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The year 2005
An environmental status report of the Skagerrak, Kattegat and the North Sea

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Institute of Marine Research

Cover ilustration:
Satellite image: Coccolithophorid bloom
Terra MODIS 2004-05-31
Data from NASA processed by SMHI

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An environmental status report of the Skagerrak, Kattegat and the North Sea

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CONTENTS

1 Introduction

This is the second year joint status report for the North Sea, Skagerrak and Kattegat area (Fig.1) carried out by SMHI, IMR and DHI as a part of the project BANSAI, supported by the Nordic Council of Ministers' Sea and Air Group. The aim of the project is to integrate marine observations and ecological model simulations in an annual assessment of the Baltic and the North seas. The present report is mainly based on model estimates of some of the indicators suggested by the OSPAR Common Procedure (c.f. Appendix) for the identification of the eutrophication status of the maritime area (OSPAR, 2002 and 2003). This first joint report serve as a basis for the on-going discussions about the ecological quality indicators included in the assessment, and the way to merge results from different models and observations for the assessment.

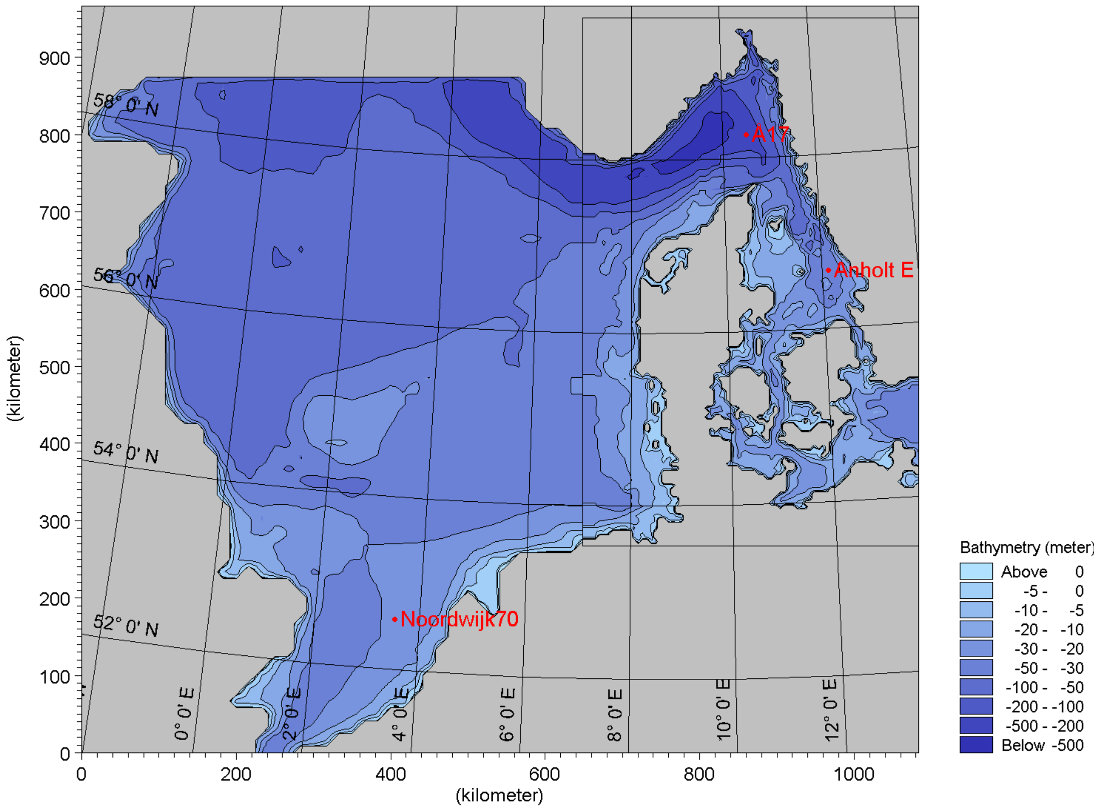

Fig. 1. Bathymetries map of the North Sea and the Kattegat-Skagerrak area. Monitoring stations used for model validation are shown by red dots.

Estimations of river discharges and model results are used to describe the degree of nutrient enrichment (Category I) defined by the riverine loadings of nitrogen and phosphorus, and winter surface concentrations and ratios of DIN and DIP. The direct effects of nutrient enrichment during the growing season (Category II) are described in terms of the mean and maximum chlorophyll concentrations and model estimations of primary production. The ratio between diatoms and flagellates is used as an indicator of region specific phytoplankton indicator species (Category II). The indirect effects of nutrient enrichment (Category III) are discussed in terms of oxygen depletion in bottom waters. Estimations of region specific background concentrations and threshold values are gathered from the literature and used for the model assessment.

The three model systems used for the joint assessment (Fig. 2) cover different parts of the North Sea, Skagerrak and the Kattegat area. Detailed descriptions of the models may be found on the websites presented below the figure.

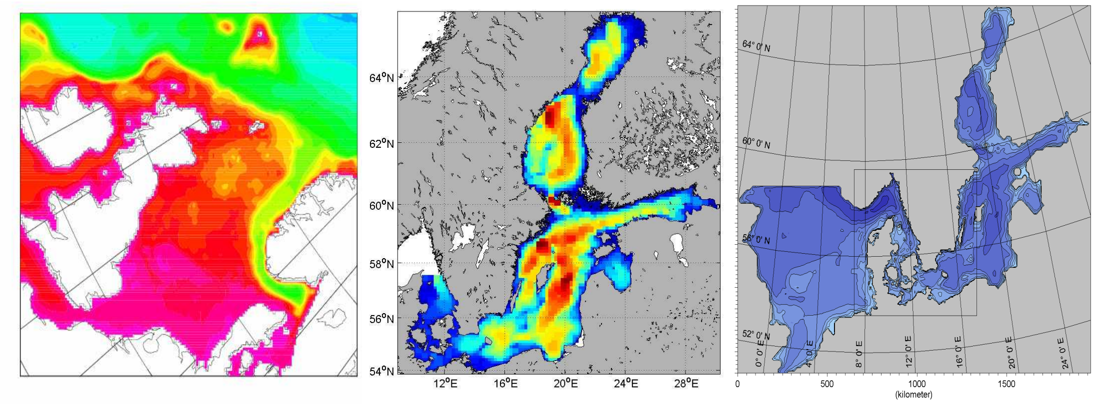

Fig. 2. Overview of model domains. The colors indicate depth ranges (not shown).
Left: *IMR – Norwecom model* (http://www.imr.no/~morten/norwecom).
Middle: *SMHI – RcoScobi model* (*http://www.smhi.se*).
Right: *DHI – Mike III model* (*http://www.dhigroup.com*).

In section 2 the key messages from this assessment will be presented. In section 3, each country gives a brief observations overview for 2005 and some references to other sources and reports that might be useful for the readers. The methods of the assessment are described in section 4. Statistical characteristics of model results and in-situ data are presented in section 5 and the model assessment of eutrophication status is done in section 6. Conclusions and comments to the assessment are presented in section 7.

2 Key messages

The report presents results obtained with a preliminary method of assessment. The assessment results depend much on the threshold values used for the classification of eutrophication status. One should note that the threshold values used here will be discussed and revised for the next report. The conclusions of the present report also points out other issues of the assessment method for the third year joint report from the BANSAI project in 2007.

The present assessment that will be improved of the eutrophication status according to the integration of the categorized assessment parameters indicates that the entire southern and eastern part of the North Sea and the Kattegat-Skagerrak area may, with small exceptions, be classified as problem areas. The rest of the North Sea is classified as non-problem areas except for parts of the east coast of Great Britain and the northern Atlantic waters which are classified as potential problem areas. A smaller coastal area of the northeastern Great Britain is also classified as a problem area.

