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Long-term effects of reduced nutrient inputs to the North Sea

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A B S T R A C T

The OSPAR Commission has identified a set of Ecological Quality Objectives (EcoQOs) to assess eutrophication in the North Sea. In order to assess the long-term effects of different river nutrient reduction scenarios in terms of these EcoQOs, a 3-dimensional coupled physical–chemical–biological model, NORWECOM, has been used. The model results show that there is a decreasing response gradient from near-shore to offshore, where the largest effects are identified along the Dutch coast, and that the full potential of a reduction is seen after 2–3 years. The EcoQOs on winter nutrients and chlorophyll are achieved for most areas. Oxygen concentrations displace no or very low response to the modelled nutrient reductions. The study also shows that the ecological quality is controlled to a large extent by winds and ocean circulation.

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1. Introduction

The OSPAR definition of eutrophication is *the enrichment of water by nutrients causing an accelerated growth of algae and higher forms of plant life to produce an undesirable disturbance of the balance of the organisms present in the water and to the quality of the water concerned*, and nutrient enrichment, due to anthropogenic activities, has been identified as the main cause of eutrophication in coastal areas (Cloern, 2001). This is in particular linked to river discharges and enhanced concentrations of inorganic nitrogen in estuaries. In 1988, the PARCOM Recommendation on reducing nutrients to the North Sea was signed by the contracting parties. This paper outlined that the inorganic nitrogen and phosphorus inputs to the coastal areas should be reduced by 50% of the 1985 concentrations (OSPAR, 1988) for those areas where nutrients cause, or are likely to cause, pollution. This decision was based on the fact that the loads in many European rivers were extremely high, an increasing frequency of harmful algal blooms was apparent, and in some areas significant bottom water oxygen reductions were occasionally observed (Anon., 1993). The recommendations are not legally binding, but function as guidelines for contracting parties in the process of designing effective measures to reduce nutrient inputs.

Assessing the eutrophication status of the North Sea is a very complex operation, where several considerations need to be taken into account. A complete assessment of all system parameters would be far too time and labor consuming to be desirable. Therefore, OSPAR developed the Common Procedure (OSPAR CP) for the Identification of the Eutrophication Status of Maritime Areas of the Oslo and Paris Convention (1997) which was updated in 2005 (OSPAR, 2005a). It provides the common framework for Contracting Parties to assess and classify the eutrophication status of the waters of the OSPAR maritime area under their jurisdiction. OSPAR CP includes guidance on the characterization of water bodies for assessment purposes including assessment parameters and threshold levels. It also gives a common understanding of the classification of areas in cases involving trans boundary nutrient fluxes, and the alignment of the classification scheme with that of the Water Framework Directive (WFD). The reporting through OSPAR CP is a national process that also includes the report on source loads and total loads of DIN and DIP in the rivers to the OSPAR Eutrophication Committee (EUC). A set of Ecological Quality Objectives (EcoQO) and Indicators (EcoQI) have been accepted as criteria to assess the eutrophication status (OSPAR, 2005b). The criteria include parameters like winter nutrients, mean chlorophyll and oxygen minimum levels.

An important tool for understanding nutrient and ecosystem dynamics is 3D models, and an increasing number of ecological models exist for the North Sea. Moll and Radach (2003) provided an

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overview of three-dimensional models that describe and predict how the marine ecosystem of the greater North Sea functions and how concentrations and fluxes of biologically important elements vary in space and time, throughout the shelf and over years, in response to physical forcing. The models differ in the complexity of the biochemical cycles included, the area covered, and the forcing ocean circulation. From the comparison between the models of the greater North Sea and observations, it has become clear that ecosystem models should be three-dimensional and should be coupled with or forced by state-of-the-art circulation models (Moll and Radach, 2003). Consequently, Skogen and Moll (2005) concluded that the single most important factor for a reliable modelling of phytoplankton and nutrient distributions and transports within the North Sea is a proper physical model.

The short term effects of reducing nutrient loads to the North Sea have been investigated in a number of studies (Lenhart et al., 1997; Anon., 1998; Skogen and Moll, 2000; Lenhart, 2001; Skogen et al., 2004; Byun et al., 2005; Wirtz and Wiltshire, 2005). The OSPAR Joint Assessment and Monitoring Programme (JAMP) required an assessment by 2006 of the expected eutrophication status of the OSPAR maritime area following the implementation of agreed measures. To assist the delivery of JAMP, EUC agreed in 2005 on an Intersessional Correspondence Group for Ecosystem MOdelling (ICG-EMO, http://www.cefas.co.uk/eutmod) to produce an assessment in the format of the Common Procedure showing the predicted environmental consequences for problem areas of achieving the 50% nutrient reduction target and, where this does not indicate non-problem area status, to predict the reduction target needed to achieve non-problem area status. The aim was also to get an overview of predictive models for eutrophication assessment and nutrient reduction scenarios and of the possibilities of adopting relevant models for use by OSPAR Contracting Parties. The main conclusion from all these studies (simulating 1–2 years) was that when reducing the river DIN and DIP loads by 50% the largest effect could be detected in the coastal areas (15–20% reduction in primary production) whereas the offshore areas had little or no response to these reductions (OSPAR, 2008).

