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SMHI

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1. Summary

The Swedish Coastal and Ocean Biogeochemical model (SCOBI) is used for the assessment of eutrophication status in the Skagerrak and the Kattegat, and of the following long-term effects on the ecosystem for the 50% nutrient reduction target (PARCOM Recommendation 88/2). Model validation and the final reporting of the results in accordance with the OSPAR comprehensive procedure are presented.

The model is validated by a comparison of a long time series (1985-2002) of the model results to data from a number of stations representing different parts of the model domain. A quantitative examination of the model performance is done by a comparison between the seasonal and annual averages of the model results and in-situ data.

The model response to nutrient reductions shows that reducing nutrient inputs from land have the largest effects on the nitrate concentrations in the Kattegat and along the Swedish coast in the Skagerrak. The effects on phosphate concentrations are relatively small. The largest effect obtained from a 50% reduction of anthropogenic nitrogen and phosphorus from the runoff in one country alone is obtained for Sweden. This model experiment reduces the nitrate and chlorophyll concentrations in the Swedish coastal waters by 5%-10% and 3%-6%, respectively. The annual net production is reduced by 2%-4% and changes in sedimentation are less than 1%. The largest reduction is found in the Kattegat.

The combined effect from a 50% reduction of anthropogenic nutrient supplies from land and an anticipated realistic reduction of nutrient concentrations in the Baltic Sea and the North Sea reduces the nitrate and phosphate concentrations in the Kattegat and the Swedish parts of the Skagerrak coastal area by 20%-30%. The average chlorophyll concentrations are reduced by 8%-11%. The annual net production and the sedimentation are reduced by 12%-20% and 5%-12%, respectively.

2. Introduction

The Ministerial Meeting of the OSPAR Commission at Sintra, Portugal, in 1998 adopted a number of strategies on the protection and conservation of the ecosystems and biological diversity of the marine environment of the north-east Atlantic. As regards eutrophication, the aim of the Commission is to make every effort to combat eutrophication in the maritime area, in order to achieve, by the year 2010, a healthy marine environment where eutrophication does not occur (OSPAR 2003). The Common Procedure for the Identification of the Eutrophication Status of the Maritime Area, which was adopted by OSPAR in 1997, is a main element of that strategy.

The Common Procedure comprises 2 steps.

1. The screening procedure. A broadbrush process to identify obvious non-problem areas with regard to eutrophication.
2. All areas not identified as non-problem areas shall be subject to the *Comprehensive* Procedure. It consists of a set of assessment criteria that may be linked to form a holistic and common assessment of the eutrophication status of the maritime area. Through this process the OSPAR maritime area is classified into areas which are considered to be problem, potential problem, or non-problem areas with regard to eutrophication. Repeated application of the Comprehensive Procedure should identify any change in the eutrophication status of a particular area (OSPAR, 2002A).

In 1998, the OSPAR Commission adopted the PARCOM recommendation 88/2 which requests the contracting parties to take effective national steps in order to reduce nutrient inputs into areas where these inputs are likely, directly or indirectly, to cause pollution. The aim was to achieve a substantial reduction (of the order of 50%) in inputs of phosphorus and nitrogen into these areas between 1985 and 1995, or earlier if possible. The OSPAR Convention requires the member states, amongst other things, to cooperate in implementing monitoring programmes and to carry out assessments of the status of the marine environment. The Joint Assessment and Monitoring Programme (JAMP) sets out the basis on which the OSPAR member states will work together in fulfilling their obligations over the period until 2010 (ASMO, 2003). According to the time schedule of the JAMP implementation plan, assessments shall be made in 2005 of the effectiveness of the implementation of the measures on the state of the marine ecosystem. The results will be reported to the commission in 2006.

The aim of the present report is to assess the eutrophication status in the Skagerrak and the Kattegat (Figure 1) coastal and offshore areas and the following long-term effects on the ecosystem for nutrient reductions as suggested by the PARCOM Recommendation 88/2. Model validation, model sensitivity to variation in forcing, the processing of model results and the final reporting of the results in accordance with the comprehensive procedure will be presented. The main tasks are defined in accordance with recommendations from the OSPAR workshop on eutrophication modelling held in Hamburg 2005 (ICG_EMO, 2005):

a. Predict the environmental consequences if the 50% nutrient reduction target was achieved;
b. Predict the reduction target to achieve a non-problem area status;

c. Discuss the reliability of model predictions for the different nutrient reduction scenarios.

The report is organised as follows:

A large part of the model description and the model results are presented in appendices. The OSPAR common procedure is presented in Appendix A. The validation method and the station data used for the model validation are discussed in section 3.1. The methods used for the OSPAR assessments and the evaluations of effects of nutrient reduction scenarios are discussed in section 3.2.

The results of the model validation and the nutrient reduction scenarios are discussed in section 4.1 and 4.2 respectively. Final conclusions and discussions are presented in section 5.

3. Material and methods

The preliminary aim of the OSPAR model assessment is to obtain estimates of some of the parameters suggested by the OSPAR to describe the eutrophication status in the sea. The procedure should enable a classification of the maritime areas in terms of problem areas, potential problem areas and non-problem areas with regard to eutrophication. A secondary aim of the model assessments within the OSPAR modelling community is to discuss the relevance of the selected set of parameters and possibly to suggest improvements of the same. The checklist of qualitative parameters and the assessment criteria that are suggested for the classification are presented in Appendix A.

The Swedish SCOBI model is used to describe the degree of nutrient enrichment (Category I) defined by the winter surface concentrations and ratios of DIN and DIP. The direct effects of nutrient enrichment during growing season (Category II) are described in terms of the mean and maximum chlorophyll concentrations and model estimations of net primary production and sedimentation. The indirect effects of nutrient enrichment (Category III) may be discussed in terms of oxygen depletion in bottom waters. Region specific background concentrations and threshold values used for the model assessment here are from the OSPAR 2002 data assessment of the 1990s (OSPAR assessment 2002).

The model system (Figure 1), below called the OSPAR model, covers the Skagerrak and the Kattegat area. The open sea area has been divided into six large basins. Two describe the offshore areas and four describe the coastal areas along the Swedish and Norwegian coasts. The coastal elements are connected to three Swedish coastal zone models which all together make up the OSPAR model system of 83 sub basins. The model and the forcing of the model are further described in Appendix B.

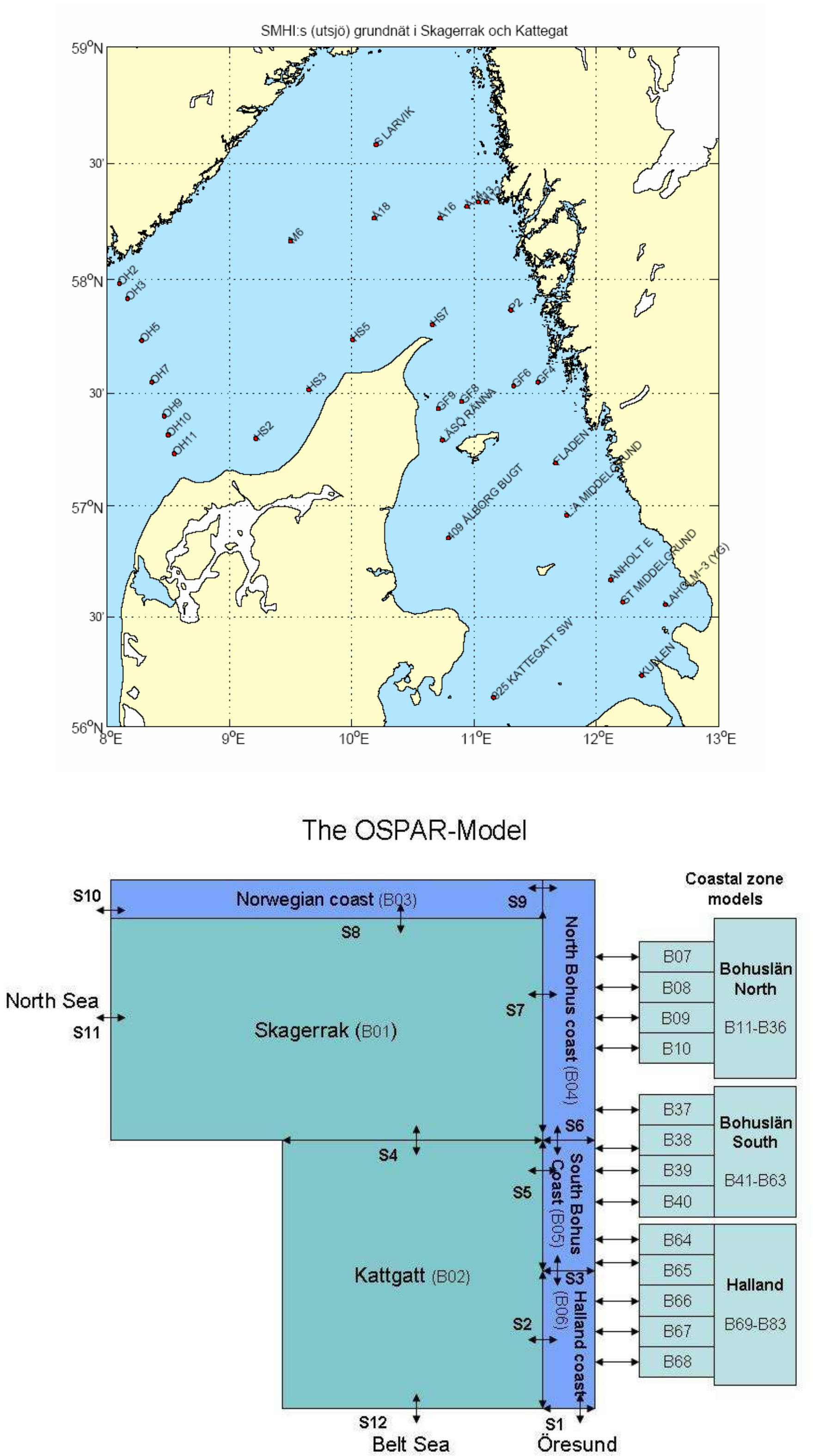


Figure 1. Above: Map showing the SMHI standard monitoring stations of the Kattegat and Skagerrak area. The sampling stations used for model evaluation here are included.
Below: A schematic figure of the OSPAR model showing the location of the six main basins (marked with B) and the 12 sounds (marked with S) including the coupling to the Swedish coastal zone models.

3.1. Model validation method

The model is validated by a comparison of a long time series (1985-2002) of the model results to data from a number of stations representing different parts of the model domain. This comparison gives a qualitative impression about the correlation between model results and in-situ data and it indicates how well the model responses to varying natural forcing. A more quantitative examination of the model performance is also done by a comparison between the seasonal and annual averages of the model results and in-situ data. For this comparison we used a cost function, an equation which is applied to give a quantitative measure of the agreement between the model results and data. The cost function is described below.