3 Observations overview 2005

3.1 Sweden

The year started with the big storm "Gudrun" in the beginning of January. At some places the gusts reached the level of hurricane strength, i.e. more than 37.2 m/s. Highest mean wind speed, 33 m/s, was measured on the island Hanö, which is situated south of Sweden. On the same place the highest gust speed of 42 m/s was observed. The year 2005 was a relatively warm year, with an average temperature of 1.5 ºC warmer than the normal average temperature. The precipitation was about 5 % higher than normal, which is about the same as for 2004 (Karlström and Alexandersson, 2005). The total river runoff during 2005 was a bit higher than the average runoff between the years 1961-1990 (Fig. 3). Although, there were some considerable differences between the basins, the river runoff to the Bothnian Bay and Bothnian Sea was higher than the average, but to the Baltic Proper and to Kattegat and Skagerrak the runoff was lower (Jutman et al., 2006). The flow in Göta Älv, which contributes about 60 % of the total runoff to the Kattegat and Skagerrak, is regulated at a power station at the lake Vänern. The flow was kept low during a great part of the year to maintain an acceptable water level in the lake. In January, however, the river runoff to the Baltic proper was about 50 % higher, and to Kattegat and Skagerrak about 60 % higher than the long time average value.

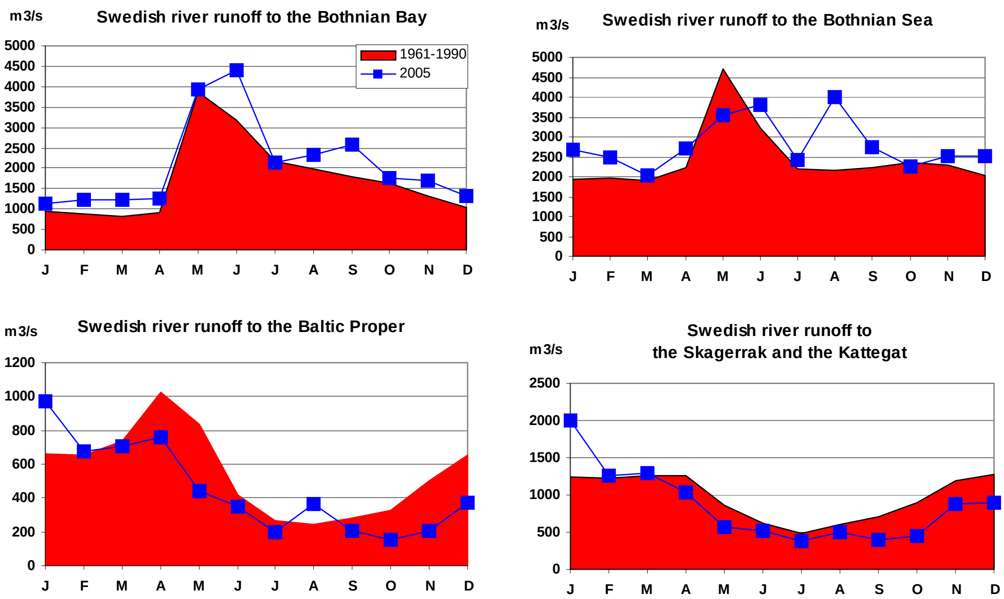

Fig. 3. Measured river runoff 2005 compared to long time average (Jutman et al., 2006).

The spring bloom of silicon algae began in the open Sea in March and started later on in the fjords of Bohuslän at the Swedish west coast. In April the bloom had ended. In May some toxic species were observed, e.g. *Alexandrium* spp. (Fig. 4) which at some stations exceeded the acceptable threshold concentrations. In June SMHI got out with warnings about the occurrence of *Alexandrium* spp. at some areas around the west coast.

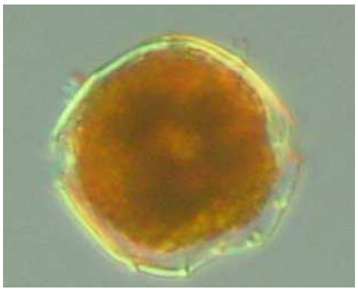

Fig. 4. Alexandrium tamarense. Photo: Ann-Turi Skjevik, SMHI.

Fig. 5. Pseudo-nitzschia. Photo: Ann-Turi Skjevik, SMHI.

A bloom of calcium flagellates began in June and continued into July. In July also a couple of toxic species occurred, e.g. *Pseudo-nitzschia* spp. (Fig. 5), *Dinophysis* spp. and *Alexandrium* spp.

In the fjords Havstensfjorden and Koljöfjorden *Dinophysis acuta* occurred in concentrations greater than the marginal value in October and November, respectively.

During the autumn water samples had high diversity in October and November, with a couple of toxic species present. In December a bloom of the toxic alga *Pseudo-nitzschia* spp. was in full action in Kattegat while the Skagerrak showed low winter concentrations of algae (Jutman et al., 2006). The annual oceanographic report summarizing hydrographic and hydrochemical observations in the area and the monthly reports of the algal situations are available on the SMHI web-site: http://www.smhi.se/oceanografi/oce_info_data/reports/aarsrapp/annual_sv.html

3.2 Norway

The year 2005 was as a whole the 6th warmest year since 1867, 1.5 degrees above normal. The temperature was especially high in Finnmark and eastern Norway where the mean temperature was 2-2.5 degrees above normal. The temperature was highest (relatively) in winter and fall, while the summer temperature was almost on average the whole country seen as one.

The rainfall was 115% of the normal, the 4th wettest ever for the whole country. The rainfall was highest in the western and northern parts of the country, and at some stations all time high. Relatively the precipitation was highest in winter (130%) and spring (120%). Large parts of eastern Norway had very little snow, and combined with dry conditions in spring, this resulted in the lower than normal river freshwater runoff in spring and summer to Skagerrak (Fig. 6). Note that three of the rivers (Glomma, Numedal and Drammen) are in the eastern part of Norway, while Otra is in the south

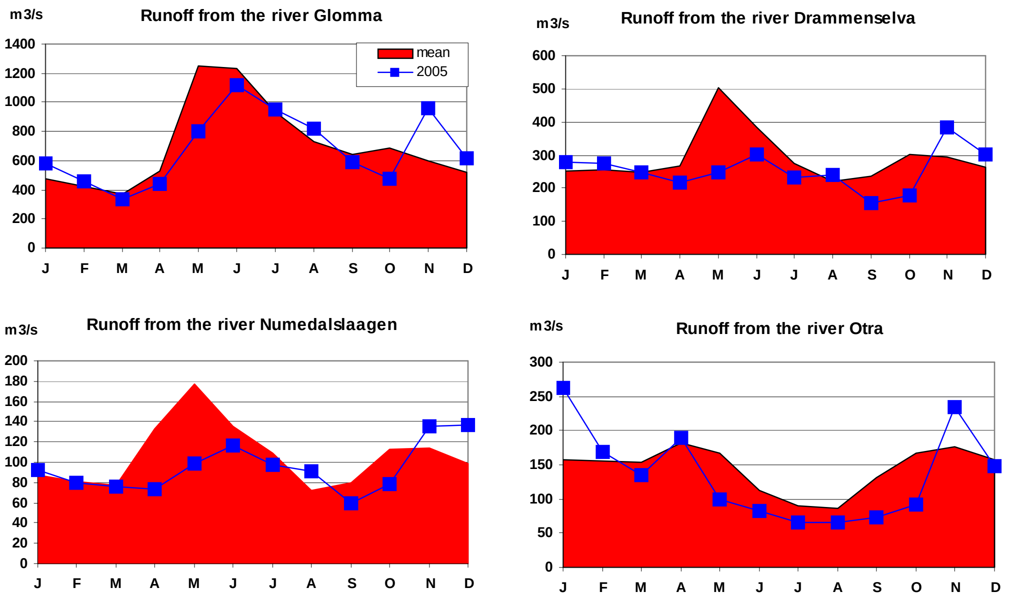

Fig. 6. Measured river runoff 2005 compared to long time average. River runoff data are from Norwegian Water Resources and Energy Directorate.

