Marine Pollution Bulletin 58 (2009) 565–572

Contents lists available at ScienceDirect

Marine Pollution Bulletin

journal homepage: www.elsevier.com/locate/marpolbul

Temporal and spatial changes in marine benthic habitats in relation to the EU Water Framework Directive: The use of sediment profile imagery

Rutger Rosenberg [a,*], Marina Magnusson [b], Hans C. Nilsson [c]

[a] Department of Marine Ecology, University of Gothenburg, Kristineberg 566, SE-450 34 Fiskebäckskil, Sweden
[b] Marine Monitoring at Kristineberg AB, Kristineberg 566, SE-450 34 Fiskebäckskil, Sweden
[c] Norwegian Institute for Water Research, Gaustadalléen 21, NO-0349 Oslo, Norway

ARTICLE INFO

Keywords:
SPI
Benthic fauna
Sediment
Redox potential
Bioturbation
Water directive

ABSTRACT

In 2002 to 2006, sediment profile imagery (SPI) was used to study the environmental impact of eutrophication-induced irregular and seasonal hypoxia on marine benthic habitats in six regions in the Skagerrak and Kattegat (West Sweden). The benthic habitat quality (BHQ) was assessed by parameterisation of biogenic structures observed by the SPI technique, and benthic quality status was related to the EU Water Framework Directive (EU-WFD). The temporal changes were analysed by a 5-factor nested ANOVA and significant temporal differences were recorded within three of the regions. Two of these were affected by hypoxia in the deeper parts and one was probably affected by hypoxia below the halocline. The environmental quality status according to the EU-WFD was *bad* to *high* in two regions, *moderate* to *good* in three regions, and *good* to *high*, i.e., acceptable according to the EU-WFD, in only one region. As BHQ is highly correlated to benthic faunal data, measures have to be taken to improve the coastal water quality in five of the six studied areas.

1. Introduction

Most anthropogenic inputs to the sea will sooner or later end up in coastal marine sediments and eventually impact the sedimentary habitat and the benthic animals. For ecosystem health and management purposes it is of vital importance to know the status of the environment and to detect any changes. The structure of benthic communities is known to change in a predictable pattern to organic enrichment and oxygen deficiency (Pearson and Rosenberg, 1978). When conditions change for the worse, some species will be eliminated and only those that adapt to the new conditions survive. The result will be reduced species diversity and biomass.

Benthic animal activity has a wide influence on the physical and chemical conditions in the sediment. Bioturbation, bioirrigation and biodeposition have significant impacts on the conditions of life in the sediment and influence the vertical distribution of organisms and the sediment redox conditions (Rhoads, 1974). In addition, species diversity has consequences for the functioning of the marine ecosystem. In particular, large and deep-burrowing species are important for ecosystem processes in the sediment (Norling et al., 2007).

The sedimentary habitat contains information that mirrors the functional biodiversity and activity pattern of the macrofauna. Burrows, tubes, voids, pits and mounds are examples of structures in the sediment that relate to animal activities (Rhoads and Germano, 1982; Schaffner, 1990). These biogenic activities could also be related to the vertical distribution of the redox potential discontinuity (RPD). Thus, benthic communities in late successional stages have a high functional biodiversity and associated deep vertical distribution of the RPD, whereas the opposite is found for communities in early successional stages (Pearson and Rosenberg, 1978; Rhoads and Germano, 1986). Information on animal activity and the apparent RPD (aRPD) layer depth in the sediment can be obtained *in situ* by using the sediment profile imaging (SPI) technique (Rhoads and Cande, 1971; Rhoads and Germano, 1986). The images can be digitally analysed for features on the sediment surface, within the sediment, and the mean vertical distribution of the aRPD. Parameterisation of this information can be summarised into a benthic habitat quality (BHQ) index for the assessment of the benthic environmental quality (Nilsson and Rosenberg, 1997). This index has been shown to correlate significantly to the number of species, abundance and biomass of the macrofauna during different phases of faunal succession influenced by changes in dissolved oxygen (Nilsson and Rosenberg, 2000; Rosenberg et al., 2002). SPI has been used in evaluating the impact of different stressors; e.g. pollution (Valente et al., 1992), fish farms (Karakassis et al., 2002; Mulsow et al., 2006), demersal trawling (Nilsson and Rosenberg, 2003) and dumping (Birchenough et al., 2006), on benthic

* Corresponding author. Tel.: +46 52318500; fax: +46 52318502.
E-mail address: Rutger.Rosenberg@marecol.gu.se (R. Rosenberg).

0025-326X/$ - see front matter © 2008 Elsevier Ltd. All rights reserved.
doi:10.1016/j.marpolbul.2008.11.023

habitats. It has also been suggested that the SPI technique is useful for rapid assessment of the benthic status in costal areas according to the EU Water Framework Directive (Rosenberg et al., 2004).

In the present study, the BHQ index was used to assess the benthic environmental quality in six regions: three fjords in the Skagerrak (west Sweden) and three coastal areas in the Kattegat and Öresund (southwest Sweden) in the period 2002–2006 (Fig. 1). The main purpose was to detect possible changes due to eutrophication (organic enrichment) or eutrophication-induced oxygen deficiency.