The model results are validated against data extracted from the Swedish ocean data base (SHARK). For each basin, except for the Norwegian coastal basin (B03) because of lack of data, one standard monitoring station was selected as a reference.

The corresponding stations used here are (see also Figure 1):

B01 – Station M6	(N5810, E0930)
B02 – Station Anholt	(N5640, E1207)
B03 – No Data	
B04 – Station Å13	(N5820, E1102)
B05 – Station GF4	(N5733, E1131)
B06 – Kullen	(N5614, E1222)

In Kattegat (B02) the time series of model results of salinity and oxygen are also compared to the station Fladen (N5711, E1140) to show differences between the stations within the basin. In each basin the time development of the model results (1985-2002) for temperature (T), salinity (S), chlorophyll (Chl), total nitrogen (TotN), nitrate (NO3), total phosphorus (TotP), phosphate (PO4) and oxygen (O2) are compared against available observations in the surface layer (0m) and at a standard depth from the deeper layers (Appendix C). The composition of organic matter in the model is based on the Redfield molar ratio (C:N:P=106:16:1), where C is carbon, and a constant C:Chl ratio (1:50) is used to express the model phytoplankton biomass in chlorophyll values.

Seasonal and annual statistics for the period 1990-1994 for the same parameters as shown in the time plots are presented for the Kattegat (B02) data (Appendix D) and for the Skagerrak (B01) data (Appendix E).

The surface layer Cost Function for all pelagic variables in all basins is presented in Appendix F. The annual average transports of nutrients and water both from land and from the open boundaries are presented in Appendix G. Atmospheric deposition and budget calculations for the Kattegat–Skagerrak model area are also presented there.

The results from the validation exercises are summarised in section 4.1.

The Cost Function is a mathematical function which provides a useful means of comparing data from two different sources. The cost function gives a non-dimensional number which is indicative of the ‘goodness of fit’ between two sets of data. It can also be used to quantify the difference between two simulations of the same model. For the ASMO Eutrophication modelling workshop in 1996 the Cost Functions were used for model validation exercises.

The Cost Function in the present report is computed for each standard depth in each sub-basin of the Skagerrak and the Kattegat as described below.

Function:

$$C_{z,x,t} = \left| \frac{M_{z,x,t} - D_{z,x,t}}{sd_{z,x,t}} \right|$$

with

$C_{z,x,t}$ normalised (in sd units) deviation between model and data for each standard depth z, sub-basin x and season t

$M_{z,x,t}$ mean value of the model results within z, x and t

$D_{z,x,t}$ mean value of the in situ data within z, x and t

$sd_{z,x,t}$ standard deviation of the in situ data within z, x and t

From the figures of the results shown in section Appendix D and Appendix E it is possible to get an image of how the Cost Function relates to the difference between model results and measurement data at different depths and during different seasons. In accordance with the ASMO Eutrophication modelling workshop in 1996 we (subjectively) define the following ranges for the interpretation of the Cost Function values.

Good	< 1 std. deviation
Reasonable	1-2 std. deviations
Poor	>2 std. deviations

One may note that the value of the Cost Function becomes large if the modelled mean value differs much from the mean value of the in situ data. In these cases it is important to identify the cause of the differences and to find measures that may improve the model performance. The Cost Function may also obtain high values when the mean values are close to zero and the standard deviation is small. In this case the difference in absolute values may be small though the Cost Function may indicate poor results. 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.

3.2. OSPAR assessment and reduction scenarios method

For the nutrient reduction scenarios the reference case of the model is here defined by the year 1994. Nutrient supplies and physical forcing of the model is taken from this year. This year the inflow of nutrients from the Baltic Sea was rather normal for the investigated period. The results of this year are compared to results from the year 1994 in the original run 1985-2002 and to results from the OSPAR 2002 data assessment of the 1990s. Available data found from the SHARK database in the same year 1994 are also presented for comparison. The investigation shows that nitrate concentrations in 1994 were higher than average in the 1990s.

The same year is run over and over again until a “steady state” is obtained in the results. By this the standard case is defined to which effects of changed supplies of nutrients are evaluated. For each nutrient reduction scenario the 1994 model is run to a new “steady state” with the only difference given by the suggested nutrient reduction. Any effects obtained in this way should therefore give a clear signal connected to the actions taken. The “steady state” situations of the different cases may then be evaluated in accordance with the common procedure. The effects of nutrient reductions are presented in tables in accordance with the OSPAR work shop on eutrophication modelling held in Hamburg September 2005 (ICG_EMO, 2005).

A 20 year investigation of the model response to nutrient reductions show that it takes about 8-10 years for the phosphorus concentrations at the sea surface to reach 99% of the steady state conditions. The response time for the benthic phosphorus concentrations is a couple of years longer. For the reduction scenarios the model year 1994 is therefore repeated 10 times and the evaluation of the effects of the proposed reduction is performed on the last year of the run. Results from the repeated year are compared to results from the 10th year of the 1994 reference run without reduction. In Appendix H results from the repeated year are compared to results from the year 1994 in the original run 1985-2002, and to results from the OSPAR 2002 data assessment of the 1990s, and to data from the SHARK database in the year 1994.

The present report includes results from 9 nutrient reduction scenarios (see section 4.2). The first three experiments (section 4.2.1-4.2.3) aim to show the responsiveness of the model to nutrient reductions performed at different sources. Four scenarios (section 4.2.4-4.2.7) show the model response to a 50% reduction of the anthropogenic fraction of the land loads of nitrogen and phosphorus. The OSPAR 2002 assessment concluded from a special study on Swedish source apportionment that 70% of the total nitrogen and 40% of the total phosphorus was due to anthropogenic activities. These fractions are also used here for the Norwegian and Danish runoff.

One scenario (section 4.2.8) includes an attempt to estimate reduction of nitrogen and phosphorus from the Baltic Sea. This scenario is based on the assumption that the nutrient concentrations of the south western Baltic Sea are reduced to the level of a non problem area according to HELCOM EUTRO Swedish National report (2005). The winter surface values of DIP, TotP and DIN, TotN are therefore assumed to become 0.38 mmolDIPm^{-3}, 0.75 mmolTotPm^{-3}, 4.5 mmolDINm^{-3} and 26.0 mmolTotNm^{-3} when the effects of nutrient reductions have been established. The winter surface values of 1994 were about 0.60 mmolDIPm^{-3}, 0.97 mmolTotPm^{-3}, 6.5 mmolDINm^{-3}, and 27.6 mmolTotNm^{-3}, respectively. The 1994 data (SHARK) was extracted from the central Arkona basin for this comparison. This corresponds to a reduction of about 0.22 mmolDIPm^{-3} (37%) of DIP and about 2.0 mmolDINm^{-3} (31%) of DIN which is fairly well in accordance with the suggested reduction of winter concentrations of TotP (0.22 mmolTotPm^{-3}) and TotN (1.6 mmolTotNm^{-3}). The reduction of nutrient concentrations in summer time is assumed to be less than in winter. The reduction scenario used in section 4.2.8 is therefore set to 35% TotN and 20% TotP from land in all counties + a reduction from the Baltic Sea of 35% DIN and DIP in winter, and 10% TotN and TotP in summer. Winter is here defined as the period reaching from October to March. The other half of the year is defined as summer.

The last scenario (section 4.2.9) includes an assumed reduction of total nitrogen and total phosphorus also from the North Sea. The results of other model exercises (e.g. Skogen & al., 2004) indicate that the effect of nutrient reductions at the continental rivers in the North Sea may have a significant effect on the winter nutrient concentrations on the downstream side in Skagerrak. The reduction of the primary production in the Skagerrak of their model is of the order of 5-10%. The reduction scenario used in section 4.2.9 is set to 35% TotN and 20% TotP from land in all counties + a reduction from the Baltic Sea of 35% DIN and DIP in winter, and 10% TotN and TotP in summer+ an all year reduction from the North Sea of 10% TotN and TotP.

4. Results

4.1. Model validation

The model validation exercises have shown that the results are mainly in good agreement with observations from the different basins. The time series validation shows that the model reproduces the variations in the surface layers rather good. This is also confirmed by the surface layer Cost Function which for all variables in all basins normally is in the range 0-1 standard deviations with only a few exceptions. The major characteristics of the lower layers are also fairly well captured. The variability of the model is less than seen from observations especially in the lower layers of the Swedish coastal basins. The statistical comparison especially in the Kattegat show good results for the model – data comparison. There are problems capturing the low oxygen concentrations during late summer and autumn mainly due to the horizontal resolution of the model. This also moderates the phosphorus dynamics in the bottom waters of the Kattegat model. The results might be improved by a separation of the northern and southern parts of the Kattegat. The intermediate waters below the summer stratification in the Skagerrak are not well described due to the rough boundary conditions applied at the North Sea boundary. This erroneous stratification also has some implications for the Kattegat and the coastal areas as well. Increasing the vertical resolution of the forcing at the western boundary would definitely improve the model results. Introducing a separate basin for the Jutlandic current might also improve some of the characteristics of the model in the Kattegat and the Swedish coastal waters of the Skagerrak. The surface layer salinity of the Swedish coastal basin B05 is somewhat too low. This is partly due to the runoff from the river Göta Älv that has its outlet from the coastal zone to this model basin. It is however likely that a fraction of the river runoff should be directed to the Skagerrak coastal basin B04 instead.

The OSPAR assessment of the model year 1994 show that there are small differences between the reference run, where the year 1994 is repeated 10 times, and the year 1994 seen from the original run 1985-2002. The results are also fairly well in accordance with available observations from this year. The environmental conditions in the year 1994 is however somewhat different from the average conditions reported for the 1990s in the OSPAR 2002 report. The nitrogen concentrations are generally higher and the phosphate concentrations are lower in the south eastern Kattegat. The annual netproduction of phytoplankton in the model ranges from 62 $gCm^{-2}yr^{-1}$ in the central Skagerrak, to 87 $gCm^{-2}yr^{-1}$ in the eastern Kattegat. The amount of sinking organic matter reaching the model sediments ranges from 28 $gCm^{-2}yr^{-1}$ in the Skagerrak, to 48 $gCm^{-2}yr^{-1}$ in the Kattegat. The sedimentation is less than the export production estimation of 63-76 $gCm^{-2}yr^{-1}$ derived using an f-ratio of 1/3 on the primary production (190-230 $gCm^{-2}yr^{-1}$) reported for the Kattegat area by OSPAR (2002). Including the supply of dissolved organic nutrients from the open boundaries into the biogeochemical cycle would increase the production capacity and the sedimentation of the model and it would also have some impact on the oxygen consumption of the bottom layers. It is however unclear at present how much of these nutrients that are available for primary production. The dissolved organic nutrients are therefore modelled as biogeochemically inert substances in the present model.

Proposed model improvements

- Separate the northern and southern parts of the Kattegat.
- Increase the vertical resolution of the forcing at the western boundary.
- Introduce a separate basin for the Jutlandic current.
- Improve the location of Göta Älv river runoff to the coastal basins.
- Implement and investigate the importance of dissolved organic nutrients in the model.

