

A vertical ruler on the left side of the page, showing depth markings in centimeters. The markings are 4, 10, 20, 30, 40, 50, 20, 30. The ruler is blue and white, with the numbers in white on a blue background.

Structural and functional biodiversity of North Sea ecosystems: species and their habitats as indicators for a sustainable development of the Belgian continental shelf

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The Belgian Continental Shelf (BCS) is characterized by numerous subtidal sandbanks. Their close position to the coastline and the shallowness of the area make them unique, both from an ecological and geological point of view. It has recently been shown that the sandbank system in the Belgian coastal area acts as an internationally important resting and foraging area for various seabird species.

The project aims to assess the factors that determine and influence the marine biodiversity of the Belgian Continental Shelf. Existing and new biodiversity information (at the community, population and genetic level) is considered from all benthic compartments, including demersal fish, their parasites and birds. The question whether the structuring of ecosystem and species diversity and its functioning is reflected in the genetic structuring of marine taxa on the Belgian Continental Shelf is addressed for the first time.

Monitoring of the Belgian Continental Shelf

Clear patterns in species abundance have been observed for the meiobenthos, the macrobenthos, and the hyperbenthos. The species number of inshore benthic assemblages changes dramatically between the eastern and western end of the Belgian coast. A second gradient runs perpendicular to the coastline and involves an increasing species number and diversity offshore. An offshore decrease in density has also been observed for macrobenthos and hyperbenthos. Avifauna data do not confirm these patterns even though seabird assemblages offshore differ from the inshore avifauna. The monitoring of the hyperbenthos shows that the estuarine outflow on the one hand and the hydrodynamic setting and protective function of the sandbanks on the other hand create a diverse environment along the Belgian coastal zone. The sandbanks system extends moreover in gently sloping sandy beaches. This makes the setting of the Belgian coastal sandbank system ecologically unique.

Spatial patterns on sandbank ecosystems

Benthos

The meiobenthos of the Flemish Banks, the Hinder Banks and the Zeeland Banks is divided into four different communities which do not reflect the geographical position but are influenced by local differences in sedimentological characteristics within sandbanks. Sediments with a median grain size below 300 μm were poor in terms of densities and number of taxa, while coarser sediments were richer in taxon diversity. Sediments with a median grain size between 300-450 μm were rich both in terms of diversity and density, while sediments with a median grain size of > 450 μm still showed high diversity but lower densities. The information on the species diversity of the most dominant group within the meiobenthos, the free-living marine nematodes indicates that sandbanks can be seen as geographically isolated "islands" since tidal current patterns around these sandbanks prevent nematodes from being transported from one sandbank to another. A detailed study of the Kwintebank, which is heavily exploited for sand and gravel extraction, shows that a depression has been created in the middle of the sandbank due to sand extraction (comparison between 1978 and 1997). In the centre of the sandbank, copepod diversity decreased and a shift was recorded from a species rich northern community to a less diverse southern community (less species, high dominance of *Paraleptastacus espinulatus*,

Leptastacus laticaudatus s. str. and *Kliopsyllus constrictus* s. str.) as a result of changes in sediment characteristics. The altered sediment composition may be the result of an accretion of fine sediments, as a consequence of changed current patterns in the depression. The extension of the present depression due to sand extraction can become quite problematic if the human-induced physical disturbances may cause a continuing erosion and impoverishment.

A thorough analysis of all available data of macrobenthos of the BCS (with an extensive survey on the sandbank systems) shows that five different macrobenthic communities (1. *Abra alba-Mysella bidentata*; 2. *Nephtys cirrosa*; 3. *Ophelia limacina-Glycera lapidum*; 4. *Eurydice pulchra-Scolecopsis squamata* and 5. *Barnea candida* community) can be distinguished with five transitional groups in between them. All these groups are clearly linked to sediment characteristics and their occurrence is also related to the geographical position on the sandbanks. These communities are ecologically important, because they are a representation of the different habitats that are characteristic for the BCS. Obviously, different macrobenthic communities and species associations show different temporal dynamics. A successful recruitment and survival of one species, for instance, will only take place in the community where this species belongs to and not in any other community. Instead of putting a lot of effort, time and money in working out time-series of large numbers of macrobenthic samples, randomly spread over the area under consideration, monitoring of the macrobenthos should concentrate on the spatial distribution of the macrobenthic 'potentials'. This can be done by the identification of (1) the spatial distribution of the macrobenthic communities actually present, (2) the communities' environmental 'needs', and, finally, (3) the communities' 'potentials' by means of long-term monitoring of some selected stations within each community.

