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Estuarine, Coastal and Shelf Science 75 (2007) 281–295
ESTUARINE COASTAL AND SHELF SCIENCE
www.elsevier.com/locate/ecss

Interplay between filter-feeding zoobenthos and hydrodynamics in the shallow Odense Fjord (Denmark) – Earlier and recent studies, perspectives and modelling

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Received 26 November 2005; accepted 30 April 2007
Available online 5 July 2007

Abstract

The shallow Odense Fjord (Denmark) is characterized by a large biomass of filter-feeding polychaetes (*Nereis diversicolor*), clams (*Mya arenaria*), cockles (*Cerastoderma glaucum*), and amphipods (*Corophium volutator*). The present paper summarizes studies on zoobenthic filter-feeding in Odense Fjord from the last 10 years. The general principles discovered are extracted and compared to available tools for modelling of the primary characteristics of interplay between benthic filter-feeders and hydrodynamics. Earlier works have been supplemented with data from a recent field study conducted in the shallow inner part of the fjord. Based on data from this study site, the reduction in phytoplankton for fully mixed and incompletely mixed flows has been modelled. It was found that fully mixed flow results in a potential half-life for phytoplankton of only 1.3 h, whereas for the incompletely mixed water the half-life is 2.7 times longer. The field measurements clearly demonstrate the presence of a strong interplay between filter-feeders and hydrodynamics, but although a certain grazing impact is evident from vertical chlorophyll *a* profiles with often strongly reduced near-bottom concentrations it is not straightforward to identify and model even the main bio-physical processes that prevent the dense populations of filter-feeders to completely control the phytoplankton biomass in Odense Fjord.

Keywords: benthic macrofauna; grazing impact; chlorophyll *a*; turbulent mixing; tidal currents; modelling

1. Introduction

The shallow eutrophicated Odense Fjord (Denmark) is characterized by a large biomass of filter-feeding zoobenthos, especially polychaetes (*Nereis diversicolor*), clams (*Mya arenaria*) and cockles (*Cerastoderma glaucum*). Based on recorded population densities of these filter-feeders, and assuming efficient vertical mixing, it has been predicted that the half-life for phytoplankton may potentially be less than 1 h in the inner part of Odense Fjord and about 1.3 h on the average. But obviously, the actual grazing impact depends on hydrodynamic processes, such as horizontal currents and vertical mixing of the overlying water column. Therefore, the grazing impact is enhanced by turbulent mixing of the water mass due to wind and current actions, coupling the benthic filter-feeders to whole water column. A key to the understanding of spatial and temporal variations in phytoplankton biomasses is the knowledge of the circumstances under which such a coupling or decoupling of benthic filter-feeders takes place. The present paper gives an overview of earlier studies from last decade, supplemented with data from a recent field study conducted in the inner Odense Fjord. Finally, the

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doi:10.1016/j.ecss.2007.04.032

broader and general perspectives of the work conducted in Odense Fjord are extracted and compared to available tools for modelling of the most important characteristics of interplay between filter-feeding zoobenthos and hydrodynamics.

2. Earlier studies on filter-feeding zoobenthos in Odense Fjord

2.1. Odense Fjord and potential grazing impact

The outer Odense Fjord has a surface area of about 50 km^2 and a mean depth of 2.7 m, and the inner Odense Fjord has a surface area of about 10 km^2 and a mean depth of 0.8 m (Fig. 1). The catchments area to Odense Fjord is 1060 km^2 (about one-third of the Island of Fyn), and the load of nutrients entering the fjord – mainly via Odense River – is high, causing eutrophication (Fyn County, 2003; Riisgård et al., 2007). The water exchange between Odense Fjord and the open sea (Northern Belt Sea) takes place through a narrow opening in the northern part of the outer fjord. The tidal amplitude is about 0.5 m and hydrodynamic modelling has shown an annual average residence time for Odense River water of 17 days in the fjord as a whole, and of 9 days in the inner fjord. The salinity in the inner fjord varies during the year between 10 and 15 psu. In the surface water of the outer fjord the annual salinity ranges are on average 16–20 psu. The low residence time of the water in the fjord, the large freshwater input, and the dynamic water exchange with the bordering sea create strong estuarine nutrient gradients in the fjord (Fyn County, 2003).

The phytoplankton community in Odense Fjord is dominated by diatoms. On an annual scale, 50–75% of the phytoplankton carbon biomass and most blooms are due to diatoms, typical for eutrophicated fjords (Fyn County, 2003; Riisgård et al., 2007). However, the biomass level of pelagic phytoplankton in Odense Fjord is relatively low, despite the high nutrient loads and high concentrations in the fjord. Furthermore, the seasonal development of the phytoplankton biomass is very dynamic, with rapidly shifting concentrations of chlorophyll *a*. Besides the dynamic water exchange, Odense Fjord is characterized by a large biomass of filter-feeding polychaetes (*Nereis diversicolor*), clams (*Mya arenaria*) and cockles (*Cerastoderma glaucum*), which together make up about 70% of the total animal biomass (Fyn County, 2001). Other species of bivalves in Odense Fjord are *Mytilus edulis*, *Macoma balthica*, *Scrobicularia plana*, and *Ensis* sp.

