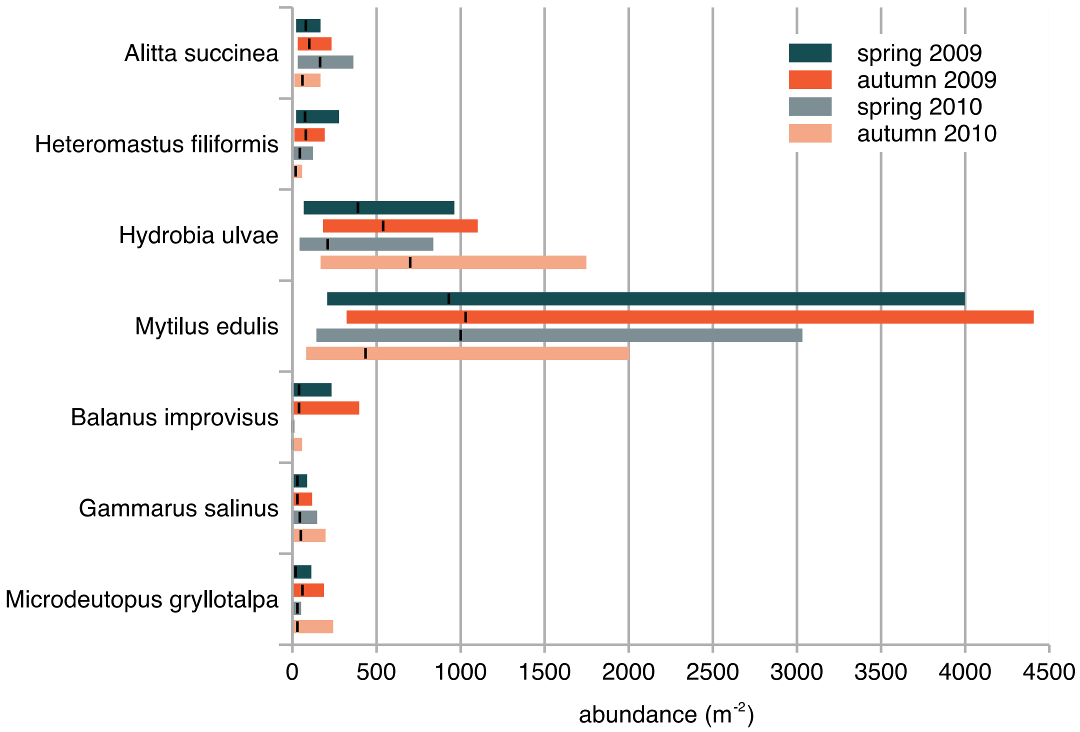

Figure 4-65 Seasonal variation in abundances (m^{-2}) of the main representatives of the Mytilus community during the baseline investigations 2009–2010. Box: 25–75th percentile, Line in box: median.

The biomass data show a different distribution (Figure 4-66). First, biomass data for *Mytilus edulis* are not covered here, because a dedicated mussel sampling was done in order to model the biomass spatially in the complete investigation area. For this, a special mussel sampling was conducted. These investigations indicate that *Mytilus* median biomass is around 60 g AFDW m^{-2} (see Section 5.3.1). This value is two orders of magnitude higher than the values of the other species and again shows the dominance and importance of the mussels. The second-most abundant species in terms of biomass is *Alitta succinea*. This mobile polychaete can occur in large numbers (up to 146 individuals per samples) in this community. The corresponding median biomass is higher than the one of *Hydrobia ulvae*, because these animals can be several centimetres long compared to 3 mm as the typical size of the snail.

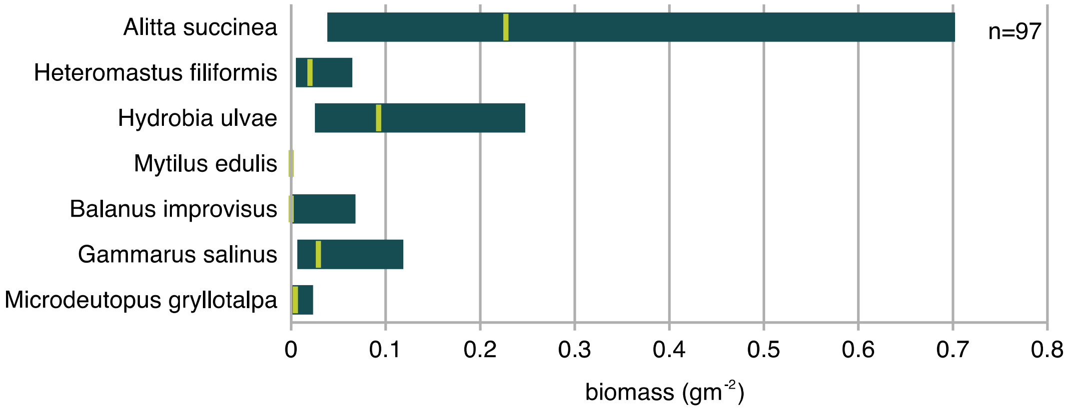

Figure 4-66 *Biomass (AFDW gm^{-2}) of the main representatives of the Mytilus community during the baseline investigations 2009–2010. The biomass value for* Mytilus edulis *is missing in the graph, since a special mussel sampling was done for this (see Section 5.3.1) indicating a value of approx. 120 gm^{-2}. Box: 25–75th percentile, Line in box: median.*

Some of the main species show a seasonal pattern in biomass. The mud snail *Hydrobia ulvae* has lower biomass in spring and higher biomass in autumn, while the opposite is true for *Alitta succinea* (Figure 4-67). The reasons for this pattern are not clear, but may be connected with the life cycles or food availability for these species.

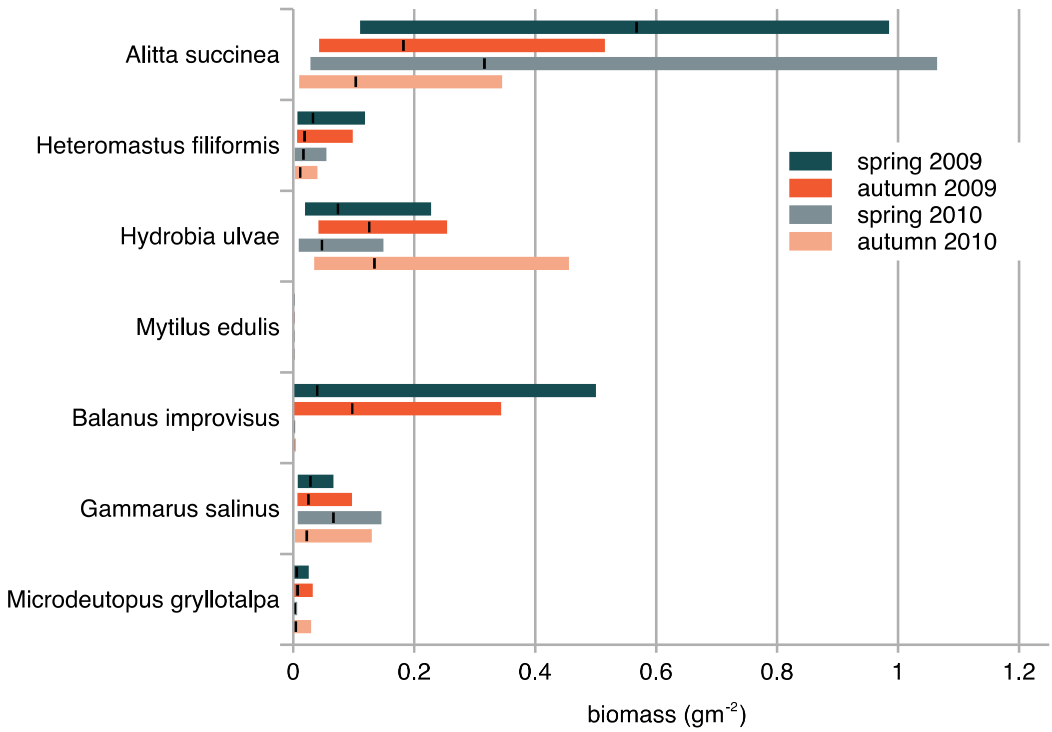

Figure 4-67 *Seasonal variation in biomass (AFDW gm^{-2}) of the main representatives of the Mytilus community during the baseline investigations 2009–2010. The biomass value for* Mytilus edulis *is missing in the graph, since a special mussel sampling was done for this (see Section 5.3.1) indicating a value of approx. 120 gm^{-2}. Box: 25–75th percentile, Line in box: median.*

4.3.8 *Rissoa community*

The Rissoa community is a shallow water epifauna community that is associated with eelgrass meadows (*Zostera marina*). Within the investigation area, this community was only observed in the western part of the Rødsand lagoon (Figure 4-68 and Table 4-15). However, beside the Rødsand Lagoon, the fauna community model also predicts this community in the Orth Bight, where dense eelgrass meadows occur, see (FEMA 2013a). Since this bight is outside the range of the investigation area, there are only historical data available for Orth Bight. These, however, confirm the presence of the Rissoa community. The species found and their composition is the same as in the Rødsand lagoon (Meyer et al. 2002).

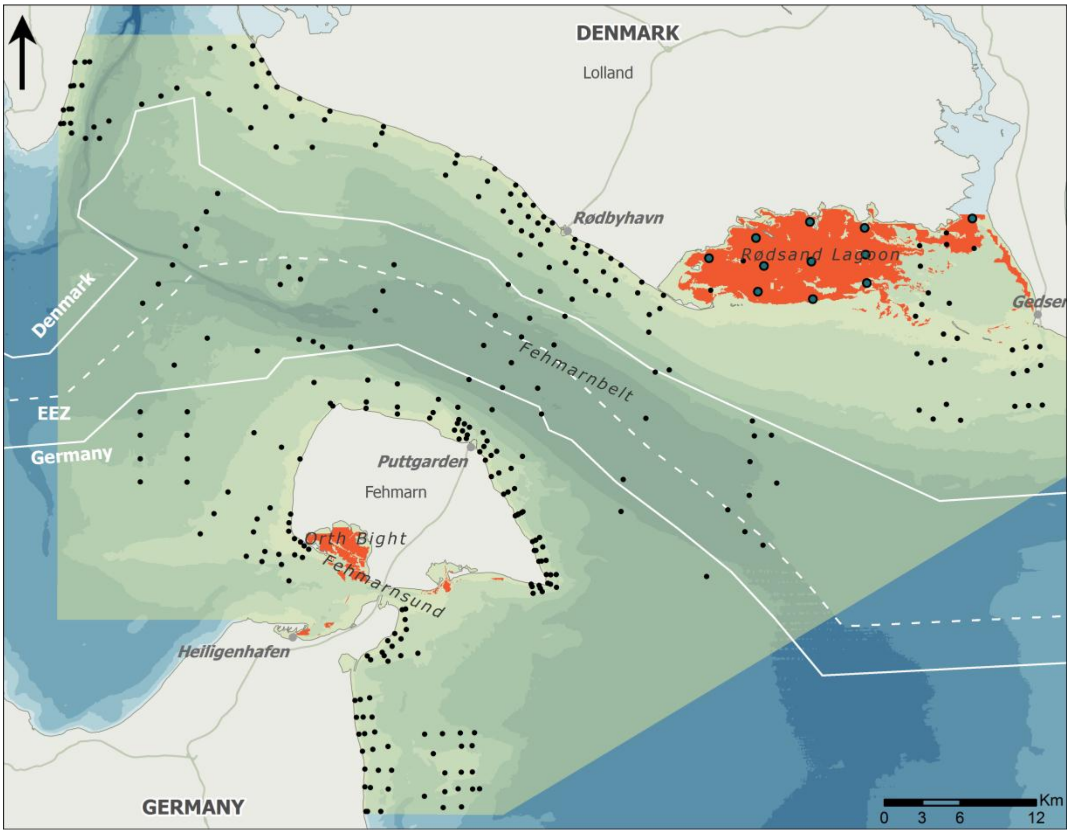

Figure 4-68 Overview of the spatial distribution of the Rissoa community in the Fehmarnbelt region. Green area = study area. Large, blue circles = sampled stations. Red polygons = predicted areas.

The Rissoa community is composed of species that can adapt und utilize the conditions in eelgrass communities (Figure 4-69). The namesake snail genus *Rissoa* belongs to the family Rissoidae which contains a number of snails represented in the community: *Pusillina sarsi*, *Rissoa membranacae*, *Rissoa parva*, and *Rissa violacea*. These snails typically sit on the leaves of eelgrass and feed on microalgae. Another typical species in this community are the aquatic larvae of the insect family Chironomidae (non-biting midges). They inhabit the eelgrass community when the salinity is low enough (maximum salinity at around 15 psu).

Figure 4-69 Typical sediment appearance of the Rissoa community with a mixed sediment (left) and a specimen of the namesake genus Rissoa *(right).*

Table 4-15 Summary of sampled stations, predicted surface area, mean number of species, mean abundance (m^{-2}) and mean biomass (g AFDW m^{-2}) in each administrative area for the Rissoa community.

Administrative area	No. of stations	Predicted area (km^2)	No. of species	Abundance	Biomass
Overall	11	116	22	7780	5.77
Danish waters	11	106	22	7780	5.77
German waters	0	11			
German coastal zone	0	11			
German EEZ	0	0			
DE 1332-301 (Fehmarnbelt)	0	0			
DE 1533-301 (Staberhuk)	0	0			
DE 1631-392 (Östliche Kieler Bucht)	0	10			
DE 1632-392 (Ostsee östlich Wagrien)	0	0			
DE 1733-301 (Sagas Bank)	0	0			
DK 006X238 (Rødsand lagoon)	11	106	22	7780	5.77
DK00VA200 (Langeland)	0	0			

Taxonomic composition

This community is the most species-poor of all observed communities (Figure 4-70). Only few species are characteristic of eelgrass meadows and besides the three main taxonomic groups, only the chironomids (Insecta) and ribbon worms (Nemertina) were found. Many of the species are soft bottom species that inhabit the sediment on which the eelgrass grows. This is typical for the Rissoa community since the soft bottom and the root zone of the eelgrass plants form a large part of the habitat. Like the Gammarus or Mytilus community, which are both also a mosaic of soft sediment and other substrates, , the sediment is typically not completely covered by the eelgrass. The abundant species *Pygospio elegans*, *Scoloplos armiger*, *Cerastoderma glaucum*, *Mya arenaria*, and *Arenicola marina* belong to this soft bottom community and resemble the Cerastoderma community. The occurrence of *Cerastoderma glaucum* in Rødsand lagoon also indicates a lower salinity compared to the open coast.

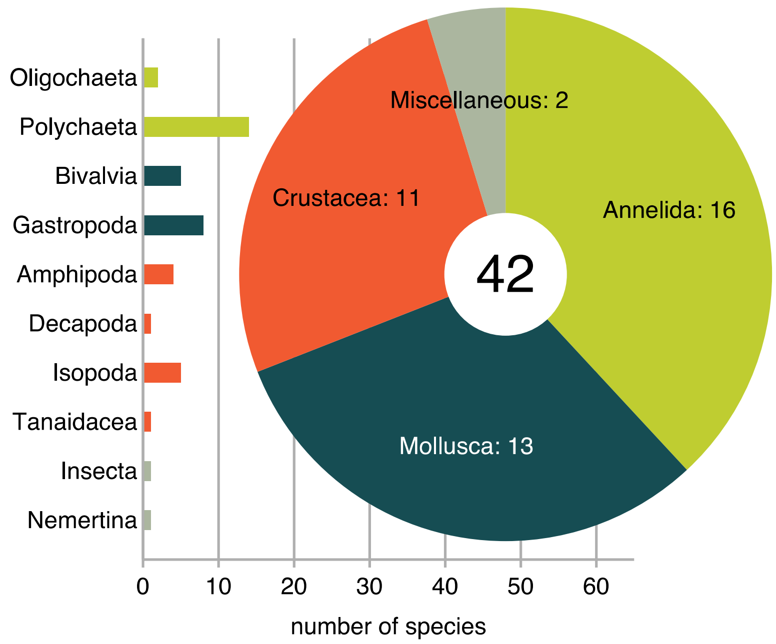

Figure 4-70 Macrozoobenthos species composition of the Rissoa community during the baseline investigations 2009–2010.

Additionally, also an element of the Mytilus community is present since eelgrass meadows often are used by mussels as settling ground. Besides *Mytilus edulis*, also *Littorina* spp., *Heteromastus filiformis*, *Polydora cornuta*, or *Parvicardium hauniense* can be found, but especially *Littorina* spp. and *Parvicardium hauniense* are also typical for the Rissoa community without the presence of *Mytilus*.

The seasonal variation is only partly covered, since samples from the Rødsand Lagoon only were taken in 2009. The data show no significant seasonal variability and species numbers are around 15 per sample (Figure 4-71).

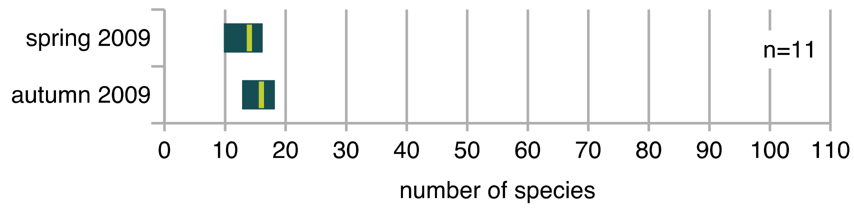

Figure 4-71 Seasonal variation of the number of species per sample in the Rissoa community during the baseline investigations 2009–2010. Box: 25–75th percentile, Line in box: median.

Abundance and biomass

In terms of abundance *Hydrobia ulvae* is the most dominant species (Figure 4-72). With a median abundance of 4970 m^{-2} (not shown in the figure) it is an order of magnitudes more abundant than the second-most dominant species *Mytilus edulis* (320 m^{-2}). The other species have median abundances around or below 100 m^{-2}. It must be taken into account here that the samples not directly targeted the epifauna, so the numbers are probably lower than they would be when sampling the eel-grass directly.

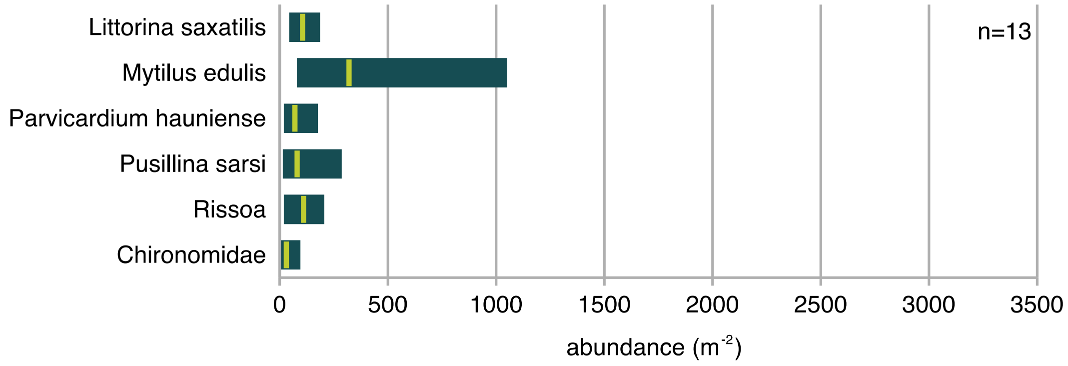

Figure 4-72 *Abundances (m^{-2}) of the main representatives of the Rissoa community during the baseline investigations 2009–2010. Box: 25–75th percentile, Line in box: median.*

The abundances of the main representative species generally showed higher values in autumn 2009 compared to spring 2009 (Figure 4-73). The species here follow the suitability of the habitat. In summer and autumn the eelgrass meadow has the most biomass and thus also enables denser epifauna.

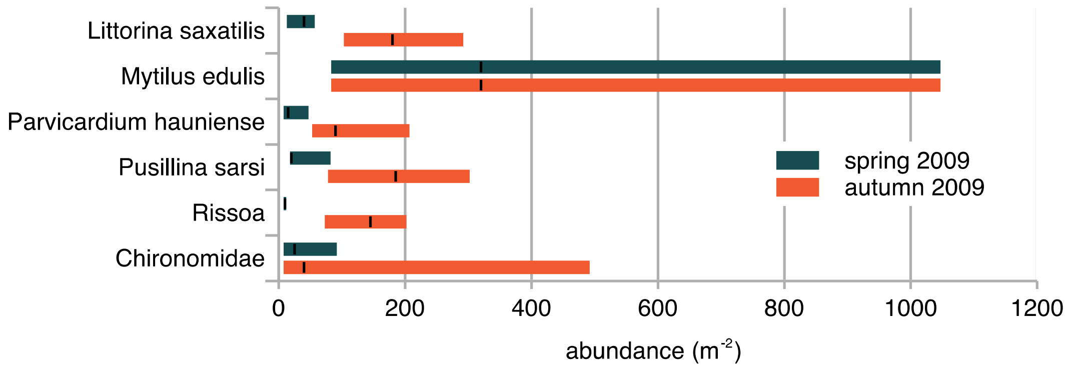

Figure 4-73 *Seasonal variation in abundances (m^{-2}) of the main representatives of the Rissoa community during the baseline investigations 2009–2010. Box: 25–75th percentile, Line in box: median.*

A similar pattern is present for the biomass data (Figure 4-74), but because of the size of *Mytilus edulis*, this species is the most dominant in terms of biomass (around 100 gm^{-2}). Again, these data for the biomass of *Mytilus* are obtained from the dedicated mussel sampling (see Section 5). *Hydrobia ulvae* as the second-most important species in terms of biomass reaches a median value of 2.4 gm^{-2} (not shown in the figure). All other species range around or below a value of 0.1 gm^{-2}.

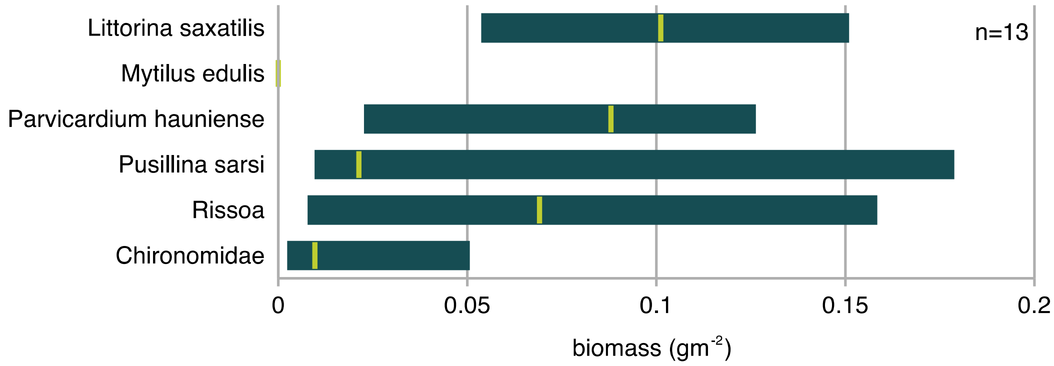

Figure 4-74 *Biomass (AFDW gm^{-2}) of the main representatives of the Rissoa community during the baseline investigations 2009–2010. The biomass value for* Mytilus edulis *is missing in the graph, since a special mussel sampling was done for this (see Section 5.3.1) indicating a value of approx. 100 gm^{-2}. Box: 25–75th percentile, Line in box: median.*

Following the seasonal variation in abundance higher biomasses were found in autumn compared to spring 2009 (Figure 4-75). This difference in species biomass is tied to the conditions in the habitat, because the larger eelgrass biomass in autumn can support a larger biomass of fauna that use leaves as habitat.

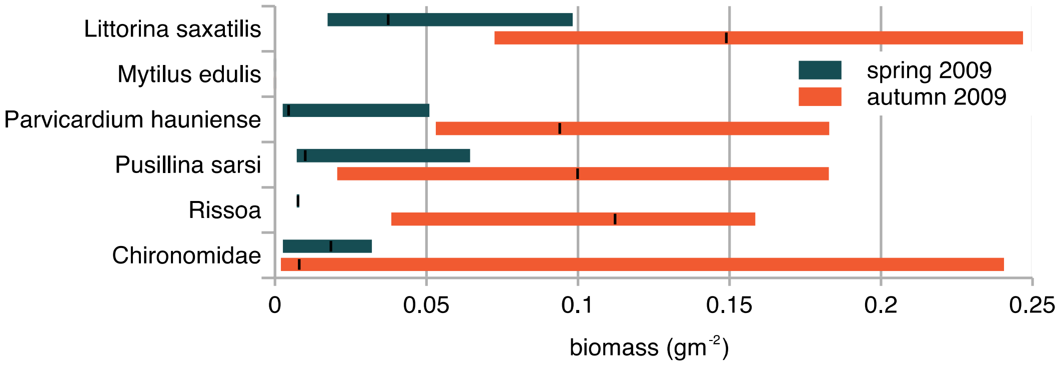

Figure 4-75 *Seasonal variation in biomass (AFDW gm^{-2}) of the main representatives of the Rissoa community during the baseline investigations 2009–2010. The biomass value for* Mytilus edulis *is missing in the graph, since a special mussel sampling was done for this (see Section 5.3.1) indicating a value of approx. 100 gm^{-2}. Box: 25–75th percentile, Line in box: median.*

4.3.9 *Tanaissus community*

Some small areas, scattered over the Fehmarnbelt region, are occupied by the Tanaissus community. It is characterised by sandy, partially coarse sediments in waters of around 15–22 m depth.

