BENTHIC COPEPOD COMMUNITIES IN RELATION TO NATURAL AND ANTHROPOGENIC INFLUENCES IN THE NORTH SEA

Bonne Wendy

University of Ghent, Marine Biology Section
Krijgslaan 281/S8, B-9000 Gent
Present address: AZTI Foundation, Department of Oceanography and Marine Environment, Herrera Kaia – Portualdea z/g, E-20110 Pasaia (Gipuzkoa), Spain
E-mail: wbonne@pas.azti.es

The Belgian Continental Shelf is situated in the Southern Bight of the North Sea and consists of a number of sandbank systems separated by gullies. Benthic copepod (= harpacticoid) communities were investigated, focusing on the Flemish Banks system and the Gootebank, belonging to the Zeeland Banks.

Chapter I – (Natural influences - sediments)

Structural biodiversity of benthic copepod communities on two subtidal sandbanks

In 1997 ten stations were sampled on the Kwintebank and five stations on the Middelkerkebank at regular distances along the sandbank crest. At each side and near the middle of the sandbank one station was sampled in the gully. Low harpacticoid density and high diversity characterized the two Flemish Banks. Sandbank tops differed from the gullies from a sedimentological and biological point of view. Harpacticoid densities and diversities were higher on sandbank tops than in the gullies.

In general, two distinct parts are distinguished on the Flemish Banks. The northern landscape of the sandbanks is characterized by big sand waves of coarser sands while the southern parts consist of a flat plateau of finer sands. These morphological characteristics and granulometric gradient result from the local tidal current patterns. The northern sandwave area was inhabited by a typical interstitial community with a high density and diversity while the finer grained southern parts were much poorer. The sandwave areas at the Kwintebank and the Middelkerkebank were similar whereas the topographically flat areas of both sandbanks yielded totally different communities. A dense community of interstitial species was found in the finer sediments of the Kwintebank, whereas endobenthic species predominated in the finer sands in the south of the Middelkerkebank, though in low abundance. Remarkably, the Kwintebank showed a more patchy community distribution than the Middelkerkebank.

Sediment characteristics were related to harpacticoid density and diversity gradients along the sandbanks but could not explain the differences between the southern parts of the sandbanks. Near-bottom current dynamics seem to be as important as sediment characteristics in accounting for community variation. Strong tidal currents, wave action or storm events may generate these strong near-bottom current velocities.

The conclusion from these results is that biological community composition is not controlled by one or a combination of simple granulometric properties of the sediments. It is considered more likely that biological community composition is controlled by an array of environmental variables, many of them reflecting an interaction between particle mobility at the sediment-water interface and complex associations of chemical and biological factors. Coarse sands, well-sorted fine sands as well as mixed deposits under different hydrodynamic conditions with their respective harpacticoid communities create a heterogeneous environment, with highest diversity in the most dynamic parts at the sandbank top. In comparison with subtidal sandy habitats world-wide the relatively low densities and relatively high diversity indicate that the Flemish Banks system is quite a stressed but rich environment.

Chapter II – (Natural and anthropogenic influences - spring phytoplankton blooms)

Impact of spring phytoplankton blooms on benthic copepod communities of subtidal sandbanks

Eutrophication in the North Sea is characterized by a shift from moderate early spring diatom growth to a *Phaeocystis* dominated phytoplankton community. In spring 1999 one station on the Kwintebank and one station on the Gootebank were repeatedly sampled to examine the changes in the benthic copepod community in relation to the phytoplankton bloom in the water column. Deposition of phytoplankton derived organic matter on the bottom was observed in the beginning of the diatom bloom and at the end of the *Phaeocystis* bloom. Over the whole period a minimum of about 60 % harpacticoids was present in the upper 5 cm of the sediment, with a mean of 75 %.

During the spring phytoplankton bloom there were clear temporal changes in the harpacticoid community with high diversity in April and high density and dominance in June. The high diversity in April during the diatom bloom may be attributed to the presence of subordinate species or specialist feeders. After *Phaeocystis* deposition opportunists predominated. Changes in community structure and density followed the same pattern on the Kwintebank and the Gootebank while diversity behaved differently. At the Kwintebank the organic matter is probably mixed through the upper layers of the sediment and reworked continuously. A great part of the deposited matter is resuspended during flood and hence not assimilated in a great extent by the infauna. The fraction of the deposited matter that is consumed by the harpacticoids continuously increases density and species richness. Yet, the *Phaeocystis* derived material increased the dominance in the community.