In the beginning of the year the temperature in most of the North Sea was 1-1.5 above the normal due to a long period dominated by warm southwesterly winds in December 2004 - January 2005. A relatively cold winter resulted in a cooling, and the temperature was close to normal until fall. An unusual warm late summer and fall gave very high temperatures, and at the end of the year the temperature in the upper layers was around 2 degrees higher than normal (the highest over the last 35 years). The deeper parts of the Skagerrak were, except for January, dominated by Atlantic water masses with high salinity (see Fig. 7). In the upper layers of Skagerrak the amount of water coming from the Baltic in spring was the highest observed since the late 1980s. Further information and a better overview with detailed descriptions can be obtained from the web-site: http://www.imr.no/produkter/publikasjoner/havets_ressurser/2006.

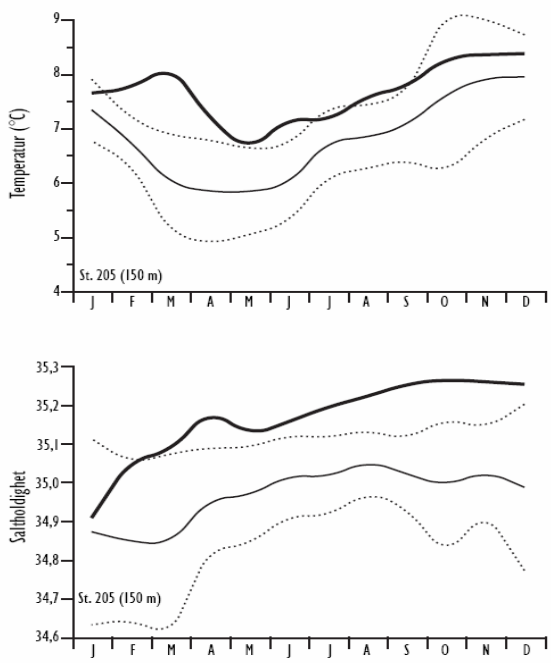

Fig. 7. Temperature and salinity at 150m depth 10km off Arendal (from Svendsen et. al, 2006). The values of 2005, the long-term mean, and the standard deviation are denoted with thick solid, thin solid and dotted lines, respectively.

3.3 Denmark

Also in Denmark the year 2005 was warmer than normal (+0.6 ºC), even February and March came out lower than normal. The year had a total precipitation of 10% less than normal, especially because the autumn was relatively dry. July was the wettest month with about 45% more rain than normally. The total runoff from Denmark in 2005 and the mean 1991-98 is shown in Figure 8. The annually runoff is near normal, but with significantly less runoff in the autumn due to the lower precipitation.

Fig. 9 shows the stratification in the Great Belt throughout 2005. The water column is seen to have been nearly well mixed in January, with a bottom water intrusion in March. Hereafter, the stratification is strong all the time until November. The events of stronger outflows of brackish water from the Baltic Sea are shown by the low surface salinity recordings, e.g. at the end of February and beginning of July.

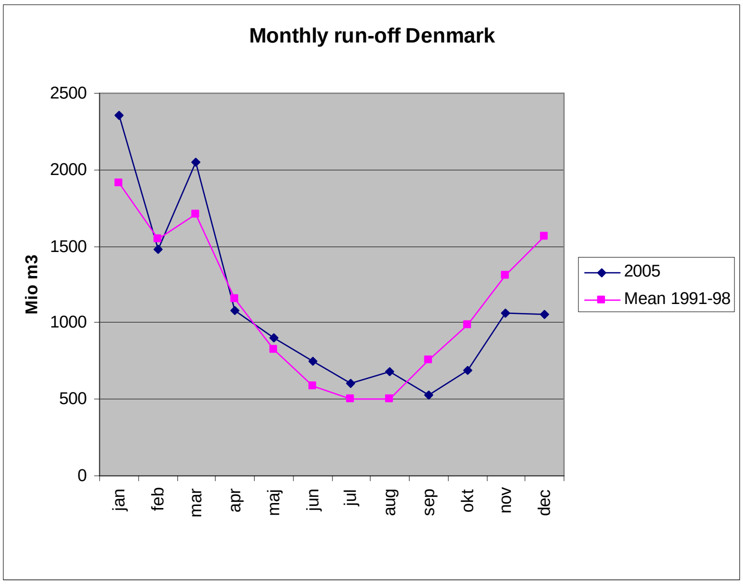

Fig. 8. Runoff from the Danish catchments compared to the long time average. Data from the Danish National Environmental Research Institute.

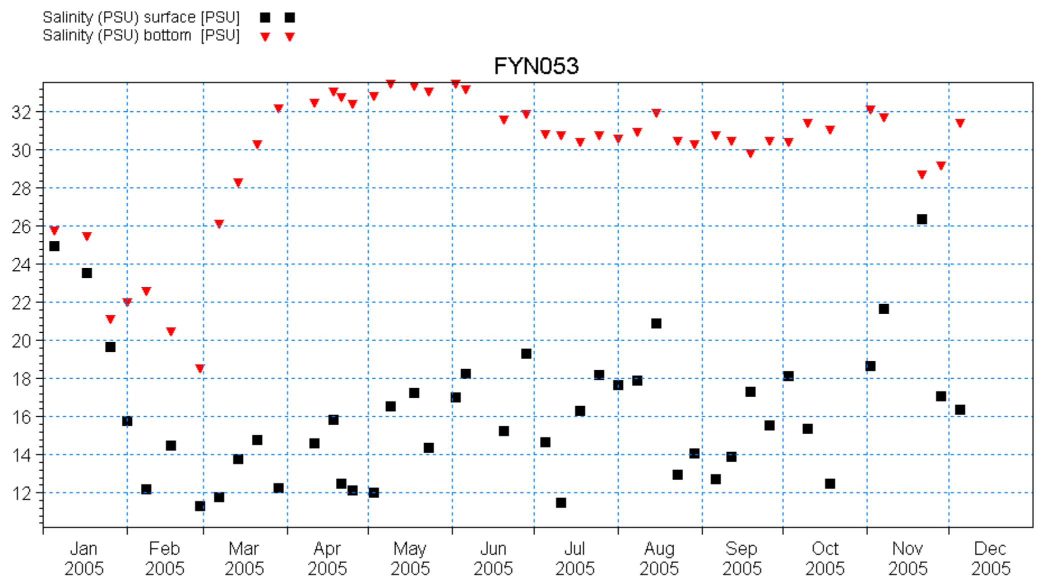

Fig. 9. Salinity at surface and bottom in the Great Belt (data from station 6700065 by the County of Funen).

4 Methods

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

1. Surface layer = Average for the depth interval 0-10m. For the model results we use the 5m model value to represent the surface layer.
2. Winter = Average for the period January-February
3. Summer (production period) = Average for the period March-October

Observational data for the period 2001-2005 from one station in Kattegat, Skagerrak and the North Sea (see Fig. 1) are used in the present comparison of model results and in-situ data. Mean values and standard deviation for a selected set of variables from the year 2005 are computed and compared to the 5 year average 2001-2005. The stations used are:

Kattegat:	**Anholt East**	**Lat +56 40.0**	**Lon +012 07.0**	(data from SMHI database)
Skagerrak:	**Å17**	**Lat +58 16.5**	**Lon +010 30.8**	(data from SMHI database)
North Sea:	**Noordwijk70**	**Lat +52 35.1**	**Lon +003 31.9**	(Dutch data, www.waterbase.nl)

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 oxygen concentrations (O_2) are computed from below 40m depth at Anholt and from 200m depth at Å17 in the period August-September.

To compare the model results with observations we use a cost function (*C*) which is computed from:

$$C = \left| \frac{M - D}{Sd} \right|$$

were *C* is the normalized deviation (in *Sd* units) between model results and in-situ data. *M* is the mean value of the 2005 model results, *D* is the mean value of the 2005 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* becomes large if the modeled 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	$0 \le C < 1$	std. deviations
Reasonable	$1 \le C < 2$	std. deviations
Poor	$2 \le C$	std. deviations

The following plots will be presented for all models.