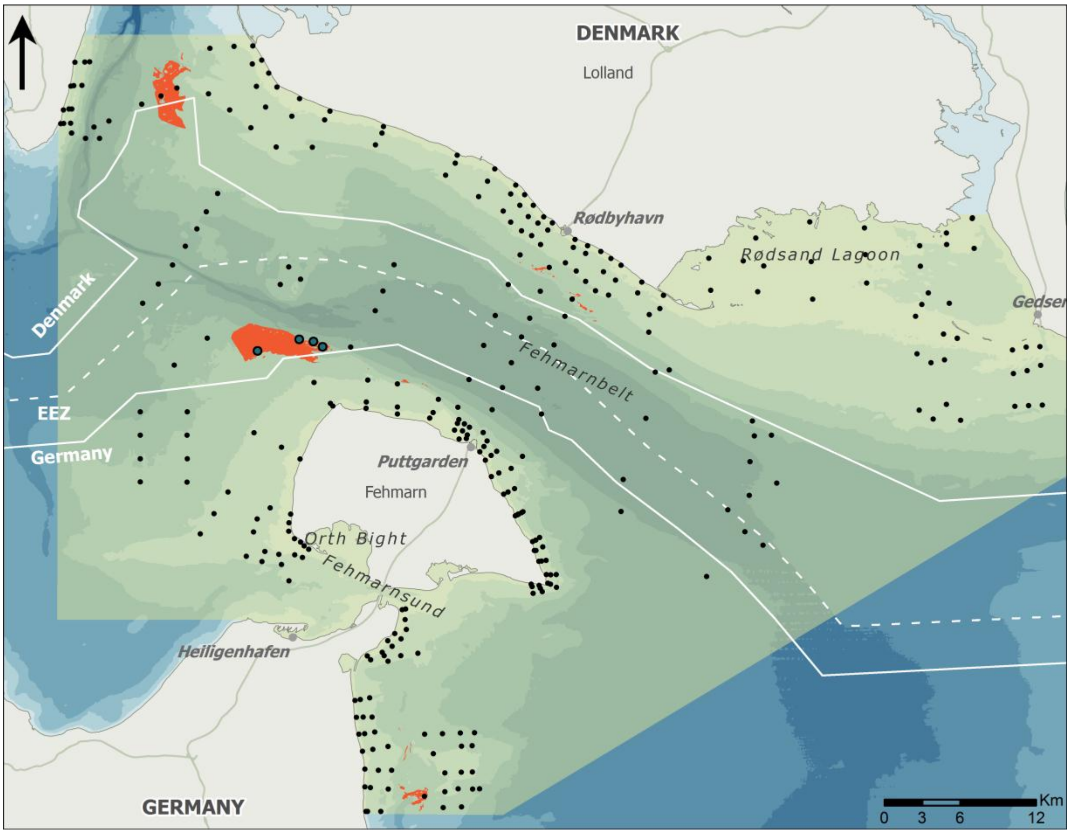

Figure 4-76 Overview of the spatial distribution of the Tanaissus community in the Fehmarnbelt region. Green area = study area. Large, blue circles = sampled stations. Red polygons = predicted areas.

Figure 4-77 Typical sediment appearance of Tanaissus community (left) and a specimen of the namesake species Tanaissus lilljeborgi *(right).*

The *Tanaissus* community was observed in one area west offshore Fehmarn (Figure 4-76). Based on comparable environmental conditions, the predicted areas of the *Tanaissus* community were north-west offshore Fehmarn and west offshore Lolland, in the southern part of the Langeland Belt. The sizes of the areas are listed in Table 4-16.

The community featured a moderate number of species that were most often present, and a large proportion of infrequent species (Figure 4-77). Only a few filter feeding species and several large predators dominated the biomass, whereas many small-sized species of several groups, including bivalves, polychaetes and crustaceans reach high abundances in this community.

Taxonomic composition

In total, 182 species of 24 different taxonomical groups were found in the Tanaissus community (Figure 4-78). The polychaetes constituted the most abundant group of this community, with 57 different species. Other prominent groups within this community were amphipods (25 species), bivalves (22 species), gastropods (16 species) and bryozoans (13 species). The species richness of other taxonomic groups was clearly lower.

For the Tanaissus community, a clear seasonal trend was found. The cumulative number of species increased from 129 to 159 in 2009 and subsequently from 167 to the total maximum of 182 species at the end of the 2010 campaign. This trend suggests a high variability within this community. However, because of the many uncommon species observed the number of species will simply increase with increasing sampling effort. The increasing trend in (uncommon) species does therefore not unambiguously indicate a high temporal variability in the community. The inference based on expert knowledge of the natural habitat of this community, namely the very dynamic sandy areas in somewhat deeper waters, does warrant the statement of high temporal variability. A spatial variability in taxonomic composition was not observed.

Table 4-16 Summary of sampled stations, predicted surface area, mean number of species, mean abundance (m^{-2}) and mean biomass (g AFDW m^{-2}) in each administrative area for the Tanaissus community.

Administrative area	No. of stations	Predicted area (km^2)	No. of species	Abundance	Biomass
Overall	4	23	119	2920	20.29
Danish waters	0	9			
German waters	4	15	119	2920	20.29
German coastal zone	0	2			
German EEZ	4	12	119	2920	20.29
DE 1332-301 (Fehmarnbelt)	4	12	119	2920	20.29
DE 1533-301 (Staberhuk)	0	0			
DE 1631-392 (Östliche Kieler Bucht)	0	0.6			
DE 1632-392 (Ostsee östlich Wagrien)	0	0			
DE 1733-301 (Sagas Bank)	0	1			
DK 006X238 (Rødsand lagoon)	0	0			
DK00VA200 (Langeland)	0	0			

Total number of species was almost constant between samplings (Figure 4-79). The median number of species was around 70 in the Tanaissus community, which is distinctively lower than the total of 182.

A high variability of species richness occurred in this area, which was reflected in different frequencies of occurrence of species. A total of 22% (40 species) were found only once and about the same percentage (44 species) occurred only twice during the investigation period.

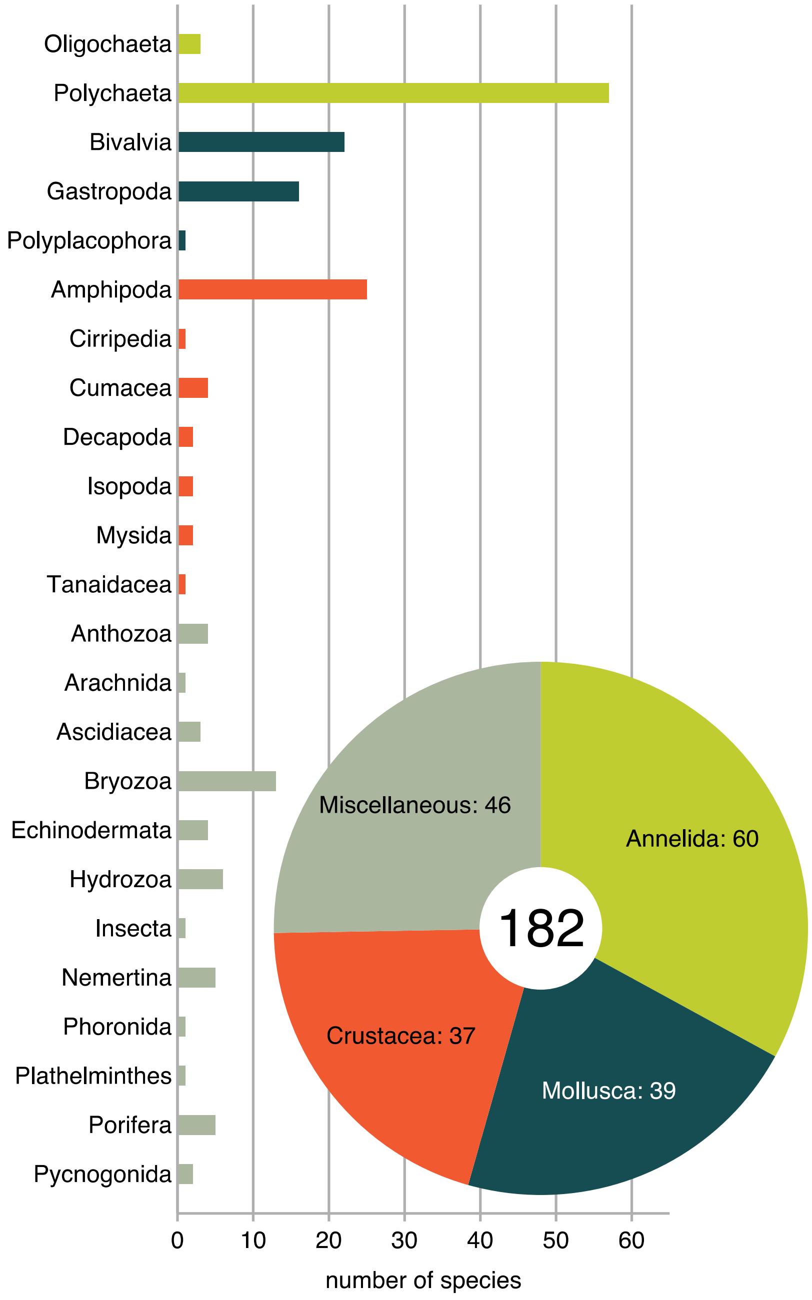

Figure 4-78 Macrozoobenthos species composition of the Tanaissus community during the baseline investigation campaigns in 2009–2010.

Only a small part of the community (4% = 7 species) was always present: *Asterias rubens*, *Eteone longa*, *Kurtiella bidentata*, *Mytilus edulis*, *Phoxocephalus holbolli*, *Scoloplos armiger*, and *Spio goniocephala*. The large proportions of low-frequent species led to considerable seasonal and spatial variations in species composition of Tanaissus community in general.

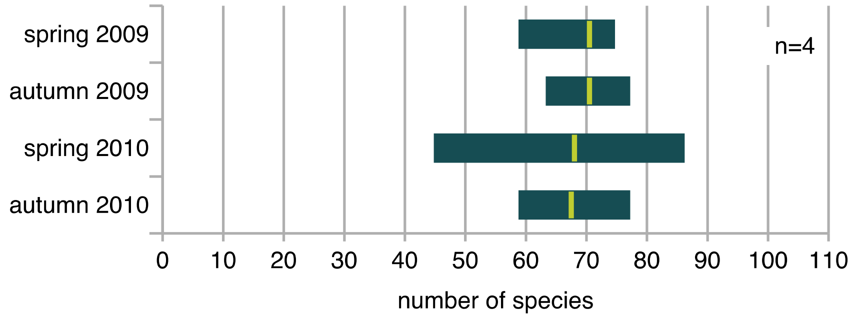

Figure 4-79 Number of species per station in the Tanaissus community during the four investigation campaigns in 2009 and 2010. Box: 25–75th percentile, Line in box: median.

Abundance and biomass

The Tanaissus community was characterised by the high abundance of several high-frequent key species, which belong mainly to the bivalves, polychaetes and crustaceans (Figure 4-80). The combined abundances of these species were in the same range as the abundances of the remaining "Other" community members. Several low-frequent species may also reach mean abundances higher than 100 m^{-2}, e.g. *Bathyporeia pilosa*, *Amphitrite cirrata*, *Bittium reticulatum* and *Corophium insidiosum*.

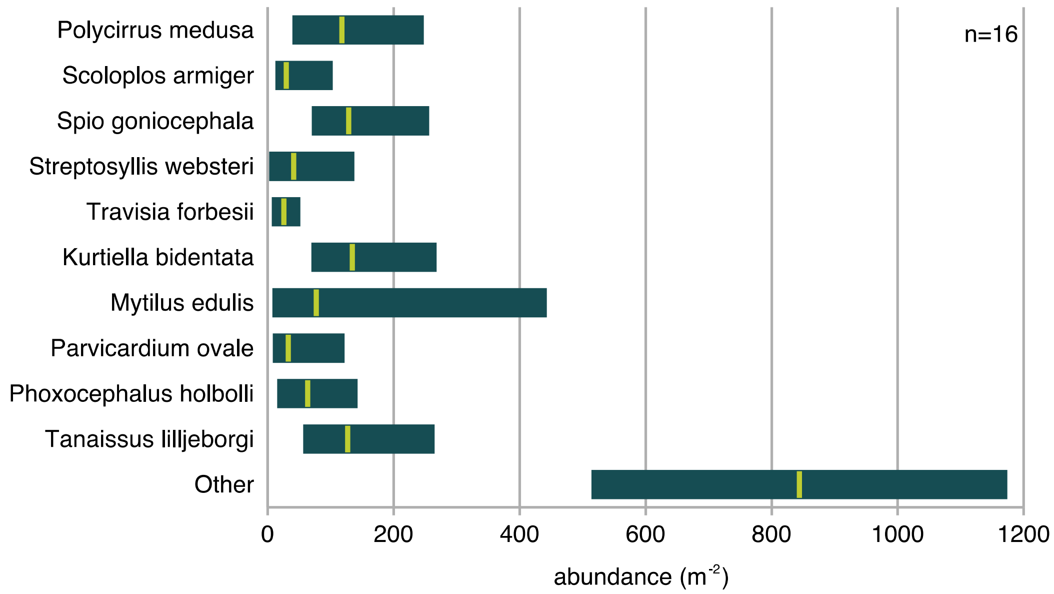

Figure 4-80 Abundances (m^{-2}) of the main representatives of the Tanaissus community during the investigation period 2009–2010. Box: 25–75th percentile, Line in box: median.

Several of the dominant species varied seasonally (Figure 4-81). The highest variation was found for the mussel *Mytilus edulis*. The one-time occurrence of juveniles (< 5 mm) was observed in autumn 2009, while in contrast only few individuals of *M. edulis* were found in 2010.

The median abundances of *Kurtiella bidentata*, *Spio goniocephala*, *Streptosyllis websteri*, and *Tanaissus lilljeborgi* increased consistently over a period of three campaigns until they dropped in autumn 2010. For *Parvicardium ovale*, low abundances were found in spring and consistently higher abundances in autumn.

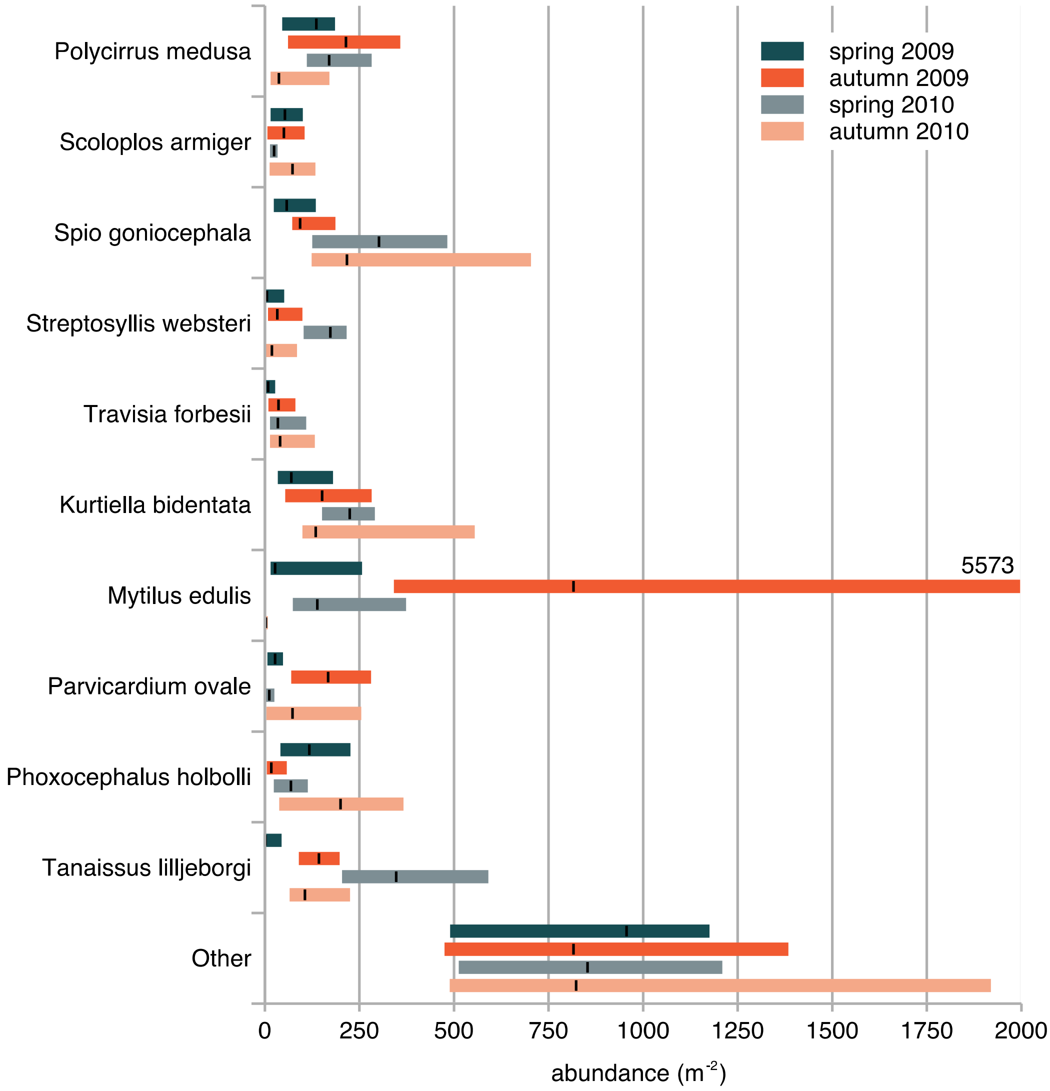

Figure 4-81 Abundances (m^{-2}) of the main representatives of the Tanaissus community during the four investigation campaigns in 2009 and 2010. Box: 25–75th percentile, Line in box: median. Number in plot means value of upper box boundary.

The biomass of the Tanaissus community was dominated by *Arctica islandica* (Figure 4-82). This long-living bivalve reached values higher than all other species. However, for the other smaller bivalve *Astarte borealis* and the large polychaete *Nephtys caeca*, considerable biomasses were observed.

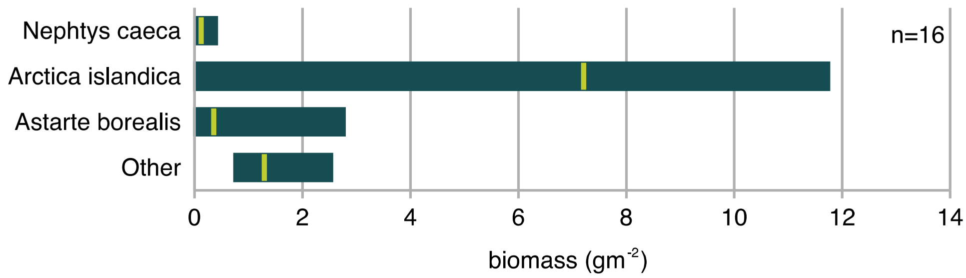

Figure 4-82 Biomass (AFDW gm^{-2}) of the main representatives of the Dendrodoa community during the investigation period 2009–2010. Box: 25–75th percentile, Line in box: median.

Most of the *Arctica islandica* individuals were adults, measuring more than 50 mm in shell length. *A. islandica* was only moderately abundant in the area, which led to higher variability in biomass values.

The biomasses of the other main species and the remaining "Other" species showed low seasonal variability. Furthermore, the very mobile polychaete *Alitta virens* showed consistently higher biomass values in the spring campaigns (Figure 4-83). The starfish *Asterias rubens* attained somewhat higher biomass values on a seasonal basis.

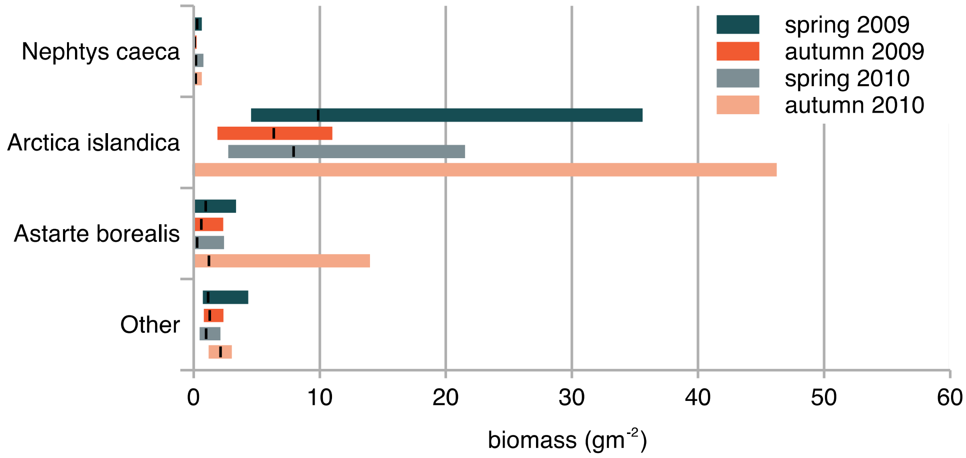

Figure 4-83 Biomass (AFDW gm^{-2}) of the main representatives of the Tanaissus community observed in each of the four investigation campaigns in 2009 and 2010. Box: 25–75th percentile, Line in box: median.

5 BLUE MUSSELS IN FEHMARNBELT

This section contains an assessment of the distribution, abundance, biomass, condition and filtering capacity of the Blue Mussel (*Mytilus edulis*) in the Fehmarnbelt, based on samplings carried out both in 2008, in 2009 and in 2010 (see Section 2.2 for sampling details).

*Figure 5-1 Blue mussels (*Mytilus edulis*) in Fehmarnbelt.*

5.1 Main trends

5.1.1 Spatial distribution and coverage

Along most of the coastal transects, Blue Mussels were observed (Figure 5-1). However, the cover was highly variable both within and between the transects. Generally, the highest cover percentage (coverage) of Blue Mussels was recorded southwest offshore Lolland (Albuen Bank), south offshore the Lagoon of Rødsand, Gedser Reef and along the west coast of Fehmarn.

Areas where particularly low coverage was observed are notably the deeper waters of the central Fehmarnbelt and Sagas Bank (Figure 5-3). In the Lagoon of Rødsand, mussels were very scarce and more than 90% of the video observations showed no mussels.

Blue Mussels are highly dependent on the availability of food (phytoplankton) and depending on the physical environment including in particular presence of suitable substrate (boulders, rocks etc.) to which they can attach with their byssus threads. In some cases, however, presence of hard substrate is not required, e.g. at 100% coverage mussels can form a continuous ‘blanket’ where individuals are tightly connected by byssus threads. In such cases the population creates their own hard substrate and boulders are not needed to support their presence. Such situations are typical in the Wadden Sea where mussel biomass locally easily can exceed 25 kg wet weight per m^2.

On a large scale, the presence of hard substrate (boulders, stones, gobbles) in the Fehmarnbelt seems to be of minor importance for mussel coverage as evidenced by a scatter-plot between percentage of hard substrate at a locality and the corresponding cover percentage by mussels (Figure 5-2). Coverage data shown in Figure 5-2 was limited to the depth interval showing the highest mussel coverage (see below), but outside this depth interval trends were also very low.

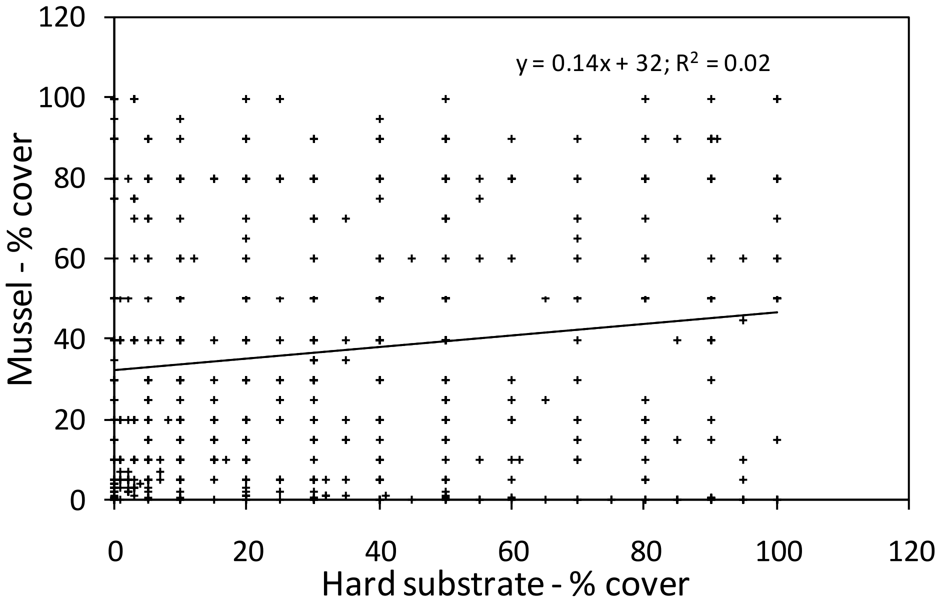

Figure 5-2 *Scatter plot of coverage of hard substrate and Blue Mussels (Mytilus edulis) on seabed. Video data from the depth interval 6-12 m. Slope of linear regression line is not significantly different from zero, meaning that cover of hard substrate are not important for coverage of mussels.*

A map of mussel coverage was established using a Generalized Additive Model (GAM) relating 5220 video observations of coverage to depth, modelled yearly average current speed in near bed layer, proportion of hard substrate at position where coverage was recorded. The most important predictors in the model was depth and current speed while proportion of hard substrate was of less importance but still significant in the GAM model. The GAM model explained 62.1% of the variability in mussel cover (deviance explained). The model was evaluated by fitting the model based on a calibration data set (70%), and the model predictions were further evaluated by using a semi-independent data set (30 %), samples not used in model building (Guisan and Zimmermann 2000; Araújo et al. 2005; Heikkinen et al. 2006). The predictive accuracy was assessed by using Pearson's and Spearman's correlation; a Pearson's correlation coefficient of 0.74 was obtained and a Spearman's correlation coefficient of 0.77. The predictability (Q^2) of the model was 53%, which must be considered as very satisfactory (Figure 5-3).

