

Eutrophication Status Report of the North Sea, Skagerrak, Kattegat and the Baltic Sea: A model study Years 2001-2005

K. Eilola¹, J. Hansen⁴, H.E.M. Meier¹, K. Myrberg⁵, V.A. Ryabchenko³ and M.D. Skogen²

¹ Swedish Meteorological and Hydrological Institute, Sweden

² Institute of Marine Research, Norway

³ St. Petersburg Branch, P.P.Shirshov Institute of Oceanology, Russia

⁴ National Environmental Research Institute, Aarhus University, Denmark

⁵ Finnish Environment Institute, Finland



Finnish Environment Institute (SYKE)

Nordic Council of Ministers' Air and Sea Group project ABNORMAL 2010
A Baltic and North Sea Model eutrophication Assessment in future climate

OCEANOGRAPHI Nr 110, 2011

**Eutrophication Status Report of the North Sea,
Skagerrak, Kattegat and the Baltic Sea:
A model study
Years 2001-2005**

K. Eilola¹, J. Hansen⁴, H.E.M. Meier¹, K. Myrberg⁵, V.A. Ryabchenko³ and M.D. Skogen²

¹ Swedish Meteorological and Hydrological Institute, Sweden

² Institute of Marine Research, Norway

³ St. Petersburg Branch, P.P.Shirshov Institute of Oceanology, Russia

⁴ National Environmental Research Institute, Aarhus University, Denmark

⁵ Finnish Environment Institute, Finland

Summary:

This joint status report for the North Sea, Skagerrak, Kattegat and the Baltic Sea area is carried out by SMHI Sweden, IMR Norway, NERI Denmark, SPBIO Russia, and SYKE Finland as a part of the project “A Baltic and North sea Model eutrophication Assessment in a future cLimate” (ABNORMAL), supported by the Nordic Council of Ministers’ Sea and Air Group (NMR-HLG). The previous NMR-HLG projects NO COMMENTS and BANSAL focused on the establishment and maintenance of operational models and the use of these to develop methods for assessing the eutrophication status. Within ABNORMAL the issues are brought forward with a focus also on the use of ecological models for an assessment of marine eutrophication in a future climate. The main finding of this study is the proposed way of combining observations and results from an ensemble of ecological models to make an assessment of the eutrophication status in present climate for five different years (2001-2005). Threshold values and methodology from the Oslo and Paris Commissions (OSPAR) and the Helsinki Commission (HELCOM) are used and possible improvements of the methods are briefly discussed. The assessment of eutrophication status according to the integration of the categorized assessment parameters indicates that the Kattegat, the Danish Straits, the Gulf of Finland, the Gotland Basin as well as main parts of the Arkona Basin, the Bornholm Basin, and the Baltic proper may be classified as problem areas. The main part of the North Sea and also the Skagerrak are non-problem areas while the main parts of the Gulf of Bothnia, Gulf of Riga and the entire southeastern continental coast of the North Sea may be classified as potential problem areas.

Sammanfattning:

Följande statusrapport för Nordsjön, Skagerrak, Kattegatt och Östersjön har genomförts av SMHI Sverige, IMR Norge, NERI Danmark, SPBIO Ryssland, och SYKE Finland som del av projektet “A Baltic and North sea Model eutrophication Assessment in a future cLimate” (ABNORMAL), vilket finansierats av the Nordic Council of Ministers’ Sea and Air Group (NMR-HLG). De tidigare NMR-HLG projekten NO COMMENTS och BANSAL fokuserades på etablering och underhållsstöd till operationella modeller samt utvecklingen av metoder för deras användning till utvärdering av eutrofieringstillstånd. Inom ABNORMAL har frågorna vidare fokuserats på användningen av ekologiska modeller för att utvärdera eutrofieringstillståndet in framtida klimat. Viktigaste rönet från studien är det föreslagna sättet att sammanföra observationer med resultat från en ensemble av ekologiska modeller för att utvärdera eutrofieringstillståndet i dagens klimat under fem olika år (2001-2005). Tröskelvärden och metoder från Oslo and Paris Commissionen (OSPAR) och Helsinki Commission (HELCOM) används och möjliga förbättringar av metoder diskuteras kort. Bedömningen av eutrofieringstillståndet visar att Kattegatt, de danska sunden, Finska viken, Gotlandsbassängen, samt största delarna av Arkonabassängen, Bornholmsbassängen och Egentliga Östersjön kan klassificeras som problemområden. Huvuddelen av Nordsjön och Skagerrak är icke-problem områden medan huvuddelarna av Bottenhavet, Bottenviken, Riga Bukten och hela sydöstra kontinentalkusten av Nordsjön kan klassificeras som potentiella problemområden.

1. Contents

1.	Contents.....	3
2.	Introduction	4
3.	Methods.....	6
	Model descriptions	6
	<i>NORWECOM</i>	7
	<i>RCO-SCOB</i>	7
	<i>SPBEM</i>	7
	<i>NERI model</i>	8
	In situ data	9
	Costfunction	9
	Eutrophication assessment	11
4.	Comparison to in-situ data	13
5.	Models weighted mean assessment.....	23
	Nutrients (DIP, DIN and DIN:DIP)	23
	<i>DIP</i>	23
	<i>DIN</i>	26
	<i>DIN to DIP ratio</i>	28
	Chlorophyll-a	30
	Oxygen conditions.....	32
	Eutrophication status	34
6.	Discussion	35
7.	Conclusions	36
8.	Acknowledgement.....	36
9.	References	36
10.	Appendix A; Comprehensive procedure	39
11.	Appendix B; Results of individual models	42
	IMR Figures: 2001-2005	43
	SMHI Figures: 2001-2005	46
	SPBIO Figures: 2001-2005	50
	NERI Figures: 2001-2003	54
12.	Appendix C; NERI 3D-model oxygen sinks.....	55

2. Introduction

This joint status report for the North Sea, Skagerrak, Kattegat and the Baltic Sea area (Fig.1) is carried out by SMHI (Swedish Meteorological and Hydrological Institute) Sweden, IMR (Institute of Marine Research) Norway, NERI (National Environmental Research Institute) Denmark, SPBIO (St.Petersburg Branch, P.P.Shirshov Institute of Oceanology) Russia, and SYKE (Finnish Environment Institute) Finland as a part of the project “A Baltic and North sea Model eutrophication Assessment in a future cLimate” (ABNORMAL), supported by the Nordic Council of Ministers’ Sea and Air Group (NMR-HLG). The present project is a follow-up of two earlier projects funded by NMR-HLG: NO COMMENTS and BANSAL. These projects focused on the establishment and maintenance of operational models for the Baltic and North Seas and the use of these to develop methods for assessing the eutrophication status. Within ABNORMAL these issues are brought forward with a focus also on the use of ecological models for an assessment of marine eutrophication in a future climate.

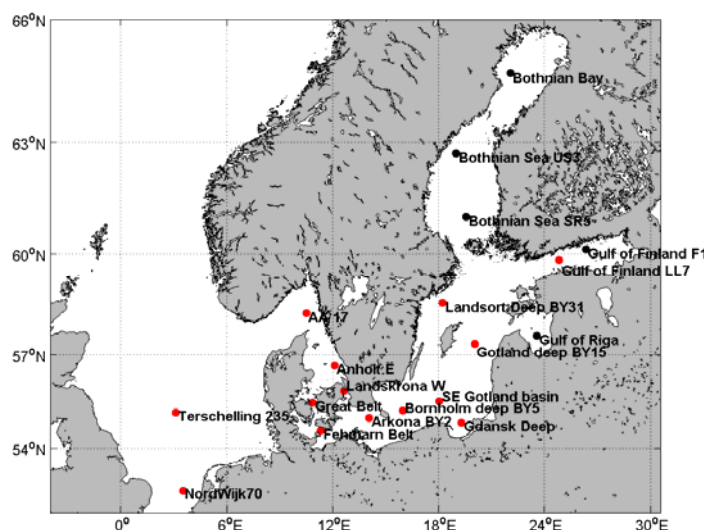


Figure 1. A map of the North Sea and Baltic Sea area. Monitoring stations with data used for the model validation are shown by red dots. Note: The number of stations may vary between the studied variables due to availability of data.

Within HELCOM eutrophication assessment is based on the method for calculating Ecological Quality Ratio (EQR) (Andersen et al., 2010). EQR is calculated for several indicators, of which winter nutrients (DIN, DIP), chlorophyll-a and Secchi depth are either direct or indirect products e.g. of the SYKE-EIA 3D model used at the Finnish Environment Institute (ongoing analysis of model results). The status of the biological quality elements is compared to the reference values, and this gives the Ecological Quality Ratio (Fig.2). An EQR value and a set of class boundaries are calculated for each indicator, but the overall status classification depends on a combination of indicators. First, indicator EQR values are combined to give an EQR value for a specific Quality Element (QE), and similarly the indicator class boundaries are combined to give the class boundaries for the QE. The grouping method used is following the EU Water Framework Directive (Anon. 2000, OSPAR

2005b) quality elements (physical-chemical features, phytoplankton, submerged aquatic vegetation, benthic invertebrates) corresponding to HELCOM eutrophication objectives i, ii, iii (physical-chemical features), iv (phytoplankton) and v (submerged aquatic vegetation & benthic invertebrates); subsequently combined into a final classification of eutrophication status.

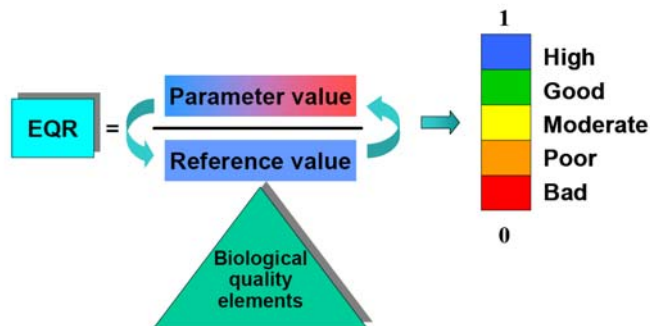


Figure 2. *Ecological Quality Ratio*

Basically the same method is used in OSPAR, to which the eutrophication assessment of the other models in this study is based on. The main difference is in the method of combining the different indicator groups into one assessment. HELCOM uses one-out-all-out principle, which means that the worst value of the biological quality elements is the determining value in each area. OSPAR is using a different approach, where the final assessment is dependent on which parameter that exceeds the limit (see Appendix A for more details).

An assessment of eutrophication status from measurements of all system parameters with a proper resolution in both time and space would be far to time and labour consuming to be desirable due to the complex nature of the system. Therefore, models have become an important tool for evaluating nutrient and ecosystem dynamics. All models have to deal with uncertainties due to limitations in both their forcing and process formulations, and one way to try to reduce uncertainty is to add more models in a study and report on the ensemble mean. For instance in the model-intercomparison study of hydrodynamic models in the Baltic Sea (Eutrophication-Maps, an NMR-funded project) the best results was gained by the ensemble of the 6 participating models (Myrberg et al., 2010). In BANSAI an integration of observations and a weighted ensemble mean of ecosystem models was used to assess marine eutrophication in the Baltic Sea and North Sea using a set of existing environmental targets for identification of the eutrophication status set by politicians (HELCOM, 2006, OSPAR 2005b). The weights were computed from model accuracy based on model validation exercises using available observations from distinct areas/boxes in the area (Almroth & Skogen, 2010).

In the present report, the focus has been on the eutrophication assessment of a reference situation. As a reference situation representative of today, marine observations and model simulations are used in an assessment of eutrophication status in the Baltic and the North seas for the years 2001, 2002, 2003, 2004 and 2005. The proposed method for assessing eutrophication using an ensemble of models and a set of indicators (Almroth & Skogen, 2010) is used. Necessary forcing and loads were collected together with appropriate data for model validation and to compute the weights used in the ensemble assessment. The status report include an assessments based on winter nutrients N and P, the N:P ratio, summer average chlorophyll and oxygen levels, and a final assessment based on the procedure of Integration of Categorized Assessment Parameters (OSPAR., 2005b). Estimations of region

specific background concentrations and threshold values (Almroth & Skogen, 2010) gathered from the literature (Helcom, 2006; OSPAR, 2005b) have in the present study been updated by Oleg Savchuk (BNI Sweden) in personal comm. with Jesper Andersen (DHI, Denmark) to be in accordance with the thematic assessment of Baltic Sea eutrophication status by the HELCOM Eutrophication Assessment Tool (HEAT) (Andersen et al., 2010).

The models, in-situ data and methods of the assessment are described in Section 3. Statistical characteristics of model results and in-situ data are presented in Section 4 and the model assessment of eutrophication status is done in Section 5. Conclusions and comments to the assessment are presented in Section 6. In Section 7 the key messages from this assessment will be presented.

3. Methods

Model descriptions

The model systems used for the joint assessment (Fig. 3) cover different parts of the North Sea, Skagerrak, Kattegat and the Baltic Sea area. More detailed descriptions of the models may be found either on the web-sites or from the references cited below.

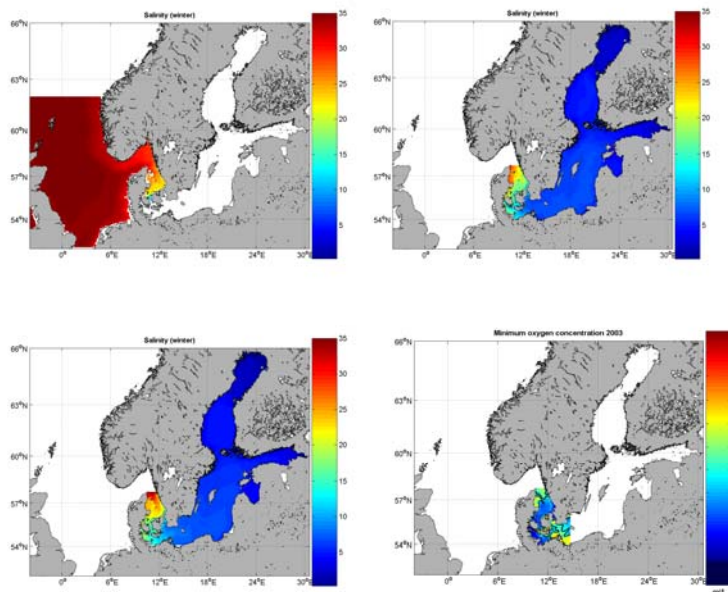


Figure 3. Overview of model domains. The colours indicate salinity in the winter 2001

Upper Left: IMR – Norwecom model (<http://www.imr.no/~morten/norwecom>)

Upper Right: SMHI – RCO-SCOB model (<http://www.smhi.se>)

Lower Left: SPBIO – model (<http://www.ocean.ru>).

Lower Right: NERI – model (<http://www.dmu.dk>).

NORWECOM

The NORWegian ECOlogical Model system (NORWECOM) is a coupled physical, chemical, biological model system (Skogen et al., 1995; Skogen and Søliland, 1998) applied to study primary production, nutrient budgets and dispersion of particles such as fish larvae and pollution. The model has been validated by comparison with field data in the North Sea/Skagerrak in e.g. Søliland and Skogen (2000); Skogen et al. (2004); Skogen & Mathisen (2009) and Hjøllø et al. (2009). The physical model is based on the three dimensional, primitive equation, time dependent, wind and density driven Princeton Ocean Model (POM). In the present study the model is used with a horizontal resolution of 10 km. In the vertical, 20 bottom following sigma layers are used. The chemical-biological model is coupled to the physical model through the subsurface light, the hydrography and the horizontal and the vertical movement of the water masses. The prognostic variables are dissolved inorganic nitrogen (DIN), phosphorous (PHO) and silicate (SI), two different types of phytoplankton (diatoms and flagellates), two detritus (dead organic matter) pools (N and P), diatom skeletons (biogenic silica) and oxygen. The simulation used here are taken from a 25 year hindcast (Skogen & Mathisen (2009)), starting in 1985. The forcing variables are six-hourly hindcast atmospheric pressure fields and wind stress from the European Center for Medium-Range Weather Forecasts (ECMWF), four tidal constituents at the lateral boundaries and freshwater runoff. Surface heat fluxes are calculated using data available from the ECMWF archive, while initial values and open boundary conditions are taken from monthly climatologies (Martinsen et al., 1992).

RCO-SCOBI

RCO-SCOBI is a coupled physical-biogeochemical model for the Baltic Sea consisting of the Swedish Coastal and Ocean Biogeochemical model (SCOBI) and the Rossby Centre Ocean model (RCO) (Eilola et al., 2009; Meier et al., 2011a). RCO is a Bryan-Cox-Semtner primitive equation circulation model with a free surface (Killworth et al., 1991) and open boundary conditions following Stevens (1991) in the northern Kattegat (Fig.3). In the present study, RCO was used with a horizontal resolution of 3.7km (2 nautical miles) and with 83 vertical levels with layer thicknesses of 3m. In SCOBI the dynamics of nitrogen, oxygen and phosphorus including the inorganic nutrients nitrate, ammonia and phosphate, and particulate organic matter consisting of phytoplankton (autotrophs), dead organic matter (detritus) and zooplankton (heterotrophs) are calculated. Autochthonous organic matter is produced from the inorganic nutrients by three functional groups of phytoplankton, diatoms, flagellates and others, and cyanobacteria. Organic material sinks and enters the model sediment as benthic nitrogen and phosphorus. The model results of the five selected years were extracted from a long-term simulation for 1961-2007. The forcing is based on dynamical downscaling of the ERA-40 re-analysis (Uppala et al., 2005) using a high-resolution regional atmosphere model (the Rossby Centre Atmosphere model, RCA; see e.g. Kjellström et al., 2005). The resolution of the atmospheric model grid is 25x25 km. Underestimated high wind speeds in the downscaled atmospheric forcing have been corrected using a gustiness parameterization following Höglund et al. (2009), see also Meier et al. (2011b). Nutrient flows are calculated as the product of climatologically monthly mean concentrations of 1970-2000 and monthly volume flows. Point sources and atmospheric nitrogen deposition are based on an average of HELCOM estimates from the 1980s and 1990s.

SPBEM

The St. Petersburg Baltic Eutrophication Model (SPBEM) is an existing eco-hydrodynamical model that includes 3D hydrodynamic ocean-sea ice module (Neelov et al., 2003; Myrberg et

al., 2010) and biogeochemical (BGC) module developed by Savchuk (2002). The hydrodynamic module includes original $k-l$ turbulent closure scheme for vertical mixing and uses Arakawa B spherical grid. The BGC module describes nutrient cycling in the coupled pelagic and sediment sub-systems and contains 12 pelagic (zooplankton, diatoms, cyanobacteria, flagellates, nitrogen, phosphorus and silica detritus ammonium, nitrite + nitrate, phosphate, silicate and dissolved oxygen) and 3 sediment (benthic nitrogen, phosphorus and silica) state variables. The model version used to simulate the state of the Baltic Sea in 2001-2005 had horizontal resolution 5 nm and 35 levels of with $dz=2m$ in the layer (0,20m), $dz=5m$ in the layer (20,40m) and $dz=10m$ below 40m. Atmospheric physical forcing (wind velocity, cloudiness, air temperature and relative humidity, precipitation) having temporal resolution of 3h was taken from NCEP re-analysis (Kalnay et al., 1996). The atmospheric deposition of nitrogen and phosphorus was assumed to be zero. At the boundary with the North Sea, current velocity, temperature, salinity and all biogeochemical variables were prescribed from a hydrodynamic –biogeochemical model of the North Atlantic and Arctic Ocean, developed by I. Neelov. The riverine discharges are taken from Myrberg et al. (2010) as climatological mean monthly values for 51 aggregated rivers flowing in the Baltic Sea. Prescribing nutrient land loads are based on estimates obtained within the MARE program (Savchuk and Wulff, (2007). The run with SPBEM started in 1995 and finished in 2005. Initial distributions of physical and biogeochemical fields in the Baltic Sea were constructed from the data available in the Baltic Environmental Database (<http://nest.su.se/bed>) for 3 wintertime months (January –March) of two consecutive years (1995-96). Further a comparison of observed chlorophyll with phytoplankton biomass calculated in the model will be performed using phytoplankton Chl:N ratio =1.5 mg Chl /mmol N. It should be noted that the ratio is highly variable during the vegetation season depending on many factors such as temperature, nutrients, photosynthetic available radiation and others (see, for example, Sathyendranath et al., 2009).

NERI model

The NERI model is a nested high resolution circulation model covering the Kattegat, the Belt Sea and the western Baltic Sea e.g. the transition zone between the North Sea and the Baltic. The model is based on the COHERENS model (Luyten et al., 1999), which is a primitive equation three dimensional circulation model. The model is formulated on a 2×2 nautical mile horizontal spherical grid (approximately 3700 m x 3700 m) with 30 vertical sigma layers and covers the region from northern Kattegat to the Arkona Sea. The water level along the open boundaries is determined from a regional 4×4 nautical mile resolution model of the whole North Sea and Baltic Sea area. Temperature and salinity at the open boundaries are determined from observations at sta.1004 (58.9 °N, 11.3 °E) just north of the model domain and data from a station in Hanöbugten (55.62 °N, 14.87 °E) close to the eastern open boundary. Measurements for about every month in the period have been interpolated linearly in time and in the vertical and are also horizontally uniform along the boundaries. Vertical mixing is based on a $k-\epsilon$ turbulence scheme and a convective adjustment scheme when the water column becomes unstable. The model setup has been analyzed for the period 2001 – 2003 and validated against temperature, salinity, and water level in the area (Bendtsen et al. 2009). In addition to temperature and salinity, the model also solves transport equations for a conservative tracer (c), an age tracer ($\square$) and oxygen (O_2) (Bendtsen et al. 2009). The parameterization of oxygen sinks in the NERI 3D-model that is much simplified relative to oxygen calculations in the biogeochemical models is described in Appendix C.

In situ data

For the evaluation of results the following definitions will be used.

Surface layer = Average for the depth interval 0-10m. For the model results we use the 5m model value to represent the surface layer.

Winter = Average for the period January-February

Summer (production period) = Average for the period March-October

Late summer for oxygen = Average for the period August-September

Observational data from stations situated in the North Sea, Skagerrak, Kattegat, Great Belt, Öresund, Arkona Basin, Bornholm Basin, SE Gotland Basin, E Gotland Basin and N Gotland Basin (Fig 1 and Table 1) are used. The observational data in the Baltic Sea and Kattegat were extracted from the Baltic Environmental Database (BED, personal comm. with Bo Gustafson BNI). Data from the Skagerrak station were obtained from SHARK (Swedish Oceanographic Data Centre at the Swedish Meteorological and Hydrological Institute, <http://www.smhi.se>). In the North Sea the data were extracted from the Netherland Waterbase of the North Sea at the Rijkswaterstaat (<http://www.waterbase.nl>). Mean values from the years 2001-2005 and the average and the standard deviation of the mean values for all years in the period 2001-2005 are computed. Note that due to the availability of data the specific stations used differ between the surface and deeper layer assessments.

Table 1. *The reference stations used in the comparison of model results and in-situ data and their positions. All stations within a bounding box around stations in the Baltic Sea are selected. The sizes of the bounding boxes are: 1)+/- 5 nm, 2)+/- 10 nm, 3)+/- 8 nm, 4)+/- 2 nm and 5)+/-3 nm.*

Station Name	Ref. LAT	Ref. LON
AA 17	5816.5	1030.8
Anholt E ¹	5640	1207
Arkona BY2 ¹	5500	1405
Bornholm deep BY5 ²	5515	1559
Fehmarn Belt ⁵	5434	1120
Gdansk Deep ³	5450	1919
Gotland deep BY15 ²	5720	2003
Great Belt ⁵	5531	1052
Gulf of Finland LL7 ¹	5951	2450
Landskrona W ⁴	5552	1245
Landsort Deep BY31 ¹	5835	1814
NordWijk70	5235.1	0331.9
SE Gotland basin ¹	5533	1824
Terschelling 235	5510.3	0309.5

Costfunction

The mean value (Mv) and standard deviation (Sd) of surface layer (0-10 m) winter time observations (January-February) for salinity (S), dissolved inorganic nitrogen and phosphorus (DIN and DIP), and the ratio DIN/DIP are computed. The Mv and Sd of chlorophyll-a (CHL) for the production period in the surface layer (0-10m) are from March-October. The Mv and Sd for the late summer lower layer dissolved oxygen concentrations (O₂) are computed in the period August-September.

To compare the model results with observations we use a cost function (C_i) which for each year is computed from the mean bias:

$$C_i = \left| \frac{M_i - D}{Sd} \right| \quad Eq 1$$

where C_i is the normalized deviation (in Sd units) between model results and in-situ data for the model i (i =individual model). M_i is the mean value of the model results, D is the mean value of the in situ data, and Sd is the long term (2001-2005) standard deviation of the in situ data.

One may note that the value of C_i becomes large if the modelled mean value differs much from the mean value of the in situ data. The cost function may also obtain high values when the standard deviation is very small. Finally one should bear in mind that the model data are sampled every day while the sampling of in situ data may vary between variables and between different seasons and locations.

The following ranges are used for the interpretation of the cost function values of the models.

Good	$0 \leq C < 1$	std. deviations
Reasonable	$1 \leq C < 2$	std. deviations
Poor	$2 \leq C$	std. deviations

The following plots will be presented for all models.