1. Salinity (winter and summer surface layer average)
2. Winter surface layer average DIN, DIP (µmol /l), and DIN/DIP ratio
3. Chlorophyll_a summer surface layer average (µg Chl /l)
4. Annual surface layer chlorophyll_a maximum (µg Chl /l)
5. Oxygen annual bottom layer minimum (ml/l)

6. Annual integrated production of Diatoms/Non-Diatoms (carbon)
7. Annual integrated total production ($gCm^{-2}yr^{-1}$)

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 and DHI were used. The assessment areas with separate threshold values (Table 1) are described by colors and basin numbers (Bnr) in Fig. 10. Similarly the average value between models is computed for all the variables used for the assessment, except for the lower layer oxygen minimum concentrations. For this variable the minimum value from the three models are used instead.

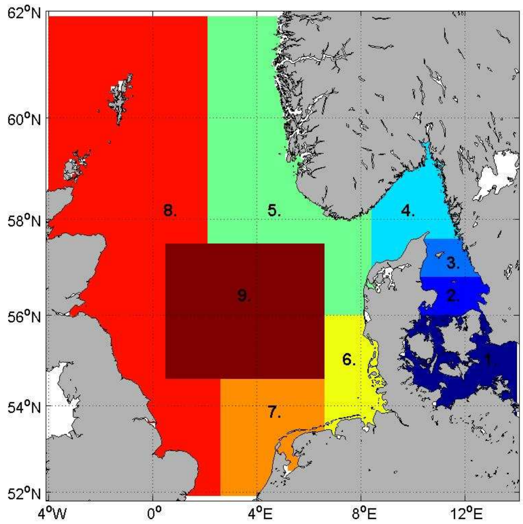

Fig. 10. The North Sea, Skagerrak and Kattegat are divided into 9 sub-basins with separate threshold values for the ecological quality indicators. Areas with same color (basin number) have same assessment threshold values. Areas west of Great Britain are not included in the assessment.

Reference values and threshold values are collected from various sources. DIN and DIP reference values and threshold values in the Baltic (Bnr 1), Kattegat (Bnr 2 and 3) and the Skagerrak (Bnr 4) are from an unpublished SMHI-report for the ongoing implementation of the Water Frame Work Directive in Sweden (Hansson and Håkansson, 2006). This work includes values for the open ocean as well as for the low-saline coastal areas. The values will be revised in 2007. Reference values of DIN and DIP for the central North Sea (Bnr 9) and north eastern North Sea (Bnr 5) are from QSR 1993. The reference value for chlorophyll in the open sea of Kattegat is from a HELCOM report (2005). Due to lack of other information the same value was used in the south-west Baltic (Bnr 1), Kattegat (Bnr 2 and 3), Skagerrak (Bnr 4) and in the north-eastern North Sea (Bnr 5). The threshold values in the western and southern North Sea (Bnr 6, 7 and 8) are from a user guide for the OSPAR ICG-EMO (Intersessional Correspondence Group on Eutrophication MOdelling) workshop on eutrophication modelling held in Hamburg 2005 (ICG-EMO User guide, version 150605). For the N/P reference value the Redfield ratio was used and the threshold value was taken from Table A1 in Appendix and is used in all basins. The threshold values were calculated by multiplying the reference value with 1.5 when only reference values were available.

Table 1. *Reference values and threshold values used in the present report. Please note that most threshold values are determined by national parties (within the OSPAR community) why the local situation may lead to different levels being adopted by different contracting parties.*

Basin number	Basin names	Salinity range psu	DIN ref. value µmol/l	DIP ref. value µmol/l	N/P ref. value -	CHL ref. value µg/l	DIN Thres. Value µmol/l	DIP thres. value µmol/l	N/P thres. value -	CHL thres. value µg/l
1	**Baltic Proper South West**	≤ 0.5	35.0	0.11	16	1.25	52.0	0.16	25	1.9
		≤ 3.0	30.0	0.13	16	1.25	44.0	0.20	25	1.9
		≤ 6.0	18.0	0.18	16	1.25	27.0	0.28	25	1.9
		> 6.0	3.0	0.25	16	1.25	4.5	0.38	25	1.9
2	**Kattegat South**	≤ 0.5	27.0	0.20	16	1.25	40.0	0.31	25	1.9
		≤ 3.0	25.0	0.21	16	1.25	38.0	0.32	25	1.9
		≤ 6.0	23.0	0.24	16	1.25	34.0	0.35	25	1.9
		≤ 22.0	14.0	0.31	16	1.25	22.0	0.47	25	1.9
		≤ 30.0	4.5	0.40	16	1.25	6.8	0.60	25	1.9
		>30.0	4.5	0.40	16	1.25	7.0	0.60	25	1.9
3	**Kattegat North**	≤ 0.5	14.0	0.20	16	1.25	21.0	0.31	25	1.9
		≤ 3.0	13.0	0.21	16	1.25	20.0	0.32	25	1.9
		≤ 6.0	13.0	0.23	16	1.25	19.0	0.35	25	1.9
		≤ 22.0	9.6	0.29	16	1.25	14.0	0.44	25	1.9
		≤ 30.0	5.8	0.37	16	1.25	9.0	0.56	25	1.9
		>30.0	4.5	0.40	16	1.25	7.0	0.60	25	1.9
4	**Skagerrak**	≤ 0.5	24.0	0.21	16	1.25	36.0	0.31	25	1.9
		≤ 3.0	23.0	0.22	16	1.25	35.0	0.34	25	1.9
		≤ 6.0	22.0	0.26	16	1.25	33.0	0.39	25	1.9
		≤ 22.0	18.0	0.39	16	1.25	26.0	0.58	25	1.9
		≤ 30.0	12.0	0.55	16	1.25	18.0	0.82	25	1.9
		> 30.0	10.0	0.60	16	1.25	15.0	0.90	25	1.9
5	**North Sea North East**	> 0.0	9.0	0.80	16	1.25	13.5	1.20	25	1.9
6	**North Sea South East**	≤ 30.0	-	-	16	-	19.0	0.80	25	1.0
		≤ 34.5	-	-	16	-	19.0	0.80	25	4.5
		> 34.5	-	-	16	-	13.0	0.90	25	3.0
7	**North Sea South West**	≤ 30.0	-	-	16	-	30.0	0.80	25	18.0
		≤ 34.5	-	-	16	-	30.0	0.80	25	15.0
		>34.5	-	-	16	-	15.0	0.80	25	4.5
8	**North Sea West**	≤ 30.0	-	-	16	-	10.8	0.68	25	15.0
		≤ 34.5	-	-	16	-	10.8	0.68	25	15.0
		> 34.5	-	-	16	-	10.8	0.68	25	10.0
9	**North Sea Central**	> 0.0	8.0	0.60	16	-	12.0	0.90	25	10.0

5 Comparison to in-situ data

In-situ data from 2005 indicate higher concentrations of winter DIN and DIP, and lower DIN to DIP ratios in the Skagerrak and Kattegat relative to the 5 year average. The summer chlorophyll concentrations 2005 decreased while the lower layer oxygen concentrations improved relative to the 5 year average (Table 2).

The model results from 2005 (Table 3) indicate reasonable or good cost function values for most variables (Table 4) except for a poor description of lower layer oxygen concentrations in Kattegat (SMHI, IMR) and in Skagerrak (DHI). The DHI model also indicates poor results for DIP and CHL in southern North Sea and the IMR model for DIN in Kattegat.