4.2. Nutrient reduction scenarios

The results from the following nutrient reduction scenarios are presented in this section.

Section 4.2.1: Case 1. Reduction 50% TotN and TotP from land, all countries.
Section 4.2.2: Case 2. Reduction 50% TotN and TotP from the Baltic Sea.
Section 4.2.3: Case 3. Reduction 30% TotN and TotP from the North Sea.
Section 4.2.4: Case 4. Reduction 35% TotN and 20% TotP from land, all countries
Section 4.2.5: Case 5. Reduction 35% TotN and 20% TotP from land, only Sweden
Section 4.2.6: Case 6. Reduction 35% TotN and 20% TotP from land, only Norway
Section 4.2.7: Case 7. Reduction 35% TotN and 20% TotP from land, only Denmark
Section 4.2.8: Case 8. Reduction 35% TotN and 20% TotP from land, all counties + reduction from the Baltic Sea 35% DIN and DIP in winter, and 10% TotN and TotP in summer.
Section 4.2.9: Case 9. Reduction 35% TotN and 20% TotP from land, all counties + reduction from the Baltic Sea 35% DIN and DIP in winter, and 10% TotN and TotP in summer + reduction from the North Sea 10% DIN and DIP in winter, and 10% TotN and TotP in summer.

The results of the reference run, i.e. the year 1994 repeated 10 times, are presented separately in Appendix H with an assessment for each of the six sub basins of the Skagerrak and Kattegat model. The results of the reference run are compared to the original run 1985-2002 and to the OSPAR 2002 data assessment and to available in-situ data from the SHARK database.

The results for each reduction case are presented in tables including an assessment for each of the six sub basins of the Skagerrak and Kattegat model. The assessment is done on the surface layer characteristics taken from the upper most cell of the model. The maximum values of chlorophyll, dissolved inorganic nitrogen and phosphorus values and the corresponding N:P ratio are presented. The average winter (January-February) values of dissolved inorganic nitrogen and phosphorus values and the corresponding N:P ratio are presented. The average production period (March-October) chlorophyll values are presented. Cases 4-9 also include values of the vertically integrated annual net production and sedimentation of organic matter in the model. The contents of the tables in this section are described here.

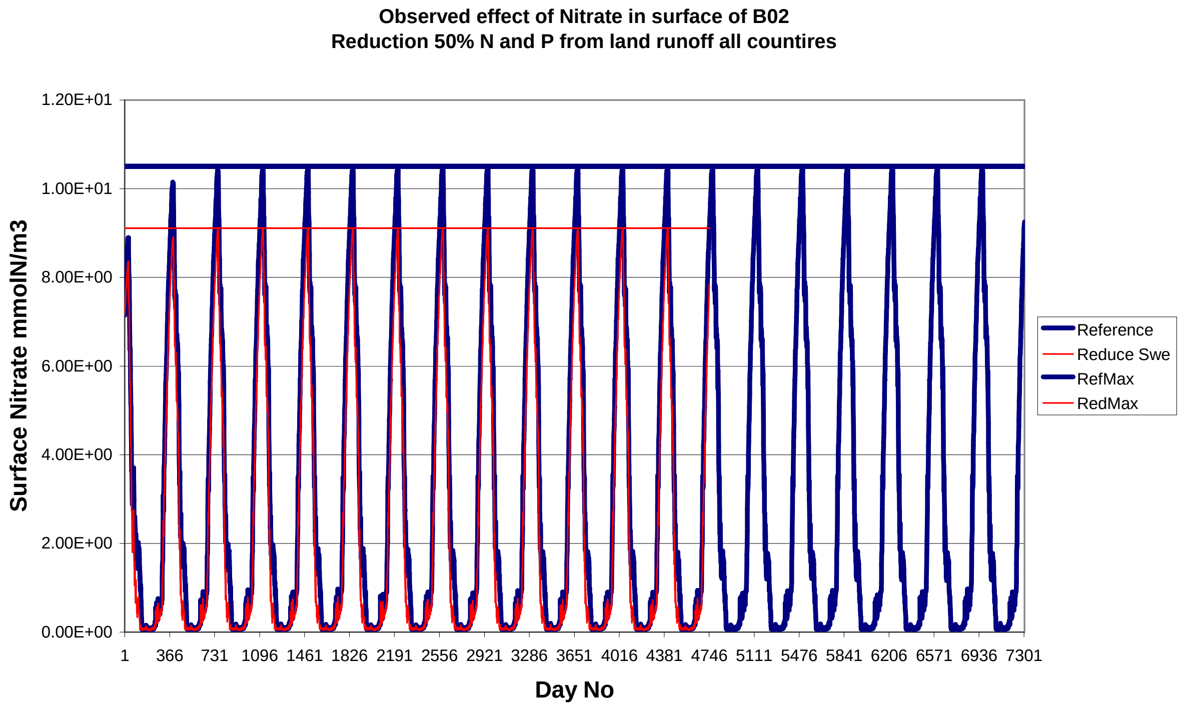
The header of each table shows the name of the basin and the index used in the OSPAR model. Columns 3-7 show numerical values and columns 8-10 show the sign convention used for OSPAR assessment (Appendix A). Blue background colour is used here to highlight the negative sign (-) which is used to indicate acceptable conditions for the actual parameter. Red indicates elevated levels (+).

- Column 1: The OSPAR assessment category that the investigated parameter belongs to.
- Column 2: The OSPAR assessment parameter.
- Column 3: The results of the reference run, i.e. the year 1994 repeated 10 times (Reference).
- Column 4: The results of the reduction case (Reduce).
- Column 5: The difference between the reduction case and the reference run expressed in %.
- Column 6: Results from the OSPAR 2002 data assessment of the 1990s (CP 2002).
- Column 7: The threshold value for elevated levels according to CP 2002 (Treshold).
- Column 8: The OSPAR assessment results for the reference run.
- Column 9: The OSPAR assessment results for the reduction case.
- Column 10: The OSPAR assessment results for CP 2002.

To illustrate the effects of nutrient reduction in the model and to interpret the results of the reduction scenarios it is informative to look at two different cases with somewhat different results. The first case (Figure 2) shows the model response for a 50% reduction of TotN and TotP from the runoff in all countries (Case 1). The results from the surface layer (0m) of the Kattegat (B02) are compared to the reference case without reduction. The nitrate concentrations reach the steady state conditions within 3 years and the phosphate concentrations within about 10 years as mentioned earlier. One may note that the maximum winter concentrations of the reduction run are lower than the reference case in all years.

The second case (Figure 3) shows the model response for a 35% reduction of TotN and a 20% of TotP from the runoff in Sweden (Case 5). The results from the surface layer (0m) of the Kattegat (B02) are again compared to the reference case without reduction. The nitrate concentrations reach the steady state conditions within 5 years and the phosphate concentrations within about 10 years as mentioned above. One may however note that the maximum winter concentrations of the reduction run become higher than the reference case in the beginning of the run. This situation still remain for phosphorus after 10 years of model run since the concentrations of the reference case increases and approaches the steady state concentrations “from below” while the reduction case has decreasing concentrations approaching the steady state concentrations “from above”. However, after 20 years of model run the maximum winter concentrations of the reduction run has become slightly lower than in the reference case as one would have expected. To further investigate the cause of the increase of nutrient concentrations during the first years of the model run is out of the scope of the present project. It is however likely that this effect is caused by an interaction with the nutrients stored in the model sediments which act as a memory of the past environmental conditions in the model.

Hence, the exercise shows that there are still changes going on in the phosphorus pool of the model domain after 10 years of model run but that these changes are quite small. The results also show that looking on short term effects one may obtain a bit confusing results of a nutrient reduction in the model.



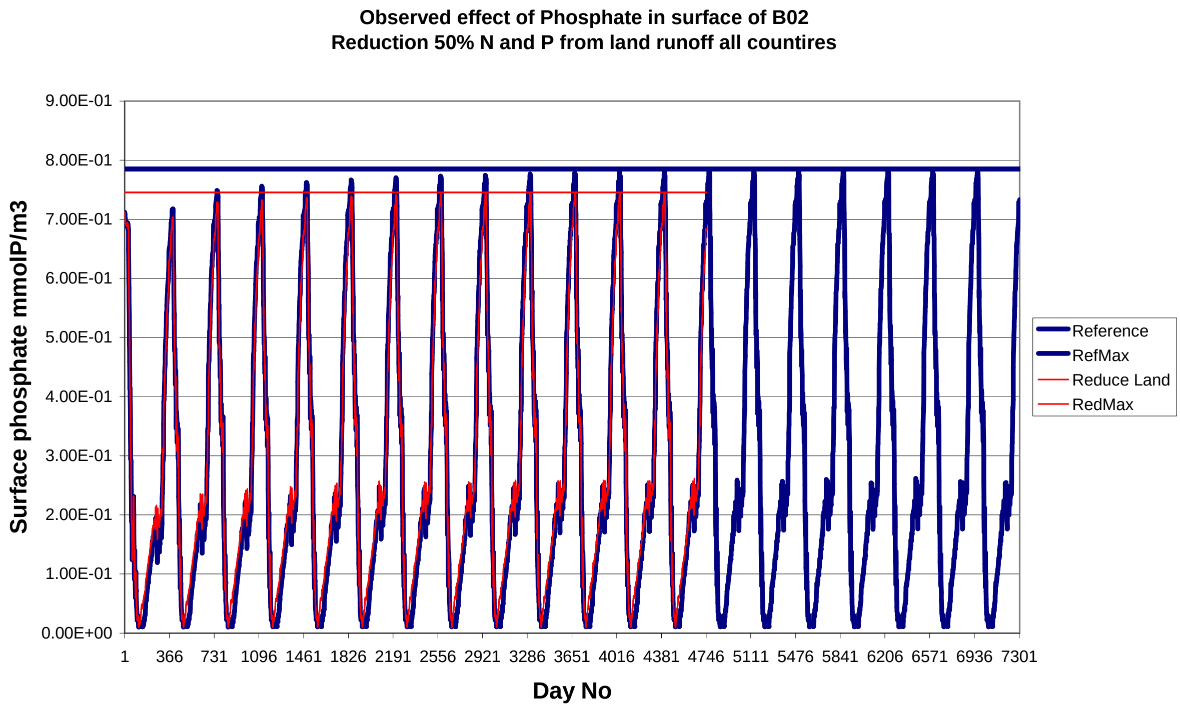
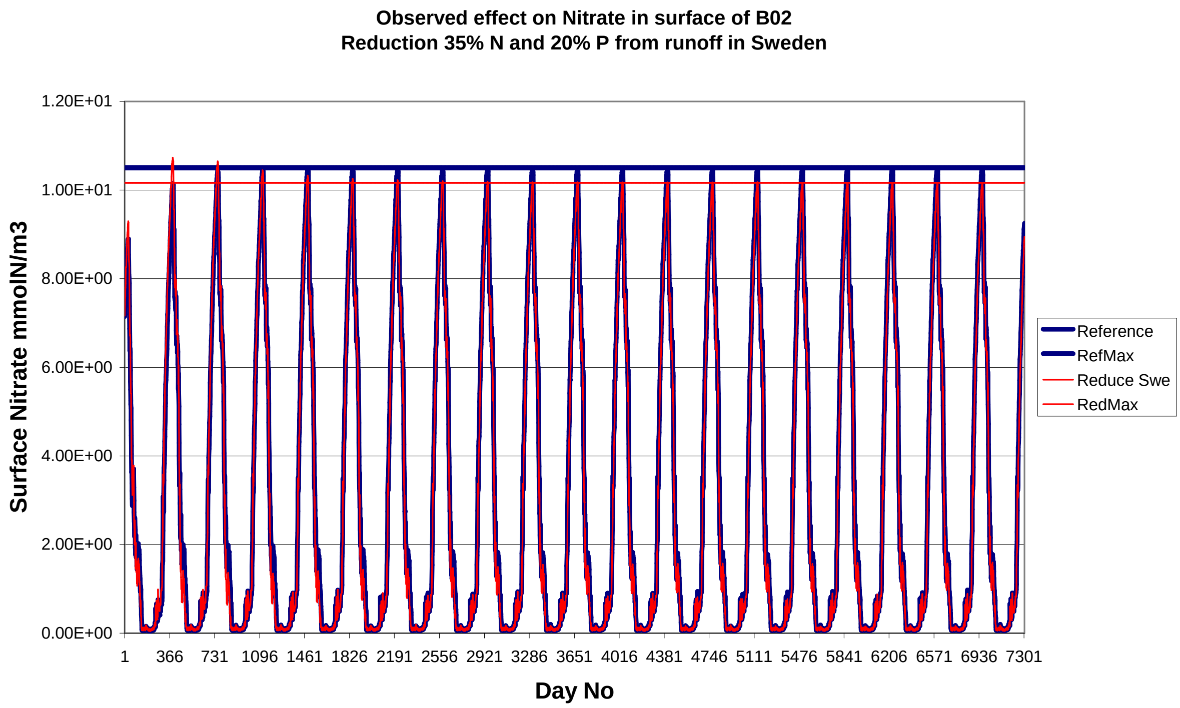