Table 5-1 *F-values and significance of the smooth terms for the environmental predictor variables used in the final predictive model of blue mussel cover.*

Predictor variable	F value	P-value
Depth	18.69	*< 0.001*
Current speed	20.61	*< 0.001*
X, Y	7.69	*< 0.001*

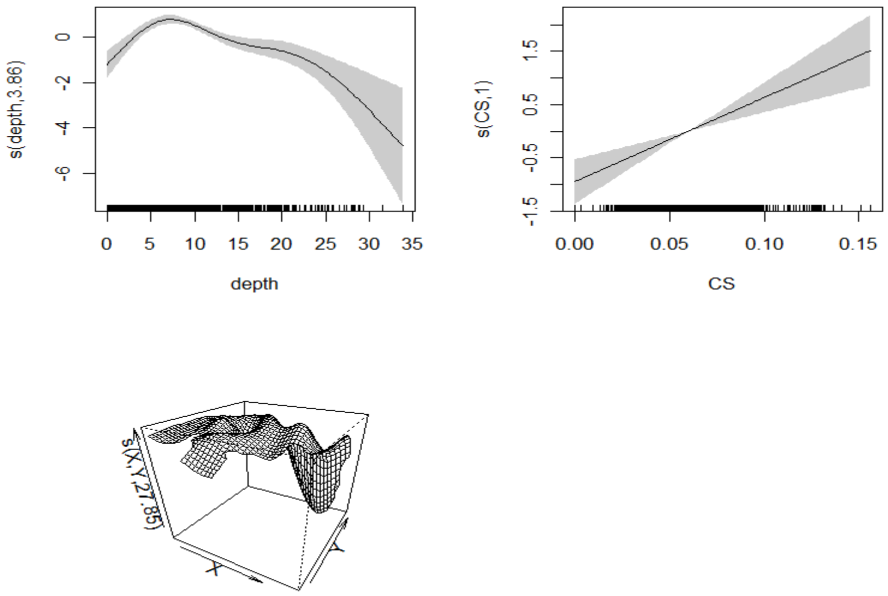

Figure 5-3 *Partial GAM plots for the blue mussel model. The values of the environmental variables, depth and current speed (CS) are shown on the X-axis and the probability on the Y-axis in logit scale [logit(p) = log(p) - log(1-p)]. The degree of smoothing is indicated in the legend of the Y-axis. The dotted lines indicate the 95% confidence bands. For the 2-d term (X and Y) a perspective plot is shown.*

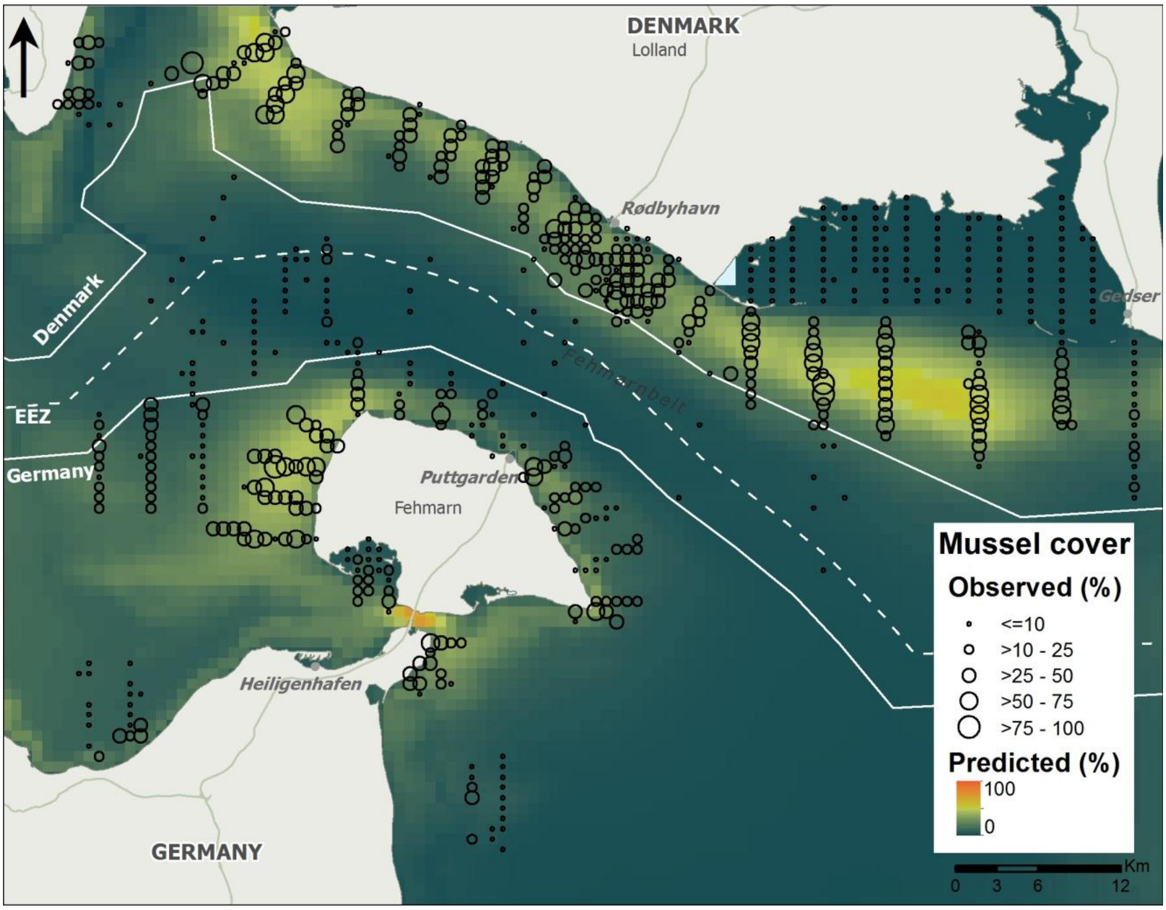

Figure 5-4 Observed and predicted (GAM-modelled) coverage (%) of mussels in the Fehmarnbelt (see text for explanation). "Observed" coverage from the deep stations was inferred indirectly from the biomass in infauna sampling.

Overall, depth was the single most influential independent variable affecting mussel coverage. Both along the German and the Danish coasts coverage could roughly be described by a quadratic function of depth with a wide peak in coverage around 6-12 m depth (Figure 5-5). Obviously, the quadratic model did not capture the narrow peak between 6 and 9 m occurring both in Danish and German waters. The peak in mussel coverage around 6-12 m is likely an effect of the highest food availability, i.e. in a mixed water column phytoplankton concentration (per m^2) will increase with water depth until an 'optimum'. At larger depth a decreasing efficiency of vertical mixing will result in reduced down-ward mixing of food and reducing abundance and thus the coverage. Below the pycnocline (≈ 13-14 m) the average current speed decreases and the replenishment of food (plankton algae) across pycnocline is limited.

In a comparison of the distribution of the percentage mussel coverage over the depth gradient (Figure 5-5), it appears that *M. edulis* coverage is lower along the Danish (Lolland) coast at shallow waters than along the German (Fehmarn) coast. Also, it appears that the mussel coverage extends to larger depths on Fehmarn, albeit slightly. Likely explanations could be a higher wave exposure along the Lolland that prevents a permanent occurrence of mussels in shallow waters, and that a steeper gradient in the pycnocline is more dominant along the Lolland that along the Fehmarn.

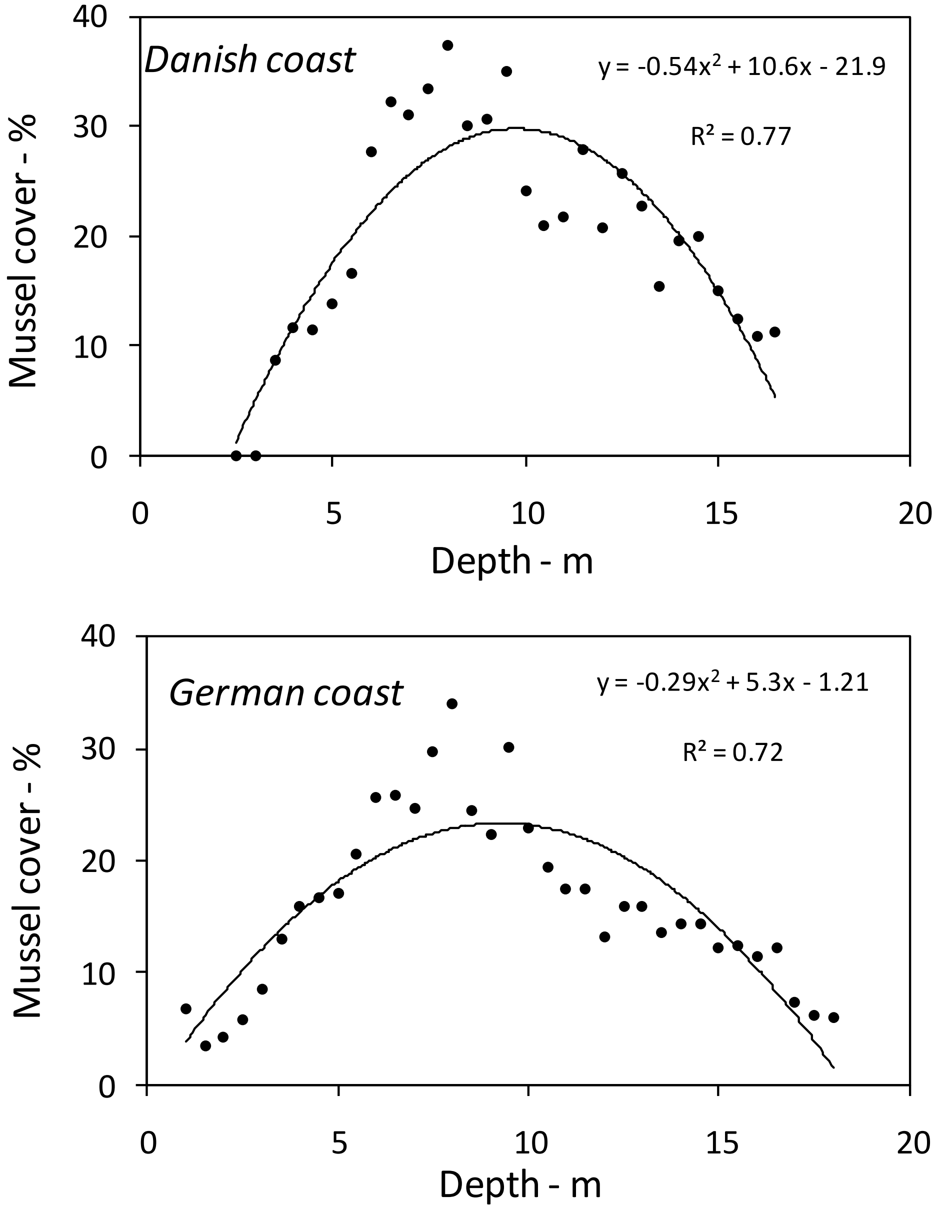

Figure 5-5 *Relation between mussel coverage and depth along the Danish (upper) and German (lower) coasts. Each point represents an average mussel coverage occurring in 0.5 m depth intervals. R^2 of a quadratic function fitted to data is shown.*

5.1.2 Abundance and Biomass

Mytilus edulis individuals were recorded, counted and weighed at 342 stations, of which 159 stations were located in the 'deep water' (>13 m). Average values and standard deviations of both abundance and biomass for depth intervals 4-7.5 m (nominal 6m), 7.5-13m (nominal 10m) and at depth larger than 14 m are shown in Table 5-1 and Table 5-2, and the spatial distribution of biomass is shown in Figure 5-6.

The mussel abundance was observed to be much higher at the shallow stations (6 m and 10 m nominal depths), compared to the deep water stations (14-24 m). The abundance did not differ significantly between 6 m and 10 m stations. Within the total pool of shallow water stations, mussel abundance was 2-3 times higher along the Fehmarn coast compared to the Lolland coast.

*Table 5-2 Abundance in individuals per m² of Blue Mussels (*Mytilus edulis*) recorded during baseline investigations in 2008 and 2009. Values shown are mean and standard deviations (SD).*

		Nominal depth	Abundance (ind. m^{-2})	
			Mean	**SD**
Shallow				
	Denmark	6 m	9333	5022
		10 m	10029	9650
	Germany	6 m	27136	22066
		10 m	19891	19641
Deep		14 - 24 m	737	2006

The biomass of Blue Mussels at the stations, calculated as the biomass in the samples times the percent cover of the population in the vicinity of the stations (divers' observations), were highly variable. Within the shallow water average mussel biomass was lower at the 'shallowest' (i.e. 6 m nominal depth) stations compared to the 'deep' (i.e. 10 m nominal depth) stations both around Fehmarn and Lolland. For the shallow stations mussel biomass did not differ between the Danish and German side, while biomass at 10 m was higher around Lolland compared to Fehmarn at similar depth.

The higher abundance, in combination with lower biomass around Fehmarn, shows that mussels on average are smaller along the German coast than along the Danish coast.

Table 5-3 Biomass in g AFDW per m^2 of mussels (Mytilus edulis) recorded during supplementary investigations in winter 2008/2009 and during baseline investigations in 2009. Values shown are mean and standard deviations (SD).

		Nominal depth	Biomass (g AFDW m^{-2})	
			Mean	**SD**
Shallow				
	Denmark	6 m	118	55
		10 m	212	147
	Germany	6 m	106	51
		10 m	139	74
Deep		14 - 24 m	5	18

The spatial distribution of mussel biomass at stations is shown in Figure 5-6. With few exceptions, biomass was highest in the depth range 8-12 m. High biomass was consistently found along the Fehmarn and Lolland coast around the alignment area, on the east coast of Fehmarn (Staberhuk), at Großenbrode, offshore Rødsand Lagoon, southeast of Gedser and at Albuen Bank (offshore SW Lolland). In contrast, mussel biomass was low south of Großenbrode and on the 10-14 m slope west offshore Fehmarn.

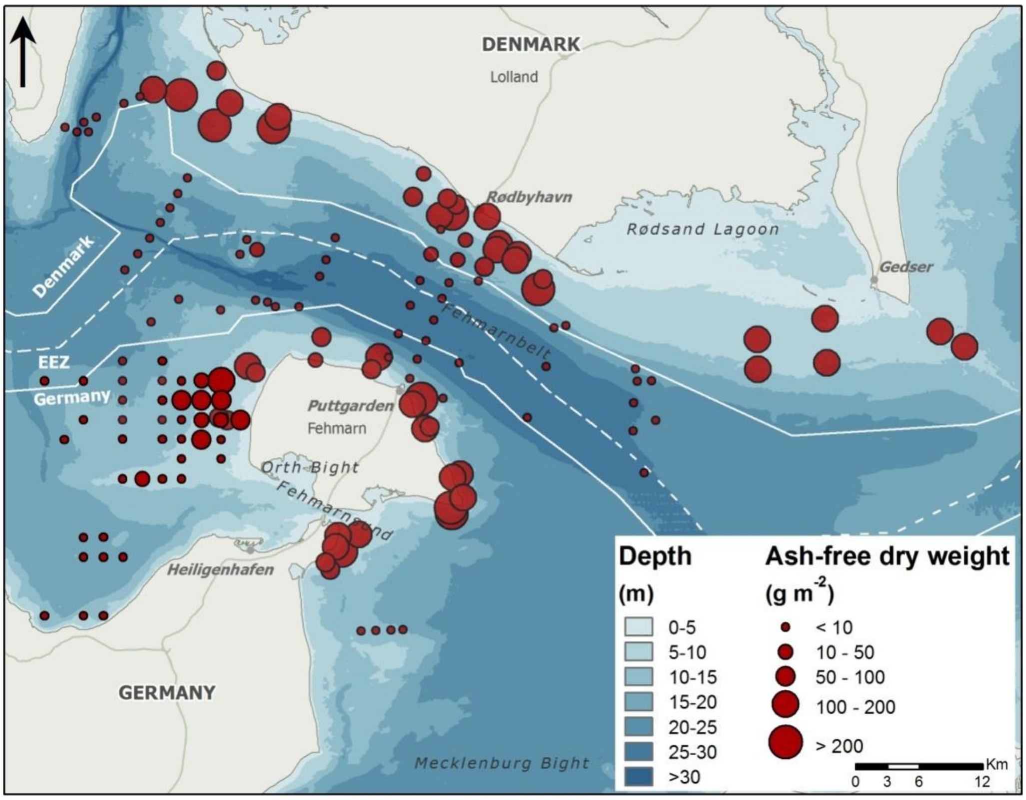

Figure 5-6 Spatial distribution of mussel biomass (AFDW m^{-2}) in 2008-2009. Only stations with AFDW above 0.1 g m^{-2} are included, (that is: the class "<10" excludes any stations where the AFDW <0.1 g m^{-2}).

5.1.3 Size distribution of biomass

In the Fehmarnbelt Blue Mussels vary in length from less than 5mm to larger than 70 mm. Although not directly coupled to age, shell length is considered to be a relatively good proxy to determine the age in mussels. Theoretically, length distributions allow for the identification of year classes and appropriate food sources for (size-) selective predators like diving sea birds (i.e. Eider ducks).

Examples of mussel biomass (ash-free dry weight: AFDW) per size class along the Lolland coast, around Fehmarn and east of Großenbrode is shown in Figure 5-7 to Figure 5-16. All biomass data in the following has been corrected for mussel cover in the sampling area. Size distribution at individual stations is shown in Appendix 8.

The composition of the mussel populations varied strongly between localities along both Lolland and Fehmarn coasts and differed somewhat between samples taken in November-December 2008 and sampling carried out during summer 2009.

Along the coast of Lolland, the population was dominated by adult mussels (shell length $\geq$ 10 mm) at almost all transects west of the proposed alignment. Albue Bank, the relatively shallow area located south-west offshore Lolland, is an important area for sea birds. Here the mussel population was dominated by size classes between 10 mm and 45 mm.

Neglecting the uncertainty related to not sampling at exact identical positions, mussel biomass decreased slightly at the shallow stations (6m) (from 173 to 152 g AFDW/m^2) and increased at the deeper stations (10m) (from 202 to 255 g AFDW/m^2) at Albue Bank from November 2008 to summer 2009. While the calculated changes in the overall biomass may be debatable because of sample variation, the change in size distribution probably is more reliable due to a much lower variation between samples and stations. Based on biomass of size classes loss occurred in the size groups 15-20 mm and 20-25 mm (Figure 5-7 – Figure 5-8), while the larger size groups either increased or was unchanged. The 'loss' of biomass in the lower size groups during winter and spring could be due to predation from the wintering eiders or simply due to growth of mussels and the resulting shift of biomass to larger size classes.

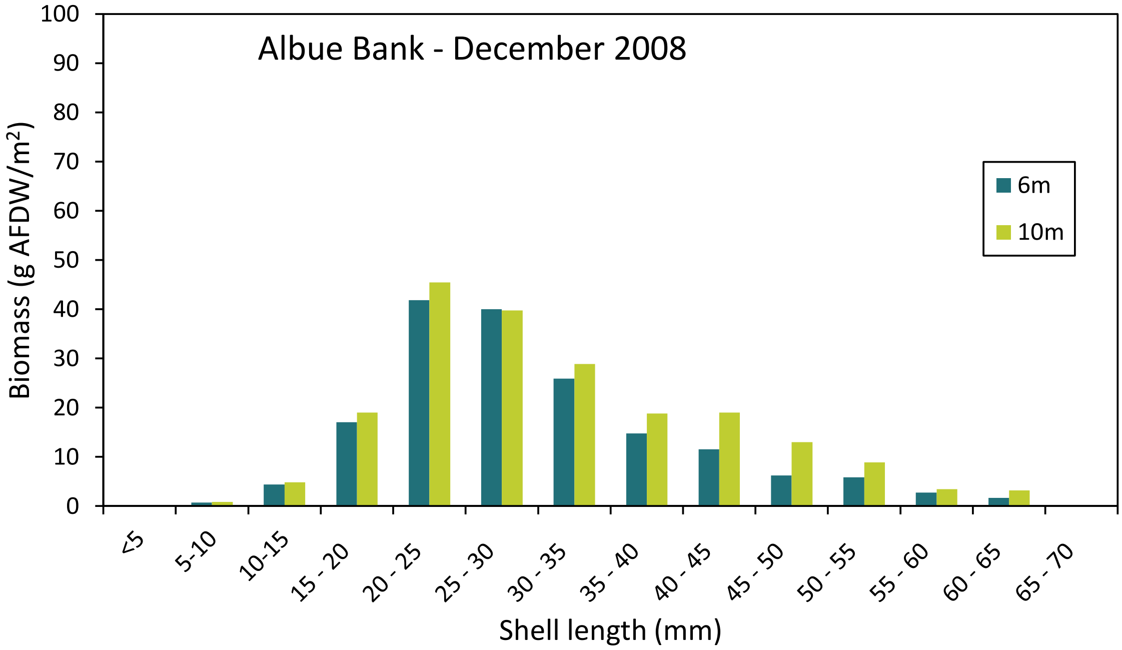

Figure 5-7 *Size distribution of AFDW in mussels sampled at 2 depths along transects within the 'west reference area', Albue Bank located west of alignment off Lolland. Data from supplementary Urgent investigations (winter 2008/2009), based on averages from stations 1-1, 1-2, 1-3 (6m), 1-2, 2-2, 2-3, 3-2 (10m).*

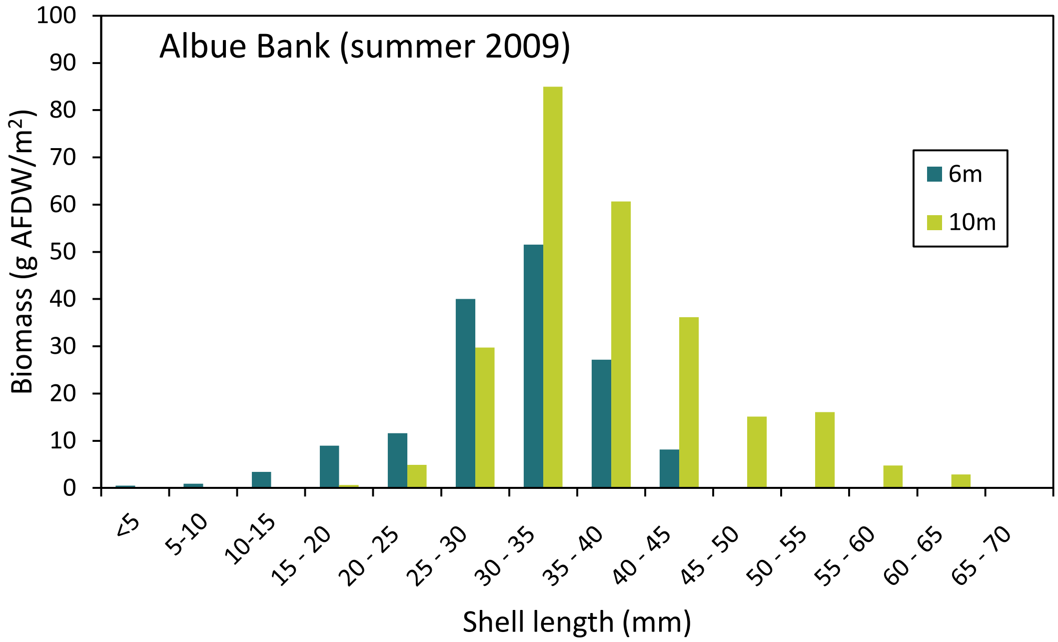

Figure 5-8 Size distribution of AFDW in mussels sampled at 2 depths along transects within the 'west reference area', Albue Bank located west of alignment on Lolland. Data from baseline investigation (2009) is based on averages from stations W7-1, W8-1, W9-1 (6m) and W7-2, W8-2, W9-2 (10m).

In the link alignment area the changes in size distribution from December 2008 to summer 2009 was modest. Biomass of mussels less than 30 mm in shell length was practically zero both in 2008 and 2009. For the larger mussels the size distribution was rather similar in 2008 and 2009 for both depths (Figure 5-9– Figure 5-10). Due to low sample number in 2008 (and the associated high uncertainty) we cannot draw further conclusion about the minor differences in size distributions in 2008 and 2009.