- Salinity (winter and summer surface layer average)
- Winter surface layer average DIN, DIP ($\mu\text{mol /l}$), and DIN/DIP ratio
- Chlorophyll a summer surface layer average ($\mu\text{g Chl /l}$)
- Annual dissolved oxygen minimum at bottom layer (ml/l)

The average salinity from the models is computed and used as a reference for the area specific threshold values of ecological quality indicators. In the Skagerrak and North Sea only values from IMR were used. In the Kattegat all models are included. In the Danish Straits and Öresund are model values only used from SMHI, SPBIO and NERI. From the Baltic Sea east of Bornholm only the SMHI and SPBIO model values were used. The assessment areas with separate threshold values (Table 2) are described by colors and basin numbers (Bnr) in Fig.4.

Since the accuracy of models differs between parameters and areas a weighted average value of the models has been used to calculate the environmental assessments. The weighted model average value (WMA) between the models is defined as:

$$WMA = C \cdot \sum_{i=1}^4 (W_i \cdot M_i) \quad Eq 2$$

Where M_i defined in all points (x, y) is the value from model i and C is defined as:

$$C = \frac{1}{\sum_{i=1}^4 W_i} \quad Eq 3$$

W_i is the corresponding weight defined as $W_i = 1/(C_i + B)$, where C_i is the cost function value for model i for the actual assessment parameter and area, and B is a constant used to avoid the weight of one or several models going to infinity when C_i becomes small. In our example, we have used $B = 0.1$.

The weighted average value was calculated for all assessment parameters. In areas without observations a simple average between the models was used hence assuming that W is equal for all models in these areas.

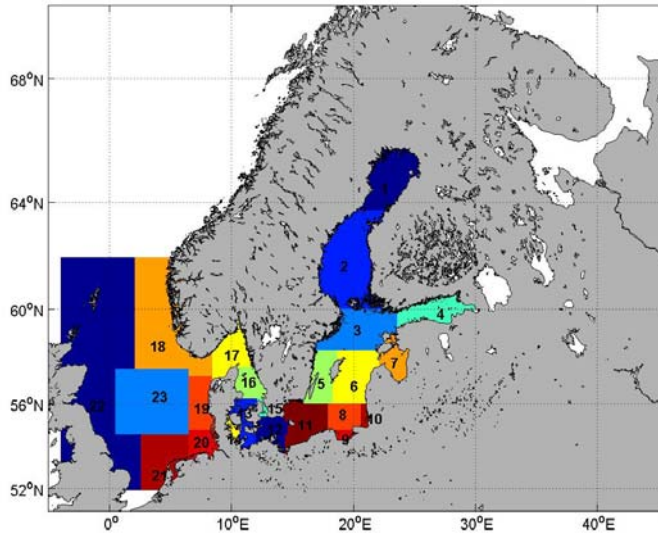


Figure 4. The North Sea, Skagerrak, Kattegat and the Baltic Sea are divided into 23 sub-basins with separate threshold values for the ecological quality indicators. Areas in each basin have same assessment threshold values. Areas west of Great Britain are not included in the assessment.

Eutrophication assessment

To assess eutrophication the OSPAR CP (OSPAR 2005a) distinguishes between parameters in four different categories (see Almroth & Skogen, 2010): degree of nutrient enrichment (Cat. I), direct effects of nutrient enrichment (II), indirect effects of nutrient enrichment (III), and other possible effects of nutrient enrichments (IV). Several of these—winter DIN and DIP and the DIN:DIP ratio (Cat. I), CHL (II), and O₂ (III)—can easily be explored by models and, in accordance with current management practices, these parameters have been investigated and reported in this study. The agreed EcoQO for eutrophication is that winter DIN and DIP should be below elevated levels, defined as >50% above the background/reference concentration, and that CHL mean value during the growing season should remain below elevated levels, defined as >50% above the spatial (offshore) or historical background concentration. For O₂, the agreed EcoQO is that the concentrations should be above O₂ deficiency levels. In this study, reference and threshold values for the Baltic Sea, the Danish Straits, the Öresund, and the Kattegat are from HELCOM (2006). For Skagerrak and the North Sea, the reference values and threshold values are from OSPAR (2005b), except for DIN and DIP for the central and northern North Sea, which are taken from NSTF (1993). For the N:P ratio, a few area specific reference values are found in HELCOM (2006), whereas OSPAR uses the Redfield ratio (16:1) as reference for the whole North Sea (OSPAR 2005b). In areas without an N:P reference value, the Redfield ratio has been used, and the EcoQO for the N:P ratio are set to $\pm 50\%$, in accordance with the OSPAR CP. Table 2 provides an overview of the assessment levels that have been used in this study. In total, 23 different areas are classified. The assessment areas with separate threshold values are described by colours and basin numbers in Fig. 4. The average salinity from the models is used where the areas specific threshold value is within a salinity range. The final

classification of eutrophication status in the different basins in the model area is done using three categories: problem area, potential problem area, and non-problem area. An area is said to be a potential problem area if there are elevated levels of nutrients (Cat. I) relative to the actual threshold values used in that assessment area. To become a problem area, there has to be an elevated level in the direct (CHL) or indirect (O_2) effects. This classification is based on the procedure of Integration of Categorized Assessment Parameters as suggested in the OSPAR CP (OSPAR 2005a), except that in this study, the HELCOM classification (HELCOM 2006) is used for the O_2 status.

Table 2. Reference values and threshold values used in the present report with origin from Helcom (2006) and OSPAR (2005b) and Almroth and Skogen (2010) and revision by O. Sachuk in pers. comm. with Jesper Andersen.

Basin Nr.	Basin Names	Salinity range psu	DIN Winter ref. value $\mu\text{mol/l}$	DIP Winter ref. value $\mu\text{mol/l}$	N/P Winter Ref. value -	CHL Summer ref. value $\mu\text{g/l}$	DIN Winter thres. value $\mu\text{mol/l}$	DIP Winter thres. value $\mu\text{mol/l}$	N/P Winter thres. value Hi/Lo	CHL Summer thres. value $\mu\text{g/l}$
1	Bothnian Bay	>0	3.50	0.10	16.00	1.30	5.25	0.15	24.0/8.0	1.95
2	Bothnian Sea	>0	2.00	0.20	16.00	1.00	3.00	0.30	24.0/8.0	1.50
3	Northern Gotland Basin	>0	2.00	0.25	16.00	1.10	3.00	0.38	24.0/8.0	1.65
4	Gulf of Finland	>0	2.50	0.50	16.00	1.20	3.75	0.75	24.0/8.0	1.80
5	Western Gotland Basin	>0	2.00	0.25	16.00	1.00	3.00	0.38	24.0/8.0	1.50
6	Eastern Gotland	>0	1.40	0.20	16.00	1.20	2.10	0.30	24.0/8.0	1.80
7	Gulf of Riga	>0	6.60	0.13	16.00	1.80	9.90	0.20	24.0/8.0	2.70
8	South east Gotland B	>0	2.50	0.25	10.00	0.70	3.75	0.38	15.0/5.0	1.05
9	Gdansk deep	>0	4.25	0.25	17.00	-	6.38	0.38	25.5/8.5	4.50
10	Lithuanian water	>0	5.00	0.30	16.00	3.00	7.50	0.45	24.0/8.0	4.50
11	Bornholm basin	>0	2.00	0.25	16.00	1.20	3.00	0.38	24.0/8.0	1.80
12	Arkona Basin	>0	2.25	0.27	16.00	1.20	3.38	0.41	24.0/8.0	1.80
13	Danish straits	>0	1.83	0.22	16.00	0.55	2.74	0.33	20.0/12.0	0.82
14	Danish straits	>0	1.25	0.48	16.00	0.90	1.56	0.60	20.0/12.0	1.13
15	Oeresund	>0	-	-	16.00	1.70	1.56	0.60	20.0/12.0	2.13
16	KattegatS	>0	3.70	0.51	11.25	0.80	5.55	0.76	14.1/8.4	1.20
17	Skagerrak	>0	10.00	0.60	16.00	1.50	15.00	0.90	25.0/8.0	2.00
18	NorthSeaNE	>0	-	0.60	16.00	3.00	13.50	0.80	25.0/8.0	4.50
19	NorthSeaDenmark	< 34.5	15.00	0.60	16.00	6.00	26.00	0.80	25.0/8.0	9.00
19	NorthSeaDenmark	>= 34.5	10.00	0.65	16.00	3.00	12.50	0.80	25.0/8.0	4.50
20	NorthSeaSE	< 34.5	12.50	0.55	16.00	3.00	19.00	0.83	25.0/8.0	4.50
20	NorthSeaSE	>= 34.5	8.50	0.60	16.00	2.00	13.00	0.90	25.0/8.0	3.00
21	NorthSeaSV	< 34.5	19.00	0.60	16.00	10.00	28.50	0.80	25.0/8.0	15.00
21	NorthSeaSV	>= 34.5	-	-	16.00	3.00	15.00	0.80	25.0/8.0	4.50
22	NorthSeaV	< 34.5	15.50	0.80	16.00	10.00	21.00	1.20	25.0/8.0	20.00
22	NorthSeaV	>= 34.5	10.00	0.80	16.00	7.50	15.00	1.20	25.0/8.0	10.00
23	NorthSeaC	> 0	8.00	0.60	16.00	-	12.00	0.90	25.0/8.0	10.00

4. Comparison to in-situ data

Comparison of average (2001-2005) surface layer winter DIP of the observations and models (Fig.5) shows that there is a quite good agreement between the data and all models in the North Sea, Skagerrak, Kattegat and the Baltic Sea excepting deep water regions 3, 6, 8, 11 (see numbering in Fig.4). In these regions, the SPBIO model strongly overestimated the average (2001-2005) in-situ data at stations Landsort Deep BY31 and Gotland deep BY15, whereas the SMHI model strongly underestimated them at stations Landsort Deep BY31 and Bornholm deep BY5. The SPBIO model, as a rule, overestimated the observed DIP (7 cases against 1), the SMHI model underestimated them (6 cases against 2), whereas the IMR model overestimated the observations at 2 stations and underestimated them at 3 stations. The largest differences between models and observations occurred in 2005, the best fit to the data was achieved in 2003 (Table 3).

Calculated average (2001-2005) surface layer winter DIN of the different models demonstrates less good agreement with the observational data in Skagerrak (AA 17), Kattegat (Anholt E) and the Danish Straits (Landskrona W, Great Belt) (Fig.6). The IMR and SMHI models overestimated the observed DIN in 4 and 6 cases against 1 and 2 underestimations, respectively, whereas the SPBIO model overestimated the observations at 4 stations and underestimated them also at 4 stations. Judging by cost functions (Table 4), there is no remarkable difference in the accuracy of simulating of different years. The IMR model is permanently good in simulating the North Sea stations.

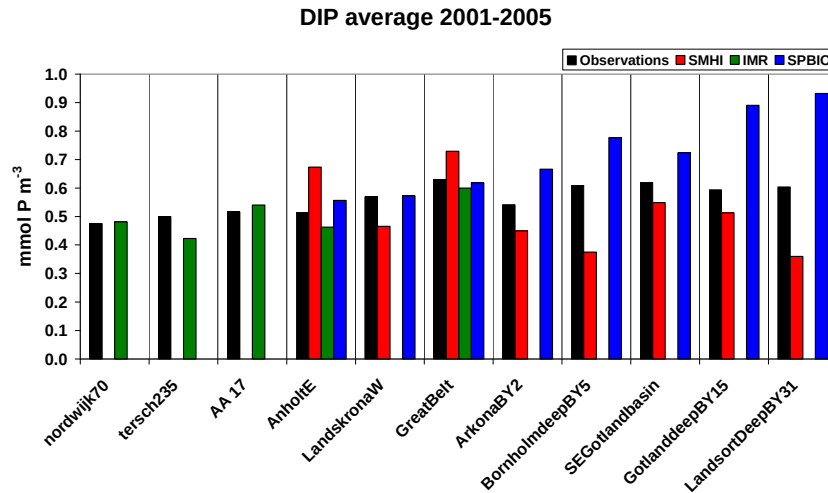
Looking at average (2001-2005) surface layer winter DIN:DIP ratio of the observations and models (Fig.7), one can see that the SMHI and IMR models overestimated the observations in 8 and 4 cases against none and 1 underestimations, respectively, while the SPBIO model overestimated the observations in 3 cases and underestimated them in 5. In general the SPBIO model was the best from participating models judging by the DIN:DIP cost functions which were 'good' and 'reasonable' in 33 cases and 'poor' in 7 cases (Table 5). The cost function values for the IMR model were 'good' and 'reasonable' at the North Sea stations and at the Great Belt and 'poor' at Skagerrak and Kattegat stations. The cost function values for the SMHI model were 'good' and 'reasonable', as a rule, at Landskrona W, Landsort Deep BY31 and SE Gotland basin and 'poor' in all other cases. The reason of this overestimation of winter DIN:DIP ratio by SMHI model is explained by the fact that it overestimates DIN and underestimates DIP contributing to the overestimation of the ratio. As for the SPBIO model, it overestimates DIP that compensates the overestimation of DIN at 4 stations and leads to overall decreasing of winter DIN:DIP ratio.

Simulated average (2001-2005) surface layer summer chlorophyll-a differs significantly from in-situ data (Fig.8). The SMHI model are in a good agreement with the summer chlorophyll-a in the Baltic Proper, but overestimates it in Kattegat and Danish Straits. The IMR and especially SPBIO models underestimate chlorophyll-a everywhere and in all years considered (Table 6). One from possible reason of these discrepancies between models and data is connected with prescribing a constant coefficient to convert modelled phytoplankton biomass into observed chlorophyll-a. The coefficient is highly variable during the vegetation season depending on many factors such as temperature, nutrients, photosynthetic available radiation and others (Sathyendranath et al., 2009).

Observed average (2001-2005) deep water late summer mean oxygen is simulated better by the SMHI model than by the other two models (Fig.9). The SMHI model fails only at station SE Gotland basin in the Baltic Sea and in the Danish Straits (Landskrona W and Fehmarn

Belt) where it strongly overestimates the observations and its cost function values are ‘poor’ (Table 7). The SPBIO model simulates well the Baltic Proper stations (Bornholm deep BY5, Gdansk Deep, Gotland deep BY15, Landsort Deep BY31, SE Gotland basin), but fails at other stations in Kattegat, the Danish Straits, the Gulf of Finland. The IMR model produces deep water late summer mean oxygen values exceeding the observations by a factor of 2.

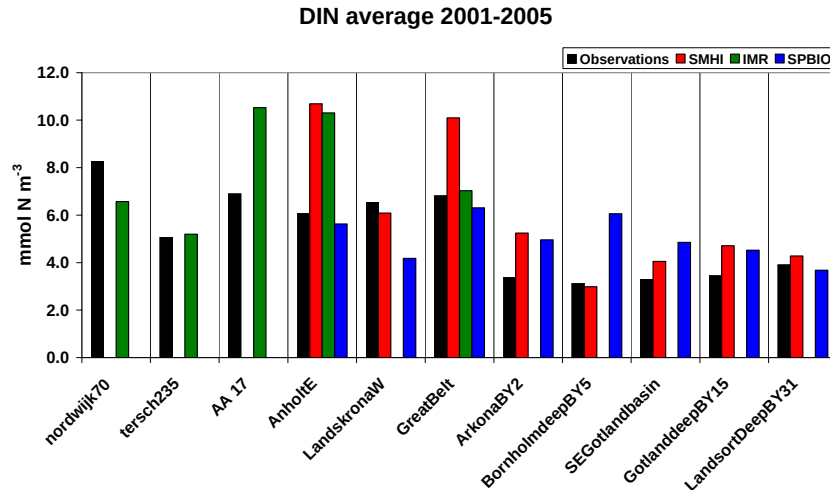
Simulated average (2001-2005) surface layer winter and summer salinity values (Figs.10 and 11) show a good agreement with in-situ data in the North and Baltic Seas and a worse agreement in Skagerrak, Kattegat and Danish Straits. The high values of the cost function for the annual average surface layer winter and, especially, summer salinity (Tables 8 and 9) are due to the low values of corresponding long term standard deviations.



Observations 0-10m in January-February		DIP	DIP	Model values			Cost function values		
Period	Station	Mv	Sd	SMHI	IMR	SPBIO	SMHI	IMR	SPBIO
2001-2005	AA 17	0.52	0.04	-	0.54	-	-	0.6	-
2001-2005	AnholtE	0.51	0.06	0.67	0.46	0.56	2.7	0.9	0.7
2001-2005	ArkonaBY2	0.54	0.16	0.45	-	0.67	0.6	-	0.8
2001-2005	BornholmdeepBY5	0.61	0.17	0.38	-	0.78	1.4	-	1.0
2001-2005	GotlanddeepBY15	0.59	0.18	0.51	-	0.89	0.5	-	1.7
2001-2005	GreatBelt	0.63	0.12	0.73	0.60	0.62	0.8	0.3	0.1
2001-2005	LandskronaW	0.57	0.09	0.47	-	0.57	1.1	-	0.0
2001-2005	LandsortDeepBY31	0.60	0.19	0.36	-	0.93	1.3	-	1.7
2001-2005	nordwijk70	0.48	0.09	-	0.48	-	-	0.1	-
2001-2005	SEGotlandbasin	0.62	0.18	0.55	-	0.72	0.4	-	0.6
2001-2005	tersch235	0.50	0.11	-	0.42	-	-	0.7	-
2001	AA 17	0.54	-	-	0.50	-	-	1.0	-
2001	AnholtE	0.56	-	0.63	0.50	0.65	1.1	1.1	1.5
2001	ArkonaBY2	0.54	-	0.44	-	0.90	0.6	-	2.3
2001	BornholmdeepBY5	0.62	-	0.35	-	0.85	1.6	-	1.4
2001	GotlanddeepBY15	0.36	-	0.46	-	0.90	0.5	-	3.0
2001	GreatBelt	0.75	-	0.68	0.60	0.89	0.7	1.3	1.2
2001	LandskronaW	0.62	-	0.42	-	0.71	2.2	-	1.0
2001	LandsortDeepBY31	0.34	-	0.21	-	0.71	0.7	-	1.9
2001	nordwijk70	0.47	-	-	0.60	-	-	1.4	-
2001	SEGotlandbasin	0.48	-	0.50	-	0.64	0.2	-	0.9
2001	tersch235	0.58	-	-	0.50	-	-	0.7	-
2002	AA 17	0.46	-	-	0.60	-	-	3.6	-
2002	AnholtE	0.47	-	0.74	0.50	0.68	4.7	0.6	3.6
2002	ArkonaBY2	0.46	-	0.40	-	0.66	0.4	-	1.2
2002	BornholmdeepBY5	0.57	-	0.40	-	0.81	1.0	-	1.5
2002	GotlanddeepBY15	-	-	0.50	-	0.77	-	-	-
2002	GreatBelt	0.70	-	0.87	0.60	0.76	1.5	0.8	0.5
2002	LandskronaW	0.53	-	0.57	-	0.62	0.4	-	1.0
2002	LandsortDeepBY31	0.55	-	0.40	-	0.89	0.8	-	1.8
2002	nordwijk70	0.56	-	-	0.44	-	-	1.4	-
2002	SEGotlandbasin	0.54	-	0.59	-	0.84	0.3	-	1.7
2002	tersch235	0.42	-	-	0.40	-	-	0.2	-
2003	AA 17	0.53	-	-	0.50	-	-	0.6	-
2003	AnholtE	0.50	-	0.52	0.51	0.50	0.3	0.2	0.0
2003	ArkonaBY2	0.58	-	0.62	-	0.75	0.3	-	1.1
2003	BornholmdeepBY5	0.55	-	0.35	-	0.87	1.2	-	1.9
2003	GotlanddeepBY15	0.60	-	0.51	-	0.91	0.5	-	1.8
2003	GreatBelt	-	-	0.63	0.60	0.59	-	-	-
2003	LandskronaW	0.56	-	0.38	-	0.63	1.9	-	0.7
2003	LandsortDeepBY31	0.54	-	0.20	-	0.79	1.7	-	1.3
2003	nordwijk70	0.45	-	-	0.51	-	-	0.6	-
2003	SEGotlandbasin	0.60	-	0.39	-	0.79	1.1	-	1.0
2003	tersch235	0.39	-	-	0.40	-	-	0.1	-
2004	AA 17	0.50	-	-	0.60	-	-	2.5	-
2004	AnholtE	0.46	-	0.61	0.40	0.47	2.7	1.0	0.3
2004	ArkonaBY2	0.35	-	0.28	-	0.41	0.5	-	0.4
2004	BornholmdeepBY5	0.43	-	0.25	-	0.63	1.1	-	1.2
2004	GotlanddeepBY15	0.62	-	0.39	-	0.85	1.3	-	1.3
2004	GreatBelt	0.49	-	0.57	0.60	0.43	0.7	1.0	0.5
2004	LandskronaW	0.44	-	0.31	-	0.43	1.4	-	0.2
2004	LandsortDeepBY31	0.85	-	0.45	-	0.93	2.1	-	0.4
2004	nordwijk70	0.55	-	-	0.50	-	-	0.5	-
2004	SEGotlandbasin	0.55	-	0.54	-	0.60	0.0	-	0.3
2004	tersch235	-	-	-	0.40	-	-	-	-
2005	AA 17	0.56	-	-	0.50	-	-	1.5	-
2005	AnholtE	0.59	-	0.87	0.40	0.49	5.0	3.3	1.8
2005	ArkonaBY2	0.78	-	0.50	-	0.62	1.7	-	1.0
2005	BornholmdeepBY5	0.88	-	0.52	-	0.73	2.2	-	0.9
2005	GotlanddeepBY15	0.80	-	0.72	-	1.02	0.5	-	1.2
2005	GreatBelt	0.59	-	0.90	0.60	0.44	2.7	0.1	1.3
2005	LandskronaW	0.68	-	0.65	-	0.47	0.4	-	2.3
2005	LandsortDeepBY31	0.74	-	0.54	-	1.34	1.0	-	3.1
2005	nordwijk70	0.34	-	-	0.36	-	-	0.2	-
2005	SEGotlandbasin	0.94	-	0.72	-	0.74	1.2	-	1.1
2005	tersch235	0.61	-	-	0.41	-	-	1.8	-

Figure 5 (above). Average (2001-2005) surface layer winter DIP ($\mu\text{molP l}^{-1}$) of the observations (black) and models (red=SMHI, green=IMR, blue=SPBIO). See Fig. 1 for location of stations.

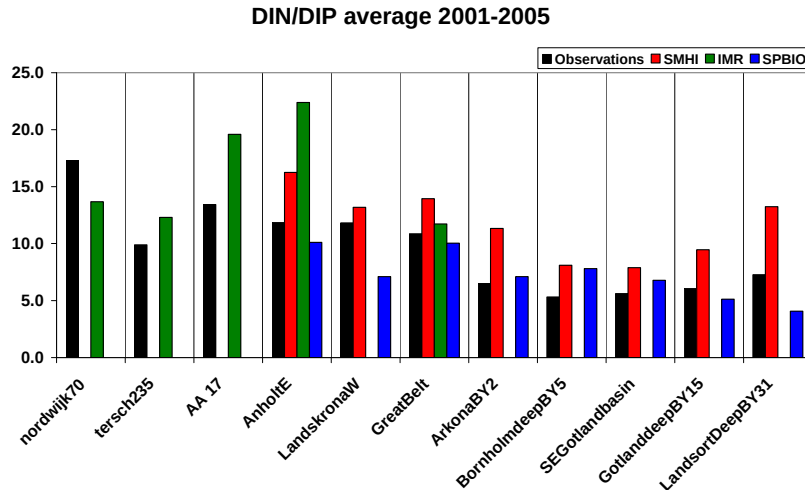
Table 3 (left). Average surface layer winter DIP ($\mu\text{molP l}^{-1}$) of the observations (yellow header) and the individual models (blue header) is shown with the corresponding cost function values (golden header) in the right columns. The average for the years 2001-2005 (see figure) and the corresponding standard deviation is shown in the upper part while the values of each year are shown in the lower part of the table.



