CAUSES OF OXYGEN DEPLETION IN THE SUMMER STRATIFIED OYSTER GROUNDS OF THE NORTH SEA: A MODELLING STUDY

by David Mills [1], Job Baretta [2], Paul McCloghrie [1], Piet Ruardij [3] and Suzanne Painting [1]

CEFAS
The Centre for Environment, Fisheries & Aquaculture Science

Introduction

The aim of this work is to assess the importance of climate variability in contributing to low oxygen concentration observed at the Dutch Oyster Grounds (54.5°N 4.3°E). In addition, we assess the ecological significance of low oxygen and whether the causes are natural or derive from any human interactions.

Methods

A 1D coupled biogeochemical model was used to simulate temporal changes in physical processes and the dynamics of biogeochemical fluxes through the pelagic and benthic compartments at this site. The Oyster Grounds has a mean water depth of 45 m and is thermally stratified in the summer.

Long-term high-frequency (6 h) meteorology from the ECMWF ERA reanalysis data were used to force the model. The model was initialised with winter oceanic nutrient concentrations apart from a constant atmospheric nutrient deposition. Two 5-year periods were chosen to represent warmer and colder periods and detailed results are shown for 1 year from each period.

Description of the model

The Biogeochemical Flux Model (BFM) used in this study is a development of ERSEM3. Coupled to the Princeton Ocean Model (POM) it has been described and applied in ealier work (Vichi, 2002; Vichi *et al.*, 2004). BFM is being coupled to a 3D hydrodynamic model, the General Estuarine Transport Model (GETM), described by McCloghrie *et al.*, at this meeting.

References

McCloghrie, P., Mills, D.K., Baretta, J., Bolding, K., Vichi, M., Ruardij., P. van der Molen, J and S. Painting. Towards an improved 3D ecosystem model. AMEMR, Plymouth, June 2005. Poster.

Vichi M. (2002). Predictability studies of coastal marine ecosystem behavior. Tesi di dottorato per il conseguimento del titolo di Doc. Rer. Nat. alla Facolt à di Biologia, Geologia e Scienze Ambientali dell Università di Oldenburg, Germania, 288 pp. (http://docserver.bis.uni-oldenburg.de/publikationen/dissertation/2002/vicpre02/vicpre02.html)

Vichi M., Baretta, J.W., and Ruardij, P. (2004). Link or sink: a modelling interpretation of the open Baltic biogeochemistry. Biogeosciences, 1, pp. 79-100.

Results

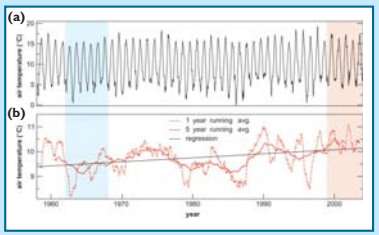


Figure 1: Air temperature from the ECMWF ERA reanalysis 6 h met forcing data for 1958-2003 for the Oyster Ground showing the monthly running average (a) and the 1 and 5 year running averages together with a linear regression trendline (b).

1963-1968: cooler period - higher windspeeds

1999-2004: warmer period - slower windspeeds

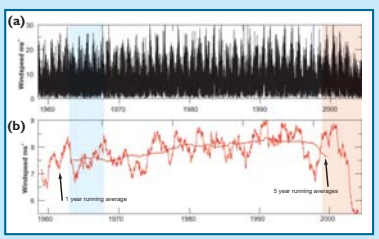
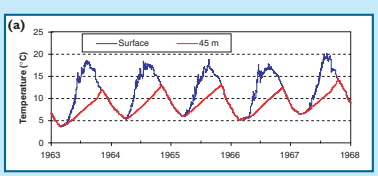


Figure 2: Wind speed from from the ECMWF ERA reanalysis 6 h met forcing data for 1958-2003 for the Oyster Ground showing the monthly running averages (a) and the 1 and 5 year running averages (b).