At the Gootebank the deposited organic matter is not reworked as intensively, resulting in a more stable food supply to the benthos. More harpacticoid species were present in the upper centimetres of the sediment in comparison with the Kwintebank, being concentrated in the upper 2 cm after *Phaeocystis* deposition. The dense interstitial fauna in the upper sediment layers reflects that deposited *Phaeocystis* derived organic matter is effectively assimilated and incorporated in the sediment through the microbial food web. Vertical migration of harpacticoids took place after the bloom reached the sediment surface in May, animals from deeper sediment layers attracted by the fresh food supply. In June and July particle and pore-water transport provided food particles at greater depth. A significant structuring effect is thus recorded in the interstitial community, which relies indirectly on sedimented phytoplankton, and not in the directly assimilating epibenthic harpacticoids, although these copepods are regarded as very mobile and may colonize food patches very quickly. Diversity increased remarkably during the diatom bloom, whereas the community was completely dominated by the most successful opportunistic interstitial species, *Apodopsyllus* n.spec.1, which exploits the detrital/bacterial food sources after *Phaeocystis* deposition. *Apodopsyllus* n.spec.1 may be the harpacticoid counterpart of the macrobenthic *Capitella capitata* and *Polydora* species.

Increased reproductive effort in May and June indicate that the reproductive cycles of most of the dominant harpacticoid species were related to the spring bloom sedimentation event. While not denying the role of temperature, the results suggest that breeding periodicity is also strongly related to food resource availability as a result of phytoplankton deposition. For some species migratory behaviour and reproductive activity were interrelated, whereas the total distribution of life history stages per depth layer did not reveal any changes in the vertical distribution over time.

Chapter III – (Anthropogenic influences - sand extraction)

The impact of marine sand extraction on benthic copepod communities of a subtidal sandbank

On the Kwintebank, sand is very intensively extracted for the building industry. More than 95 % of the sand extraction on the Belgian Continental Shelf occurs on the Kwintebank, being concentrated at the northwestern top and in the centre of the bank.

The copepod distribution data of 1997 of the Kwintebank were compared with data of 1978 prior to intensive sand extraction. Harpacticoid community analysis distinguished only two parts on the Kwintebank in the seventies: a high variable northern part and a southern part with a high similarity. This pattern was more complicated in the nineties as indirect impacts of sand extraction were visible. In the nineties the Kwintebank was split up in four communities. Analogies were found in the occurrence of erosion and extraction areas and the distribution of harpacticoid communities. The northern top of the sandbank is very intensively exploited and subject to strong erosion, resulting in the formation of a depression. In this part a separate harpacticoid community has evolved from 1978 to 1997. Density and species richness, however, were still remarkably high in the nineties. The copepods of the dynamic area of sandwaves may be more resilient to extraction activities in terms of density and species richness than in the central part of the sandbank.

The centre of the sandbank is also very intensively exploited. A geomorphological survey indicated the presence of a distinct depression in this central area, which was not observed in the seventies. Due to sand extraction depth increased, sand waves were flattened and a depression was formed. In this depression changes in sediment characteristics from coarse sands in the seventies to fine sands in the nineties induced a shift from a species rich northern bank community to a species poor southern bank community with a high dominance of a few species. The altered sediment composition may be the result of a local accretion of fine sediments, as a consequence of overflow and changed current patterns in the depression. A station with a very low density and diversity, similar to the poor gully stations, was located near the southern border of the depression, although the sediment composition of this station was comparable to the richer bank stations. The sediment near this border coarsened, probably due to erosion, induced by sand extraction and enhanced by the strong currents.

The community in between the northern top and the central area still showed resemblance with the species assemblage defined for the northern part in the seventies. This community occurred in a less intensively exploited zone and a non-exploited zone, corresponding respectively with a zone of weak erosion and a zone of accumulation of sediment.
The southern part of the bank was characterized by low sand extraction intensity and no changes in the top volume of the bank except for one zone with weak erosion. The community structure of the southern part was still comparable after 20 years and hence stable in time.

A significantly higher density of juveniles was found in the intensively exploited areas and may be an indication of a direct impact of sand extraction. The abundance of big epi- and endobenthic species decreased and species composition altered in favour of very small interstitial species, which reproduce more frequently and are able to hide deeper into the sediment. Specific species correlate with disturbance intensity but the distribution and ecology of these species need to be studied more into detail in order to define them with certainty as indicator species for disturbance.

This study revealed that natural conditions define which harpacticoid species and communities occur but sand extraction can influence species composition both in a direct and an indirect way. Sand extraction on the Kwintebank is very patchy and much too intensive in the centre. The northern part and especially the centre of the Kwintebank can be defined as strongly impacted areas, while the harpacticoid community structure of the southern part of the bank is stable in time. The extension of the present depression in the centre of the sandbank due to sand extraction can become quite problematic if these human-induced physical disturbances may cause a continuing erosion and impoverishment.