Observations 0-10m in January-February		DIN	DIN	Model values DIN Mv			Cost function values DIN		
Period	Station	Mv	Sd	SMHI	IMR	SPBIO	SMHI	IMR	SPBIO
2001-2005	AA 17	6.90	1.02	-	10.53	-	-	3.5	-
2001-2005	Anholte	6.07	0.62	10.68	10.30	5.63	7.4	6.8	0.7
2001-2005	ArkonaBY2	3.39	0.86	5.24	-	4.96	2.2	-	1.8
2001-2005	BornholmdeepBY5	3.13	0.64	2.98	-	6.06	0.2	-	4.6
2001-2005	GotlanddeepBY15	3.45	0.42	4.71	-	4.52	3.0	-	2.6
2001-2005	GreatBelt	6.82	1.22	10.10	7.03	6.31	2.7	0.2	0.4
2001-2005	Landskronaw	6.55	1.12	6.08	-	4.18	0.4	-	2.1
2001-2005	LandsortDeepBY31	3.91	0.40	4.27	-	3.68	0.9	-	0.6
2001-2005	nordwijk70	8.27	2.52	-	6.57	-	-	0.7	-
2001-2005	SEGotlandbasin	3.30	0.37	4.05	-	4.85	2.0	-	4.2
2001-2005	tersch235	5.07	1.84	-	5.19	-	-	0.1	-
2001	AA 17	7.81	-	-	11.13	-	-	3.3	-
2001	Anholte	5.95	-	9.04	10.72	6.29	5.0	7.7	0.6
2001	ArkonaBY2	3.38	-	4.60	-	7.86	1.4	-	5.2
2001	BornholmdeepBY5	3.10	-	2.89	-	6.66	0.3	-	5.6
2001	GotlanddeepBY15	3.23	-	4.15	-	4.92	2.2	-	4.1
2001	GreatBelt	7.69	-	9.06	6.43	8.57	1.1	1.0	0.7
2001	Landskronaw	6.46	-	4.74	-	5.33	1.5	-	1.0
2001	LandsortDeepBY31	4.20	-	4.21	-	3.25	0.0	-	2.4
2001	nordwijk70	8.76	-	-	8.80	-	-	0.0	-
2001	SEGotlandbasin	3.20	-	3.54	-	4.75	0.9	-	4.3
2001	tersch235	6.57	-	-	6.16	-	-	0.2	-
2002	AA 17	7.26	-	-	9.90	-	-	2.6	-
2002	Anholte	6.60	-	10.56	11.07	7.25	6.4	7.2	1.0
2002	ArkonaBY2	3.31	-	4.23	-	3.88	1.1	-	0.7
2002	BornholmdeepBY5	3.11	-	3.35	-	5.04	0.4	-	3.0
2002	GotlanddeepBY15	3.86	-	4.75	-	4.20	2.1	-	0.8
2002	GreatBelt	8.04	-	11.56	7.78	8.96	2.9	0.2	0.7
2002	Landskronaw	8.47	-	7.96	-	4.99	0.5	-	3.1
2002	LandsortDeepBY31	4.10	-	5.42	-	4.60	3.3	-	1.2
2002	nordwijk70	12.25	-	-	6.95	-	-	2.1	-
2002	SEGotlandbasin	3.65	-	4.21	-	4.97	1.5	-	3.6
2002	tersch235	3.86	-	-	4.39	-	-	0.3	-
2003	AA 17	6.81	-	-	11.47	-	-	4.6	-
2003	Anholte	6.09	-	11.29	11.07	4.86	8.4	8.0	2.0
2003	ArkonaBY2	4.80	-	9.63	-	6.94	5.6	-	2.5
2003	BornholmdeepBY5	4.05	-	3.81	-	7.80	0.4	-	5.9
2003	GotlanddeepBY15	3.92	-	6.52	-	5.99	6.2	-	5.0
2003	GreatBelt	-	-	9.12	8.15	6.15	-	-	-
2003	Landskronaw	6.31	-	5.68	-	5.67	0.6	-	0.6
2003	LandsortDeepBY31	4.05	-	3.14	-	3.28	2.3	-	1.9
2003	nordwijk70	7.79	-	-	6.71	-	-	0.4	-
2003	SEGotlandbasin	3.63	-	5.19	-	5.52	4.3	-	5.2
2003	tersch235	3.14	-	-	5.96	-	-	1.5	-
2004	AA 17	5.19	-	-	12.03	-	-	6.7	-
2004	Anholte	5.10	-	9.93	8.71	4.79	7.8	5.8	0.5
2004	ArkonaBY2	2.55	-	3.06	-	2.09	0.6	-	0.5
2004	BornholmdeepBY5	2.25	-	1.76	-	5.52	0.8	-	5.1
2004	GotlanddeepBY15	2.97	-	3.76	-	4.14	1.9	-	2.8
2004	GreatBelt	5.93	-	8.44	6.61	4.28	2.1	0.5	1.4
2004	Landskronaw	5.91	-	4.34	-	2.57	1.4	-	3.0
2004	LandsortDeepBY31	3.21	-	3.32	-	3.04	0.3	-	0.4
2004	nordwijk70	7.00	-	-	6.11	-	-	0.4	-
2004	SEGotlandbasin	2.76	-	3.80	-	4.71	2.8	-	5.3
2004	tersch235	-	-	-	4.40	-	-	-	-
2005	AA 17	7.44	-	-	8.10	-	-	0.6	-
2005	Anholte	6.62	-	12.61	9.94	4.96	9.6	5.3	2.7
2005	ArkonaBY2	2.90	-	4.68	-	4.05	2.1	-	1.3
2005	BornholmdeepBY5	3.14	-	3.11	-	5.26	0.0	-	3.3
2005	GotlanddeepBY15	3.28	-	4.36	-	3.35	2.6	-	0.2
2005	GreatBelt	5.61	-	12.29	6.17	3.60	5.5	0.5	1.6
2005	Landskronaw	5.61	-	7.71	-	2.35	1.9	-	2.9
2005	LandsortDeepBY31	3.98	-	5.28	-	4.21	3.3	-	0.6
2005	nordwijk70	5.54	-	-	4.30	-	-	0.5	-
2005	SEGotlandbasin	3.28	-	3.51	-	4.29	0.6	-	2.8
2005	tersch235	6.71	-	-	5.05	-	-	0.9	-

Figure 6 (above). Average (2001-2005) surface layer winter DIN ($\mu\text{molN l}^{-1}$) of the observations (black) and models (red=SMHI, green=IMR, blue=SPBIO). See Fig. 1 for location of stations.

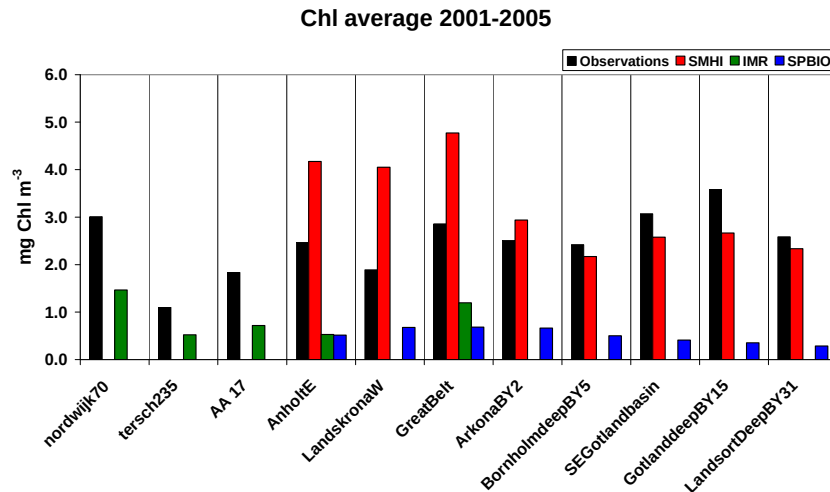
Table 4 (left). Average surface layer winter DIN ($\mu\text{molN l}^{-1}$) of the observations (yellow header) and the individual models (blue header) is shown with the corresponding cost function values (golden header) in the right columns. The average for the years 2001-2005 (see figure) and the corresponding standard deviation is shown in the upper part while the values of each year are shown in the lower part of the table.



Observations 0-10m in January-February				Model values DIN/DIP Mv			Cost function values DIN/DIP		
Period	Station	DIN/DIP Mv	DIN/DIP Sd	SMHI	IMR	SPBIO	SMHI	IMR	SPBIO
2001-2005	AA 17	13.43	2.05	-	19.59	-	-	3.0	-
2001-2005	Anholte	11.86	1.39	16.24	22.37	10.10	3.2	7.6	1.3
2001-2005	ArkonaBY2	6.54	1.72	11.32	-	7.11	2.8	-	0.3
2001-2005	BornholmdeepBY5	5.32	1.36	8.10	-	7.81	2.0	-	1.8
2001-2005	GotlanddeepBY15	6.09	2.12	9.47	-	5.13	1.6	-	0.5
2001-2005	GreatBelt	10.86	1.19	13.94	11.71	10.04	2.6	0.7	0.7
2001-2005	LandskronaW	11.81	2.93	13.19	-	7.11	0.5	-	1.6
2001-2005	LandsortDeepBY31	7.27	3.17	13.25	-	4.06	1.9	-	1.0
2001-2005	nordwijk70	17.31	3.25	-	13.67	-	-	1.1	-
2001-2005	SEGotlandbasin	5.62	1.38	7.88	-	6.78	1.6	-	0.8
2001-2005	tersch235	9.90	1.50	-	12.29	-	-	1.6	-
2001	AA 17	14.45	-	-	22.27	-	-	3.8	-
2001	Anholte	10.59	-	14.45	21.44	9.68	2.8	7.8	0.7
2001	ArkonaBY2	6.31	-	10.57	-	8.77	2.5	-	1.4
2001	BornholmdeepBY5	5.01	-	8.29	-	7.87	2.4	-	2.1
2001	GotlanddeepBY15	8.87	-	9.11	-	5.47	0.1	-	1.6
2001	GreatBelt	10.23	-	13.41	10.71	9.66	2.7	0.4	0.5
2001	LandskronaW	10.35	-	11.33	-	7.46	0.3	-	1.0
2001	LandsortDeepBY31	12.21	-	19.95	-	4.58	2.4	-	2.4
2001	nordwijk70	18.52	-	-	14.67	-	-	1.2	-
2001	SEGotlandbasin	6.73	-	7.01	-	7.42	0.2	-	0.5
2001	tersch235	11.32	-	-	12.32	-	-	0.7	-
2002	AA 17	15.97	-	-	16.50	-	-	0.3	-
2002	Anholte	14.12	-	14.36	22.15	10.73	0.2	5.8	2.4
2002	ArkonaBY2	7.15	-	10.49	-	5.88	1.9	-	0.7
2002	BornholmdeepBY5	5.48	-	8.29	-	6.24	2.1	-	0.6
2002	GotlanddeepBY15	-	-	9.58	-	5.46	-	-	-
2002	GreatBelt	11.54	-	13.24	12.97	11.84	1.4	1.2	0.2
2002	LandskronaW	15.86	-	13.93	-	8.00	0.7	-	2.7
2002	LandsortDeepBY31	7.41	-	13.45	-	5.14	1.9	-	0.7
2002	nordwijk70	21.70	-	-	16.02	-	-	1.7	-
2002	SEGotlandbasin	6.80	-	7.19	-	5.91	0.3	-	0.6
2002	tersch235	9.20	-	-	10.97	-	-	1.2	-
2003	AA 17	12.96	-	-	22.93	-	-	4.9	-
2003	Anholte	12.19	-	21.79	21.64	9.77	6.9	6.8	1.7
2003	ArkonaBY2	8.31	-	15.50	-	9.27	4.2	-	0.6
2003	BornholmdeepBY5	7.37	-	10.80	-	8.96	2.5	-	1.2
2003	GotlanddeepBY15	6.58	-	12.88	-	6.57	3.0	-	0.0
2003	GreatBelt	-	-	14.53	13.59	10.51	-	-	-
2003	LandskronaW	11.30	-	14.91	-	9.04	1.2	-	0.8
2003	LandsortDeepBY31	7.55	-	15.53	-	4.15	2.5	-	1.1
2003	nordwijk70	17.24	-	-	13.26	-	-	1.2	-
2003	SEGotlandbasin	6.05	-	13.27	-	6.98	5.2	-	0.7
2003	tersch235	8.12	-	-	14.90	-	-	4.5	-
2004	AA 17	10.42	-	-	20.06	-	-	4.7	-
2004	Anholte	11.15	-	16.20	21.78	10.10	3.6	7.7	0.8
2004	ArkonaBY2	7.19	-	10.78	-	5.06	2.1	-	1.2
2004	BornholmdeepBY5	5.18	-	7.18	-	8.71	1.5	-	2.6
2004	GotlanddeepBY15	4.83	-	9.69	-	4.88	2.3	-	0.0
2004	GreatBelt	12.14	-	14.87	11.01	10.00	2.3	0.9	1.8
2004	LandskronaW	13.35	-	13.87	-	6.03	0.2	-	2.5
2004	LandsortDeepBY31	3.79	-	7.44	-	3.28	1.2	-	0.2
2004	nordwijk70	12.76	-	-	12.21	-	-	0.2	-
2004	SEGotlandbasin	5.03	-	7.06	-	7.78	1.5	-	2.0
2004	tersch235	-	-	-	11.00	-	-	-	-
2005	AA 17	13.33	-	-	16.20	-	-	1.4	-
2005	Anholte	11.27	-	14.41	24.85	10.23	2.3	9.8	0.8
2005	ArkonaBY2	3.73	-	9.26	-	6.56	3.2	-	1.6
2005	BornholmdeepBY5	3.56	-	5.94	-	7.26	1.7	-	2.7
2005	GotlanddeepBY15	4.10	-	6.09	-	3.28	0.9	-	0.4
2005	GreatBelt	9.54	-	13.66	10.29	8.21	3.5	0.6	1.1
2005	LandskronaW	8.19	-	11.91	-	5.01	1.3	-	1.1
2005	LandsortDeepBY31	5.40	-	9.86	-	3.15	1.4	-	0.7
2005	nordwijk70	16.34	-	-	12.22	-	-	1.3	-
2005	SEGotlandbasin	3.49	-	4.87	-	5.80	1.0	-	1.7
2005	tersch235	10.95	-	-	12.28	-	-	0.9	-

Figure 7 (above). Average (2001-2005) surface layer winter DIN:DIP ratio of the observations (black) and models (red=SMHI, green=IMR, blue=SPBIO). See Fig. 1 for location of stations.

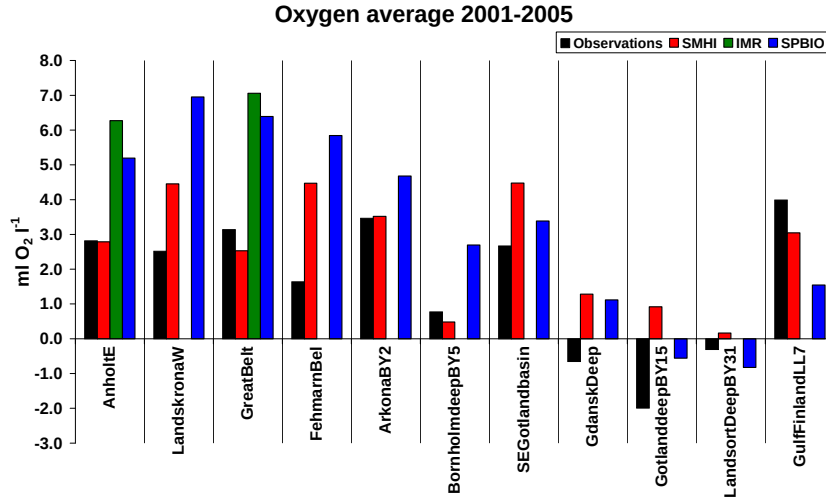
Table 5 (left). Average surface layer winter DIN:DIP ratio of the observations (yellow header) and the individual models (blue header) is shown with the corresponding cost function values (golden header) in the right columns. The average for the years 2001-2005 (see figure) and the corresponding standard deviation is shown in the upper part while the values of each year are shown in the lower part of the table.



Observations 0-10m in March-October		Chl		Model values Chl Mv			Cost function values Chl		
Period	Station	Mv	Sd	SMHI	IMR	SPBIO	SMHI	IMR	SPBIO
2001-2005	AA 17	1.84	1.02	-	0.72	-	-	1.1	-
2001-2005	Anholte	2.47	0.60	4.17	0.53	0.51	2.9	3.2	3.3
2001-2005	ArkonaBY2	2.51	0.53	2.94	-	0.66	0.8	-	3.5
2001-2005	BornholmdeepBY5	2.42	0.73	2.17	-	0.50	0.3	-	2.6
2001-2005	GotlanddeepBY15	3.58	0.75	2.66	-	0.36	1.2	-	4.3
2001-2005	GreatBelt	2.86	0.23	4.77	1.19	0.68	8.5	7.4	9.7
2001-2005	LandskronaW	1.89	0.42	4.05	-	0.68	5.2	-	2.9
2001-2005	LandsortDeepBY31	2.58	0.25	2.34	-	0.29	1.0	-	9.3
2001-2005	nordwijk70	3.01	0.77	-	1.47	-	-	2.0	-
2001-2005	SEGotlandbasin	3.07	0.32	2.58	-	0.41	1.5	-	8.3
2001-2005	tersch235	1.10	0.32	-	0.52	-	-	1.8	-
2001	AA 17	1.71	-	-	0.70	-	-	1.0	-
2001	Anholte	2.78	-	3.42	0.44	0.58	1.1	3.9	3.7
2001	ArkonaBY2	3.33	-	2.62	-	0.66	1.3	-	5.0
2001	BornholmdeepBY5	3.64	-	2.04	-	0.49	2.2	-	4.3
2001	GotlanddeepBY15	4.38	-	2.61	-	0.33	2.4	-	5.4
2001	GreatBelt	2.80	-	3.99	1.35	0.77	5.3	6.5	9.0
2001	LandskronaW	1.95	-	3.93	-	0.70	4.7	-	3.0
2001	LandsortDeepBY31	2.82	-	1.96	-	0.29	3.5	-	10.2
2001	nordwijk70	3.32	-	-	1.52	-	-	2.3	-
2001	SEGotlandbasin	3.47	-	2.62	-	0.35	2.7	-	9.8
2001	tersch235	1.62	-	-	0.71	-	-	2.8	-
2002	AA 17	3.55	-	-	0.70	-	-	2.8	-
2002	Anholte	3.15	-	4.05	0.60	0.65	1.5	4.3	4.2
2002	ArkonaBY2	2.67	-	3.35	-	0.86	1.3	-	3.4
2002	BornholmdeepBY5	2.02	-	2.22	-	0.60	0.3	-	1.9
2002	GotlanddeepBY15	4.15	-	2.90	-	0.39	1.7	-	5.0
2002	GreatBelt	2.70	-	5.10	1.24	0.93	10.6	6.5	7.9
2002	LandskronaW	1.79	-	3.82	-	0.82	4.9	-	2.3
2002	LandsortDeepBY31	-	-	2.84	-	0.32	-	-	-
2002	nordwijk70	4.21	-	-	1.45	-	-	3.6	-
2002	SEGotlandbasin	3.18	-	2.60	-	0.53	1.8	-	8.3
2002	tersch235	1.20	-	-	0.49	-	-	2.2	-
2003	AA 17	1.00	-	-	0.70	-	-	0.3	-
2003	Anholte	1.55	-	3.90	0.60	0.46	3.9	1.6	1.8
2003	ArkonaBY2	1.91	-	2.58	-	0.58	1.3	-	2.5
2003	BornholmdeepBY5	1.87	-	2.59	-	0.52	1.0	-	1.8
2003	GotlanddeepBY15	2.45	-	2.78	-	0.38	0.4	-	2.8
2003	GreatBelt	-	-	4.66	1.07	0.62	-	-	-
2003	LandskronaW	2.57	-	4.00	-	0.65	3.4	-	4.6
2003	LandsortDeepBY31	2.60	-	1.77	-	0.27	3.3	-	9.4
2003	nordwijk70	2.37	-	-	1.55	-	-	1.1	-
2003	SEGotlandbasin	2.73	-	2.72	-	0.35	0.0	-	7.4
2003	tersch235	0.95	-	-	0.47	-	-	1.5	-
2004	AA 17	1.82	-	-	0.80	-	-	1.0	-
2004	Anholte	2.39	-	4.95	0.50	0.41	4.3	3.2	3.3
2004	ArkonaBY2	2.38	-	2.62	-	0.53	0.5	-	3.5
2004	BornholmdeepBY5	2.02	-	1.78	-	0.40	0.3	-	2.2
2004	GotlanddeepBY15	3.42	-	2.35	-	0.32	1.4	-	4.1
2004	GreatBelt	3.19	-	5.10	1.09	0.54	8.5	9.3	11.8
2004	LandskronaW	1.66	-	3.99	-	0.54	5.6	-	2.7
2004	LandsortDeepBY31	-	-	2.50	-	0.29	-	-	-
2004	nordwijk70	2.64	-	-	1.39	-	-	1.6	-
2004	SEGotlandbasin	2.76	-	2.11	-	0.39	2.1	-	7.4
2004	tersch235	0.92	-	-	0.47	-	-	1.4	-
2005	AA 17	1.11	-	-	0.70	-	-	0.4	-
2005	Anholte	2.46	-	4.55	0.50	0.47	3.5	3.3	3.3
2005	ArkonaBY2	2.29	-	3.53	-	0.69	2.3	-	3.0
2005	BornholmdeepBY5	2.54	-	2.24	-	0.50	0.4	-	2.8
2005	GotlanddeepBY15	3.51	-	2.68	-	0.36	1.1	-	4.2
2005	GreatBelt	2.73	-	5.01	1.21	0.56	10.1	6.8	9.7
2005	LandskronaW	1.48	-	4.51	-	0.66	7.2	-	2.0
2005	LandsortDeepBY31	2.33	-	2.60	-	0.27	1.1	-	8.3
2005	nordwijk70	2.49	-	-	1.41	-	-	1.4	-
2005	SEGotlandbasin	3.21	-	2.85	-	0.43	1.1	-	8.7
2005	tersch235	0.81	-	-	0.49	-	-	1.0	-

Figure 8 (above). Average (2001-2005) surface layer summer Chlorophyll-a ($\mu\text{g Chl-a l}^{-1}$) of the observations (black) and models (red=SMHI, green=IMR, blue=SPBIO). See Fig. 1 for location of stations.

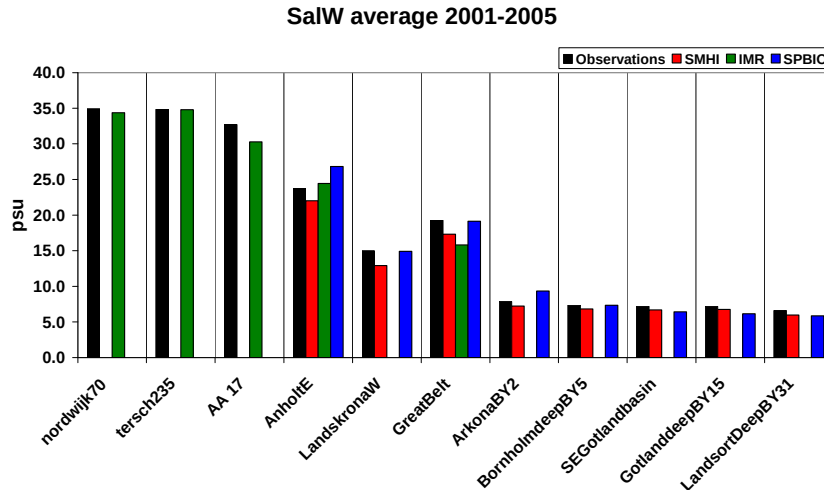
Table 6 (left). Average surface layer summer Chlorophyll-a ($\mu\text{g Chl-a l}^{-1}$) of the observations (yellow header) and the individual models (blue header) is shown with the corresponding cost function values (golden header) in the right columns. The average for the years 2001-2005 (see figure) and the corresponding standard deviation is shown in the upper part while the values of each year are shown in the lower part of the table.