Figure 2. Development of surface layer(0m) nitrate (upper) and phosphate (lower) in the offshore Kattegat basin (B02). The blue line represents the reference run when the year 1994 is repeated 20 times. The maximum value is indicated by the blue horizontal line. The red line represents the reduction run when the year 1994 is repeated 13 times with a 50% reduction of TotN and TotP from land in all countries (Sweden, Norway and Denmark). The maximum value is indicated by the red horizontal line.



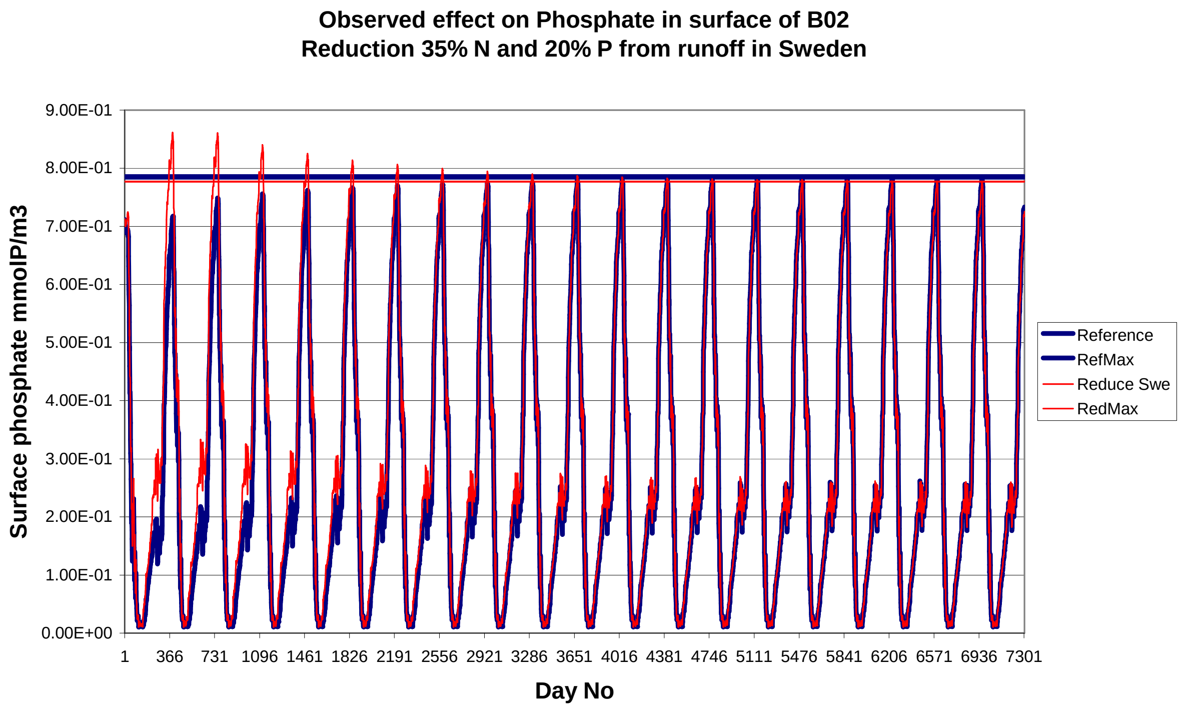


Figure 3. Development of surface layer (0m) nitrate (upper) and phosphate (lower) in the offshore Kattegat basin (B02). The blue line represents the reference run when the year 1994 is repeated 20 times. The maximum value is indicated by the blue horizontal line. The red line represents the reduction run when the year 1994 is repeated 13 times with a 35% reduction of TotN and a 20% reduction of TotP from land runoff in Sweden. The maximum value is indicated by the red horizontal line.

4.2.1. Reduction case 1

Results from Case 1: Reduction 50% TotN and TotP from land, all counties.

The absolute values of average winter nutrient concentrations in the results of the Reference run and the Original run show greatest differences on the nitrate values with the largest reduction effects found in the Kattegat (14%) and the coastal areas of Kattegat (15%-20%). The phosphorus values are reduced by 5% in the same area. The effects in the Swedish parts of the Skagerrak coastal area are only slightly lower than in the Kattegat. The central Skagerrak and the Norwegian coastal basins show less than 8% reduction of nitrate and 2% reduction of phosphate values. The reduction of the average chlorophyll values is 5%-8% in the Kattegat and the coastal areas of Kattegat and Skagerrak.

OSPAR assessment: The differences between the reference run and the reduction case are found in B05 where the DIP value is changed and in B04 where the mean chlorophyll value is changed. The greatest difference of the assessment is in the Skagerrak coastal basin B04 which is classified as a problem area by the reference run but not by the reduction case.

Table 1. Results of reduction case 1.

	Skagerrak offshore	B01				OSPAR assessment			
	Surface	Reference	Reduce	Diff %	CP 2002	Treshold	Reference	Reduce	CP 2002
Cat I	Max DIN (µM)	8.79	8.23	-6.43					
	Max DIP (µM)	0.65	0.64	-1.53					
	N:P ratio	13.52	12.85	-4.98					
Cat I	Mean jan-feb DIN (µM)	8.11	7.67	-5.44	8.00	15.00	-	-	-
	Mean jan-feb DIP (µM)	0.60	0.59	-1.87	0.60	0.90	-	-	-
	N:P ratio	13.46	12.97	-3.63	16.00	25.00	-	-	-
Cat II	Max Chl (µg/l)	3.65	3.63	-0.62					
	Mean mar-oct Chl (µg/l)	2.03	1.98	-2.70	2.00	2.25	-	-	-

	Kattegatt offshore	B02				OSPAR assessment			
	Surface	Reference	Reduce	Diff %	CP 2002	Treshold	Reference	Reduce	CP 2002
Cat I	Max DIN (µM)	11.60	10.03	-13.5					
	Max DIP (µM)	0.78	0.74	-4.2					
	N:P ratio	14.94	13.48	-9.7					
Cat I	Mean jan-feb DIN (µM)	9.82	8.42	-14.2	7.00	6.00	+	+	+
	Mean jan-feb DIP (µM)	0.65	0.62	-4.1	0.65	0.60	+	+	+
	N:P ratio	15.20	13.60	-10.5	16.00	25.00	-	-	-
Cat II	Max Chl (µg/l)	4.87	4.77	-2.2					
	Mean mar-oct Chl (µg/l)	2.40	2.28	-5.1	2.00	2.25	+	+	-

	Skagerrak coastal	B03				OSPAR assessment			
	Surface	Reference	Reduce	Diff %	CP 2002	Treshold	Reference	Reduce	CP 2002
Cat I	Max DIN (µM)	8.94	8.17	-8.62					
	Max DIP (µM)	0.63	0.62	-1.34					
	N:P ratio	14.16	13.12	-7.38					
Cat I	Mean jan-feb DIN (µM)	8.17	7.53	-7.77	8.00	15.00	-	-	-
	Mean jan-feb DIP (µM)	0.59	0.58	-2.02	0.60	0.90	-	-	-
	N:P ratio	13.91	13.09	-5.86	16.00	25.00	-	-	-
Cat II	Max Chl (µg/l)	3.45	3.43	-0.58					
	Mean mar-oct Chl (µg/l)	2.08	1.97	-5.29	3.00	2.25	-	-	+

	Skagerrak coastal	B04				OSPAR assessment			
	Surface	Reference	Reduce	Diff %	CP 2002	Treshold	Reference	Reduce	CP 2002
Cat I	Max DIN (µM)	10.75	8.99	-16.4					
	Max DIP (µM)	0.70	0.67	-4.2					
	N:P ratio	15.42	13.46	-12.7					
Cat I	Mean jan-feb DIN (µM)	8.99	7.80	-13.2	8.00	15.00	-	-	-
	Mean jan-feb DIP (µM)	0.61	0.58	-4.1	0.60	0.90	-	-	-
	N:P ratio	14.76	13.36	-9.50	16.00	25.00	-	-	-
Cat II	Max Chl (µg/l)	6.26	6.01	-4.04					
	Mean mar-oct Chl (µg/l)	2.33	2.14	-7.96	3.00	2.25	+	-	+

	Kattegatt coastal	B05				OSPAR assessment			
	Surface	Reference	Reduce	Diff %	CP 2002	Treshold	Reference	Reduce	CP 2002
Cat I	Max DIN (µM)	13.84	10.46	-24.41					
	Max DIP (µM)	0.76	0.72	-4.81					
	N:P ratio	18.24	14.48	-20.60					
Cat I	Mean jan-feb DIN (µM)	9.96	8.06	-19.05	7.00	6.00	+	+	+
	Mean jan-feb DIP (µM)	0.60	0.56	-5.61	0.65	0.60	+	-	+
	N:P ratio	16.69	14.32	-14.23	16.00	25.00	-	-	-
Cat II	Max Chl (µg/l)	6.24	5.94	-4.85					
	Mean mar-oct Chl (µg/l)	2.68	2.46	-8.41	2.50	2.25	+	+	+

	Kattegatt coastal	B06				OSPAR assessment			
	Surface	Reference	Reduce	Diff %	CP 2002	Treshold	Reference	Reduce	CP 2002
Cat I	Max DIN (µM)	12.94	10.50	-18.81					
	Max DIP (µM)	0.78	0.75	-4.16					
	N:P ratio	16.60	14.06	-15.28					
Cat I	Mean jan-feb DIN (µM)	8.12	6.94	-14.47	7.00	6.00	+	+	+
	Mean jan-feb DIP (µM)	0.52	0.50	-4.03	0.65	0.60	-	-	+
	N:P ratio	15.60	13.90	-10.88	16.00	25.00	-	-	-
Cat II	Max Chl (µg/l)	6.50	6.31	-2.84					
	Mean mar-oct Chl (µg/l)	2.80	2.63	-6.08	2.50	2.25	+	+	+

4.2.2. Reduction case 2

Results from Case 2: Reduction 50% TotN and TotP from the Baltic Sea.