The density of the facultative filter-feeding *Nereis diversicolor* (Riisgård, 1991; Riisgård and Kamermans, 2001) is unusually high in the inner part of Odense Fjord. Therefore, it may be hypothesised that *N. diversicolor* (when in its filter-feeding mode, see later) along with *Mya arenaria* and *Cerastoderma glaucum* play an essential role for the regulation of the biomass of phytoplankton in the inner part of the fjord. A recent work conducted by Riisgård et al. (2004) has thrown light on the grazing impact of the filter-feeding zoobenthos in Odense Fjord. Thus, the filtration rate of each population (F_{tot}) of *N. diversicolor*, *M. arenaria* and *C. glaucum* was related to the total water volume (V_{tot}) in the different areas of Odense Fjord and expressed as 'the grazing impact': $Q = V_{tot}/F_{tot}$ which is related to the half-life for phytoplankton

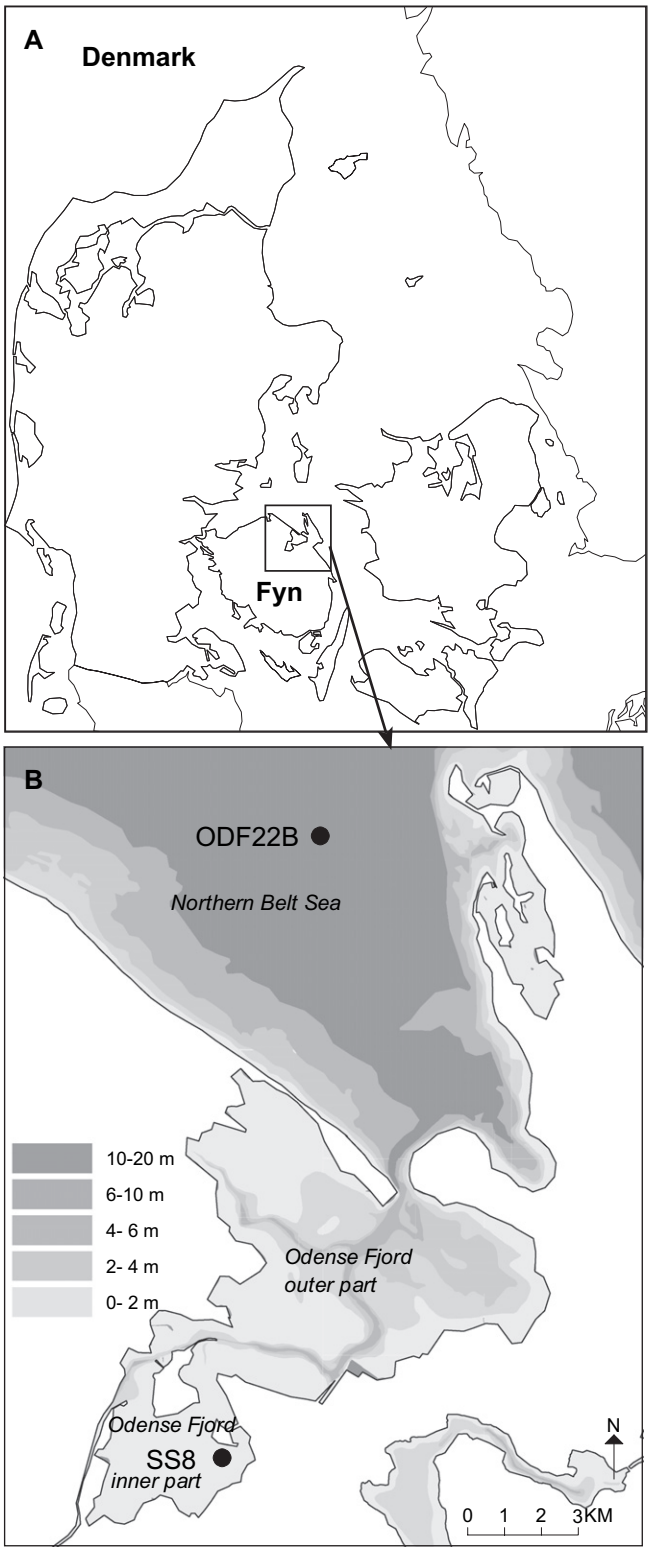

Fig. 1. (A) Map of Denmark, (B) map of Odense Fjord in the north-eastern part of Fyn with St. SS8 and the bordering Northern Belt Sea with St. ODF22B.