Table 2. *Observations from 2005 (above) and from 2001 to 2005 (below). Mean values (Mv) and standard deviations (Sd) of surface layer winter concentrations of S (psu), DIN (µmol/l), DIP (µmol/l), DIN/DIP ratio, the production period CHL (µg/l) and the lower layer* O_2 *(ml/l).*

		DIP Mv	DIP Sd	DIN Mv	DIN Sd	N/P Mv	N/P Sd	CHL Mv	CHL Sd	O_2 Mv	O_2 Sd	S Mv	S Sd
2005	Anholt	0.55	0.09	5.98	1.12	11.22	0.40	1.83	1.84	3.35	0.39	23.64	4.33
	Å17	0.56	0.00	7.37	1.43	12.86	1.93	1.11	0.61	5.91	0.15	33.21	1.26
	N70	0.33	0.01	5.20	0.70	15.76	-	2.49	2.09	-	-	35.18	0.005
2001-2005	Anholt	0.49	0.12	5.44	1.43	11.57	1.89	1.91	2.22	2.87	0.82	23.27	2.72
	Å17	0.52	0.04	6.73	1.29	13.56	2.67	1.80	3.11	5.78	0.16	32.71	1.46
	N70	0.48	0.14	7.20	2.40	15.00	-	2.45	2.28	-	-	34.96	0.25

Table 3. *Model results year 2005. Upper, middle and lower rows shows results from IMR, SMHI and DHI models, respectively. See definitions of the variables in Table 2.*

		DIP Mv	DIN Mv	N/P Mv	CHL Mv	O2 Mv	S Mv
IMR	Anholt	0.41	9.86	24.05	0.48	5.48	-
	Å17	0.51	8.17	16.02	0.66	6.32	-
	N70	0.36	4.2	11.67	1.24	-	-
SMHI	Anholt	0.51	4.70	9.22	2.50	8.03	-
	Å17	-	-	-	-	-	-
	N70	-	-	-	-	-	-
DHI	Anholt	0.49	6.5	13.27	1.8	3.39	-
	Å17	0.62	9.2	14.84	4.3	5.41	-
	N70	0.94	10.1	10.74	6.8	-	-

Table 4. *Cost function value (C) of year 2005. Upper, middle and lower rows shows the C value when available for the IMR, SMHI and DHI models, respectively. See definitions of the variables in Table 2.*

		DIP	DIN	N/P	CHL	O2	S
IMR	**Anholt**	1.17	2.71	6.79	0.61	2.60	-
	Å17	1.25	0.62	1.18	0.14	2.56	-
	N70	0.14	0.27	-	0.55	-	-
SMHI	**Anholt**	0.33	0.90	1.06	0.30	5.71	-
	Å17	-	-	-	-	-	-
	N70	-	-	-	-	-	-
DHI	**Anholt**	0.50	0.36	1.08	0.01	0.05	-
	Å17	1.50	1.42	0.74	1.03	3.13	-
	N70	2.90	1.34	-	1.89	-	-

6 Model assessment

The model results for the variables used in the assessment of ecological quality indicators are presented here. The average values of the variables computed from the model results are used for the classification of the eutrophication status according to the threshold values valid for each area. Where possible, the results of the assessments are presented.

6.1 Winter situation

6.1.1 Salinity

The average wintertime surface layer salinity (Fig. 11) shows increasing concentrations from about 10 psu in the south-western Baltic Sea to about 35 psu in the central North Sea.

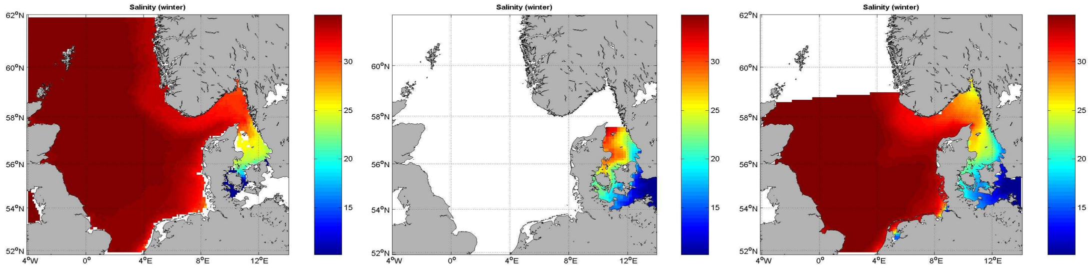

Fig. 11. Winter average surface layer salinity (psu). Left: IMR, Middle: SMHI, Right: DHI.

6.1.2 DIP

The average wintertime surface layer DIP (Fig. 12) in general shows values below 1 µmolP/l. The highest concentrations are found in the south-western Baltic Sea, northern North Sea and along the Danish west-coast. There is a clear discrepancy between the IMR and DHI models concerning the southern and central North Sea. According to the cost function and the in-situ data it seems that the DHI model may overestimate the DIP concentrations in these areas.

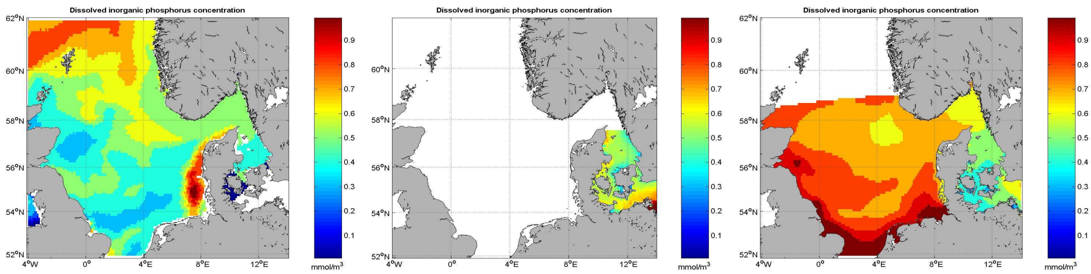

Fig. 12. Winter average surface layer DIP (µmolP/l). Left: IMR, Middle: SMHI, Right: DHI.

6.1.3 DIN

The average wintertime surface layer DIN (Fig. 13) in general shows values below 15 µmolN/l. The highest concentrations are found in the southern North Sea and along the Danish west-coast. There is a clear discrepancy between the IMR and DHI-SMHI models concerning the Kattegat. According to the cost function and the in-situ data it seems that the IMR model may overestimate the DIN concentrations in Kattegat.

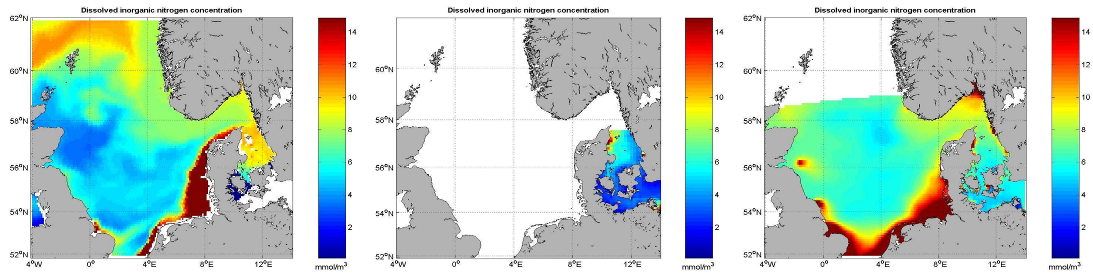

Fig. 13. Winter average surface layer DIN (µmolN/l). Left: IMR, Middle: SMHI, Right: DHI.

6.1.4 DIN to DIP ratio

The average wintertime surface layer DIN/DIP ratio (Fig. 14) in the North Sea shows values below 16 (Redfield molar ratio). Higher values are found at the rivers in Kattegat and Skagerrak, and in the southern North Sea and along the Danish west-coast. There is a clear difference between the IMR and DHI-SMHI models concerning the Kattegat. According to the cost function and the in-situ data it seems that the IMR model may overestimate the DIN/DIP ratio in this area.

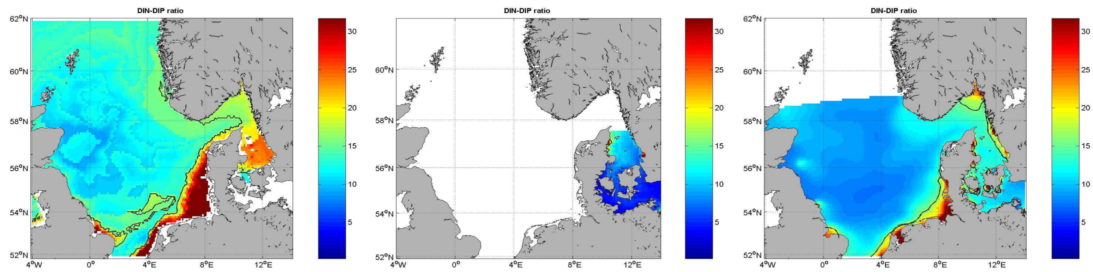

Fig. 14. Winter average surface layer DIN to DIP ratio. The contour line indicates the isoline of the Readfield molar ratio (16). Left: IMR, Middle: SMHI, Right: DHI.

