OSPAR WORKSHOP ON EUTROPHICATION MODELLING

Workshop Report

Workshop Report on Eutrophication Modelling

Agenda Item 1 – Opening, Welcome and Adoption of the Agenda

1.1 The OSPAR Workshop on Eutrophication Modelling was held at the Cefas Laboratories at Lowestoft (UK) on 10 – 13 September 2007, at the kind invitation of the Centre for Environment, Fisheries & Aquaculture Science (Cefas), an agency of the UK Government's Department for Environment, Food and Rural Affairs (DEFRA). Dr Bill Camplin, the head of the Cefas Ecosystem Interaction Group welcomed the participants to the laboratories at Lowestoft which are one of currently three laboratory sites of Cefas. He highlighted the importance of the workshop's work, especially on transboundary nutrient fluxes, to provide the necessary scientific basis for policy and legal discussion relating to eutrophication (e.g. under the Urban Waste Water Treatment Directive). He also pointed to changes in the field of marine science and that the workshop showed that this discipline is well alive. He wished the workshop luck in their work and looked forward to an opportunity to welcome participants back to a new Cefas building in the centre of Lowestoft which is envisaged to be ready by 2010.

1.2 The workshop was chaired by Dr David Mills (United Kingdom) and was attended by representatives from the following seven Contracting Parties: Belgium, France, Germany, the Netherlands, Norway, Portugal and the United Kingdom. A list of participants is at Annex 1.

1.3 The chairman welcomed the participants to the meeting and whished the meeting good discussions and fruitful results.

1.4 The draft agenda for the meeting (ICG-EMO 05/1/1) was adopted without amendment. The agenda of the meeting is at Annex 2.

Agenda Item 2 – Introduction to the Workshop

2.1 The workshop noted its terms of reference at Annex 3 as agreed by EUC(1) 2006.

2.2 The chairman Dr David Mills (UK) set the scene for the workshop (click here for the presentation). He recalled the role of the Intersessional Correspondence Group on Eutrophication Modelling (ICG-EMO), the background to the ICG-EMO work, the various activities with which the ICG-EMO and the workshop had been tasked by the OSPAR Eutrophication Committee (EUC), and the requirements for reporting the results to OSPAR. The objective of the workshop was to contribute to the work under the OSPAR Joint Assessment and Monitoring Programme on:

a. an assessment of the expected eutrophication status of the OSPAR maritime area following the implementation of agreed measures (JAMP product EA-5), addressed under agenda item 3;

b. an overview of predictive models for eutrophication assessment and nutrient reduction scenarios, including transboundary nutrient fluxes within the OSPAR area and of the possibilities of adopting relevant models for use by OSPAR Contracting Parties (JAMP product ET-7). The use of models to calculate transboundary nutrient fluxes in an assessment context is addressed under agenda item 4.

2.3 On JAMP product EA-5 and nutrient reduction scenarios, the chairman recalled the results of the 2005 workshop on eutrophication modelling held in Hamburg (Germany) in September 2005. The workshop report and presentations of that workshop are available on the Cefas website http://www.cefas.co.uk/eutmod. The chairman highlighted that the main conclusions from that workshop remained still valid but that a number of uncertainties identified by that workshop needed to be addressed to build confidence in the model results. This was partly achieved through intersessional work in preparation of this 2007 workshop, compiling the forcing and validation data necessary for consistent model applications. This involved a considerable effort and resource restrictions had to be recognised.

2.4 On JAMP product EA-7, the main task of the workshop was to set up a detailed Work Programme that allows to progress work on transboundary nutrient transport with a view to delivering calculations for their use in an eutrophication assessment context.

Agenda Item 3 – National Presentations on Model Applications

3.1 Introduction

3.1 Dr Hermann Lenhart (Germany) gave an introduction to the specifications for the work on nutrient reduction scenarios carried out for this workshop (click here for the presentation). The specification of methods and data to be used in the model applications by participants had been prepared by the organising group in form of a User Guide, and data compilations, including a Data Description. He highlighted that within the conceptual approach to the workshop specifications, it had been necessary to strike a balance between the need to achieve comparable results from the different national model applications and the feasibility to achieve these results, keeping in mind that most of the participants were not funded specifically for this work.

3.2 Dr Lenhart pointed out that the message from the last workshop in Hamburg remained that improvement in model performance could only be achieved by the participants if the necessary spin-up was carried out for the models to reach equilibrium (as a minimum a spin up time of three years had been recommended), and if a consistent set of boundary conditions was used. He thanked Dr Roger Proctor from the Proudman Oceanographic Laboratory (POL) for providing a consistent set of boundary conditions derived from a large area model. In addition, data for river loads, atmospheric inputs data (from EMEP[1]) and meteorological forcing data (from ECMWF[2]) were compiled to provide consistent forcing for the models. Data were collected for the year 1988/1989 for calibration and 2002 for validation. Following a proposal from the organising group, EUC agreed in a written procedure in the 2006/2007 cycle of meetings that reduction scenarios will be performed for the year 2002, taking into account the reductions achieved in the period 1985 to 2002. The reason for the change in the reference year as agreed in the terms of reference was that no validation data were available for 1985. Another change in the conditions for model applications compared to the last 2005 workshop concerned the definition of target areas; these were changed to allow future work on transboundary nutrient fluxes to build on the results of this workshop. There were still a number of open questions which the organising group had identified and on which participants were asked to give their feedback. This included for example the question on the need for a common set of forcing data on suspended matter to calculate light attenuation for use in future model applications.

3.2 National presentations of model applications

a. United Kingdom – model application

aa. Presentation by Cefas

3.3 Dr Sonja van Leeuwen (UK) presented the results of the Cefas GETM-BFM model application to one calibration station (out of five used), five target areas for validation, and the six target areas for the reduction scenarios (click here for the presentation). The General Estuarine Transport Model GETM is a three-dimensional hydrodynamics model, and includes the one-dimensional model GOTM to resolve processes in the vertical. Biogeochemical Flux Model BFM is an ecosystem model developed from the ERSEM model, and includes nutrients, phytoplankton, micro and mesozooplankton, bacteria and organic matter, and also a benthic module including nutrients, filter feeders, bacteria, zoobenthos and organic matter. The basic variables are nitrogen, phosphorus, silicate and carbon. In the pelagic system, biological material is transported by the hydrodynamic model. For the workshop, the model was amended to specifically include a North Sea diatom type as one of the 4 phytoplankton functional groups, and a parameterisation was implemented for local SPM resuspension by surface waves. The model was run on a 6 nautical mile grid, with 25 layers in the vertical, spanning the North Sea, English Channel, and part of the Baltic Sea. The model was calibrated for 1989 by tuning the SPM parameterisation on five widely separated stations of the NERC North Sea Project data set. The spin up procedure included ten years for the standard run, and a subsequent 9 and 7 years for the 50% and 70% reduction scenarios respectively. Spin up achieved approximate equilibrium for the pelagic system, but not for the benthic system. Further spin up was not carried out because of time constraints.

[1] The Co-operative Programme for Monitoring and Evaluation of the Long-range Transmissions of Air Pollutant in Europe (EMEP), set up under the UNECE Convention on Long-range Transboundary Air Pollution.
[2] The European Centre for Medium-Range Weather Forecasts (ECMWF).

3.4 The validation of the hydrodynamics showed good performance for temperature and stratification, and reasonable results for salinity. Largest deviations were found near the Norwegian coast in the Skagerrak. The results suggest that the model may overestimate the mean northward residual flow through the Strait of Dover. The validation of the biology for the target areas showed reasonable model performance, but results were poorer than those achieved for the calibration. The results were particularly good for phosphate. For nitrate, offshore values were too high through-out (in contrast to the calibration), whereas near-shore winter values were too low. Oxygen levels were under predicted in some areas and overpredicted in others. Offshore summer mean chlorophyll levels were overpredicted. The SPM parameterisation captured the seasonal cycle, and some of the observed high frequency variability. It was suspected that at least a number of the discrepancies between model results and observations were related to the reduced ability of the model to transfer nutrients from the pelagic to the benthic system, which, in combination with the spin up procedure of repeating a year with high runoff lead to saturation of the pelagic system with non-limiting nutrients. The benthic-pelagic coupling was still regarded as requiring further development.

3.5 The reduction scenarios showed the largest effect in terms of reductions of winter nitrate and phosphate concentrations. Mean chlorophyll, minimum oxygen and net primary production were much less responsive to reducing nutrient inputs. These results were evident both from maps of the spatial distribution, and from the results for the target areas. Maximum chlorophyll concentrations showed an intermediate response. Apart from maximum chlorophyll, all variables, which had exceeded the thresholds in the standard run, fell beneath the threshold for a 50% reduction. The strong influence of the reductions seemed to suggest that the suspected saturation with nutrients that we suspected in the standard run did not occur in the reduction runs.

3.6 In the discussion, the following views were expressed:

a. the results suggested that for model purposes chlorophyll maximum was not a meaningful parameter. The use of the 90th percentile would be more appropriate;

b. there were only limited effects in response to nutrient reductions at the boundaries. This could be explained by the negligible effect of river inputs on nutrients received from the Atlantic as specified by the boundary condition;

c. the inconsistent spatial distribution patterns of DIN and DIP could be explained by the spin-up for the year 2002 which was a particularly wet year, resulting in stronger than normal near-shore salinity gradients. By repeating the year in the spin up, the system might have been biased towards higher spatial distribution.

bb. Presentation by POL

3.7 Dr. Roger Proctor presented the results of the Atlantic Margin Model (POLCOMS-ERSEM), which was also used to derive boundary conditions for the application of the national models presented at this workshop (click here for the presentation)[3]. The physical model POLCOMS calculates hydrodynamics, temperature and salinity. The biological model ERSEM calculates nitrogen, phosphorus, silicate and carbon cycling in coupled pelagic and benthic systems. The pelagic includes 4 types of phytoplankton, bacteria and 3 types of zooplankton. The benthic system includes suspension feeders, bacteria, deposit feeders and meiobenthos. The model spans the North-East Atlantic ocean and North Sea, and is nested in FOAM, which covers the North and South Atlantic. It has approximately 12 km resolution, and 34 s-levels in the vertical. Inherent Optical Property (IOP) fields from SeaWiFSs remote sensing data were used to represent non-biotic absorption concentrations (a proxy for SPM). Spin-up included a realistic run from 1988 to 2001, with subsequent repeated runs of 2001 and 2002 (both 3 times). The model is routinely used at the UK Met Office for forecasting, and was modified for the workshop by adopting the supplied river data.

3.8 The following comparisons of output from the physical model with observations were presented:

- winter and summer SST fields compared with AVHRR satellite observations
- summer temperature and salinity cross-sections compared with the provided observations.

3.9 The SST fields showed that the model reproduced the spatial distribution of the general features with an annual mean underestimation of approximately 0.5ºC and an RMS of 1ºC. The cross-sections indicated

[3] Following the workshop, the model results presented at the workshop were recalculated to correct calculation errors; at the time of adopting the workshop report, the recalculated results were still under review by UK-POL.

that the model captured the main density structures, although underestimating the depth of the thermocline by about 5m.

3.10 Graphs of the seasonal cycle of standard and reduction scenarios at stations CS northwest of Dogger Bank and West Gabbard in the southern Bight showed negligible change at CS and very limited change in the nutrient concentrations at West Gabbard but not in chlorophyll, silicate and oxygen.

3.11 The assessment results showed no change in the offshore target areas, and only minor changes in coastal target areas.

3.12 In the discussion, general consideration was given to methods for validating SPM. It was observed that satellite imagery often showed lower SPM values than observed. This was linked to uncertainties of satellite images which would miss high values, usually associated with cloudy conditions. Also ship-based monitoring missed these values. Only appropriately located buoys with continuous measurements could pick up realistic values..

b. Belgium – model application

3.13 Dr. Geneviève Lacroix (Belgium) presented the results of the Belgian MIRO&CO-3D model applied to the Belgian and adjacent French waters (Channel) for validation and to one of the five target areas (UK-C1) for reduction scenarios (click here for the presentation)[4]. MIRO&CO-3D is a biogeochemical model designed to study eutrophication in the Channel and the Southern Bight of the North Sea. It simulates the annual cycle of inorganic and organic carbon and nutrients (nitrogen, phosphorus and silica), phytoplankton (diatoms, nanoflagellates and *Phaeocystis*), bacteria and zooplankton (microzooplankton and copepods) with realistic forcing (meteorological conditions and river loads). A spin-up of three years was sufficient to reach equilibrium. The model was set up in accordance with the Workshop User Guide.

3.14 Validation was with monitoring data showed adequate agreement with model results in the assessed areas, with the model tending to;

- underestimate nitrogen (except for an overestimation for UK waters);
- overestimate phosphate concentrations, and;
- delayed onset of the spring bloom and possibly chlorophyll maximum concentrations.

3.15 Reduction scenarios were run for Belgian and French (Channel) waters and target area UK-C1. With the exception of chlorophyll, hardly any change was observed in the reduction scenarios for target area UK-C1. This could be explained by the fact that the model had not been calibrated for UK waters and by the proximity of the area to the boundary condition. For the Belgian waters, reduction of nutrient loads and primary production showed clear reduction responses in winter nitrogen concentrations. Winter DIN concentrations moved below the assessment level only at a reduction at 70%. Responses of chlorophyll concentrations were less explicit but resulted in concentrations below assessment levels.

3.16 For assessment and nutrient reduction purposes, three scenarios were applied showing the role of *Phaeocystis* in the classification of Belgian waters under the Common Procedure if (i) the parameter was not taken into account, and if it was taken into account using (ii) the national assessment level agreed under the Common Procedure (10^6 cells/l) or (iii) an "ecological" criterion of >150 mg C/m^3 (*Rousseau*, personal communication).

3.17 The model results showed that the model was sensitive to the choice of spatial dimensions. This raised the question how to derive an acceptable spatial dimension to better support policy conclusions. The model also showed sensitivity to total suspended matter (TSM); this was demonstrated in the different results when applying either the Belgian TSM forcing data or the TSM forcing provided for the workshop.

3.18 In the discussion, it was noted that model performance could be improved by avoiding any attempt to smooth TSM (suspended particulate matter is regarded as equivalent to TSM) derived from observations. Approaches that introduced random fluctuations in the TSM field were recognised to be desirable rather than imposition of any smoothing. An alternative to using observations, that were often sparse in spatial and temporal resolution, was to use a simple model of the type developed and implemented by Cefas. The

[4] Following the workshop, the model results for UK-C1 were recalculated for their scoring to ensure comparability with the scoring method used by other participants.

modelled TSM (SPM) fields generated by the model provided a sufficiently good fit with field observations to provide confidence in its wider use.

c. Netherlands – model application

3.19 Mr Hans Los and Ms Nicki Villars (the Netherlands) presented the results of the Dutch Delft3D-ECO/GEM model application (click here for the presentation). GEM is part of DELWAQ and is based on a suite of models with hydrodynamics supplied by Delft3D-Flow, nutrients and primary production from Deflt3D-ECO, and suspended particulate matter (SPM) from Deflt3D-SED. SPM forcing was used from a dynamic SPM model to simulate the weekly SPM fluctuation and the subsequent availability of light for phytoplankton growth. The model system is highly flexible in terms of the grid size and resolution, the time step, the processes that are modelled and the ability to include other user defined processes. The variables modelled include nitrate, phosphorus, silicate and oxygen with three forms of detritus at different decay rates. The biological model simulates primary production and includes 4 phytoplankton functional groups, including *Phaeocystis*, but secondary production was not included. The model set up and the calibration for 1989 followed the instructions of the Workshop User Guide. Validation was done for the year 2002, based on two series of simulations: (i) results from a model run using Dutch data for boundary conditions was compared to observations from six Dutch monitoring stations, for the period 1981 – 2003; monthly mean data were used for calculating the cost function; and (ii) a calculation using the workshop boundary conditions was compared to the data from target boxes, using the cost function.

3.20 Validation for Dutch stations showed adequate agreement between simulations and observations with some delay in modelled depletion of silicate and higher winter phosphorus and low winter chlorophyll concentrations in some areas. The result of the validation for Dutch stations using OSPAR forcing data was generally very good with the exception of SiO_2 and PO_4 at northern stations which was related to the use of the boundary condition. In conclusion, model results when forced with observed (Dutch) data provided better results than use of OSPAR forcing data. The cost function values resulting from this exercise for the individual Dutch monitoring stations were good. Surprisingly, the cost functions derived for the OSPAR target areas did not reflect the good agreement seen when measured and modelled data were plotted on the same graphs. Overall, the validation results gave confidence in the model for reductions scenarios and related results.

3.21 The reduction scenarios for 50% and 70% showed that the nutrient parameters were particularly sensitive to reduction in nutrient loads. Reduction of nutrient concentrations were most apparent where freshwater formed a significant component of the water fraction. Chlorophyll mean concentrations showed only small changes in the reduction experiments, including in (coastal) areas where reductions in nitrogen concentrations were highest. This suggested that light limitation may be responsible. The light regime was strongly influenced by SPM and it raised the question how light regimes were derived in the different models presented at the workshop. Another factor to take into account was the potential importance of phosphorus limitation which may occur in these (continental) coastal areas as a result of the reduction in load since the 1980s. Responses of chlorophyll maximum concentrations were even smaller and showed hardly any improvement in the scenarios. The results for primary production showed, similar to chlorophyll, a correlation with the combined factors of significant nutrient reduction and light availability. Finally, the reduction scenarios showed that Channel water and North Atlantic water had a significant influence on the nutrient input and concentrations for large areas of the North Sea for which sources were not significantly reduced in the boundary condition. Overall, the reduction scenarios for the five target areas suggested some but modest improvement of nutrient parameters (DIN and DIP) at the coastal boxes NL-C2, G-C1 and UK-C1. For chlorophyll load reductions had limited effect on scoring against the assessment levels: maximum chlorophyll was mostly above the assessment level except for UK-C1, whereas mean chlorophyll was mostly scored as below or at the assessment level, except for G-C1. *Phaeocystis* remained above assessment levels at G-C1, G-O2 and NL-C and showed only modest improvement in areas in relation to load reductions. Oxygen was consistently above assessment levels.

3.22 In the discussion, the following views were expressed:

a. the different responses of chlorophyll mean and maximum concentrations to nutrient reductions indicated that mean chlorophyll was not primarily controlled by nutrients but by light limitation in the simulation;

b. lack of sensitivity to chlorophyll (mean/max) may also be linked to silicate which is being reduced in the model.

d. Germany – model application

3.23 Dr Wilfried Kühn (Germany) presented the results of the application of the ECOHAM4 model to the five target areas (click here for the presentation)[5]. The model is a further developed version of the model used for the first workshop in 2005 which is more complex including more state variables. The model includes the state variables nitrate, phosphorus, carbon, silicate, 2 phytoplankton groups (flagellates and diatoms), 2 zooplankton groups (micro/meso), bacteria and detritus. The model was calibrated with the year 1995 with an overall satisfactory result. There was only some deviation due to high simulated chlorophyll concentrations in the central North Sea. For the spin up the year 2002 was run three times. The model was set up in accordance with the Workshop User Guide. It was noted that 2002 was a special year as it had a positive winter NAOI (North Atlantic Oscillation Index). In the future, improvements were planned of the benthic model and in the development of a dynamic silt module.

3.24 Validation for the year 2002 was carried out for the five target areas. The results indicated an underestimation of winter nutrients which might be a consequence of the boundary conditions, especially at the northern boundary with the open North Atlantic. Nitrogen, but also phosphorus and chlorophyll, behave differently depending on the boundary data used either from the POLCOMS model or from WOD (World Ocean Database). In the standard run, problems occurred in relation to oxygen which has subsequently been excluded from the German assessment.

3.25 In general, the reduction scenarios resulted in considerable reductions of nutrients, especially winter DIN (up to 50%); responses of winter DIP were much less pronounced in the reduction scenario. North-West of the Danish coast, a remarkable reduction (25 – 25%) in phytoplankton carbon biomass could be observed as response to 50% nitrogen reduction. The results of the reduction scenarios varied for the target areas, with pronounced reductions in nutrient concentrations in NL-C2 and less pronounced reduction in environmental parameters in the German and Dutch offshore areas (G-O2 and NL-O2). For G-C1 modelled assessment parameters were still above assessment levels (thresholds) even at a nutrient reduction of 70%.

3.26 In the discussion, the following views were expressed:

a. UK-POL doubted that the use of forcing from POLCOMS had significant impact on the winter nutrient concentrations along the boundaries. A comparison of the POLCOMS winter nutrients with World Ocean Database data showed that there was an underestimation but not an unreasonable agreement;

b. there was a pronounced reduction of nitrogen concentrations in response to nutrient reductions North-West of the Danish coast. It was not clear whether this could be explained by light limitation in the German Bight. Another explanation could be rapid export of nutrient rich water that washed out nutrients from the inner German Bight and were subsequently transported further North;

c. the simulated reduction in nutrient concentrations of up to, and even higher than, 50% (with only a 50% nutrient load reduction scenario) could be explained if riverine nutrient inputs in 2002 were greater than in 1985;

d. the results for chlorophyll confirmed Dutch model results in which no phosphorus reduction was applied in the reductions scenarios, as a 70% reduction in actual riverine nutrient inputs had already been achieved. In a situation of large nitrogen surplus, phosphorus becomes the limiting growth factor. When reducing nitrogen loads in the scenario, the N/P ratio changed. This explains why chlorophyll is not responsive.

[5] Following the workshop, the model results presented at the workshop were recalculated to correct calculation errors.

e. Norway – model application

3.27 Dr Morten Skogen (Norway) presented the results of the NORWECOM model application to the five target areas (click here for the presentation). The model is a coupled physical-chemical-biological model for the whole North Sea. The set up of the model, the boundary conditions and the forcing used did not follow the Workshop User Guide. The model had been set up with time series for the period 1985 – 2005 in one run and with a spin-up of 4 years based on 1985.

3.28 For the reduction scenario of 50%, the year 2002 was used with 1985 river loads with a spin-up of 5 years. For validation a realistic run was carried out for the period 1985 – 2005 of time series for nutrient concentrations, chlorophyll and oxygen. The long time series showed that in coastal boxes the reductions in winter DIP concentrations were larger than for winter DIN whereas in the offshore boxes no trends could be detected. This was probably due to too many different water masses influencing the offshore boxes and UK-C1; for the Netherlands and Germany, the mean values were not much affected by river inputs. Similarly, chlorophyll and oxygen showed only weak trends.

3.29 The nutrient reduction by 50% resulted in very little environmental response offshore, especially in the UK box. The scoring of the model results did not necessarily reflect the absolute reduction achieved due to the applicability of different assessment levels in the various boxes. This was illustrated for example for chlorophyll maximum, which was scored below assessment level for the Netherlands but above for Germany although the values simulated for Germany were lower than those for the Netherlands.

3.30 In the discussion, the following views were expressed:

a. the mean of the oxygen minimum concentration over large boxes like the target areas was limited in its meaning and interpretation. The more appropriate scale would be to look at the values for example at the scale of the river plume;

b. the model results showed that offshore areas were not affected by riverine nutrient reductions but only coastal areas were. This raised the question about the usefulness of assessing offshore areas for anthropogenically induced eutrophication;

c. the lack of trends in the minimum oxygen concentrations pointed to the fact that this parameter was mainly driven by meteorological conditions (e.g. wind) and not by nutrients;

d. the capability of oxygen to indicate a cause-effect relationship in the eutrophication process was limited (especially in the offshore region) and would need to be carefully considered in the light of the environmental factors of the area concerned in cases in which the oxygen concentration would determine a shift in the area classification under the Common Procedure.

f. Portugal – model application

3.31 Professor Ramiro Neves and Mr Bartolomeu Bernardes (Portugal) presented the results of the MOHID model application to the Tagus estuary and the five target areas (click here for the presentation). MOHID is a hydrographical model with a suite of modules for water properties, water quality module (i.e. ecological processes), bottom interface module, sediment consolidation and bioturbation, sediment properties and quality. The model is designed to assess water quality following the implementation of the Water Framework Directive, Urban Waste Water Treatment Directive, Nitrates Directive and under the OSPAR Common Procedure. By dividing an area into volume boxes, the fluxes of water masses in time (residence time) and space (transboundary transport) can be simulated.