The absolute values of average winter nutrient concentrations in the results of the Reference run and the Original run show greatest differences on the phosphate values with the largest reduction effects found in the Kattegat (28%) and the coastal areas of Kattegat (26%-31%). The nitrate values are reduced by 20%-25% in the same area. The effects in the Swedish parts of the Skagerrak coastal area are 12%-15% for both phosphate and nitrate. The central Skagerrak and the Norwegian coastal basins show less than 8% reduction of both nitrate phosphate values. The reduction of the average chlorophyll values is 8%-13% in the Kattegat and the coastal areas of Kattegat. The effects are much less in the Skagerrak.

OSPAR assessment: The differences between the reference run and the reduction case are found in B02 and B05 where the DIP value is changed and in B02 and B04 where the mean chlorophyll value is changed. The greatest difference of the assessment is in the Kattegat B02 and the Skagerrak coastal basin B04 which is classified as a problem area by the reference run but not by the reduction case.

Table 2. Results of reduction case 2.

	Skagerrak offshore	B01				OSPAR assessment			
	Surface	Reference	Reduce	Diff %	CP 2002	Treshold	Reference	Reduce	CP 2002
Cat I	Max DIN (µM)	8.79	8.12	-7.59					
	Max DIP (µM)	0.65	0.62	-4.75					
	N:P ratio	13.52	13.16	-2.99					
Cat I	Mean jan-feb DIN (µM)	8.11	7.53	-7.13	8.00	15.00	-	-	-
	Mean jan-feb DIP (µM)	0.60	0.56	-7.45	0.60	0.90	-	-	-
	N:P ratio	13.46	13.55	0.35	16.00	25.00	-	-	-
Cat II	Max Chl (µg/l)	3.65	3.54	-2.86					
	Mean mar-oct Chl (µg/l)	2.03	2.02	-0.92	2.00	2.25	-	-	-

	Kattegatt offshore	B02				OSPAR assessment			
	Surface	Reference	Reduce	Diff %	CP 2002	Treshold	Reference	Reduce	CP 2002
Cat I	Max DIN (µM)	11.60	9.02	-22.2					
	Max DIP (µM)	0.78	0.59	-23.8					
	N:P ratio	14.94	15.37	2.1					
Cat I	Mean jan-feb DIN (µM)	9.82	7.41	-24.5	7.00	6.00	+	+	+
	Mean jan-feb DIP (µM)	0.65	0.46	-28.3	0.65	0.60	+	-	+
	N:P ratio	15.20	16.13	5.3	16.00	25.00	-	-	-
Cat II	Max Chl (µg/l)	4.87	4.22	-13.9					
	Mean mar-oct Chl (µg/l)	2.40	2.21	-7.8	2.00	2.25	+	-	-

	Skagerrak coastal	B03				OSPAR assessment			
	Surface	Reference	Reduce	Diff %	CP 2002	Treshold	Reference	Reduce	CP 2002
Cat I	Max DIN (µM)	8.94	8.36	-6.38					
	Max DIP (µM)	0.63	0.60	-4.62					
	N:P ratio	14.16	13.93	-1.84					
Cat I	Mean jan-feb DIN (µM)	8.17	7.65	-6.27	8.00	15.00	-	-	-
	Mean jan-feb DIP (µM)	0.59	0.54	-6.84	0.60	0.90	-	-	-
	N:P ratio	13.91	14.04	0.62	16.00	25.00	-	-	-
Cat II	Max Chl (µg/l)	3.45	3.41	-2.87					
	Mean mar-oct Chl (µg/l)	2.08	2.07	-0.67	3.00	2.25	-	-	+

	Skagerrak coastal	B04				OSPAR assessment			
	Surface	Reference	Reduce	Diff %	CP 2002	Treshold	Reference	Reduce	CP 2002
Cat I	Max DIN (µM)	10.75	9.27	-13.3					
	Max DIP (µM)	0.70	0.60	-12.3					
	N:P ratio	15.42	15.34	-1.1					
Cat I	Mean jan-feb DIN (µM)	8.99	7.85	-12.6	8.00	15.00	-	-	-
	Mean jan-feb DIP (µM)	0.61	0.52	-14.6	0.60	0.90	-	-	-
	N:P ratio	14.76	15.23	2.34	16.00	25.00	-	-	-
Cat II	Max Chl (µg/l)	6.26	5.32	-14.60					
	Mean mar-oct Chl (µg/l)	2.33	2.24	-4.00	3.00	2.25	+	-	+

	Kattegatt coastal	B05				OSPAR assessment			
	Surface	Reference	Reduce	Diff %	CP 2002	Treshold	Reference	Reduce	CP 2002
Cat I	Max DIN (µM)	13.84	11.45	-16.91					
	Max DIP (µM)	0.76	0.58	-22.16					
	N:P ratio	18.24	19.58	6.74					
Cat I	Mean jan-feb DIN (µM)	9.96	7.90	-20.70	7.00	6.00	+	+	+
	Mean jan-feb DIP (µM)	0.60	0.43	-26.87	0.65	0.60	+	-	+
	N:P ratio	16.69	18.31	8.44	16.00	25.00	-	-	-
Cat II	Max Chl (µg/l)	6.24	5.01	-18.20					
	Mean mar-oct Chl (µg/l)	2.68	2.45	-8.82	2.50	2.25	+	+	+

	Kattegatt coastal	B06				OSPAR assessment			
	Surface	Reference	Reduce	Diff %	CP 2002	Treshold	Reference	Reduce	CP 2002
Cat I	Max DIN (µM)	12.94	10.04	-22.25					
	Max DIP (µM)	0.78	0.59	-23.29					
	N:P ratio	16.60	16.93	1.35					
Cat I	Mean jan-feb DIN (µM)	8.12	6.02	-25.92	7.00	6.00	+	+	+
	Mean jan-feb DIP (µM)	0.52	0.36	-31.00	0.65	0.60	-	-	+
	N:P ratio	15.60	16.88	7.36	16.00	25.00	-	-	-
Cat II	Max Chl (µg/l)	6.50	5.20	-19.46					
	Mean mar-oct Chl (µg/l)	2.80	2.43	-13.17	2.50	2.25	+	+	+

4.2.3. Reduction case 3

Results from Case 3: Reduction 30% TotN and TotP from the North Sea.

The absolute values of average winter nutrient concentrations in the results of the Reference run and the Original run show greatest differences on the phosphate values with the largest reduction effects found in the Skagerrak (27%) and the coastal areas of Skagerrak (22%-27%). The nitrate values are slightly less reduced, by 18%-25% in the same areas. The effects in the Kattegat basins are 12%-15% for phosphate and 10% for nitrate. The reduction of the average chlorophyll values is 7%-10% in the Skagerrak basins and 3%-5% in the Kattegat basins.

OSPAR assessment: The differences between the reference run and the reduction case are found in B02 and B05 where the DIP value is changed and in B04 where the mean chlorophyll value is changed. The greatest difference of the assessment is in the Skagerrak coastal basin B04 which is classified as a problem area by the reference run but not by the reduction case.

Table 3. Results of reduction case 3.

	Skagerrak offshore	**B01**				**OSPAR**	**assessment**		
	Surface	Reference	Reduce	Diff %	CP 2002	Treshold	Reference	Reduce	CP 2002
Cat I	Max DIN (µM)	8.79	6.65	-24.40					
	Max DIP (µM)	0.65	0.48	-26.37					
	N:P ratio	13.52	13.89	2.69					
Cat I	Mean jan-feb DIN (µM)	8.11	6.11	-24.74	8.00	15.00	-	-	-
	Mean jan-feb DIP (µM)	0.60	0.44	-26.64	0.60	0.90	-	-	-
	N:P ratio	13.46	13.81	2.60	16.00	25.00	-	-	-
Cat II	Max Chl (µg/l)	3.65	3.22	-11.85					
	Mean mar-oct Chl (µg/l)	2.03	1.84	-9.16	2.00	2.25	-	-	-

	Kattegatt offshore	**B02**				**OSPAR**	**assessment**		
	Surface	Reference	Reduce	Diff %	CP 2002	Treshold	Reference	Reduce	CP 2002
Cat I	Max DIN (µM)	11.60	10.24	-11.7					
	Max DIP (µM)	0.78	0.66	-14.7					
	N:P ratio	14.94	15.46	3.5					
Cat I	Mean jan-feb DIN (µM)	9.82	8.81	-10.2	7.00	6.00	+	+	+
	Mean jan-feb DIP (µM)	0.65	0.56	-13.6	0.65	0.60	+	-	+
	N:P ratio	15.20	15.80	3.9	16.00	25.00	-	-	-
Cat II	Max Chl (µg/l)	4.87	4.28	-12.2					
	Mean mar-oct Chl (µg/l)	2.40	2.33	-3.0	2.00	2.25	+	+	-

	Skagerrak coastal	**B03**				**OSPAR**	**assessment**		
	Surface	Reference	Reduce	Diff %	CP 2002	Treshold	Reference	Reduce	CP 2002
Cat I	Max DIN (µM)	8.94	7.01	-21.61					
	Max DIP (µM)	0.63	0.46	-27.57					
	N:P ratio	14.16	15.33	8.23					
Cat I	Mean jan-feb DIN (µM)	8.17	6.21	-24.01	8.00	15.00	-	-	-
	Mean jan-feb DIP (µM)	0.59	0.43	-27.23	0.60	0.90	-	-	-
	N:P ratio	13.91	14.52	4.43	16.00	25.00	-	-	-
Cat II	Max Chl (µg/l)	3.45	3.04	-11.87					
	Mean mar-oct Chl (µg/l)	2.08	1.88	-9.75	3.00	2.25	-	-	+