1963-1968



1999-2004

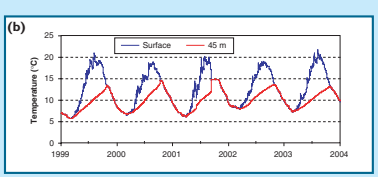


Figure 3: Modelled water temperature at the surface and just above the seabed (45 m) during 1963-1968 (a) and from 1999-2004 (b). Surface waters are warmer than bottom waters during summer, due to thermal stratification.

1999-2004

Higher water column temperatures

1963 **2003**

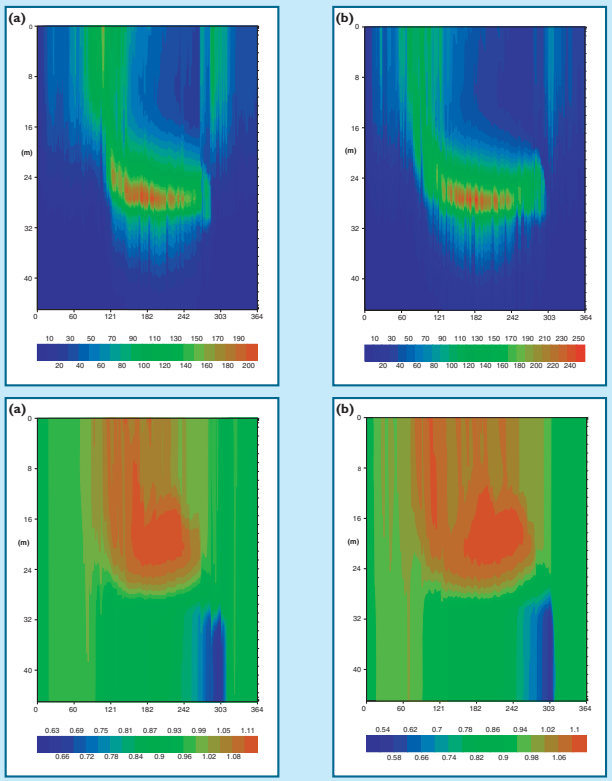


Figure 4: The vertical distribution of modelled gross primary productivity (mg C m^{-3} d^{-1}) during 1963 (a) and 2003 (b) showing the shift of the bulk of productivity from the surface layers in spring to the thermocline during summer.

Higher biological rates:

- greater annual primary production (net is 365 vs 350g C m^{-2} y^{-1})

Figure 5: Modelled oxygen saturation throughout the water column in 1963 (a) and 2003 (b) (1=100%) Note the change of scales, especially for water in bottom mixed layer.

Lower % oxygen saturation:

- BUT there is significant oxygen depletion in both years

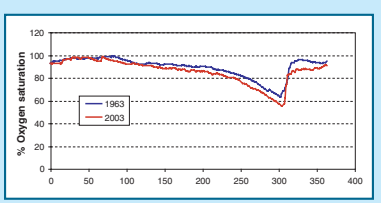


Figure 6: Time series of modelled percentage oxygen saturation in 1963 and 2003.

More oxygen depletion in bottom mixed layer

- Percentage saturation was approximately 10% lower

Conclusions

1. The 1D model showed that cold vs warm periods affect biological processes, such as production, and oxygen saturation.
2. Atmospheric climate trends promote depletion of modelled bottom water oxygen levels in the absence of anthropogenic nutrient input.
3. Further work within a 3D framework is required to quantify the role of horizontally transported anthropogenic nutrients in promoting oxygen depletion.

[1] The Centre for Environment, Fisheries and Aquaculture Science (CEFAS), Lowestoft Laboratory, Pakefield Road, Lowestoft, Suffolk NR33 0HT, UK. http://www.cefas.co.uk
[2] Noctiluca, Wassenaar, the Netherlands. [3] Netherlands Institute for Sea Research (NIOZ), P.O. Box 59-1790 AB Den Burg, Texel, The Netherlands.