3.32 The application of the model to the Tagus estuary showed good agreement with monitoring results with a slight overestimation of nitrogen. A 50% reduction of nitrogen in the Tagus estuary showed a clear response of nitrate (~ -50%) but hardly any effects on phytoplankton, organic matter and ammonium. In the light of the environmental situation of the Tagus estuary this confirmed that reduction of nitrogen discharges under the Urban Waste Water Treatment Directive would not modify the trophic level of the estuary. The reason for this was that primary production was light limited. As a consequence, nitrate had a conservative behaviour that was demonstrated by a linear evolution along the salinity gradient. The absence of any correlation between chlorophyll and nutrient was also a consequence of light limitation. The limiting factor for chlorophyll was turbidity resulting in chlorophyll responses mainly in areas with low turbidity. The N/P ratio indicated that in the last 25 years the system had been shifting towards a situation where phosphorus was becoming the limiting factor.

3.33 For application in the North Sea, a 3D ecological model was set up for the year 1998. Therefore, the model did not use the forcing data (except for riverine inputs) and boundary conditions provided for the workshop. The model was nested into a 2D hydrodynamical model that had been validated at tide and showed good comparison with observation data. The spin-up was 1 year. River channels were set up to identify freshwater fluxes. The model was validated with observations from the monitoring stations in the target boxes and with satellite imagery (phytoplankton). The model fitted well with observations in temperature, salinity, ammonium and phytoplankton concentration and distribution (except for the most northern Dutch station) but overestimated nitrogen and phosphorus. The difficulty in validating the model for phytoplankton distribution was the short life time of the bloom (~ 4 days from start to end) and the difficulty for satellite images to capture this event (clouds masking the surface). The model seemed to fit well with early and late summer observations but was overestimating phytoplankton in the time between. It was not expected that phytoplankton reacted to nutrient reductions as light was a limiting factor; SPM played a key role in the region. The limitations of the model were the boundary conditions used and the model's complexity (it can simulate more species).

3.34 In the discussion, the following views were expressed:

a. before adding more complexity to the model to improve results, a more detailed analysis of the model's behaviour would be advised;

b. the use of a 2D hydrographic model was not recommended in relation to investigation of nutrient reduction scenarios. Experience in use of such models showed that they have problems in simulating the flow through the Channel affecting the Dutch coast; the flow was mostly underestimated and deviated from known transport pathways;

c. caution should be observed in considering the role of light and nutrients. The way the model was set up enhanced the role of light and did not support a global conclusion of light being the limiting factor. Light levels had not changed over the last decades;

d. nitrogen was still the limiting factor in the North Sea. This may have been masked in the model because of its high level of nutrients which resulted in any other factor being the limiting one.

g. France – model application

3.35 Dr Alain Ménesguen (France) presented the application of ECO-MARS3D (3D code using finite difference ADI and anti-diffusive TVD schemes) to the Bay of the Seine, the northern coast of France and the Belgian coast, and target area UK-C1 (click here for the presentation). The model was designed to simulate the primary production in the Channel with focus on the bloom of two harmful algal species: *Phaeocystis* which is relevant for the eutrophication in the eastern English Channel and the Southern Bight of the North Sea, and *Karenia mikimotoi* whose occurrence is not linked to eutrophication. The models also quantified the contribution of the main river inputs along the French and Belgian coast to primary production. The model outputs winter DIN and DIP, N/P ratio, chlorophyll mean and maximum concentration and the diatom/non-diatom ratio. It had not been possible to follow the instructions of the Workshop User Guide to full extent. Therefore the set up of the model, the boundary conditions and the forcing applied did not fully comply with the workshop specification.

3.36 Validation was done using satellite imagery for temperature for 2003. This was an especially hot summer resulting in stratified water. For chlorophyll satellite imagery was used and *in-situ* observations for *Phaeocystis*, respectively, for 2002. The model compared well with observations, tending to

a. overestimate temperature by 1°C. In the Bay of Seine, temperature seemed to be slightly too low;

b. overestimate time and concentrations of chlorophyll in April and May in the Bay of Seine;

c. overestimate *Phaeocystis*, especially in the Bay of Seine.

3.37 The standard run for 2002 showed high nutrient concentrations, especially of nitrogen in the Bay of Seine. Mean chlorophyll concentrations were surprisingly low, except in estuaries (e.g. Somme), given the high productivity in the area. Chlorophyll maximum was very high for the plumes of Seine, Scheldt, Rhine and Thames. Primary production could be particularly high in the Bay of Seine. The diatom/non-diatom ratio could be low in some areas due to blooming of *Karenia* which is not related to nutrient enrichment.

3.38 The reduction scenarios included a reduction of both nitrogen and phosphorus, by 30% and 70% each. Results for a 50% reduction were derived from interpolation of the 30% and 70% reduction. The 70% reduction showed clear effects on winter DIN concentrations along the French, Belgian and Dutch coast with less pronounced reductions in winter DIP concentrations. The reduction in nutrient concentrations was particularly high off the UK coast in surface water; this pointed to the in-homogeneity of the area (salinity range of 30 – 34.5). While there were clear reductions in chlorophyll maximum concentrations relating to Seine, Scheldt and Rhine this was not so much the case for the Thames, and was less pronounced for chlorophyll mean concentrations in all areas. At a 70% reduction, the French coastal strip responded with a clear decrease in nutrient concentrations, a non-linear response of chlorophyll, and a strong response in *Phaeocystis* but no change in diatom/non-diatom ratio. For the Belgian coastal zone, there was a reduction in winter DIN but not for DIP, a better reduction for *Phaeocystis* but hardly any difference in response of chlorophyll to the 30% and 70% reduction. This is surprising as reduction was mainly linked to nitrogen reductions; through excess of diatom bloom even very low levels of phosphorus were taken up. One possible explanation could be that the *Phaeocystis* module of the model was too sensitive as it was designed to simulate the different stages of the life cycle of *Phaeocystis* (e.g. linking to silicate).

3.39 In the discussion, the following views were expressed:

a. comparability with the Belgian results on *Phaeocystis* was difficult as both loads – nitrogen and phosphorus – were reduced;

b. the limiting factor for *Phaeocystis* may be different in local systems, e.g. nitrogen in Belgian waters and phosphorus in French waters.

h. Wadden Sea model application

3.40 Dr Bert Brinkman (the Netherlands) presented the results of the EcoWasp model application to the Western part of the Dutch Wadden Sea area (click here for the presentation). The model is set up for the Wadden Sea and designed to simulate effects of human activities, including fisheries, shellfish research, extension of the Rotterdam harbour, or effects of harbour sludge disposal. The model uses a simple hydrodynamic model coupled with an ecological module (including filter feeders). For suspended particulate matter computed forcing data had been used from a simple sediment model to simulate high frequency data. For Lake Ijssel the boundary conditions provided for the workshop were used which matched well with the conditions normally used; boundary conditions for the North Sea were compiled separately. A spin up of 20 – 30 years was needed. Reduction scenarios showed good response of nitrogen. Due to nitrogen removal, phosphorus became the limiting factor and the N/P ratio increased. The results were sensitive for organic matter input from Lake Ijssel.

3.3 Discussion and conclusions

3.41 The workshop critically reviewed the conditions provided for the model applications, the performance of the models and their results. Among the main issues discussed were:

a. forcing data provided for the workshop;

b. a need for forcing models with organic riverine load and suspended particulate matter;

c. the boundary conditions provided for the workshop;

d. the spin-up results and lessons learnt;

e. validation of model results;

f. the use of cost-functions for comparing model performance;

g. the sensitivity of parameters in the reduction scenarios;

h. the results of the reduction scenarios.

3.42 The workshop also considered a request from Belgium and France to extend the reduction scenarios to the Belgian and French areas they had assessed to allow a better comparison of model results. The representatives from Germany, the Netherlands and the UK indicated that they were willing to prepare such reductions.

3.43 Based on the discussion, the workshop agreed:

a. on the draft assessment of the environmental consequences for problem areas following nutrient reductions at **Annex 4;**

b. that the organising group should update **Annex 4** and circulate it for comments to the workshop participants. The update should include a review of sections 3 and 4 in the light of confirmed UK-POL model results and primary production values reported by participants for inclusion in the report. The update in written procedure should be complete by 30 November 2007;

c. to invite participants to prepare reduction scenarios for two additional target areas for the Belgian and the French coast by 18 January 2008. To facilitate this, the organising group of the ICG-EMO will provide to the participants by 2 November 2007 a definition of the target areas and forcing data for these areas from Belgium and France;

d. that the organising group of the ICG-EMO should prepare a further update of **Annex 4** of the workshop report with results for reduction scenarios of the two additional target areas and will

(i) circulate it to those participants who took part in this additional exercise by 15 February for comments;

(ii) finalise the updated report by 10 March for presentation to EUC in April 2008;

e. to publish the results of the workshop in a common paper in a peer reviewed scientific journal.

Agenda Item 4 – Transboundary nutrient transport

4.1 Introduction

4.1 The workshop noted the agenda for the discussion of transboundary nutrient transport (Annex 2).

4.2 Dr David Mills (UK) introduced the aspects of the terms of reference on transboundary nutrient transport set out by EUC(1) 2006 (Annex 3) that need to be addressed by the workshop (click here for the presentation). He recalled that the priority would be to agree the basic concepts and approaches for calculating transboundary nutrient transport as the basis for further work, and to set up a work programme for implementing this. He recalled the definition of eutrophication in the OSPAR framework requiring anthropogenic nutrient enrichment causing accelerated algae growth to produce undesirable disturbance to the balance of organisms present in the water and to the quality of water concerned. This definition meant that not only the fluxes of nutrient but also their subsequent consequences in terms of eutrophication status for the receiving target area needed to be considered. The objective was to present results to OSPAR in time so that these could be taken into account in the Quality Status Report (QSR) in 2010. For this purpose, it was crucial to achieve further input from EUC on how the results from transboundary nutrient transport calculations should be presented to best contribute to EUC's work and the QSR.

4.3 Mr Richard Moxon (UK) set out the policy perspective for work on transboundary nutrient transport (click here for presentation). He illustrated the different general policy drivers (sustainable use, precautionary principle, prudent use of tax-payers money) and more specific drivers such as the OSPAR Eutrophication Strategy and EC legislation (including for example the Urban Waste Water Treatment Directive, the Nitrates Directive, the Water Framework Directive and related implementation instruments, and the proposed Marine Strategy Directive). Under the OSPAR Common Procedure as well as EC legislation, areas needed to be identified, which may be affected by nutrient inputs where these may cause undesirable disturbance, with a view to informing actions to combat eutrophication. In this context, transboundary transport of nutrients may play a role in identifying the sources of nutrients and where the priorities for action should be. A practical use of results from transboundary nutrient transport calculations may be to provide evidence base in disputes over identifying such areas or implementing related measures where a state claims that eutrophication in its waters is caused by nutrient inputs of another state. Such disputes may arise under the OSPAR Common Procedure and EC legislation. In conclusion, the question to which policy makers sought answers was: How significant are the nutrient loads from different sources, and will reductions of loads from these sources solve the eutrophication problem in a particular area? This would help guiding decision where actions were most cost-efficient.

4.4 In the discussion, the following views were expressed:

a. a simple mass balance of loads, comparing relevant river loads with e.g. Channel inputs could give a indication of sources and their contributions to nutrient loads without need for modelling;

b. there was a good understanding of physical process to address mass balance components and simulate residence time;

c. the current understanding of the ecosystem in relation to organic matter had not yet sufficiently developed to adequately address matter in nutrient budgets;

d. there was a need to define what a "significant load" is which is received through transport by an area; otherwise any contributions through transport (e.g. in the order of 10%) could be used as an excuse for not reducing inputs from upstream sources.

4.2 Presentations

a. United Kingdom

4.5 Dr Liam Fernand (UK) presented results from the 2002 Dutch project "Plume and Bloom" on the transport and fate of UK nutrient inputs into the southern North Sea (click here for the presentation). The project had been set up to provide evidence on the question raised by the Netherlands with the UK that nutrient inputs from English East-coast rivers were transported to the Dutch coast where they contributed to eutrophication effects. It was the task of the project to address the questions whether the water from English East-coast rivers was transported to the Dutch coast, whether it contained nutrients, whether growth occurs and what limited it, what else might be occurring and how important this was in comparison to other sources. These questions were addressed based on observations from fixed and drifting buoys, current meter mooring, and scanfish and CD lines. One of the challenges in assessing these observations was to tackle the different time scales, an issue which would also need to be addressed by models. For biological variables in models, correct timing would be essential; small errors may be critical for the outcome. The messages from the project were that:

a. particulate nutrient transport was important and a distinction needed to be made between the local sources, riverine loads and the loads coming from other sea areas;

b. the role of nutrient regeneration needed to be considered to give a better understanding of chlorophyll observations. A quantification could for example be achieved by nitrate/ammonium ratio giving an indication of the nutrients taken up and those regenerated;

c. there was a need to better combine models and observations from operational oceanography;

d. effective use could be made of existing ecosystem models provided that an appropriate scale was used. Models were for example well suited to calculate land-based sources to the total flux across a given maritime area;

e. what were the best parameters to use in an eutrophication assessment framework? For example, what was gained by focussing on chlorophyll which was not a natural product of models and would it be more useful to measure rates than states?

4.7 In the discussion, the following views were expressed:

a. there was also an issue of spatial scale for models given the possible small spatial extent of blooms which might not be supported by the grid;

b. the oxygen observations provided a good example of time resolution needed for validating model results;

c. the observations showed a persistent slight oxygen under-saturation in winter which pointed to ongoing remineralisation or benthic activities in this part of the year and to oxygen production being dominated by oxygen consumption over the years.

b. Norway

4.8 Dr Morten Skogen (Norway) presented the outcome of a master thesis[6] to identify long-term effects of reducing nutrient loads to the North Sea (click here for the presentation). The work draws on the results of nutrient reduction scenarios of the 2005 OSPAR workshop on eutrophication modelling in Hamburg. One aspect of particular interest was to identify main forcing for observed interannual variability. A comparison of oxygen depletion with the North Atlantic Oscillation (NAO) confirmed that oxygen concentrations were primarily driven by wind. The observed interannual variability also indicated possible nutrient transports. Dr Skogen illustrated examples that models were already capable of tracking water masses. This included different ways of using conservative tracers to calculate transport rates for water masses through North Sea sections, to reconstruct winter DIN fluxes and their interannual variability, to label water masses to track their passage through the sea, and to use salinity-based tracers of monthly transport of German Bight water fractions.

4.9 In the discussion, the following views were expressed:

a. there was a difficulty in scales for comparing oxygen concentration with NAO;

b. oxygen depletion was biologically controlled, and only at the endpoint of the processes wind events played an important role in defining what the oxygen minimum was;

c. tracing water masses might be straight forward but it did not say anything about the sources of the water or their contribution to eutrophication effects. These latter two issues were demanding to implement through models.

c. Netherlands

4.10 Dr Meinte Blaas (Netherlands) presented three available methods to address transboundary nutrient transport (click here for the presentation). Passive tracer transport models helped to trace inert substances and water masses while process-based models helped to relate local responses to sources when non-linear and interacting biogeochemical processes acted. Tracer model methods included:

a. a derivative method which was based on sensitivity testing and would work for any type of conceptual model. It gave insight in response in terms of ecological effects but only in linearised sense. It was only applicable for small changes in loads and only for one source at a time (per run). This needed considerable computing resources;

b. a decay method which was based on simulation of total nitrogen and phosphorus removal. It only gavei estimates on contribution of sources to total nitrogen and phosphorus but not in terms of specific ecological effects (primary production, chlorophyll);

c. a nutrient labelling (nutrient tracer) method. It labelled substances per groups of sources and initial water like isotopes. The model could be run once for all sources and could distinguish effects on all relevant variables at once. It would give information on effects during (species specific) bloom.

The faster and easier decay method yielded similar results as the labelling method but no breakdown into parameters. All methods had already been implemented and applied at Delft. The difficulty was how to validate these model tools.

4.11 In the discussion, it was noted that the presented methods could take into account background loads to distinguish between natural and anthropogenic loads. Based on the presented methods, a two step approach was advised, in which first the contributing source (e.g. river) of concern was identified and then further scrutiny of the river loads was undertaken and their sources upstream were traced.

d. Belgium

4.12 Dr Geneviève Lacroix (Belgium) presented in a case study for the Belgian waters the capability of the MIRO&CO-3D model to trace the origin and fate of nutrients through salinity and passive tracer simulations and through sensitivity testing (click here for the presentation). In a three step approach the model traced water mass origin, nutrients origin and the transboundary transport of nutrients. Applied to the

[6] *Lene Røkke Mathisen,* Modelling the long-term effects of reducing nutrient inputs to the North Sea, Master Thesis, submitted to the University of Bergen (Norway), Biological Institute, 1 June 2007.

Belgian waters, the study showed that the influence of the Seine was less pronounced for Belgian coastal waters than thought but that it critically impacted the central North Sea. The main contributing freshwater sources to the Belgian coast were the Rhine/Meuse (1.3%) and the Scheldt and Seine (both around 0.9%). Using reduction scenarios (1%) of river loads (DIN/PO4) on surface concentrations, the models simulated the origin of the nutrients. For the Belgian waters, Atlantic water supplied the biggest single fraction of nutrients. The sum of rivers supplied more DIN (53.7%) than PO4 (38%) compared to the Atlantic (46.3% and 62% respectively). In the third step the transport of nutrients was computed by means of net nutrient budgets for Belgian waters, showing a net export of PO_4 and a net import of DIN. The case study pointed to the importance of the period chosen for computing fluxes (integer number of tidal cycles/whole year) and the interannual variability (there was always an export of PO_4 but export/import of DIN varied each year).

4.13 In the discussion, the workshop noted that caution was needed in interpreting nutrient transport results as these did not indicate the contribution of the nutrients to eutrophication effects (e.g. algae growth) elsewhere.

e. France

4.14 Dr Alain Ménesguen (France) presented a study on how to compute the chemical part of nitrogen of any ecological compartment in any specified marine area which comes from a particular source using the role of French river loads in the eutrophication of the French and Belgian coastal zones as example (click here for the presentation). He presented a new method for tracking nitrogen in the trophic network which is based on computing a changing property attached to a state variable in a marine ecosystem. This method had been applied for instance to identify the river mainly responsible for nitrogen fuelling of *Ulva* blooms in the Bay of Brest. The method applied there was to break down diatom or *Phaeocystis* nitrogen into nitrogen from French rivers and nitrogen of Belgian and Dutch rivers. The study also explored the role of benthos in the tagging process: benthos did not alter steady state percentages of origin in water state variables, but only delayed the convergence to the steady state values. Thanks to the same technique, computing the age of nitrogen content would provide a valuable assessment of the time necessary to observe the full effect in the North Sea if the load in one river was reduced. Further work on the presented methods should focus for a next workshop to

a. add a complete cycle of nitrogen (or phosphorus) for each national loading;

b. flag the non-living nitrogen (or phosphorus) coming from all the rivers of a nation, all the year long, or only during a season;

c. map the % of each national nitrogen (or phosphorus) in the phytoplanktonic state variables, and;

d. integrate those % in target areas.

4.15 In the discussion, it was proposed that the relative importance of sources for eutrophication effects could be tested by suppressing one source, as commonly done in the past. Against this, it was argued that the response of an over-enriched ecosystem would not be linear: when one source is suppressed, living variables of the system compensate by taking up surplus nutrients from other sources, and possibly no effect to the nutrient reduction can be observed. This, however, did not mean that the suppressed source of nutrient did not contribute any way to the eutrophication. For the given task of tracing transport of nutrients and their actual contribution to eutrophication effects, it seemed therefore important that the model system remained unchanged.

4.3 Discussion and conclusions

4.16 Dr Hanneke Baretta-Bekker (Netherlands) introduced a discussion paper on transboundary nutrient transport which had been prepared by the organising group and circulated to workshop participants prior to the workshop. She introduced the various questions of detail that would need to be answered to determine the corner stones of the work on transboundary nutrient transport in a work programme and to allow intersessional work to proceed. This comprised issues of defining transboundary nutrient fluxes, definition of target areas, application years, validation protocols, the sources to be addressed, the variables to be taken into account and the conceptual approach to model application (click here for the presentation). In this context, Dr Dave Mills (UK) recalled the definition of eutrophication and with its three elements of nutrient enrichment, accelerated growth and undesirable disturbance to the balance of organisms and made available to the workshop recent results of the UK Defra-funded Undesirable Disturbance Study Team, to provide further background to discussion.

4.17 In the discussion, the following main points were made:

On "transboundary flux"

a. flux means integrating concentration multiplied by velocity over a certain time interval and over a certain cross-sectional surface (e.g. of a box or a transect);

b. the interest was to determine the contribution of a load from one particular source to a specific area. What needed to be computed was what crosses the boundary and where it does come from;

c. a number of participants supported the view that fluxes needed to be computed in both directions across the boundary (i.e. gross fluxes). Some participants did not share this view because what was of interest was residual transport.

d. the right time scale was essential. Small time step would be important to compute a particular flux across the boundary (e.g. using model time steps) but for multi-year simulation of fluxes monthly averaged fluxes could be suitable, provided they were calculated using small timesteps;

e. as a minimum, fluxes should be computed over 1 year or a minimum number of tides;

f. flux computation would need to be done online;

g. there was a challenge in temporal and spatial integration of fluxes.

On target areas and subdivision of the North Sea

h. the EUROGOOS/NOOS transects should be included to allow validation of model results with NOOS observations;

i. smaller target areas may be advised to facilitate use of observation data for validation (see sub-paragraph r below);

j. national boundaries should be followed to ensure that policy driven questions about transports could be answered;

k. to satisfy various demands it might be desirable to use smaller boxes on which national boundaries and NOOS transects could be imposed;

On years for the calculation

l. as 2002 was a fairly wet year, the year 2001 should be used in addition for the spin-up. If it was feasible to gather forcing data for more years (e.g. 2003), this should be included in the spin-up to improve models on interannual variability;

m. participants with models with multi-decadal runs should be invited to provide and share data.

On validation

n. NOOS observations should be used;

o. for suspended particulate matter (SPM), it was desirable to share the same data set;

p. interpolated data from satellite imagery and measurements on a daily/weekly basis should be used. The uncertainty linked to data sets derived in this way needed to be flagged;

q. for the southern part of the North Sea, SPM data at hourly temporal resolution for 2003 would become available by end of 2007;

r. in additional smaller target areas, validation could also be done at a station level, or for a collection of station locations, especially in heterogeneous areas with sufficient sample coverage (high frequency measurements from e.g. smart buoys);

s. where measurement data were scarce, data for longer time periods should be included to compensate for that and provide the necessary variability in the data;

t. due to the large effort and resources required, a climatology based on observations, regarded by some participants as a desirable data set for comparison with model results, could not be done for every target area but only for some selected ones;

On sources

u. rivers could be aggregated by box. Alternatively rivers could be addressed individually;

Variables

v. not all models could simulate the full range of variables required and there might be a need to share tasks;

w. among the form of nutrients (dissolved, particulate, organic, total) the minimum to address would be dissolved and particulate nutrients but an attempt should be made to address all forms;

x. in the light of an improved understanding of undesirable disturbance, information on phytoplankton community structure is highly relevant. However, it needed to be recognized that there are limitations in the number of variables to be addressed by some models.

4.18 On possibilities how to present model results on transboundary nutrient transport to EUC, the following proposals were noted:

a. tabular form presenting the transports in winter and summer;

b. a pie chart could be used to provide the relative contribution of each sources in the given area;

c. a horizontal map summarizing for each box the import from a source. An example will be provided by Dr Alain Menésguen (France);

d. examples from the presentations of the Belgian, Dutch and French presentation could be compiled and presented to EUC as examples for further consideration;

e. it is desirable to provide a weighting tool for putting measured impacts and transported water masses and environmental features in relation.

4.19 Following discussion, the workshop agreed:

a. to recommend to EUC that in a first step towards calculating transboundary nutrient transport,

(i) a run with the coupled hydrodynamic-ecosystem model in the standard set-up should be prepared in order to calculate

- the nutrient dynamics,
- the nutrient loads, transported over specified boundaries,
- the nutrient budgets in the defined areas.

(ii) on a voluntary basis, where workshop participants have the capability, to add on to (i) the use of a 'tagged variable' system (*e.g.*, Ménesguen, 2006; Wijsman, 2003) that allows tracking of specific nutrients from specific rivers through the nutrient cycle and to calculate:

- the nutrient loads from a specified river, transported over specified boundaries,
- the proportions of the nutrient budgets in the defined areas originating from a specified rivers;

(iii) where workshop participants have the additional capability, multi-year runs which would repeat part or all of the above (i) and (ii) simulations.

b. on the work programme at **Annex 5**;

c. to recommend to EUC that an OSPAR workshop on transboundary nutrient transport should be held in May 2009;

d. that the organising group should prepare a document to EUC for options and with examples of presenting model results drawing on paragraph 4.19 above and workshop presentations, and to invite EUC to specify how the results of the proposed future workshop should be reported to OSPAR to meet the needs of EUC's work and the QSR 2010.