Chapter IV – (Anthropogenic influences - sand extraction)

Impact assessment of sand extraction on subtidal sandbanks using macrobenthos

Macrobenthic community analysis, based on data of different sampling campaigns in the nineties on the Kwintebank, distinguished between a bank community, covering the whole sandbank from north to south, a slope community and a gully community. The community on the sandbank was characterized by low density and diversity, which is typical for mobile sands. Differences within the bank community reflected slight year-to-year variability but differences between areas of different levels of sand extraction intensity were not detected in the nineties.

The comparison of intensively exploited areas between the seventies and the nineties revealed that the *Spisula* species disappeared and the abundance of *Ophelia limacina* clearly decreased, which may be attributed to sand extraction activities. The potential impact of sand extraction on the macrobenthos of the Kwintebank was however not confirmed by clear changes in other biological characteristics, since density and diversity did not change. Only seasonal fluctuations were observed.

Increasing sand extraction intensity from the late seventies onwards did not result in an increase of the biotic coefficient. Moreover, the biotic coefficient did not differ between the stations, characterized by different sand extraction intensity. The biotic coefficient of a sporadically exploited station was even higher than at intensively exploited stations in 2001.

The investigation at community level, density and diversity measurements and the ecological groups used in the biotic coefficient were not sufficient to detect differences between impacted and non-impacted sites. The species composition of some areas changed and has become similar to the surrounding area, hampering the distinction between extracted and non-extracted sites at a fixed moment in time. In order to be able to use a biotic coefficient to measure dredging impacts in clean sands, a suggestion may be to modify the classification of the ecological groups used for the biotic coefficient, focusing on differences between the (interstitial) polychaetes and amphipods prevailing in these habitats or to examine the percentages of juveniles or biomasses.

Conclusions

Natural influences

Sediments

Although sandbanks look like a homogeneous desert of sand with huge dunes and covered with sand ripples, they are very complex entities. Sediment characteristics cannot always explain the occurrence of clearly different harpacticoid communities. Natural disturbances such as different current bottom velocities, wave action and cycles of tidal mixing are supposed to be as important. The tight relation between sediment composition and hydrodynamics probably has to be refined. The potential interrelation between the topography of the sandbanks (sandwave *vs*. flattened areas) and other environmental characteristics implies still unrevealed secrets.

Diatom bloom

Settling diatoms during the diatom bloom increase diversity in the harpacticoid community, probably favouring subordinate species or specialist feeders. Density however does not rise.

Anthropogenic influences

Eutrophication

Deposition of *Phaeocystis* detritus has a structuring impact on the harpacticoid community, mainly favouring interstitial species and increasing productivity and species dominance within the community.

Phaeocystis colonies sedimentation does not significantly influence the importance of the directly assimilating epibenthic or endobenthic species in the community but triggers a response of opportunistic species through the detrital/bacterial food web.

Eutrophication may cause an increase in species richness in specific areas, an impoverishment in others, dependent on the amount of organic matter incorporated in the sediment, which is assumed to be dependent on tidal mixing.

Sand extraction

Harpacticoids seem to be useful monitoring tools displaying a spatial variation at an appropriate scale (one sandbank) to detect community changes that are related to small-scale changes induced by sand extraction.

Species richness and density measurements, however, were not appropriate to assess extraction effects at each impacted area in a simple way but species composition offered a more sensitive means of assessing environmental characteristics.

Community changes are more difficult to detect if dealing with a faunal group consisting of a poor community of very mobile species, as is the case for the macrofauna on the Kwintebank. Differences between the macrobenthos of areas of different levels of human disturbance on the Kwintebank are not detected yet, because of potential homogenisation by the extractions, the poverty and wide niche width of the community and the extent to which the community is adapted to high levels of sediment disturbance in these dynamic systems. However, the poverty of samples so far is definitely an additional problem and comparisons with the macrofauna of similar undisturbed areas should be made.

Impact assessment

Tidal mixing on the Kwintebank probably decreases potential negative effects of organic enrichment.

The fauna on the Kwintebank is adapted to the prevailing dynamic conditions and hence more resilient to sand extraction activities.

A threshold value does however exist in respect to sand extraction and care should be taken not to exceed the recovery capacity of the naturally present communities.

Harpacticoid responses to environmental changes can clearly be detected because harpacticoid communities of clear sands on sandbanks are very rich, containing a lot of species differing in fitness and competitive abilities. In predominantly sandy sediments especially interstitial harpacticoids have a high value as ecological indicators. A slight community shift can be assessed by changes in the dominant species, because of the tight zonated occurrence of the indicator species.

An increase of juveniles and interstitial species may reflect stressful conditions due to frequent disturbances, as a result of natural dynamics as well as a result of human-induced stress.

The importance of harpacticoids in marine benthic community analysis and impact assessment cannot continue to be overlooked.

An efficient monitoring should be maintained including the investigation of spatial and temporal variability.