6.2 Summer situation

6.2.1 Salinity

The average summertime surface layer salinity (Fig. 15) shows increasing concentrations from about 10 psu in south-western Baltic Sea to about 35 psu in the central North Sea. The amount of freshwater is higher than in winter (Fig. 11) which is reflected by lower salinities in the Kattegat-Skagerrak and eastern North Sea.

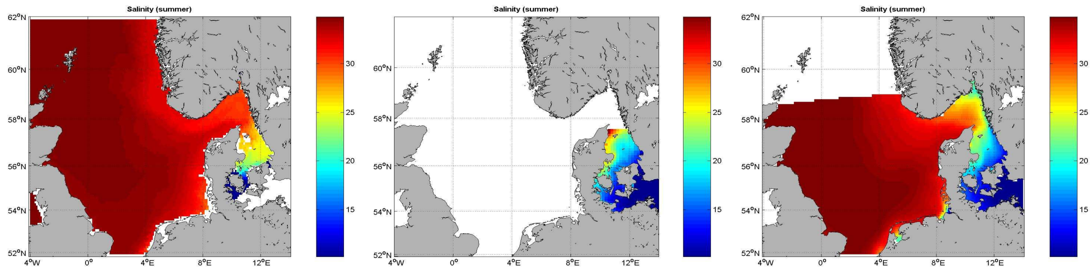

Fig. 15. Summer average surface layer salinity (psu). Left: IMR, Middle: SMHI, Right: DHI.

6.2.2 Chlorophyll_a

The average summertime surface layer CHL (Fig. 16) in general shows highest values in Skagerrak and at the coasts of the North Sea while the Kattegat and the central North Sea show lower concentrations. There is a clear discrepancy between the IMR and DHI-SMHI models. According to the cost function and the in-situ data it seems that the IMR model results are in the low-end while the DHI model results (except in Kattegat) are in the upper-end of the observed CHL concentrations.

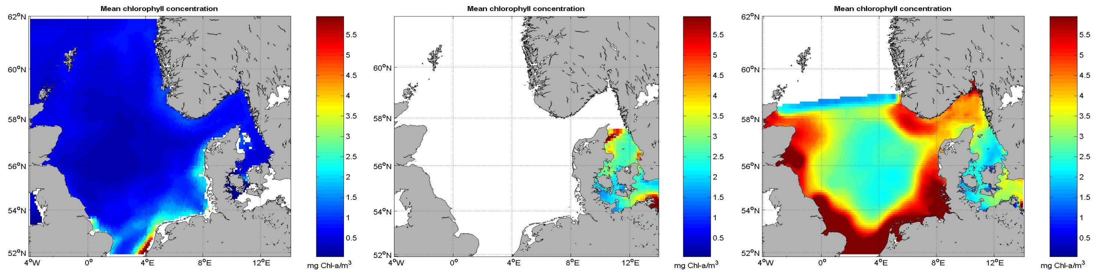

Fig. 16. Summer average surface layer chlorophyll_a (μg/l). Left: IMR, Middle: SMHI, Right: DHI.

6.3 Oxygen conditions

The annual bottom layer oxygen minimum (Fig. 17) in general shows lowest values (< 3-4ml/l) in the Kattegat and in the eastern-central parts of the North Sea. There is a clear discrepancy between the IMR-DHI and SMHI models in the Kattegat. According to the cost function and the in-situ data it seems that the SMHI model results may overestimate bottom layer oxygen concentrations in the Kattegat.

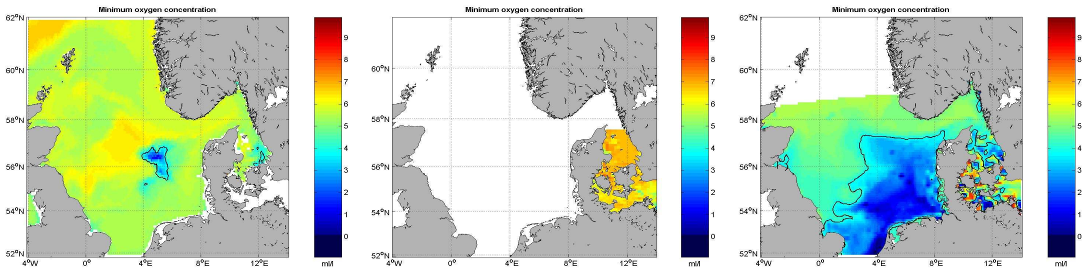

Fig. 17. Annual bottom layer oxygen minimum concentration (ml/l). The contour line indicates the 4 ml/l isoline. Left: IMR, Middle: SMHI, Right: DHI.

6.4 Primary production

The vertically integrated annual primary production (Fig. 18) in general shows highest values along the eastern and southern parts of the North Sea and in the Skagerrak. In the south eastern parts of the North Sea the production exceeds 350-400 $gCm^{-2}yr^{-1}$ while the production in Skagerrak exceeds 150 $gCm^{-2}yr^{-1}$. The central parts of the North Sea shows the lowest production but with clear differences between the models. The difference between the results of the IMR and DHI models in general follows much the patterns of summertime average CHL (Fig. 16).

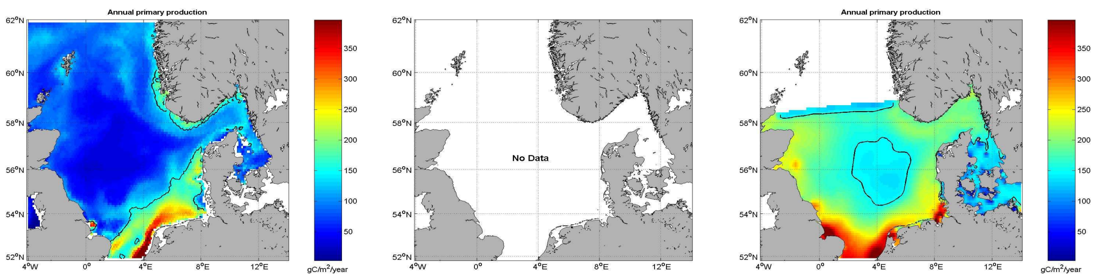

Fig. 18. Annual primary production ($gCm^{-2}yr^{-1}$). The contour line indicates the 150 $gCm^{-2}yr^{-1}$ isoline. Left: IMR, Middle: SMHI, Right: DHI.

6.5 Maximum chlorophyll_a

The maximum annual surface layer CHL (Fig. 19) in general follows much the patterns of summertime average CHL (Fig. 16). There is a clear discrepancy between the IMR-SMHI and DHI models. The maximum CHL concentrations of the DHI model results are generally much higher. For this report, no in-situ data were available for comparison.

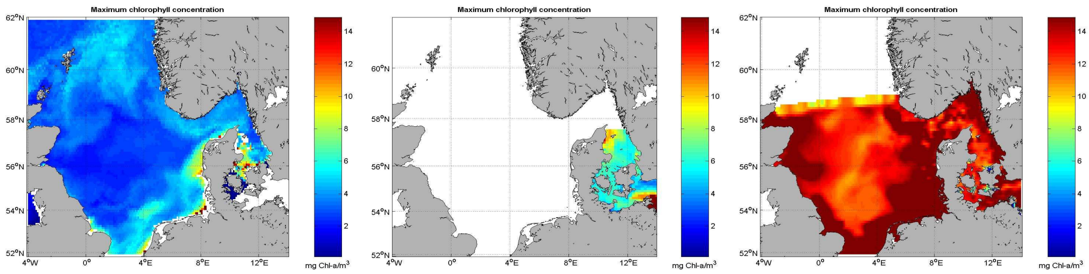

Fig. 19. Maximum annual surface layer chlorophyll_a concentrations (µg/l). Left: IMR, Middle: SMHI, Right: DHI.