	Skagerrak coastal	**B04**				**OSPAR**	**assessment**		
	Surface	Reference	Reduce	Diff %	CP 2002	Treshold	Reference	Reduce	CP 2002
Cat I	Max DIN (µM)	10.75	9.16	-14.7					
	Max DIP (µM)	0.70	0.55	-21.0					
	N:P ratio	15.42	16.64	8.0					
Cat I	Mean jan-feb DIN (µM)	8.99	7.38	-17.9	8.00	15.00	-	-	-
	Mean jan-feb DIP (µM)	0.61	0.47	-22.1	0.60	0.90	-	-	-
	N:P ratio	14.76	15.56	5.42	16.00	25.00	-	-	-
Cat II	Max Chl (µg/l)	6.26	5.15	-17.73					
	Mean mar-oct Chl (µg/l)	2.33	2.16	-7.14	3.00	2.25	+	-	+

	Kattegatt coastal	**B05**				**OSPAR**	**assessment**		
	Surface	Reference	Reduce	Diff %	CP 2002	Treshold	Reference	Reduce	CP 2002
Cat I	Max DIN (µM)	13.84	12.58	-9.10					
	Max DIP (µM)	0.76	0.65	-14.67					
	N:P ratio	18.24	19.43	6.53					
Cat I	Mean jan-feb DIN (µM)	9.96	8.98	-9.77	7.00	6.00	+	+	+
	Mean jan-feb DIP (µM)	0.60	0.51	-14.29	0.65	0.60	+	-	+
	N:P ratio	16.69	17.57	5.28	16.00	25.00	-	-	-
Cat II	Max Chl (µg/l)	6.24	5.26	-15.61					
	Mean mar-oct Chl (µg/l)	2.68	2.56	-4.48	2.50	2.25	+	+	+

	Kattegatt coastal	**B06**				**OSPAR**	**assessment**		
	Surface	Reference	Reduce	Diff %	CP 2002	Treshold	Reference	Reduce	CP 2002
Cat I	Max DIN (µM)	12.94	11.71	-9.52					
	Max DIP (µM)	0.78	0.66	-15.07					
	N:P ratio	16.60	17.69	6.53					
Cat I	Mean jan-feb DIN (µM)	8.12	7.38	-9.07	7.00	6.00	+	+	+
	Mean jan-feb DIP (µM)	0.52	0.46	-12.32	0.65	0.60	-	-	+
	N:P ratio	15.60	16.18	3.71	16.00	25.00	-	-	-
Cat II	Max Chl (µg/l)	6.50	5.61	-13.62					
	Mean mar-oct Chl (µg/l)	2.80	2.65	-5.44	2.50	2.25	+	+	+

4.2.4. Reduction case 4

Results from Case 4: Reduction 35% TotN and 20% TotP from land, all countries.

The absolute values of average winter nutrient concentrations in the results of the Reference run and the Original run show greatest differences on the nitrate values with the largest reduction effects found in the Kattegat (10%) and the coastal areas of Kattegat (10%-14%). The phosphorus values remain unchanged in the same area. The effects in the Swedish parts of the Skagerrak coastal area are only slightly lower than in the Kattegat. The central Skagerrak and the Norwegian coastal basins show less than 6% reduction of nitrate and no reduction of phosphate values. The reduction of the average chlorophyll values is 3%-6% in the Kattegat and the coastal areas of Kattegat and Skagerrak. The netproduction is reduced by 3%-8% in the Swedish coastal basins B04, B05 and B06. The effects on sedimentation are less than 1%.

OSPAR assessment: The differences between the reference run and the reduction case are found in B05 where the DIP value is changed and in B04 where the mean chlorophyll value is changed. The greatest difference of the assessment is in the Skagerrak coastal basin B04 which is classified as a problem area by the reference run but not by the reduction case.

Table 4. Results of reduction case 4.

	Area	Results				OSPAR	assessment		
B01	Skagerrak offshore	Reference	Reduce	Diff %	CP 2002	Treshold	Reference	Reduce	CP 2002
Cat I	Max DIN (µM)	8.79	8.41	-4.3					
	Max DIP (µM)	0.65	0.65	0.0					
	N:P ratio	13.52	12.95	-4.3					
Cat I	Mean jan-feb DIN (µM)	8.11	7.82	-3.6	8.00	15.00	-	-	-
	Mean jan-feb DIP (µM)	0.60	0.60	-0.1	0.60	0.90	-	-	-
	N:P ratio	13.46	12.99	-3.5	16.00	25.00	-	-	-
Cat II	Max Chl (µg/l)	3.65	3.65	-0.1					
	Mean mar-oct Chl (µg/l)	2.03	1.99	-2.0	2.00	2.25	-	-	-
	Net production ($gCm^{-2}yr^{-1}$)	62.46	62.31	-0.2					
	Sedimentation (gCm-2yr-1)	32.06	32.17	0.3					

B02	Kattegatt offshore	Reference	Reduce	Diff %	CP 2002	Treshold	Reference	Reduce	CP 2002
Cat I	Max DIN (µM)	11.60	10.53	-9.2					
	Max DIP (µM)	0.78	0.78	0.1					
	N:P ratio	14.94	13.56	-9.2					
Cat I	Mean jan-feb DIN (µM)	9.82	8.87	-9.7	7.00	6.00	+	+	+
	Mean jan-feb DIP (µM)	0.65	0.65	0.0	0.65	0.60	+	+	+
	N:P ratio	15.20	13.73	-9.7	16.00	25.00	-	-	-
Cat II	Max Chl (µg/l)	4.87	4.91	0.8					
	Mean mar-oct Chl (µg/l)	2.40	2.32	-3.4	2.00	2.25	+	+	-
	Net production ($gCm^{-2}yr^{-1}$)	69.28	68.58	-1.0					
	Sedimentation (gCm-2yr-1)	47.78	47.71	-0.1					

B03	Skagerrak coastal	Reference	Reduce	Diff %	CP 2002	Treshold	Reference	Reduce	CP 2002
Cat I	Max DIN (µM)	8.94	8.41	-6.00					
	Max DIP (µM)	0.63	0.63	-0.04					
	N:P ratio	14.16	13.32	-5.96					
Cat I	Mean jan-feb DIN (µM)	8.17	7.74	-5.29	8.00	15.00	-	-	-
	Mean jan-feb DIP (µM)	0.59	0.59	-0.25	0.60	0.90	-	-	-
	N:P ratio	13.91	13.20	-5.06	16.00	25.00	-	-	-
Cat II	Max Chl (µg/l)	3.45	3.51	1.85					
	Mean mar-oct Chl (µg/l)	2.08	2.01	-3.30	3.00	2.25	-	-	+
	Net production ($gCm^{-2}yr^{-1}$)	66.97	66.86	-0.2					
	Sedimentation (gCm-2yr-1)	27.90	27.98	0.3					

B04	Skagerrak coastal	Reference	Reduce	Diff %	CP 2002	Treshold	Reference	Reduce	CP 2002
Cat I	Max DIN (µM)	10.75	9.43	-12.2					
	Max DIP (µM)	0.70	0.69	-0.7					
	N:P ratio	15.42	13.63	-11.6					
Cat I	Mean jan-feb DIN (µM)	8.99	8.16	-9.2	8.00	15.00	-	-	-
	Mean jan-feb DIP (µM)	0.61	0.60	-0.8	0.60	0.90	-	-	-
	N:P ratio	14.76	13.51	-8.51	16.00	25.00	-	-	-
Cat II	Max Chl (µg/l)	6.26	5.92	-5.50					
	Mean mar-oct Chl (µg/l)	2.33	2.19	-5.85	3.00	2.25	+	-	+
	Net production ($gCm^{-2}yr^{-1}$)	61.95	59.83	-3.4					
	Sedimentation (gCm-2yr-1)	40.15	40.19	0.1					

B05	Kattegatt coastal	Reference	Reduce	Diff %	CP 2002	Treshold	Reference	Reduce	CP 2002
Cat I	Max DIN (µM)	13.84	11.40	-17.58					
	Max DIP (µM)	0.76	0.76	-0.36					
	N:P ratio	18.24	15.09	-17.28					
Cat I	Mean jan-feb DIN (µM)	9.96	8.59	-13.77	7.00	6.00	+	+	+
	Mean jan-feb DIP (µM)	0.60	0.59	-0.98	0.65	0.60	+	-	+
	N:P ratio	16.69	14.54	-12.92	16.00	25.00	-	-	-
Cat II	Max Chl (µg/l)	6.24	5.97	-4.25					
	Mean mar-oct Chl (µg/l)	2.68	2.54	-5.52	2.50	2.25	+	+	+
	Net production ($gCm^{-2}yr^{-1}$)	74.15	67.66	-8.8					
	Sedimentation (gCm-2yr-1)	40.13	39.64	-1.2					

B06	Kattegatt coastal	Reference	Reduce	Diff %	CP 2002	Treshold	Reference	Reduce	CP 2002
Cat I	Max DIN (µM)	12.94	11.21	-13.34					
	Max DIP (µM)	0.78	0.78	0.18					
	N:P ratio	16.60	14.36	-13.49					
Cat I	Mean jan-feb DIN (µM)	8.12	7.29	-10.18	7.00	6.00	+	+	+
	Mean jan-feb DIP (µM)	0.52	0.52	-0.07	0.65	0.60	-	-	+
	N:P ratio	15.60	14.02	-10.12	16.00	25.00	-	-	-
Cat II	Max Chl (µg/l)	6.50	6.52	0.37					
	Mean mar-oct Chl (µg/l)	2.80	2.70	-3.59	2.50	2.25	+	+	+
	Net production ($gCm^{-2}yr^{-1}$)	86.98	84.29	-3.1					
	Sedimentation (gCm-2yr-1)	47.13	46.43	-1.5					

4.2.5. Reduction case 5

Results from Case 5: Reduction 35% TotN and 20% TotP from land, only Sweden.

The absolute values of average winter nutrient concentrations in the results of the Reference run and the Original run show greatest differences on the nitrate values with the largest reduction effects found in the coastal areas of Kattegat (6%-9%). The effects in the Swedish parts of the Skagerrak coastal area are only slightly lower (5%) than in the Kattegat. The central Skagerrak and the Norwegian coastal basins show 1% reduction of nitrate. The reduction of the average chlorophyll values is 3%-6% in the Kattegat and the coastal areas of Kattegat and Skagerrak. The netproduction is reduced by 2%-4% in the Swedish coastal basins B04, B05 and B06. The effects on sedimentation are less than 1%. The phosphorus values are not useful in this case since the system has not reached the final concentrations as discussed above. The conclusion is however that the effect on phosphorus is very small on longer time scales.

OSPAR assessment: There are no differences found between the reference run and the reduction case.

Table 5. Results of reduction case 5.