Agenda Item 5 – Report of the Workshop

5.1 The report of the workshop on eutrophication modelling was adopted by a written procedure.

ANNEX 1
(Ref. § 1.2)

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ANNEX 2
(Ref. §2.1)

Annotated Agenda and Time Table

2nd OSPAR Workshop on Eutrophication Modelling (ICG-EMO)

10-12th September 2007 at the
Centre for Environment, Fisheries and Aquaculture Sciences (Cefas)
Lowestoft Laboratory NR33, 0HT

Monday, 10th September 2007 - Nutrient Reduction Scenarios

Agenda item 1: Opening, Welcome and Adoption of the Draft Agenda

13:00	Workshop opening by Host Housekeeping arrangements and local information
13:15	Welcome address by Chair Adoption of Agenda

Agenda item 2: Introduction to Workshop

13:30 Background to the meeting – Dave Mills

- *Review of the scope, aims and desired outcomes of the meeting*
- *Reporting requirements for OSPAR*
- *Arrangement for initial report to OSPAR EUC*

Agenda item 3: Nutrient Reduction Scenario Testing

Session 1	**Presentation of Results of Model Applications**
14:00	Introduction to session – Hermann Lenhart • *see Appendix 1 (attached) for suggested format for presentations*
14:30	UK, Cefas presentation
15:00	Dutch presentation – North Sea
15:30	***Tea and Coffee***
Continued:	**Session 1**
16:00	Germany - Presentation
16:30	Belgium - Presentation
17:00	France – Presentation
17:30	Norway – Presentation
18:00	***Close of Day 1***

Tuesday, 11th September 2007 - Nutrient Reduction Scenarios continued

***Continued*:** **Agenda item 3 – Session 1**

09:00 Portugal – Presentation

09:30 UK, POL – Presentation

10:00 Dutch presentation – Wadden Sea

10:30 Coffee and Tea

Session 2: Issues arising from model applications

11:00 Discussion

Structured discussion in which participants may bring forward items for discussion arising from their experience in carrying the nutrient reduction scenarios or issues concerning underlying limitation either scientific or technical. Examples could include:

- implications of not including organic loads in reduction scenarios
- sensitivity of model to nutrient reductions, system memory
- significance of common boundary conditions in aiding comparison of model derived assessments
- causes of divergence between model results

12:30 Lunch

Session 3: Conclusions

13:30 Discussion

Synthesis of results and conclusions

15:00 Tea and Coffee

15:30 Session 3 continued

Session 4: Publication of Workshop Results

16:30 Publication of the workshop results in the scientific literature

- Presentation from organizing committee on options and possible approaches to publishing the workshop results
- Open discussion on ‘straw man’ proposal for publication

***17:30 Close of Day* 2**

Social Evening!

Wednesday, 12th September 2007 – Transboundary nutrient transport

Agenda item 4: Transboundary nutrient transport

Session 1:	**Setting the Scene**
09:00	Welcome & Housekeeping matters
09:10	Background to the meeting (Aims, Objectives and Terms of Reference and outcomes)
09:25	Policy perspective on Transboundary Nutrient Transport – Richard Moxon, UK
Session 2:	**What do measurements tell us?**
09:45	Fate and transport of UK nutrients in the North Sea – Liam Fernand, UK
10:05	Transboundary nutrient transports, and long-term effects of reduced nutrient inputs to the North Sea, Morten Skogen, N
10 :25	What have we learnt from observations, Discussion
10:40	***Tea and coffee***
Session 3:	**What do the models tell us?**
11:00	TBNT model study with GEM (WL) – Meinte Blaas, NL
11:20	Origin and fate of nutrients in the Belgian waters with MIRO&CO3D – Geneviève Lacroix, B
11:40	How to compute the part of nitrogen of any ecological compartment in a specified marine area which comes from a particular source; application to the role of French loadings in the eutrophication of the French and Belgian coastal zones– Alain Ménesguen & Marc Sourisseau, F
Session 4:	**Discussion and conclusions**
12:00	Calculating transboundary nutrient fluxes in the North Sea – Planning Group Representative

- *Review of background document and the questions to be addressed in subsequent discussion*

12:30	***Lunch***
Continued:	**Session 4**
13:30	Discussion and conclusions

The remaining session aims to deliver a set of recommendations to OSPAR in the form of a report. The report will provide an agreed specification for future work on calculating nutrient fluxes. It will also provide a suggested timetable for implementation and identify the responsibilities for the key tasks required. The discussion will be structured around the document on calculating transboundary nutrient fluxes and will focus upon:

- *Definitions to include sources, definition of fluxes, selection of predefined areas and agreed boundaries*
- *Variables to be simulated*
- *Simulation period*
- *Data*
    - *Calibration and validation*
    - *River loads*
    - *Boundary conditions*
    - *Met Data*
    - *Atmospheric data*
- *Detailed approach*
- *Anticipated results*

The discussion needs to take account of the specific requirements of OSPAR and the Contracting Parties, what we have learnt from prior observations and from prior modelling of nutrient transport.

15:30 ***Tea and coffee***

Continued: **Session 4**

16:00 Summing up

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Agenda item 5: Report of the workshop

16:30 ***Close of workshop***

Following the close of the workshop a report drafting team will remain in Lowestoft for 13 and 14th September. Any volunteers to joint this team that currently consists of Andrea Weis (OSPAR secretariat), Hanneke Baretta, Hermann Lenhart, Johan van der Molen, and Dave Mills will be most welcome.

Appendix 1 - Suggested Format for Presentations of Model Applications on Nutrient Reduction Scenarios

1. Model Overview (see S. 14 User Guide)
2. Forcing
3. Present spinup used
4. Surface T und S Distribution (other physical parameters?)
5. Calibration run: Calibration of ecological parameters
6. Standard run: Validation of ecological parameters
7. Standard run: CP-model-assessment (User guide S. 8+9)
8. Reduction run 50 %: new CP-model-assessment
9. Reduction runs with 70%,
10. Individual perspectives on OSPAR ICG-EMO topic (e.g. sensitive parameter or processes) that may be used to stimulate discussion in session 4.

ANNEX 3
(Ref. §2.1)

Terms of reference for an OSPAR workshop on eutrophication modelling

(Source: EUC(1) 2006 Summary Record – EUC(1) 06/9/1, Annex 5)

1. The Joint Assessment and Monitoring Programme (JAMP) requires

   a. an assessment in 2006 of the expected eutrophication status of the OSPAR maritime area following the implementation of agreed measures (JAMP product EA-5);

   b. an overview by 2006 of predictive models for eutrophication assessment and nutrient reduction scenarios, including transboundary nutrient fluxes within the OSPAR area and of the possibilities of adopting relevant models for use by OSPAR Contracting Parties (JAMP product ET-7).

2. In reviewing the results of the eutrophication modelling workshop held in Hamburg in September 2005 to assist the preparation of the assessment of the expected eutrophication status (JAMP product EA-5), EUC(2) 2005 had agreed to delay the assessment until 2008 and to carry out further intersessional work (EUC(2) 2005 Summary Record – EUC(2) 05/10/1, Annex 8) in which priority should be given to activities:

   a. aiming at improved model performance and activities which are essential for a robust prediction of the eutrophication status of the OSPAR maritime area following nutrient reductions;

   b. directly supporting the delivery of JAMP product EA-5 as part of the preparation and the carrying out of a second eutrophication modelling workshop;

   c. initiating work on modelling transboundary nutrient fluxes.

3. OSPAR 2006 endorsed the arrangements agreed by EUC(2) 2005 for further intersessional work on eutrophication modelling and agreed that an OSPAR workshop should be held in spring 2007 to assist the delivery of JAMP product EA-5 by OSPAR 2008. Detailed terms of reference for this workshop should be prepared by the ICG EMO and adopted by EUC 2006.

4. Based on these arrangements, this document sets out the terms of reference for an OSPAR workshop on eutrophication modelling, and for related intersessional preparatory work. The workshop is hosted by the United Kingdom at the Cefas Lowestoft Laboratory, Lowestoft (UK) on [7 – 10 May 2007][7]. It is convened by Dr David Mills (UK) (contact for nutrient reduction scenarios), assisted by Dr Alain Menesguen (France), Dr Hanneke Baretta-Bekker (Netherlands) (contact for tranboundary transport fluxes) and Dr Herman Lenhart (Germany) (contact for workshop data).

1. Objectives

5. The objective of intersessional work is to prepare and hold a workshop on eutrophication modelling which will prepare

   a. nutrient reduction scenarios showing the predicted consequences for selected eutrophication assessment parameters in problem areas if nutrient reduction was achieved by 50% and 70%, or any other voluntary reduction scenarios predicting the reduction required for eutrophication effect parameters to be at or below the relevant assessment levels of the Common Procedure;

   b. specifications for OSPAR model applications of a step-wise comparison of model results and for validation with data;

   c. specifications for the application of models for transboundary nutrient fluxes in the context of the eutrophication assessment under the Common Procedure, taking into account any recent or forthcoming results from calculating transboundary fluxes, and a Work Programme for such work giving priority, in a first phase, to calculating nutrient budgets for defined areas.

[7] Date is subject to confirmation.

6. In preparing specifications for these activities (for example on target areas or reference years), ICG EMO should give consideration to the assessment needs under the JAMP, in particular under the Common Procedure and for the QSR 2010, with a view to exploring how future results of intersessional work on transboundary nutrient transport could possibly inform these assessments.

7. Participants to the workshop will be asked to prepare a nutrient reduction scenario. The planning group will aim to ensure that all target areas defined following the first application of the OSPAR Comprehensive Procedure are covered by reduction scenarios for the purpose of JAMP product EA-5.

2. Nutrient reduction scenarios

8. The objective of the preparatory work is to address limitations in nutrient reduction scenarios experienced at the 2005 Hamburg workshop through activities designed to improve the quality of model results which are essential for a more robust prediction of the status of eutrophication parameters following nutrient reductions. The planning group will prepare data sets for consistent use by participants comprising data sets for boundary and forcing conditions and instructions on their use. These include:

(i) one set of boundary conditions for all models extracted from a shelf-wide model; the different sensitivity of models to boundary conditions would need to be addressed in the presentation of the model results;

(ii) quality assured extended river discharge and nutrient load data compiled by the *Institut für Meereskunde*, University of Hamburg, from recognised sources being as compatible as possible with RID data held by OSPAR;

(iii) atmospheric deposition data from EMEP (including, as appropriate, EMEP data on nutrient deposition in the OSPAR maritime area which are forthcoming under the co-operation programme with OSPAR in 2007);

(iv) meteorological data for example from the European Centre for Medium-Range Weather Forecasts (ECMWF).

9. A separate user guide describing the procedure for model applications will be provided that will include the following items:

a. data sets for calibration and validation will be generated from NERC North Sea Project data set, from the Dutch database (http://www.waterbase.nl), and from additional sources such as from research programmes. Formats for the model comparison will be specified;

b. definitions for target areas in form of adjacent boxes. Overlapping model domains will allow comparison of model results of nutrient reductions;

c. specification for calibration and validation. Calibrated models should only be used. Where calibration has not already been carried out, data for years 1988/89 are provided. Validation is a requirement with data provided for the year 2002;

d the year 1985 is used for nutrient reduction scenarios based on 50% and 70% nutrient reductions in order to determine the effects on selected harmonised assessment parameters under the Common Procedure;

e. a spin-up procedure is required in order to allow the model to reach a steady state;

f. detailed description of the required output format together with an example output and example post-processing routines used to generate the example output;

g. use of the same calculation for cost-functions as applied at the ASMO workshop “Modelling of Eutrophication Issues” held in The Hague on 5-8 November 1996;

h. initial specifications for a step-wise comparison of model results and validation with data;

10. The workshop will carry out the following tasks:

a. to report the results of the reduction scenarios for 1985 in the form of tables showing percentage differences compared to the reference year, with a view to facilitating easier and more effective comparison for the different models;

b. to compare and explain differences between model results and, for 2002, between model results and measured data, and to report on the reliability of model predictions of the consequences of nutrient reduction scenarios taking into account changes to the procedure for model application;

c. to evaluate the results and report the conclusions that can be drawn from modelling the consequences of the nutrient reduction scenarios;

d. to report on a comparison between new work carried out by the ICG EMO and previous work carried out and reported in the 1996 ASMO workshop and the 2005 Hamburg workshop;

e. to prepare specifications for OSPAR model applications of a step-wise comparison of model results and validation with data.

3. Work Programme on transboundary nutrient transport

11. The purpose of JAMP product EA-7 is described by the JAMP implementation plan to develop models showing a quantitative relationship between inputs into the maritime area, transboundary fluxes within areas of the maritime area and their eutrophication effects in order to provide the necessary understanding of the outcome to possible reduction scenarios.

12. The Common Procedure recognises that despite large anthropogenic nutrient inputs and high nutrient concentrations, an area may exhibit few if any direct and/or indirect effects. There is, however, a risk, that nutrient inputs may be transferred to adjacent areas where they can cause detrimental environmental effects and Contracting Parties should recognise that they may contribute significantly to so-called “transboundary affected” problem areas and potential problem areas with regard to eutrophication outside their national jurisdiction.

13. OSPAR work on transboundary nutrient transport will therefore need to address the issues in the following prioritised list:

a. nutrient fluxes between areas within the OSPAR maritime area and the calculation of related nutrient budgets;

b. quantifying the relative contributions of the various nutrient sources, with their natural and anthropogenic fractions, to transboundary transport and the consequences for the eutrophication status;

c. tracking nutrients back to source.

14. In doing so, the workshop should look at examples of applications of available models (for example that of the *Bundesamt für Seeschiffahrt und Hydrographie (BSH)*) to inform the discussion.

15. The objective of the intersessional work is to prepare the necessary material for detailed discussions at the workshop on specifications of model applications for transboundary nutrient transport in the context of the eutrophication assessment under the Common Procedure and a related Work Programme (products C1 and C2 of the Terms of Reference for eutrophication modelling – EUC(2) 2005 Summary Record, Annex 8). The planning group will identify specific locations of boxes (target areas) within maritime areas. Participants with models capable of calculating transboundary fluxes are invited to present these, as far as possible, and the results of their application to the workshop.

16. The workshop will prepare a Work Programme for work on transboundary nutrient transport described in § 13 above with a focus on delivering, with the assistance of a workshop if necessary, calculations of nutrient budgets for a number of defined target areas in 2007/2008. To this end, the workshop will carry out the following tasks:

a. agree a working definition for transboundary nutrient transport;

b. agree an approach to identify locations for estimation of transport flows (transects along maritime boundaries) and determine a suite of adjacent target areas (for example adjacent areas Skagerrak/German Bight, France/Belgium and UK/Netherlands);

c. develop protocols for the application of models for calculating transboundary nutrient transport. This will include:

   (i) specification of the variables and the form of nutrients to be reported on;

   (ii) determining the simulation period and target years and the frequency of flux calculations across the defined transects (daily/monthly/seasonal/annual/interannual);

   (iii) identifying the best approach to obtain and distribute data;

d. prepare arrangements for calculating nutrient budgets for identified target areas for consideration by EUC in 2007/2008 (§ 13a) and indicate resource requirements for their implementation. This will include a run with the hydrodynamical model to estimate the water flux through a defined boundary, together with a conservative tracer to allow calculation of the fraction of this water which originates as river inputs. Calculation will include nutrient dynamics; nutrient loads, transported over specific boundaries; and nutrient budgets in defined areas;

e. consider the need for inter-comparison of model results and how this should be organised. If a workshop is considered necessary, prepare a proposal for detailed terms of reference for that workshop including a time table for preparatory intersessional work;

f. give consideration to the work elements and the time scale for preparing quantifications of the relative contribution of the various nutrient sources to transboundary transport and for tracking nutrients back to source (§ 13b and c above).

4. Time table for intersessional work

Product	What	Who	When
1	Invitation to the workshop to ICG EMO, EUC HODs and other experts	Convenor ICG EMO	as soon as possible
2	Model domain specification for nutrient reductions	Workshop participants	3 November 2006
3	Target area for nutrient reductions	Planning group	10 November 2006
4	Draft user guide	Planning group	4 December 2006
5	Circulate draft user guide for comments to ICG EMO	Planning group	4 December 2006
6	Comments of ICG EMO on draft user guide	ICG EMO	22 December 2006
7	Data sets for workshop made available	Dr Hermann Lenhart	22 December 2006
8	Finalised user guide	Planning group	15 January 2007
9	Excel sheets with cost-functions	Workshop participants	1 week before workshop
10	Model results (50% and 70% reduction) and any additional model results on reduction scenarios and transboundary nutrient reductions	Workshop participants	1 week before workshop
11	Workshop and report	Workshop participants	[7-10 May 2007] [8]
12	Presentation of results to EUC 2007	ICG EMO	Autumn 2007

[8] Date subject to confirmation.

ANNEX 4
(Ref. 3.43)

Draft assessment of the predicted environmental consequences for problem areas following nutrient reductions

1. Introduction

1. This report presents the results of nutrient reduction scenarios for the North Sea to provide an insight in the response of selected eutrophication assessment parameters to the reduction of nutrient loads to the marine environment. The purpose of this assessment is to assist delivery under the 2003 Strategy for a Joint Assessment and Monitoring Programme (JAMP) of an assessment of the expected eutrophication status of the OSPAR maritime area following the implementation of agreed measures (JAMP product EA-5).

1.1 Policy context

2. The objective of the revised 2003 OSPAR Eutrophication Strategy is to combat eutrophication in the OSPAR maritime area, in order to achieve and maintain, by 2010, a healthy marine environment where eutrophication does not occur.

3. The 2003 Eutrophication Strategy builds on long-standing work of OSPAR on eutrophication. This includes the commitment of Contracting Parties to achieve a substantial reduction at source, in the order of 50% compared to 1985, in inputs of phosphorus and nitrogen into areas where these inputs are likely, directly or indirectly, to cause pollution (PARCOM Recommendation 88/2). To assist Contracting Parties in identifying those areas in a consistent way, OSPAR adopted the Common Procedure for the Identification of the Eutrophication Status of the OSPAR Maritime Area (the "Common Procedure") in order to characterise marine areas in terms of problem areas, potential problem areas and non-problem areas with regard to eutrophication. A first application of the Common Procedure was finalised in 2002 resulting in the 2003 OSPAR integrated report on the eutrophication status of the OSPAR maritime area (OSPAR publication 189/2003). In 2007, Contracting Parties had been invited to report their results of the second application of the Comprehensive Procedure of the Common Procedure to OSPAR to contribute to a second integrated report for adoption by OSPAR 2008.

4. By 2003, Contracting Parties had not yet achieved the 50% reduction target for nitrogen. The purpose of the nutrient reduction scenarios under the 2003 JAMP is to assist evaluation of the effectiveness of this measure on the quality of the marine environment and to provide indication of progress towards achieving the objectives agreed under the Eutrophication Strategy.

1.2 OSPAR work on eutrophication modelling

5. A first assessment of the expected eutrophication status of the OSPAR maritime area following implementation of agreed measures was carried out by OSPAR in 2001 (OSPAR publication 140/2001). That assessment built on the results of a 1996 OSPAR workshop which already showed good performance of the various models with regard to hindcast.

6. To assist the delivery of JAMP product EA-5, an OSPAR workshop was held in Hamburg in September 2005 to produce an assessment in the format of the Common Procedure (tables, maps and text) showing the predicted environmental consequences for problem areas if the 50% nutrient reduction target was achieved and, where this does not indicate non-problem area status, to predict the reduction target needed to achieve non-problem area status. The results of this workshop are available from the Cefas homepage (http://www.cefas.co.uk/eutmod).

7. The 2005 workshop built on the previous 1996 workshop experience, the results of the EU funded project on European catchment, catchment changes and their impact on the coast (EUROCAT) and on intersessional work to provide the necessary specification for an intercomparison exercise of model applications in nutrient reduction scenarios. The workshop identified a number of issues to improve confidence in model results.

8. This work resulted in an interim report on the use of eutrophication modelling for predicting expected eutrophication status of the OSPAR maritime area following the implementation of agreed measures (OSPAR publication 286/2006) which informs about progress achieved in using models in a eutrophication assessment context. OSPAR agreed that further intersessional work should be carried out to prepare a second OSPAR workshop in September 2007 to assist the preparation for OSPAR 2008 of an assessment of the expected eutrophication status of the OSPAR maritime area following agreed measures.

1.3 2007 OSPAR workshop

9. Following intersessional work to address limitations to model performance identified at the 2005 workshop, the task of the 2007 OSPAR workshop was:

a. to report the results of the reduction scenarios for 1985 in the form of tables showing percentage differences compared to the reference year, with a view to facilitating easier and more effective comparison for the different models;

b. to compare and explain differences between model results and, for 2002, between model results and measured data, and to report on the reliability of model predictions of the consequences of nutrient reduction scenarios taking into account changes to the procedure for model application;

c. to evaluate the results and report the conclusions that can be drawn from modelling the consequences of the nutrient reduction scenarios;

d. to report on a comparison between new work carried out by the ICG EMO and previous work carried out and reported in the 1996 ASMO workshop and the 2005 Hamburg workshop;

e. to prepare specifications for OSPAR model applications of a step-wise comparison of model results and validation with data.

10. These results are reported in this assessment. The full report from the workshop is available on the Cefas website http://www.cefas.co.uk/eutmod.

2. Methods

11. A full description of the methods and data used in the workshop is set out in a User Guide and Data Description.

12. These documents implement the tasks identified by OSPAR to enhance performance of model applications and the comparability of their results. This includes:

a. the use of a common set of river load data;

b. specification for a recommended three-year spin-up of models for the year 2002;

c. the provision of common boundary condition provided from the model POLCOMS-ERSEM;

d. the use of the ERA operational data from ECMWF as meteorological forcing, and;

e. the use of the EMEP monthly data for atmospheric nitrogen deposition.

13. The forcing data compiled for common use in the model applications are available on the ftp site of the University of Hamburg ftp://ftp.ifm.uni-hamburg.de/outgoing/lenhart/OSPAR/.

14. The workshop reviewed the methods and data used with a view to evaluating their fitness-for-purpose in the light of experience obtained and to identify any additional issues on conditions for model applications that would need to be addressed in future.

2.1 River loads

15. The reference year for the reduction target set in PARCOM Recommendation 88/2 is 1985. No validation data were available for that year so that it could not be used in the model application. Instead, the 50% and 70% reduction scenarios were carried out for the year 2002 but taking into account the nutrient load reductions that had already been achieved by Contracting Parties in the period 1985 – 2002. To this end, the available river load data were grouped by country to estimate regionally differing reduction percentages.

16. The time series of annual loads for the countries are presented in Figures 2.1 and 2.2 for ToxN and PO_4 (NH_4 is not presented here). While TOxN (NO_3+NO_2) displays considerable interannual variability, PO_4 has less variability and for most countries a clear reduction signal. The variability in data is caused by interannual variability in river discharges, data availability and changes in monitoring practice.

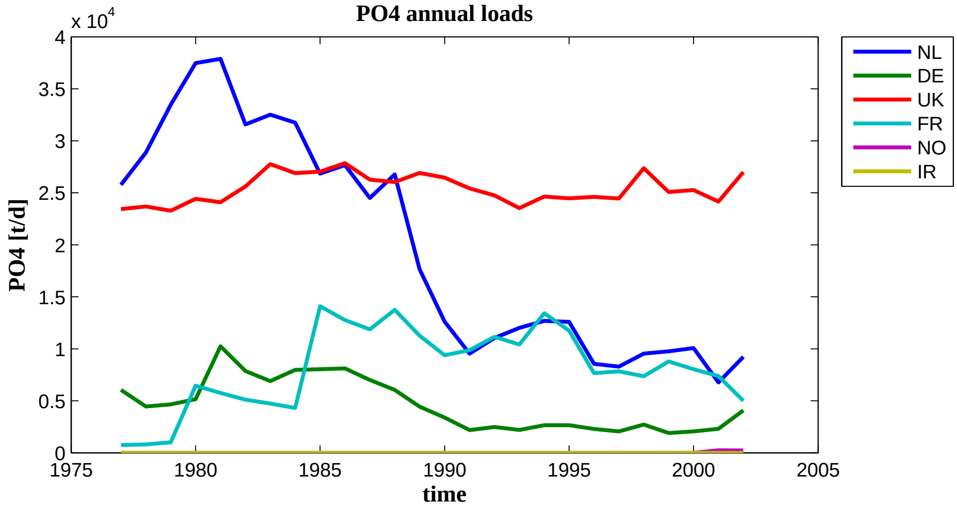


Figure 2.1. Available annual river loads of PO_4, cumulative by country. Data for Norway prior to 2001 and for Ireland were absent and taken as zero.