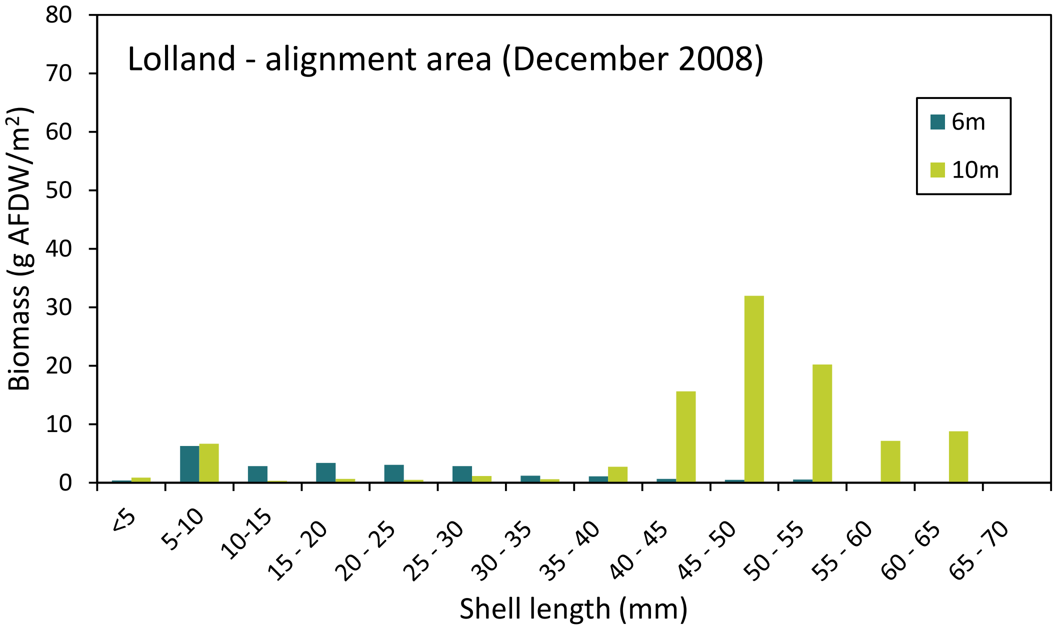

Figure 5-9 *Size distribution of AFDW in mussels sampled at 2 depths along transects within the 'alignment area', on Lolland. Data from supplementary investigation (winter 2008/2009) is based on averages from stations 6-1, 7-1 (6m), 5-2, 7-2 (10m).*

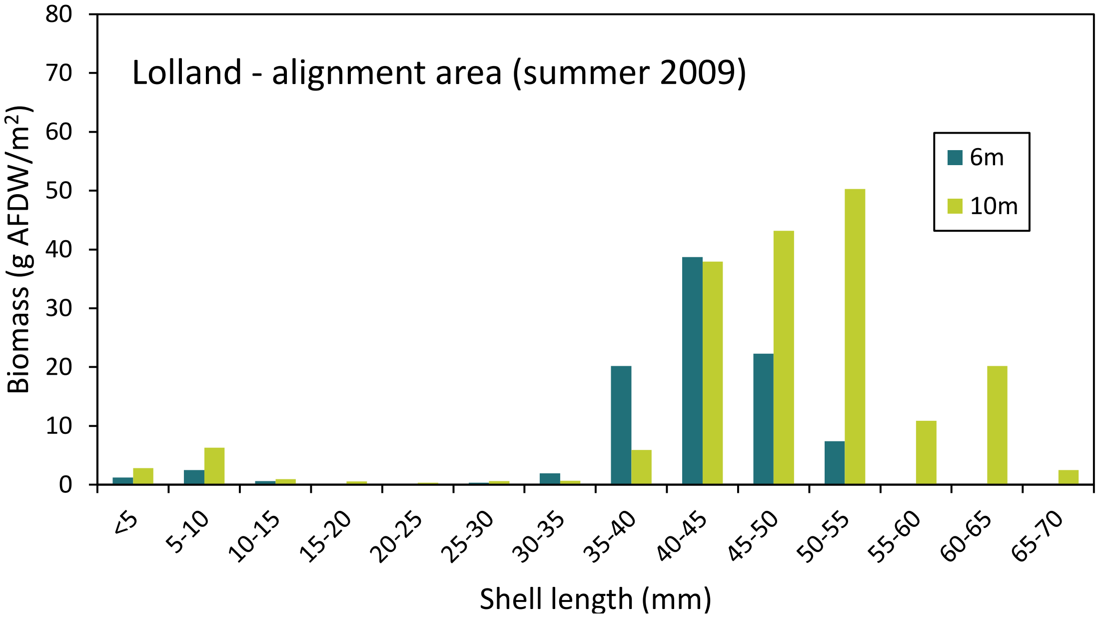

Figure 5-10 *Size distribution of AFDW in mussels sampled at 2 depths along transects within the 'alignment area', on Lolland. Data from baseline investigation (2009) is based on averages from stations LO-00-1, LO-E-02-1, LO-03-1, LO-E04-1, LO-W-01-1, LO-W-02-1 (6m) and LO-E-02-2, LO-03-2, LO-E-04-2, LO-W-01-2, LO-W-02-2 (10m).*

In the area offshore Rødsand Lagoon there was only minor correspondence of the size distribution in samples from December 2008 and summer 2009, underlining that exact matching of sample location is important if the population structure differs spatially. In 2009 the size distribution was unimodal at 6m with a biomass peak at 15-20m size class. At 10m the size distribution was bi-modal with broad peaks both at 10-25mm and at 35-50mm size classes (Figure 5-11– Figure 5-12).

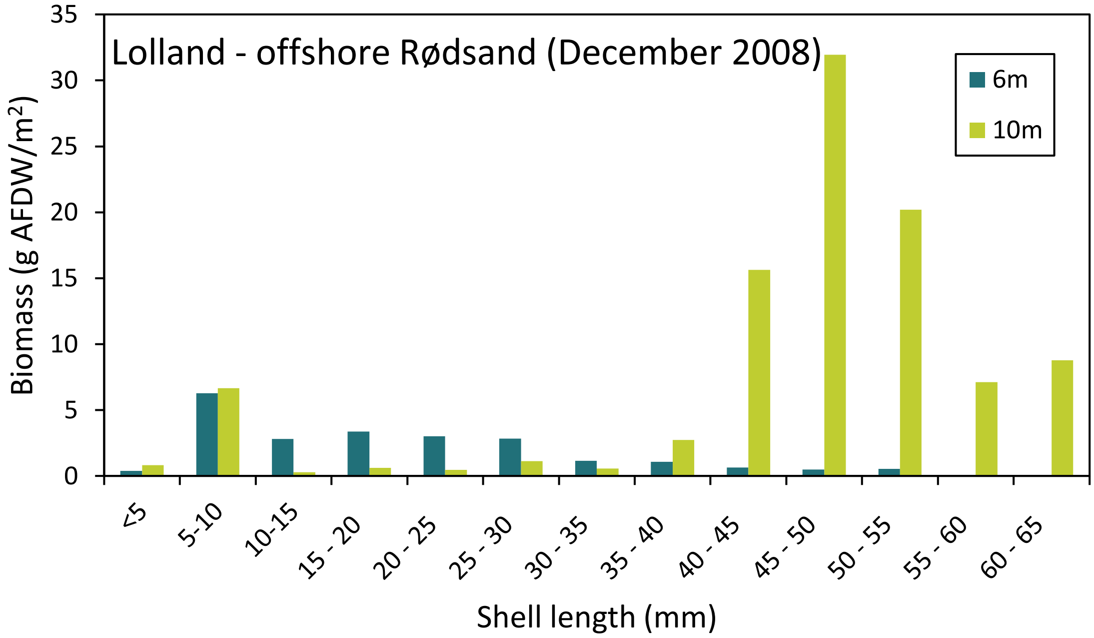

Figure 5-11 Data from supplementary investigation (winter 2008/2098) is based on averages from stations 9-1, 10-1, 11-1, 12-1 (6m), 9-2, 10-2, 11-2 (10m).

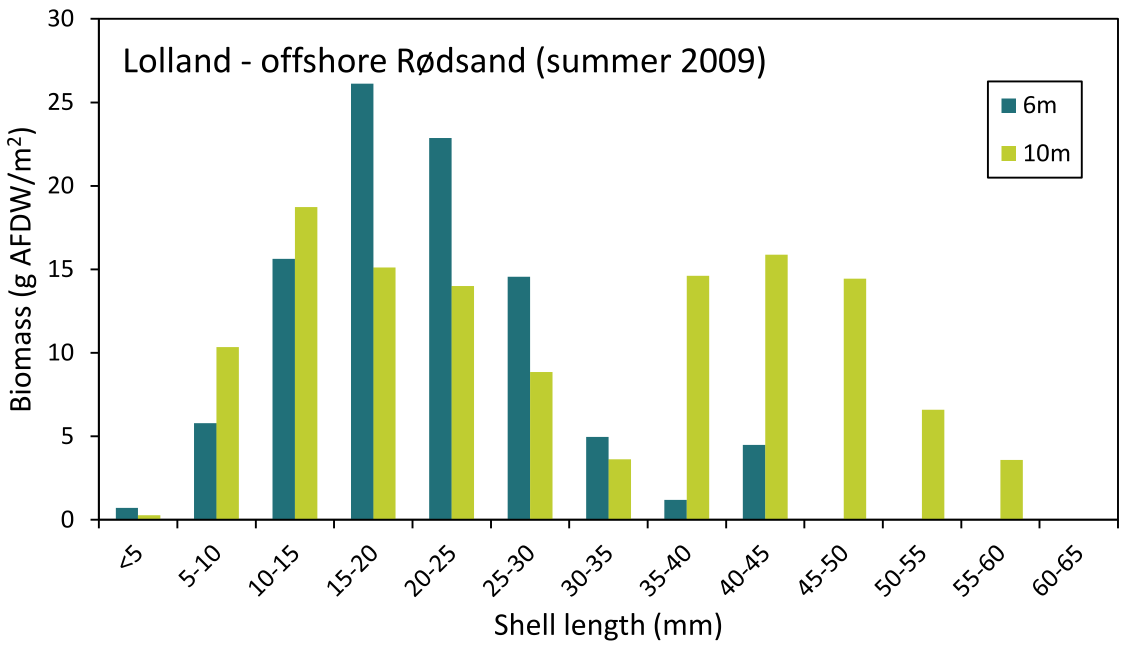

Figure 5-12 Size distribution of AFDW in mussels sampled at 2 depths along transects east of the 'alignment area', offshore Rødsand Lagoon on Lolland. Data from baseline investigation (2009) is based on averages from stations LOR-E-05-1, LOR-E-06-1, LOR-E-07-1 (6m) and LOR-E-05-2, LOR-E-06-2, LOR-E-07-2 (10m).

In the alignment area off Fehmarn mussel biomass was almost uniformly distributed over shell lengths, but with slight trends for bimodal distributions with biomass peaks of small individuals (5-20 mm) and larger individuals (40-65 mm). The bimodal distribution was most evident for mussels occurring at shallower waters (Figure 5-13).

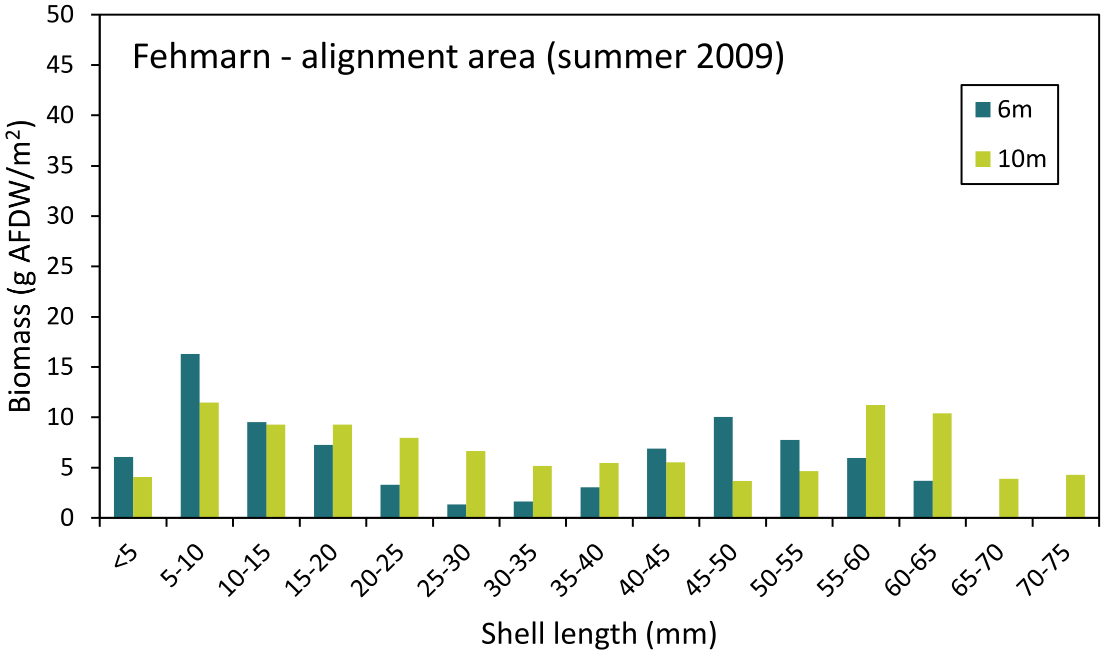

Figure 5-13 *Size distribution of AFDW in mussels sampled at 2 depths along transects west of the 'alignment area' and within the alignment area. Data from alignment area based on averages from stations Fe-M-E01_01/02, Fe-M-E02_01/2, Fe-M-E04_01/02, Fe-M-W02_01/02, Fe-M-W04_01/02.*

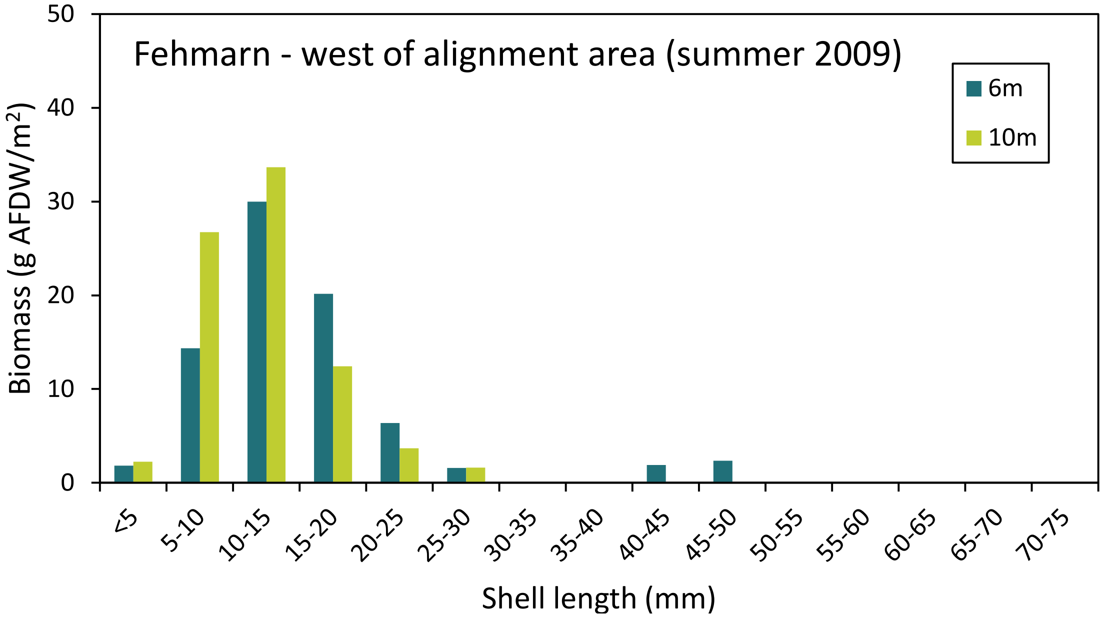

Figure 5-14 *Size distribution of AFDW in mussels sampled at 2 depths along transects west of the 'alignment area' and within the alignment area. Data from west of alignment area are based on averages from stations Fe-M-W06 01/02, Fe-M-W08_01/02 (01/02 = 6m/10m).*

In the area west of the proposed alignment along the Fehmarn coast, the biomass was mainly made up by small-sized mussels, peaking at 10-30 mm shell length (Figure 5-14). Off the eastern coast of Fehmarn at Staberhuk and south of Fehmarn, at Großenbrode, size distributions were unimodal with biomass peaks at shell lengths between 15 and 35 mm (Figure 5-16).

The size distribution of Blue Mussels belonging to the different size classes is shown in Appendix 8.

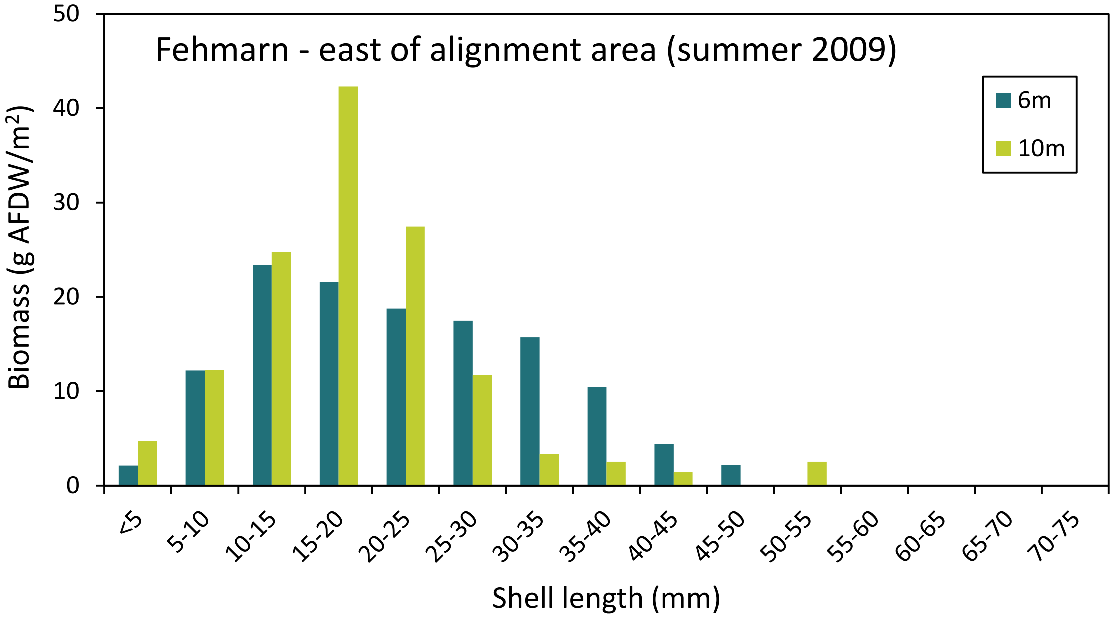

Figure 5-15 Size distribution of AFDW in mussels sampled at 2 depths along transects east of the 'alignment area' and along east coast of Großenbrode. Data from east of alignment area based on averages from stations Fe-M-E06_01/02 and Fe-M-E09_01/02.

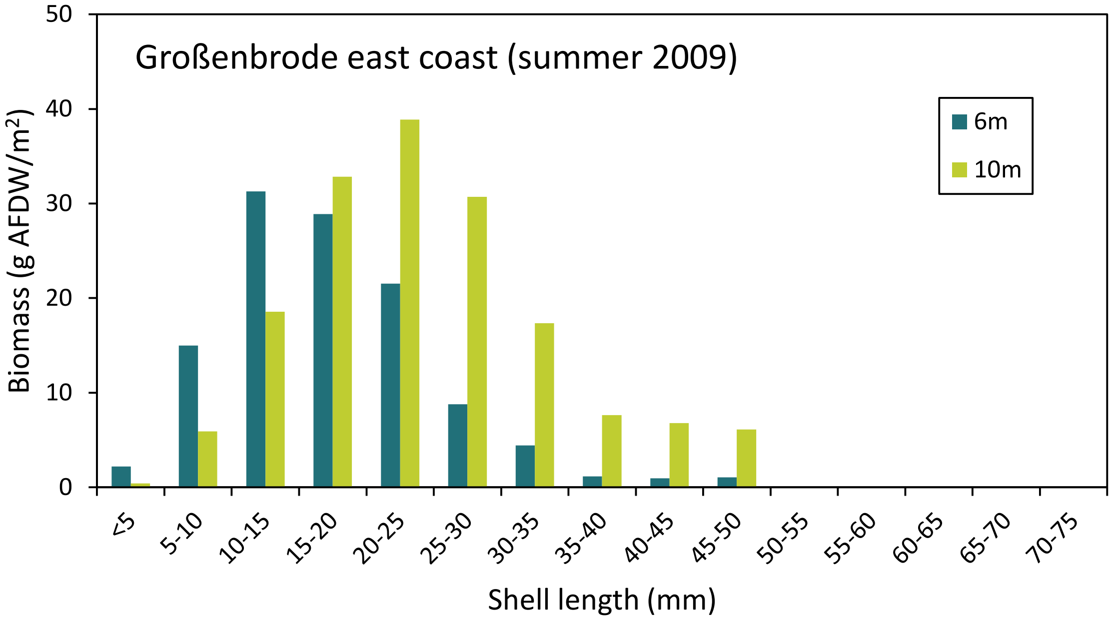

Figure 5-16 Size distribution of AFDW in mussels sampled at 2 depths along transects east of the 'alignment area' and along east coast of Großenbrode. Data from Großenbrode are based on averages from stations Gr-M-E02_01/02, Gr-M-E04_01/02, Gr-M-E06_01/02 (01/02 = 6m/10m).

5.2 Condition and growth

The condition of the mussels largely reflects the integrated growth conditions during the preceding period (usually weeks to months) at the particular sampling station. Favourable growth conditions are linked to phytoplankton and, high phytoplankton concentration generally results in both fast growth and increase in condition of mussels (Smaal & van Stralen 1990; Ren & Ross 2005).

In this study mussel condition was calculated from non-linear relationships between shell length and AFDW of the soft parts (mussel meat). Based on power functions derived from the data from each station, the AFDW of a 'standard average' 25 mm shell-length mussel was calculated for each station (see examples in Figure 5-17 to Figure 5-20).

The coefficient and exponent of the power function often differed between stations and sampling time reflecting differences in growth conditions but probably also an effect of spawning. Large individuals (> 55 mm) can lose up to 40% of their body mass due to spawning, while the spawning loss is much less in smaller sized individuals (Rodhouse et al 1984). An additional factor affecting the shell length-biomass relation is the variation in biomass turnover (P/B ratio; where P can be negative or positive) that differs with size (biomass). Hence, small individuals increase weight (%-wise) faster that large individuals when growth conditions are good but also looses weight faster under poor growth conditions.

In the examples, the mussel condition was highest at the shallow stations around Fehmarn, while condition on the contrary was highest at the deep stations along the Lolland coast.

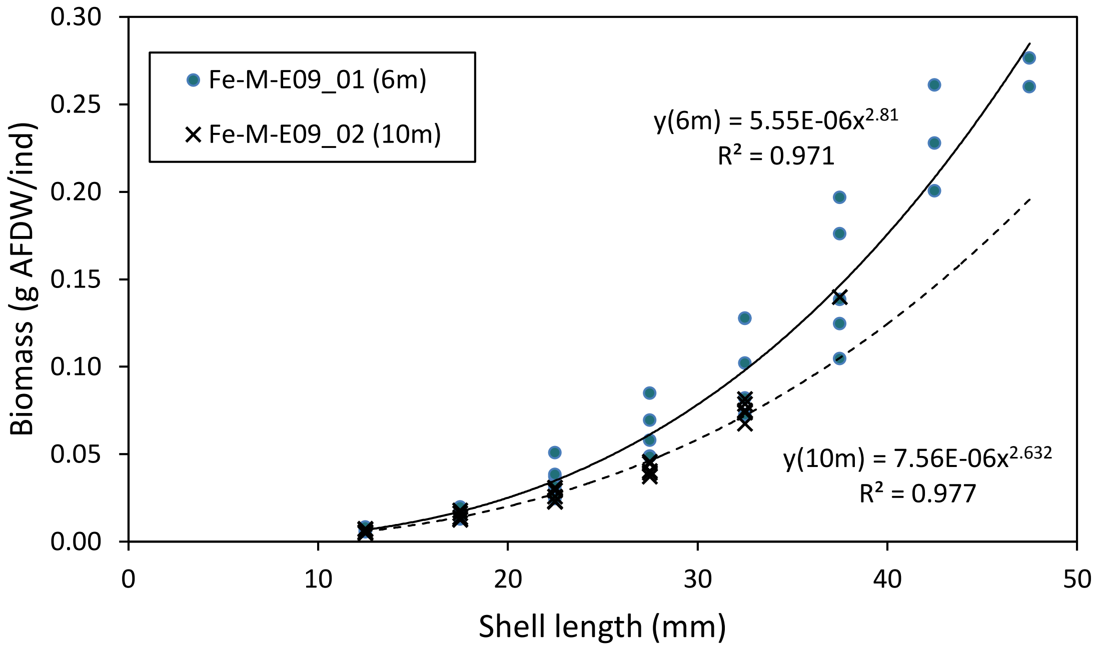

Figure 5-17 Relation between shell length (5 mm intervals) and AFDW (g ind.$^{-1}$) of individuals described by a power function $W=a \cdot L^b$. Data from eastern Fehmarn (Staberhok) from nominal depths of 6m and 10m.

