

Benthic Community Response to Sand Dredging and Shoreface Nourishment in Dutch Coastal Waters

JAN A. VAN DALFSEN & KAREL ESSINK

With 5 Text-Figures

Keywords: benthos, dredging, nourishment, North Sea, recolonization.

Abstract

[DALFSEN, J. A. VAN & ESSINK, K. (2001): Benthic community response to sand dredging and shoreface nourishment in Dutch coastal waters. – *Senckenbergiana marit.*, 31 (2): 329-332, 5 figs.; Frankfurt a. M.]

In the Netherlands marine sands are increasingly used for coastal protection and land infrastructural works. Both sand extraction and coastal nourishment cause disturbances of the seabed and its ecological functions. The results of three studies are used to discuss patterns in recovery of the benthic community. Survival, migration and recruitment may all contribute to the recovery of the benthic community after a disturbance. Following such an event a short-term opportunistic response was observed followed by an almost complete recovery of community composition and structure after four years.

Introduction

The use of marine sand has significantly increased since the 1960s in a number of countries around the North Sea and the Baltic Sea. In the Netherlands, about 23 million m³ of sand are extracted annually from the North Sea for coastal protection and various land uses. Beach as well as shoreface nourishment are used to counteract coastal erosion. According to current policy, the sand needed is extracted in the North Sea at depths of at least 20 m. The effect of increasing sand extraction and coastal nourishment on the marine environment and particularly on the benthic communities is of growing concern for marine management.

Whereas extraction of sand leads to an immediate removal of the benthic fauna at the borrow site, shoreface nourishment will lead to the burial of the local benthic community and, therefore, both will influence the ecological functions of the seabed. In this paper general patterns in disturbance and recovery of the benthos are discussed as observed in three environmental impact assessment studies carried out in the Netherlands (VAN DALFSEN & ESSINK 1997; VAN DALFSEN 1998; VAN DALFSEN et al. 1999) (Fig. 1).

Authors' addresses:

JAN A. VAN DALFSEN, TNO Environment, Energy and Process Innovation, Department for Ecological Risk Studies, P.O. Box 57, NL-1780 AB Den Helder, The Netherlands. – KAREL ESSINK, Ministry of Transport, Public Works and Water Management, National Institute for Coastal and Marine Management/RIKZ, P.O. Box 207, NL-9750 AE Haren, The Netherlands.

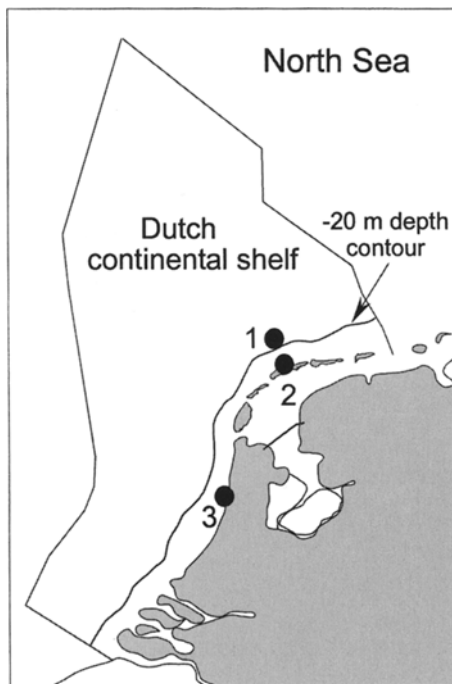


Fig. 1. Location of three study areas of the effects of sand dredging or shoreface nourishment on marine benthic communities in The Netherlands. – (1) extraction; (2) nourishment; (3) Heemskerk (nourishment).