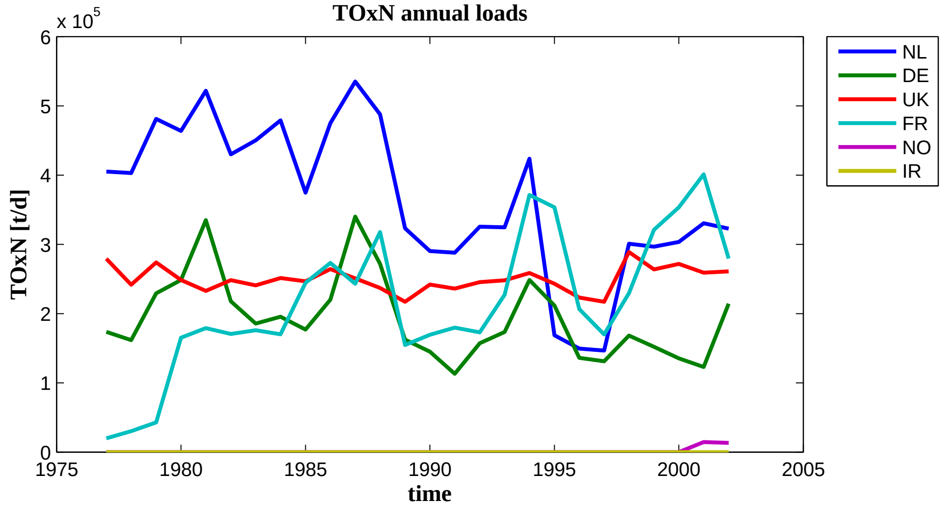


Figure 2.2. Available annual river loads of TOxN (NO_3+NO_2), cumulative by country. Low values for the Netherlands in the mid 1990s are related to missing data. Data for Norway prior to 2001 and for Ireland were absent and taken as zero.

17. Given the interannual variability and minor apparent changes of TOxN (NO_3+NO_2), 2002 and 1985 loads were considered as equal (no change). For PO_4 and NH_4 proportional reductions were calculated as follows:

a. percentage change calculated between 1985 and 2002;

b. rounded to nearest 10% interval to account for variability (uncertainty);

c. only the countries with major rivers for which sufficient data was available were taken into account.

18. The so calculated reductions for 2002 are presented in Table 2.1. Where the reduction target of 50% was already met in 2002, the corresponding additional reduction for this scenario was set to zero.

Table 2.1: Reductions in nitrogen and phosphorus loads achieved by Contracting Parties for target areas in their waters in the period 1985 – 2002 and resulting % reduction to be applied for the year 2002 to achieve a 50% and 70% reduction scenario for nitrogen and phosphorus.

Contracting Party	TOxN (%)	NH_4 (%)	PO_4 (%)
Reductions achieved between 1985 and 2002			
Netherlands	0	70	70
Germany	0	90	50
UK	0	20	0
France	0	10	60
Reductions of 2002 national loads necessary to achieve 50% reduction compared to 1985			
Netherlands	50	0	0
Germany	50	0	0
UK	50	40	50
France	50	40	0
Reductions of 2002 loads necessary to achieve 70% reduction compared t0 1985			
Netherlands	70	0	0
Germany	70	0	40
UK	70	60	70
France	70	70	20

19. Since no load reduction was prescribed for the organic part of the load, a point for discussion at the workshop was how the organic load should be reduced in relation to the lowering of the prescribed inorganic loads. First it was considered that organic load comprises of the organic matter which is degradable within a reasonable time-scale and the refractory part, but that only the degradable part is relevant. The common feeling among the group was that the organic load is negligible and even that potential shortfalls in organically derived nutrients might be compensated for by the models. Only in local areas, such as shallow areas like the Wadden Sea or Lake Ijssel or deposition areas, may the organic load become an important factor, but this does not hold for the selected target areas. The argument was brought forward that measurements tend to underestimate the particulate load of rivers since they are flow dependent and that the organic load is mainly found in the bedload. The general view of the group was that estuary models were needed to better understand these processes. However, studies of the Humber estuary showed within an UK project (LOIS) that, using a catchment, estuarine and coastal model, models were unable to reconstruct the organic load. Taking into account the differences between the estuaries which are too variable to allow for a generalized conclusion, one way to address this problem would be to carry out sensitivity analysis to identify the importance of the organic load and determine the required complexity of the ecosystem model (e.g. the incorporation of zooplankton or bacteria). The general conclusion so far from the group was that organic degradable load seems to be negligible and does not bias the model results.

2.2 Spin-up time

20. The participants had been asked to run their models repeatedly for one year for a sufficient number of years (with a minimum of 3 years) to achieve a repeating seasonal cycle. The year 2002 using 2002 nutrient inputs and boundary conditions was suggested to be repeated 3 times in order to reach a repeating annual cycle indicating that the model is in equilibrium. The end state of this spin-up should be used as a starting condition for the reference (or standard) year 2002 and all reduction scenarios.

21. In the discussion it was pointed out that more complex models, e.g. with detailed benthic modules, as well as model applications in deeper waters needed more spin-up time than the proposed 3 years. The experience with the use of longer spin-up times in comparison to the Hamburg workshop resulted in a larger reduction in the N/P ratios. In order to demonstrate that a “stable equilibrium” had been reached the results for a number of relevant variables should show that the simulated time series converged.

22. For the purpose of validating the standard run it would be desirable in future to do the spin up for the years previous to the standard run for 2002, otherwise the comparison with January/February observations are biased. Forcing data are currently available for 2001 and 2002 while future spin-ups with a series of years will be restricted to availability of data and resources for aggregation of common forcing data for application.

23. Finally, the participants were convinced that the spin-ups applied for the individual models were carried out successfully to reach a "stable equilibrium", either by applying longer spin-up times for more complex models or, in shallower coastal areas, by using the proposed 3 years. The spin-up procedure using the year 2002 was accepted to be suitable for reaching a balance between river loads and the system and provided a reliable basis for the simulation. Prolonging the spin-up for a series of years would achieve a further robustness to enhance the model capability to reproduce interannual variability, however, differences in the model results to the proposed adjustments of the spin-up procedure would only be in minor details.

2.3 Boundary condition

24. In order to achieve a consistent set of boundary data for all model application as suggested by the last workshop, the only feasible approach was to extract these data from a wider area model whose domain covered the spatial extent of all the other models. Therefore, the boundary data were provided by AMM POLCOMS-ERSEM model runs for 51 pelagic parameters for each boundary location of the different national models (Belgium, France, Germany, the Netherlands, Norway, Portugal and the UK (Cefas and POL)). In addition, 12 benthic parameters for the initialisation fields were made available. This consistent dataset was not only provided for the standard run but also for both reduction runs on a daily basis for the year 2002.

2.4 Meteorological Forcing

25. To ensure consistency with the boundary conditions, the same meteorological forcing data used by POL (ECMWF ERA 40 operational data for the years 2001 and 2002) were supplied, with the kind permission of ECMWF, to workshop participants for use in their simulations.

2.5 Atmospheric N-deposition

26. The data fields for the atmospheric nitrogen deposition were provided by EMEP (Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe) on a monthly basis for the years 2001 and 2002. The variables provided included: dry deposition of oxidized nitrogen (NO_x); wet deposition of oxidized nitrogen (NO_x); dry deposition of reduced nitrogen (NH_4); and wet deposition of reduced nitrogen (NH_4).

2.6 Suspended particulate matter (SPM)

27. Difficulties were reported by the participants in forcing the models with SPM data in order to achieve reliable light attenuation especially for the coastal region. Since observations were not fit for purpose, different methods were used for SPM forcing of the national model applications. It was observed that while satellite imagery carried uncertainties due to cloud conditions, model based SPM concentrations were limited due to the size of the area over which SPM was computed. There is a need to look further into the best way of resolving this issue e.g. by combining the best features of satellite imagery (i.e. the gradients and spatial extent) with *in-situ* observations or by using simple SPM model routines that could be shared by all participants.

2.7 Target areas

28. One important change in procedure since the 2005 workshop is the choice of a new set of target areas. These areas roughly correspond to the target areas used in the previous workshop in terms of their location and in their definition as coastal and offshore boxes. However, their shapes have been significantly modified in anticipation of the subsequent work on transboundary nutrient transport. Most of the target areas correspond to areas classified as a Problem Area in German and Dutch maritime waters following the first application of the OSPAR Common Procedure. One UK non-problem area has been added. The workshop also agreed arrangements for preparing reduction scenarios for two additional target areas covering the Belgian continental shelf and the French coastal waters and for updating this draft assessment with the additional model results.

2.8 Validation data

29. For validation the year 2002 was chosen as it is the year in which the first application of the OSPAR Common Procedure was carried out and it is also the standard year for this modelling workshop. A data set to validate the models was provided. In contrast to the first workshop the raw data were made available in a

common format for the target areas. For the six target areas an excel spreadsheet was set up to enable the participants to calculate cost functions that had to be used for the validation. This enabled more rigorous comparison of model performance in order to gauge the uncertainty in model results.

3. Model performance

30. Details of all the models used at the workshop are given in table format at Appendix 1. The technical details presented can provide the further information necessary to appreciate the model results.

3.1 Calibration and validation

31. The calibration procedures adopted by participants are described in the national reports. Details of the validation are given in the full reports for each application available on the Cefas website (Eutmod).

32. Data from all kind of sources have been used for validation. Details on the data are given in the Data Description. In Figure 3.1 the spatial distribution of all sample locations are given. For each target area and each variable data from 0 - 15 m deep are combined in surface data, while the deeper samples are combined in bottom samples. Monthly means have been calculated per variable and per target area.

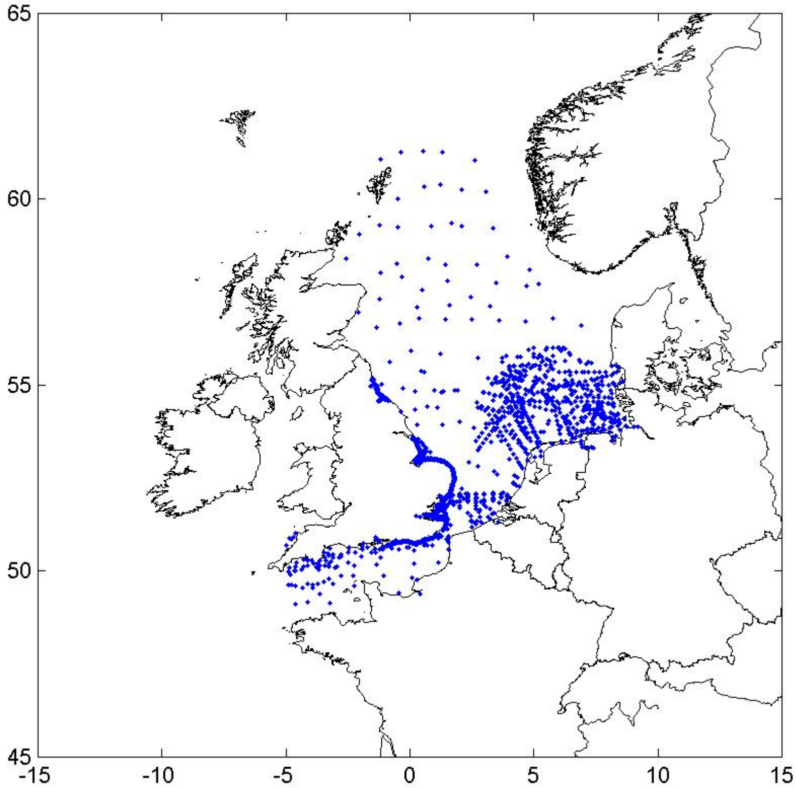


Figure 3.1 Spatial distribution of sampling locations from which 2002 data for validation were generated.

33. As can be seen from Table 3.1 the standard deviations for some of the assessment variables are very large, especially in two of the coastal boxes. A possible explanation can be the heterogeneity of these areas concerning salinities and subsequently nutrient concentrations. In Table 3.2 also the ranges of the monthly salinities are given. For the areas NL-C3 and G-C1 the ranges are well below salinity 30, indicating an overrepresentation of low-salinity samples which can also be traced back to the sampling stations in Figure 3.1.

Table 3.1: Observation data for validation of model results in the target boxes giving the mean value (mean), the standard deviation (std) and the number of observations (n) for 2002. The salinities of the data of the areas NL-C3 and G-C1 were very low, which explains (partly) the high nutrient values.

Target areas	Winter DIN (µmol/l)			Winter DIP (µmol/l)			Summer chlorophyll a (µg/l)			O2 minimum (mg/l)	Salinity in January and February			
	mean	std	n	mean	std*	n	mean	std*	n		mean	std*	n	Range**
UKC1	40.6	21.4	85	1.9		124	7.9		257	5.27	33.5		318	33.0 – 33.8
NLC2	51.6	11.7	8	1.0		8	11.55		61	6.93	31.9		36	30.7 – 31.9
NLC3	84.9	56.5	28	1.3		28	4.9		46	6.7	24.2		27	23.6 – 24.7
NLO2	3.1	0.8	3	0.5		3	0.59		171	7.49	32.1		201	32.1 – 32.1
GC1	127.0	124.7	29	1.4		29	1.87		6	4.61	27.6		124	23.7 – 28.9
GO2	8.2	3.6	6	0.56		6	0.64		40	5.48	34.4		86	34.3 – 34.4

** Note: the table will be updated with the values for the standard deviations after 1 November 2007.*

*** Note: This is the range of the monthly means, so the actual range will be larger. The table will be updated after 1 November 2007.*

34. There were some generic findings from the validation. In general the models perform better in the offshore areas than in the coastal areas. Winter DIN and DIP (defined as mean January and February concentrations) at the surface are in the range of observations or slightly overestimated, while the mean growing season chlorophyll concentrations are overestimated in the offshore areas. All models underestimated winter DIN at the surface and mean growing season chlorophyll coastal concentrations for coastal target areas. Winter DIP is also underestimated in the coastal areas, but to a much lesser extent than winter DIN.

35. Four of the six models (Germany, Netherlands, UK-Cefas and UK-POL) were three-dimensional and provided nutrient concentrations at the surface as well as at the bottom. In most models the differences between surface concentrations and bottom concentrations were zero or negligible. Only the German model gave differences between surface and bottom nutrient concentrations, which were in the range of –7 to +30%. A comparison with measurements has not been made.

36. One possible explanation for the discrepancy in coastal target areas was cited by a number of participants as due to the heterogeneity of these areas that encompass salinities from 30-34.5. The large standard deviations observed in the monitored winter DIN concentrations give credibility to this view (Table 3.1). There was also some misunderstanding of the participants of the guidance provided such that data associated with salinities outside of the appropriate range for a specific water body type (coastal or offshore) may have been included in calculations. There are also some suggestions from the presenters. Dr Lacroix noted that their model results were sensitive to the spatial dimensions of the target area. Nevertheless, these validation results were not fully understood and further work is required to establish the reasons for these systematic differences and whether these are specific to each model or result from externally imposed conditions.

3.2 Cost functions

37. To quantify the difference between model results and measurement data we have made use of the cost function as described in Villars & de Vries (1998). The cost function is a mathematical function and gives a non-dimensional number which is indicative of the correspondence between two sets of data. This method makes also comparison between results of different models possible.

38. For each target area and each variable the participants calculated monthly means of their model results. The monthly means are compared with monthly means of measurements of that variable and in that target area. The outcome of these monthly cost functions can be positive (over-estimation) or negative (underestimation). A value zero means that the model results are exactly equal to the measurements. The absolute value depends critically on the standard deviation of the observations. Figure 3.2 shows an example of the performance of three models in the target area NL-C2 for the parameters included in the cost function.

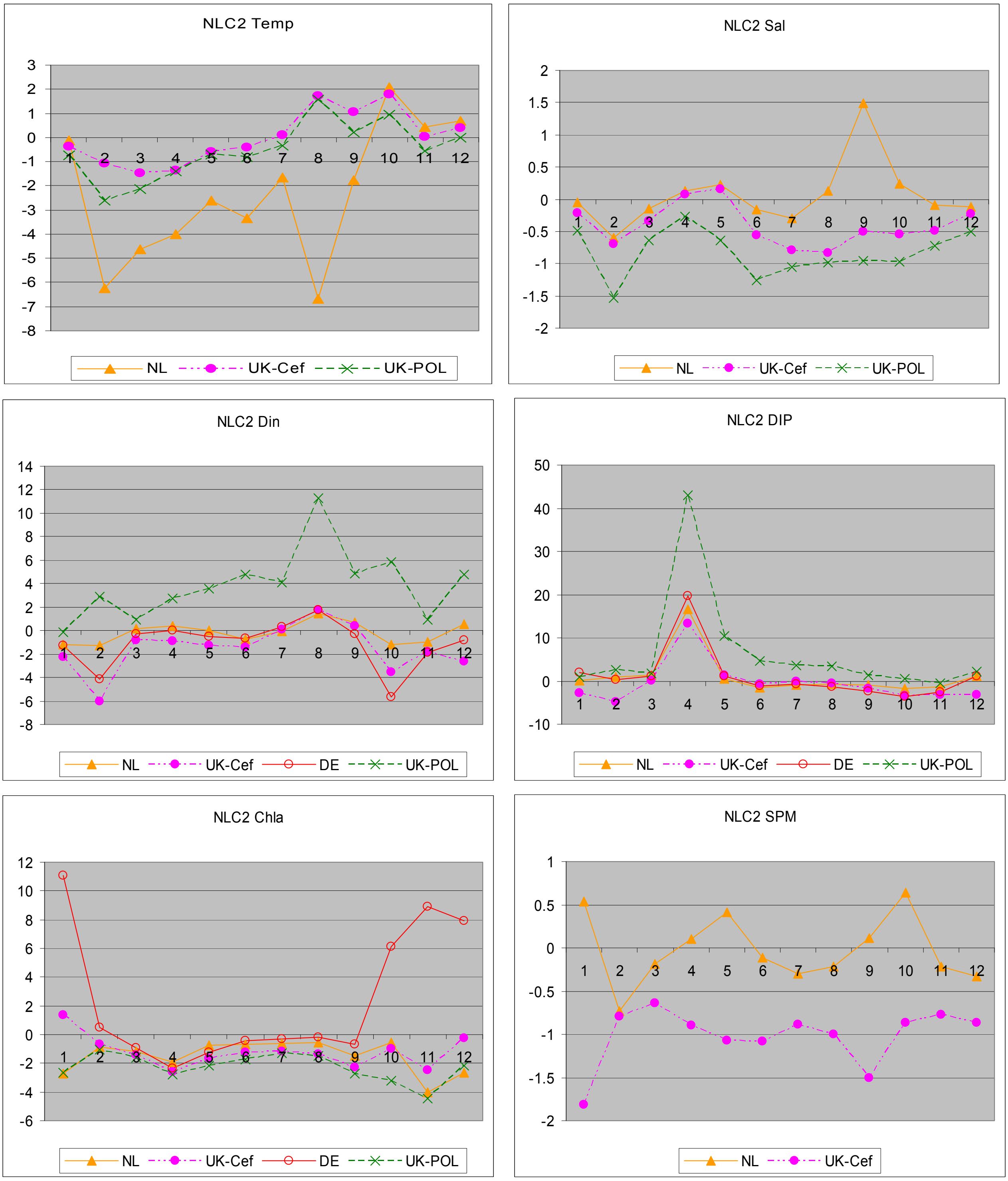


Figure 3.2. Monthly cost functions for temperature (^{0}C), salinity, DIN, DIP, chlorophyll, and SPM for four models (Germany, the Netherlands, UK-Cefas and UK-POL) in target area NL-C2. No validation data were available for cost functions for temperature, salinity and SPM from Germany, and for SPM from UK-POL. *[Note: The graphs will be updated following completion of the review of UK-POL model results.]*

39. An annual mean has been calculated from the absolute values of the monthly means. For a number of variables in each of the target areas the annual mean cost functions according to four of the models are given in Figure 3.3. For the performance of a model, Radach and Moll (2006) defined four classes for the values of the cost function: 0-1: excellent; 1-2: good; 2-3: reasonable and values >3: poor.

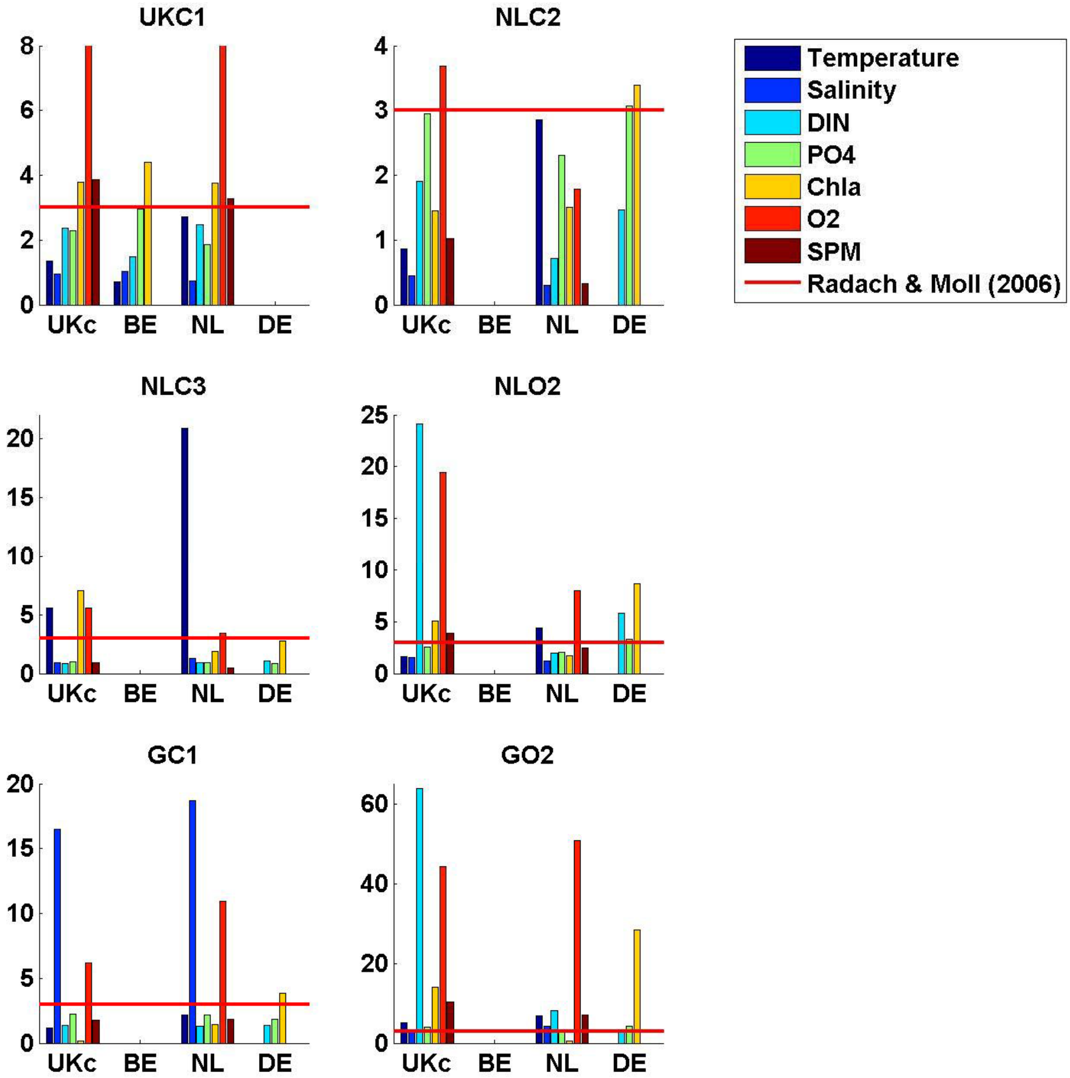


Figure 3.3: Annual mean cost functions for the models presented by, UK/Cefas (UKc), Belgium, the Netherlands and Germany for each target areas. The red line indicates the boundary between reasonable and poor according to Radach & Moll (2006). *[Note: The graphs will be updated with UK-POL model results, following completion of their review.]*

4. Reduction scenarios

40. For the purposes of the OSPAR Common Procedure, offshore target areas encompass waters with salinities > 34.5 and coastal target areas salinities of 30-34.5. In general, offshore areas will be deeper and potentially subject to summer time thermal stratification. These offshore waters will also be less turbid with relatively high water clarity. In shallow waters turbidity is generally higher and light conditions less favourable for growth. In deeper waters (>60 m approximately), however, waters are optically deep and require the onset of thermal stratification to create a surface mixed layer in which there is sufficient light to enable net phytoplankton growth to occur.