Observations in August-September		Depth (m)	Oxygen		Model values Oxygen Mv			Cost function values Oxygen		
Period	Station		Mv	Sd	SMHI	IMR	SPBIO	SMHI	IMR	SPBIO
2001-2005	Anholte	50	2.81	0.85	2.79	6.27	5.19	0.0	4.1	2.8
2001-2005	ArkonaBY2	40	3.47	0.56	3.52	-	4.68	0.1	-	2.2
2001-2005	BornholmdeepBY5	85	0.77	1.46	0.48	-	2.69	0.2	-	1.3
2001-2005	FehmarnBel	26	1.63	1.02	4.47	-	5.84	2.8	-	4.1
2001-2005	GdanskDeep	100	-0.66	2.59	1.28	-	1.12	0.7	-	0.7
2001-2005	GotlanddeepBY15	240	-2.00	3.28	0.92	-	-0.56	0.9	-	0.4
2001-2005	GreatBelt	33	3.14	0.71	2.53	7.06	6.39	0.9	5.5	4.6
2001-2005	GulfFinlandLL7	70	3.99	0.86	3.04	-	1.54	1.1	-	2.8
2001-2005	LandskronaW	50	2.52	0.72	4.45	-	6.95	2.7	-	6.2
2001-2005	LandsortDeepBY31	250	-0.31	0.46	0.16	-	-0.82	1.0	-	1.1
2001-2005	SEGotlandbasin	80	2.67	0.66	4.47	-	3.39	2.7	-	1.1
2001	Anholte	50	3.20	-	1.35	6.33	5.07	2.2	3.7	2.2
2001	ArkonaBY2	40	-	-	2.79	-	4.65	-	-	-
2001	BornholmdeepBY5	85	-	-	-0.73	-	0.91	-	-	-
2001	FehmarnBel	26	3.20	-	3.72	-	5.95	0.5	-	2.7
2001	GdanskDeep	100	-	-	1.65	-	-1.28	-	-	-
2001	GotlanddeepBY15	240	-	-	-0.35	-	-1.99	-	-	-
2001	GreatBelt	33	3.77	-	0.73	7.07	6.44	4.3	4.6	3.8
2001	GulfFinlandLL7	70	-	-	2.77	-	1.98	-	-	-
2001	LandskronaW	50	3.20	-	3.91	-	6.97	1.0	-	5.3
2001	LandsortDeepBY31	250	-	-	-0.11	-	-1.43	-	-	-
2001	SEGotlandbasin	80	2.04	-	4.26	-	3.54	3.4	-	2.3
2002	Anholte	50	1.64	-	1.34	6.18	5.15	0.4	5.3	4.1
2002	ArkonaBY2	40	2.72	-	3.10	-	3.83	0.7	-	2.0
2002	BornholmdeepBY5	85	0.64	-	-0.89	-	2.24	1.1	-	1.1
2002	FehmarnBel	26	0.78	-	3.93	-	4.79	3.1	-	3.9
2002	GdanskDeep	100	-	-	0.17	-	1.15	-	-	-
2002	GotlanddeepBY15	240	-5.66	-	-0.52	-	-2.74	1.6	-	0.9
2002	GreatBelt	33	2.10	-	1.36	7.04	5.89	1.0	6.9	5.3
2002	GulfFinlandLL7	70	4.32	-	3.10	-	2.69	1.4	-	1.9
2002	LandskronaW	50	1.43	-	3.36	-	6.76	2.7	-	7.4
2002	LandsortDeepBY31	250	-0.55	-	-0.30	-	-1.41	0.6	-	1.9
2002	SEGotlandbasin	80	3.79	-	5.27	-	2.80	2.2	-	1.5
2003	Anholte	50	2.27	-	4.07	6.34	5.16	2.1	4.8	3.4
2003	ArkonaBY2	40	3.36	-	3.93	-	5.02	1.0	-	3.0
2003	BornholmdeepBY5	85	2.73	-	3.30	-	4.79	0.4	-	1.4
2003	FehmarnBel	26	1.80	-	5.08	-	6.00	3.2	-	4.1
2003	GdanskDeep	100	2.30	-	3.41	-	3.02	0.4	-	0.3
2003	GotlanddeepBY15	240	2.11	-	2.51	-	-0.41	0.1	-	0.8
2003	GreatBelt	33	2.79	-	4.17	7.05	6.36	1.9	6.0	5.0
2003	Gulf of Finland LL7	70	-	-	2.66	-	0.71	-	-	-
2003	LandskronaW	50	2.42	-	5.52	-	7.08	4.3	-	6.5
2003	LandsortDeepBY31	250	-0.80	-	-0.02	-	-1.48	1.7	-	1.5
2003	SEGotlandbasin	80	2.42	-	4.69	-	3.31	3.4	-	1.3
2004	Anholte	50	3.80	-	3.70	6.18	5.20	0.1	2.8	1.6
2004	ArkonaBY2	40	3.89	-	3.12	-	5.35	1.4	-	2.6
2004	BornholmdeepBY5	85	0.52	-	0.97	-	3.55	0.3	-	2.1
2004	FehmarnBel	26	1.73	-	4.60	-	6.33	2.8	-	4.5
2004	GdanskDeep	100	-2.53	-	1.01	-	1.16	1.4	-	1.4
2004	GotlanddeepBY15	240	-1.22	-	1.87	-	0.80	0.9	-	0.6
2004	GreatBelt	33	3.23	-	3.14	7.09	6.65	0.1	5.4	4.8
2004	GulfFinlandLL7	70	3.01	-	2.02	-	0.73	1.1	-	2.6
2004	LandskronaW	50	2.39	-	4.80	-	7.02	3.4	-	6.5
2004	LandsortDeepBY31	250	0.24	-	0.73	-	-0.33	1.1	-	1.2
2004	SEGotlandbasin	80	2.53	-	2.66	-	3.65	0.2	-	1.7
2005	Anholte	50	3.17	-	3.47	6.33	5.39	0.4	3.7	2.6
2005	ArkonaBY2	40	3.91	-	4.65	-	4.54	1.3	-	1.1
2005	BornholmdeepBY5	85	-0.80	-	-0.24	-	1.97	0.4	-	1.9
2005	FehmarnBel	26	0.67	-	5.03	-	6.15	4.3	-	5.4
2005	GdanskDeep	100	-1.74	-	0.17	-	1.53	0.7	-	1.3
2005	GotlanddeepBY15	240	-3.21	-	1.08	-	1.57	1.3	-	1.5
2005	GreatBelt	33	3.80	-	3.24	7.06	6.61	0.8	4.6	3.9
2005	GulfFinlandLL7	70	4.64	-	4.67	-	1.61	0.0	-	3.5
2005	LandskronaW	50	3.13	-	4.68	-	6.95	2.2	-	5.3
2005	LandsortDeepBY31	250	-0.13	-	0.49	-	0.53	1.4	-	1.4
2005	SEGotlandbasin	80	2.56	-	5.49	-	3.63	4.4	-	1.6

Figure 9 (above). Average (2001-2005) deep water late summer mean oxygen ($\text{ml O}_2 \text{ l}^{-1}$) of the observations (black) and models (red=SMHI, green=IMR, blue=SPBIO). See Fig. 1 for location of stations. Hydrogen sulfide concentrations are shown as “negative oxygen” equivalents ($1 \text{ ml H}_2\text{S l}^{-1} = -2 \text{ ml O}_2 \text{ l}^{-1}$).

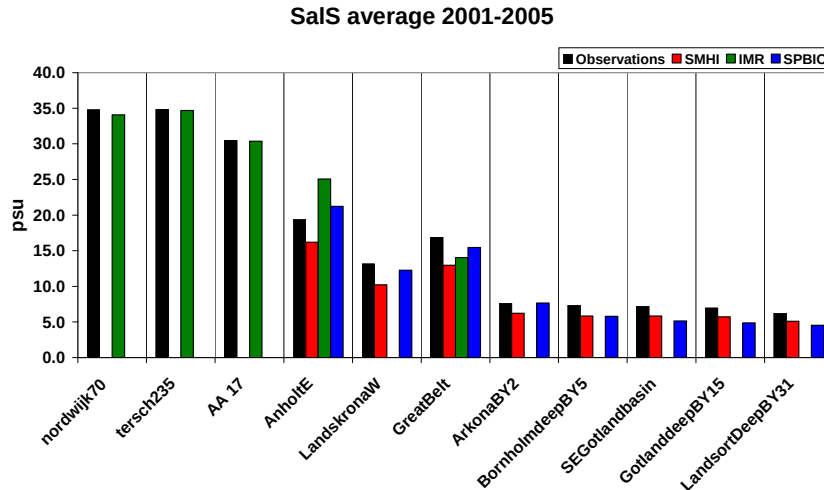
Table 7 (left). Average deep water late summer mean oxygen ($\text{ml O}_2 \text{ l}^{-1}$) of the observations (yellow header) and the individual models (blue header) is shown with the corresponding cost function values (golden header) in the right columns. The average for the years 2001-2005 (see figure) and the corresponding standard deviation is shown in the upper part while the values of each year are shown in the lower part of the table.



Observations 0-10m in January-February		SalW	SalW	Model values SalW Mv			Cost function values SalW		
Period	Station	Mv	Sd	SMHI	IMR	SPBIO	SMHI	IMR	SPBIO
2001-2005	AA 17	32.71	1.19	-	30.27	-	-	2.0	-
2001-2005	Anholte	23.77	2.13	22.02	24.44	26.82	0.8	0.3	1.4
2001-2005	ArkonaBY2	7.87	0.18	7.24	-	9.35	3.5	-	8.2
2001-2005	BornholmdeepBY5	7.37	0.24	6.82	-	7.35	2.3	-	0.1
2001-2005	GotlanddeepBY15	7.17	0.15	6.77	-	6.15	2.8	-	7.0
2001-2005	GreatBelt	19.28	1.63	17.34	15.81	19.15	1.2	2.1	0.1
2001-2005	LandskronaW	15.01	2.18	12.92	-	14.93	1.0	-	0.0
2001-2005	LandsortDeepBY31	6.60	0.30	5.97	-	5.85	2.1	-	2.5
2001-2005	nordwijk70	34.92	0.30	-	34.37	-	-	1.9	-
2001-2005	SEGotlandbasin	7.19	0.13	6.68	-	6.43	3.9	-	5.8
2001-2005	tersch235	34.84	0.21	-	34.80	-	-	0.2	-
2001	AA 17	32.72	-	-	29.33	-	-	2.8	-
2001	Anholte	20.47	-	19.78	23.88	23.99	0.3	1.6	1.6
2001	ArkonaBY2	7.81	-	6.95	-	8.21	4.8	-	2.2
2001	BornholmdeepBY5	7.38	-	6.74	-	7.10	2.7	-	1.2
2001	GotlanddeepBY15	7.08	-	6.66	-	6.50	2.8	-	3.9
2001	GreatBelt	18.13	-	15.84	11.93	16.14	1.4	3.8	1.2
2001	LandskronaW	13.64	-	11.63	-	13.76	0.9	-	0.1
2001	LandsortDeepBY31	6.23	-	5.74	-	5.84	1.6	-	1.3
2001	nordwijk70	35.02	-	-	34.45	-	-	1.9	-
2001	SEGotlandbasin	7.10	-	6.57	-	6.64	4.0	-	3.5
2001	tersch235	34.82	-	-	34.79	-	-	0.2	-
2002	AA 17	32.95	-	-	30.63	-	-	1.9	-
2002	Anholte	24.03	-	23.58	24.70	27.88	0.2	0.3	1.8
2002	ArkonaBY2	7.74	-	7.20	-	9.20	3.0	-	8.1
2002	BornholmdeepBY5	7.02	-	6.55	-	7.02	2.0	-	0.0
2002	GotlanddeepBY15	7.23	-	6.81	-	6.10	2.8	-	7.7
2002	GreatBelt	21.75	-	19.62	18.15	19.74	1.3	2.2	1.2
2002	LandskronaW	18.16	-	15.28	-	18.02	1.3	-	0.1
2002	LandsortDeepBY31	6.57	-	5.94	-	5.85	2.0	-	2.3
2002	nordwijk70	34.43	-	-	34.37	-	-	0.2	-
2002	SEGotlandbasin	7.10	-	6.73	-	6.34	2.8	-	5.8
2002	tersch235	34.88	-	-	34.80	-	-	0.4	-
2003	AA 17	30.74	-	-	30.00	-	-	0.6	-
2003	Anholte	26.12	-	22.59	25.02	27.85	1.7	0.5	0.8
2003	ArkonaBY2	7.69	-	7.03	-	9.69	3.7	-	11.2
2003	BornholmdeepBY5	7.33	-	6.86	-	7.09	2.0	-	1.0
2003	GotlanddeepBY15	7.09	-	6.65	-	6.17	3.0	-	6.2
2003	GreatBelt	20.15	-	18.37	18.35	20.25	-	-	-
2003	LandskronaW	16.09	-	12.83	-	15.70	1.5	-	0.2
2003	LandsortDeepBY31	6.41	-	5.63	-	5.80	2.5	-	2.0
2003	nordwijk70	35.09	-	-	34.39	-	-	2.4	-
2003	SEGotlandbasin	7.12	-	6.54	-	6.40	4.4	-	5.5
2003	tersch235	34.57	-	-	34.70	-	-	0.6	-
2004	AA 17	33.94	-	-	30.70	-	-	2.7	-
2004	Anholte	23.24	-	21.84	24.17	26.38	0.7	0.4	1.5
2004	ArkonaBY2	7.97	-	7.26	-	9.91	3.9	-	10.8
2004	BornholmdeepBY5	7.49	-	6.94	-	7.61	2.3	-	0.5
2004	GotlanddeepBY15	7.07	-	6.75	-	6.02	2.2	-	7.2
2004	GreatBelt	18.22	-	15.74	14.75	19.37	1.5	2.1	0.7
2004	LandskronaW	12.59	-	11.47	-	12.79	0.5	-	0.1
2004	LandsortDeepBY31	6.83	-	6.12	-	5.55	2.4	-	4.2
2004	nordwijk70	34.89	-	-	34.37	-	-	1.8	-
2004	SEGotlandbasin	7.26	-	6.72	-	6.28	4.1	-	7.5
2004	tersch235	-	-	-	34.80	-	-	-	-
2005	AA 17	33.21	-	-	30.70	-	-	2.1	-
2005	Anholte	24.98	-	22.32	24.43	28.02	1.2	0.3	1.4
2005	ArkonaBY2	8.13	-	7.78	-	9.73	1.9	-	8.9
2005	BornholmdeepBY5	7.66	-	7.03	-	7.92	2.7	-	1.1
2005	GotlanddeepBY15	7.41	-	6.96	-	5.96	3.1	-	9.9
2005	GreatBelt	18.13	-	17.10	15.85	20.24	0.6	1.4	1.3
2005	LandskronaW	14.59	-	13.39	-	14.36	0.5	-	0.1
2005	LandsortDeepBY31	6.97	-	6.41	-	6.19	1.8	-	2.6
2005	nordwijk70	35.19	-	-	34.31	-	-	3.0	-
2005	SEGotlandbasin	7.40	-	6.81	-	6.50	4.5	-	6.9
2005	tersch235	35.09	-	-	34.90	-	-	0.9	-

Figure 10 (above). Average (2001-2005) surface layer winter salinity (psu) of the observations (black) and models (red=SMHI, green=IMR, blue=SPBIO). See Fig. 1 for location of stations.

Table 8 (left). Average surface layer winter salinity (psu) of the observations (yellow header) and the individual models (blue header) is shown with the corresponding cost function values (golden header) in the right columns. The average for the years 2001-2005 (see figure) and the corresponding standard deviation is shown in the upper part while the values of each year are shown in the lower part of the table.



Observations 0-10m in March-October		SalS	SalS	Model values SalS Mv			Cost function values SalS		
Period	Station	Mv	Sd	SMHI	IMR	SPBIO	SMHI	IMR	SPBIO
2001-2005	AA 17	30.52	0.67	-	30.39	-	-	0.2	-
2001-2005	Anholte	19.36	1.30	16.20	25.08	21.23	2.4	4.4	1.4
2001-2005	ArkonaBY2	7.61	0.15	6.21	-	7.65	9.2	-	0.3
2001-2005	BornholmdeepBY5	7.36	0.17	5.83	-	5.80	9.1	-	9.3
2001-2005	GotlanddeepBY15	6.96	0.08	5.71	-	4.87	15.3	-	25.7
2001-2005	GreatBelt	16.87	0.85	12.95	14.03	15.47	4.6	3.3	1.6
2001-2005	Landskronaw	13.17	1.21	10.21	-	12.27	2.5	-	0.7
2001-2005	LandsortDeepBY31	6.25	0.17	5.09	-	4.53	6.8	-	10.0
2001-2005	nordwijk70	34.79	0.19	-	34.09	-	-	3.8	-
2001-2005	SEGotlandbasin	7.16	0.11	5.84	-	5.14	12.2	-	18.7
2001-2005	tersch235	34.84	0.15	-	34.70	-	-	0.9	-
2001	AA 17	31.11	-	-	30.43	-	-	1.0	-
2001	Anholte	20.58	-	18.21	25.05	26.13	1.8	3.4	4.3
2001	ArkonaBY2	7.42	-	6.84	-	9.12	3.8	-	11.1
2001	BornholmdeepBY5	7.22	-	6.68	-	7.27	3.3	-	0.3
2001	GotlanddeepBY15	6.83	-	6.43	-	6.14	4.9	-	8.5
2001	GreatBelt	16.64	-	14.60	13.78	17.94	2.4	3.4	1.5
2001	Landskronaw	13.34	-	11.32	-	14.75	1.7	-	1.2
2001	LandsortDeepBY31	5.97	-	5.54	-	5.59	2.5	-	2.2
2001	nordwijk70	34.56	-	-	34.10	-	-	2.5	-
2001	SEGotlandbasin	7.08	-	6.65	-	6.59	4.0	-	4.5
2001	tersch235	34.76	-	-	34.69	-	-	0.5	-
2002	AA 17	29.94	-	-	30.33	-	-	0.6	-
2002	Anholte	17.51	-	17.66	24.92	25.03	0.1	5.7	5.8
2002	ArkonaBY2	7.51	-	6.85	-	8.93	4.3	-	9.3
2002	BornholmdeepBY5	7.22	-	6.59	-	6.99	3.7	-	1.4
2002	GotlanddeepBY15	6.98	-	6.59	-	6.00	4.8	-	12.0
2002	GreatBelt	15.89	-	14.53	13.97	17.25	1.6	2.3	1.6
2002	Landskronaw	11.69	-	11.15	-	13.89	0.4	-	1.8
2002	LandsortDeepBY31	6.21	-	5.68	-	5.72	-	-	-
2002	nordwijk70	34.63	-	-	34.09	-	-	2.9	-
2002	SEGotlandbasin	7.09	-	6.58	-	6.18	4.8	-	8.5
2002	tersch235	34.73	-	-	34.70	-	-	0.2	-
2003	AA 17	31.38	-	-	30.43	-	-	1.4	-
2003	Anholte	20.53	-	20.25	25.20	27.30	0.2	3.6	5.2
2003	ArkonaBY2	7.61	-	6.99	-	9.65	4.1	-	13.4
2003	BornholmdeepBY5	7.29	-	6.83	-	7.03	2.7	-	1.6
2003	GotlanddeepBY15	6.95	-	6.31	-	5.84	7.8	-	13.6
2003	GreatBelt	18.04	-	15.43	14.37	21.44	-	-	-
2003	Landskronaw	14.32	-	12.43	-	16.29	1.6	-	1.6
2003	LandsortDeepBY31	6.40	-	5.95	-	5.62	2.6	-	4.5
2003	nordwijk70	34.95	-	-	34.09	-	-	4.6	-
2003	SEGotlandbasin	7.10	-	6.55	-	6.25	5.0	-	7.8
2003	tersch235	34.70	-	-	34.70	-	-	0.0	-
2004	AA 17	30.11	-	-	30.40	-	-	0.4	-
2004	Anholte	19.48	-	20.31	25.10	27.22	0.6	4.3	6.0
2004	ArkonaBY2	7.67	-	6.84	-	9.87	5.5	-	14.4
2004	BornholmdeepBY5	7.46	-	6.80	-	7.22	3.9	-	1.4
2004	GotlanddeepBY15	7.02	-	6.56	-	6.00	5.6	-	12.6
2004	GreatBelt	17.39	-	15.16	13.94	20.14	2.6	4.1	3.2
2004	Landskronaw	14.33	-	11.64	-	15.77	2.2	-	1.2
2004	LandsortDeepBY31	6.30	-	5.68	-	5.47	-	-	-
2004	nordwijk70	34.95	-	-	34.10	-	-	4.6	-
2004	SEGotlandbasin	7.19	-	6.59	-	6.27	5.5	-	8.6
2004	tersch235	35.00	-	-	34.70	-	-	2.0	-
2005	AA 17	30.04	-	-	30.333	-	-	0.4	-
2005	Anholte	18.68	-	4.55	25.113	0.47	10.9	5.0	14.0
2005	ArkonaBY2	7.82	-	3.53	-	0.69	28.2	-	46.9
2005	BornholmdeepBY5	7.61	-	2.24	-	0.50	32.0	-	42.3
2005	GotlanddeepBY15	7.03	-	2.68	-	0.36	53.4	-	81.9
2005	GreatBelt	16.37	-	5.01	14.087	0.56	13.3	2.7	18.6
2005	Landskronaw	12.20	-	4.51	-	0.66	6.4	-	9.5
2005	LandsortDeepBY31	6.38	-	2.60	-	0.27	22.0	-	35.5
2005	nordwijk70	34.88	-	-	34.073	-	-	4.4	-
2005	SEGotlandbasin	7.34	-	2.85	-	0.43	41.6	-	63.9
2005	tersch235	35.00	-	-	34.7	-	-	2.0	-

Figure 11 (above). Average (2001-2005) surface layer summer salinity (psu) of the observations (black) and models (red=SMHI, green=IMR, blue=SPBIO). See Fig. 1 for location of stations.

Table 9 (left). Average surface layer summer salinity (psu) of the observations (yellow header) and the individual models (blue header) is shown with the corresponding cost function values (golden header) in the right columns. The average for the years 2001-2005 (see figure) and the corresponding standard deviation is shown in the upper part while the values of each year are shown in the lower part of the table.

Calculation of cost functions based on outputs from the NERI- model

The cost functions calculated for 2001- 2003 for the NERI model represents the seasonal oxygen minimum period from August to October for the Kattegat (the Anholt East- station) and the Belt Sea (the Great Belt station). At the Great Belt station the cost functions is calculated for the same depth layer (the deepest layer) as in the other models whereas the cost function calculation for the Anholt East is calculated for 30 m depth as the bathymetry of the NERI model differs somewhat from the depth of that particular station.

Table 10. *NERI Oxygen*

			mean (ox)
Anholt E	cost function	2001	0,787
	cost function	2002	-0,674
	cost function	2003	0,317
Great Belt ⁵	cost function	2001	1,639
	cost function	2002	0,576
	cost function	2003	-0,866

5. Models weighted mean assessment

The model results for the variables used in the assessment of ecological quality indicators are presented here. The weighted average values of the variables computed from the model results using the cost function values are used for the classification of the eutrophication status according to the threshold values valid for each area (Fig.4). Where possible, the results of the assessments are presented. The new revisions in threshold values are compared to the old HELCOM (2006) values in Figs. 12, 14, 16 and 18. One may point out relatively large differences for DIP (Fig.12) in sub-basins 4, 6, 8, 13 and 16 (see map in Fig.4) and for DIN (Fig.14) in sub-basins 6 and 7. For DIN:DIP (Fig.16) there is no difference but for chlorophyll-a (Fig.18) there are relatively large changes in sub-basins 6, 7, 8 11, 12 and 13.

Nutrients (DIP, DIN and DIN:DIP)

The model averaged winter nutrients levels are high in the Baltic Sea all years (Figures 13 and 15). For phosphorous the levels are above the threshold in all areas except for the Bothnian Bay and the Gulf of Finland. In addition there is an area on the Swedish Bothnian Sea coast which is below the threshold during three out of five years. For nitrate the general picture is that the levels are above the threshold over all years, but there are some small areas every year that are still below the threshold. These are mainly seen in the Bothnian Bay. For the N:P ratio (Figure 17) the picture is different. The Bothnian Bay are all years above the threshold, while for the remaining parts of the Baltic Sea the situation varies between the years with large areas below the threshold all years. The situation in the Bothnian Bay is consistent with the picture shown from the nutrients (high N and low P), while the N:P ratio in the rest of the Baltic indicates a situation where the P levels generally is higher than the N values.

In the North Sea the assessment from nutrients indicates a much better situation. For winter P the levels are below the threshold all over except for the southern part of Kattegat and some occasional high values on the Danish west coast and in the German Bight. The situation is almost the same for winter N, but here the problem area is the entire Kattegat and the German Bight, with elevated levels along the Danish west coast and on the Dutch coast some years. The winter N:P ratio is elevated all years along the European continental coast and outside the Thames estuary, while the levels are above the threshold in Kattegat in 2002.

DIP

The average surface layer DIP.

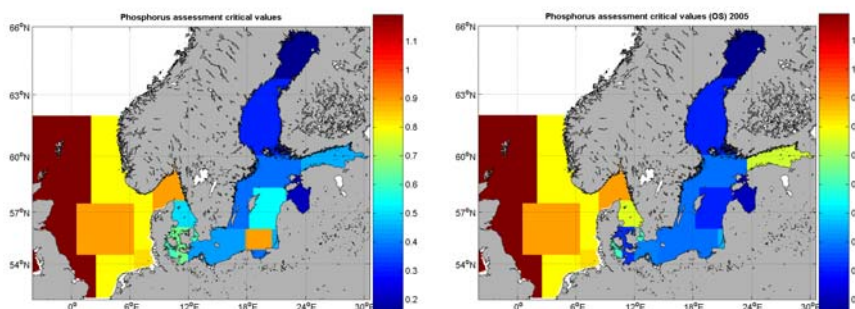


Figure 12. *Critical threshold values used for the ecological quality indicator of DIP ($\mu\text{molP l}^{-1}$). The left panel show the “old” (OSPAR 2005b, HELCOM 2006) thresholds and the right panel show revised numbers used in the present report (pers. Comm. Oleg Savchuk in discussion with Jesper Andersen).*

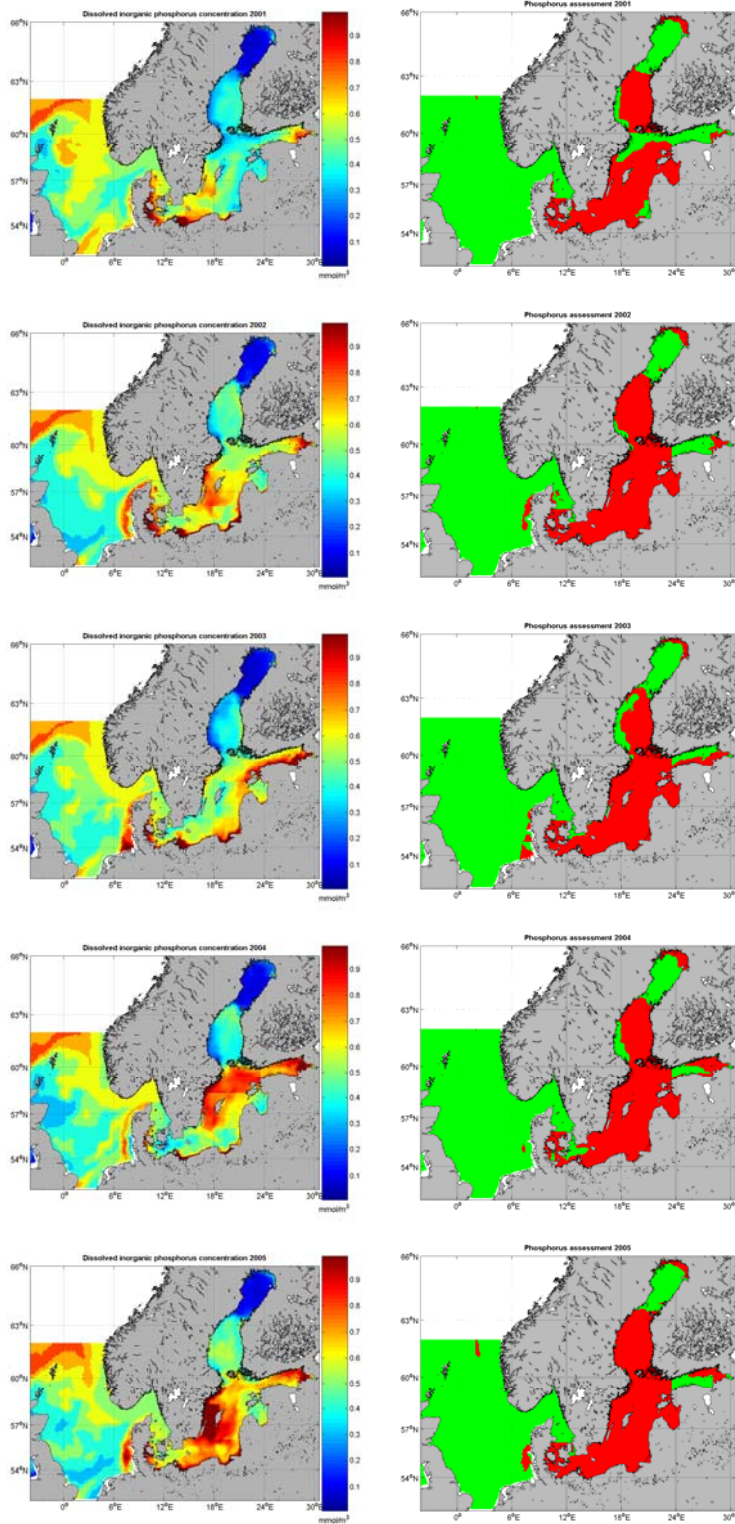


Figure 13. Average surface layer DIP ($\mu\text{molP l}^{-1}$) of the ensemble weighted means in winter (left) and the corresponding assessment (right) and for the years 2001 to 2005 starting from the upper panels. The assessment levels are indicated by colours, green (good), red (bad).