2. Materials and methods

Sampling was conducted every year in May from 2002 to 2006 by deploying the sediment profile camera at 72 stations (with four replicates). Samples were equally divided in three regions in the Skagerrak (Gullmarsfjord, Havstensfjord and Koljöfjord) and in three regions in the Kattegat/Öresund (Laholm Bay, Skälderviken, and Öresund)(Fig. 1). Statistical comparisons were made between two different sea areas: Skagerrak and Kattegat/Öresund. In each of the six regions, four samples were taken at random each year

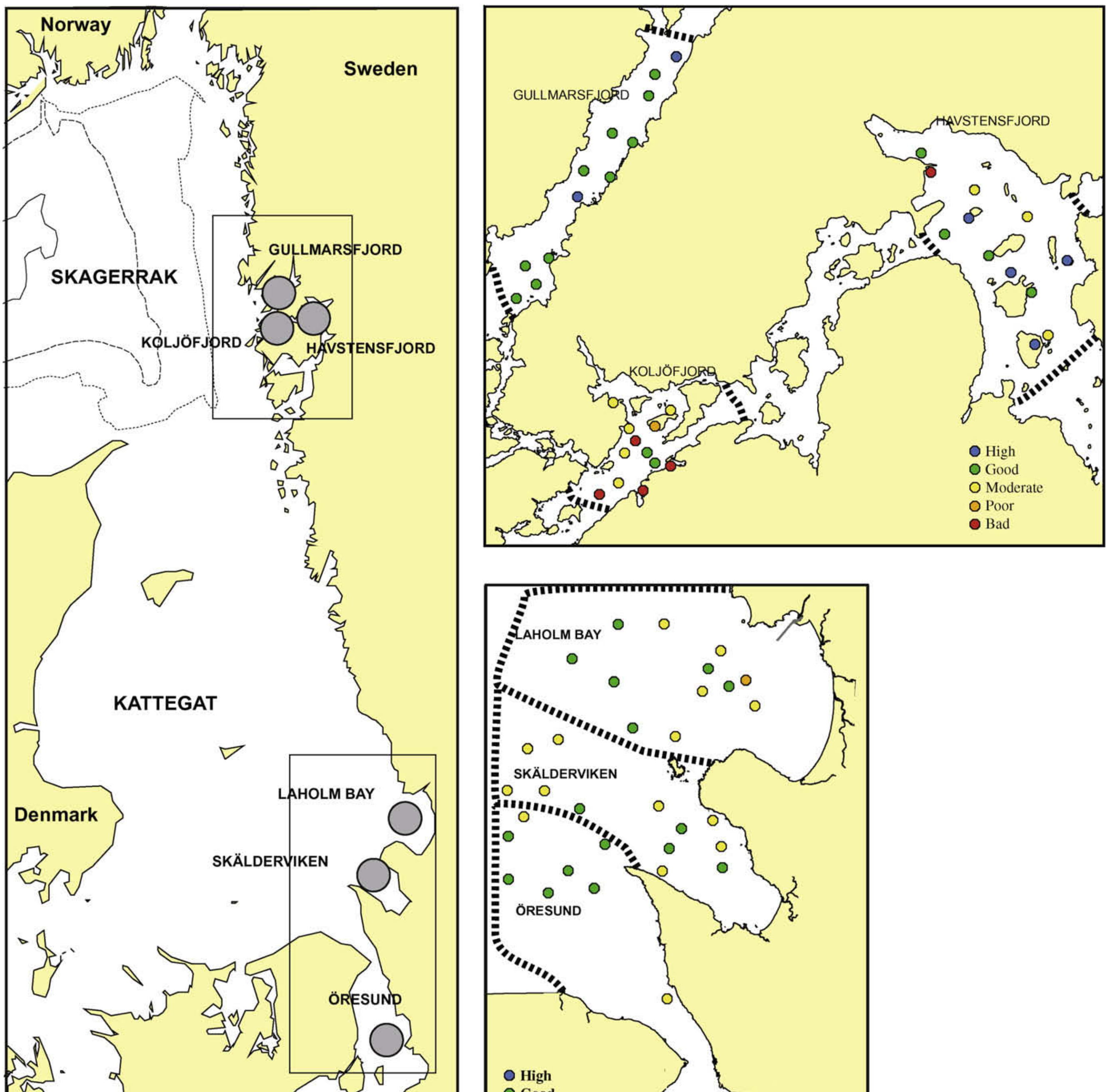

Fig. 1. Map showing the studied fjords in the Skagerrak (Gullmarsfjord, Koljöfjord and Havstensfjord) and the coastal areas in the Kattegat/Öresund (Laholm Bay, Skälderviken and Öresund). The delimitation of each area is shown by the dotted lines. The stations sampled in 2006 (randomized) are shown to the right with the benthic quality status according to the EU Water Frame Work Directive (EU-WFD) classification suggested by Rosenberg et al. (2004).