Parasites

The study concentrates on ectoparasites belonging to the genus *Gyrodactylus* (Monogenea, Platyhelminthes) parasitizing the threespine stickleback (*Gasterosteus aculeatus*, Gasterosteidae, Teleostei) and gobies from the genus *Pomatoschistus* (Gobiidae, Teleostei). Many new species have been found most of them infecting a single or few hosts. Thanks to the molecular markers in combination with morphometric analyses the detection of putative new species and their description has become considerably easier.

Avifauna

Out of the 121 bird species encountered at sea during the period 1992-98, 23 were selected as being true marine species that occur in relatively high densities within the Belgian waters. Of these 23 species, six can be classified as 'focal species' (little gull, diver spp., common scoter, sandwich tern, common tern and little tern) and another five as 'locally important species'. A cumulative picture of the abundance and conservation value of six focal species indicates that the Westkustbanken (Trapegeer, Nieuwpoort Bank, Stroombank, Balandbank, and Smal Bank), the Vlakte van de Raan and most of the Vlaamse Banken are avian hotspots throughout the year. The Oostkustbanken (Wenduinebank and to a lesser extent the Paardenmarkt) are very important from spring till autumn, mainly as feeding grounds for the three tern species. In winter this area is of marginal importance. On comparison the deep-water zone, the Zeeland ridges and the offshore Hinderbanken are less important.

Ecological indicators

In general, the characteristics (density, biomass, biodiversity, species composition) of biological communities can be linked to habitat disturbance. However, since biological communities are quite complex to investigate, a set of ecological indicators is proposed as easy measures for community change due to general disturbances. Four 'easy measures' will be discussed : 1. Nematode Biomass Spectra, 2. Occurrence of *Lanice conchilega*, 3. Speciation patterns in parasites and 4. Distribution patterns of seabirds.

Nematodes : the biomass distribution over size requires no taxonomical knowledge and can be used by non-specialist. Nematode biomass spectra (NBS) were constructed for undisturbed sandbanks, physically disturbed sandbanks (sand extraction on the Kwinte Bank), eutrophicated and less eutrophicated coastal stations and during a pulsed supply of fresh phytodetritus following a spring phytoplankton bloom. Using NBS allows in tracking changes in all the communities mentioned above.

Lanice conchilega : *Lanice conchilega* is a tube-building, suspension or deposit feeding polychaete, of which the tube has a length of up to 45 cm. *Lanice conchilega* typically occurs within the macrobenthos-rich *Abra alba* – *Mysella bidentata* community. On the western Coastal Banks the polychaete was also found in the *Magelona mirabilis* species association. Within both communities, a positive correlation between the macrobenthic density and the number of species per sample and the density of *L. conchilega* was found. The increase in habitat complexity in dense patches of *L. conchilega* might be responsible for the increasing macrobenthic density and diversity.

Parasites : Parasite speciation is influenced by ecological and phylogenetic factors. By comparing host and parasite phylogenies a differentiation can be made between the various speciation modes. In the case of strict co-speciation parasite phylogeny mirrors host phylogeny. This mirror association is absent in the present study, suggesting the important influence of ecological factors in this host-parasite system.

Seabirds : occupying high trophic levels, seabirds accumulate persistent chemicals and are extremely vulnerable to their effects, making them of value as sensitive indicators of marine pollution with chemicals. Monitoring of their numbers and distribution at the BCS can be a strong tool and an early warning system for changes within the marine ecosystem. Monitoring of contaminants in tern eggs and feathers can be used as an indicator of pollution in the Belgian waters. At present it is too early to use seabirds as indicators of changes in marine prey stock (pelagic fish, bivalves) since detailed knowledge on their feeding ecology and on food-chain interactions is still missing.

Ecological sensitive areas

The Belgian sandbank system harbours important numbers of fish and macrocrustaceans such as sole (*Solea solea*) and the common shrimp (*Crangon crangon*). Young macrocrustaceans have their maximum abundance during summer. Recruitment of fish larvae is well defined in time and happens for most species during April and May. The Flemish Banks have the most abundant patterns in density for the young decapod larvae. This distribution pattern can be explained on the basis of the hydrodynamical regime in the area. Older decapod larvae reach their highest densities on the Coastal Banks. Also the sheltered and food-enriched Coastal Banks

provide suitable adult habitats. For example, zoea larvae of common shrimp *Crangon crangon* reach the highest densities at the Flemish Banks, its postlarval stage is most abundant at the Coastal Banks, while the adults are dominant users of the adjacent beaches. It has also been shown that postlarval stages of *Crangon crangon* enter the Westerschelde estuary and use the nearby tidal marshes as a nursery. Information on the macrobenthos of the sandbank systems in ecological sensitive areas is given in the 'HABITAT' project (Degraer *et al.*, this volume).