	Area	Results				OSPAR assessment			
B01	**Skagerrak offshore**	**Reference**	**Reduce**	**Diff %**	**CP 2002**	**Treshold**	**Reference**	**Reduce**	**CP 2002**
Cat I	Max DIN (µM)	8.79	8.66	-1.5					
	Max DIP (µM)	0.65	0.65	0.6					
	N:P ratio	13.52	13.25	-2.0					
Cat I	Mean jan-feb DIN (µM)	8.11	8.01	-1.2	8.00	15.00	-	-	-
	Mean jan-feb DIP (µM)	0.60	0.61	0.6	0.60	0.90	-	-	-
	N:P ratio	13.46	13.22	-1.8	16.00	25.00	-	-	-
Cat II	Max Chl (µg/l)	3.65	3.66	0.1					
	Mean mar-oct Chl (µg/l)	2.03	2.02	-0.4	2.00	2.25	-	-	-
	Net production (gCm^{-2}yr^{-1})	62.46	62.31	-0.2					
	Sedimentation (gCm-2yr-1)	32.06	32.17	0.3					

B02	**Kattegatt offshore**	**Reference**	**Reduce**	**Diff %**	**CP 2002**	**Treshold**	**Reference**	**Reduce**	**CP 2002**
Cat I	Max DIN (µM)	11.60	11.25	-3.0					
	Max DIP (µM)	0.78	0.79	1.7					
	N:P ratio	14.94	14.24	-4.7					
Cat I	Mean jan-feb DIN (µM)	9.82	9.55	-2.8	7.00	6.00	+	+	+
	Mean jan-feb DIP (µM)	0.65	0.66	1.7	0.65	0.60	+	+	+
	N:P ratio	15.20	14.54	-4.4	16.00	25.00	-	-	-
Cat II	Max Chl (µg/l)	4.87	4.97	2.0					
	Mean mar-oct Chl (µg/l)	2.40	2.39	-0.4	2.00	2.25	+	+	-
	Net production (gCm^{-2}yr^{-1})	69.28	68.58	-1.0					
	Sedimentation (gCm-2yr-1)	47.78	47.71	-0.1					

B03	**Skagerrak coastal**	**Reference**	**Reduce**	**Diff %**	**CP 2002**	**Treshold**	**Reference**	**Reduce**	**CP 2002**
Cat I	Max DIN (µM)	8.94	8.79	-1.75					
	Max DIP (µM)	0.63	0.63	0.49					
	N:P ratio	14.16	13.85	-2.23					
Cat I	Mean jan-feb DIN (µM)	8.17	8.06	-1.33	8.00	15.00	-	-	-
	Mean jan-feb DIP (µM)	0.59	0.59	0.55	0.60	0.90	-	-	-
	N:P ratio	13.91	13.64	-1.87	16.00	25.00	-	-	-
Cat II	Max Chl (µg/l)	3.45	3.52	2.11					
	Mean mar-oct Chl (µg/l)	2.08	2.08	0.10	3.00	2.25	-	-	+
	Net production (gCm^{-2}yr^{-1})	66.97	66.86	-0.2					
	Sedimentation (gCm-2yr-1)	27.90	27.98	0.3					

B04	**Skagerrak coastal**	**Reference**	**Reduce**	**Diff %**	**CP 2002**	**Treshold**	**Reference**	**Reduce**	**CP 2002**
Cat I	Max DIN (µM)	10.75	10.00	-7.0					
	Max DIP (µM)	0.70	0.70	0.8					
	N:P ratio	15.42	14.23	-7.7					
Cat I	Mean jan-feb DIN (µM)	8.99	8.53	-5.0	8.00	15.00	-	-	-
	Mean jan-feb DIP (µM)	0.61	0.61	0.6	0.60	0.90	-	-	-
	N:P ratio	14.76	13.94	-5.60	16.00	25.00	-	-	-
Cat II	Max Chl (µg/l)	6.26	5.98	-4.48					
	Mean mar-oct Chl (µg/l)	2.33	2.25	-3.14	3.00	2.25	+	+	+
	Net production (gCm^{-2}yr^{-1})	61.95	59.83	-3.4					
	Sedimentation (gCm-2yr-1)	40.15	40.19	0.1					

B05	**Kattegatt coastal**	**Reference**	**Reduce**	**Diff %**	**CP 2002**	**Treshold**	**Reference**	**Reduce**	**CP 2002**
Cat I	Max DIN (µM)	13.84	11.95	-13.62					
	Max DIP (µM)	0.76	0.77	1.20					
	N:P ratio	18.24	15.57	-14.64					
Cat I	Mean jan-feb DIN (µM)	9.96	9.05	-9.06	7.00	6.00	+	+	+
	Mean jan-feb DIP (µM)	0.60	0.60	0.69	0.65	0.60	+	+	+
	N:P ratio	16.69	15.08	-9.68	16.00	25.00	-	-	-
Cat II	Max Chl (µg/l)	6.24	6.03	-3.30					
	Mean mar-oct Chl (µg/l)	2.68	2.58	-3.78	2.50	2.25	+	+	+
	Net production (gCm^{-2}yr^{-1})	74.15	67.66	-8.8					
	Sedimentation (gCm-2yr-1)	40.13	39.64	-1.2					

B06	**Kattegatt coastal**	**Reference**	**Reduce**	**Diff %**	**CP 2002**	**Treshold**	**Reference**	**Reduce**	**CP 2002**
Cat I	Max DIN (µM)	12.94	11.77	-9.01					
	Max DIP (µM)	0.78	0.79	1.67					
	N:P ratio	16.60	14.86	-10.51					
Cat I	Mean jan-feb DIN (µM)	8.12	7.65	-5.80	7.00	6.00	+	+	+
	Mean jan-feb DIP (µM)	0.52	0.53	1.36	0.65	0.60	-	-	+
	N:P ratio	15.60	14.50	-7.06	16.00	25.00	-	-	-
Cat II	Max Chl (µg/l)	6.50	6.58	1.24					
	Mean mar-oct Chl (µg/l)	2.80	2.75	-1.70	2.50	2.25	+	+	+
	Net production (gCm^{-2}yr^{-1})	86.98	84.29	-3.1					
	Sedimentation (gCm-2yr-1)	47.13	46.43	-1.5					

4.2.6. Reduction case 6

Results from Case 6: Reduction 35% TotN and 20% TotP from land, only Norway.

The absolute values of average winter nutrient concentrations in the results of the Reference run and the Original run show less than 2 % differences. The reduction of the average chlorophyll values is less than 3% in the coastal areas Skagerrak. The netproduction is reduced by 2%-3% in the coastal basins B03, B04, B05 and B06. The effects on sedimentation are less than 1%. The phosphorus values are not useful in this case since the system has not reached the final concentrations as discussed above. The conclusion is however that the effect on phosphorus is very small on longer time scales.

OSPAR assessment: There are no differences found between the reference run and the reduction case.

Table 6. Results of reduction case 6.

	Area	Results				OSPAR	assessment		
B01	**Skagerrak offshore**	**Reference**	**Reduce**	**Diff %**	**CP 2002**	**Treshold**	**Reference**	**Reduce**	**CP 2002**
Cat I	Max DIN (µM)	8.79	8.74	-0.5					
	Max DIP (µM)	0.65	0.66	0.8					
	N:P ratio	13.52	13.35	-1.3					
Cat I	Mean jan-feb DIN (µM)	8.11	8.07	-0.5	8.00	15.00	-	-	-
	Mean jan-feb DIP (µM)	0.60	0.61	0.9	0.60	0.90	-	-	-
	N:P ratio	13.46	13.28	-1.3	16.00	25.00	-	-	-
Cat II	Max Chl (µg/l)	3.65	3.66	0.2					
	Mean mar-oct Chl (µg/l)	2.03	2.01	-0.8	2.00	2.25	-	-	-
	Net production ($gCm^{-2}yr^{-1}$)	62.46	62.13	-0.5					
	Sedimentation (gCm-2yr-1)	32.06	32.05	0.0					

B02	**Kattegatt offshore**	**Reference**	**Reduce**	**Diff %**	**CP 2002**	**Treshold**	**Reference**	**Reduce**	**CP 2002**
Cat I	Max DIN (µM)	11.60	11.57	-0.2					
	Max DIP (µM)	0.78	0.80	2.5					
	N:P ratio	14.94	14.55	-2.6					
Cat I	Mean jan-feb DIN (µM)	9.82	9.79	-0.3	7.00	6.00	+	+	+
	Mean jan-feb DIP (µM)	0.65	0.66	2.4	0.65	0.60	+	+	+
	N:P ratio	15.20	14.80	-2.7	16.00	25.00	-	-	-
Cat II	Max Chl (µg/l)	4.87	5.00	2.6					
	Mean mar-oct Chl (µg/l)	2.40	2.40	0.0	2.00	2.25	+	+	-
	Net production ($gCm^{-2}yr^{-1}$)	69.28	69.34	0.1					
	Sedimentation (gCm-2yr-1)	47.78	47.99	0.4					

B03	**Skagerrak coastal**	**Reference**	**Reduce**	**Diff %**	**CP 2002**	**Treshold**	**Reference**	**Reduce**	**CP 2002**
Cat I	Max DIN (µM)	8.94	8.71	-2.55					
	Max DIP (µM)	0.63	0.64	0.66					
	N:P ratio	14.16	13.71	-3.18					
Cat I	Mean jan-feb DIN (µM)	8.17	7.98	-2.31	8.00	15.00	-	-	-
	Mean jan-feb DIP (µM)	0.59	0.59	0.82	0.60	0.90	-	-	-
	N:P ratio	13.91	13.47	-3.10	16.00	25.00	-	-	-
Cat II	Max Chl (µg/l)	3.45	3.52	2.23					
	Mean mar-oct Chl (µg/l)	2.08	2.02	-2.95	3.00	2.25	-	-	+
	Net production ($gCm^{-2}yr^{-1}$)	66.97	64.40	-3.8					
	Sedimentation (gCm-2yr-1)	27.90	27.76	-0.5					

B04	**Skagerrak coastal**	**Reference**	**Reduce**	**Diff %**	**CP 2002**	**Treshold**	**Reference**	**Reduce**	**CP 2002**
Cat I	Max DIN (µM)	10.75	10.49	-2.4					
	Max DIP (µM)	0.70	0.71	1.4					
	N:P ratio	15.42	14.85	-3.7					
Cat I	Mean jan-feb DIN (µM)	8.99	8.84	-1.7	8.00	15.00	-	-	-
	Mean jan-feb DIP (µM)	0.61	0.62	1.4	0.60	0.90	-	-	-
	N:P ratio	14.76	14.32	-2.98	16.00	25.00	-	-	-
Cat II	Max Chl (µg/l)	6.26	6.04	-3.63					
	Mean mar-oct Chl (µg/l)	2.33	2.29	-1.65	3.00	2.25	+	+	+
	Net production ($gCm^{-2}yr^{-1}$)	61.95	60.12	-3.0					
	Sedimentation (gCm-2yr-1)	40.15	40.15	0.0					