6.6 Diatoms to Non-Diatoms production ratio

The vertically integrated annual primary production of diatoms relative to non-diatoms (Fig. 20) shows that non-diatoms dominate in general. Diatom production is larger mainly in some local areas in the Kattegat and the southern North Sea and in the northern Atlantic waters. There is also an indication of enhanced production of diatoms at the Norwegian coast and in the frontal areas between coastal waters and central North Sea and Skagerrak waters.

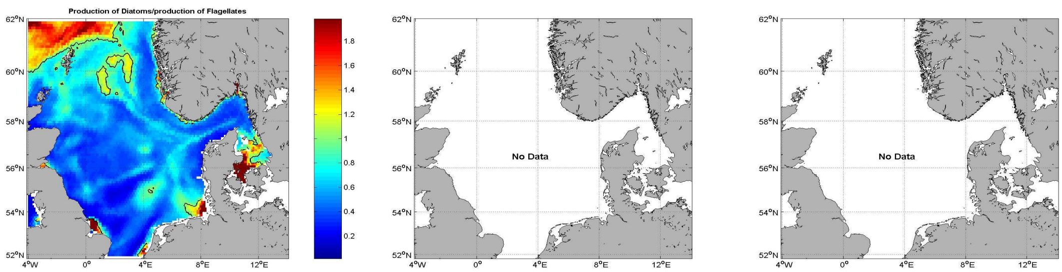

Fig. 20. The ratio of annual production of diatoms to non-diatoms. The contour line indicates the isoline of equal production (ratio=1). Left: IMR, Middle: SMHI, Right: DHI.

6.7 Transports

The generalized currents in the Skagerrak and the Kattegat are shown in Fig. 21. The Baltic and Norwegian Coastal currents transport Baltic water to the North Sea. A high-saline inflow from the central and northern North Sea circulates and forms the bulk of the Skagerrak water while a less saline inflow from the southern North Sea takes place along the northern Danish coast (the Jutland current).

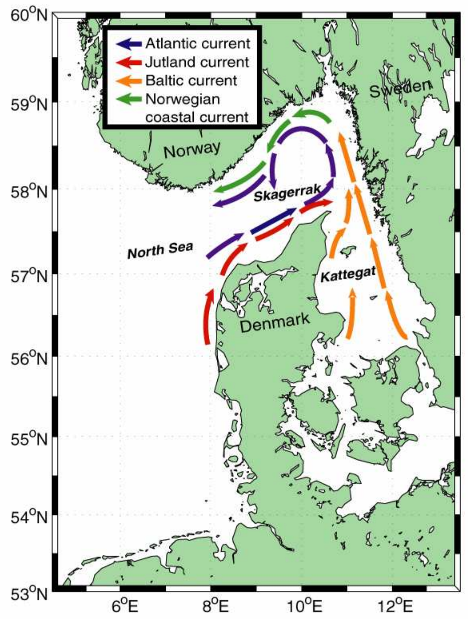

Fig. 21. Generalized current pattern in the Skagerrak and Kattegat area (B.Karlsson, SMHI).

The Jutland current transports of water volume, and dissolved inorganic nitrogen (DIN) and phosphorus (DIP) into Skagerrak are shown in Table 5. The modelled transports 2005 are in the range of previous estimates from model experiments and literature.

Table 5. *Annual transports in the year 2005 of inorganic nutrients and water from the North Sea to Skagerrak through a section from Hanstholm (Denmark) to Kristiansand (Norway). The results show the Danish part of the section (out to 3/7 of the section from Hanstholm) and in the upper 50 meters. Results are from IMR model. Average model results for the years 2002-2005 are shown in brackets.*

		Transport		
Watermass classification	**Salinity range**	**Water $km^3 yr^{-1}$**	**DIN $kton\ yr^{-1}$**	**DIP $kton\ yr^{-1}$**
Jutland Coastal Water (JCW)	**Sal < 34.5**	881 *(743)*	764 *(754)*	114 *(103)*

6.8 Eutrophication status

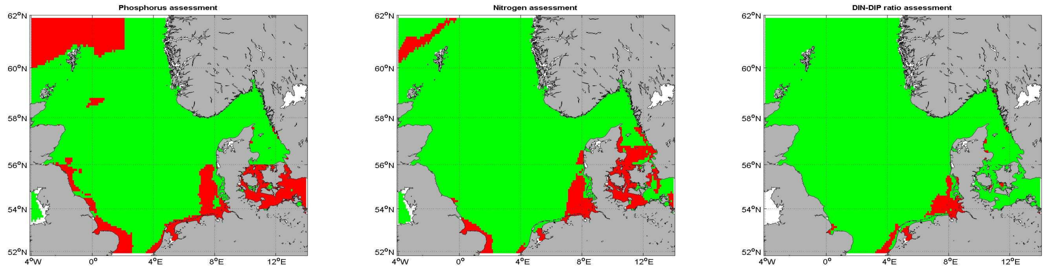

Fig. 22. Assessment results of DIP (left), DIN (middle) and the DIN/DIP ratio (right). The assessment levels are indicated by colors, green (good), red (bad).

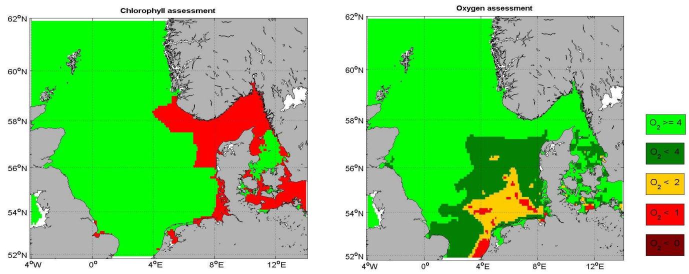

Fig. 23. Assessment results of summertime average chlorophyll_a (left). The assessment levels are indicated by colors, green (good), red (bad). Assessment results of annual minimum oxygen concentrations (right). The assessment levels are indicated by colors, light green ($O_2 \geq 4ml/l$), dark green ($O_2 < 4ml/l$, decreased level), yellow ($O_2 < 2ml/l$, toxic level), red ($O_2 < 1ml/l$), brown ($O_2 < 0ml/l$, anoxic level).

The assessment of eutrophication status according to the threshold values for winter DIN and DIP (causative factors) (Fig. 22) indicates elevated levels in the coastal regions of the southern North Sea and in the Kattegat.

The assessment of eutrophication status according to the threshold values for summer chlorophyll_a concentrations (direct effects) (Fig. 23; left) indicate elevated levels in the coastal regions of the southeastern North Sea and in the Skagerrak and northern Kattegat.

The assessment of eutrophication status according to the annual minimum oxygen concentrations (indirect effects) (Fig. 23; right) indicate decreased levels ($O_2 < 4ml/l$) in large parts of the eastern North Sea and Kattegat. Toxic levels ($O_2 < 2ml/l$) are also found in the southeastern North Sea and some local areas in the Kattegat.

There is a lack of reference values for an assessment of the eutrophication status for primary production, maximum chlorophyll_a and diatoms to non-diatoms ratio.

The assessment of the eutrophication status according to the integration of the categorized assessment parameters (Fig. 24) indicate that the entire southern and eastern part of the North Sea and the Kattegat-Skagerrak area may be classified as a problem areas. Some small locations in Kattegat obtain the classification potential problem area and non-problem area. The western and northwestern parts of the North Sea are classified as non-problem areas and the northern Atlantic waters as potential problem areas. Parts of the east coast of Great Britain are classified as potential problem areas and a smaller area of the northeastern coast of Great Britain is classified as a problem area. One should note that the results in some areas may be questionable due to the assessment methods used in the report. The results are based on rough figures of the threshold values as well as on the averaging of model results without any weighting according to the quality of the model results in different regions. Improving the methods will be an important task for the future project as will be discussed below.