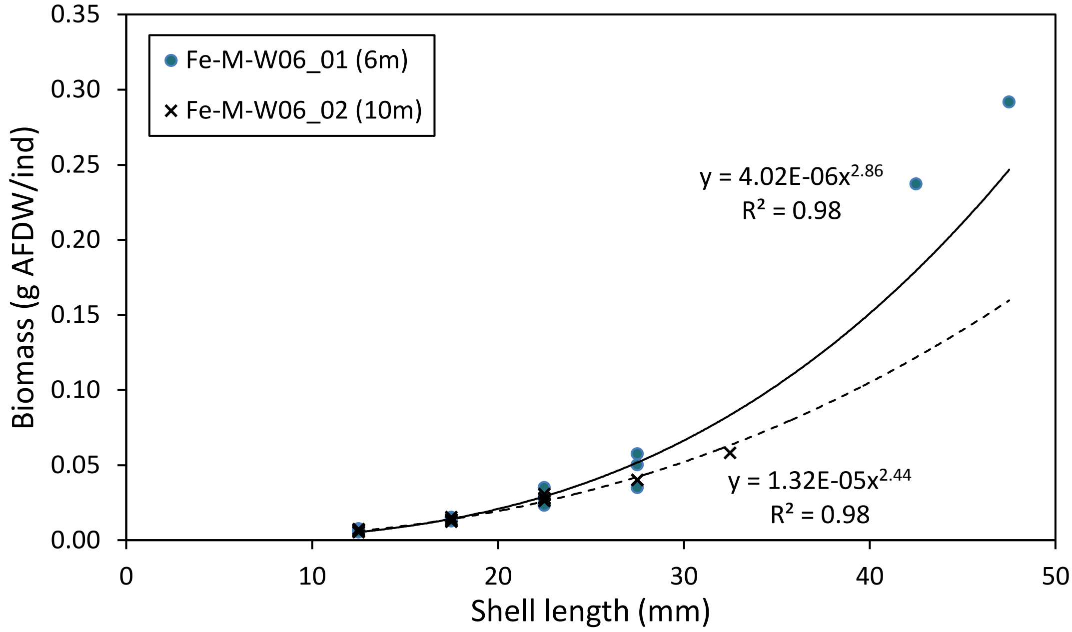

Figure 5-18 *Relation between shell length (5 mm intervals) and AFDW (g ind.$^{-1}$) of individuals described by a power function $W=a{\cdot}L^b$. Data from western Fehmarn from nominal depths of 6m and 10m.*

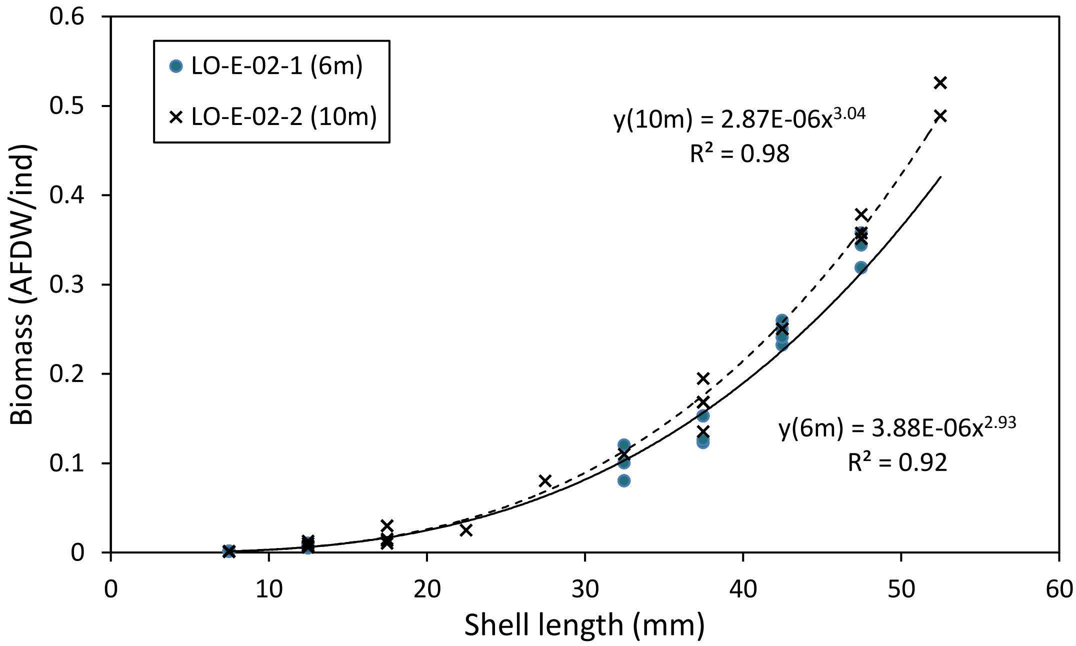

Figure 5-19 *Relation between shell length (5 mm intervals) and AFDW (g ind.$^{-1}$) of individuals described by a power function $W=a{\cdot}L^b$. Data from Lolland (east of alignment) from the nominal depths of 6m and 10m.*

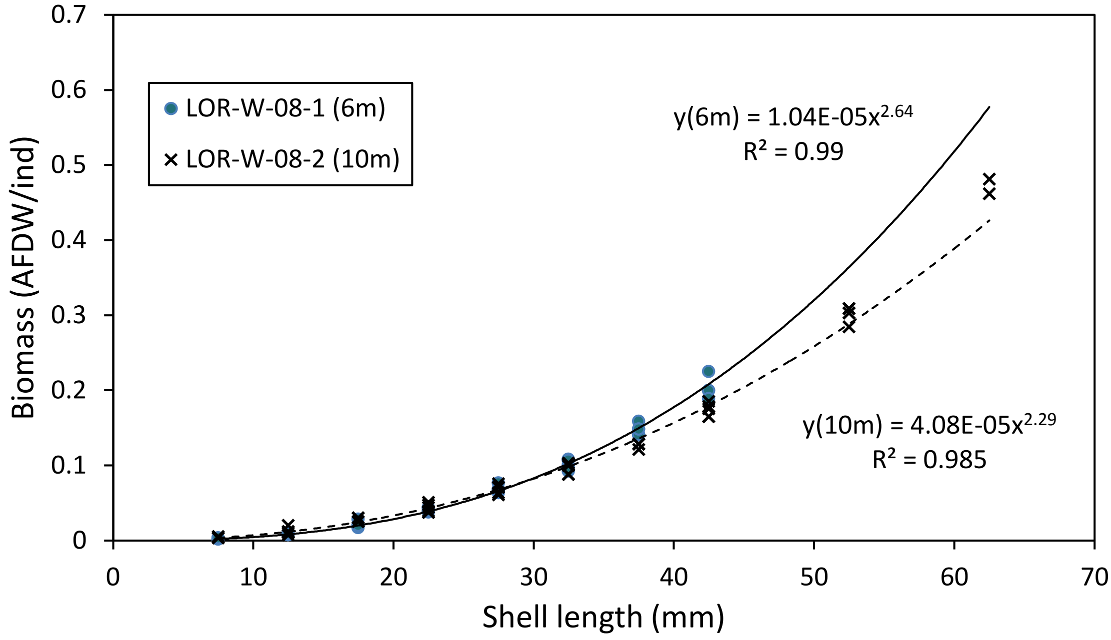

Figure 5-20 Relation between shell length (5 mm intervals) and AFDW (g ind.$^{-1}$) of individuals described by a power function $W=a{\cdot}L^{b}$. Data from Albue Bank from the nominal depths of 6m and 10m.

The temporal variation in mussel condition through winter and spring was followed at 4 stations around Fehmarn and at 6 stations along Lolland to provide data for calibration of a mussel population model to be used in the impact assessment. Examples of biomass variation from two stations are shown in Figure 5-21 and Figure 5-22.

East of Fehmarn at Staberhuk (Figure 5-21) the individual biomass increased dramatically from November 2009 through May 2010. Depending on shell length, individual biomass increased between 20 and 50% from November 2009 to March 2010 and again 5% to 50% from March to May. East of the alignment off Lolland the temporal variation was smaller (Figure 5-22); biomass was unchanged from January to March 2010; from March to April, in 33 days the biomass increased between 28 and 48% depending on shell length and from April to May biomass remained unchanged. Coinciding with the phytoplankton spring bloom, the mussel growth occurred from March to April, with growth rates of 1.5% per day for the samller size classes. This growth rate is astonishingly high, despite the low temperatures of 2-4^{o}C.

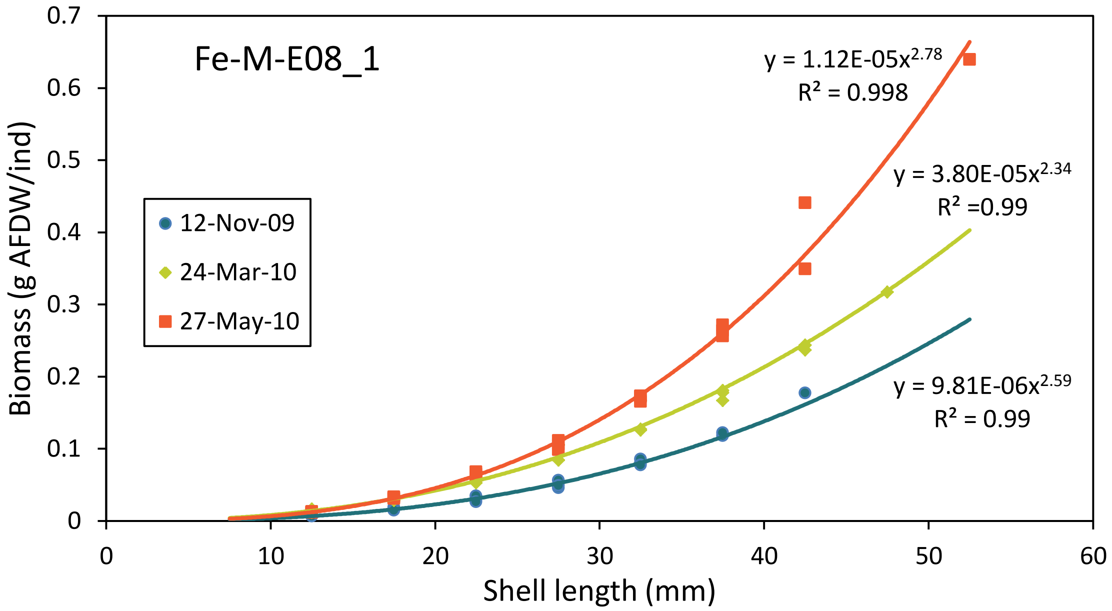

Figure 5-21 Temporal variation in individual biomass of mussels of different size during winter and spring (2009-2010). Data from Staberhuk (FE-M-E8_1). Regression lines shown for each sampling date.

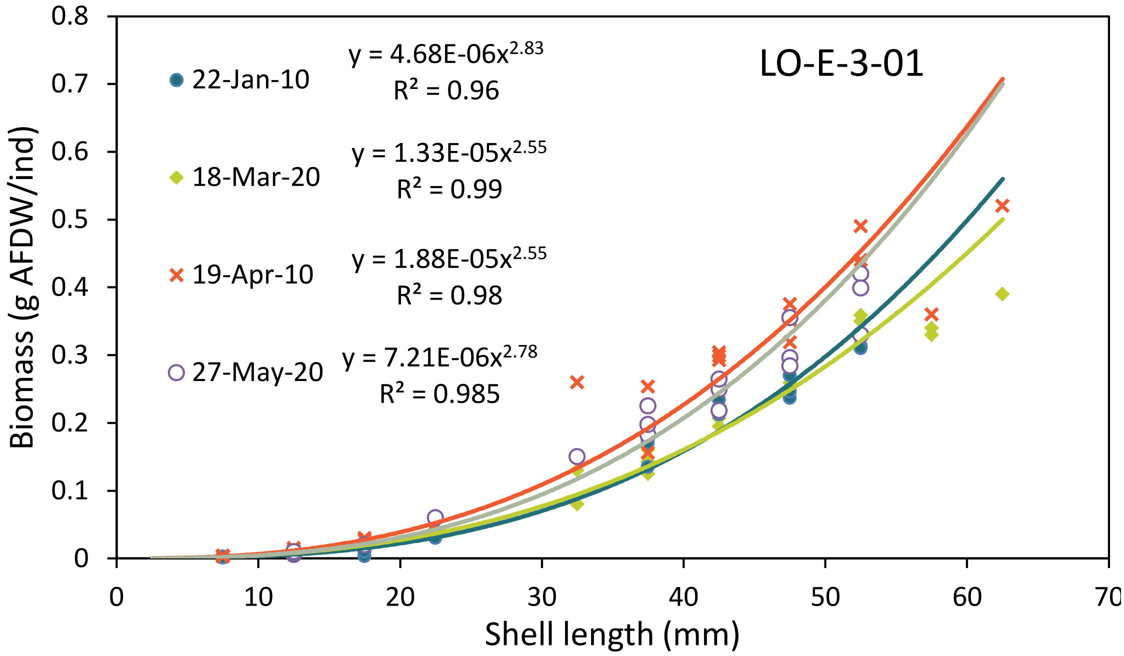

Figure 5-22 Temporal variation in individual biomass of mussels of different size during winter and spring (2009-2010). Data from east of alignment off Lolland (LO-E-3-01). Regression lines shown for each sampling date.

Given the high seasonal variability in condition as demonstrated above it gives little meaning to compare the spatial distribution of condition if the sampling is not syn-optic.

In the following the AFDW value of 25 mm mussels is taken as an index for 'condition' of the population at a site including only samples collected during summer 2009.

Spatial distribution of mussel condition (i.e. AFDW of 'standard average' mussel) during summer 2009 is shown in Figure 5.23. Within the Fehmarnbelt, the condition of mussels varied more than threefold with both low and high conditions found in the area near alignment. Noticeable features were low conditions off Gedser, outside the Rødsand Lagoon and West of Fehmarn.

Mussel condition strongly reflects the growth rate, which again depends on phytoplankton availability. On a large scale (10^2 - 10^4 m), the biomass and condition of mussels are determined by the flux of food (i.e. the product of current speed and food concentration). Therefore, it is the magnitude of food flux that determines the biomass of mussels that can be sustained in an area. At the same time, on smaller, local scales (10^0 - 10^2 m), factors like intraspecific competition for food also contribute to variation in condition. Hence, a high individual biomass combined with high densities (thus yielding high overall biomass and high densities) at both Albue Bank and east of Fehmarn, indicate that growth conditions are exceptionally good compared to most other localities in the Fehmarnbelt.

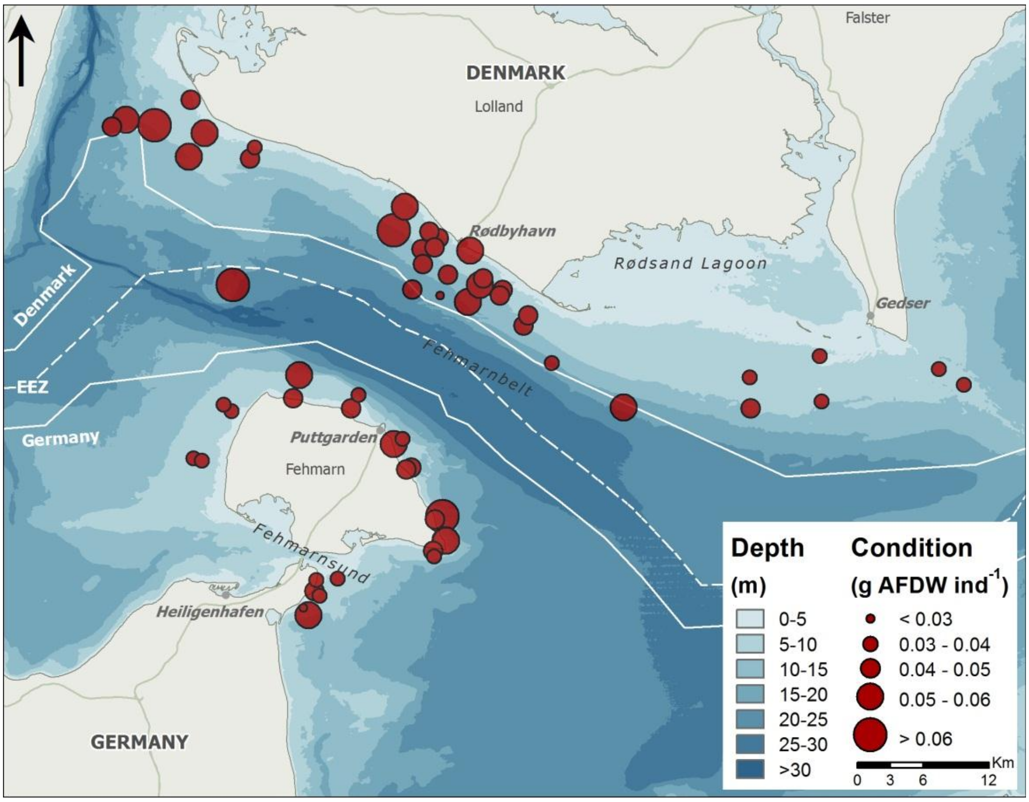

Figure 5-23 Spatial distribution of the condition of mussels in summer 2009. Values are g AFDW of a 25 mm length 'standard average' mussel.

5.3 Population assessment

5.3.1 Biomass distribution

Based on wet weight (which was the only biomass measure used in the Feasibility study), the average mussel biomass was similar in the Feasibility Study (carried out in 1998) and in the present baseline study (samplings in winter/spring of 2008/09 and summer 2009), see Table 5-4. While the average biomass was similar, the variability was much higher in the Baseline Study of 2009. This was most probably due to the fact that stations were sampled over a wider range of localities with a correspondingly wide range of environmental conditions. Still, because the wet weight biomass values have not been corrected for mussel coverage (not possible for the Feasibility study) the values in Table 5-4 should be taken as guidance only.

Table 5-4 Wet weights [g] of mussels in frame samples (0.0625 m^2) recorded during the feasibility study in 1998 and during baseline investigations in 2009. Average, standard deviation (SD), maximum and minimum values are shown along with number of stations sampled (AFDW was not measured during Feasibility study). Values are not corrected for mussel coverage.

Study	Year	Mean	SD	Max.	Min.	No. of stations
Feasibility	1998	266	122	550	89	21
Baseline	Winter 2008-'09	224	147	649	18	25
Baseline	summer 2009	282	270	1838	60	49

Assessment of the entire mussel population in the Fehmarnbelt was carried out by two different approaches; 1) based on statistical models building on mussel coverage and biomass and, 2) using a numerical population model where the population is divided in 5mm size classes. The numerical model was calibrated against measured abundance and biomass (resolved in size classes) for 2009. The numerical model was developed for impact assessment purposes (FEMA 2013b) but biomass results are presented to provide an independent measure of total mussel biomass.

The distribution of mussel biomass in the Fehmarnbelt was estimated by stepwise constructing maps of mussel cover by GAM modelling (see Figure 5-3) followed by converting cover to biomass using a power relation between cover and biomass (see Figure 2-9), and finally 'adjusting' biomass in two areas where condition was much below (off Rødsand Lagoon) or markedly higher (Albue Bank) that the average condition (see Figure 5-22).

Mussel biomass varied between 0 and a maximum of 120 g AFDW m^{-2} averaged over model grid-cell areas of 750 × 750 m^2. At smaller scales (sample size) mussel biomass approached 1100g AFDW m^{-2} (2 samples).

Within the Fehmarnbelt area, the total mussel biomass was calculated to 27,000 tons AFDW, which is equivalent to 480,000 tons wet weight (Figure 5-24).

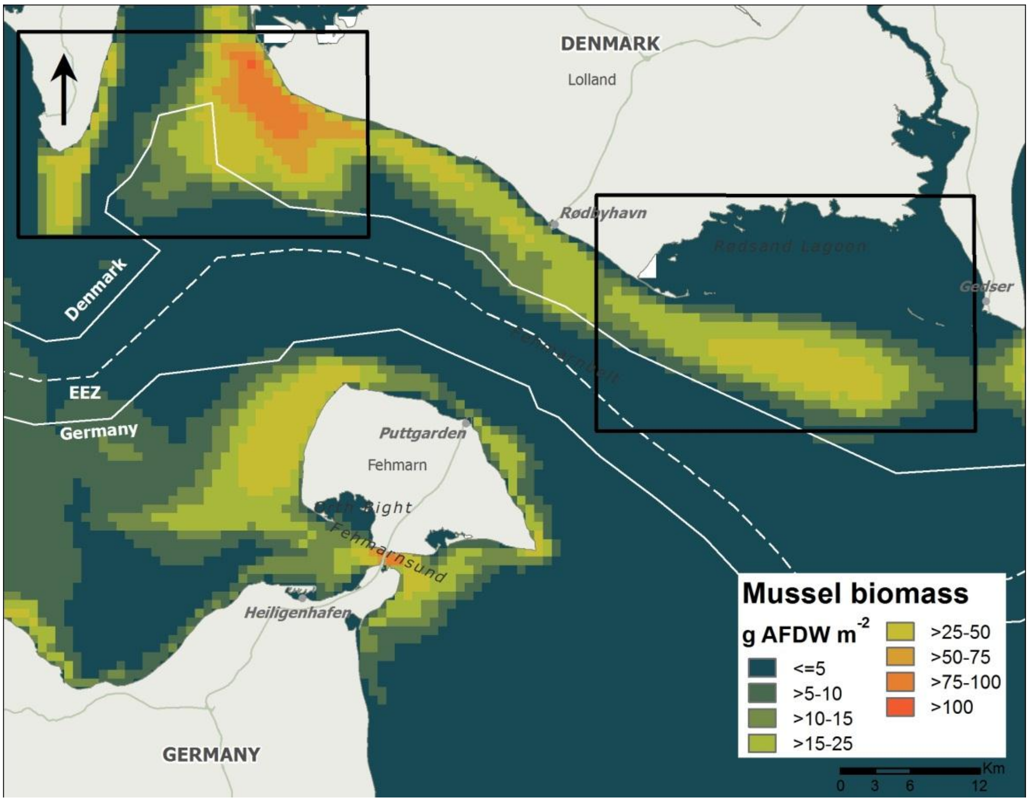

Figure 5-24 Map of mussel biomass (g AFDW m^{-2}) in the Fehmarnbelt region. Results from statistical GAM modelling (see text).Rectangles inserted delineate areas where biomass was corrected for mussel condition. The biomass values refer to averages over 750 x 750 m grid cells.

The distribution and range in biomass estimated by the numerical population model (Figure 5-25) was very similar to the distribution of biomass estimated by statistical modelling (Figure 5-23). The most notable differences relate to the distribution of high mussel biomass NW of Fehmarn, and off Rødsand lagoon and West of Gedser where the numerical model predicted a higher biomass than the statistical model. But overall, the general distribution patterns are rather similar.

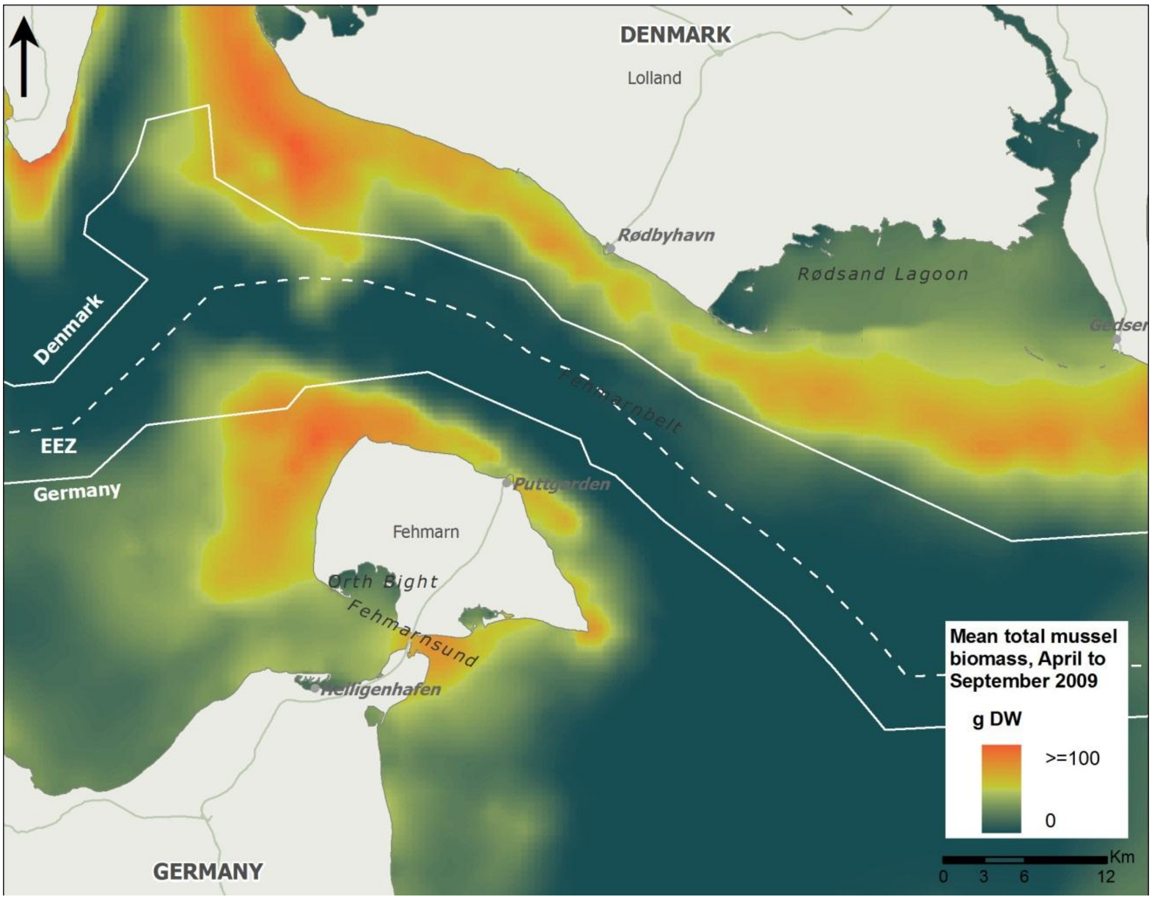

Figure 5-25 Map of modelled mussel biomass (g AFDW m^{-2}) in the Fehmarnbelt. Results from numerical modelling (see text for explanation). Distribution of biomass based on summed biomass of all size classes averaged over the period 1 April – 30 September 2009.

5.3.2 Filtration capacity

Besides population biomass, the most important feature of mussel populations is their high filtering capacity. By filter feeding, mussels can exert a high grazing pressure on phytoplankton and where mussel populations are large they can effectively control blooms of phytoplankton (Møhlenberg 1995).