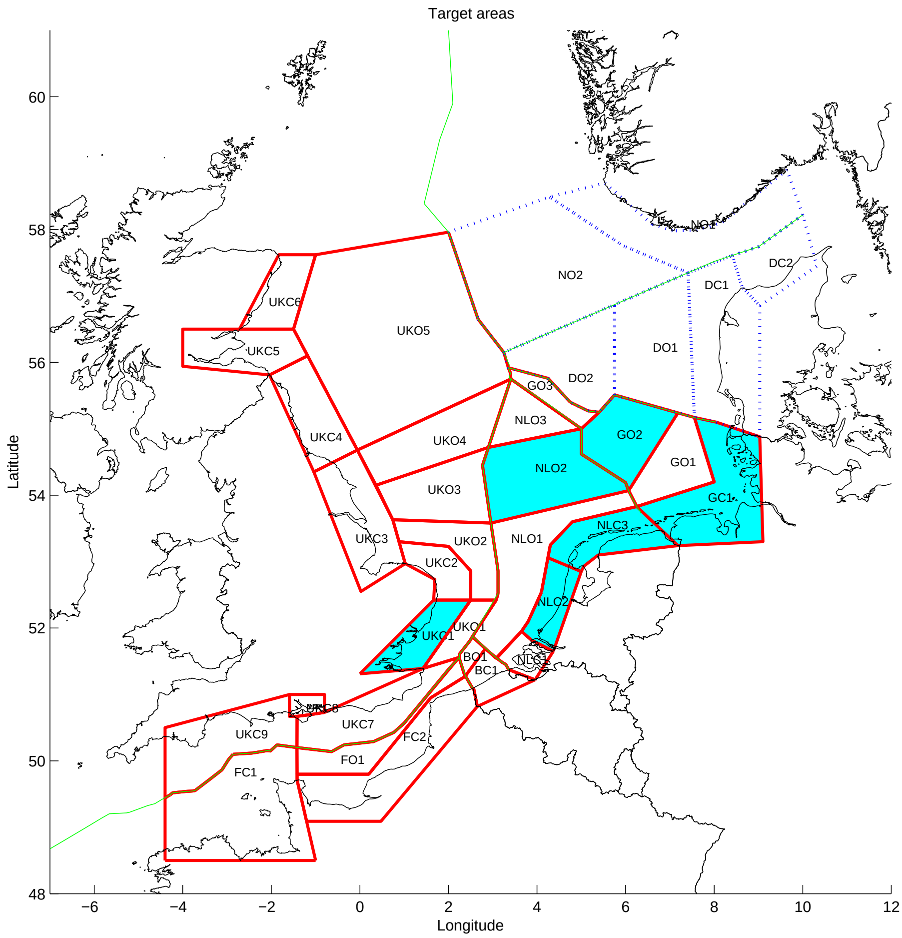


Figure 4.1 Target areas for nutrient reduction scenarios

41. The results of the nutrient reduction scenarios are presented for those models which followed the Workshop User Guide and used the same forcing data.[9] The results are presented in the following as real value changes and % changes of eutrophication parameters in response to reductions in nutrient loads. Appendix 2 presents the results of the reduction scenarios in the scoring format of the OSPAR Common Procedure. The model results are presented and scored against the area-specific assessment levels for the target area which the relevant Contracting Party used in the first application of the Comprehensive Procedure in 2002. The purpose is to put the model results into the context of the OSPAR Comprehensive Procedure and give an indication of direction of change. The assessment levels of 2002 were chosen to ensure comparability of the model results with the monitoring-based Comprehensive Procedure, especially when comparing the scoring results for the year 2002.

[9] *Note: The model results of UK-POL are still under review. They have been included in the following presentations of graphs and in Appendix 2, but they were not included in the calculation of the mean % reduction and in the description of the model results. The UK-POL model output will be incorporated and the description of model results in this chapter adjusted in an updated report following completion of the review of UK-POL values.*

42. For each of the target areas two sets of figures are presented. The first set presents a summary of the % reduction achieved in selected assessment variables for the two (50% and 70%) reduction scenarios and include a mean % reduction derived from all of the model results available for that variable and target area. The first set of figures (e.g. Figure 4.1), termed response plots, enables more ready comparison between models in terms of sensitivity and the robustness of conclusions drawn from the nutrient reduction scenarios. Calculation of the % reduction is carried out in the following manner:

> For a given model the concentration of the simulated assessment variable in the 50% and 70% reduction scenario is converted to a percentage where the standard run (for the year 2002 without reduction in riverine nutrients) is regarded as representing the 100% value. This calculation is carried out for each target area, for each model and the results presented separately for winter DIN, winter DIP, mean chlorophyll and minimum dissolved oxygen concentration.

43. The second set of figures (e.g. Figure 4.2) presents the results of reduction scenarios in terms of concentrations for each of the assessment variables for all of the models for each target area. This second set of figures makes it possible to better judge the differences between model results based on simulated concentrations.

44. The new steps introduced into the procedures for this work on testing nutrient reduction scenarios have increased comparability between model results. In particular, the specification of a minimum spin-up of 3 years (a number of participants used a larger number of years), shared boundary conditions and improvements in forcing data all contributed to the increase in comparability and in confidence in the individual model application.

45. With regard to OSPAR requirements there is a need to indicate a level of confidence in the outcome to nutrient reduction scenarios. Therefore, a tentative assessment of confidence is made based upon the following criteria:

Criteria 1: the level of agreement, in terms of simulated concentrations, between model results for the same assessment parameters;

Criteria 2: the degree of similarity between the gradients of the response plots.

46. So, where the range of simulated values (criteria 1) from all of the model results available, for example, of winter DIN for the UK coastal target area, is similar (based on a visual inspection of the data), and where there is an acceptable degree of similarity (established by visual inspection of the data) between the slopes of the response lines (criteria 2), then a high confidence is attributed to that set of results. If only one of the two criteria be reached, the attributed confidence is medium. If both criteria are not deemed to have been fulfilled, only a low confidence can be attributed. The limitations of this approach to determining the level of confidence in the results of the reduction scenario are recognised, and it may be that further work is carried out to improve the method. It should also be noted that failure to attribute high confidence to the ensemble of model results for certain target areas and/or parameters does not mean that the results are unreliable rather that more caution may be required in drawing conclusions about the specific outcome to a nutrient reduction scenario. A deliberately cautious method has been taken to the assessment of confidence.

4.1 German offshore target area: G-O2

47. This is an offshore water body that is situated close to the northern boundary of the models. It is relatively deep and is subject to summer time thermal stratification.

DIN

48. On average a 29% reduction in winter DIN is achieved with 50% reduction in loads and 45% reduction with 70% reduction in loads There is a wide range of simulated concentrations in the standard run but much less variability in concentrations for the reduction scenarios. Differences in the gradients of the response plots result in designating the results as of low confidence.

DIP

49. On average a 7% reduction in winter DIP is achieved with 50% reduction in loads and 12% reduction with 70% reduction in loads. Model responsiveness is low and similar for the 4 models applied. It should be noted that the DIP reductions in the river loads are small in the German rivers. However, the range of simulated concentrations that vary by a factor of >2 lead to classification as results with a medium confidence level.

Chlorophyll

50. On average a 19% reduction in chlorophyll is achieved with 50% reduction in loads and 23% reduction with 70% reduction in loads. Model sensitivity is low and similar for the 4 models applied. Agreement between the model results provides high confidence in this result.

Oxygen

51. On average a 6% increase in mean minimum dissolved oxygen concentration is achieved with 50% reduction in loads and 9% increase with 70% reduction in loads. Model responsiveness is very similar for the 3 sets of model results considered. The relatively limited range of simulated concentrations leads to a high confidence in this result.

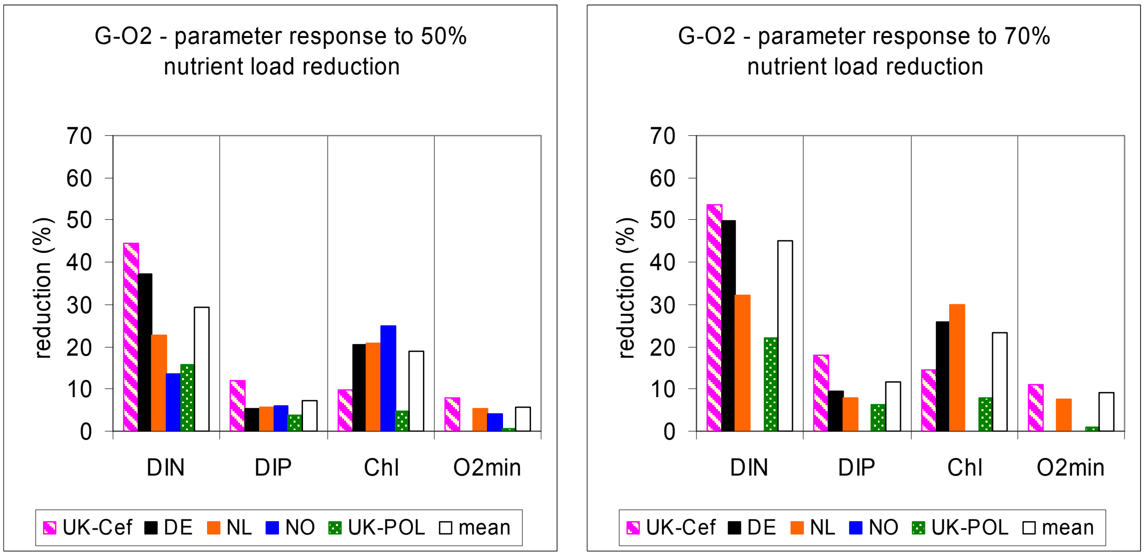


Figure 4.2 % reduction in mean winter DIN and DIP and mean summer chlorophyll, and % increase in annual minimum oxygen computed by the different models as a response to the reduction of nutrient loads to G-O2 by 50% and 70% respectively. Norway did not simulate a 70% reduction scenario; there are no mean oxygen data for Germany. *[Note: The calculation of the mean % reduction does not include UK-POL model results. The chart, including the mean calculation, be updated following completion of the review of UK-POL values].*

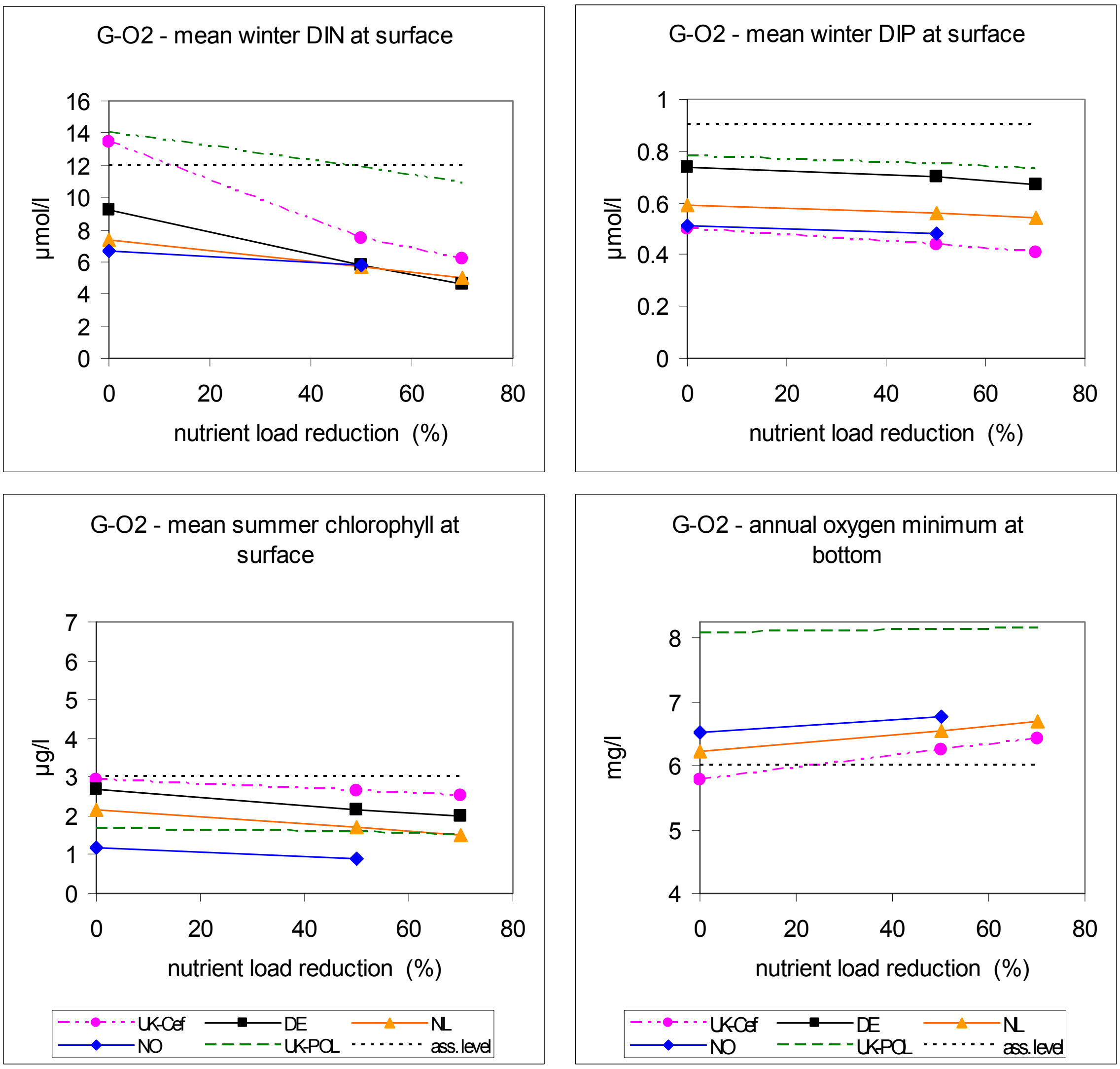


Figure 4.3 Concentrations of mean winter DIN and DIP at the surface, mean summer chlorophyll at the surface, and annual minimal oxygen concentration at the bottom for the year 2002 (standard run at 0% reduction) and for nutrient load reduction of 50% and 70% respectively. Norway did not simulate a 70% reduction scenario and there are no mean oxygen data from Germany. The concentrations are shown against the assessment levels (ass. level) used by Germany for their areas reflected in the target box in the first application of the Comprehensive Procedure (OSPAR publication 189/2003). *[Note: UK-POL concentrations are under review.]*

4.2 Netherlands offshore area: NL-O2

52. This is an offshore (>34 salinity) water body with summer thermally stratified waters, ranging from approximately 40 – 80 m depth.

DIN

53. On average a 24% reduction in winter DIN is achieved with 50% reduction in loads and 38% reduction with a 70% reduction in loads. Model responsiveness varied and despite different starting concentrations in the standard run for each model the results tended to converge resulting in a similar simulated concentration for each model for each scenario. Although criteria 1 is fulfilled, criteria 2 is only partially fulfilled and consequently only a medium confidence is attributed to these results.

DIP

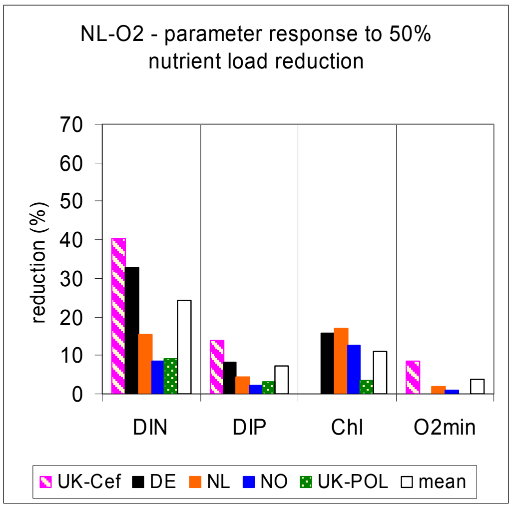
54. On average a 7% reduction in winter DIP is achieved with 50% reduction in loads and 12% reduction with 70% reduction in loads. Model responsiveness is similar between 3 of the 4 models considered. However, the range of simulated concentrations showed a degree of variability that on balance fails to fulfil criteria 1, therefore a medium confidence in assigned.

Chlorophyll

55. On average an 11 % reduction in chlorophyll is achieved with 50% reduction in loads and 15% reduction with a 70% reduction in loads. Low and similar responsiveness was apparent in all model results accounting for the relatively small changes in simulated chlorophyll concentrations observed. However, the range of simulated concentrations showed a degree of variability that on balance fails to fulfil criteria 1 leading to a classification of the result as having medium confidence.

Oxygen

56. On average a 4% increase in mean minimum dissolved oxygen concentration is achieved with 50% reduction in loads and 7% increase with 70% reduction in loads. Model responsiveness is very similar for 2 of the 3 model results. The range of simulated concentrations is <1 mg/l. A precautionary approach does not lead to a conclusion of high confidence in this result.



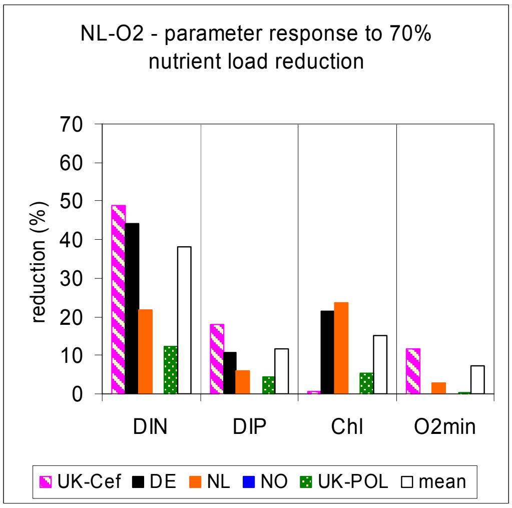


Figure 4.4 % reduction in mean winter DIN and DIP and mean summer chlorophyll, and % increase in annual minimal oxygen computed by the different models as a response to the reduction of nutrient loads to NL-O2 by 50% and 70% respectively. Norway did not simulate a 70% reduction scenario; there are no mean oxygen data from Germany. Percentage increase in oxygen for UK-POL at 50% is too small to show in the graph. *[Note: The calculation of the mean % reduction does not include UK-POL model results. The chart, including the mean calculation, will be updated following completion of the review of UK-POL values]*.

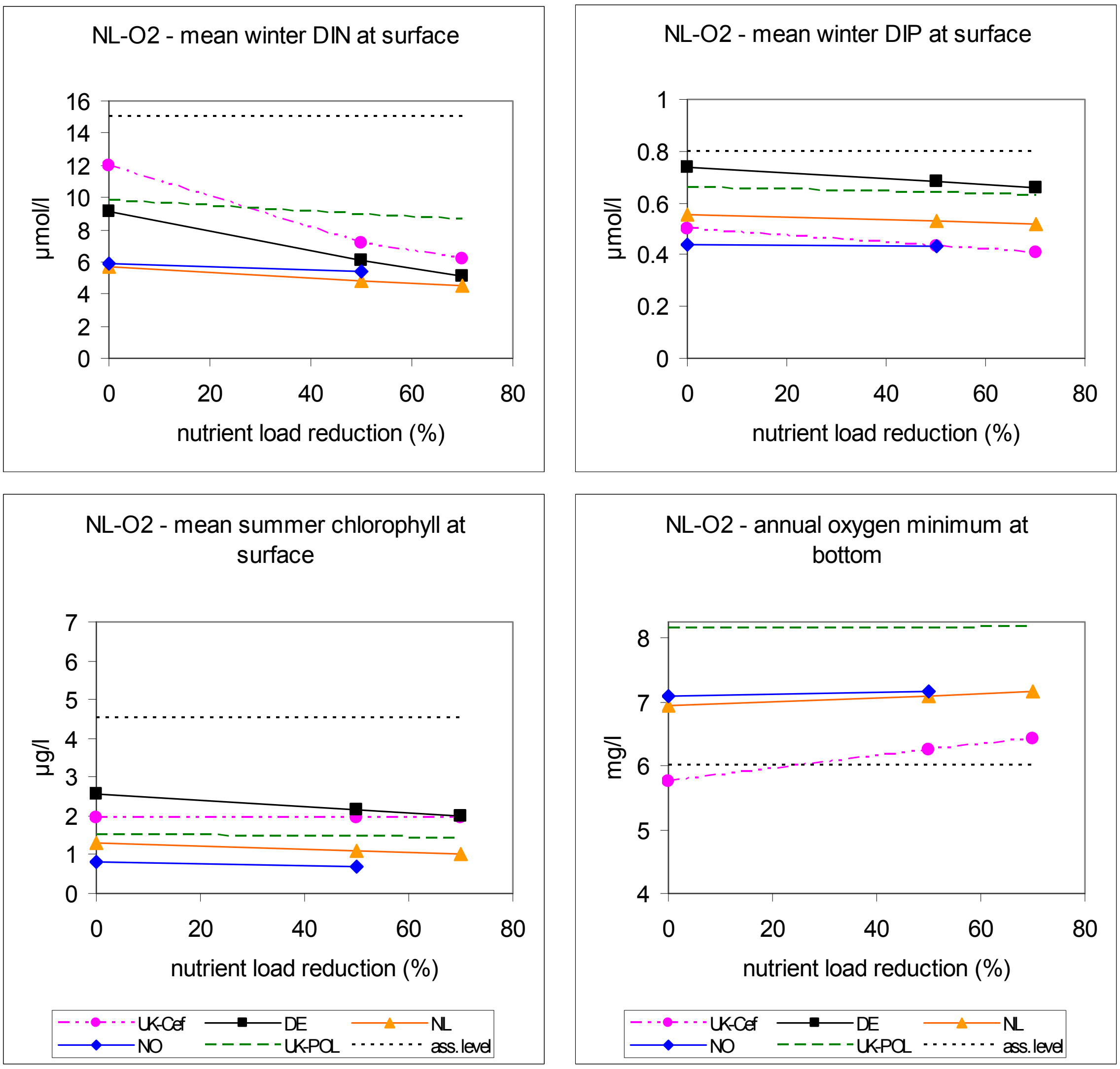


Figure 4.5 Concentrations of mean winter DIN and DIP at the surface, mean summer chlorophyll at the surface, and annual minimal oxygen concentration at the bottom for the year 2002 (standard run at 0% reduction) and for nutrient load reduction of 50% and 70% respectively. Norway did not simulate a 70% reduction scenario and there are no mean oxygen data for Germany. The concentrations are shown against the assessment levels used by the Netherlands for their areas reflected in the target box NL-O2 in the first application of the Comprehensive Procedure (OSPAR publication 189/2003). *[Note: UK-POL concentrations are under review.]*

4.3 Netherlands coastal waters: NL-C2

57. This is a coastal water body that includes Rhine waters with salinities at a range from 32 – 33 and depths from 5 m close to the coast to 20 m farther from the coast (source: http://www.noordzeeatlas.nl).

DIN

58. On average a 44% reduction in winter DIN is achieved with 50% reduction in loads and 59% reduction with 70% reduction in loads. Model responsiveness was very similar for the 4 simulations considered. The range of simulated concentrations for the reduction scenarios varies by a factor of about 2 and therefore the results are classified as of medium confidence.

DIP

59. On average a 12% reduction in winter DIP is achieved with both a 50% and a 70% reduction in loads. There is a relatively large range in model results for the reduction scenarios. Responsiveness of 3 of the 4 models considered is similar. Therefore, it is possible to designate the result as of medium confidence.

Chlorophyll

60. On average a 13% reduction in chlorophyll is achieved with 50% reduction in loads and 14% reduction with 70% reduction in loads. Low responsiveness was apparent in all model results accounting for the relatively small changes observed. One model showed a slightly higher degree of responsiveness. There is a relatively large range in model results between the reduction scenarios. Therefore, the results are classified as of medium confidence.

Oxygen

61. On average a 1% increase in mean minimum dissolved oxygen concentration is achieved with 50% reduction in loads and 2% increase with 70% reduction in loads. Model responsiveness is very similar for the 2 model results. The range of simulated oxygen concentrations is relatively narrow. The agreement between the models results provides medium confidence in this result.