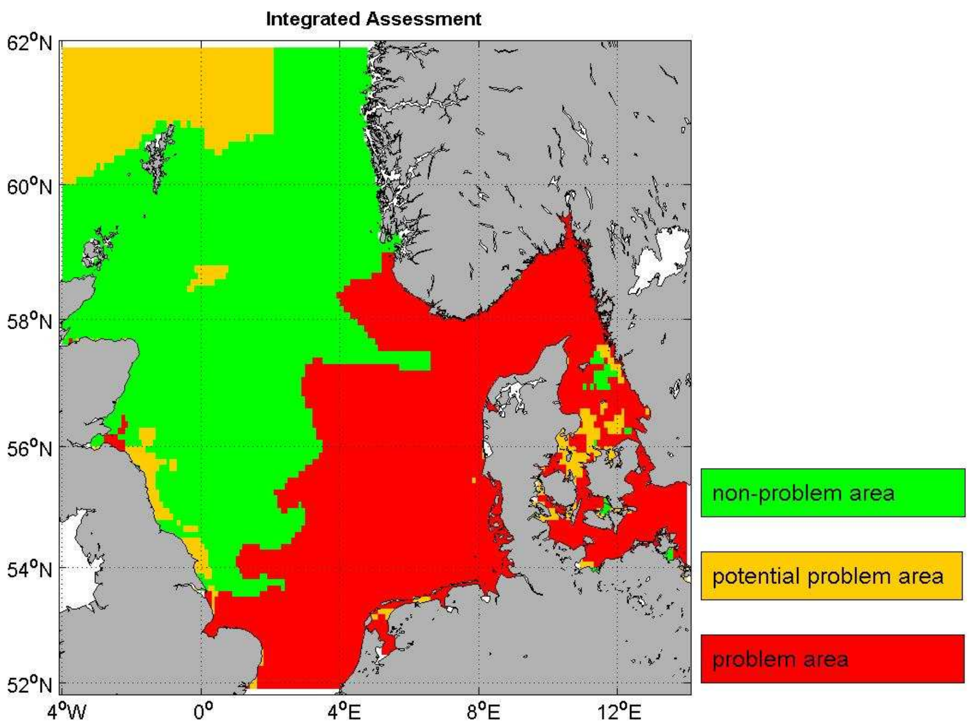

Fig. 24. Assessment results of integrated categorized assessment parameters. The assessment levels are indicated by colors, green (non-problem area), yellow (potential problem area), and red (problem area).

7 Conclusions

The present report gives a brief background description of river runoff and meteorological conditions and presents results of three ecosystem models from Nordic countries. The models describe the North Sea, Skagerrak and the Kattegat area. The average results of the three models are used to assess the eutrophication status according to the OSPAR Common Procedure.

The river loadings of nutrients were not computed explicitly in this assessment. The river runoff to the Kattegat and Skagerrak was however lower than normal indicating lower loadings of nitrogen and phosphorus to the sea since the nutrient load to a large extent is determined by the runoff (Håkansson, 2003). Håkansson (2003) concluded that the riverine input to the Skagerrak and Kattegat is much above pristine conditions. The estimated transports of nutrients into Skagerrak from the southern North Sea (Jutland current) were similar to previous years.

The winter surface concentrations and ratios of DIN and DIP showed elevated levels in the coastal regions of the southern North Sea and in the Kattegat. The mean chlorophyll_a concentrations indicated elevated levels in the coastal regions of the south eastern North Sea and in the Skagerrak and northern Kattegat. The annual minimum oxygen concentrations showed decreased levels in large parts of the eastern North Sea and Kattegat. Toxic levels were found in the south eastern North Sea and some local areas in the Kattegat.

The assessment of the ecological status according to the integration of the categorized assessment parameters indicates that the entire southern and eastern part of the North Sea and the Kattegat-Skagerrak area may, with small exceptions, be classified as problem areas. The rest of the North Sea is classified as non-problem areas except for parts of the east coast of Great Britain and the northern Atlantic waters which are classified as potential problem areas. A smaller area in the northeastern Great Britain is also classified as a problem area.

An area is defined to be a potential problem area if there are increased levels of nutrients relative to the actual threshold value used in that assessment area. The results therefore rely much on the reliability of the threshold values. For instance it may be questioned if the northern Atlantic waters should be classified as potential problem areas. The assessment results for problem areas depend highly on the variables that relate to the direct (chlorophyll) or indirect effects (oxygen) (cf. Appendix Table 2) and large parts of the North Sea are by this declared as problem areas due to the low oxygen conditions predicted by the DHI model (Fig. 19). This shows that results from one model may dominate the assessment results and one should therefore bear in mind that the models show different skills in different assessment areas as discussed in sections 6.1 to 6.6.

Finally we conclude that the report has pointed out some shortcomings that will be improved in the third year joint report from the BANSAI project.

1. The models have different skill in different areas and the model results for different parameters may therefore differ quantitatively quite much from each other. This asks for a method to bring together the model results that may enhance the quality of the assessment. In the present report the results between models were averaged. The quality of this approach should be quantified and other methods should be tested for the next report.

2. One aim of the BANSAI project is to integrate marine observations and ecological model simulations. In the present report observations have been used for the background description and for the description of some characteristics of three stations representing the Kattegat, Skagerrak and the North Sea. The observations have been used for a comparison by the cost function method. The assessment of eutrophication in the present report is based only on model results. For the next report the use of observations should be enlarged and incorporated into the

assessment. This would also increase the reliability of the final assessment. One idea could be to use the values of the cost function to weight the results from the models in the different regions before the averaging. One could use only model results with a value of the cost function lower than a defined limit. I.e., the averaging would rely more on model results with a low cost function value.

3. For this report there was a lack of good references and threshold values for a comprehensive assessment of eutrophication status for many parameters in several sea areas. The assessment is based on rough figures found from the literature. It is possible that new reference values will be approved and made available for the next BANSAI report in 2007. The division of areas into boxes gives sharp gradients between regions with different threshold values. Methods to even out the gradients also need to be discussed.

4. Estimations of nutrient transports were done for the Jutland current in the present report. Computing surface layer transports through the boundaries between the North Sea and the Skagerrak and Baltic Sea and the Kattegat could provide a basis for budget computations in the area.

8 Acknowledgement

The BANSAI project is funded by the Nordic Council of Minister's Air and Sea group.

9 References

Edquist, E., Alexandersson, H. and Ivarsson, K.-I., 2005. Januaristormen 2005, SMHI, Norrköping.

Jutman, T. et al., 2006. Vattenåret 2005. Faktablad Nr 28, SMHI, http://www.smhi.se/sgn0102/n0205/faktablad.htm.

Håkansson, B., 2003, Editor, Swedish national report on eutrophication status in the Kattegat and the Skagerrak; OSPAR assessment 2002, SMHI Reports Oceanography, RO No 31.

Karlström, C.E. and Alexandersson, H., 2005. Årets väder. 13, SMHI, Norrköping.

OSPAR, 2002, Common Assessment Criteria, their Assessment Levels and Area, Classification within the Comprehensive Procedure of the Common Procedure, Reference number: 2002-20.

OSPAR, 2003, Strategies of the OSPAR Commission for the Protection of the Marine, Environment of the North-East Atlantic, Reference number: 2003-21.

QSR: 1993, 'The Wadden Sea', De Jong, F., Bakker, J. F., Dahl, K., Dankers, N., Farke, H., Jäppelt, W., Koßmagk-Stephan, K. and Madsen, P. B. (eds.), *Quality Status Report of the North Sea. Subregion 10*, Common Wadden Sea Secretariat, Wilhelmshaven, 174 pp.

Svendsen, E., Danielssen, D. and Skogen, M.D., 2006, Økosystem Nordsjøen og Skagerrak. Fysikk (sirkulasjon, vannmasser og klima). Pages 112-118 in Iversen, S.A., Fossum, P., Gjøsæter, H., Skogen, M.D., & Toresen, R. (eds) (2006). Havets ressurser og miljø 2006. Fisken og havet særnummer 1 - 2006. Institute of Marine Research, Bergen, Norway.

10 Appendix; Comprehensive procedure

From: OSPAR Integrated Report 2003 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
- 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 A1. *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 <u>a</u> 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. *Ulva*)
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 A2. *Integration of Categorised Assessment Parameters*

	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.

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3 Cecilia Ambjörn (1986).
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