DIN

The average wintertime surface layer DIN.

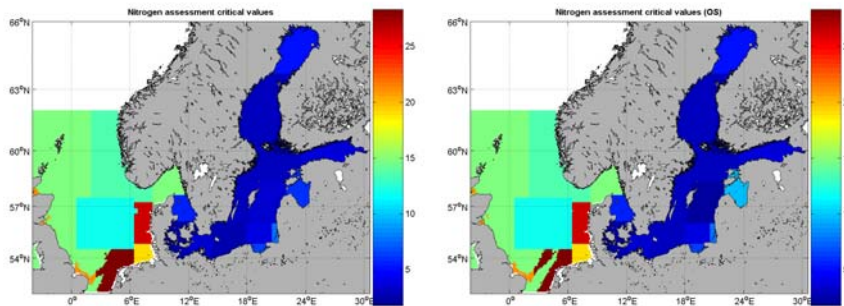


Figure14. Critical threshold values used for the ecological quality indicator of DIN ($\mu\text{molN l}^{-1}$). The left panel show the “old” (OSPAR 2005b, HELCOM 2006) thresholds and the right panels show revised numbers used in the present report (pers. Comm. Oleg Savchuk in discussion with Jesper Andersen).

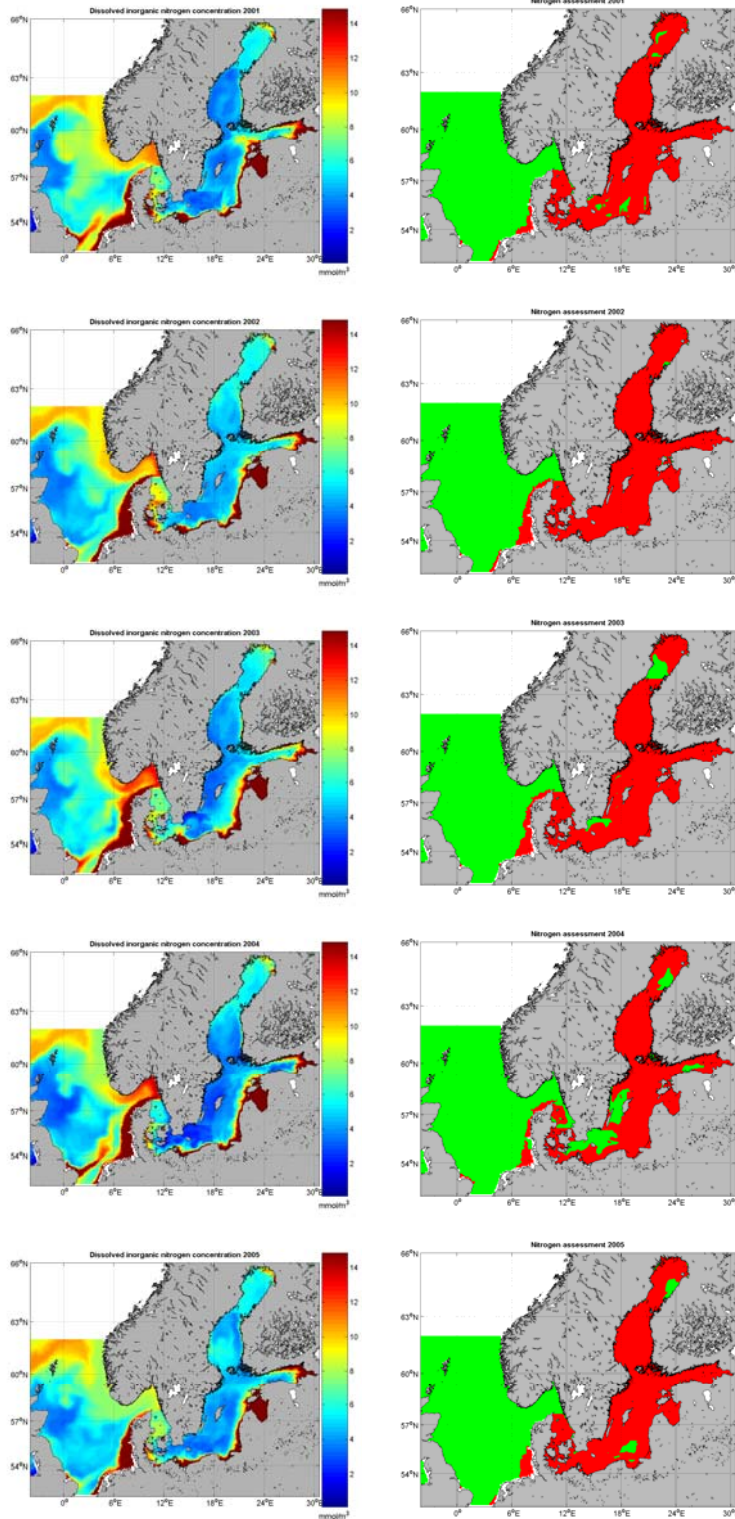


Figure 15. Average surface layer DIN ($\mu\text{molN l}^{-1}$) of the ensemble weighted means in winter (left) and the corresponding assessment (right) and for the years 2001 to 2005 starting from the upper panels. The assessment levels are indicated by colours, green (good), red (bad).

DIN to DIP ratio

The average surface layer DIN/DIP ratio.

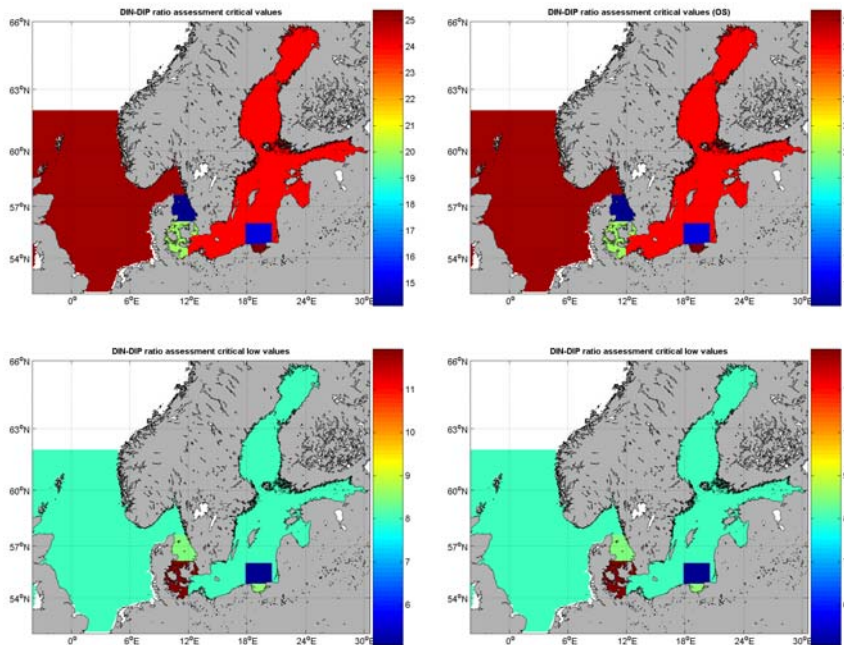


Figure 16. Critical threshold values used for the ecological quality indicator of DIN:DIP ratio. The left panel show the “old” (OSPAR 2005b, HELCOM 2006) thresholds and the right panels show revised numbers used in the present report (pers. Comm. Oleg Savchuk in discussion with Jesper Andersen).

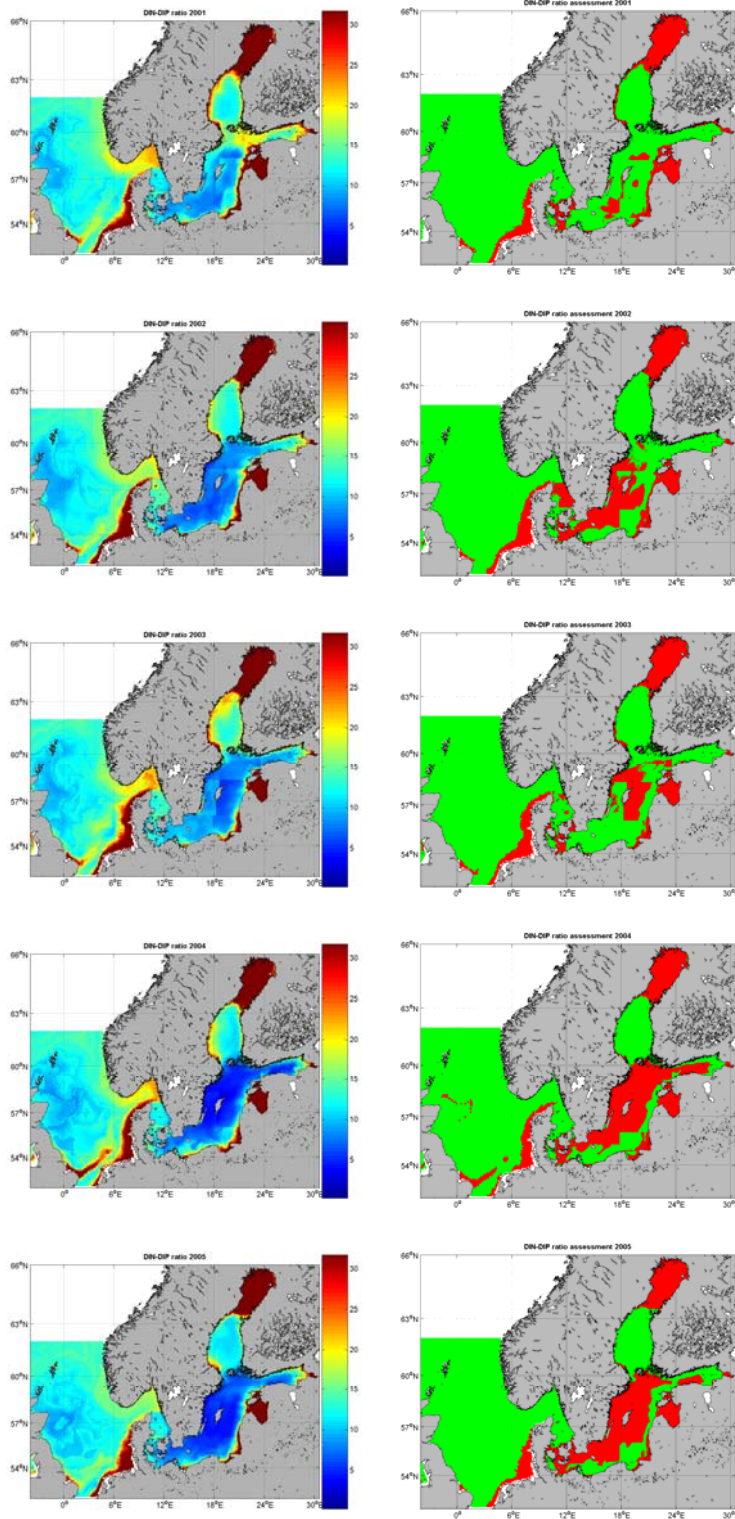


Figure 17. Average surface layer DIN:DIP ratio of the ensemble weighted means in winter (left) and the corresponding assessment (right) and for the years 2001 to 2005 starting from the upper panels. The assessment levels are indicated by colours, green (good), red (bad).

Chlorophyll-a

The average summertime surface layer Chlorophyll-a shows values 0.2-6 $\mu\text{g Chl-a l}^{-1}$ (Fig. 19) with highest values in the coastal zone of the south-eastern North Sea, of the western Kattegat, and in the southern and eastern Baltic Sea. The corresponding assessment of the eutrophication status is good (non-problem area) for the North Sea, Skagerrak, most of the Gdansk Deep, the Lithuanian water, the Gulf of Riga, the Bothnian Sea and the Bothnian Bay during the whole period considered. The assessments in other basins of the study area can be divided into 2 categories: 1) permanently problem area (basins 6, 8, 12, 13, 14) with bad assessment level everywhere in this area during the whole period considered, and 2) partly problem area (basins 2, 3, 5, 11, 15, 16) with good assessment level in a part of this area in some years from the period 2001-2005. The period considered can be divided into years with better status (2001, 2003, 2004) and with worse status (2002, 2005).

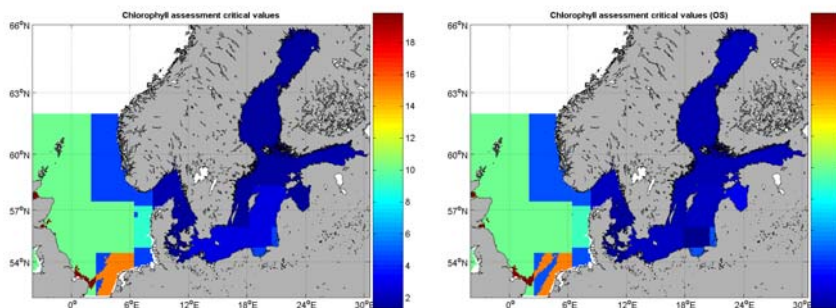


Figure 18. Critical threshold values used for the ecological quality indicator of Chlorophyll-a ($\mu\text{g Chl-a l}^{-1}$). The left panel show the “old” (OSPAR 2005b, HELCOM 2006) thresholds and the right panels show revised numbers used in the present report (pers. Comm. Oleg Savchuk in discussion with Jesper Andersen).

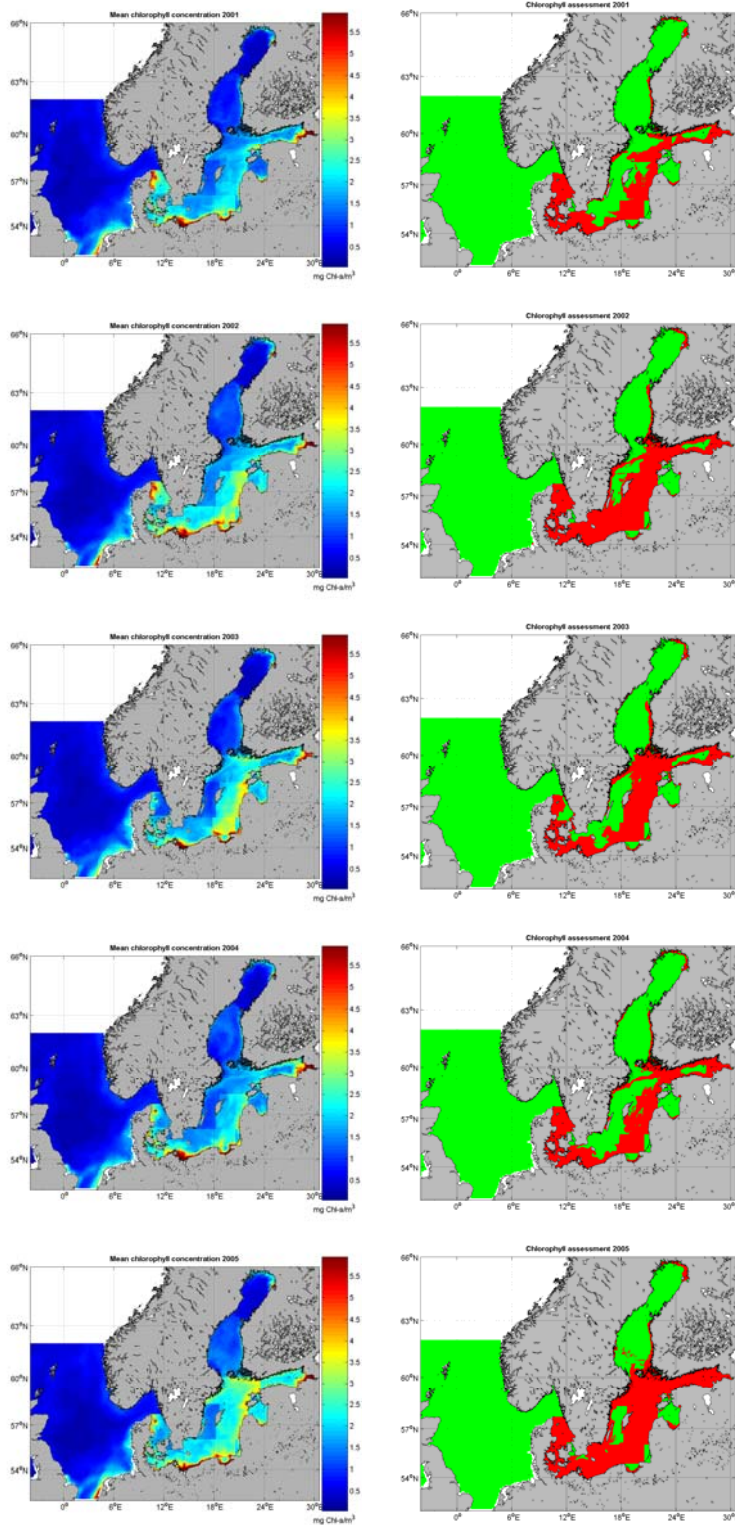


Figure 19. Average surface layer Chlorophyll-a ($\mu\text{g Chl-a l}^{-1}$) of the ensemble weighted means in summer (left) and the corresponding assessment (right) and for the years 2001 to 2005 starting from the upper panels. The assessment levels are indicated by colours, green (good), red (bad).

Oxygen conditions

The distribution of annual bottom layer oxygen minimum in general follows the bathymetry of each of the basins in the Baltic Sea as well as in the Kattegat and Belt Sea. In contrast the distribution of oxygen in the North Sea correlates with high nutrient concentration and chlorophyll concentrations. The strong correlation with water depth is due to the estuarine stratification of Baltic Sea as well as the transition zone in the Danish straits. There are however differences between the Baltic Sea and The Danish straits in the temporal dynamics of the oxygen concentration. The Danish straits is characterised by short term changes in the oxygen condition during the critical period from August to October. The Kattegat and the Belt Sea are persistently stratified and in the transition zone between the North Sea and the Baltic Sea where there is a strong gradient in oxygen declining from North to South (from the border in the Skagerrak to the western Baltic Sea). Short term variation in the oxygen concentrations arises from barotropic in and outflows of the bottom water and during such events the entire bottom water volume may be renewed with oxygen rich Skagerrak water. The water depth is generally shallower in the Kattegat and in the Belt Sea and mixing events may also add to the short term dynamics. In the deep basins of the central Baltic and the Bornholm deep the short term dynamic of oxygen is less pronounced because the water column is deeper, more stable and less influenced by advection. Due to the highly dynamics oxygen conditions in the Kattegat and Belt Sea oxygen minimum concentration could be somewhat misleading when compared to minimum oxygen conditions in the central Baltic Sea where oxygen minima refer to longer lasting hypoxic conditions. With respect to the environmental quality experienced by benthic life, it would be more relevant to describe these conditions as the bottom oxygen concentration average over a period from a few weeks or one month. For example Figure B10 expresses the average bottom oxygen concentration in September which is the annual minimum. The distribution of oxygen in the North Sea reflects to a larger extent the spatial pattern in the productivity, which in turn, leads to locally enhanced respiration.

The assessment of eutrophication status is done according to the annual minimum oxygen concentrations (indirect effects) ranges defined by decreased oxygen levels ($O_2 < 2.8 \text{ ml l}^{-1}$) and toxic levels ($O_2 < 1.4 \text{ ml l}^{-1}$). However, as described above the longevity of the hypoxic events is an equally important descriptor for environmental quality and there may be local differences in how long the benthic community can withstand hypoxic condition. This should be taken into account when further harmonising the description of the eutrophication status of the entire area.

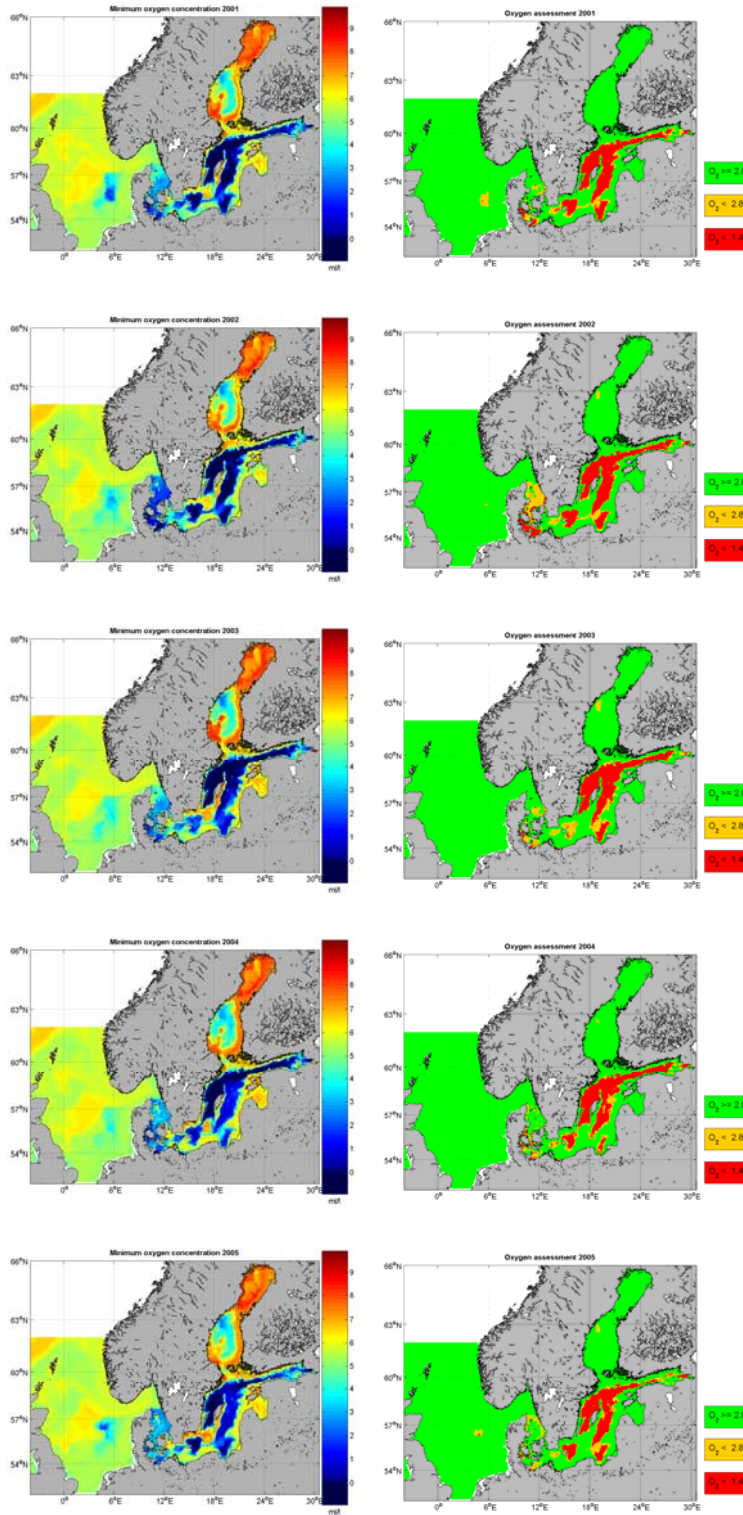


Figure 20. Annual bottom layer dissolved oxygen minimum concentration ($\text{ml } O_2 \text{ l}^{-1}$) of the ensemble weighted means and the corresponding assessment (right) and for the years 2001 to 2005 starting from the upper panels. The assessment levels are indicated by colours, green is good ($O_2 > 2.8 \text{ ml l}^{-1}$), while orange ($O_2 < 2.8 \text{ ml l}^{-1}$) and red ($O_2 < 1.4 \text{ ml l}^{-1}$) are bad.