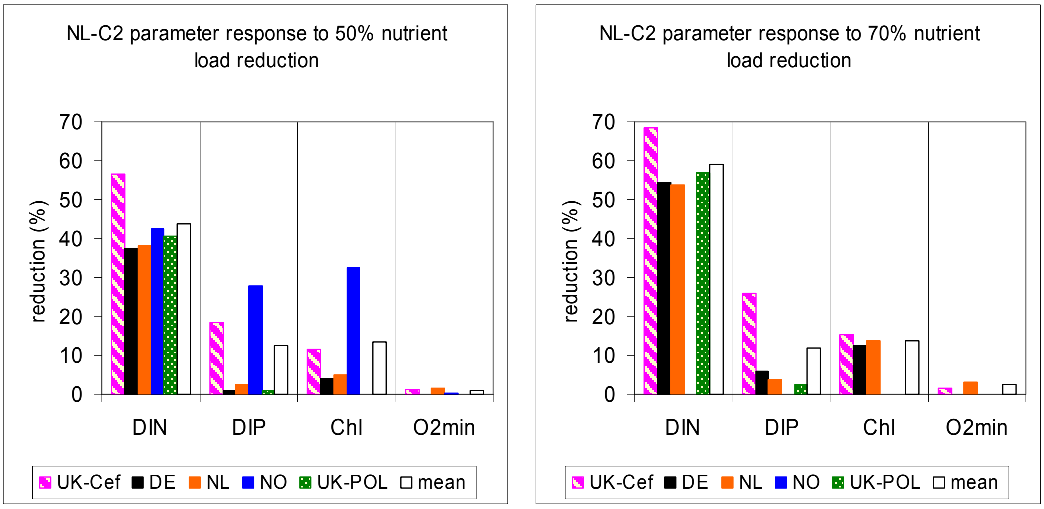


Figure 4.6 % reduction in mean winter DIN and DIP and mean summer chlorophyll, and % increase in annual minimal oxygen computed by the different models as a response to the reduction of nutrient loads to NL-C2 by 50% and 70% respectively. Norway did not simulate a 70% reduction scenario; there are no mean oxygen data from Germany. For UK-POL, % reduction in chlorophyll and % increase in oxygen is zero. *[Note: The calculation of the mean % reduction does not include UK-POL model results. The chart, including the mean calculation, will be updated following completion of the review of UK-POL values]*.

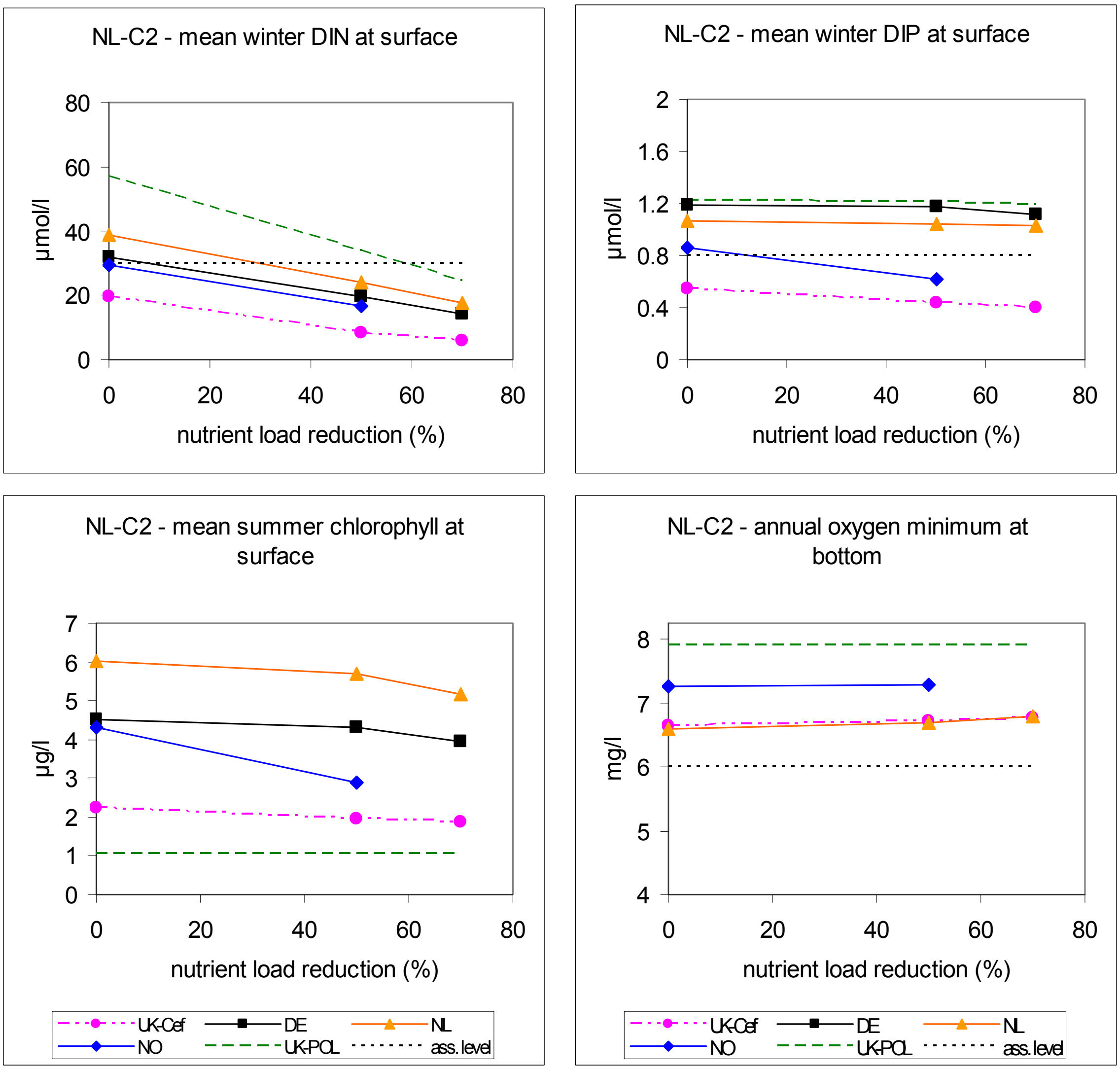


Figure 4.7 Concentrations of mean winter DIN and DIP at the surface, mean summer chlorophyll at the surface, and annual minimal oxygen concentration at the bottom for the year 2002 (standard run at 0% reduction) and for nutrient load reduction of 50% and 70% respectively. Norway did not simulate a 70% reduction scenario and there are no mean oxygen data from Germany. Except for chlorophyll, the concentrations are shown against the assessment levels (ass. level) used by the Netherlands for their areas reflected in the target box NL-C2 in the first application of the Comprehensive Procedure (OSPAR publication 189/2003). The assessment level for chlorophyll is 15 µg/l and has not been included as it is out of scale. *[Note: UK-POL concentrations are under review.]*

4.4 Netherlands coastal waters: NL-C3

62. This is a coastal water body outside the barrier islands without Wadden Sea and Ems estuary. Salinities are in the range of 30 – 34.5 and depths are from 5 m close to the coast to 30 m farther from the coast (source: www.noordzeeatlas.nl).

DIN

63. On average a 41% reduction in winter DIN is achieved with 50% reduction in loads and 56% reduction with 70% reduction in loads. Model responsiveness was very similar for the 4 simulations and there was good agreement between simulated concentrations for the two scenarios. In conclusion there is high confidence in the model results.

DIP

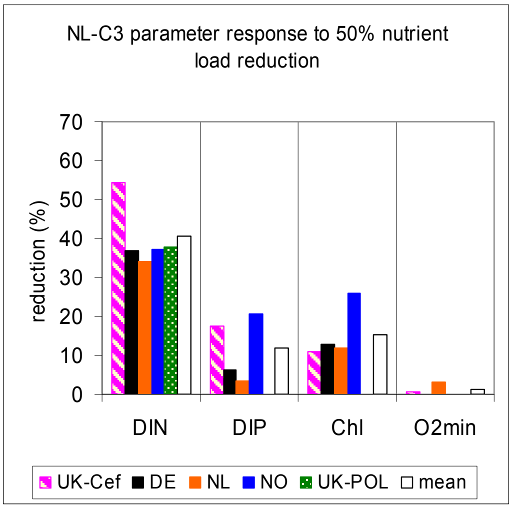
64. On average a 12% reduction in winter DIP is achieved with 50% reduction in loads and 13% reduction with 70% reduction in loads. Model responsiveness is similar between the 4 models with 3 of the 4 models in close agreement for the 50% reduction. There is medium confidence in the result as after an initial small reduction in DIP no further reduction in DIP is achieved with 70% reduction in nutrient loading.

Chlorophyll

65. On average a 15% reduction in chlorophyll is achieved with 50% reduction in loads and 20% reduction with 70% reduction in loads. A similar responsiveness was apparent in all model results accounting for the relatively small changes observed. Agreement between the 4 models results provides high confidence in this result.

Oxygen

66. On average a 1% increase in mean minimum dissolved oxygen concentration is achieved with 50% reduction in loads and 3% increase with 70% reduction in loads. Model sensitivity is low and very similar for the 3 model results. The range of model results varies by <1 mg/l and are regarded as fulfilling the requirements of criteria 1. Therefore, the results are regarded as having high confidence.



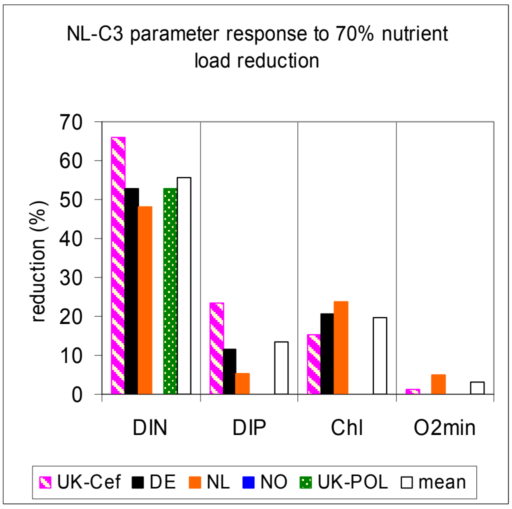


Figure 4.8 % reduction in mean winter DIN and DIP and mean summer chlorophyll, and % increase in annual minimal oxygen computed by the different models as a response to the reduction of nutrient loads to NL-C3 by 50% and 70% respectively. Norway did not simulate a 70% reduction scenario; there are no mean oxygen data from Germany. For UK-POL, % reduction in DIP, chlorophyll and oxygen is zero (DIP concentrations increased in the 50% reduction scenario). *[Note: The calculation of the mean % reduction does not include UK-POL model results. The chart, including the mean calculation, will be updated following completion of the review of UK-POL values].*

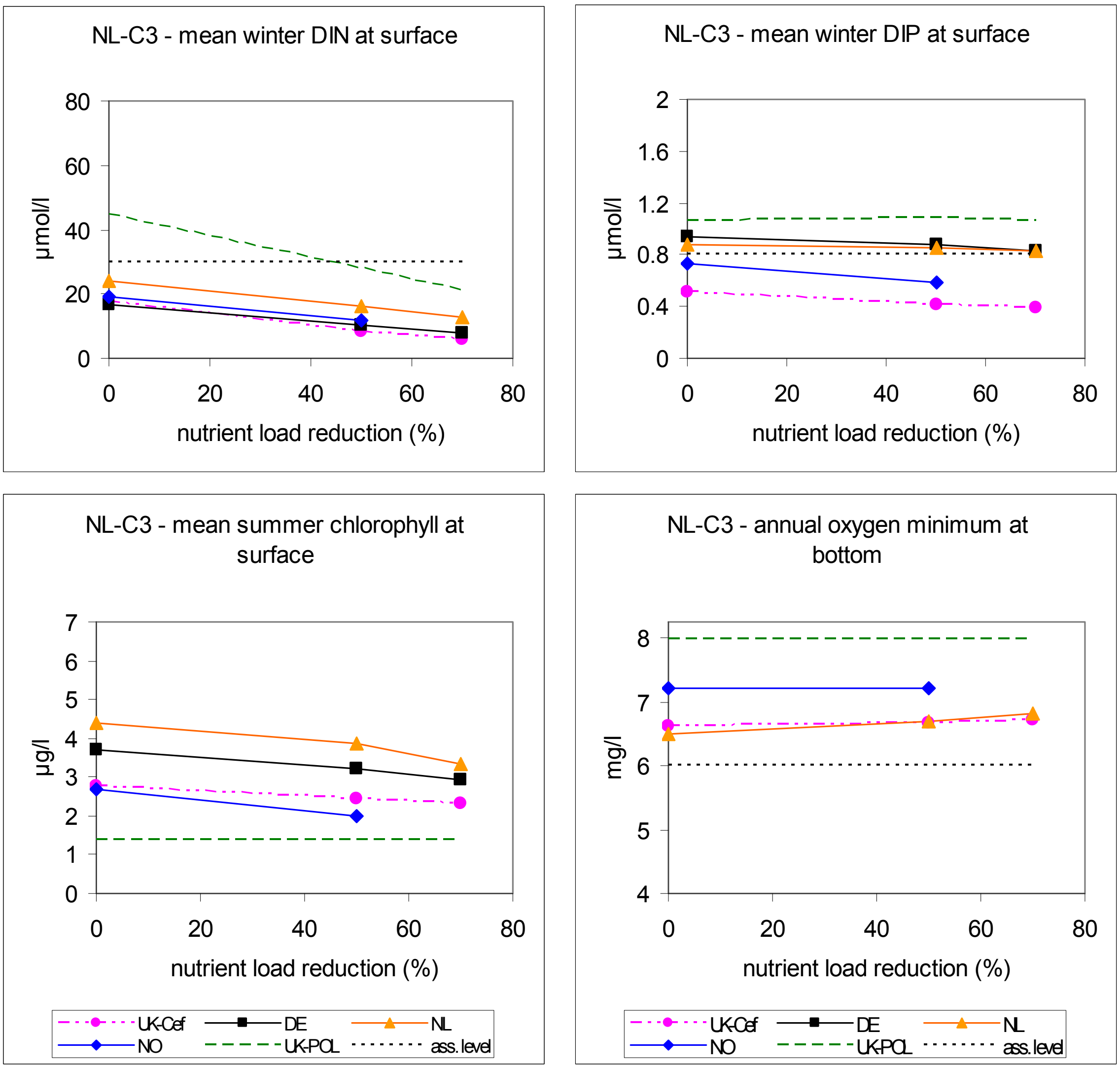


Figure 4.9 Concentrations of mean winter DIN and DIP at the surface, mean summer chlorophyll at the surface, and annual minimal oxygen concentration at the bottom for the year 2002 (standard run at 0% reduction) and for nutrient load reduction of 50% and 70% respectively. Norway did not simulate a 70% reduction scenario and there are no mean oxygen data from Germany. Except for chlorophyll, the concentrations are shown against the assessment levels (ass. level) used by the Netherlands for their areas reflected in the target box NL-C3 in the first application of the Comprehensive Procedure (OSPAR publication 189/2003). The assessment level for chlorophyll is 15 µg/l and has not been included as it is out of scale.*[Note: UK-POL concentrations are under review.]*

4.5 German coastal waters: G-C1

67. The target area G-C1 is located within the German Bight, a shallow bight with a water depth mostly below 40 m. This coastal water body with salinities between 30 and 34.5 receives large amounts of nutrients from the rivers Elbe, Weser and Ems, and from transboundary transport along with the coastal currents.

DIN

68. On average a 47% reduction in winter DIN is achieved with 50% reduction in loads and 64% reduction with 70% reduction in loads. Model responsiveness was quite pronounced and very similar for the 4 simulations. The good agreement between the 4 models in terms of the range of values for the simulations together with similar model responsiveness provides high confidence in this result.

DIP

69. On average a 14% reduction in winter DIP is achieved with 50% reduction in loads and 20% reduction with 70% reduction in loads. Model responsiveness tends to vary down to the 50% reduction and thereafter is similar. The simulated DIP concentrations are relatively widespread. Consequently, these results are regarded as having low confidence.

Chlorophyll

70. On average a 16% reduction in chlorophyll is achieved with 50% reduction in loads and 19% reduction with 70% reduction in loads. Low and to some extent variable responsiveness was apparent in model results accounting for the relatively small changes observed. The range of simulated chlorophyll concentrations varies by a factor of approximately 3. Consequently, these results are regarded as having low confidence.

Oxygen

71. On average a 2% increase in mean minimum dissolved oxygen concentration is achieved with 50% reduction in loads and 4% increase with 70% reduction in loads. Model responsiveness is very similar for the 3 model results and the range of results varies by less than 1 mg/l. Consequently, these results are regarded as having high confidence.

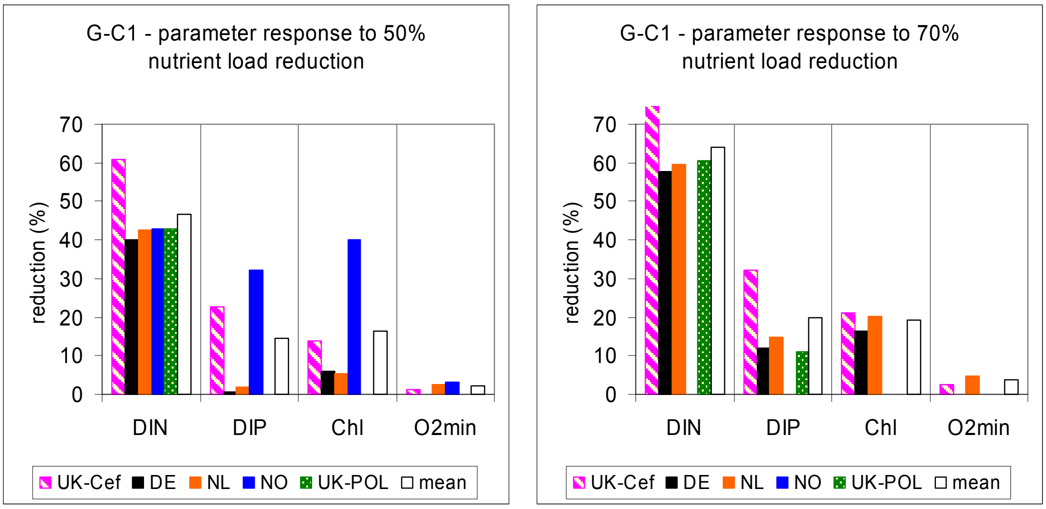


Figure 4.10 % reduction in mean winter DIN and DIP and mean summer chlorophyll, and % increase in annual minimal oxygen computed by the different models as a response to the reduction of nutrient loads to G-C1 by 50% and 70% respectively. Norway did not simulate a 70% reduction scenario, and there are no mean oxygen data from Germany. For UK-POL, % reduction in DIP, chlorophyll and oxygen is zero (DIP reduction in the 70% scenario is too small to show in the graph). *[Note: The calculation of the mean % reduction does not include UK-POL model results. The chart, including the mean calculation, will be updated following completion of the review of UK-POL values].*

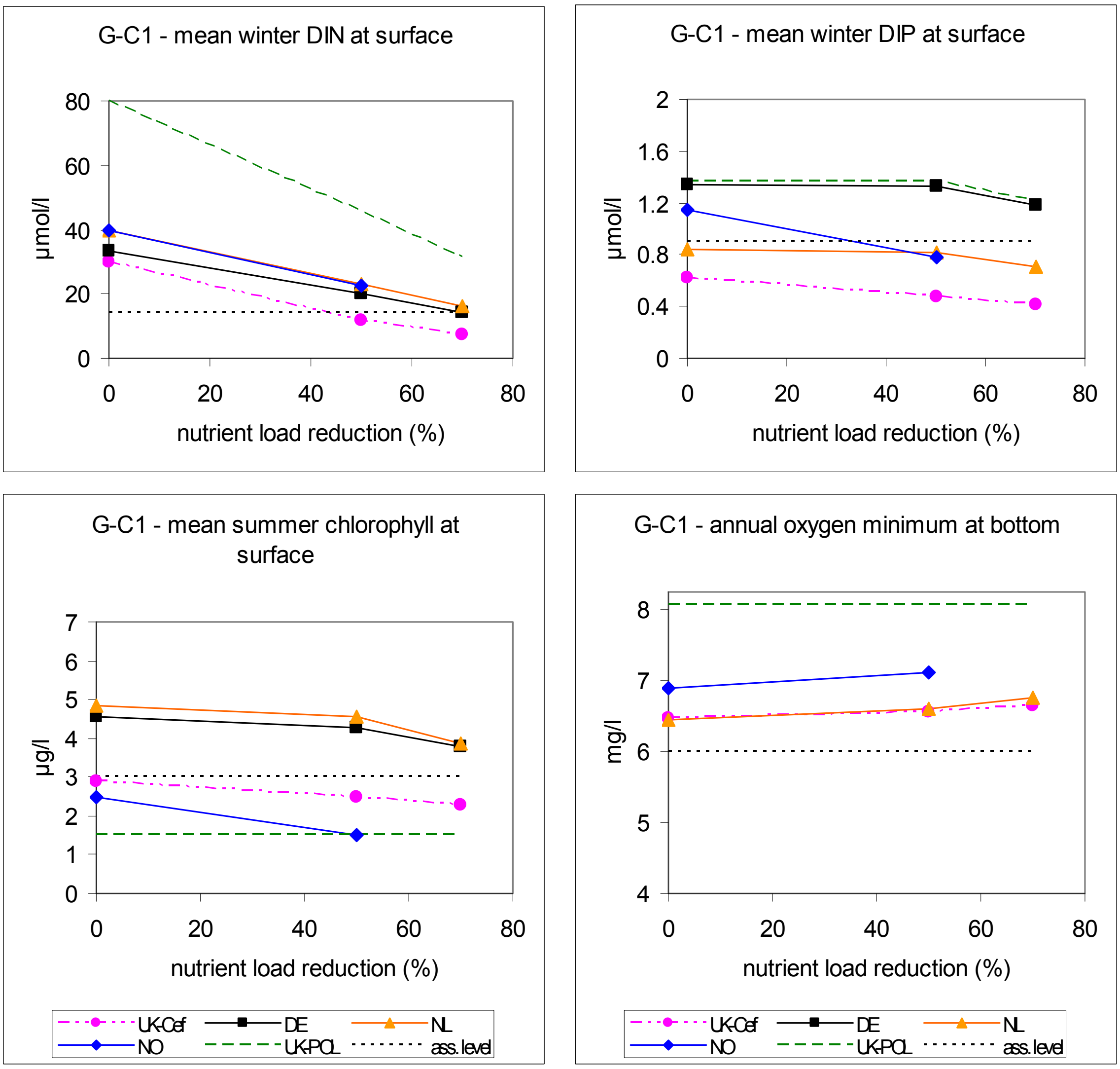


Figure 4.11 Concentrations of mean winter DIN and DIP at the surface, mean summer chlorophyll at the surface, and annual minimal oxygen concentration at the bottom for the year 2002 (standard run at 0% reduction) and for nutrient load reduction of 50% and 70% respectively. Norway did not simulate a 70% reduction scenario and there are no mean oxygen data from Germany. The concentrations are shown against the assessment levels used by Germany for their areas reflected in the target box G-C1 in the first application of the Comprehensive Procedure (OSPAR publication 189/2003). *[Note: UK-POL concentrations are under review.]*

4.6 UK coastal waters: UK-C1

72. This is a coastal water body with salinities of 30-34.5. It is well mixed with respect to density and relatively turbid.

DIN

73. On average a 28% reduction in winter DIN is achieved with 50% reduction in loads and 46% reduction with 70% reduction in loads. There are differences in model responsiveness with the range of simulated DIN concentrations varying by a factor of approximately 2. Consequently, these results are regarded as having medium confidence.

DIP

74. On average a 19% reduction in winter DIP is achieved with 50% reduction in loads and 33% reduction with 70% reduction in loads. There is considerable variability in the starting concentrations and, although there is some convergence in model results at 70%, large differences remain. The variability in model results leads to a medium confidence in the result.

Chlorophyll

75. On average a 20% reduction in chlorophyll is achieved with 50% reduction in loads and 36% reduction with 70% reduction in loads. Model responsiveness varies between models and the range of simulated DIP concentrations is quite wide. In conclusion, the results are regarded as having low confidence.

Oxygen

76. On average a 1% increase in mean minimum dissolved oxygen concentration is achieved with 50% reduction in loads and 2% increase with 70% reduction in loads. Model responsiveness is very similar for the 4 model results. The range of simulated dissolved oxygen is < 1 mg/l and thus the results are regarded as having high confidence.