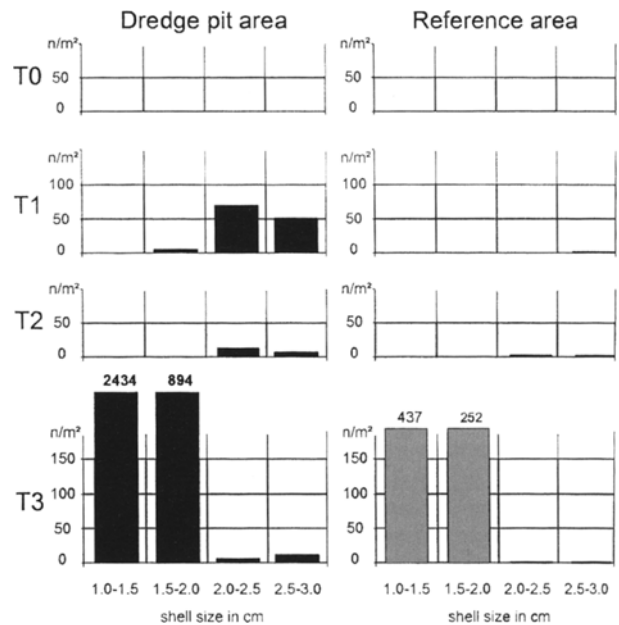


Fig. 2. Abundance of different size classes of the bivalve mollusc *Spisula subtruncata* before (T0) and after nourishment of a former dredge pit area and in a surrounding reference area near Heemskerk at four successive surveys: May 1996 (T0); February 1997 (T1); May 1997 (T2); April 1998 (T3). – Nourishment of the former dredge pit with sand from elsewhere along the Dutch coast started in December 1996 and ended in February 1997 some days before the T1 survey.

Problem Definition

When assessing the impact of seabed disturbances it is difficult to distinguish man-made from natural changes in the benthic community structure as these communities may show considerable dynamics over time. The question is how to determine whether a benthic community has 'recovered' after having been disturbed. Recovery of a benthic community may be judged in two ways:

- pre-post disturbance comparison of species composition, biomass and population structure. In this case little temporal natural dynamics is assumed.
- post-disturbance comparison of the disturbed community with a reference community in the undisturbed surroundings. This approach may be valid in highly dynamic systems.

Impact of Dredging and Nourishment

Sand extraction causes the removal of sediment and its associated organisms, leaving the remaining sediment open for recolonization. Sand nourishment involves the deposition of a layer of sand on the seabed, causing burial of its inhabitants, but also providing a new surface area to be colonised. Colonization of a disturbed area may take place by immigration from its surroundings and by settlement of larvae from the water column. At an extraction site recolonization may also take place by dispersal from

so-called 'refuge areas', i.e. areas in between sand extraction tracks which have not been directly disturbed. At a nourishment site some of its benthos may survive the dumping of material and therefore contribute to the recovery of the local community. Also import of individuals, which have survived the extraction and transport of sand from the extraction site to the nourishment area, may play a role in the recolonization process of the nourished area (VAN DALFSEN et al. 1999).

Short-Term Effects

Both after sand extraction and nourishment a decrease in species abundance and biomass occurred, followed by a development of opportunistic species, mainly polychaetes such as *Capitella capitata* (FABRICIUS 1780), *Magelona papillicornis* (F. MÜLLER 1858), *Scololepis squamata* (MÜLLER 1789), *Spio filicornis* (MÜLLER 1766) and *Spiophanes bombyx* (CLAPARÈDE 1870). In both nourishment studies a temporary increase in carnivores and scavenging polychaetes such as *Nephtys hombergii*

(SAVIGNY 1818) and *Phyllodoce mucosa* (OERSTED 1843) was observed after nourishment, being possibly attracted to dying animals or to the increased abundance of smaller worms. At one nourishment site a successful transfer of a population of the bivalve *Spisula subtruncata* (DA COSTA 1778) from an extraction site to the nourishment area was inferred from the increase of larger specimens by May 1997 (T1) (Fig. 2).

Recovery

Eight months after the extraction or nourishment was completed, developed opportunist populations had again decreased. Recovery time of the benthic community in terms of abundance was found to take 2 years. In terms of biomass and diversity, pre-disturbance values were regained within 2-4 years. Recovery of crustacean

populations, however, was still poor (Fig. 3). After four years, differences in population structure (e.g. species composition and age structure of long-lived species such as some molluscs and sea urchins) between the disturbed areas and surrounding areas, which were still clearly visible after two years, had largely disappeared (Figs. 4, 5).

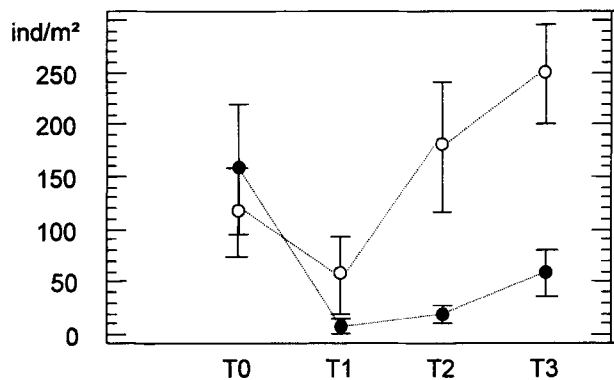


Fig. 3. Mean abundance of crustaceans ($\pm 95\%$ confidence limits) at a former dredge pit area (●) and in a surrounding reference area (○) near Heemskerk at four successive surveys: May 1996 (T0); February 1997 (T1); May 1997 (T2); April 1998 (T3). – The former dredge pit was nourished with sand from elsewhere along the Dutch coast between December 1996 and February 1997.