Eutrophication status

In the present assessment of eutrophication status according to the integration of the categorized assessment parameters indicates that the Kattegat, the Danish Straits, the Gulf of Finland, the Gotland Basin as well as main parts of the Arkona Basin, the Bornholm Basin, and the Baltic proper may be classified as problem areas. The main part of the North Sea and also the Skagerrak are non-problem areas while the main parts of the Gulf of Bothnia, Gulf of Riga and the entire southeastern continental coast of the North Sea may be classified as potential problem areas (Fig. 21). In addition to elevated nutrient levels in the whole Baltic, elevated primary production seems to be the main problem causing the areas to be classified as problem areas, except for the Western Gotland Basin where low oxygen is the reason for this classification. In the North Sea, the classification as potential problem areas are due to high nitrate and N:P ratio, except for the small isolated area west of Denmark where stagnant water some years cause oxygen depletion. The classification in all areas does not vary much between the 5 years studied, thus the level of eutrophication seems to be rather permanent.

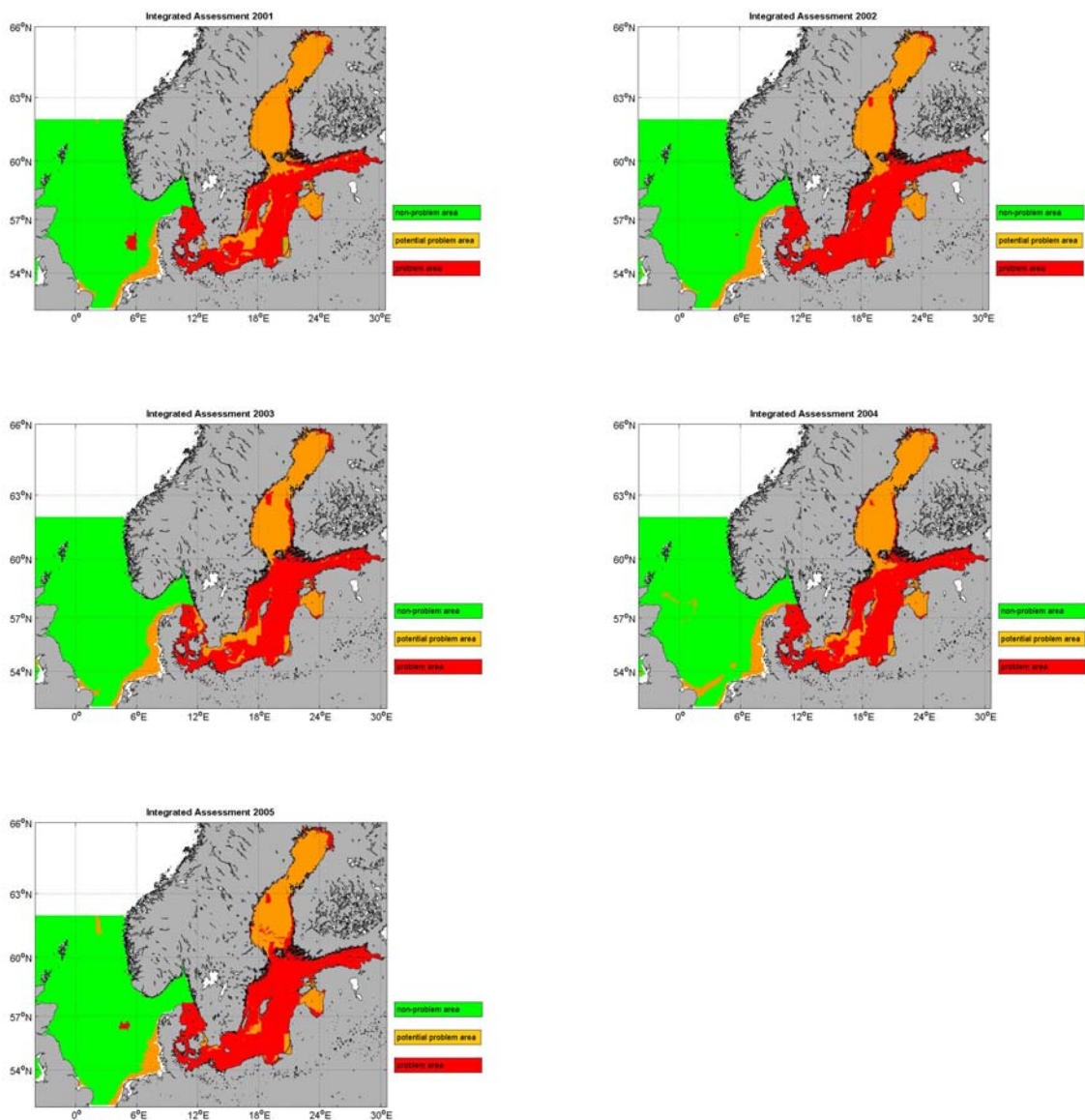


Figure 21. *Assessment results of integrated categorized assessment parameters for the years 2001 to 2005 starting from the upper left panel. The assessment levels are indicated by colours, green (non-problem area), yellow (potential problem area), and red (problem area).*

6. Discussion

The main finding of this study is the proposed way of combining observations and an ensemble of ecological models to make an assessment of the eutrophication status for five different years (2001-2005). Using the OSPAR classifications of areas (OSPAR 2005b), the different parts of the North Sea and the Baltic Sea are categorized as nonproblem, potential problem, or problem areas. Comparing the present North Sea integrated assessment to that performed by the OSPAR contracting parties in 2002, there is good agreement in space but not in level of the final classification (OSPAR 2003). In the present assessments, most of the Dutch, German, Danish, and Swedish coastal and offshore waters in the Kattegat and North Sea are categorized as potential problem areas, while they are problem areas in the OSPAR (2003). The main exception is in the Skagerrak, which in the present assessment is classified as a non-problem area, whereas in the OSPAR assessment, the Danish and Swedish waters are said to be problem areas and the Norwegian coastal area is classified as a potential problem area. However, the Norwegian classification is mainly due to the transboundary load of nutrients, which is not considered in the present assessment, while in the Swedish offshore Skagerrak, region-specific phytoplankton indicator species (not considered in the present assessment) suggest a problem area.

The HELCOM (2006) assessment is valid only for larger sea areas than in the model study. The HELCOM basins are divided into coastal waters, transitional waters, and open sea, while in the model study the classification is valid for each grid point. In the HELCOM report, they use the “one out, all out” principle, which means that if one of the categories shows an elevated value compared to the reference value, the area as a whole is classified as a problem area, otherwise it is a non-problem area. To the contrary, in our model study three classes are used—problem area, potential problem area, and non-problem area. In the HELCOM assessment, they also include more parameters than in our model assessment. In the HELCOM report, the Bothnian Sea is classified as a problem area, which is a result of skewed DIN:Silicate (SiO_4) ratios. This parameter is not used in the model study. The Bothnian Bay is classified as a problem area due to the elevated DIN:DIP ratios, but in the model study this is classified as a potential problem area. In eastern part of the Gotland Basin, the difference in assessment classification is because HELCOM treats the basin as a single area, while the model study uses a higher resolution. This is the advantage of using high-resolution models.

The classification of an area will strongly depend on the threshold values, and the EcoQOs are based on national assessments that can differ quite a lot from region to region. One of the most noticeable differences in the North Sea is the elevated levels of CHL in the neighboring Areas 20 (German Bight) and 21 (Dutch Coast) of 4.5 and 15 mg m^{-3} , respectively. With such a large discrepancy between the assessment levels, and the fact that Area 20 is downstream from 21, it will be difficult to achieve the desired goal of combating eutrophication in the German Bight without a further harmonization of the assessment levels. Related to this, areas may show the effects of eutrophication even when there is no evident increased nutrient enrichment as a result of transboundary nutrient transports. Therefore, there is a need to understand and quantify the contribution of nutrients from other marine areas relative to the

local ones. In order to address this, there is a need for further development of tools (including validated numerical models) to arrive at total nutrient budgets for specific areas (OSPAR 2003). In the CHL assessment method (Category II), modeled phytoplankton biomass is transformed to chlorophyll-a by a constant conversion factor. This could be further discussed since the relationship between biomass and chlorophyll-a may vary temporarily and spatially and therefore have some impact on the definition of a problem area. Also the method of using the annual minimum oxygen concentration and the relevant thresholds that should be used for the oxygen assessment (Category II) could be further discussed. Using the minimum of oxygen concentrations that are averaged over some time period relevant for the benthic life might be more relevant for the assessment in highly dynamic areas like in the Kattegat and Belt Sea as compared to the less dynamic deep waters in the central Baltic Sea.

In the Baltic there has been a recent revision in threshold values compared to HELCOM (2006) (see Table 2 and panels in Figure 12, 14, 16 and 18). These corrections have been made by the agencies, especially SEPA, to include better data. However, there are still some remaining issues to be discussed. The reference values for winter DIN is low (generally below 2.5-3 μM). In a 100 years back scenario simulations (Savchuk and Wulff, 2009) annual means were never lower than 3.0 in Danish Straits and Baltic Proper surface box. Thus winter values could be at least 30-50% higher. The value 1.40 μM for winter DIN in the Eastern Gotland Basin is also very low compared to all neighboring areas.

7. Conclusions

An ensemble of models has been used to assess eutrophication in the North Sea and Baltic Sea, using a method suggested in OSPAR (2005b). The assessment of eutrophication status according to the integration of the categorized assessment parameters indicates that the Kattegat, the Danish Straits, the Gulf of Finland, the Gotland Basin as well as main parts of the Arkona Basin, the Bornholm Basin, and the Baltic proper may be classified as problem areas. The main part of the North Sea and also the Skagerrak are non-problem areas while the main parts of the Gulf of Bothnia, Gulf of Riga and the entire southeastern continental coast of the North Sea may be classified as potential problem areas.

8. Acknowledgement

Thanks to Bo Gustafsson and Oleg Savchuk at BNI for discussions and providing of BED data.

The ABNORMAL project is funded by the Nordic Council of Minister's Air and Sea group. This study is also supported by the ECOSUPPORT project (Advanced modeling tool for scenarios of the Baltic Sea ECOSystem to SUPPORT decision making) which is jointly funded within the BONUS+ program by the European Commission and the Swedish Environmental Protection Agency (SEPA) (ref.no. 08/381).

9. References

- Almroth, E. and M.D. Skogen, 2010. A North Sea and Baltic Sea Model Ensemble Eutrophication Assessment. *AMBIO* 39,59-69.
- Andersen, J. H., P. Axe, H. Backer, J. Carstensen, U. Claussen, V. Fleming-Lehtinen, M. Järvinen, H. Kaartokallio, S. Knuuttila, S. Korpinen, A. Kubiliute, M. Laamanen, E. Lysiak-Pastuszak, G. Martin, C. Murray, F. Möhlenberg, G. Nausch, A. Norkko and A. Villnäs, 2010. Getting the measure of eutrophication in the Baltic Sea: towards improved assessment principles and methods, *Biogeochemistry*, DOI: 10.1007/s10533-010-9508-4.
- Anon., 2000. Directive 200/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy. *Official Journal of the European Communities* L 327/1.
- Bendtsen, J, Gustafsson, K. E., Söderkvist, J., and L. S. Hansen, 2009. Ventilation of bottom water in the North Sea – Baltic Sea transition zone, *Journal of Marine Systems* 75, 138-149 doi:10.1016/j.jmarsys.2008.08.006.
- Eilola, K., H.E.M. Meier, and E. Almroth, 2009. On the dynamics of oxygen, phosphorus and cyanobacteria in the Baltic Sea; a model study. *Journal of Marine Systems* 75, 163–184.
- HELCOM. 2006. Development of tools for assessment of eutrophication in the Baltic Sea. BSEP 104, HELCOM, Helsinki, 64 pp. www.helcom.fi.
- Hjøllo, S.S., Skogen, M.D. and E. Svendsen, 2009. Exploring currents and heat within the North Sea using a numerical model. *J.Mar.Systems*, 78,180-192, doi:10.1016/j.jmarsys.2009.06.001
- Höglund, A., H.E.M. Meier, B. Broman and E. Kriezi, 2009. Validation and correction of regionalised ERA-40 wind fields over the Baltic Sea using the Rossby Centre Atmosphere model RCA3.0, *Rapport Oceanografi No.97*, SMHI, Norrköping, Sweden.
- Kalnay, E. et al. 1996. The NCEP/NCAR 40-year reanalysis project. *Bull. Amer. Meteor. Soc.*, 77, 437-471.
- Kjellström, E., Bärring, L., Hansson, U., Jones, C., Samuelsson, P., Rummukainen, M., Ullerstig, A., Willén, U. and Wyser, K., 2005. A 140-year simulation of European climate with the new version of the Rossby Centre regional atmospheric climate model (RCA3). *SMHI Reports Meteorology and Climatology No. 108*, SMHI, SE-60176 Norrköping, Sweden, 54 pp.
- Killworth, P. D., D. Stainforth, D.J. Webb, and S. M. Paterson, 1991. The development of a free-surface Brian-Cox-Semtner ocean model, *J. of Phys. Oceanography*, 21, 9, 1333-1348.
- Luyten P.J., J.E. Jones, R. Proctor, A. Tabor, P. Tett and K. Wild-Allen, 1999. COHERENS – A coupled hydrodynamical-ecological model for regional and shelf seas: User Documentation. MUMM Report, Management Unit of the Mathematical Models of the north Sea, Belgium, 911 pp.
- Martinsen, E. A., Engedahl, H., Ottersen, G., Ådlandsvik, B., Loeng, H., Balin.o, B., 1992. MetOcean MOdeling Project, Climatological and hydrographical data for hindcast of ocean currents. Tech. Rep. 100, The Norwegian Meteorological Institute, Oslo, Norway, 93pp.
- Meier, H.E.M., Eilola, K., and E. Almroth, 2011a. Climate-related changes in marine ecosystems simulated with a three-dimensional coupled biogeochemical-physical model of the Baltic Sea, *Climate Research*, in press.
- Meier, H.E.M., Höglund, A., Döscher, R., Andersson, H., Löptien, U., and E. Kjellström, 2011b. Quality assessment of atmospheric surface fields over the Baltic Sea from an ensemble of regional climate model simulations with respect to ocean dynamics, *Oceanologia*, in press.
- Myrberg K., Ryabchenko V., Isaev A., Vankevich R., Andrejev O., Bendtsen J., Erichsen A., Funkquist L., Inkala A., Neelov I., Rasmus K., Medina M.R., Raudsepp U., Passenko J.,

- Söderkvist J., Sokolov A., Kuosa H., Anderson T.R., Lehmann A. and Skogen M. D. 2010. Validation of three-dimensional hydrodynamic models of the Gulf of Finland. *Boreal Env. Res.* 15, 453–479
- Neelov I.A., Eremina T.R., Isaev A.V., Ryabchenko V.A., Savchuk O.P., Vankevich R.E., 2003. A simulation of the Gulf of Finland ecosystem with a 3-D model. *Proc. Estonian Academy of Sciences, Biology, Ecology*, 52(3), 346-359.
- NSTF 1993. North Sea quality status report 1993. North Sea Task Force, Oslo and Paris Commissions, London. Olsen & Olsen. 132 pp.
- OSPAR, 2003. OSPAR integrated report 2003 on the eutrophication status of the OSPAR maritime areas based upon the first application of the comprehensive procedure. OSPAR Commission, 59 pp.
- OSPAR, 2005a. Common procedure for the identification of the eutrophication status of the OSPAR maritime area. OSPAR, Reference number: 2005–3, London, 36 pp. www.ospar.org.
- OSPAR, 2005b. Ecological quality objectives for the greater North Sea with regard to nutrients and eutrophication effects. OSPAR Eutrophication Series: 229/2005, London, 33 pp. www.ospar.org.
- Sathyendranath S., Stuart V., Nair A., Oka K., Nakane T., Bouman H., Forget M.-H., Heidi Maass H., Platt T., 2009. Carbon-to-chlorophyll ratio and growth rate of phytoplankton in the sea. *Mar. Ecol. Prog. Ser.* 383, 73–84.
- Savchuk, O.P., 2002. Nutrient biogeochemical cycles in the Gulf of Riga: scaling up field studies with a mathematical model. *J. Mar. Syst.* 32, 253-280.
- Savchuk, O.P., and F. Wulff, 2007. Modeling the Baltic Sea eutrophication in a decision support system. *AMBIO* 36, 141–148.
- Savchuk, O.P. and F. Wulff, 2009. Long-term modeling of large-scale nutrient cycles in the entire Baltic Sea, *Hydrobiologia* (2009) 629,209—224, DOI 10.1007/s10750-009-9775-z online: 23.04. 2009.
- Skogen, M.D. and H. Søliland, 1998. A user's guide to NORWECOM v2.0. Tech. Rept. Fisker og Havet 18/98. Institute of Marine Research, Norway, 42 pp.
- Skogen, M.D., and L.R. Mathisen, 2009. Long term effects of reduced nutrient inputs to the North Sea. *Estuarine, Coastal and Shelf Science* 82, 433–442.
- Skogen, M., Svendsen, E., Berntsen, J., Aksnes, D., Ulvestad, K., 1995. Modelling the primary production in the North Sea using a coupled 3 dimensional Physical Chemical Biological Ocean model. *Estuarine, Coastal and Shelf Science* 41, 545-565.
- Skogen, M., H. Søliland, and E. Svendsen, 2004. Effects of changing nutrient loads to the North Sea. *Journal of Marine Systems* 46, 23–38.
- Stevens, D. P., 1991. The Open Boundary Condition in the United Kingdom Fine-Resolution Antarctic Model. *J. Phys. Oceanogr.*, 21, 1494–1499.
- Søliland, H., Skogen, M., 2000. Validation of a 3-D biophysical model using nutrient observations in the North Sea. *ICES J.Mar.Sci* 57 (4), 816-823.
- Uppala, S.M. and 45 co-authors, 2005. The ERA-40 re-analysis. *Quarterly Journal of the Royal Meteorological Society*, vol. 131, issue 612, pp. 2961-3012.

10. Appendix A; Comprehensive procedure

From: OSPAR Integrated Report 2005 on the Eutrophication Status of the

OSPAR Maritime Area Based Upon the First Application of the Comprehensive Procedure

All areas not being identified as non-problem areas with regard to eutrophication through the Screening Procedure are subject to the Comprehensive Procedure which comprises a checklist of qualitative parameters for a holistic assessment (cf. § 4.2.1. in the Common Procedure OSPAR 97/15/1, Annex 24):

The qualitative assessment parameters are as follows:

- a. the causative factors
 - the degree of nutrient enrichment
 - with regard to inorganic/organic nitrogen
 - with regard to inorganic/organic phosphorus
 - with regard to silicon
 - taking account of:
 - sources (differentiating between anthropogenic and natural sources)
 - increased/upward trends in concentration
 - elevated concentrations
 - increased N/P, N/Si, P/Si ratios
 - fluxes and nutrient cycles (including across boundary fluxes, recycling within environmental compartments and riverine, direct and atmospheric inputs)
- b. the supporting environmental factors, including:
 - light availability (irradiance, turbidity, suspended load)
 - hydrodynamic conditions (stratification, flushing, retention time, upwelling, salinity, gradients, deposition)
 - climatic/weather conditions (wind, temperature)
 - zooplankton grazing (which may be influenced by other anthropogenic activities)
- c. the direct effects of nutrient enrichment
 - i. phytoplankton;
 - increased biomass (e.g. chlorophyll a, organic carbon and cell numbers)
 - increased frequency and duration of blooms
 - increased annual primary production
 - shifts in species composition (e.g. from diatoms to flagellates, some of which are nuisance or toxic species)
 - ii. macrophytes, including macroalgae;
 - increased biomass
 - shifts in species composition (from long-lived species to short-lived species, some of which are nuisance species)
 - reduced depth distribution
 - iii. microphytobenthos;
 - increased biomass and primary production
- d. the indirect effects of nutrient enrichment
 - i. organic carbon/organic matter;
 - increased dissolved/particulate organic carbon concentrations
 - occurrence of foam and/or slime
 - increased concentration of organic carbon in sediments (due to increased sedimentation rate)
 - ii. oxygen;
 - decreased concentrations and saturation percentage
 - increased frequency of low oxygen concentrations

ABNORMAL- A Baltic and North Sea Model eutrophication Assessment in future climate

- increased consumption rate
- occurrence of anoxic zones at the sediment surface (“black spots”)
- iii. zoobenthos and fish;
 - mortalities resulting from low oxygen concentrations
- iv. benthic community structure;
 - changes in abundance
 - changes in species composition
 - changes in biomass
- v. ecosystem structure;
 - structural changes
- e. other possible effects of nutrient enrichment
 - i. algal toxins (still under investigation - the recent increase in toxic events may be linked to eutrophication)

Table A 1. The agreed Harmonised Assessment Criteria and their respective assessment levels of the Comprehensive Procedure

Assessment parameters		
Category I	Degree of Nutrient Enrichment	
	1	Riverine total N and total P inputs and direct discharges (RID) Elevated inputs and/or increased trends (compared with previous years)
	2	Winter DIN- and/or DIP concentrations Elevated level(s) (defined as concentration >50 % above salinity related and/or region specific background concentration)
	3	Increased winter N/P ratio (Redfield N/P = 16) Elevated cf. Redfield (>25)
Category II	Direct Effects of Nutrient Enrichment (during growing season)	
	1	Maximum and mean Chlorophyll <i>a</i> concentration Elevated level (defined as concentration > 50 % above spatial (offshore) / historical background concentrations)
	2	Region/area specific phytoplankton indicator species Elevated levels (and increased duration)
	3	Macrophytes including macroalgae (region specific) Shift from long-lived to short-lived nuisance species (e.g. <i>Ulva</i>)
Category III	Indirect Effects of Nutrient Enrichment (during growing season)	
	1	Degree of oxygen deficiency Decreased levels (< 2 mg/l: acute toxicity; 2 - 6 mg/l: deficiency)
	2	Changes/kills in Zoobenthos and fish kills Kills (in relation to oxygen deficiency and/or toxic algae) Long term changes in zoobenthos biomass and species composition
	3	Organic Carbon/Organic Matter Elevated levels (in relation to III.1) (relevant in sedimentation areas)
Category IV	Other Possible Effects of Nutrient Enrichment (during growing season)	
	1	Algal toxins (DSP/PSP mussel infection events) Incidence (related to II.2)

Table A 2. Integration of Categorised Assessment Parameters

ABNORMAL- A Baltic and North Sea Model eutrophication Assessment in future climate

	Category I Degree of nutrient enrichment	Category II Direct effects	Category III and IV Indirect effects/ other possible effects	Classification
a	+	+	and/or +	problem area
b	-	+	and/or +	problem area
C	+	-	-	potential problem area
D	-	-	-	non-problem area

(+)= Increased trends, elevated levels, shifts or changes in the respective assessment parameters in Table 1

(-) = Neither increased trends nor elevated levels nor shifts nor changes in the respective assessment parameters in Table 1

Note:Categories I, II and/or III/IV are scored ‘+’ in cases where one or more of its respective assessment parameters is showing an increased trend, elevated level, shift or change.

11. Appendix B; Results of individual models

IMR Figures: 2001-2005

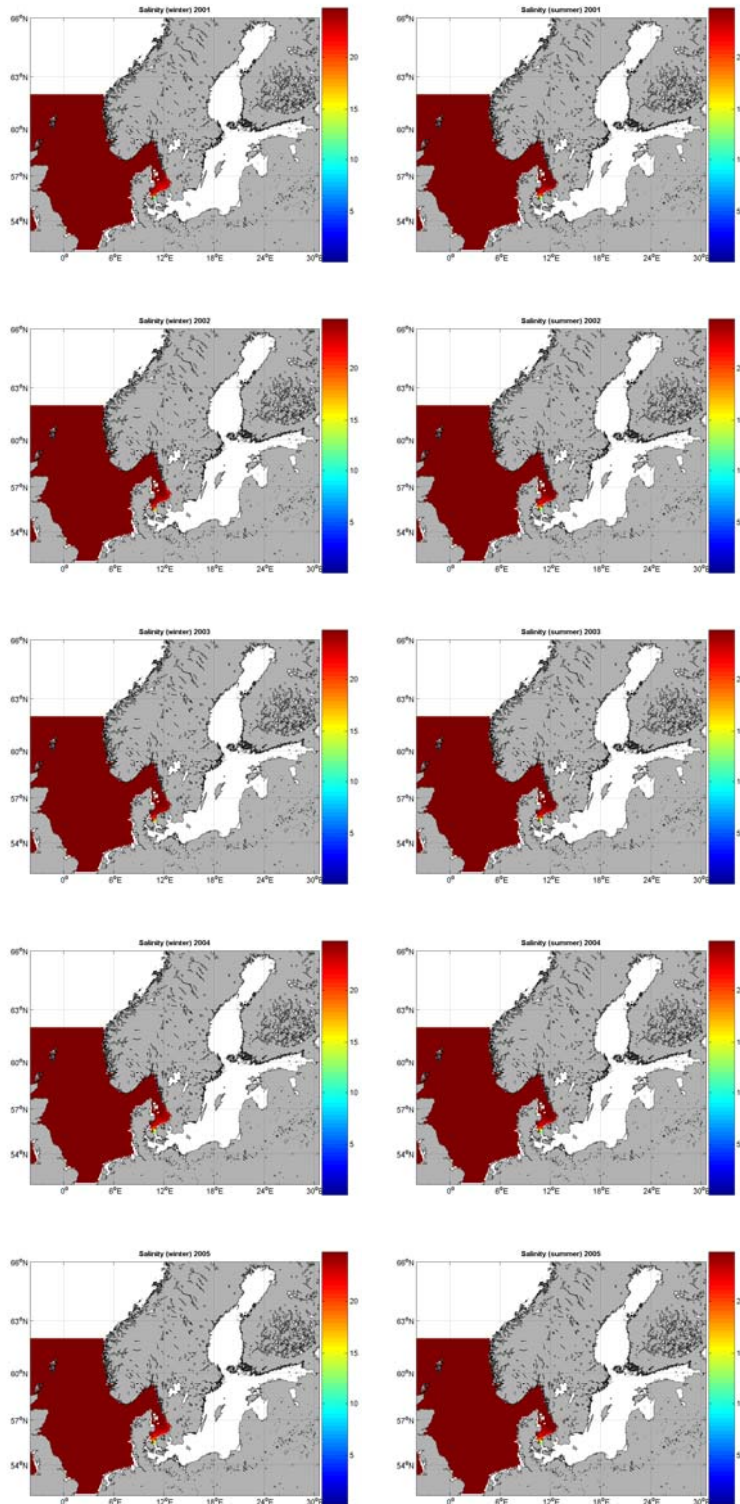


Figure B1. Average surface layer salinity in winter (left) and summer (right) of the IMR model for the years 2001 to 2005 starting from the upper panels.