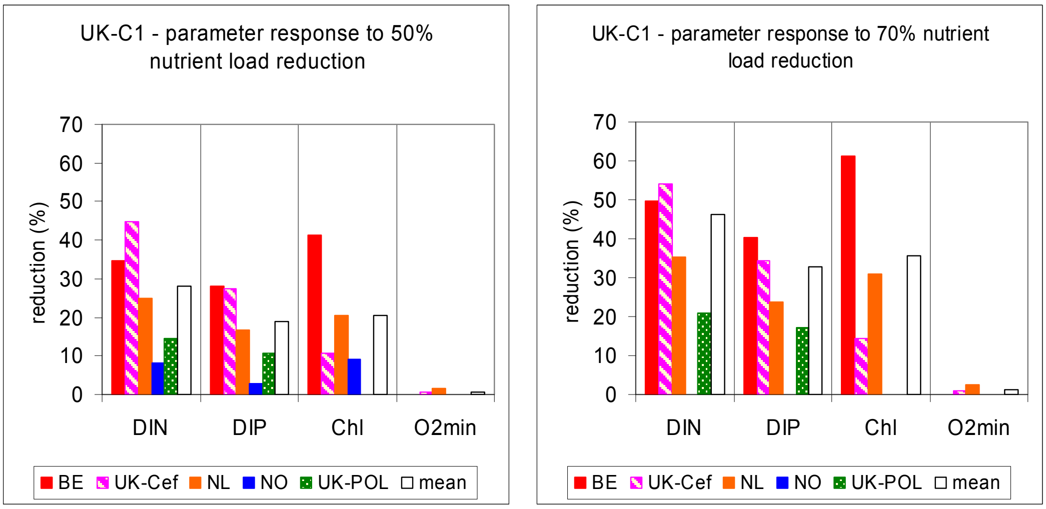


Figure 4.12 % reduction in mean winter DIN and DIP and mean summer chlorophyll, and % increase in annual minimal oxygen computed by the different models as a response to the reduction of nutrient loads to UK-C1 by 50% and 70% respectively. Norway did not simulate a 70% reduction scenario. There are no mean oxygen data from Belgium. For UK-POL, % reduction of chlorophyll and % increase in oxygen is zero. *[Note: The calculation of the mean % reduction does not include UK-POL model results. The chart, including the mean calculation, will be updated following completion of the review of UK-POL values].*

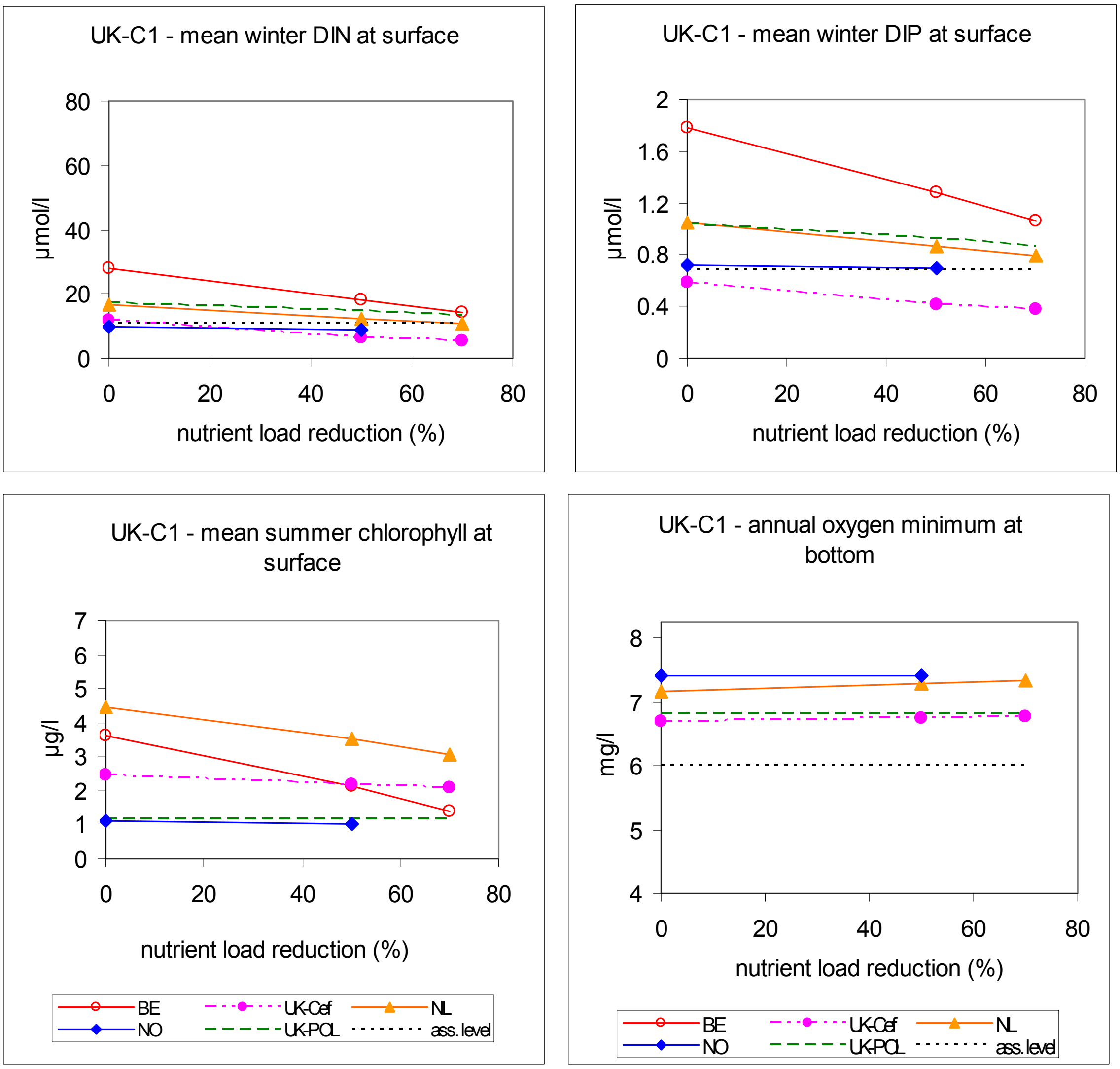


Figure 4.13 Concentrations of mean winter DIN and DIP at the surface, mean summer chlorophyll at the surface, and annual minimal oxygen concentration at the bottom for the year 2002 (standard run at 0% reduction) and for nutrient load reduction of 50% and 70% respectively. Norway did not simulate a 70% reduction scenario and there are no mean oxygen data from Belgium. Except for chlorophyll, the concentrations are shown against the assessment levels (ass. level) used by the UK for their areas reflected in the target box UK-C1 in the first application of the Comprehensive Procedure (OSPAR publication 189/2003). The assessment level for chlorophyll is 10 µg/l and has not been included in the graph as it is out of scale. *[Note: UK-POL concentrations are under review.]*

4.7 Summary

77. The results of the simulation of nutrient reduction scenarios in terms of % reductions in assessment parameters (% increase for oxygen) are summarised and presented in Table 4.1. In general largest reductions in category I parameters are seen in the coastal water target areas. The model results imply a strong, almost linear response in winter DIN concentrations to the reduced loads. Offshore the decreases are still pronounced in DIN but less so in DIP. Winter DIP concentrations do not respond as strongly to the load reductions as DIN with a decrease of up to 33% (at 70% nutrient load reduction) in UK coastal waters but results typically < 19% for all other areas and load reductions. As already noted earlier the results for winter DIP reflect the fact that for continental rivers an approximately 50% reduction in riverine inputs had already been achieved for Germany, Netherlands and France (see Table 2.1).

78. The overall range of responses in chlorophyll concentration is 11% - 36% and is similar for offshore and coastal areas with the highest decrease in coastal waters with a 70 % reduction in loads. It should be noted that there were some minor differences between participants in how mean summer chlorophyll concentration was calculated.

79. The category III assessment parameter mean annual minimum dissolved oxygen concentration increased by a maximum of 9% for the 70% reduction in offshore waters. In general, coastal waters were less responsive for this parameter than offshore waters.

Table 4.1 A summary of the results showing the range of % average decreases in concentration of the winter DIN, winter DIP and mean growing season chlorophyll concentration and % increase for mean oxygen minimum concentration following a 50% and 70 % reduction in riverine nutrient loads for 4 coastal and 2 offshore target areas. The table does not include UK-POL model results as these are still under review.

Water type	Reduction scenario	Assessment parameters							
		Category I				Category II		Category III	
		DIN		DIP		Chl		O2	
		min	max	min	max	min	max	min	max
Coastal	50%	28	47	12	19	13	20	1	2
	70%	46	64	12	33	14	36	2	4
Offshore	50%	24	29	7	7	11	19	4	6
	70%	38	45	12	12	15	23	7	9

5. Discussion

80. The workshop agreed that the new procedures introduced since the 2005 workshop in Hamburg had achieved the aim of reducing uncertainty in the model results from the nutrient reduction scenario experiments. Notably the provision of common boundary conditions, increased spin-up time, further improvements in the shared riverine nutrient input data, common meteorological data and atmospheric data considerably improved comparability between model results. As a result of these and other improved procedures adopted for this workshop confidence in the outcome has been improved.

81. By considering the reductions in riverine nutrient inputs for nitrogen and phosphorous already achieved by Contracting Parties (Table 2.1) a more realistic reduction scenario has been constructed. The riverine inputs for individual rivers themselves have been improved. For example, an improved interpolation technique was adopted for the UK rivers to deal with any gaps in observations. Even though the river data provided for the workshop had achieved the best coverage in space and time that was available in the modelling community to date there are some limitations in these data arising from poor temporal resolution of the measured nutrient concentrations. In addition, and more recently there has been a tendency to stop measurement of silicate concentration in continental rivers.

82. To aid assessment of individual model performance, the use of cost functions has been introduced. This is regarded as a useful mechanism for judging performance and further contributing to confidence in the outcome of the workshop but concern was expressed about the choice of the cost function used.

83. Whilst many improvements had been made to the procedures, the workshop concluded that future work would benefit from a shared solution to generating SPM fields either through making use of remote and *in situ* measurements or by the use of simple SPM model routines that could be shared by participants. SPM

is important as it is the most important explanatory variable for light attenuation in the models. Nevertheless, most participants had made advances since the previous workshop.

84. The reduction scenarios demonstrated clear differences between coastal and offshore target areas in terms of the response of assessment variables to reduction in nutrient loads. For winter DIN highest percentage reductions took place in coastal waters while for winter DIP much smaller reductions were evident for coastal and offshore areas. The highest reductions in winter DIP occurred in the UK and German coastal target areas and the least reductions in Dutch waters. The result reflects the fact that the Netherlands and Germany had already achieved significant reductions in their riverine loads of phosphorus as noted earlier (see section 2.1). The 50% reduction scenario for the Netherlands and Germany required no change in the actual river load for phosphorus since the reduction, in comparison to 1985, had already reached this level. For the Netherlands this was also the case for the 70% reduction, while for Germany a reduction of 40 % in phosphorus load was still required.

85. For mean summer chlorophyll concentrations greatest reductions took place in coastal target areas with a much greater reduction in the UK box. However, apart from this target area this parameter was not highly responsive to reduced nutrient loading. This does not imply that there is no reaction in the modelled biological system, but only that the parameter mean summer chlorophyll concentration is relatively insensitive to the level of the nutrient load. It was recognised by the participants that net primary production could serve as a more suitable parameter for indicating accelerated growth, but it was also noted that this parameter is not routinely monitored. In this context the question should be raised in which way the ecosystem models will be used to support management questions. Therefore biological parameters should be tested to reflect the information needed to judge the change in the ecosystem related to nutrient reduction scenarios. The participants also recognised that, as phytoplankton biomass is represented in most models as carbon and a conversion to chlorophyll is required (either simply or using a dynamic formulation), a better method of inter-comparison would be to use carbon content directly. Such an approach avoids the introduction of complications in cases where incomparable units would need changing to chlorophyll content.

86. The least sensitive parameter was mean minimum dissolved oxygen concentration. Highest increases in this parameter occurred offshore and in the largest reduction scenario. In all models, oxygen had a low responsiveness to nutrient reductions. The general question was raised as to whether the mean oxygen content calculated over a relative large target area is the correct method to represent this parameter. While some participants argued that the occurrence of low oxygen concentrations is mainly driven by meteorological factors (especially wind), others did not agree and pointed out that it is also related to the biological degradation process of organic matter by bacteria in the model. A correct representation of this process is important and differences between models in terms of the complexity of the benthic modules are a likely source of disagreement between model results. In discussion, it was noted that monitoring of an oxygen minimum was a difficult task and only achievable with continuous (buoy) measurements. However, models do have the capability to resolve small scale events such as oxygen minima. Bearing in mind the importance of oxygen as an assessment parameter, well validated models could play a role in bolstering the 'monitoring' based assessments by providing information not only on the oxygen minima but also on the duration of 'above-threshold' levels and their spatial extent in water bodies. Such an approach would add value to the monitoring effort and provide (supplementary) information to help interpret monitoring data.

87. The workshop identified specific issues for consideration with regard to modelling dissolved oxygen concentration:

- Can models address whether oxygen deficiency is of anthropogenic nature? Models can point to areas which are sensitive to oxygen deficiency and where anthropogenic causes may have impact and where not. Models can help constructing and evaluating cause-effect relationships.
- Models can also help optimize monitoring programmes by identifying those areas where oxygen measurements are most cost-efficient in relation to the sensitivity of an area to eutrophication effects.
- Infrequent monitoring makes it difficult to detect the actual oxygen concentration minimum. This could be achieved by models in combination with monitoring.

88. The capability of models to better resolve the spatial and temporal variability of simulated dissolved oxygen concentration also applies to other assessment parameters. For example, short lived events such as phytoplankton blooms are particularly difficult to detect with *in situ* measurements unless they are

continuous or at least of sufficient temporal resolution to capture episodic events of a few days' duration. Consequently, validated models can be used to provide supplementary information to bolster the monitoring-based assessments of eutrophication and, therefore, contribute to increased confidence in the outcome of assessments of eutrophication status.

89. Model results presented from Norway included a multi-year model run and demonstrated important inter-annual variability in assessment parameters. Such an approach deals with the possibility of bias in the results to nutrient scenario testing, for example, as a result of dealing with extreme years (wet and dry years) by putting results into a wider temporal context.

6. Conclusions

90. We have reduced uncertainty and within the context of limitations of modelling have confidence in our results.

- The participants convincingly demonstrated that through the recommended spin-up procedure the models used had reached a stable state and were therefore fit for reduction scenario testing.
- Sharing common boundary conditions and other forcing data together with the spin-up procedure enhanced comparability of model results.
- A range of changes have been introduced to the nutrient reduction scenario testing that have contributed to a significant reduction in uncertainty associated with the use of models and therefore contributed to an increase in confidence to the results reported here.
- In general winter DIN and DIP were most responsive in coastal target areas with about half a reduction in DIN achieved compared to the % reduction in riverine nitrogen load.
- Mean summer chlorophyll concentration was less responsive to load reduction than DIN or DIP and generally had a similar response in offshore and coastal target areas.
- Mean minimum dissolved oxygen concentration was the least responsive of all parameters but with greatest response offshore. Questions were raised about the robustness of this parameter as an indicator of eutrophication especially offshore where wind speed was regarded as an important explanatory variable.

91. The above conclusions should be set against the known merits and limitations of numerical modelling. The model results should be regarded as indicating the direction of changes in levels and effects but do not forecast the exact results of the eutrophication status in the marine environment with respect to nutrient enrichment (nutrient concentrations and N/P ratios), and direct and indirect effects following the achievement of the 50 % reduction targets for nutrient inputs.

7. Recommendations

92. To achieve further improvements in the use of models by reducing uncertainty the following improvements should be considered:

- In order to improve the simulation of the water column light climate in the model in future, SPM fields should be supplied either by using remote and in situ measurements or by supplying model routines to simulate the SPM accurately.
- To take into account inter-annual variability, the use of multi-year simulations should be encouraged but recognising that the additional data needs (e.g. multi-year riverine nutrient inputs) to support such an approach are substantial.
- To improve the quality of model results more data from measurements are required with the appropriate spatial and temporal resolution for validation purposes.

8. Acknowledgements

93. The Workshop organisers gratefully acknowledge the ECMWF (European Centre for Medium Range Weather Forecasting) for allowing us to provide meteorological data to the participants for specific use at this workshop.

9. References

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Radach, G. and Moll, A., 2006. Review of three-dimensional ecological modelling related to the North Sea shelf system - Part 2: Model validation and data needs. Oceanography and Marine Biology; an Annual Review, Vol. 44:1-60.

Appendix 1 Overview of models used in the reduction scenarios

Model name	MIRO&CO-3D (Belgium)	ECO-MARS3D (France)	ECOHAM4 (Germany)	Deft3D-GEM (Netherlands)	NORWECOM (Norway)	MOHID System (Portugal)	GETM-BFM (Cefas - United Kingdom)	POLCOMS-ERSEM (POL – United Kingdom)
General characteristics								
Name hydrodynamic model	COHERENS	MARS-3D	HAMSOM	Delft3D	Based on Princeton Ocean Model	MOHID	GETM	POLCOMS
Name biogeochemical model	MIRO	ECO-MARS-3D	ECOHAM4	GEM	NORWECOM	MOHID – Module Water Quality	BFM	ERSEM
Spatial Resolution Δh (km)	5' longitude (5.6 km) x 2.5' latitude (4.6 km)	4 x 4 km	20 km	Variable (min. 2x4 km, max 20x20km)	10	Variable (11km to 4km)	approx. 6 nautical miles	12
Vertical resolution	5 sigma layers	12 sigma levels	24 z-layers	10 sigma layers	21 sigma layers	10 Cartesian	25 layers, General Coordinates	32 s-levels
Longitude (degree)	4.0°W – 5.0°E	-5.5, 5.0	15° W – 14° E	4ºW 10ºE	12W-12E	1.5ºW, 6.5ºE	5.15W - 18E	20W-13E
Latitude (degree)	48.5°N – 52.5°N	47.85, 52.50	47,5° N – 64° N	49ºN – 57ºN	48N-64N	49ºN, 54,5ºN	48.5N - 60N	40-65N
Spatial extent (km)	500 km	W-E: 750, N-S: 520	1800 x 1800	~$7.2*10^2$ x ~$5*10^2$ m = $3.6*10^5$ km^2		~600x800km		2376 x 2688
Temporal resolution Δt (sec)	900 sec	variable ~400 s	60s	Transport timestep (from D3D-FLOW) 30 min. Ecological processes timestep: 24 hrs	900	60s	45 sec (stored dayly)	15s (barotropic), 300s (baroclinic), 1200s (biochemical)
Temporal range (years)	1991-2004 (2005 for hydrodynamics)	1999-2003	1y (2002)	1 (2002) Years 1975 – 2003 modelled	1985-2005	1y	1	1987, 1988-2005
Spin up time	2 years	2 times the year 1999	3 years	5 years	4 years	1y	10 years	6
Meteo data	Real 6 hours reanalysed forecasts from UKMO / ECMWF (2002) for ICG-EMO workshop	real data : ARPEGE MODEL (METEO-France) + irradiance from METEOSAT/AJONC (METEO-France)	NCEP	Air temperature: time series Light Vessel Goeree; air pressure, humidity, cloudcover, wind: ERA40 ECMWF; (solar radiation is computed from these)	ECMWF	Wind, Solar Radiation, Humidity, Air Temperature, Cloud Cover; From ERA40(ECMWF)+NCEP(NOAA)	ECMWF	ECMWF era-40 + analyses
Oxygen dynamics	No	Yes	yes	Included in model	yes	Yes	calculated	
Temperature &Salinity diagnostic or prognostic	Weekly 20 km x 20 km gridded SST (BSH) imposed – salinity prognostic	T and S are prognostic (= simulated state variables)	T: prognostic; S: diagnostic	Both are simulated	prognostic	Temperature: Forced in the boundary and initial conditions from	calculated	Prog

						NOAA OISSTv2; Temperature evolution is computed considering also surface fluxes between water and atmosphere. Salinity: Forced in the boundary and initial conditions from WOA2005 (NODC/NOAA); Evolution computed by the model.		
SPM dynamics	Seasonal TSM from SeaWiFS climatology (1997-2003) imposed at the surface / bi-monthly for ICG-EMO	SiAM3D model and satellite forcing (SeaWiFS, monthly averages)	climatology	Simulated Delft3-Sed.	no	Sediment transport model computing settling velocity and erosion/deposition processes	local resuspension by waves	IOP assim
Inclusion of tides	yes	Yes	no	Yes	M2, S2, K1, O1	FES2004 forced at the borders	yes	Yes
Pelagic description								
Pelagic matter cycle (C, N, P, Si)	C, N, P, Si	N, P, Si, O	C, N, P, Si	N, P, Si complete. C organic part only.	N, P, Si, O	C, N, P (Si optional)	C, N, P, Si	Yes
No. of Pelagic state variables	32	19	24	Variable. This application: 23	9	12 (18 available)	45	51
Pelagic Nutrients (bulk or explicit)	Explicit (NO_3, NH_4, PO_4, SiO)	explicit	Explicit	Explicit	DIN, PO4, SiO2	Explicit	?	Explicit
Types of Phytoplankton	Nanoflagellates (3), Diatoms (3), Phaeocystis (4)	diatoms, dinoflagellates, small phytoplankton, *Karenia mikimotoi*, *Phaeocystis globosa* (4 variables needed)	Diatoms and flagellates	12. Functional groups: diatoms, microflagellates, dinoflagellates, *Phaeocystis*	DIA, FLA	Flagellates (diatoms optional)	?	Diatoms, pico, flagellates, dinoflagellates
Types of Zooplankton	Microzooplankton, Copepods	microzooplankton, mesozooplankton	Micro- and mesozooplankt	Variable. This application: 0		Mesozooplankton (microzooplankton optional)	?	Micro, meso, heterotrophic nanoflagellates
Types of bacteria	Heterotrophic bacteria	None	Bacteria	0		No (Optional)	?	Heterotrophic
Pelagic POM	Particulate organic C, N & P of high (1) and low(2) biodegradability, Biogenic Silica	Yes	Slow and fast sinking detritus (7 state variables)	Not included this application		yes	?	Yes

Benthic description								
Benthic matter cycle (C, N, P, Si)	C, N, P	N, P, Si, O	C, N, P, Si	C, N, P, Si	N, P, Si	C, N, P and (Si optional), simple model	C, N, P, Si	Yes
No. of benthic state variables	6	10	5	Variable. This application: 4	6	8	?	7
Benthic Nutrients (bulk or explicit)	Diagenetic model (NO_3, NH_4, PO_4)	explicit	Bulk	Explicit	DIN, PO4, SiO2	Explicit	?	Yes
Types of Zoobenthos		one goup of suspendeed feeders	No	Variable. This application: 0		No	?	Suspension feeders, deposit feeders, meiofauna
DOM		none	No	0		Yes	?	Yes
Types of Bacteria		none	No	0		No (simple mineralization model)	?	Aerobic, anaerobic
Benthic POM		yes	5 state variables	0		Yes	?	Yes
Participant to add further characteristics if required		yes		Model is application constructed within general framework Delft3D-Eco. Level of detail ecological processes can easily be modified. Available options include various sediment modules, heterotrophic phytoplankton, DOM and several grazer modules				
Light				Extinction of visible light is a function of: inorganic suspended matter, yellow substances (freshwater), detritus, and phytoplankton SPM		Light penetration is SPM and phytoplankton dependent		Variable c:chl ratios
Area						Southern North Sea – English Channel		
Nesting ability						Yes. Can be used to nest higher resolution models to simulate areas with more detail.		

Appendix 2 Scoring tables of target area assessments in the format of the Common Procedure

German offshore target area – G-O2

Harmonised assessment parameters of the Common Procedure		Data Common Procedure 2002	Germany ECOHAM4			Netherlands Delft3D-GEM			Norway NORWECOM			UK (Cefas) GETM-BFM			UK (POL) POLCOMS-ERSEM		
			2002	50%	70%	2002	50%	70%	2002	50%	70%	2002	50%	70%	2002	50%	70%
Cat. I	Winter DIN	-	-	-	-	-	-	-	-	-	n/a	?	-	-	+	-	-
	Winter DIP	-	-	-	-	-	-	-	-	-	n/a	-	-	-	-	-	-
	N:P ratio	-	-	-	-	-	-	-	-	-	n/a	+	-	-	-	-	-
Cat. II	Chl mean	?	0	-	-	0	0	0	-	-	n/a	?	?	?	-	-	-
	Chl max 3	?	+	-	-	+	+	+	+	+	n/a	+	+	+	+	+	+
	Indicator species	?	n/a	n/a	n/a	+	0	0	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Cat. III	Oxygen min	?	n/a	n/a	n/a	-	-	-	+	+	n/a	+	-	-	+	+	+
	Organic matter	n/t	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

'+': above the assessment level; **'-'**: below the assessment level; **'0'**: mean below the assessment level but mean + standard deviation above assessment level; '?': not enough data to perform an assessment or the data available is not fit for purpose; n/a: not applied; n/t: transboundary import.