The filtering capacity of an individual mussel is determined by the area of gills that constitute the filtering organ (Jørgensen, 1990). Gill area is proportional to the square of the shell length (L^2). Thus, the filtration capacity can be calculated from length distributions recorded at the stations (Kiørboe & Møhlenberg 1981). The filtering capacity, in [m^3 m^{-2} d^{-1}] or [m water column d^{-1}], was estimated for the stations where mussels were recorded by calculating capacity within each size class according to (after Kiørboe & Møhlenberg 1981):

$$N_i \cdot 0.185 \cdot L2 \cdot 24/1000$$

Here, N_i denotes the number of individuals in the *i*-th size class, L is shell length in cm, and 0.185 is a constant representing (gill) area-specific filtration activity. The filtration capacity for the entire population was calculated by summing the capacities for all size classes occurring at a particular station.

The filtration capacity varied between 0.005 and 311 m^3 m^{-2} d^{-1} in 2009 with the highest values confined to depths <10-12 m (Figure 5-26). To illustrate: a filtering capacity value of 311 m^3 m^{-2} d^{-1} at 10 m depth expresses that the population theoretically can filter the overlaying water column 31 times per day. In reality, values higher than 5-10 $m^3\ m^{-2}\ d^{-1}$ clearly indicate that populations primarily rely on algae transported by water currents, rather than algae produced locally (i.e. in the water column above).

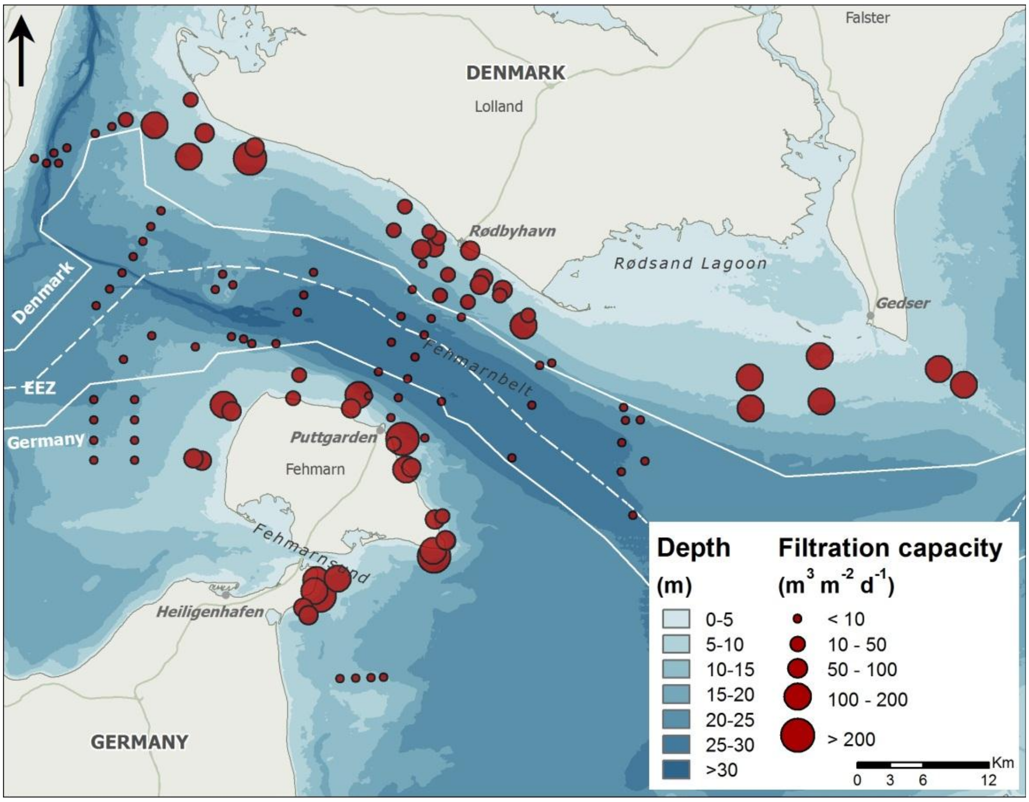

Figure 5-26 Spatial distribution of filtration capacity of mussels in summer 2009. Values are estimated from size distributions recorded at stations (see text). The filtration capacity is given in m water column cleared per day or $m^3\ m^{-2}\ d^{-1}$ (see text).

5.3.3 Station similarity

Besides AFDW, the variables abundance, condition index, filtration capacity and shell weight (i.e. ash weight) at all stations can be used as supplementary data to evaluate ecological characteristics of the mussel populations in the Fehmarnbelt.

These characteristics were used as input in a multivariate (or multidimensional) analysis providing biological information on the similarity or dissimilarity between mussel sampling stations at shallow waters. Ultimately, they may be used as a guideline for selecting 'reference' stations for later monitoring purposes.

The Multi-Dimensional Scaling (MDS) plot (Figure 5-27) shows that the western-most located stations at Albuen Bank (SW Lolland coast) and a few stations both west and east along the Fehmarn coast fall outside of the main cluster. All other sampled stations can be grouped within the same cluster and thus display a relatively high similarity. It also means that the stations that fall outside of the cluster should not be used as reference stations, as they are not comparable to the stations within the cluster.

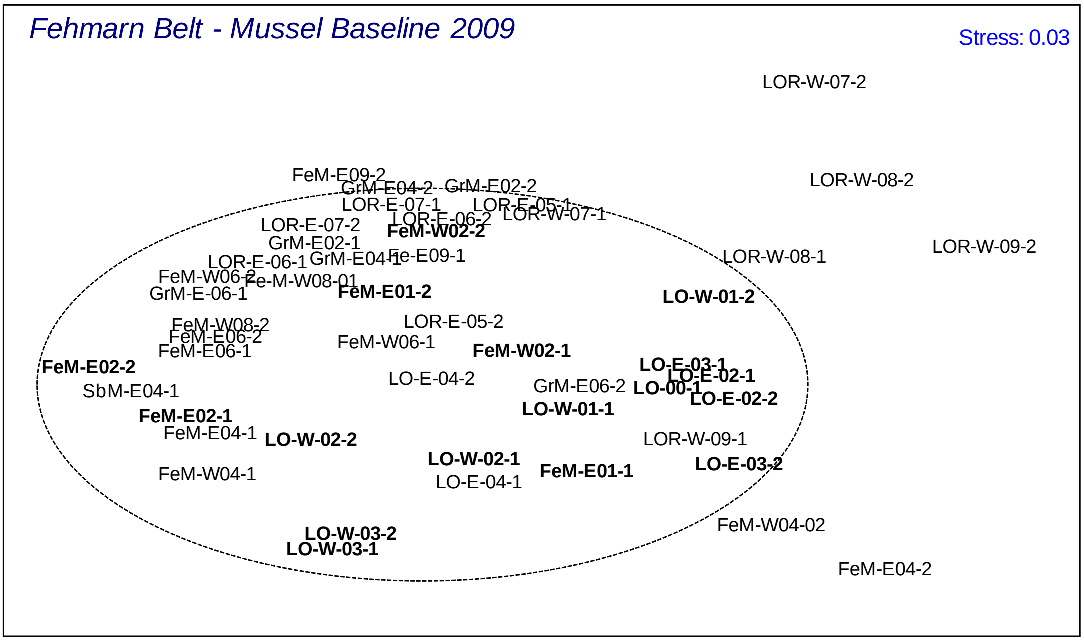

Figure 5-27 MDS plot of mussel populations sampled from shallow water stations. Stations printed in boldface indicate those located close to the alignment area. Similarity matrix was based on square root-transformed abundance, AFDW, shell weight, filtration capacity and (untransformed) condition values. The ellipsoid denotes the stations which are not substantially different amongst each other and are thus comparable (see text).

6 WFD ASSESSMENT

The European Water Framework Directive (WFD) aims at establishing a good ecological status for European surface waters. Member states have developed assessment methods for the classification of their coastal waters into five ecological quality classes (high, good, moderate, poor, bad), and benthic fauna is one of the biological quality elements for which an assessment is carried out. The ecological status is calculated for individual water bodies (Figure 6-1) and expressed as an Ecological Quality Ratio (EQR), ranging from 0 (bad status) to 1 (high status).

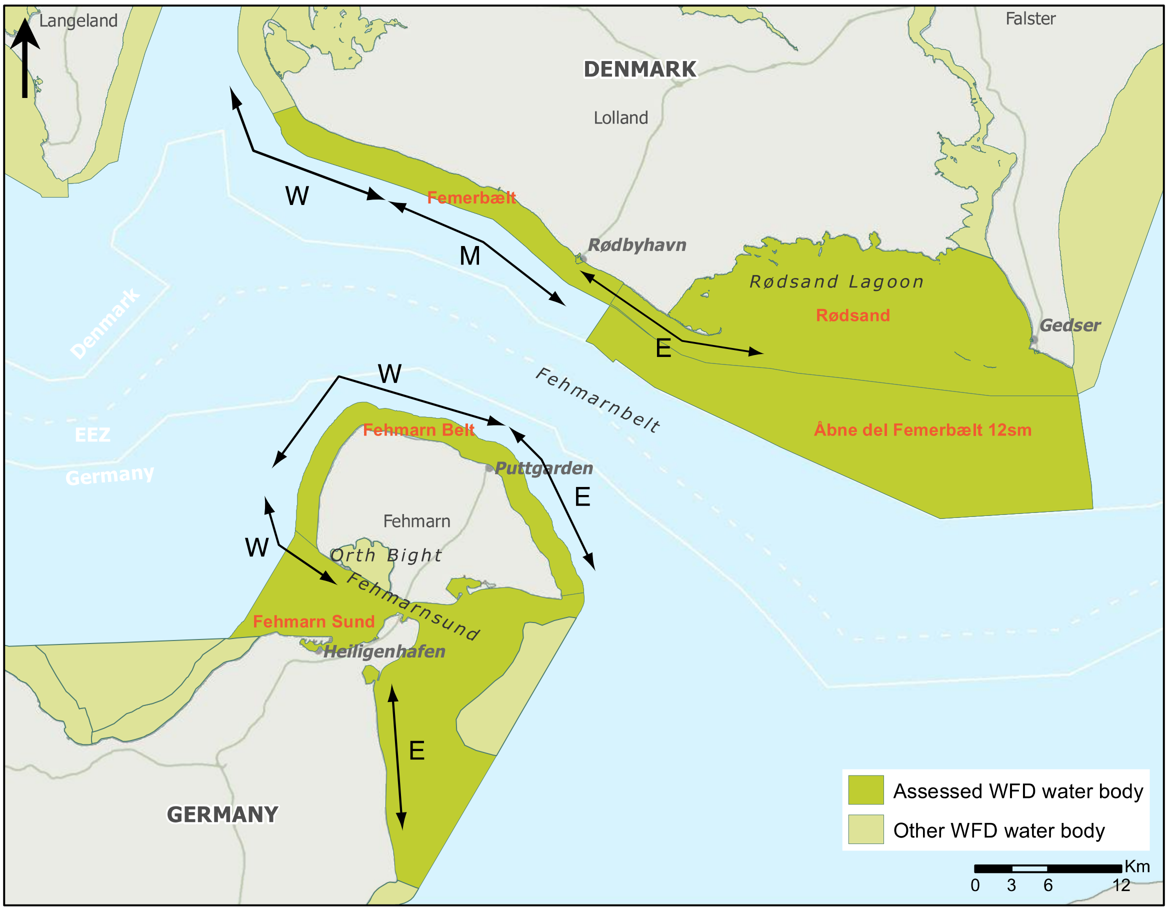

Figure 6-1 Water bodies within the Water Framework Directive in the investigation area. The red annotations are the names of the water bodies. The arrows indicate the regions on the coast (corresponding to the locations of the baseline samples) that were associated to the respective parts of the water bodies. The letters W, M, and E (western, middle, eastern) are added to the water body names for ease of reference (see text).

In the investigation area, Denmark has 3 water bodies and Germany has 2 water bodies for which an assessment was carried out based on the baseline data. Due to the high amount of data obtained in the baseline study, it was possible to give more than one assessment per water body. Thus, the German water bodies 'Fehmarnbelt' and 'Fehmarnsund' were both assessed once for the western part and once for the eastern part. The Danish water body 'Femerbælt' could be divided into three parts (western, middle, and eastern). The water body 'Åbne del Femerbælt 12sm' does not strictly belong to the scope of the WFD, but since most of the samples of the LoR-E transects are located there, an assessment was also made for this water body. The different areas assessed in relation to the corresponding water bodies are also outlined in Figure 6-1.

The results presented here are based on the current status (as per March 2011) of both national assessment systems. Within the WFD inter-calibration in the Baltic Geographical Intercalibration Group (Baltic GIG), both systems are currently being harmonised with respect to their boundaries (Table 6-1) and class agreement. Therefore the presented results are preliminary. Harmonised boundaries are only allowed to differ slightly when the same water body is assessed with different national assessment systems. The current difference can be seen when the Danish waters are classified with the German system and vice versa (grey numbers in Table 6-2 and Table 6-3). While the assessment of the German water bodies with the Danish DKI index yields results comparable to the German index, the opposite is not true.

The class boundaries on the EQR scale that were used for both assessment systems are given in Table 6-1. It is important to note that a specific EQR value in one national system does not correspond to the same EQR value in another national system, because these typically do not operate on the same ecological pressure scale. So, a DKI EQR of 0.65 does not have the same meaning as a MarBIT (Marine Biotic Index Tool) EQR value of 0.65. As long as the inter-calibration is not finished, only the resulting status class should be considered roughly comparable.

Table 6-1 Boundaries and ranges of the German and Danish WFD indices MarBIT and DKI for the 5 WFD status classes. The values are the respective national EQR values and are not directly comparable. They are only used here to derive the status class for the fauna in the respective water bodies.

Status class	MarBIT	DKI
High	0.8 – 1.0	0.85 – 1.00
Good	0.6 – 0.8	0.68 – 0.85
Moderate	0.4 – 0.6	0.46 – 0.68
Poor	0.2 – 0.4	0.23 – 0.46
Bad	0.0 – 0.2	0.00 – 0.23

6.1 WFD assessment DE

The German water bodies have been assessed with the German MarBIT method established for the Baltic Sea coastal waters in Germany (Meyer et al. 2009). The results for the assessment of the German water bodies are given in Table 6-2 (black numbers) and in Figure 6-2. They indicate a moderate ecological status of all water bodies within the investigation area, during both 2009 and 2010, with no local differences in the status class (median EQR of both years = 0.469). This indicates that no point sources of pollution or other local effects are present in terms of the WFD metrics and the ecological status of the different regions of the investigation area is thus comparable.

Table 6-2 *Calculated EQR values for the ecological status of the German water bodies within the investigation area (E = eastern part, W = western part, M = middle part). Assessments of these water bodies with the Danish DKI index are given in grey. Note that only the ecological status is directly comparable between Germany and Denmark, but not the individual EQR values, since they are from different scales.*

Water body	Season	MarBIT EQR	DKI EQR
Fehmarnbelt (E)	spring 2009	0.479 (moderate)	0.52 (moderate)
Fehmarnbelt (W)		0.436 (moderate)	0.53 (moderate)
Fehmarn Sund (E)		0.535 (moderate)	0.61 (moderate)
Fehmarn Sund (W)		0.420 (moderate)	0.57 (moderate)
Fehmarnbelt (E)	spring 2010	0.459 (moderate)	0.53 (moderate)
Fehmarnbelt (W)		0.474 (moderate)	0.60 (moderate)
Fehmarn Sund (E)		0.551 (moderate)	0.65 (moderate)
Fehmarn Sund (W)		0.492 (moderate)	0.54 (moderate)

The German MarBIT index (Meyer et al. 2009) internally consists of 4 different metrics that classify the aspects: taxonomic composition, abundance, fraction of sensitive species, and fraction of tolerant species. The final index value is the median of the four metrics and classified the German waters into the middle of the moderate status class. The detailed results (see Appendix 7) show that around half of the expected species for reference conditions (high status) were found. This is a good value compared to the status of most of the other German water bodies in the Baltic Sea. The distribution of the abundance among the observed species showed a moderate to bad status. This indicates the increased presence of many taxa with low abundance, often occurring with one or two specimens in the total set of samples, and only one dominating species in terms of abundance (see appendix 7, section "Abundance-Rank" for more information on the interpretation of results). Within the shallow part of the investigation area this is *Hydrobia ulvae*. Especially in the western areas in spring 2009, *Hydrobia ulvae* reached high abundances. The areas having the best index value for abundance have some additional species with higher abundances besides *Hydrobia ulvae* (e.g. Oligochaeta, *Pygospio elegans*, *Marenzelleria viridis, Scoloplos armiger, Pusillina inconspicua, Macoma balthica, Cyathura carinata,* and *Littorina littorea*). The fraction of sensitive species was moderate compared to the reference conditions, and the fraction of tolerant species was reflecting the good status. The reader is referred to Appendix 7 for the exact numbers.

The moderate status class found for the German baseline data corresponds well to the data known from the regular German WFD monitoring, which assessed the water body "Fehmarnsund" into the moderate status for the period 2001-2007 (EQR = 0.569) and into the good status for the period 2003-2008 (EQR = 0.623), based on data from Voß et al. 2010 prepared for the Landesamt für Landwirtschaft, Umwelt und ländliche Räume in Schleswig-Holstein (state department for agriculture, environment and rural areas, LLUR). The latter value lies at the lower end of the good status, near the class boundary to the moderate status class.

6.2 WFD assessment DK

The Danish water bodies were assessed with the DKI index, which is used for the North Sea and also for the Baltic Sea in a modified form. The results for the assessment of the Danish water bodies are given in Table 6-3 (black numbers) and in Figure 6-2. The DKI classified the Danish waters into the upper end of the moderate status class (median EQR of both years = 0.63). There is no difference in the classification of 2009 and 2010. No Danish national monitoring data exist in this area, i.e. the result cannot be compared to other data.

Table 6-3 Calculated EQR values for the ecological status of the Danish water bodies within the investigation area (E = eastern part, W = western par, M = middle part). Assessments of these water bodies with the German MarBIT index are given in grey. Note that only the ecological status is directly comparable between Germany and Denmark, not the individual EQR values since they are from different scales.

Water body	Season	MarBIT EQR	DKI EQR
Femerbælt (E)	spring 2009	0.217 (poor)	0.65 (moderate)
Femerbælt (M)		0.365 (poor)	0.63 (moderate)
Åbne del Femerbælt 12 sm		0.326 (poor)	0.63 (moderate)
Femernbælt (W)		0.235 (poor)	0.62 (moderate)
Femerbælt (E)	spring 2010	0.333 (poor)	0.65 (moderate)
Femerbælt (M)		0.300 (poor)	0.61 (moderate)
Åbne del Femerbælt 12 sm		0.359 (poor)	0.64 (moderate)
Femernbælt (W)		0.268 (poor)	0.61 (moderate)
Rødsand	spring 2009	0.561 (moderate)	0.62 (moderate)

The Danish DKI index combines the Shannon diversity (Shannon 1948) and the Spanish AMBI (Borja et al. 2000) using correction factors for low numbers of individuals (see also Appendix 7).

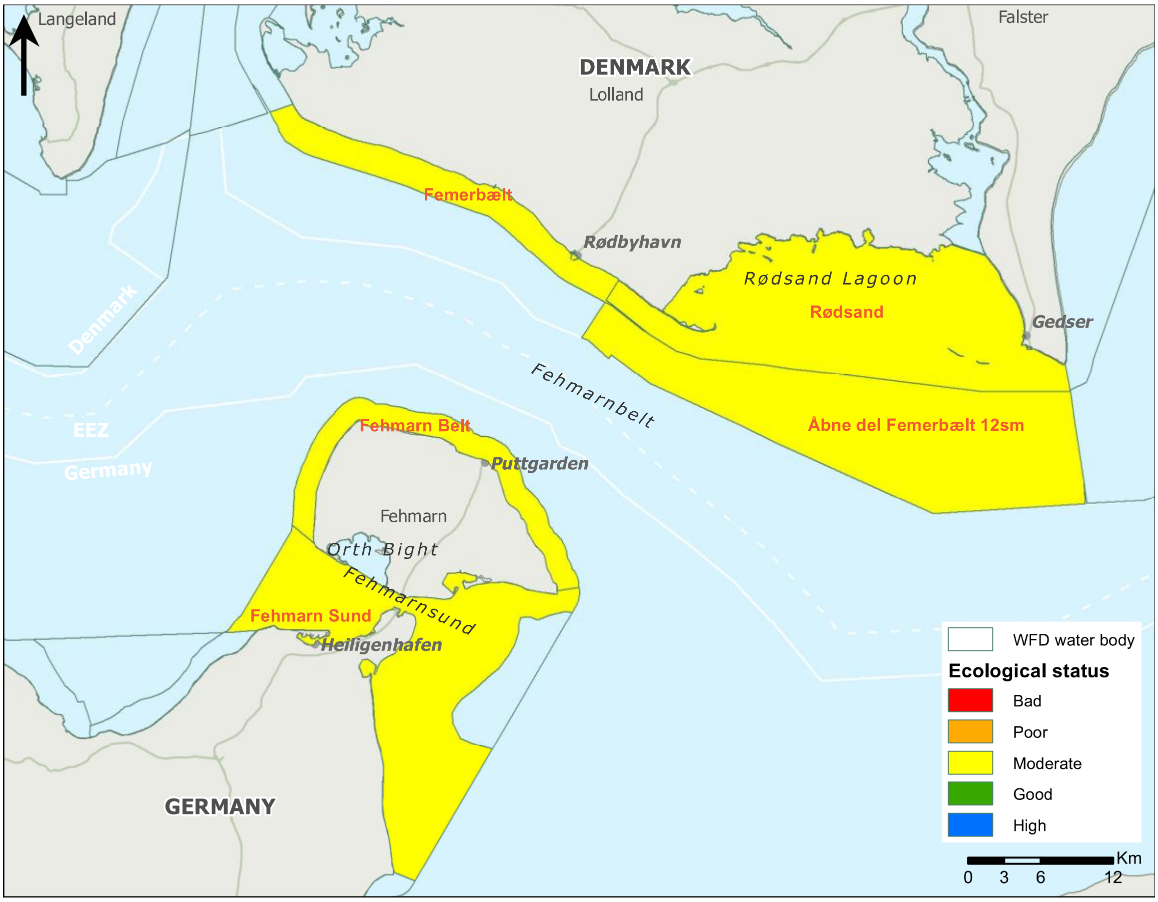

Figure 6-2 WFD assessment of the German and Danish water bodies on the basis of the baseline data for 2009-2010. All assessed water bodies were classified as having a 'moderate' ecological status. The colours used for the ecological status correspond to the ones defined in the Directive.

In order to obtain more reliable results for a MarBIT analysis on Danish waters, there would have been need for a proper reference species list. This is a "modelled" list of species that should potentially be able to live under the abiotic conditions governing the area. Such a list relies on extensive data and autecology information of all possible species, which do not exist for the Danish waters and is out of scope of this baseline study. Instead, for calculating the MarBIT for the Danish waters, the nearest German species list was used, which is only an approximation. On the other hand, the DKI can be readily calculated on samples the German waters, since no other information beyond the species abundance and the salinity is needed. This mainly explains the difference between the two EQR indices in both the Danish and the German waters.

6.3 Other assessments based on the WFD

The Marine Strategy Framework Directive (MSFD) is based on the WFD and aims at extending its objectives into the offshore waters including the EEZ. It uses an ecosystem approach with an integrative assessment to brace all major living components. The assessment criteria for the MSFD are much more detailed than for the WFD, comprising a specific list of 11 criteria that need to be met in order to obtain a good environmental status (GES), and a corresponding list of 8 pressures with several impacts each that must be incorporated into the assessment. The result is an evaluation whether a given area (on a larger scale than WFD water bodies) reaches the GES or not.

Currently, no assessment system for the MSFD exists that covers all these aspects. The exact interpretation of the assessment criteria and a definition of the indices are currently starting. For the Baltic Sea, the HELCOM HOLAS assessment (HELCOM 2010) is one step in this process, trying to define and assess the environmental status using an integrative approach. As such, it is not possible yet to give a comprehensive assessment of the status of the investigation area with respect to the MSFD. For the benthic fauna, the Swedish WFD index BQI (Benthic Quality Index) has been modified to work in the salinity gradient of the investigation area and proposed as a tool to assess the environmental status of the MSFD waters (Fleischer and Zettler 2008). This is, however, only covering part of the necessary criteria for benthic fauna and is not considering the other ecosystem components. A test-wise application of the BQI index based on the baseline data of the deeper waters (below pycnocline) indicated that the GES probably is met within the limited scope of the index.

7 LAW PROTECTED BENTHIC FAUNA

7.1 German Red List

Evaluation of benthic macrofauna data from the investigation area, based on 2009 and 2010 sampling campaigns, finds that approximately one quarter of the total 325 observed species have a dedicated conservation status (see Figure 7-1 and Appendix 4).

According to the criteria of the International Union for Conservation of Nature (IUCN), 15 species are actually threatened. Two species belong to the category "critically endangered", 7 species to the category "endangered", and 6 are "vulnerable". For 30 species a threat is expected. This means that these species belong to one of the categories mentioned above, but the status cannot be specified at present. Twenty species are classified "extremely rare" in general and have probably a zoogeographically restricted distribution. Another 16 species are placed in the category "near threatened", meaning their status shows a negative trend towards becoming threatened. Furthermore, around half of the observed species (160 species) are not threatened ("least concern"), while for another 64 species the data were insufficient to allocate them to a German Red List status. Finally, a total of 20 species are not evaluated (by Rachor et al. 2011).