ABNORMAL- A Baltic and North Sea Model eutrophication Assessment in future climate

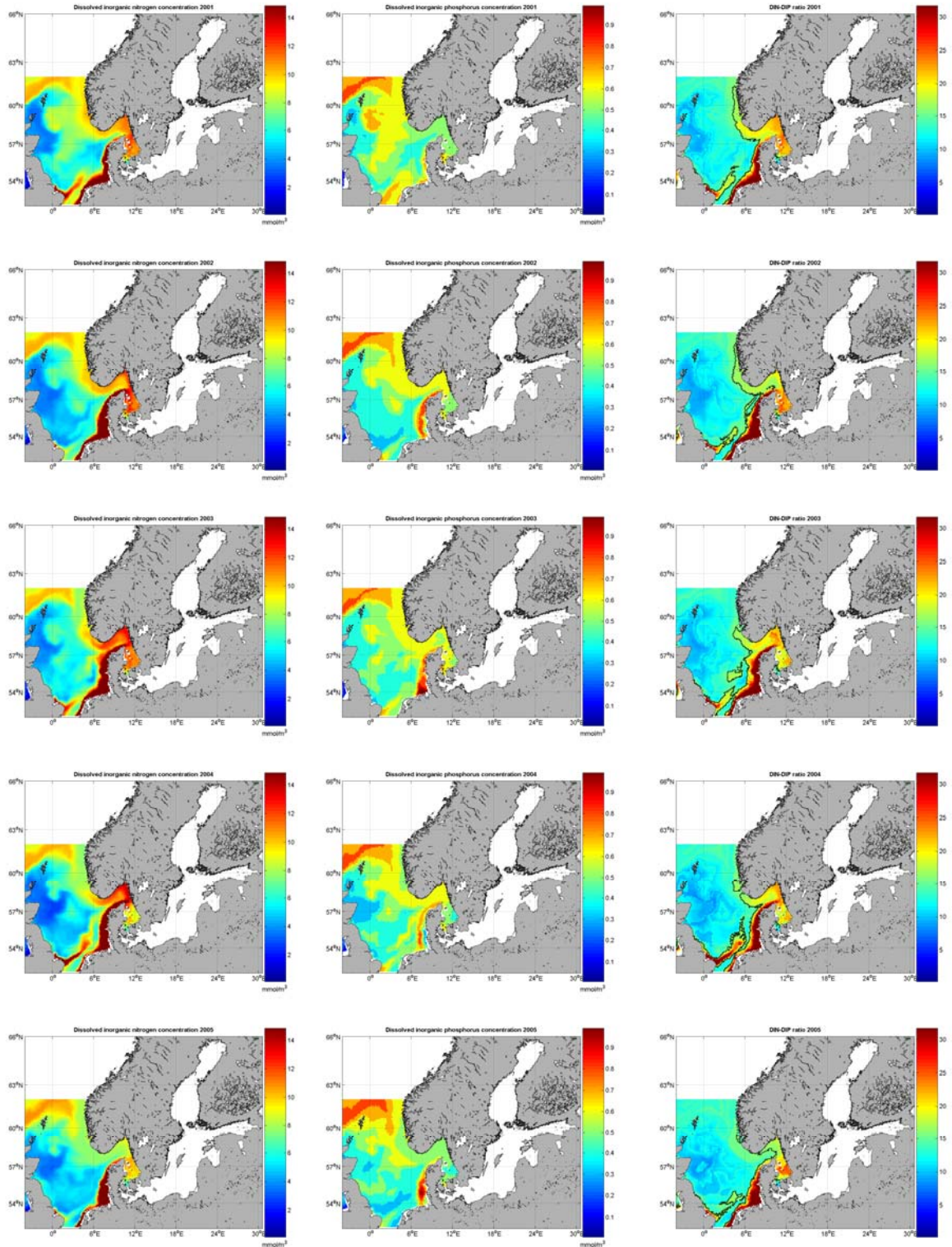


Figure B2. Average surface layer DIN ($\mu\text{mol N l}^{-1}$) in (left) and DIP ($\mu\text{mol P l}^{-1}$) (middle) and the DIN:DIP ratio (right) of the IMR model for the years 2001 to 2005 starting from the upper panels. The contour line of DIN:DIP ratio indicates the isoline of the Redfield molar ratio (16).

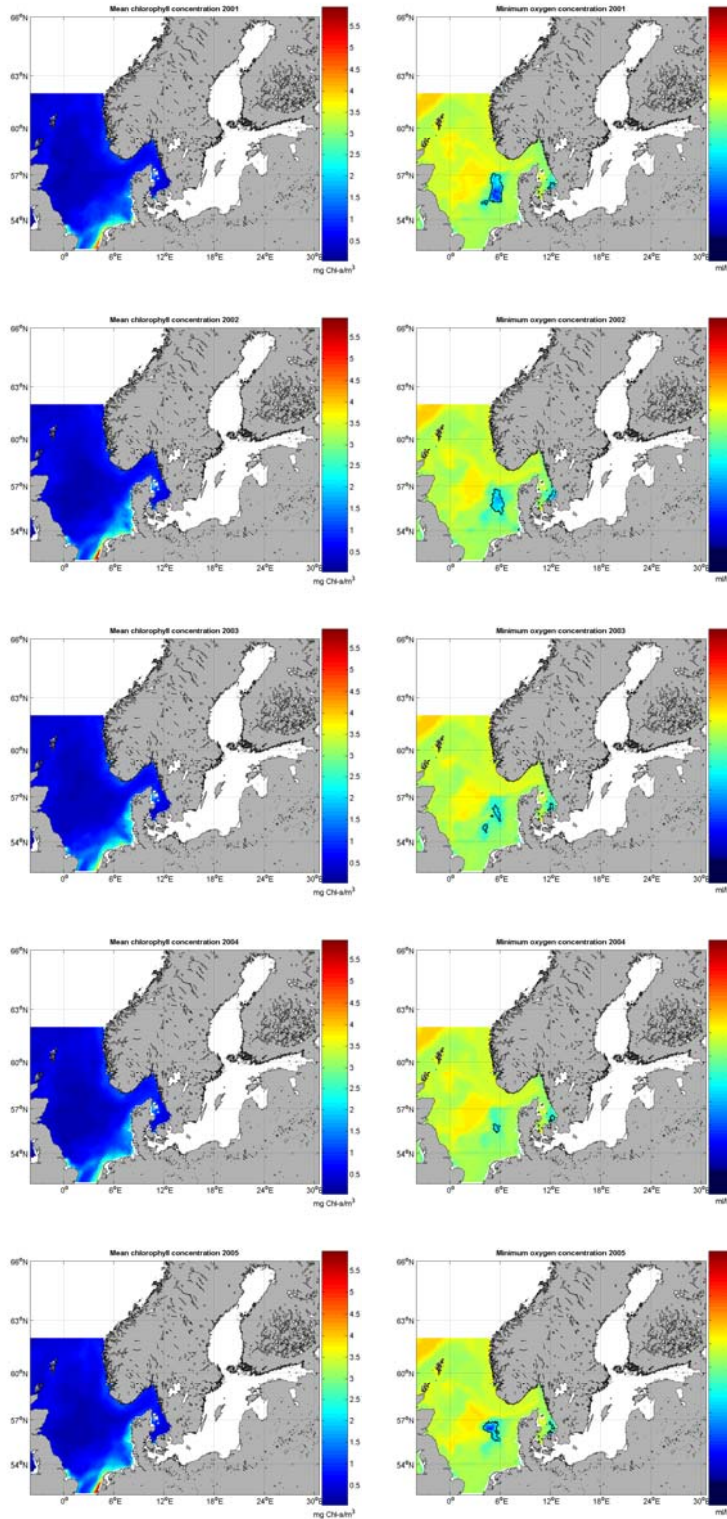


Figure B3. Average surface layer Chlorophyll-a ($\mu\text{g Chl-a l}^{-1}$) (left) and the minimum oxygen concentration (ml l^{-1}) (right) of the IMR model for the years 2001 to 2005 starting from the upper panels. The contour line of minimum oxygen concentration indicates the isoline of 4 (ml l^{-1}).

SMHI Figures: 2001-2005

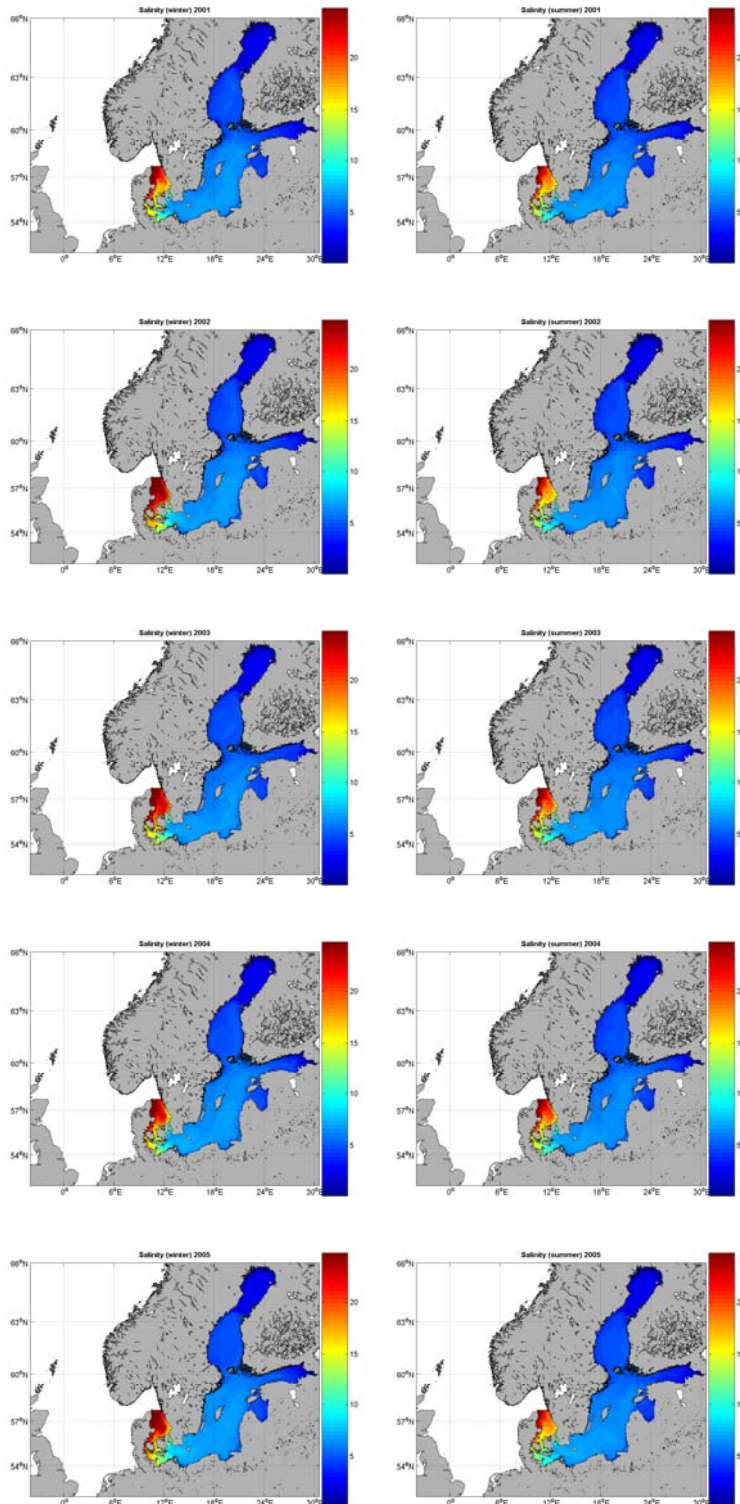


Figure B4. Average surface layer salinity in winter (left) and summer (middle) of the SMHI model for the years 2001 to 2005 starting from the upper panels.

ABNORMAL- A Baltic and North Sea Model eutrophication Assessment in future climate

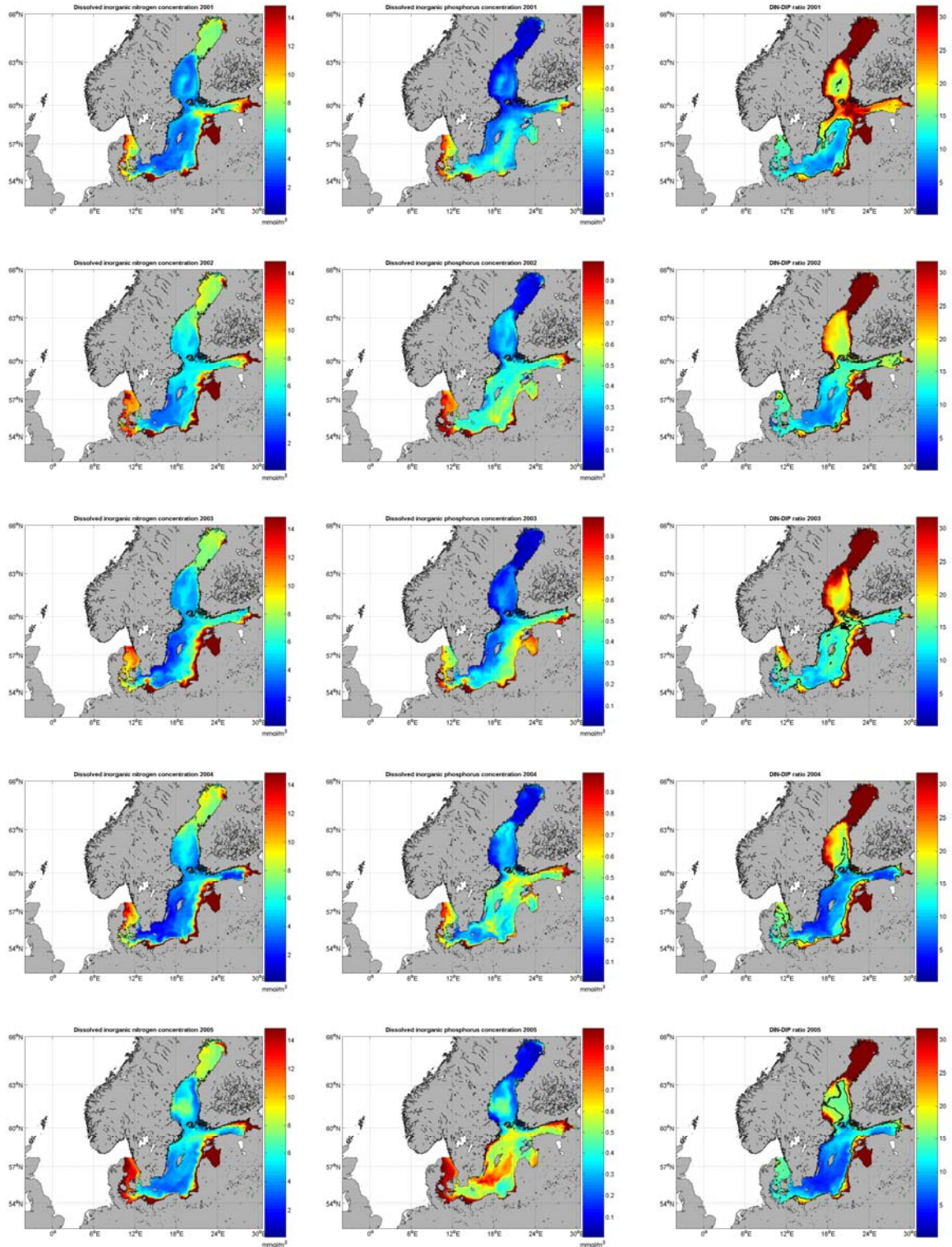


Figure B5. Average surface layer DIN ($\mu\text{molN l}^{-1}$) in (left) and DIP ($\mu\text{molP l}^{-1}$) (middle) and the DIN:DIP ratio (right) of the SMHI model for the years 2001 to 2005 starting from the upper panels. The contour line of DIN:DIP ratio indicates the isoline of the Readfield molar ratio (16).

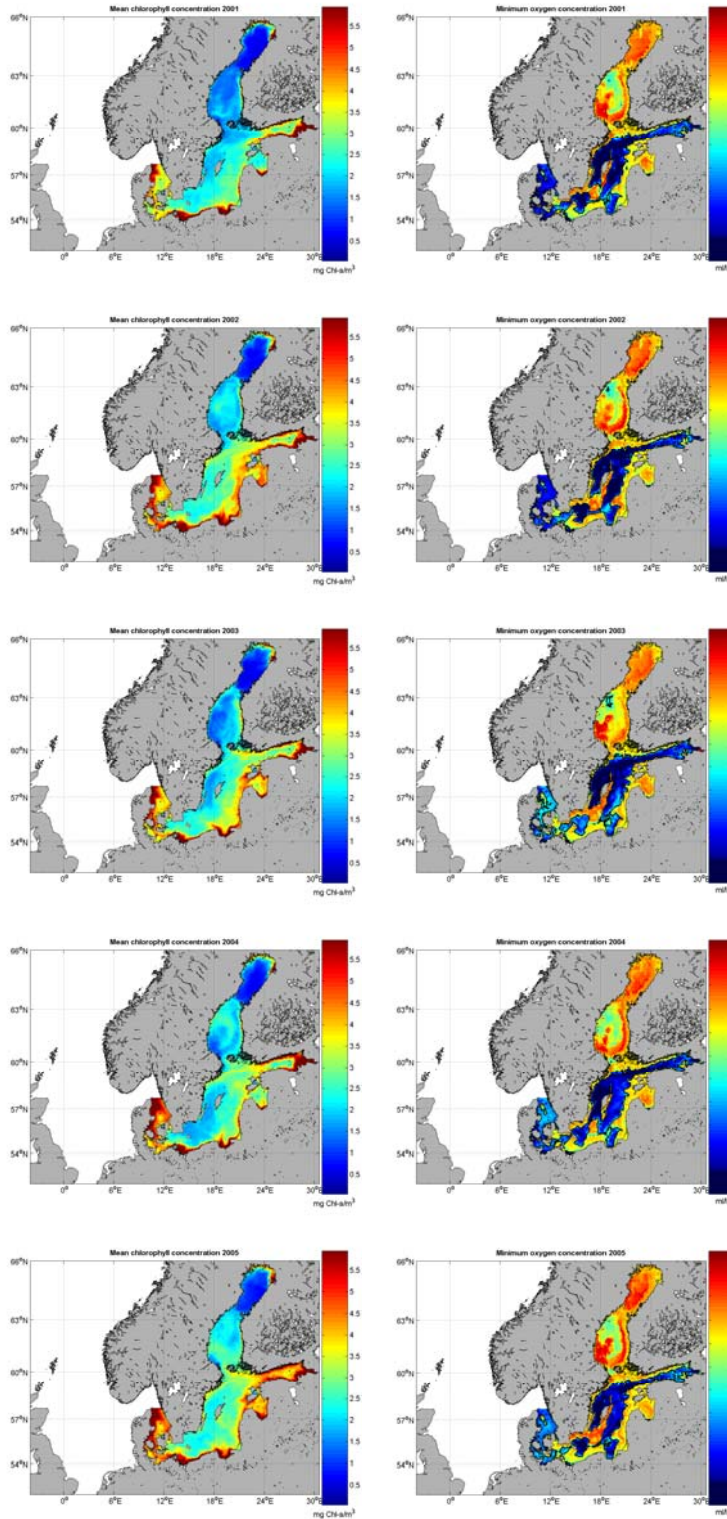


Figure B6. Average surface layer Chlorophyll-a ($\mu\text{g Chl-a l}^{-1}$) (left) and the minimum oxygen concentration (ml l^{-1}) (right) of the SMHI model for the years 2001 to 2005 starting from the upper panels. The contour line of minimum oxygen concentration indicates the isoline of 4 (ml l^{-1}).

SPBIO Figures: 2001-2005

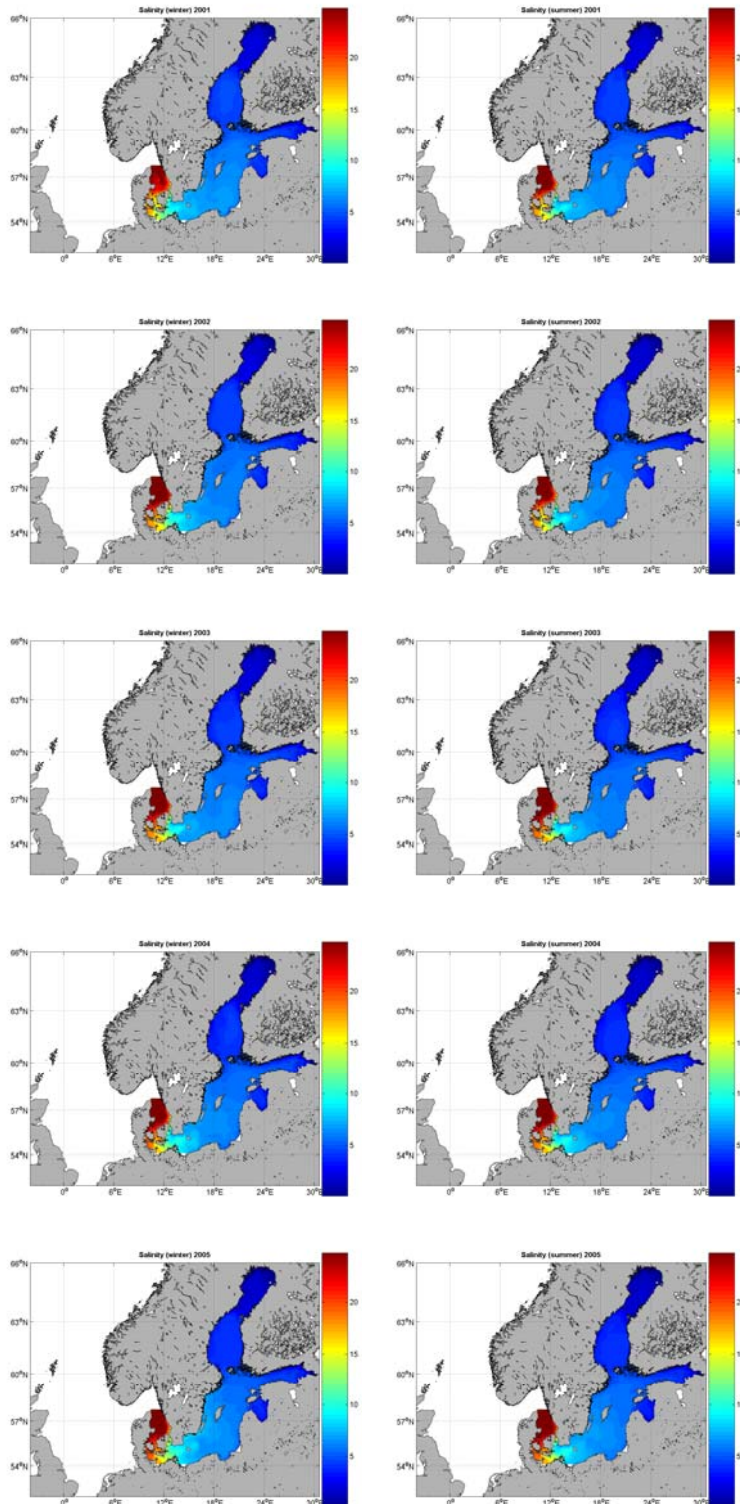


Figure B7. Average surface layer salinity in winter (left) and summer (middle) of the SPBIO model for the years 2001 to 2005 starting from the upper panels.