Netherlands offshore area – NL-O2

Harmonised assessment parameters of the Common Procedure		Data Common Procedure 2002	Germany ECOHAM4			Netherlands Delft3D-GEM			Norway NORWECOM			UK (Cefas) GETM-BFM			UK (POL) POLCOMS-ERSEM		
			2002	50%	70%	2002	50%	70%	2002	50%	70%	2002	50%	70%	2002	50%	70%
Cat. I	Winter DIN		-	-	-	-	-	-	-	-	n/a	-	-	-	-	-	-
	Winter DIP	-	-	-	-	-	-	-	-	-	n/a	-	-	-	-	-	-
	N:P ratio	-	-	-	-		-	-	-	-	n/a	+	-	-	-	-	-
Cat. II	Chl mean	-	-	-	-	-	-	-	-	-	n/a	-	-	-	-	-	-
	Chl max	-	+	-	-	+	+	+	-	-	n/a	+	+	+	+	+	+
	Indicator species	-/+	n/a	n/a	n/a	0	0	0	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Cat. III	Oxygen min	+	n/a	n/a	n/a	-	-	-	+	+	n/a	+	-	-	+	+	+
	Organic matter	+	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	na	na	na

n/a not applied; **'+'**: above the assessment level; **'-'**: below the assessment level; **'0'**: mean below the assessment level but mean + standard deviation above assessment level;

Netherlands coastal waters – NL-C2

Harmonised assessment parameters of the Common Procedure		Data Common Procedure 2002	Germany ECOHAM4			Netherlands Delft3D-GEM			Norway NORWECOM			UK (Cefas) GETM-BFM			UK (POL) POLCOMS-ERSEM		
			2002	50%	70%	2002	50%	70%	2002	50%	70%	2002	50%	70%	2002	50%	70%
Cat. I	Winter DIN	+	+	-	-	+	-	-	-	-	n/a	-	-	-	+	+	-
	Winter DIP	+	+	+	+	+	+	+	+	-	n/a	-	-	-	+	+	+
	N:P ratio	+	+	-	-	+	-	-	+	+	n/a	+	-	-	+	+	-
Cat. II	Chl mean	+	-	-	-	-	-	-	-	-	n/a	-	-	-	-	-	-
	Chl max	+	-	-	-	+	+	+	-	-	n/a	-	-	-	-	-	-
	Indicator species	+/+	n/a	n/a	n/a	0	0	0	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Cat. III	Oxygen min	+	n/a	n/a	n/a	-	-	-	+	+	n/a	-	-	-	-	-	-
	Organic matter	n/t	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

n/a not applied; **'+'**: above the assessment level; **'-'**: below the assessment level; **'0'**: mean below the assessment level but mean + standard deviation above assessment level; n/t: transboundary import.

Netherlands coastal waters – NL-C3

Harmonised assessment parameters of the Common Procedure		Data Common Procedure 2002	Germany ECOHAM4			Netherlands Delft3D-GEM			Norway NORWECOM			UK (Cefas) GETM-BFM			UK (POL) POLCOMS-ERSEM		
			2002	50%	70%	2002	50%	70%	2002	50%	70%	2002	50%	70%	2002	50%	70%
Cat. I	Winter DIN	+	-	-	-	-	-	-	-	-	n/a	-	-	-	+	+	+
	Winter DIP	+	+	0	0	+	+	+	-	-	n/a	-	-	-	+	+	+
	N:P ratio	+	-	-	-	+	-	-	+	0	n/a	+	-	-	+	+	-
Cat. II	Chl mean	+	-	-	-	-	-	-	-	-	n/a	-	-	-	-	-	-
	Chl max	+	-	-	-	+	+	+	-	-	n/a	+	+	-	+	+	+
	Indicator species	+/+	n/a	n/a	n/a	+	+	0	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Cat. III	Oxygen min	+	n/a	n/a	n/a	-	-	-	+	+	n/a	-	-	-	-	-	-
	Organic matter	n/t	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

n/a not applied; **'+'**: above the assessment level; **'-'**: below the assessment level; **'0'**: mean below the assessment level but mean + standard deviation above assessment level;

German coastal waters – G-C1

Harmonised assessment parameters of the Common Procedure		Data Common Procedure 2002	Germany ECOHAM4			Netherlands Delft3D-GEM			Norway NORWECOM			UK (Cefas) GETM-BFM			UK (POL) POLCOMS-ERSEM		
			2002	50%	70%	2002	50%	70%	2002	50%	70%	2002	50%	70%	2002	50%	70%
Cat. I	Winter DIN	+	+	(+)	(+)	+	+	0	+	+	n/a	+	-	-	+	+	+
	Winter DIP	+	+	+	+	0	0	-	+	+	n/a	-	-	-	+	+	+
	N:P ratio	-	-	-	-	+	+	-	+	+	n/a	+	+	-	+	+	+
Cat. II	Chl mean	?	0	0	(+)	+	+	0	-	-	n/a	-	-	-	-	-	-
	Chl max	?	-	+	+	+	+	+	+	+	n/a	+	+	+	+	+	+
	Indicator species	+	n/a	n/a	n/a	+	+	+	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Cat. III	Oxygen min	-/+*	n/a	n/a	n/a	-	-	-	+	+	n/a	-	-	-	-	-	-
	Organic matter	?	n/a	n/a	n/a	n/a	n/a	n/a	n/a		n/a	n/a	n/a	n/a	n/a	n/a	n/a

n/a not applied; **'+'**: above the assessment level; **'-'**: below the assessment level; **'0'**: mean below the assessment level but mean + standard deviation above assessment level; '?': not enough data to perform an assessment or the data available is not fit for purpose

* In the first application of the Comprehensive Procedure the area covered by G-C1 was reflected in two coastal areas, one of which scored '+' and one '–' for oxygen.

UK coastal waters – UK-C1

Harmonised assessment parameters of the Common Procedure		Data Common Procedure 2002	Belgium			Netherlands Delft3D-GEM			Norway NORWECOM			UK (Cefas) GETM-BFM			UK (POL) POLCOMS-ERSEM		
			2002	50%	70%	2002	50%	70%	2002	50%	70%	2002	50%	70%	2002	50%	70%
Cat. I	Winter DIN	+	+	+	+	+	+	0	-	-	n/a	+	-	-	+	+	+
	Winter DIP	+	+	+	+	+	+	+	+	+	n/a	?	-	-	+	+	+
	N:P ratio	+	-	-	-	-	-	-	-	-	n/a	-	-	-	-	-	-
Cat. II	Chl mean	+	-	-	-	-	-	-	-	-	n/a	-	-	-	-	-	-
	Chl max	+	+	-	-	-	-	-	-	-	n/a	+	-	-	-	-	-
	Indicator species	-	n/a	n/a	n/a	-	-	-	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Cat. III	Oxygen min	-	n/a	n/a	n/a	-	-	-	+	+	n/a	-	-	-	-	-	-
	Organic matter	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

n/a not applied; **'+'**: above the assessment level; **'-'**: below the assessment level; **'0'**: mean below the assessment level but mean + standard deviation above assessment level;

ANNEX 5
(Ref. § 4.20b)

Draft Work Programme for Calculating Transboundary Nutrient Transport in the North Sea and Adjacent Sea Areas

1. Introduction

1. This document provides the relevant background, rationale and a draft programme of work for the determination of transboundary nutrient transport in the context of assessments of marine eutrophication carried out for OSPAR. Its purpose is to address the tasks identified by EUC(2) 2005 for the ICG EMO in carrying out further work on transboundary nutrient transport (EUC(2) 2005 Summary Record, Annex 8) and to deliver the items EUC(1) 2006 identified as tasks for the workshop on eutrophication modeling held in Lowestoft (UK) on 10-12 September 2007 (click here for the workshop terms of reference). The terms of reference are also available from the Cefas website (Eutmod).

2. The workshop was invited to prepare specifications for model applications, including a working definition for transboundary nutrient transport, selection of suitable locations for estimating nutrient fluxes, development of protocols for model applications and agreement of arrangements for calculating nutrient fluxes for identified target areas including dynamics, nutrient loads, transported over specific boundaries and nutrient budgets in defined areas with a view to comparing model results if necessary through a workshop.

2. Context

3. For the past two decades marine eutrophication has been one of the major issues tackled by OSPAR. OSPAR has agreed measures committing Contracting Parties to achieve a substantial reduction at source, in the order of 50% compared to 1985, in inputs of phosphorus and nitrogen into areas where these inputs are likely, directly or indirectly, to cause pollution.[10] To assist Contracting Parties in identifying those areas in a consistent way and setting priorities for implementing measures to combat eutrophication, OSPAR developed a common assessment framework: the Common Procedure for the Identification of the Eutrophication Status of the OSPAR Maritime Area (the "Common Procedure"). This is essentially achieved through classifying waters as problem areas, potential problem areas and non-problem areas with regard to eutrophication.

4. Eutrophication in the North Sea may arise as a result of excessive inputs of anthropogenic nutrient loads that are discharged into the sea mainly from the large rivers. In addition to the river loads, atmospheric deposition plays a (limited) role and there are potentially significant point sources arising from the discharges from Waste Water Treatment Plants. Point sources are generally not quantified for most countries bordering the North Sea whilst diffuse sources have largely been neglected. A further contribution of nutrients to national maritime regions results from the transboundary transport of nutrients. These latter inputs are potentially important for downstream areas with coastal currents, and (temporarily) offshore depositional areas receiving nutrient inputs from adjacent marine areas. Identification and quantification of source(s) of these transboundary inputs is critical in order to be able to identify and take cost-effective measures to combat eutrophication in the OSPAR maritime area.

5. For example, for the Dutch Continental Shelf the river Rhine is the largest, anthropogenically-influenced source, but to a lesser extent the rivers Meuse, Scheldt and Ems also play a role. For these rivers the nutrient loads are not only determined by emissions in the Dutch sector of the catchment area, but also by emissions in the upstream areas of these rivers. Additionally, the nutrient loads to the Dutch Continental Shelf are also influenced by transport from the Belgian coastal zone and possibly by discharges from UK rivers. Other relevant sources include the background loads delivered through the Channel and from the Atlantic Ocean. In their turn nutrient transports from the Dutch Continental Shelf influence the German Bight.

6. As a consequence of various transport mechanisms, multiple sources and other contributions it is not straight forward to directly link effects (e.g. resulting in an assessment as a Problem Area) in maritime areas to cause in terms of the individual nutrient sources. The identification of appropriate management measures is hampered by this lack of clarity and requires further work in order to identify all potential sources/contributions and the flows of the nutrients. This proposed work programme describes how models can be used to estimate the flows of nutrients through the North Sea and to determine the relative contributions of the major sources to these flows.

[10] PARCOM Recommendation 88/2 on the reduction in inputs of nutrients to the Paris Convention; PARCOM Recommendation 89/4 on a coordinated programme for the reduction of nutrients; and PARCOM Recommendation 92/7 on the reduction of nutrient inputs from agriculture into areas where these inputs are likely, directly or indirectly, to cause pollution.

3. Objectives

7. The objectives are:

a. to quantify the relative contributions of the various nutrient sources, with their natural and anthropogenic fractions, to transboundary nutrient transports and the consequences on ecosystem function and behavior;

b. to construct nutrient budgets for a number of predefined areas;

c. to determine consequences for target areas of any nutrient transport in terms of eutrophication status and in particular accelerated growth and undesirable disturbance.

8. The third objective (paragraph 6c) is included to take into account the recognition by the workshop participants of the need to consider not only the transport of nutrients but their subsequent consequence in terms of eutrophication status for the downstream target area.

4. Approach

9. To carry out the work the participants will compute a number of defined simulations using dynamical ecological hydrodynamical models. The range of nutrient sources to be quantified are:

a. the major rivers;
b. the North Atlantic ocean and the Channel boundaries;
c. the atmosphere.

5. Definitions

5.1 Sources

10. In the framework of this work programme ‘sources’ are the different discharges into the North Sea.

11. For the southern North Sea the important loads are from:

- the Channel and the northern North Sea
- Belgian rivers
- Dutch rivers
- German rivers
- British rivers

12. For the northern North Sea:

- the Atlantic Ocean and the southern North Sea
- Scottish rivers
- Danish coast
- Norwegian coast

13. And for both

- Atmospheric deposition
- Substantial outflows from waste water treatment plants have to be taken into account.

14. In general diffuse sources are neglected.

15. Besides aggregating rivers on a national basis the rivers could be aggregated by box (target area) in order to be able to differentiate between e.g. UK Channel vs. river input from region UK-C1. This will be determined in intersessional work.

5.2 Transboundary fluxes and predefined areas

16. Fluxes across a boundary are called transboundary fluxes. Flux is the integration of concentrations over a box boundary by time and velocity. Calculating fluxes are the means to determine the contribution of a load from one particular source to a specific area. The flux to be computed is the quantity that crosses the

boundary with the additional need to identify source. These fluxes will be measured as water volumes per unit time (Sv) or amounts of nutrients, expressed as weight per time, e.g. mol/d or mol/y.

17. Fluxes will be calculated in both directions across the national maritime boundaries. The minimum requirement for participants is to compute fluxes over one year or a minimum number of tides (yet to be agreed). The length of simulation and method of calculation needs to ensure mass balance. The flux computation will need to be done online. Whether the calculation results should be presented to EUC as fluxes in both directions or as the residual flux only still needs to be specified.

18. The right time scale is essential to computing realistic fluxes. A small time step will be important to accurately compute fluxes across the boundary (e.g. using the minimum model time step). In addition, there may be a need to present results from multi-year simulations where data may better be presented on a monthly basis.

19. Targeted measures that may be required by Contracting Parties to reduce nutrient inputs to their maritime area require information on the national origin of the nutrients and on the source. Further information on the relative contribution of nutrients arising from anthropogenic and natural sources is also required.

20. The areas of particular interest for work on transboundary nutrient transport are the national maritime areas designated as problem areas following the [second[11]] application of the OSPAR Common Procedure and where transboundary nutrient transport has been cited as a causative factor in the assessment. Prime candidates are the German Bight and the Dutch Oyster Grounds. However, calculation of fluxes across all national maritime boundaries within the model domains (areas) is a feasible outcome for the proposed work.

5.3 Validation

21. Calculation of water transport and if possible nutrient fluxes will be carried out for established EuroGOOS/NOOS transects where calculations of water transport are routinely carried out.

22. The use of smaller target areas than those initially proposed should be considered by the ICG-EMO in order to facilitate use of observation data for and comparison with budget calculations and to allow for comparison with budgets that are derived from measurements. Smaller target areas could be selected that include both national boundaries and EuroGOOS/NOOS transects.

[11] Note: This will depend on the timely agreement by OSPAR on the results from the second application of the Comprehensive Procedure.

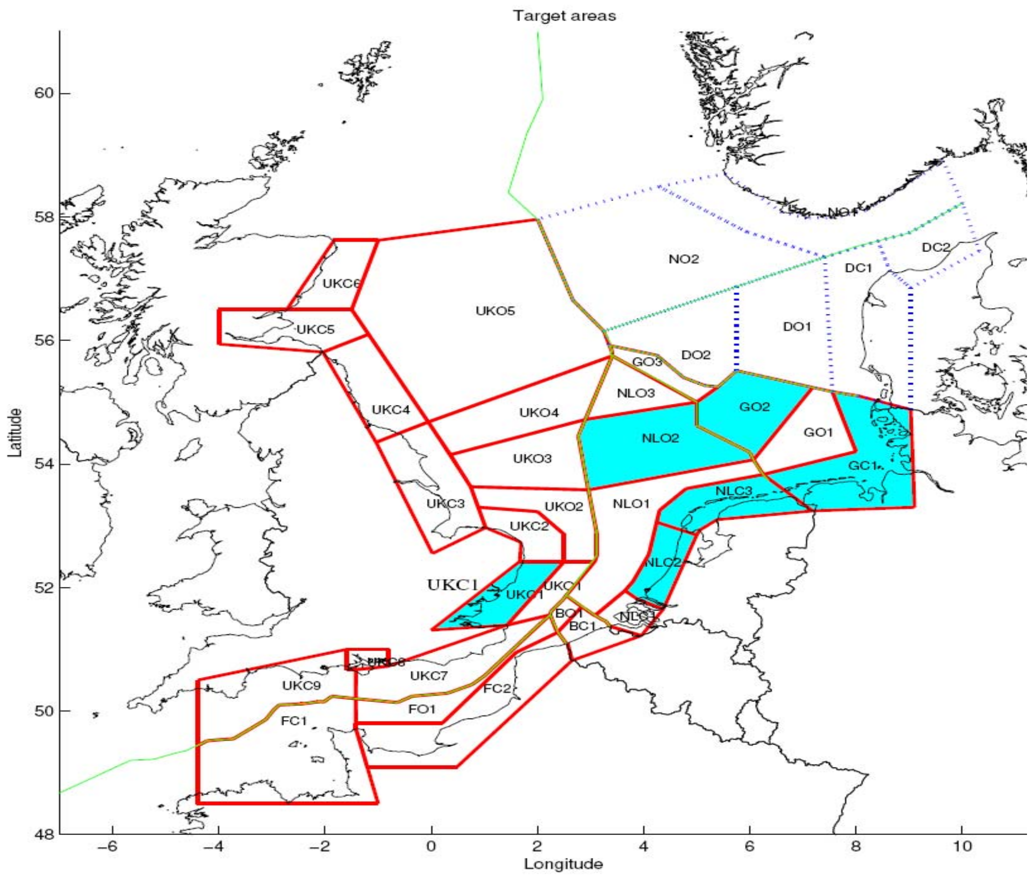

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Fig. 1. Target areas for the inter-comparison of the CP assessment. Red lines and blue dotted lines delineate target areas, green lines are the national marine boundaries. The blue shaded (highlighted) areas are the designated target areas for the nutrient reduction scenario testing for the second workshop in September 2007. The non-shaded areas are potentially available for calculation of fluxes but only a subset of these will be selected following discussion at the workshop. The target areas delineated in red lines have been discussed previously with the contact person for modelling of each country involved, the ones delineated with blue dotted lines are a first proposal.

5.4 Variables to be simulated

23. The minimum requirement is for nitrogen, phosphorus, and phytoplankton biomass (expressed as chlorophyll and/or as phytoplankton carbon or nitrogen, depending on the unit, used in the model), and primary production to be prognostic variables in the models used. It is also recommended to include benthic variables, as prognostic variables or as a closure function.

24. Nutrients exist in a variety of forms (dissolved, particulate, organic, total) but the minimum required for this work would be to simulate dissolved and particulate nutrients. However, dependant upon model capability an attempt should be made to address all forms.

25. In the light of an improved understanding of undesirable disturbance (in the context of the OSPAR definition of eutrophication), relevant variables such as those relating to phytoplankton community (structure and size) should be simulated and reported. Not all of the ecosystem models include variables relevant to the detection of undesirable disturbance but where they do they should be reported. The ICG-EMO will provide further guidance to participants on the detection of undesirable disturbance in model results arising from anthropogenic nutrient input.

5.5 Simulation period(s)

26. The calculation of fluxes will be carried out for 2002 and in addition the year 2001 should be used for the spin-up. Data for additional years, for example 2003, should be made available if resources permit in order to investigate interannual variability in nutrient fluxes. Some participants have multi-year model runs and it is proposed that such groups be invited to provide and share data with other participants.

5.6 Data

27. Data for 2002 for the 2nd ICG-EMO Workshop have been made available on the web site (ftp://ftp.ifm.uni-hamburg.de/outgoing/lenhart/OSPAR). These data comprise:

a. Calibration and validation

b. River loads

c. Boundary conditions

d. Meteorological data

e. Atmospheric data

28. For detailed description of the data, see the Data Description file for the 2nd ICG-EMO Workshop. In the case of a different or additional years being proposed, new data will have to be made available.

28bis. Following the procedure adopted for the 2nd OSPAR workshop in September 2007 a larger-area model will be used to provide common boundary conditions to other participants running smaller domains.

29. It is desirable to have a shared dataset of SPM (Suspended Particulate Matter) for use by the participants. A methodology for development and distribution of such a dataset based upon remote and *in situ* measurements will be developed by the ICG EMO. A method of inclusion in the models is also required.

5.7 Detailed Approach

30. Each participant is asked to carry out several model runs and to present their results to a workshop to be held in May 2009.

31. A run with the hydrodynamical and transport model is required to estimate the water flux through a defined boundary. Where possible, participants are asked to carry out additional work to run the transport model together with a conservative tracer to allow calculation of the fraction of this water which originates as river input and to carry out multi-year simulations to investigate interannual variability.

32. The recommended work programme is to carry out:

a. a model run with a coupled hydrodynamic-ecosystem model in the ‘standard’ set-up should be prepared in order to calculate:

- the nutrient dynamics,
- the nutrient loads, transported over specified boundaries,
- the nutrient budgets in the defined areas.

b. where workshop participants have the capability, to add on to (a) the use of a ‘tagged variable’ system (*e.g.*, Ménesguen, 2006; Wijsman, 2003) that allows tracking of specific nutrients from specific rivers through the nutrient cycle and to calculate:

- the nutrient loads from a specified river, transported over specified boundaries,
- the proportions of the nutrient budgets in the defined areas originating from specified rivers;

c. where workshop participants have the additional capability, multi-year runs which would repeat part or all of the above (a) and (b) simulations.

33. Detailed terms of reference for the workshop will be developed intersessionally and presented to EUC in April 2008.

5.8 Anticipated Results

34. The proposed workshop should result in a description of:

- the relative contribution of the different sources to the water mass of the relevant areas;
- the relative contribution of the different sources to the nutrient concentrations and -loads of the relevant areas;
- the relative contribution of the different sources to phytoplankton blooms (preferably their share in primary production, their share in biomass) in the areas chosen;
- detailed presentation of the results during the growing season (March to September).

35. Specification for the presentation of the workshop results still needs to be developed.

6. Arrangements for intersessional work

36. The following task list for the ICG-EMO[12] has been drawn up for progressing work on calculating transboundary nutrient fluxes and preparing a workshop in May 2009:

No.	Task	Target Date	Task leader
1	Agree Organising Group membership	October 2007	Mills (convenor)
2	SPM specification	December 2007	Van der Molen
3	Identify assessment/modelled variables for diagnosing Undesirable Disturbance	December 2007	Mills
4	Detailed arrangement for an OSPAR workshop for presentation to EUC April 2008	7 March 2008	Organising group
5	Draft User Guide incorporating agreed specification for calculation of transboundary nutrient fluxes (including a glossary)	August 2008	Organising group
6	Specification for presentating results	August 2008	
7	Boundary conditions for 2001 spinup, for the simulation year 2002, and any additional years	October 2008	Proctor
8	Update river loads to most recently available data	November 2008	Lenhart
9	Extend EMEP data for multi-year model runs	November 2008	
10	Draft Data Description	November 2008	
11	Seek permission from ECMWF	December 2008	
12	SPM implementation	April 2009	
13	Submit results for compilation prior to workshop	April 2009	All
14	Hold Workshop [Belgium?]	May 2009	
15	Report on 3rd OSPAR ICG-EMO Workshop	June 2009	Reporting team

References

Ménesguen, A. & P. Cugier, 2006. A new numerical technique for tracking chemical species in a multi-source coastal ecosystem applied to nitrogen causing Ulva blooms in the Bay of Brest (France). Limnol. Oceanogr. 51: 591-601.

Wijsman, J., H. Los, J. Van Beek, 2003. Filtering capacity of an estuary for nutrients. WL report Z2836. 51pp.

[12] Members are: Dr David Mills (UK) (convenor), Dr Genenviève Lacroix (Belgium), Mr Michael Kyramarios (Belgium), Mr Kevin Ruddick (Belgium), Mr Henning Karup (Denmark), Dr Alain Ménesguen (France), Dr Hermann Lenhart (Germany), Dr Hanneke Baretta-Bekker (Netherlands), Dr Wanda Zevenboom (Netherlands), Dr Morten Skogen (Norway), Prof. Ramiro Neves (Portugal), Dr Stephen Malcolm (UK), Mr Richard Moxon (UK).