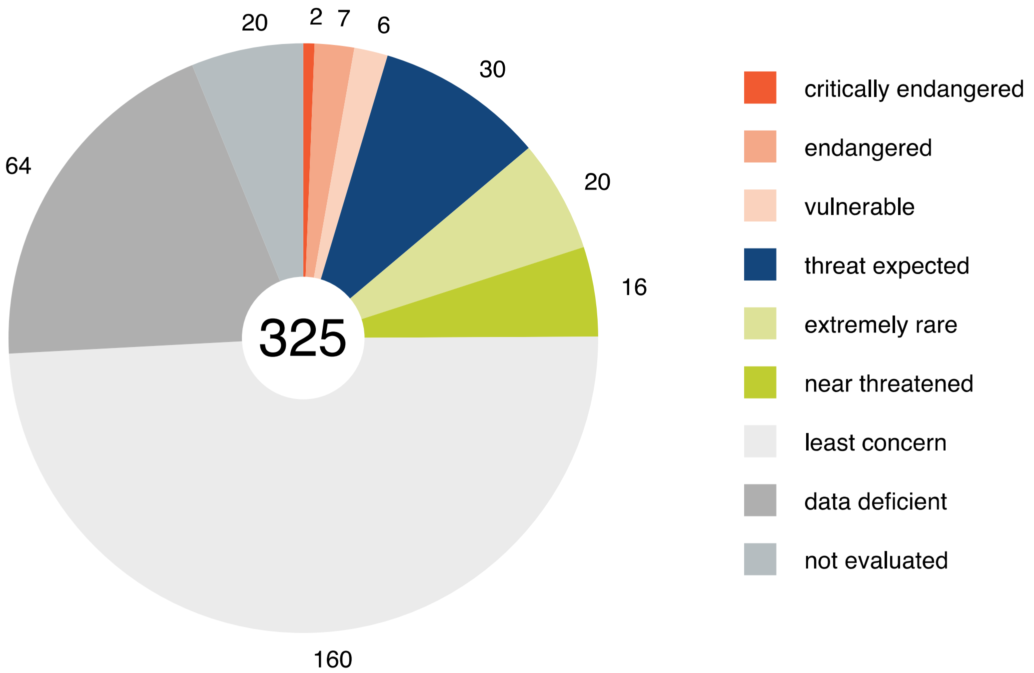

Figure 7-1 The Red List state of benthic species in the Fehmarnbelt area in 2009 and 2010 based on the German Red List of benthic marine invertebrates (Rachor et al. 2011). Altogether 325 taxa were observed during the baseline investigations.

Two species are categorised in the Red List as "critically endangered". These are the anthozoan *Halcampa duodecimcirrata* and the bivalve *Macoma calcarea*. Both these species were found in 5–10 % of all sampled stations in low abundances of 12–23 individuals per square meter.

From the species classified as "endangered" in the Red List, the bivalve *Mya truncata* is also classified as a HELCOM threatened or declining species (HELCOM 2007), and was recorded in low frequencies and abundances (see Appendix 4) in the Fehmarnbelt area. Another bivalve species, the Ocean Quahog *Arctica islandica*, which belongs to Red List category "vulnerable", has suitable living conditions in especially the deeper waters of the Fehmarnbelt area, where it occasionally reached high abundances and biomasses. The Copenhagen Cockle *Parvicardium hauniense* (Red List category "extremely rare" and HELCOM threatened or declining species) was limited to very shallow waters in sheltered bights (especially within eelgrass or eelgrass/algae mixed vegetation, like Rødsand Lagoon and Orth Bight), whereas the amphipod *Pontoporeia femorata* (Red List category "near threatened" and HELCOM threatened or declining species) was only sporadically observed in the deeper waters of the investigation area.

Some rare and endangered long-living bivalve and gastropod species also occur in the Fehmarnbelt area. Beside the species mentioned above, the Northern Horse Mussel *Modiolus modiolus*, the Common Whelk *Buccinum undatum*, and the Iceland Moonsnail *Amauropsis islandica* (all "endangered") and Montagu's Astarte *Astarte montagui* ("vulnerable") are well-known and important species in the Fehmarnbelt.

The endangered species were unequally distributed between the different parts of the investigation area (Figure 7-2). At most shallow water stations, less than 5 endangered species were found, whereas the number was higher for most deep water stations. The highest numbers of endangered species were found at stations in the NATURA 2000 site Fehmarnbelt (DE-1332-301) west and north-west of Fehmarn, and at some stations close to Langeland. A conspicuously lower number of Red List species were detected at the deep water stations in the eastern part of the Fehmarnbelt area. This gradient in Red List species follows the overall west-to-east species gradient described in section 4.1, with a higher number of species in the western part and a lower number of species towards the east. It has to be stressed that the overall species richness was in general higher in deeper than in shallower waters (see Section 4.1.1). This is mainly due to a higher salinity in deeper waters (below the pycnocline), which allows the occurrence of typically almost all marine species in the Fehmarnbelt area. The most diverse area of the Baltic Sea is situated at the entrance of the Great Belt and off the Island of Fehmarn (Zettler et al. 2008). Besides the high salinity, this "hot spot" is linked with good oxygen supply and well-structured sea floor (e.g. macrophytes, boulder grounds, mussel beds). Of course, a higher total number of species also increases the probability of a higher number of red list species.

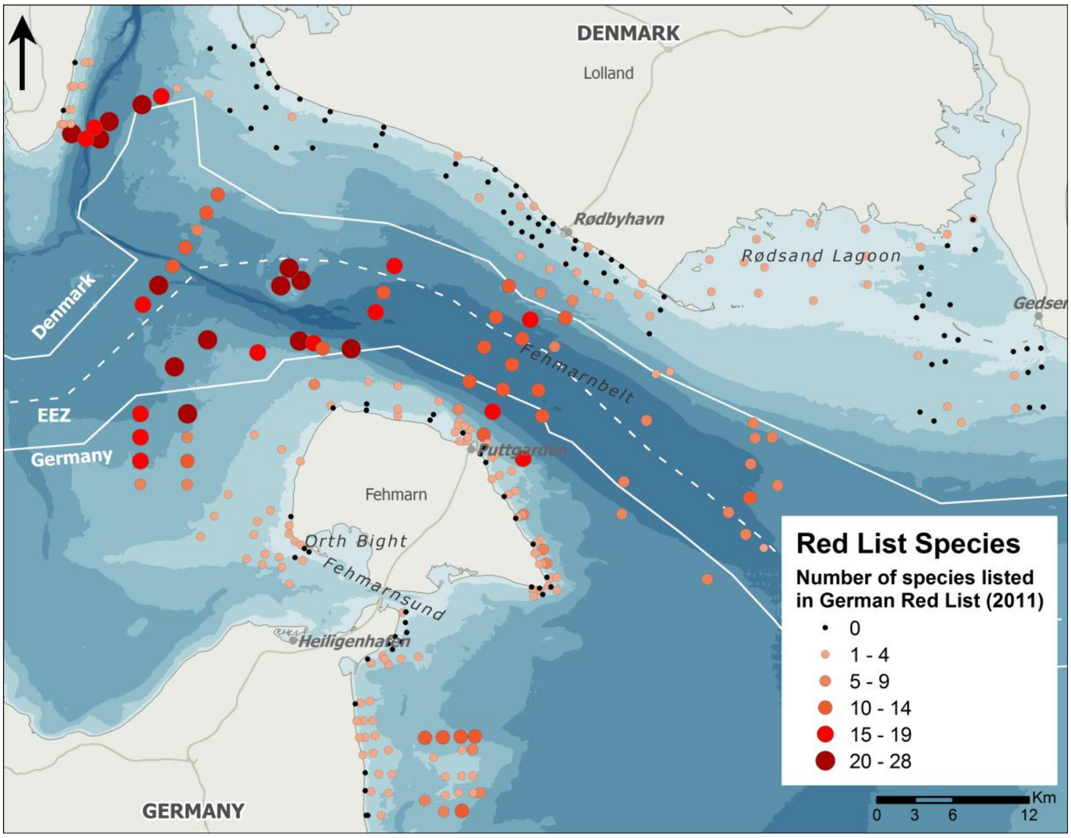

Figure 7-2 *Distribution of Red List species with the categories "critically endangered", "endangered", "vulnerable", and "threat expected" in the Fehmarnbelt area in 2009 and 2010. The colour and diameter of the circles indicate the number of Red List species found at one station.*

7.2 Nature conservation law in Germany

The German law for nature conservation is the "Bundesnaturschutzgesetz" (BNatSchG). In §30 the BNatSchG lists all biotopes that are regarded as biotopes with special importance and therefore protected by the law. For the investigation area, the following biotopes are relevant:

- Eelgrass meadows and other marine macrophyte populations
- Reefs
- Sublittoral sandbanks
- Species-rich grounds with gravel, coarse sediment, and shells (German: "Schill") in offshore and coastal waters

All actions leading to the destruction or significant impairment of these biotopes are prohibited. If the impairments can be compensated, an application for exemption can be made.

The definitions of these biotopes are derived from EU legislation and especially the Habitat Directive (92/43/EEC), which is the basis of the Natura 2000 network. The wording is relatively vague, and it is difficult to map these biotopes to the fauna communities derived from the baseline study (See Section 4.2 and 4.3). Although the protected biotopes shall be registered according to §30, paragraph 7, no such register currently exists for the above biotopes.

The federal states can add biotopes in their state laws. Schleswig-Holstein has added some biotopes in §21 of the "Landesnaturschutzgesetz" (LNatSchG), but none of these are located in the marine or coastal waters of the investigation area. Similarly, the Landesamt für Landwirtschaft, Umwelt und ländliche Räume (LLUR) in Schleswig-Holstein can recognise the abovementioned biotopes during the assessment process, based on data from these baseline investigations, if they are conform the definitions in §30 of the BNatSchG and §21 of the LNatSchG.

7.3 Danish Red List

The Danish Red List of endangered species (Stoltze and Pihl 1998) does not include any marine benthic invertebrates, and the updated list from 2010 (unpublished) will not include marine benthic invertebrates according to available information.

8 IMPORTANCE

Within the framework of the Environmental Impact Assessment (EIA) of the Fehmarnbelt Fixed Link (FEMA 2013b), the relevant environmental subcomponents (e.g. marine mammals, birds, plankton, benthic vegetation, benthic fauna) are classified according to a four-level Importance scale. The criteria for the classification are summarised in Table 8-1. They are based primarily upon legislative and secondarily on scientific and conservation arguments.

The operational basis for this classification is the macrobenthic communities as determined in Section 4.3. The Importance classification of the benthic fauna communities is based on the established criteria shown in Table 8-1 and is summarised in the Importance table (Table 8-3). The spatial extent of the different Importance areas was derived based on the map of the modelled benthic fauna communities (Figure 8-1).

8.1 Definition and criteria

The following definition of zones in the Fehmarnbelt area is used to describe the benthic fauna with respect to Importance:

- Local: a geographically or ecologically separate part of the Fehmarnbelt area, such as Rødsand lagoon, the deeper waters in the middle part of the Fehmarnbelt (central Fehmarnbelt) or the coasts of either Fehmarn or Lolland.
- Regional: the greater Fehmarnbelt area, including the eastern part of the Kiel Bight, the southern edge of the Langeland Belt, the Fehmarn Sound between the German mainland and Fehmarn, the Rødsand Lagoon and the western part of the Mecklenburg Bight.
- Pan-regional or between-regional: This scale supersedes the regional scale, and applies to processes or fluxes that play between regions and therefore interconnects them. An example would be the larval recruitment of a species from a source population in one region that settle in another, not necessarily neighbouring region. Pan-regional recruitment would make the latter (receptor) region dependent on the ecological integrity of the former (donor) region.

In order to classify the benthic fauna communities into one of the four Importance levels (very high, high, medium and minor), specific criteria are formulated (Table 8-1). Characteristic species in this context are species that discriminate fauna communities from each other (discriminate species, as derived in chapter 4.2) but also common typical species.

Table 8-1 General criteria for classification of the benthic fauna communities into one of the four Importance levels: Very high, High, Medium and Minor.

Importance level	Description
Very high	Benthic fauna communities that are determined by indicative or discriminate species which are protected under international conventions, like the FFH-guideline and/or HELCOM guidelines. The communities act on a pan- or between-regional scale with regard to ecosystem functioning.
High	Benthic fauna communities that are determined by indicative or discriminate species which are protected under national legislation (BNatSchG and LNatSchG in Germany) and/or which appear on Red Lists. The communities act on a regional scale with regard to ecosystem functioning.
Medium	Benthic fauna communities that are characteristic for the greater Fehmarnbelt region, and of importance for local ecosystem functioning.
Minor	Benthic fauna communities with a temporary character, e.g. subject to high environmental disturbance on short time-scales.

In order to actually classify the fauna communities, the general criteria in Table 8-1 were specified in more detail to allow an importance evaluation of each of the fauna communities (Table 8-2). Although the criteria also include habitat specific parameters (e.g. from the Habitat Directive), these do not necessarily directly apply to the communities. This depends on the status and composition of the community and is documented in the specific cases If the criteria used indicates different categories of importance, an expert judgement is given to derive the final importance of the community based on the relevance of the different criteria for the specific community and the specific occurrence in the investigation area.

Table 8-2 Specific assessment criteria and their usage for the importance classification of the nine benthic fauna communities.

Criterion	Usage
1. Linkage to EU Habitats Directive	Communities that are determined by characteristic species protected by the Habitats Directive should be classified as "very high". Communities that are associated to a certain Natura 2000 habitat type can have a supporting importance value, but do not qualify for "very high" importance as such (i.e. importance may be lower). The reasoning is documented in each individual case.
2. HELCOM red list of species and habitats	Communities with characteristic species from the HELCOM red list should be classified as "very high". Communities that belong to a HELCOM red list habitat, should be classified as "very high".
3. Scale of ecosystem functioning	Local scale is associated to "medium" importance, regional scale is associated to "high" importance, pan-regional or between-regional scale is associated to "very high" importance.
4. National red lists	Communities with characteristic species on national red lists

Criterion	Usage
	can be classified as "high" on Danish territory and as "very high" on German territory.
5. German national nature conservation law (BNatSchG), federal nature conservation law (LNatSchG) and federal regulation on protected biotopes (biotope regulation)	This criterion only applies to German territory only: Communities that occur in a §30 biotope (BNatSchG) can be classified as "very high", if they are in accordance to the biotope definition given in the federal biotope regulation.

8.2 Importance classification

Referring to the predicted distribution as determined in Section 4.2.2, the benthic macrofauna communities are here classified according to the established criteria in Table 8-1 and Table 8-2. Although the criteria also include habitat specific parameters (e.g. from the Habitat Directive), these do not necessarily directly apply to the communities. This depends on the status and composition of the community. The resulting ranking is presented in Table 8-3. The following paragraphs and provide a detailed reasoning of the ranking of each community.

Table 8-3 Summary of the importance of the benthic fauna communities classified according to the criteria established in Table 8-1 and Table 8-2. See Table 8-4 and the following text for the reasoning of the ranking.

Importance level	Description
Very high	Rissoa community Arctica community
High	Mytilus community Dendrodoa community Tanaissus community
Medium	Gammarus community Cerastoderma community
Minor	Corbula community Bathyporeia community

Table 8-4 Importance classification of the nine benthic fauna communities together with the specific reasoning. Cardinal numbers in the right column refer to the specific criteria from Table 8-2.

Community	Importance	Assessment
Arctica	very high	**1.** *Arctica islandica* is listed for the German Natura 2000 site Fehmarnbelt (SCI DE-1332-301) **2.** *Mya truncata* is on the HELCOM red list of species **2.** *Arctica islandica* is not threatened in the assessment area according to HELCOM, but in the adjacent Mecklenburg Bight and The Sound, and the Fehmarnbelt is important for the transport of larvae into the other Baltic areas. **2.** The habitat (deep waters) is on the HELCOM red list of habitats **3.** Pan-regional scale (source population for Baltic Proper) **4.** DE: *Macoma calcarea* and *Astarte montagui* As all criteria have very high importance and because the community is widely distributed, the community is assessed to be of "very high" importance.
Bathyporeia	minor	**3.** Local scale The community is dynamic in terms of species and abundance, has a temporary character in terms of the general criteria for minor importance, and has in general few species. The local scale of the ecological function is limited due to the low number of species and low abundances and the importance is hence assessed to be "minor".
Cerastoderma	medium	**3.** Local scale Stable community with value for other components like fish or mammals (food source) in the local ecosystem of the Fehmarnbelt. The community is hence assessed to be of "medium" importance.
Corbula	Minor	**3.** Local scale The community is a transition community between several other communities and between shallow and deep waters. The spatial distribution is very limited and the local scale of ecological functioning therefore only qualifies for "minor" importance.
Dendrodoa	High	**1.** Association to habitat type 1170 (reef) **1.** *Dendrodoa* listed for the German Natura 2000 site Fehmarnbelt (SCI DE-1332-301) **2.** The habitat (deep waters) is on the HELCOM red list of habitats **3.** Regional scale **4.** DE: *Macoma calcarea* and *Astarte montagui* **5.** Associated to §30 biotope "macrophytes", but with overall low density The spatial distribution of this community is limited and only a part of the predicted area is inhabited by a fully-developed Dendrodoa community. Therefore the importance is assessed to be "high".

Community	Importance	Assessment
Gammarus	medium	**3.** Local scale The community has a strong association to *Mytilus edulis*, macrophytes and hard substrate and thus contributes to the local scale of ecological functioning. The community is important as food source for fish and is hence assessed to be of "medium" importance.
Mytilus	high	**1.** Associated to habitat type 1170 (biogenic reef), when mussel cover is high enough **2.** The habitat (reef) is on the HELCOM red list of habitats **3.** Regional scale Most of the areas in the assessment area assigned to this community cannot be regarded as true mussel beds, but rather as mussel patches (aggregates) with soft bottom communities in between. Therefore, the importance is assessed to be "high".
Rissoa	very high	**2.** *Parvicardium hauniense* is on the HELCOM red list of species. The species is not threatened in the assessment area, but is under threat and/or in decline in the adjacent Mecklenburg Bight and The Sound **3.** Regional scale **4.** DE: *Parvicardium hauniense* (characteristic species, extremely rare) **5.** Associated to §30 macrophyte biotope "eelgrass" The community is an epifauna community and dependent on the eelgrass community of the benthic vegetation and the importance is assessed to be "very high".
Tanaissus	high	**1.** *Ophelia*, *Travisia* listed for the German Natura 2000 site Fehmarnbelt (SCI DE-1332-301) **2.** The habitat (both deep waters and gravel bottoms) is on the HELCOM red list of habitats **3.** Regional scale **5.** Association to §30 biotope "gravel bottoms" The spatial distribution of this community is very limited in the assessment area and the community is rarely fully developed. Therefore, the importance is assessed to be "high".

Arctica community

The Arctica community is the typical soft bottom community in deeper, more saline waters of the Fehmarnbelt area. It comprises a saltwater community and has therefore a high intrinsic value for the waters of the Fehmarnbelt area that constitute the transitional area from the North Sea and Belt Sea into the Baltic Proper. Some species of the Arctica community are of special importance, as they are listed in the HELCOM red list (*Mya truncata*) and the German red list (*Macoma calcarea*). The community is also inhabited by some long-living (e.g. *Arctica islandica*) and sensitive species listed in the German 'Standarddatenbogen' for the NATURA 2000 site Fehmarnbelt (SCI DE 1332-301).

The deep Fehmarnbelt NATURA 2000 site is mostly inhabited by the Arctica community. The area typically serves as a source population and a stepping stone into the Baltic Proper for the species associated with the Arctica community, which themselves are important elements in the marine food web. The ecological integrity of the Baltic ecosystem (very large spatial scale, spanning across regions) is thus dependent on the integrity of this community.

Bathyporeia community
The Bathyporeia community is characterized by shallow waters with high exposure to both currents and waves, and therefore also by highly mobile soft bottom sediments. The Bathyporeia community has furthermore been described (Section 4.3.2) to be a rather loose conglomeration of different stages of a disturbed community, with a low number of frequent and characteristic species. It is therefore also of "Minor" importance.

Cerastoderma community
The Cerastoderma community in this particular composition is probably living on the eastern limit of its salinity tolerance. *Mya arenaria* does occur in lower salinities, but *Cerastoderma edule* is a true marine species that needs salinities higher than 12 psu. The discriminate species are important components in the marine coastal food web. Along the salinity gradient of the Baltic Sea, *Cerastoderma edule* is replaced by *Cerastoderma glaucum*, a typical brackish water cockle species, which occupies a similar ecological niche as its marine nonspecific. This alternation of species composition is visible within the investigation area comparing the sandy offshore area along the Danish coasts with the inner coastal waters (e.g. Rødsand Lagoon). The Cerastoderma community has more species than the Bathyporeia community and exhibits a stable community structure.

Corbula community
The Corbula community is a transition between several communities, incorporating characteristic species of different epibenthic and infauna communities, mainly the Gammarus, Arctica, Cerastoderma and Mytilus communities. It is also affected by variable environmental conditions as it is restricted to the depth zone around the pycnocline. Thus, the composition is highly variable over space and time and the Corbula community therefore cannot fulfill a stable role in ecological functioning.

Dendrodoa community
The Dendrodoa community is a community in the deeper waters of the Fehmarnbelt. The ascidian *Dendrodoa grossularia* lives attached to algae which are fastened to hard substrates such as boulders and pebbles, but also on shells and other substrates. In between these patches of hard substrate with its reef-like character a soft bottom fauna dominates. A fully-developed Dendrodoa community is very rich in species and harbours both internationally and nationally protected species like *Macoma calcarea* and several *Astarte* species. The Standarddatenbogen for the NATURA 2000 site Fehmarnbelt (DE 1332-301), in which this community also occurs, mentions several of the species of the Dendrodoa community (e.g. *Musculus niger, Cheirocratus sundevalli, Dendrodoa grossularia, Corophium crassicorne*). The area occupied by this community within the NATURA 2000 site is relatively small. Also, the spatial distribution of this community in the whole predicted area plus abundance of protected species is not expected to be exceptionally high in the other regions

Gammarus community
The Gammarus community is a typical epifauna community. This community is strongly associated with hard substrate, macroalgae and to a lesser extent *Mytilus edulis*. It is characterised by many species that are strongly associated with hard

substrate and macroalgae, like *Littorina*, *Gammarus*, *Idotea*, the starfish *Asterias rubens* and the shore crab *Carcinus maenas*. The habitat as such is tightly connected also to fish that use the community as food source. However, the coverage of algae is quite low in most of the area predicted as occupied by the community.

Mytilus community
Mytilus communities are important habitat-structuring communities, which may (within the investigation area to a minor extent) also fall under the description "biogenic reefs" according to HELCOM. The habitat-structuring traits of these communities are of internationally recognised importance. *Mytilus* aggregations are important drivers in the transfer of energy from the pelagic to the benthic compartment and provide food for many higher trophic levels, both directly and indirectly. Typical *Mytilus* aggregations in shallow, well-mixed and thus oxygen-rich waters consist of high densities and are associated with several crustacean and gastropod species. The Mytilus community located in deeper waters consists of a high-density mussel community with typical saltwater, epibenthic species. However, the density of the community in terms of Mytilus coverage varies greatly within the investigation area and by far most of the regions assigned to this community cannot be regarded as true mussel beds, but rather as small mussel patches (aggregates) with soft bottom communities in between.

Rissoa community
The Rissoa community is not particularly species-richOne of the characteristic species, *Parvicardium hauniense,* is especially mentioned by HELCOM as a threatened species. *Parvicardium hauniense* is an epibenthic bivalve species, typically attached to *Zostera* blades in the canopy of seagrass meadows but also on other macroalgae. These blades are also inhabited by the various species of the *Rissoa* gastropod genus, which are strongly associated to eelgrass as well. The main distribution area of the Rissoa community is in the inlets of the Belt Sea and the Pomaranian Bodden. The Rødsand Lagoon and Orth Bight can therefore be considered one of the westernmost populations. The close association with seagrass beds is important, since this biotope also is listed in the HELCOM red list of threatened habitats. Additionally, the major distribution of the Rissoa community in seagrass meadows is located within NATURA 2000 sites (e.g. in Rødsand Lagoon). The Rødsand Lagoon is classified as a priority habitat type 1110 (sandbanks which are slightly covered by seawater all the time - possibly with seagrass vegetation) in the Habitat Directive (92/43/EEC).

Tanaissus community
The Tanaissus community is associated with sandy and coarse substrates in deeper waters offshore. Preservation of its characteristic species (*Ophelia* sp., *Travisia* sp.) which are also mentioned in the corresponding "Standarddatenbogen" and functioning of the community is designated as one of the conservation objectives for the NATURA 2000 site Fehmarnbelt (SCI DE 1332-301). Additionally, the community is partly related to the threatened HELCOM-biotope "Gravel bottoms with Ophelia species"The mentionedcoarse substrate community only covers narrow parts within the assessment area.

8.3 Importance map

The resulting benthic fauna community Importance map is shown in Figure 8-1. The map is based on the fauna community map (Figure 4-5) and just colours the predicted areas of the communities according to their derived importance.