ABNORMAL- A Baltic and North Sea Model eutrophication Assessment in future climate

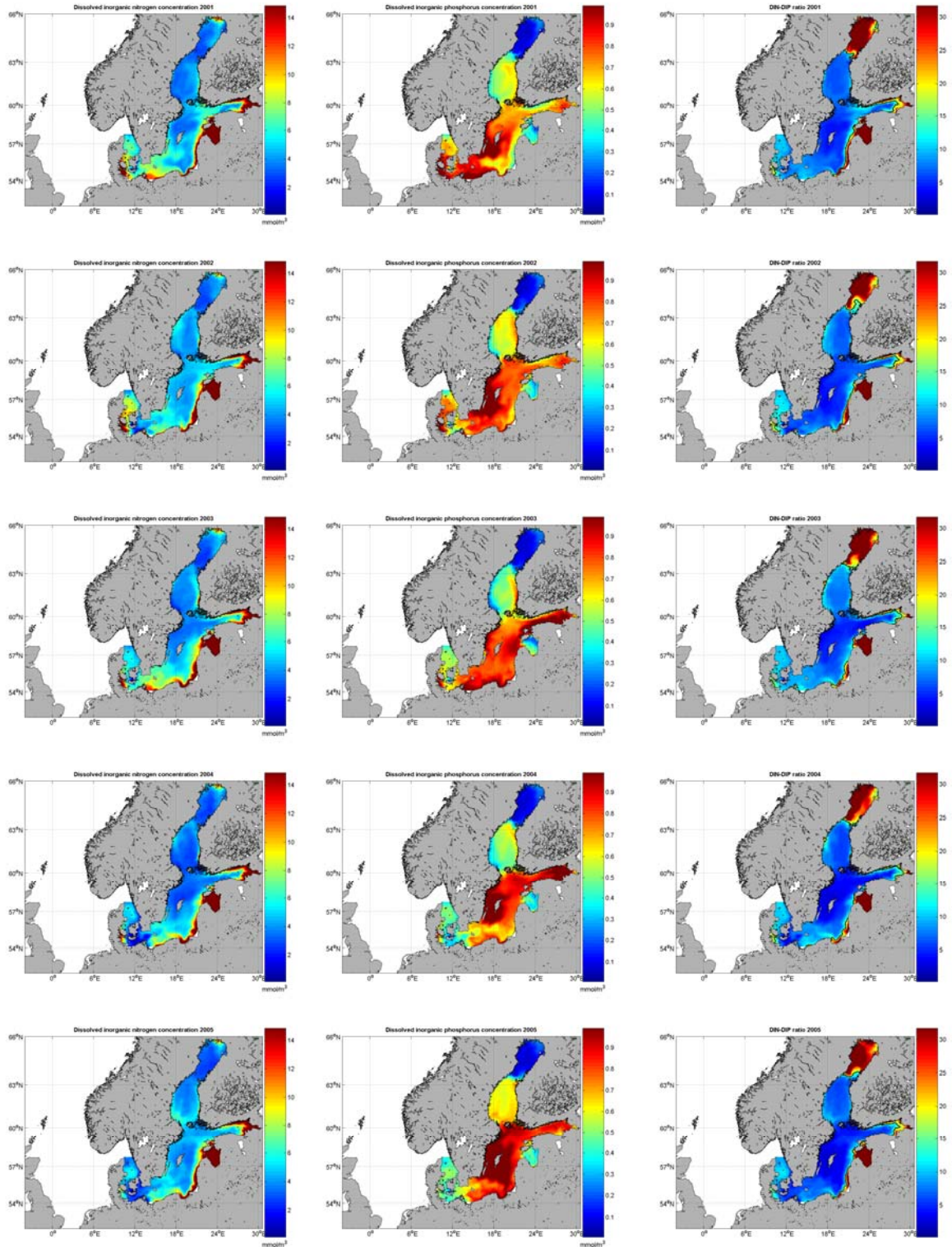


Figure B8. Average surface layer DIN ($\mu\text{molN l}^{-1}$) in (left) and DIP ($\mu\text{molP l}^{-1}$) (middle) and the DIN:DIP ratio (right) of the SPBIO model for the years 2001 to 2005 starting from the upper panels. The contour line of DIN:DIP ratio indicates the isoline of the Readfield molar ratio (16).

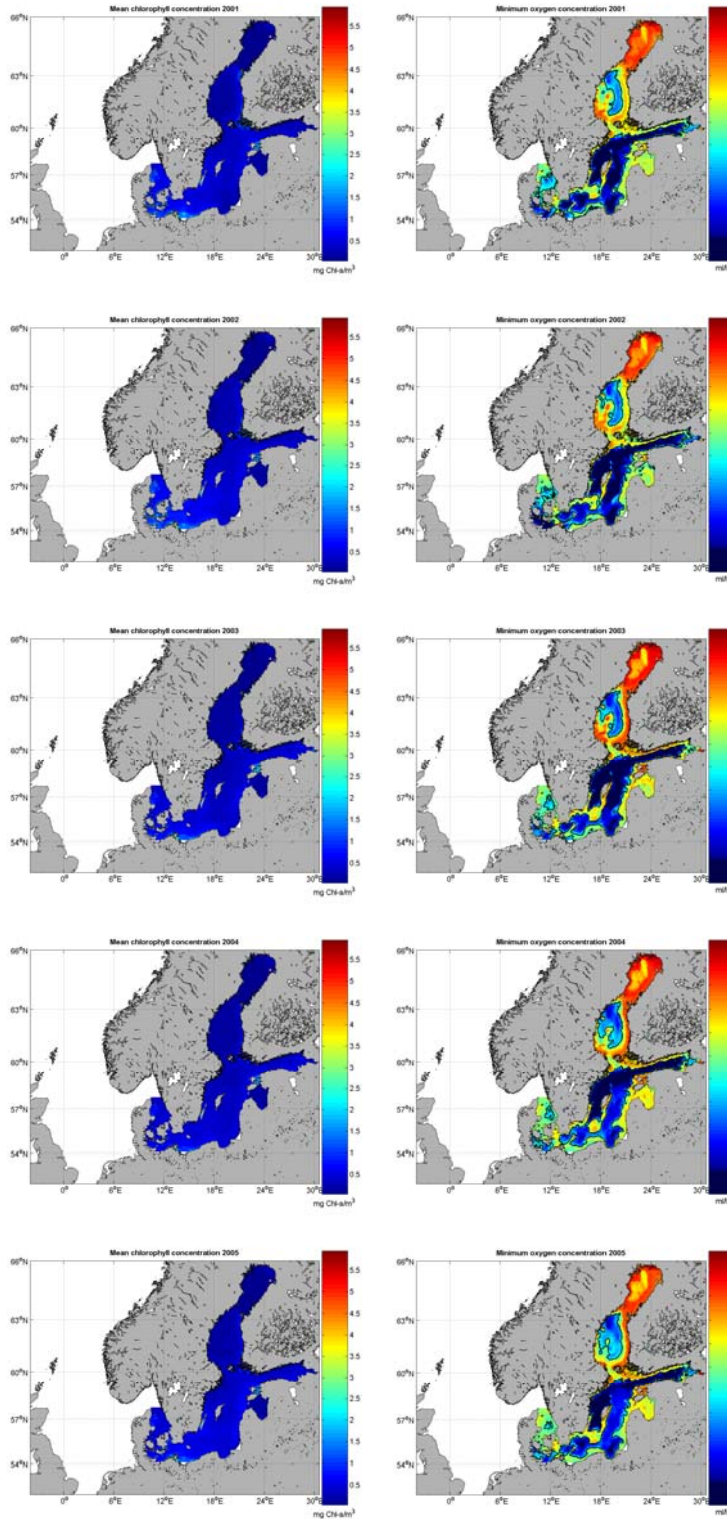


Figure B9. Average surface layer Chlorophyll-a ($\mu\text{g Chl-a l}^{-1}$) (left) and the minimum oxygen concentration (ml l^{-1}) (right) of the SPBIO model for the years 2001 to 2005 starting from the upper panels. The contour line of minimum oxygen concentration indicates the isoline of 4 ml l^{-1} .

NERI Figures: 2001-2003

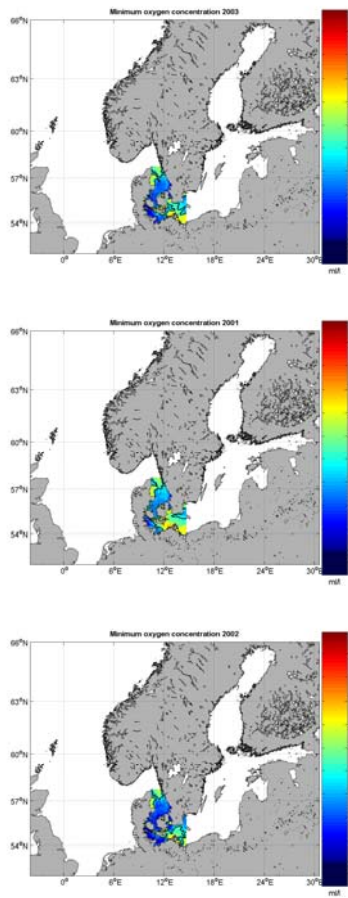


Figure B10. The minimum oxygen concentration (ml l^{-1}) (right) of the NERI model for the years 2001 to 2003 starting from the upper panels. The contour line of minimum oxygen concentration indicates the isoline of 4 (ml l^{-1}).

12. Appendix C; NERI 3D-model oxygen sinks

Parameterization of oxygen sinks in the NERI 3D-model

The oxygen dynamics is described for a heterotrophic layer of bottom water. The oxygen concentration is parameterized by a pelagic and a benthic oxygen drain where the pelagic respiration is described by (S_p), the benthic faunal respiration (S_b) according to:

$$S_p = -f(T)R_1 \frac{O_2}{O_2 + k_1}$$

$$S_b = -f(T)R_2 \frac{O_2}{O_2(sat)} - f(T)R_3 \frac{O_2}{O_2 + k_2}$$

where the pelagic sink is applied to all vertical layers in the model while the benthic sink is only applied to the bottom layer.

I serien OCEANOGRAPHI har tidigare utgivits:

- 1 Lennart Funkquist (1985)
En hydrodynamisk modell för spridnings-
och cirkulationsberäkningar i Östersjön
Slutrapport.
- 2 Barry Broman och Carsten Pettersson.
(1985)
Spridningsundersökningar i yttre fjärden
Piteå.
- 3 Cecilia Ambjörn (1986).
Utbyggnad vid Malmö hamn; effekter för
Lommabuktens vattenutbyte.
- 4 Jan Andersson och Robert Hillgren (1986).
SMHIs undersökningar i Öregrundsgrepen
perioden 84/85.
- 5 Bo Juhlin (1986)
Oceanografiska observationer utmed
svenska kusten med kustbevakningens
fartyg 1985.
- 6 Barry Broman (1986)
Uppföljning av sjövärmepump i Lilla
Värtan.
- 7 Bo Juhlin (1986)
15 års mätningar längs svenska kusten med
kustbevakningen (1970 - 1985).
- 8 Jonny Svensson (1986)
Vågdata från svenska kustvatten 1985.
- 9 Barry Broman (1986)
Oceanografiska stationsnät - Svenskt
Vattenarkiv.
- 10 -
- 11 Cecilia Ambjörn (1987)
Spridning av kylvatten från Öresundsverket
- 12 Bo Juhlin (1987)
Oceanografiska observationer utmed
svenska kusten med kustbevakningens
fartyg 1986.
- 13 Jan Andersson och Robert Hillgren (1987)
SMHIs undersökningar i Öregrundsgrepen
1986.
- 14 Jan-Erik Lundqvist (1987)
Impact of ice on Swedish offshore
lighthouses. Ice drift conditions in the area
at Sydostbotten - ice season 1986/87.
- 15 SMHI/SNV (1987)
Fasta förbindelser över Öresund - utredning
av effekter på vattenmiljön i Östersjön.
- 16 Cecilia Ambjörn och Kjell Wickström
(1987)
Undersökning av vattenmiljön vid
utfyllnaden av Kockums varvsbassäng.
Slutrapport för perioden
18 juni - 21 augusti 1987.
- 17 Erland Bergstrand (1987)
Östergötlands skärgård - Vattenmiljön.
- 18 Stig H. Fonselius (1987)
Kattegatt - havet i väster.
- 19 Erland Bergstrand (1987)
Recipientkontroll vid Breviksnäs fiskodling
1986.
- 20 Kjell Wickström (1987)
Bedömning av kylvattenrecipienten för ett
kolkraftverk vid Oskarshamnsverket.
- 21 Cecilia Ambjörn (1987)
Förstudie av ett nordiskt modellsystem för
kemikaliespridning i vatten.
- 22 Kjell Wickström (1988)
Vågdata från svenska kustvatten 1986.
- 23 Jonny Svensson, SMHI/National Swedish
Environmental Protection Board (SNV)
(1988)
A permanent traffic link across the
Öresund channel - A study of the hydro-
environmental effects in the Baltic Sea.
- 24 Jan Andersson och Robert Hillgren (1988)
SMHIs undersökningar utanför Forsmark
1987.
- 25 Carsten Peterson och Per-Olof Skoglund
(1988)
Kylvattnet från Ringhals 1974-86.

- 26 Bo Juhlin (1988)
Oceanografiska observationer runt svenska kusten med kustbevakningens fartyg 1987.
- 27 Bo Juhlin och Stefan Tobiasson (1988)
Recipientkontroll vid Breviksnäs fiskodling 1987.
- 28 Cecilia Ambjörn (1989)
Spridning och sedimentation av tippat lermaterial utanför Helsingborgs hamnområde.
- 29 Robert Hillgren (1989)
SMHIs undersökningar utanför Forsmark 1988.
- 30 Bo Juhlin (1989)
Oceanografiska observationer runt svenska kusten med kustbevakningens fartyg 1988.
- 31 Erland Bergstrand och Stefan Tobiasson (1989)
Samordnade kustvattenkontrollen i Östergötland 1988.
- 32 Cecilia Ambjörn (1989)
Oceanografiska förhållanden i Brofjorden i samband med kylvattenutsläpp i Trommekilen.
- 33a Cecilia Ambjörn (1990)
Oceanografiska förhållanden utanför Vendelsöfjorden i samband med kylvattenutsläpp.
- 33b Eleonor Marmefelt och Jonny Svensson (1990)
Numerical circulation models for the Skagerrak - Kattegat. Preparatory study.
- 34 Kjell Wickström (1990)
Oskarshamnsverket - kylvattenutsläpp i havet - slutrapport.
- 35 Bo Juhlin (1990)
Oceanografiska observationer runt svenska kusten med kustbevakningens fartyg 1989.
- 36 Bertil Håkansson och Mats Moberg (1990)
Glommaälvens spridningsområde i nord-östra Skagerrak
- 37 Robert Hillgren (1990)
SMHIs undersökningar utanför Forsmark 1989.
- 38 Stig Fonselius (1990)
Skagerrak - the gateway to the North Sea.
- 39 Stig Fonselius (1990)
Skagerrak - porten mot Nordsjön.
- 40 Cecilia Ambjörn och Kjell Wickström (1990)
Spridningsundersökningar i norra Kalmarsund för Mönsterås bruk.
- 41 Cecilia Ambjörn (1990)
Strömningsteknisk utredning avseende utbyggnad av gipsdeponi i Landskrona.
- 42 Cecilia Ambjörn, Torbjörn Grafström och Jan Andersson (1990)
Spridningsberäkningar - Klints Bank.
- 43 Kjell Wickström och Robert Hillgren (1990)
Spridningsberäkningar för EKA-NOBELS fabrik i Stockviksverken.
- 44 Jan Andersson (1990)
Brofjordens kraftstation - Kylvattenspridning i Hanneviken.
- 45 Gustaf Westring och Kjell Wickström (1990)
Spridningsberäkningar för Höganäs kommun.
- 46 Robert Hillgren och Jan Andersson (1991)
SMHIs undersökningar utanför Forsmark 1990.
- 47 Gustaf Westring (1991)
Brofjordens kraftstation - Kompletterande simulering och analys av kylvattenspridning i Trommekilen.
- 48 Gustaf Westring (1991)
Vågmätningar utanför Kristianopel - Slutrapport.
- 49 Bo Juhlin (1991)
Oceanografiska observationer runt svenska kusten med kustbevakningens fartyg 1990.
- 50A Robert Hillgren och Jan Andersson (1992)
SMHIs undersökningar utanför Forsmark 1991.

- 50B Thomas Thompson, Lars Ulander, Bertil Håkansson, Bertil Brusmark, Anders Carlström, Anders Gustavsson, Eva Cronström och Olov Fäst (1992). BEERS -92. Final edition.
- 51 Bo Juhlin (1992)
Oceanografiska observationer runt svenska kusten med kustbevakningens fartyg 1991.
- 52 Jonny Svensson och Sture Lindahl (1992)
Numerical circulation model for the Skagerrak - Kattegat.
- 53 Cecilia Ambjörn (1992)
Isproppsförebyggande muddring och dess inverkan på strömmarna i Torneälven.
- 54 Bo Juhlin (1992)
20 års mätningar längs svenska kusten med kustbevakningens fartyg (1970 - 1990).
- 55 Jan Andersson, Robert Hillgren och Gustaf Westring (1992)
Förstudie av strömmar, tidvatten och vattenstånd mellan Cebu och Leyte, Filippinerna.
- 56 Gustaf Westring, Jan Andersson, Henrik Lindh och Robert Axelsson (1993)
Forsmark - en temperaturstudie. Slutrapport.
- 57 Robert Hillgren och Jan Andersson (1993)
SMHIs undersökningar utanför Forsmark 1992.
- 58 Bo Juhlin (1993)
Oceanografiska observationer runt svenska kusten med kustbevakningens fartyg 1992.
- 59 Gustaf Westring (1993)
Isförhållandena i svenska farvatten under normalperioden 1961-90.
- 60 Torbjörn Lindkvist (1994)
Havsområdesregister 1993.
- 61 Jan Andersson och Robert Hillgren (1994)
SMHIs undersökningar utanför Forsmark 1993.
- 62 Bo Juhlin (1994)
Oceanografiska observationer runt svenska kusten med kustbevakningens fartyg 1993.
- 63 Gustaf Westring (1995)
Isförhållanden utmed Sveriges kust - isstatistik från svenska farleder och farvatten under normalperioderna 1931-60 och 1961-90.
- 64 Jan Andersson och Robert Hillgren (1995)
SMHIs undersökningar utanför Forsmark 1994.
- 65 Bo Juhlin (1995)
Oceanografiska observationer runt svenska kusten med kustbevakningens fartyg 1994.
- 66 Jan Andersson och Robert Hillgren (1996)
SMHIs undersökningar utanför Forsmark 1995.
- 67 Lennart Funkquist och Patrik Ljungemyr (1997)
Validation of HIROMB during 1995-96.
- 68 Maja Brandt, Lars Edler och Lars Andersson (1998)
Översvämningar längs Oder och Wisla sommaren 1997 samt effekterna i Östersjön.
- 69 Jörgen Sahlberg SMHI och Håkan Olsson, Länsstyrelsen, Östergötland (2000).
Kustzonsmodell för norra Östergötlands skärgård.
- 70 Barry Broman (2001)
En vågatlas för svenska farvatten.
Ej publicerad
- 71 ***Vakant – kommer ej att utnyttjas!***
- 72 Fourth Workshop on Baltic Sea Ice Climate Norrköping, Sweden 22-24 May, 2002
Conference Proceedings
Editors: Anders Omstedt and Lars Axell
- 73 Torbjörn Lindkvist, Daniel Björkert, Jenny Andersson, Anders Gyllander (2003)
Djupdata för havsområden 2003
- 74 Håkan Olsson, SMHI (2003)
Erik Årnefelt, Länsstyrelsen Östergötland
Kustzonssystemet i regional miljöanalys
- 75 Jonny Svensson och Eleonor Marmefelt (2003)
Utvärdering av kustzonsmodellen för norra Östergötlands och norra Bohusläns skärgårdar

- 76 Eleonor Marmefelt, Håkan Olsson, Helma Lindow och Jonny Svensson, Thalassos Computations (2004)
Integrerat kustzonssystem för Bohusläns skärgård
- 77 Philip Axe, Martin Hansson och Bertil Håkansson (2004)
The national monitoring programme in the Kattegat and Skagerrak
- 78 Lars Andersson, Nils Kajrup och Björn Sjöberg (2004)
Dimensionering av det nationella marina pelagialprogrammet
- 79 Jörgen Sahlberg (2005)
Randdata från öppet hav till kustzonsmodellerna (Exemplet södra Östergötland)
- 80 Eleonor Marmefelt, Håkan Olsson (2005)
Integrerat Kustzonssystem för Hallandskusten
- 81 Tobias Strömberg (2005)
Implementation of a Flux Corrected Transport scheme in the Rossby Centre Ocean model
- 82 Martin Hansson (2006)
Cyanobakterieblomningar i Östersjön, resultat från satellitövervakning 1997-2005
- 83 Kari Eilola, Jörgen Sahlberg (2006)
Model assessment of the predicted environmental consequences for OSPAR problem areas following nutrient reductions
- 84 Torbjörn Lindkvist, Helma Lindow (2006)
Fyrskottsdata. Resultat och bearbetningsmetoder med exempel från Svenska Björn 1883 – 1892
- 85 Pia Andersson (2007)
Ballast Water Exchange areas – Prospect of designating BWE areas in the Baltic Proper
- 86 Elin Almroth, Kari Eilola, M. Skogen, H. Søiland and Ian Sehested Hansen (2007)
The year 2005. An environmental status report of the Skagerrak, Kattegat and North Sea
- 87 Eleonor Marmefelt, Jörgen Sahlberg och Marie Bergstrand (2007)
HOME Vatten i södra Östersjöns vattendistrikt. Integrerat modellsystem för vattenkvalitetsberäkningar
- 88 Pia Andersson (2007)
Ballast Water Exchange areas – Prospect of designating BWE areas in the Skagerrak and the Norwegian Trench
- 89 Anna Edman, Jörgen Sahlberg, Niclas Hjerdt, Eleonor Marmefelt och Karen Lundholm (2007)
HOME Vatten i Bottenvikens vattendistrikt. Integrerat modellsystem för vattenkvalitetsberäkningar
- 90 Niclas Hjerdt, Jörgen Sahlberg, Eleonor Marmefelt och Karen Lundholm (2007)
HOME Vatten i Bottenhavets vattendistrikt. Integrerat modellsystem för vattenkvalitetsberäkningar
- 91 Elin Almroth, Morten Skogen, Ian Sehested Hansen, Tapani Stipa, Susa Niiranen (2008)
The year 2006
An Eutrophication Status Report of the North Sea, Skagerrak, Kattegat and the Baltic Sea
A demonstration Project
- 92 Pia Andersson, editor and co-authors Bertil Håkansson*, Johan Håkansson*, Elisabeth Sahlsten*, Jonathan Havenhand**, Mike Thorndyke**, Sam Dupont** * Swedish Meteorological and Hydrological Institute ** Sven Lovén, Centre of Marine Sciences (2008)
Marine Acidification – On effects and monitoring of marine acidification in the seas surrounding Sweden
- 93 Jörgen Sahlberg, Eleonor Marmefelt, Maja Brandt, Niclas Hjerdt och Karen Lundholm (2008)
HOME Vatten i norra Östersjöns vattendistrikt. Integrerat modellsystem för vattenkvalitetsberäkningar.
- 94 David Lindstedt (2008)
Effekter av djupvattenomblandning i Östersjön – en modellstudie
- 95 Ingemar Cato*, Bertil Håkansson**, Ola Hallberg*, Bernt Kjellin*, Pia Andersson**, Cecilia Erlandsson*, Johan Nyberg*, Philip Axe** (2008)
*Geological Survey of Sweden (SGU)
**The Swedish Meteorological and Hydrological Institute (SMHI)
A new approach to state the areas of oxygen deficits in the Baltic Sea

- 96 Kari Eilola, H.E. Markus Meier, Elin Almroth, Anders Höglund (2008)
Transports and budgets of oxygen and phosphorus in the Baltic Sea
- 97 Anders Höglund, H.E. Markus Meier, Barry Broman och Ekaterini Kriezi (2009)
Validation and correction of regionalised ERA-40 wind fields over the Baltic Sea using the Rossby Centre Atmosphere model RCA3.0
- 98 Jörgen Sahlberg (2009)
The Coastal Zone Model
- 99 Kari Eilola (2009)
On the dynamics of organic nutrients, nitrogen and phosphorus in the Baltic Sea
- 100 Kristin I. M. Andreasson (SMHI), Johan Wikner (UMSC), Berndt Abrahamsson (SMF), Chris Melrose (NOAA), Svante Nyberg (SMF) (2009)
Primary production measurements – an intercalibration during a cruise in the Kattegat and the Baltic Sea
- 101 K. Eilola, B. G. Gustafson, R. Hordoir, A. Höglund, I. Kuznetsov, H.E.M. Meier T. Neumann, O. P. Savchuk (2010)
Quality assessment of state-of-the-art coupled physical-biogeochemical models in hind cast simulations 1970-2005
- 102 Pia Andersson (2010)
Drivers of Marine Acidification in the Seas Surrounding Sweden
- 103 Jörgen Sahlberg, Hanna Gustavsson (2010)
HOME Vatten i Mälaren
- 104 K.V Karmanov., B.V Chubarenko, D. Domnin, A. Hansson (2010)
Attitude to climate changes in everyday management practice at the level of Kaliningrad region municipalities
- 105 Helén C. Andersson., Patrik Wallman, Chantal Donnelly (2010)
Visualization of hydrological, physical and biogeochemical modelling of the Baltic Sea using a GeoDomeTM
- 106 Maria Bergelo (2011)
Havsvattenståndets påverkan längs Sveriges kust – enkätsvar från kommuner, räddningstjänst, länsstyrelser och hamnar
- 107 H.E. Markus Meier, Kari Eilola (2011)
Future projections of ecological patterns in the Baltic Sea
- 108 Meier, H.E.M., Andersson, H., Dieterich, C., Eilola, K., Gustafsson, B., Höglund, A., Hordoir, R., Schimanke, S (2011)
Transient scenario simulations for the Baltic Sea Region during the 21st century
- 109 Ulrike Löptien, H.E. Markus Meier (2011)
Simulated distribution of colored dissolved organic matter in the Baltic Sea



Sveriges meteorologiska och hydrologiska institut
601 76 Norrköping
Tel 011-495 80 00 Fax 011-495 80 01

ISSN 0283-7714