The aim of the present study is to identify the long-term effects of reduced nutrient loads to the North Sea. This is done through three different scenarios where the effects of reduced inputs are studied over an 11 year period (1985–1995). In addition a realistic simulation (1985–2006) is done to investigate what effects the actual reduction of the river loads have had. The analysis is based on a set of boxes in the southern North Sea. Moreover the results will be linked to existing environmental targets set by OSPAR within the OSPAR CP (based on the PARCOM recommendations 88/2 and 89/4 (OSPAR, 2006)), in order to say whether the reductions are sufficient to achieve the political set management goals.

2. Material and methods

2.1. The NORWECOM model

The NORWegian ECOlogical Model system (NORWECOM) is a coupled physical, chemical, biological model system (Aksnes et al., 1995; Skogen et al., 1995; Skogen and Søiland, 1998) applied to study primary production, nutrient budgets and dispersion of particles such as fish larvae and pollution. The model has been validated by comparison with field data in the North Sea/Skagerrak in e.g. Svendsen et al. (1996), Skogen et al. (1997), Søiland and Skogen (2000), Skogen et al. (2004).

The physical model is based on the three-dimensional, primitive equation, time dependent, wind and density driven Princeton Ocean Model (POM). The model is fully described in Blumberg and Mellor (1987). In the present study the model is used with a horizontal resolution of 10 km (Fig. 1). In the vertical, 20 bottom following sigma layers are used.

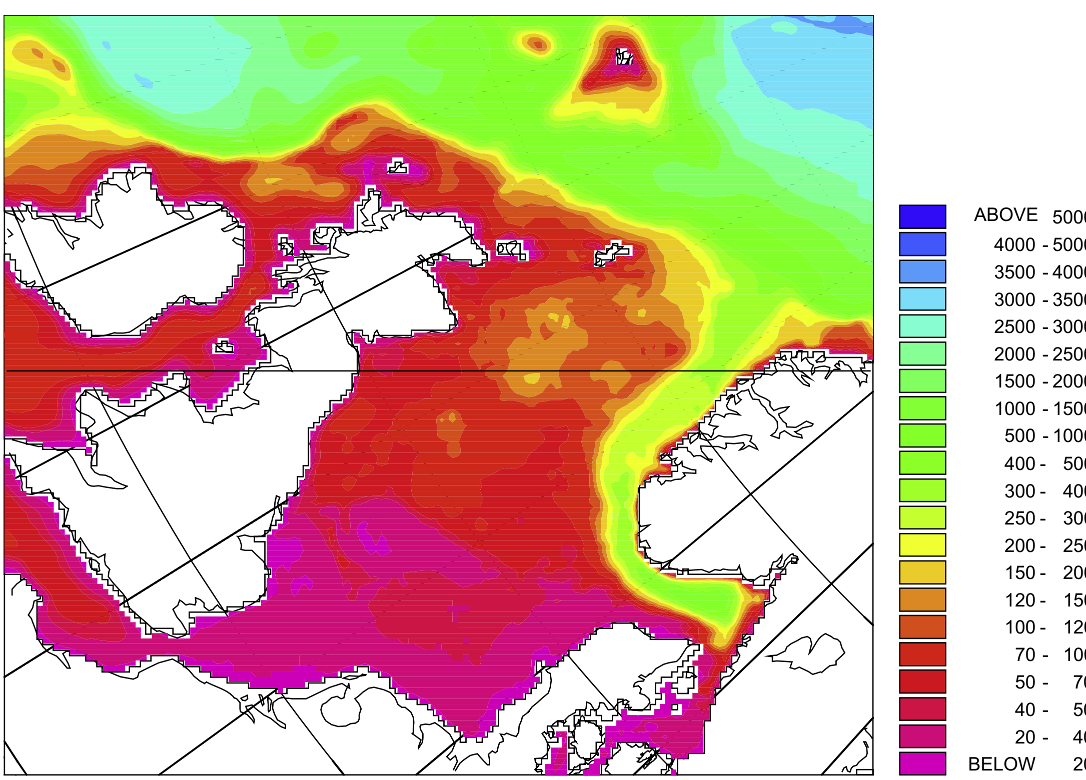

Fig. 1. Model bathymetry (depth in meters).

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