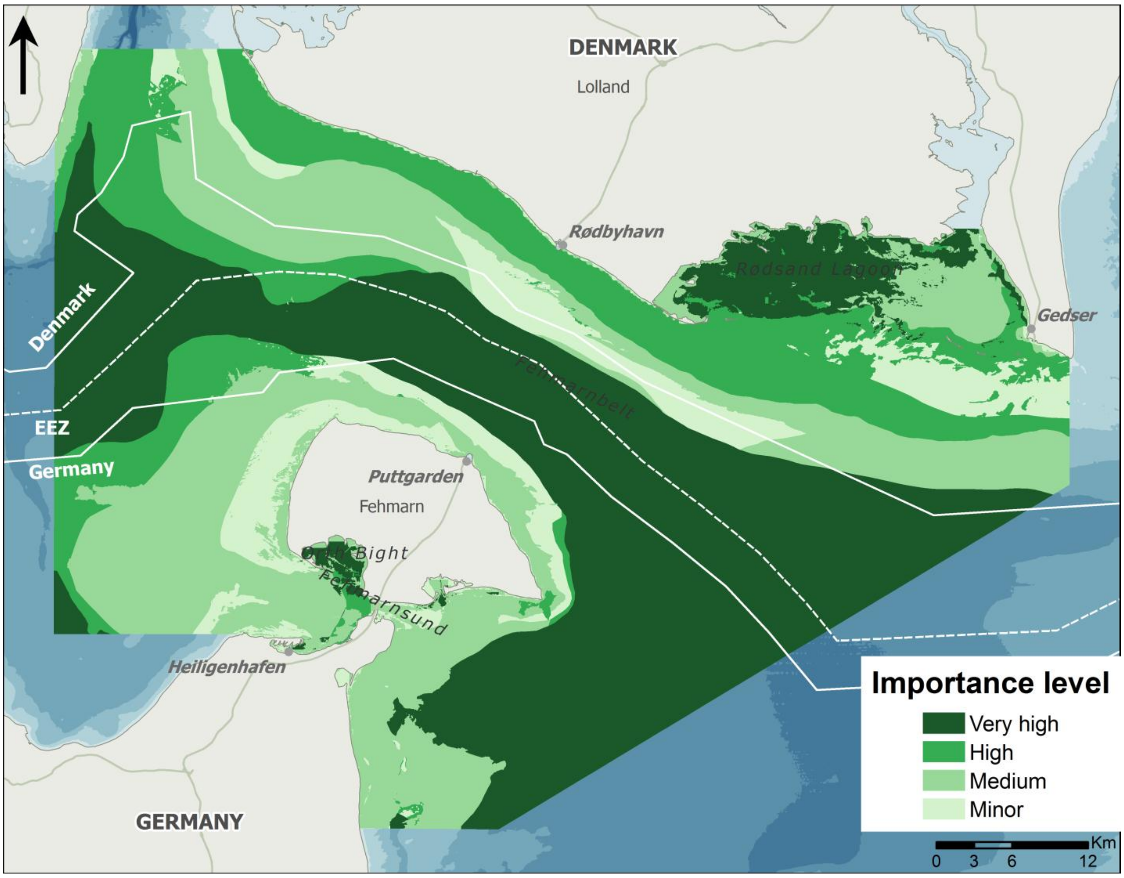

Figure 8-1 Importance map. In this map, the modelled benthic communities determined in Section 4.3, have been classified according to the four-level Importance classification (very high, high, medium, minor).

The zones which are classified particularly as "Very high" are the deepest central part of Fehmarnbelt, western part of the Lagoon of Rødsand as well as an area in the Orth Bight. These areas are dominated by either Arctica or Rissoa communities, from which they derive their "Very high" classification.

The areas classified as "High" are mainly the coastal zones of the island of Lolland, the slopes and the deeper parts in the Langeland Belt and a region in the eastern part of the Kiel Bight, as well as outer boundaries of the Lagoon of Rødsand and Albue Bank SW offshore Lolland. These areas are dominated by Mytilus, Dendrodoa or Tanaissus communities.

Areas where the Gammarus or Cerastoderma communities dominate, and therefore classified as "Medium", can be mainly found in the shallow waters around Fehmarn island, in Sagas Bank southeast of Fehmarn, in and around the Fehmarn Sound, in the near-shore parts of Orth Bight, Großenbrode and in the Eastern part of the Lagoon of Rødsand as well as in the region southeast offshore Gedser.

The coastal zones west of the island of Fehmarn, as well as highly dynamic areas southeast offshore Gedser, are the regions for the dynamic Bathyporeia and Corbula communities and are of "Minor" importance. There are also regions in the central part of Fehmarnbelt, in which the transition zones are located between the shallow mesohaline and the deeper polyhaline waters that are classified as "Minor".

9 EXISTING PRESSURES

The baseline pressure analysis, based on expert judgement, attempts to assess the existing anthropogenic pressure drivers and the pressures deriving from them.

It should be noted that some pressures are natural but may be amplified due to the anthropogenic influence on the pressure drivers.

As an example, the variability of dissolved oxygen in bottom waters is a natural stressor, which exerts considerable pressure on benthic macrofauna, especially in the deeper waters of the Baltic Sea. However, due to anthropogenic influences, the frequency and intensity of oxygen depletion events have increased. Another natural stressor is the high variability in salinity, which causes the total species pool of transitional waters in the Baltic Sea to be relatively low.

The aim of this section is to outline major existing pressure drivers that could lead to impacts, and to discuss some of the documented effects of the resulting pressures. This forms the basis for the assessment of existing anthropogenic pressure drivers with respect to their influence on the benthic macrofauna in the area of interest, and how they may interact with pressures from the planned project.

It should be noted that the situation of the baseline as we observe it the present, does not need to (and very likely does not) reflect so-called pristine conditions. In a process called "shifting baselines" (the slow and often un-noticed change of conditions; Dayton et al., 1998; Duarte et al., 2009) underlying deterioration of the environmental conditions may be masked to a point where the system experiences a sudden, irreversible regime shift (HELCOM 2010).

9.1 Overall Pressures in the Baltic Sea

In a recent peer-reviewed publication (HELCOM 2010), the Helsinki Commission (HELCOM) has established no less than 52 anthropogenic pressure drivers and derived the so-called Baltic Sea Pressure Index (BSPI). The BSPI brings together all available data layers relevant to human uses and pressures acting on the Baltic Sea and evaluates the spatial distribution of the cumulative impact of these pressures.

The Baltic Sea Impact Index (BSII) is a tool to estimate the potential anthropogenic impacts on the marine ecosystem, taking into account areas of the Baltic Sea that are sensitive to human-induced pressures. The concentration of anthropogenic pressures (=BSPI) is combined with the spatial distribution of species, biotopes and biotope complexes to yield the potential anthropogenic impacts (=BSII).

The BSII has been established for the entire Baltic Sea on a grid of 5 km × 5 km (HELCOM 2010). It was found that only the open sea areas of the Gulf of Bothnia are considered to be relatively free of human impact, whereas almost all coastal areas of the Baltic Sea are impaired. Among the most notorious and widespread of anthropogenic stressors are: eutrophication, commercial fisheries, input of hazardous substances and land/seascape modification. The Belt Sea and Arkona Basin are under relatively high pressure and focussing on the basins of the Kiel Bight and the Mecklenburg Bight (of which the Fehmarnbelt is the connecting sea strait) a number of area-specific pressures could be identified. The area-specific anthropogenic pressures that ranked highest within these basins were:

- Extraction of species by bottom trawling, gillnet fishing, surface and mid-water trawling and fishing with coastal stationary gear (standing nets, fykes)
- Input of nutrients and heavy metals (lead and cadmium)
- Abrasion of the seabed by bottom trawling
- Underwater noise by shipping activities (coastal and offshore)

The BSPI, the sum of the anthropogenic pressures within the study area in the Fehmarnbelt has a range between 47 and 90 (Figure 9-1). The areas with the highest index values are notably both ferry harbour entrances at Puttgarden and Rødby havn, the coastal waters around Gedser and the Fehmarnsund between the island of Fehmarn and the German mainland. Also, southeast offshore Langeland and areas in the central Fehmarnbelt are under noticeable pressure. Areas with notably low BSPI values are the Lagoon of Rødsand, the central Lolland coast and the eastern part of the Kiel Bight, west offshore Heiligenhafen.

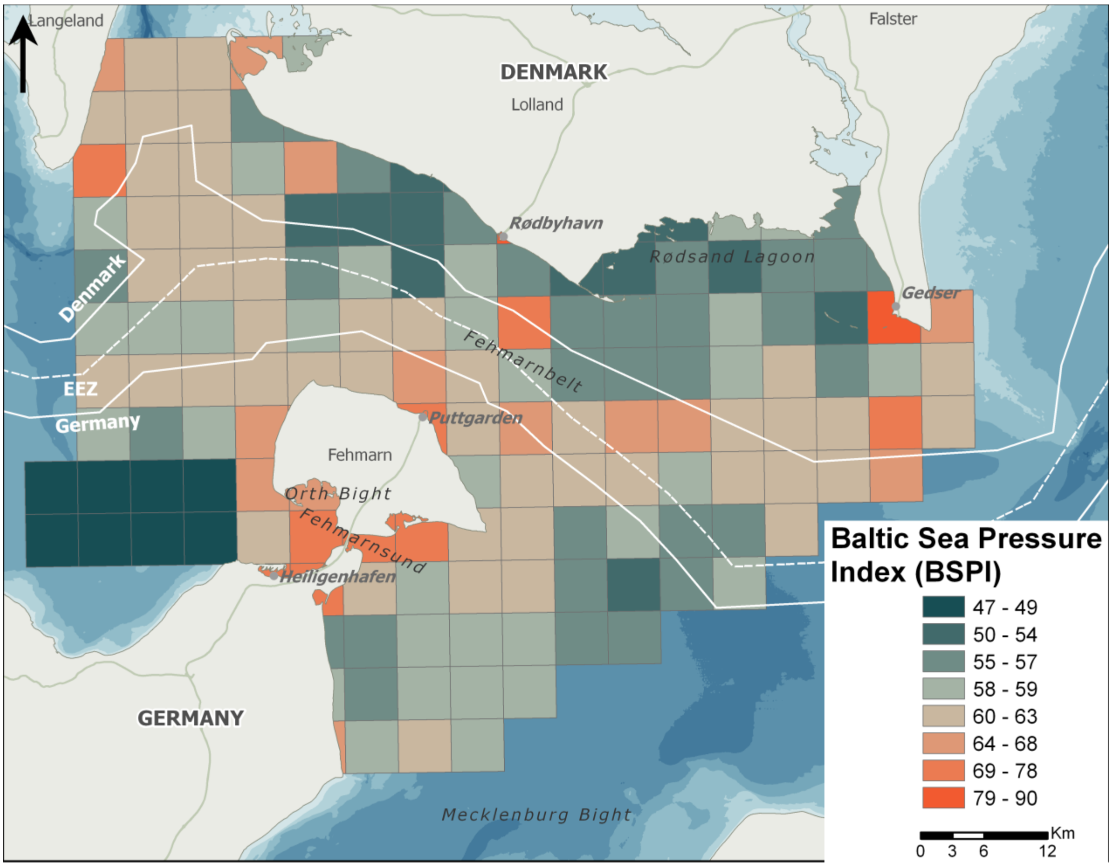

Figure 9-1 The Baltic Sea Pressure Index (BSPI) for the Fehmarnbelt area.

9.2 Eutrophication

Eutrophication is in general an increased nutrient availability compared to the natural status and one of the most serious threats to species diversity and stability of marine ecosystems worldwide (Kotta and Witman 2009). The Baltic Sea has been exposed to high amounts of nutrients throughout the last 50–80 years. According to the HELCOM Holistic Assessment (see Section 9.1), the eutrophication status of the Fehmarnbelt region is poor to bad.

Benthic fauna communities are affected by eutrophication in different ways:

Increased availability of dissolved nutrients in the sea water primarily increases the growth of phytoplankton (planktonic algae), and, thus, lead to an increase in the deposition of their remains as e.g. detritus in deeper waters. This can lead to a decrease in oxygen at the sea floor due to the bacterial decomposition of the organic material. If the oxygen is depleted, the fauna is affected. Especially epifauna is sensitive to these oxygen depletion events (e.g. amphipods like *Ampithoe*, *Microdeutopus*, *Gammarus*, *Corophium*), but also the infauna cannot survive if the duration of the oxygen depletion event is long enough (e.g. bivalves like *Macoma*, *Cerastoderma*, *Mya*). At the same time, the increased amount of detritus promotes the generation of muddy sediments with a changed or degraded fauna (Rönnberg and Bonsdorff 2004).

Eutrophication has also been found to have profound effects on the abundance, biomass and species composition at a community level. Eutrophication will essentially reverse the course of natural succession, and cause a de-diversification of macrobenthic faunal assemblages. According to the classical Pearson-Rosenberg model of macrobenthic succession (Pearson and Rosenberg, 1978), pristine marine benthic species assemblages which are exposed to conditions of eutrophication will first experience an increase in both species and biomass (Figure 9-2). Further increasing the eutrophication will cause both species number and total biomass to decline, as the benthic oxygen demand (BOD) increases. During this part of the eutrophication, total species abundance will remain constant, until a certain point where the sediment becomes rich in reduced compounds (H_2S) and poor in oxygen. These conditions are ideal for species which are weak resource competitors, but have a high physiological tolerance to high-sulfide/low-oxygen conditions. Increasing eutrophication further will first cause explosive increases in the abundance of these generally small species, which is followed by further impoverishment of the species assemblage until only a few species remain, with exceptionally high tolerances to these adverse conditions.

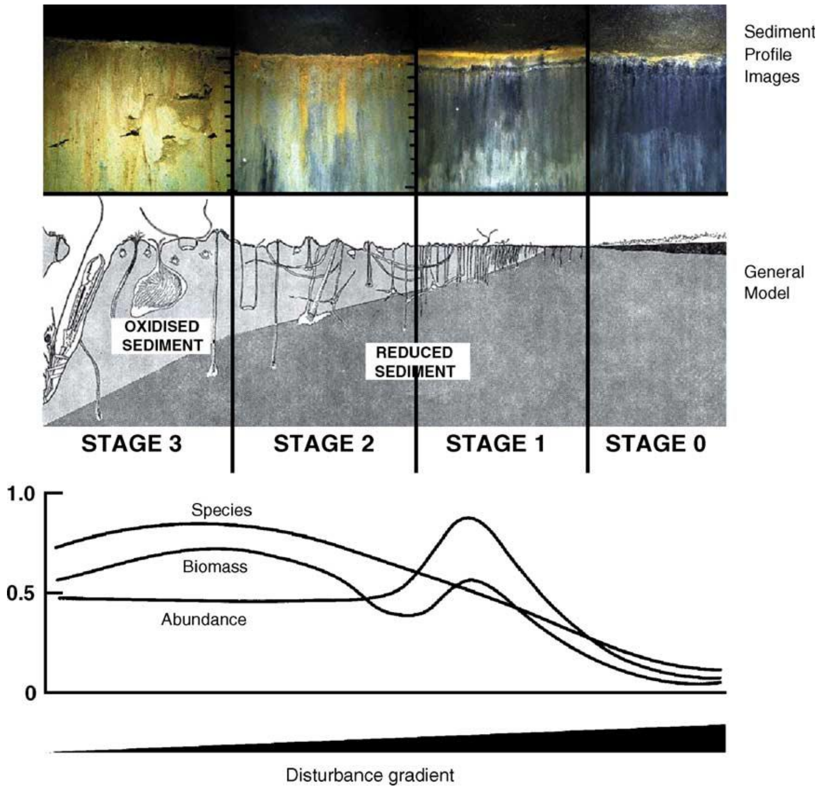

Figure 9-2 The classical Pearson-Rosenberg model of macrobenthic succession under eutrophication conditions (from: Nilsson and Rosenberg 2000).In practice, species assemblages shift from suspension feeder-dominated towards deposit feeder-dominated assemblages and from larger, deeper burrowing animals to smaller, shallower burrowing animals. Consequently, there will be less deep bioturbation and less exchange between deeper sediment layers and the sediment-water interface.

Another phenomenon of eutrophication is changes in the conditions in shallow waters, where fast-growing and opportunistic filamentous algae can build up dense coverage in spring utilizing the high amount of nutrients. Within a short time period, large areas of the sea floor can get covered by 100% opportunistic algae species. Mats of these algae may reduce water (and thus oxygen) exchange to the underlying substrate. Microbial decomposition of the algal biomass may result in oxygen deficiency and sometimes H_2S release, which can lead to a die-off of the bottom organisms (Rosenberg 1985, Norkko & Bonsdorff 1996). Additionally, the algae mats may be transported to deeper water and increase the oxygen deficiency effects in these areas.

A secondary negative effect on benthic fauna is the fact that perennial macrophytes (seaweeds and seagrasses) are negatively affected by increased nutrient levels. Increased phytoplankton growth reduces water transparency and decreases the available light (and thus the growth conditions) for benthic vegetation (e.g. Nielsen et al 2002). In connection to this, it also causes an effect on epifauna communities by decreasing the habitat availability for vegetation-associated benthic fauna.

9.3 Marine Constructions

Constructions of marine infrastructures at sea such as harbours, offshore wind farms (OWFs) or deepening of waterways result in loss of substrates in the direct impact area and sediment spill during construction. No harbours have been built around Fehmarn within the last decades. The building of Puttgarden (ferry) harbour and the Fehmarnsund Bridge in the 1960s were the last marine construction projects on a greater scale along the German coastline within the investigation area.

On the Danish coastline, just offshore the Rødsand lagoon, the Nysted OWF and the larger Rødsand II OWF are located. Although the construction phase of each has not been found to cause significant impairments of the benthic ecosystem, each of the wind farms may have local effects on the environment. Based on the EIA for Rødsand II, impacts during the operation phase of the wind farm are associated with changes in wave characteristics, long-shore sediment transport and the permanent loss of soft bottom habitats, affecting a very small area. The resulting impact on the structure and function of the benthic community in the Lagoon of Rødsand is assessed to be insignificant. Fouling communities on the additional solid substrate are likely to be containing low numbers of species and dominated by the Blue Mussel (Petersen and Malm 2006). Attraction of fish and increased predation may have a local and limited impact on the surrounding soft bottom community. On the other hand, the structural complexity and the high biomass of hard substrate communities developing on the foundations may also have an overall beneficial ("reef") effect on local populations of especially fish.

9.4 Hard substrate

The amount of suitable hard substrate has been reduced along the German coast. From 1800 to 1974 (Bock et al. 2003) extensive "stone fisheries" took place along the whole German Baltic coastline. More than 3.5 million tons of stones were used to build up spur dykes, harbours or different buildings on land. Some of the richest grounds for stones were situated around the east coast of Fehmarn between Marienleuchte and Staberhuk and Sagasbank. Interviews with former stone fishermen indicated that some of these grounds have been fished completely blank of stones during the 1960s and 1970s (Bock et al. 2003). Today stone fishery is forbidden in Germany.

In Denmark, it is estimated that 32 km^2 of stone reef have been removed from the coastal zone due to stone fishery, leaving only 2 km^2 coastal reefs. Two extraction areas have been used for stones along the Lolland coast. Although one is still active, it has not been used since 1990. The other reclamation site has been closed since 1990. The occurrence of hard substrate fauna in several parts of the investigation area is limited due to the lack of suitable hard substrate, which affects the distribution and abundance of these specialised epifauna communities.

9.5 Spill, dumping, and sedimentation

Spill plumes or sediment dumping generally have the effect that benthic assemblages experience a local and temporal (partial) mortality due to burial, inhibition of feeding, or reduction of oxygen supply. In response to burial under accreting sediment, most animals show escaping activity, where escaping or survival is characterized as establishing contact with the overlying water (Powilleit et al. 2009). The escape activity is restricted by the motility of the particular animals and many infauna species (e.g. bivalves like old *Mya arenaria* or *Arctica islandica*) are not able to actively escape or survive when the thickness of the spilled/dumped is too large.

Also, environmental factors like salinity and temperature determine the ability for buried benthic species to survive. There appears to be a negative correlation between salinity and invertebrate tolerance to burial. In brackish waters, fatal burial depth (FBD) is generally found to be higher (i.e. animals withstand thicker layer) than under marine conditions. However, these findings are based on a small number of studies (Essink 1999), and might reflect an auto-correlative relation (i.e. bacterial activity is higher in saline waters).

The type of the accreting material is also important for the overall survival of the benthic species. Rapid, incident deposition of coarse or mixed dredging material (spill dump) will directly damage epifauna by mechanical impact, but is likely to impose lower hypoxia stress. Relatively slowly accreting fine sediment (diffuse dumping, spoil mud plume) will allow fauna to undertake (successful) escaping activities and the time of compaction in mud is expected to relatively long, because of the lower density and higher porosity of the material. Accreted fine sediment will therefore be more prone to re-suspension. However, the finer the accreting sediment, the more likely hypoxic events will occur in both the overlying water and in/on the sediment. Areas (for either spoil plumes or direct disposal) with low numbers of hypoxia-tolerant species are therefore more vulnerable to burial under fine, muddy sediment. Vice versa, fauna in natural sedimentation areas are less vulnerable to the mechanical effect of deposition due to dredging activities. In general, high similarity between allochtonous accreting sediment and sediment at the target site decreases negative impact on the particular benthic species.

As some of the accreting material from dredge plumes will consist of fine muddy material, an important impact on the sediment bed will not be mechanical, but rather biogeochemical. Accreting mud has several consequences: amongst others it may increase organic carbon (OC) concentrations (adsorbed to the surface of the particles) and decrease hydraulic conductivity (sediment porosity) and will therefore decrease oxygen penetration depth. Also, the surface-to-volume ratio of mud particles is higher than that of sand, meaning that mud is characterized by higher bacterial activity. Microbial degradation rates will therefore increase non-linearly in muddy sediment. The resulting decrease in oxygen (hypoxia) due to microbial OC degradation may amount to highly sulphuric conditions, which are toxic to many species. However, benthic invertebrates display very species-specific tolerance levels to sulphuric conditions.

Dredging activities also cause an increase in the concentration of suspended sediment concentration (SSC) which may be more or less persistent depending on the specific local environmental conditions (e.g. current velocity, wind-driven wave mixing, turbulence etc.). Increased SSC affects both pelagic and benthic primary production, but may also negatively affect the food uptake efficiency of suspension feeders, respiration of fish (gill-clogging) and food acquisition of visual predators (fish, birds, marine mammals). Suspension feeders in waters with low natural or intrinsic SSC are less well suited to higher SSC conditions, but show flexibility in morphological adaption (Essink et al. 1989). Many bivalves are well adapted to increased SSC conditions and some species even benefit from slight increases in SSC (Essink 1999). However, prolonged periods of very high SSC have been reported to cause shellfish to shut their valves (Essink 1999). This decreases food intake and may have detrimental effects on the organism’s condition.

9.6 Fishery activity

Commercial trawl fishery has an impact on benthic life forms. The main impacts are the removal of (mainly) top predators, or the destruction of the habitat. This can involve the destruction of sea floor surface structures and biogenic structures such as tubes or funnels that are needed by some species for feeding (*Corophium*, *Echinocardium*, *Lagis*, *Arenicola*). Invertebrates can be torn off from hard substrate or damaged. Also, larger stones and boulders with attached epifauna are displaced and turned over during trawling. The epibenthic bivalve *Musculus niger* probably is stirred up and sinks down in another place or is even buried. The top sediment layers are heavily disturbed by the heavy shear trawl doors and forerun chains (Krost et al. 1990) which damage the shells of e.g. the bivalves *Abra alba*, *Mya* spp., and *Macoma calcarea* (Rumohr and Krost 1991). In general, larger species or species with thin shells are affected most. This can change the age distribution within long-living species like *Arctica islandica* such that the oldest and largest specimens are less represented. However, in an undisturbed community, these oldest specimens make up the largest part of the biomass.

Trawl fishery is restricted to depths over 20 m in Germany, which means that only the deeper benthic fauna communities are affected. However, the communities in deeper waters, especially the *Arctica*-community consists of large, slow-growing individuals. The physical disturbance combined with the low growth rates of indicator species, may significantly disrupt benthic fauna communities in deeper areas for longer time periods (Schroeder et al. 2008). In the shallow coastal zones, gill net and bow net fishery is carried out. Both types are expected to have only a small impact on benthic communities, as these nets are stationary and have no heavy anchors. However, the fishing pressure on predatory fish, may affect population structure and/or community composition of the prey, i.e. benthic fauna.

9.7 Tourism

Tourism may in shallow waters (< 10 m) have direct effects on benthic communities. Different kinds of aquatic sports like wind- or kite-surfing as well as swimming cause footfalls and trampling damage to fauna assemblages. Continuous periods of trampling may cause larger-scale mortality of fauna species and even shifts in community composition (Rossi et al. 2007). Within the investigation area these activities are concentrated along the south coast of Fehmarn and in Orth Bight, where the main tourism centres are located. Similar activities are located on the south coast of Lolland. Anchoring of boats can impact especially eelgrass-associated communities like the Rissoa community, if rhizome mats are torn out of the sediment. Such unvegetated holes within the eelgrass stands result in high physical exposure of the surrounding shoots that may lead to further instability of the eelgrass bed. Indirect impacts of tourism can also be seen as an increase in eutrophication, if the (often increased) sewage is not adequately or completely treated.

9.8 Invasive Species

Between 1800 and 1980, there has been an exponential increase in the introduction of invasive species (HELCOM 2010). The two largest contributors of alien species introduction are ships (release of ballast water) and aquaculture (fish farming). Since 1980, the trend shows a decline (HELCOM 2010).

Species that tolerate low salinity will be able to spread from the North Sea towards the Baltic Sea. Up till now these introduced species have their main distribution within highly anthropogenic influenced areas like harbours. Replacement or disappearance of native species, caused by invasive species, has not been observed.

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