The impact of sand and gravel extraction on benthos biodiversity has been demonstrated for the occurrence of copepods on the Kwintebank. Although the Kwintebank is not the most sensitive area in the region, investigation happened on this bank since 'historical' data of the meiofauna were available from 1978. Comparison between 1978 and 1997 was made and drastic changes have been found, both in sediment characteristics and the associated composition of the copepod communities.

Oil sensitive areas for seabirds : Winter and to a lesser extent early spring turn out to be the most delicate periods for oil-pollution. And the closer an oil-slick approaches the coastline the worse the presumed impact on seabirds will be. Within each season the western sandbank systems Westkustbanken and Vlaamse Banken are highly oil-sensitive. During winter the Oostkustbanken (with the exception of the Vlakte van de Raan) are less vulnerable than the western part of Belgian inshore waters. In spring and summer the Oostkustbanken are most vulnerable.

Disturbance-sensitive seabirds such as scoters, divers, auks and grebes are most abundant in Belgian marine waters in winter and early spring. Higher disturbance-sensitivity values in autumn compared to summer are due to increasing numbers of sensitive species from October onwards. Most vulnerable sites in terms of disturbance are the Westkustbanken and Vlaamse Banken, both in winter and early spring.

Bentho-pelagic coupling

The Belgian coastal zone is characterized by accumulation zones of deposited organic matter originating from primary production. The importance of the primary production in the water as structuring factor for benthic communities is investigated in a coastal, enriched station and an offshore station (less enriched). For the nematode community the response to the enhanced supply of organic matter was obvious in terms of abundance, community composition and feeding type distribution at both stations. At the offshore station the increase of freshly deposited organic matter is more episodic and favoured opportunistic nematode species. At the coastal station, a rather continuous supply of organic matter occurs throughout the year. Nevertheless, pulses of higher organic matter input, resulting from the spring bloom event, have an obvious impact on the total nematode association.

An impact on the macrobenthos community was only observed at the coastal station, by increased densities of mainly young individuals in May. At the offshore station, enhanced densities - mainly mobile organisms - a rather seasonal effect in the summer months were present. It was hypothesised that dominant macrobenthic species were rather dependent on decomposition processes during summer months.

Genetic biodiversity of ecologically important fishes

The physical structure of the BCS is characterized by the presence of a series of sand banks; this heterogeneity is also reflected in the ecosystem by the presence of species associations, mostly positioned on an inshore-offshore gradient. The question whether the structuring of ecosystem and species diversity and its functioning is reflected in the genetic diversity and structuring of marine taxa was addressed for the first time. The main questions dealt with in this study relate to a characterisation of genetic diversity among the various gobies species with mitochondrial and nuclear (allozymes and DNA microsatellites) markers. From this genetic diversity an estimate is made of the genetic structure, the gene flow (or conversely of genetic isolation) and of the effective population size. The allozyme and microsatellite data on the sand goby *P. minutus* point to a high level of diversity and a pattern of genetic homogeneity. This might be attributed to substantial larval dispersal, at least on a scale of tens of kilometres. Otherwise stated, the sand banks do not seem to act as a landscape element promoting isolation; the strong tidal currents homogenise the populations. On a larger spatial scale, sand gobies from the North Sea belong to the same unit, but differentiate from populations from the Gulf of Biscay and the Mediterranean Sea. The related species, Lozano's goby, *P. lozanoi*, occupies a more specialised niche. Again, genetic diversity is high, but it is higher than in the sand goby. Inshore populations do not show any peculiar genetic structure, but there is a clear inshore-offshore gradient on the BCS, largely due to the allozyme locus GPI-1. An explanation might be that the pattern is due to selection but further research with hypervariable markers should provide a decisive answer. The effective population sizes of both populations are very high and reflect their abundance in the field. We conclude that a genetic disequilibrium characterises the North Sea fish populations, which might relate to the recent post-glacial colonisation.

Marine organisms show a high potential for species-specific dispersal because of historical, physical and biological factors. A gradient in the genetic structure of sole *Solea solea* (Soleidae, Teleostei) (also called genetic isolation by distance) has been demonstrated, which translates a high genetic exchange between populations. The core of each spawning unit along the Atlantic shelf is separated by a distance of about 100 km, which is exactly the distance where the genetic structure changes. We screened a limited number of populations across the natural range on the Atlantic and Mediterranean continental shelf to detail the genetic diversity and structure with markers complementary to the allozyme markers reported so far. The mitochondrial marker cytochrome b, the nuclear intron (EPIC) marker aldolase and several nuclear microsatellite markers seem to provide high quality information. We confirmed the genetic distinction between Mediterranean, southern Atlantic and north eastern Atlantic populations. However, we are about to reach a higher resolution than reported in the literature to discriminate among the populations (also called stocks by fisheries managers) over short distances. Our research should result in the fine-tuning of the stock management of Dover sole, a task well needed as many commercial stocks are under heavy fishing pressure.