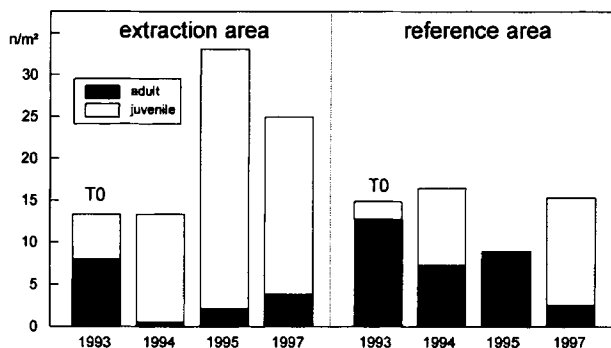


Fig. 4. Abundance of adults and juveniles of the sea urchin *Echinocardium cordatum* in a sand extraction and reference area north of the island of Terschelling between 1993 and 1997. – Dredging took place from April till November 1993.

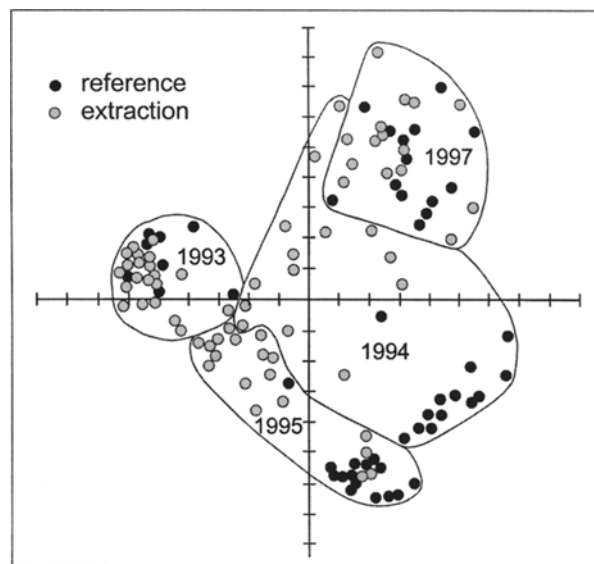


Fig. 5. PCA-ordination diagram of benthic community data from four successive sampling surveys before (1993) and after sand extraction (1994-1997) north of the island of Terschelling. – Densities of taxonomical groups were $\log(n+1)$ transformed. Sampling stations from extraction and reference areas are indicated with different symbols. – Envelopes are drawn by hand and do not show 'statistical clusters'.

Discussion

Assessment of the direct effects of sand extraction and/or nourishment on a benthic community, and its subsequent recovery, is difficult as benthic organisms may survive the dredging activities and colonization takes place almost instantaneously by immigration and recruitment. The response of the benthic community after the disturbance by sand extraction or nourishment appears to follow rather well defined patterns:

1. rapid development of 'opportunistic' species.
2. subsequent recovery of community composition and structure.

Survival of the benthos in the impacted area and the import of benthic organisms from an extraction site to a nourishment area may contribute to the recovery process. In the dynamic coastal areas of the Netherlands recovery of the benthic community is relatively fast. No long lasting effects on the benthos are expected of a single disturbance event. Complete recovery time was estimated to take at least 4 years. This is in good congruence of the

2-4 year estimate of recovery time for gravel and sand habitats summarized by NEWELL et al. (1998). However, examples in which recovery took as much as 10 years also exist (NEWELL et al. 1998). Natural fluctuations in benthic communities, however, are likely to result in a deviation of a recovered benthic community from its pre-disturbance structure. The pre-post disturbance comparison is found to be useful to study the impact of a disturbance, whereas the post-disturbance comparison of the recovered community with a community in an undisturbed nearby reference area is considered to be more useful to study the recovery process after an impact as it also takes in account a natural development of the system. This conclusion may be of additional value to the BACI design for impact studies as described by STEWART-OATEN et al. (1986).

Acknowledgements

We would like to thank Dr. EIKE RACHOR and an anonymous referee for their advice and comments on the manuscript.

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Submitted: 18 August 2000
 Reviewed: 26 February 2001
 accepted: 22 May 2001