B05	**Kattegatt coastal**	**Reference**	**Reduce**	**Diff %**	**CP 2002**	**Treshold**	**Reference**	**Reduce**	**CP 2002**
Cat I	Max DIN (µM)	13.84	13.59	-1.76					
	Max DIP (µM)	0.76	0.78	2.39					
	N:P ratio	18.24	17.50	-4.06					
Cat I	Mean jan-feb DIN (µM)	9.96	9.80	-1.55	7.00	6.00	+	+	+
	Mean jan-feb DIP (µM)	0.60	0.61	2.23	0.65	0.60	+	+	+
	N:P ratio	16.69	16.08	-3.69	16.00	25.00	-	-	-
Cat II	Max Chl (µg/l)	6.24	6.10	-2.14					
	Mean mar-oct Chl (µg/l)	2.68	2.67	-0.37	2.50	2.25	+	+	+
	Net production ($gCm^{-2}yr^{-1}$)	74.15	72.51	-2.2					
	Sedimentation (gCm-2yr-1)	40.13	39.97	-0.4					

B06	**Kattegatt coastal**	**Reference**	**Reduce**	**Diff %**	**CP 2002**	**Treshold**	**Reference**	**Reduce**	**CP 2002**
Cat I	Max DIN (µM)	12.94	12.75	-1.48					
	Max DIP (µM)	0.78	0.80	2.64					
	N:P ratio	16.60	15.94	-4.01					
Cat I	Mean jan-feb DIN (µM)	8.12	8.05	-0.83	7.00	6.00	+	+	+
	Mean jan-feb DIP (µM)	0.52	0.53	2.25	0.65	0.60	-	-	+
	N:P ratio	15.60	15.13	-3.01	16.00	25.00	-	-	-
Cat II	Max Chl (µg/l)	6.50	6.62	1.89					
	Mean mar-oct Chl (µg/l)	2.80	2.81	0.28	2.50	2.25	+	+	+
	Net production ($gCm^{-2}yr^{-1}$)	86.98	86.61	-0.4					
	Sedimentation (gCm-2yr-1)	47.13	47.32	0.4					

4.2.7. Reduction case 7

Results from Case 7: Reduction 35% TotN and 20% TotP from land, only Denmark.

The absolute values of average winter nutrient concentrations in the results of the Reference run and the Original run show greatest differences on the nitrate values with the largest reduction effects found in the Kattegat and the coastal areas of Kattegat (4%-6%). The effects in the Swedish parts of the Skagerrak coastal area are only slightly lower than in the Kattegat. The central Skagerrak and the Norwegian coastal basins show less than 2% reduction of nitrate. The reduction of the average chlorophyll values is less than 3%. The phosphorus values are not useful in this case since the system has not reached the final concentrations as discussed above. The conclusion is however that the effect on phosphorus is very small on longer time scales.

OSPAR assessment: There are no differences found between the reference run and the reduction case.

Table 7. Results of reduction case 7.

	Area	Results				OSPAR assessment			
B01	**Skagerrak offshore**	**Reference**	**Reduce**	**Diff %**	**CP 2002**	**Treshold**	**Reference**	**Reduce**	**CP 2002**
Cat I	Max DIN (µM)	8.79	8.60	-2.2					
	Max DIP (µM)	0.65	0.65	0.5					
	N:P ratio	13.52	13.16	-2.7					
Cat I	Mean jan-feb DIN (µM)	8.11	7.96	-1.8	8.00	15.00	-	-	-
	Mean jan-feb DIP (µM)	0.60	0.61	0.5	0.60	0.90	-	-	-
	N:P ratio	13.46	13.15	-2.3	16.00	25.00	-	-	-
Cat II	Max Chl (µg/l)	3.65	3.66	0.1					
	Mean mar-oct Chl (µg/l)	2.03	2.01	-0.9	2.00	2.25	-	-	-
	Net production (gCm^{-2}yr^{-1})	62.46	62.56	0.2					
	Sedimentation (gCm-2yr-1)	32.06	32.19	0.4					
B02	**Kattegatt offshore**	**Reference**	**Reduce**	**Diff %**	**CP 2002**	**Treshold**	**Reference**	**Reduce**	**CP 2002**
Cat I	Max DIN (µM)	11.60	10.95	-5.6					
	Max DIP (µM)	0.78	0.79	1.4					
	N:P ratio	14.94	13.92	-6.8					
Cat I	Mean jan-feb DIN (µM)	9.82	9.17	-6.6	7.00	6.00	+	+	+
	Mean jan-feb DIP (µM)	0.65	0.65	1.2	0.65	0.60	+	+	+
	N:P ratio	15.20	14.02	-7.8	16.00	25.00	-	-	-
Cat II	Max Chl (µg/l)	4.87	4.96	1.8					
	Mean mar-oct Chl (µg/l)	2.40	2.33	-3.0	2.00	2.25	+	+	-
	Net production (gCm^{-2}yr^{-1})	69.28	69.61	0.5					
	Sedimentation (gCm-2yr-1)	47.78	48.11	0.7					
B03	**Skagerrak coastal**	**Reference**	**Reduce**	**Diff %**	**CP 2002**	**Treshold**	**Reference**	**Reduce**	**CP 2002**
Cat I	Max DIN (µM)	8.94	8.76	-2.05					
	Max DIP (µM)	0.63	0.63	0.45					
	N:P ratio	14.16	13.81	-2.49					
Cat I	Mean jan-feb DIN (µM)	8.17	8.04	-1.62	8.00	15.00	-	-	-
	Mean jan-feb DIP (µM)	0.59	0.59	0.48	0.60	0.90	-	-	-
	N:P ratio	13.91	13.61	-2.10	16.00	25.00	-	-	-
Cat II	Max Chl (µg/l)	3.45	3.52	2.15					
	Mean mar-oct Chl (µg/l)	2.08	2.08	0.09	3.00	2.25	-	-	+
	Net production (gCm^{-2}yr^{-1})	66.97	66.93	-0.1					
	Sedimentation (gCm-2yr-1)	27.90	27.95	0.2					
B04	**Skagerrak coastal**	**Reference**	**Reduce**	**Diff %**	**CP 2002**	**Treshold**	**Reference**	**Reduce**	**CP 2002**
Cat I	Max DIN (µM)	10.75	10.35	-3.7					
	Max DIP (µM)	0.70	0.70	1.1					
	N:P ratio	15.42	14.69	-4.7					
Cat I	Mean jan-feb DIN (µM)	8.99	8.69	-3.3	8.00	15.00	-	-	-
	Mean jan-feb DIP (µM)	0.61	0.61	0.8	0.60	0.90	-	-	-
	N:P ratio	14.76	14.15	-4.13	16.00	25.00	-	-	-
Cat II	Max Chl (µg/l)	6.26	6.01	-4.00					
	Mean mar-oct Chl (µg/l)	2.33	2.29	-1.53	3.00	2.25	+	+	+
	Net production (gCm^{-2}yr^{-1})	61.95	61.57	-0.6					
	Sedimentation (gCm-2yr-1)	40.15	40.47	0.8					
B05	**Kattegatt coastal**	**Reference**	**Reduce**	**Diff %**	**CP 2002**	**Treshold**	**Reference**	**Reduce**	**CP 2002**
Cat I	Max DIN (µM)	13.84	13.14	-5.04					
	Max DIP (µM)	0.76	0.77	1.40					
	N:P ratio	18.24	17.08	-6.35					
Cat I	Mean jan-feb DIN (µM)	9.96	9.40	-5.55	7.00	6.00	+	+	+
	Mean jan-feb DIP (µM)	0.60	0.60	1.15	0.65	0.60	+	+	+
	N:P ratio	16.69	15.59	-6.62	16.00	25.00	-	-	-
Cat II	Max Chl (µg/l)	6.24	6.07	-2.72					
	Mean mar-oct Chl (µg/l)	2.68	2.64	-1.58	2.50	2.25	+	+	+
	Net production (gCm^{-2}yr^{-1})	74.15	72.79	-1.8					
	Sedimentation (gCm-2yr-1)	40.13	40.05	-0.2					
B06	**Kattegatt coastal**	**Reference**	**Reduce**	**Diff %**	**CP 2002**	**Treshold**	**Reference**	**Reduce**	**CP 2002**
Cat I	Max DIN (µM)	12.94	12.29	-5.02					
	Max DIP (µM)	0.78	0.79	1.61					
	N:P ratio	16.60	15.52	-6.53					
Cat I	Mean jan-feb DIN (µM)	8.12	7.74	-4.66	7.00	6.00	+	+	+
	Mean jan-feb DIP (µM)	0.52	0.53	1.28	0.65	0.60	-	-	+
	N:P ratio	15.60	14.68	-5.86	16.00	25.00	-	-	-
Cat II	Max Chl (µg/l)	6.50	6.58	1.31					
	Mean mar-oct Chl (µg/l)	2.80	2.76	-1.32	2.50	2.25	+	+	+
	Net production (gCm^{-2}yr^{-1})	86.98	86.74	-0.3					
	Sedimentation (gCm-2yr-1)	47.13	47.43	0.6					

4.2.8. Reduction case 8

Results from Case 8: Reduction 35% TotN and 20% TotP from land, all counties + reduction from the Baltic Sea 35% DIN and DIP in winter, and 10% TotN and TotP in summer.

The absolute values of average winter nutrient concentrations in the results of the Reference run and the Original run show greatest differences on the nitrate values with the largest reduction effects found in the Kattegat (26%) and the coastal areas of Kattegat (26%-27%). The phosphate values are reduced by 20%-23% in the same area. The effects in the Swedish parts of the Skagerrak coastal area are 12% and 17% for phosphate and nitrate, respectively. The central Skagerrak and the Norwegian coastal basins show 8%-9% reduction of nitrate and 5%-6% of phosphate values. The reduction of the average chlorophyll values is 7%-9% in the Kattegat and the coastal areas of Kattegat and the Swedish parts of the Skagerrak. The effects are 2%-4% in the rest of the Skagerrak. The netproduction is reduced by 10%-15% in the Kattegat. The effects in the Skagerrak coastal area is somewhat less (6%-9%). The effects on sedimentation are 8%-10% in Kattegat basin B02 and B06 and less than or 3% in the other basins.

OSPAR assessment: The differences between the reference run and the reduction case are found in B02 and B05 where the DIP value is changed, and in B06 where the Din value is changed and in B02 and B04 where the mean chlorophyll value is changed. The greatest difference of the assessment is in the Kattegat B02 and the Skagerrak coastal basin B04 which is classified as a problem area by the reference run but not by the reduction case.

Table 8. Results of reduction case 8.

	Area	Results				OSPAR	assessment		
B01	**Skagerrak offshore**	**Reference**	**Reduce**	**Diff %**	**CP 2002**	**Treshold**	**Reference**	**Reduce**	**CP 2002**
Cat I	Max DIN (µM)	8.79	8.04	-8.5					
	Max DIP (µM)	0.65	0.62	-3.9					
	N:P ratio	13.52	12.87	-4.8					
Cat I	Mean jan-feb DIN (µM)	8.11	7.45	-8.1	8.00	15.00	-	-	-
	Mean jan-feb DIP (µM)	0.60	0.57	-5.8	0.60	0.90	-	-	-
	N:P ratio	13.46	13.13	-2.5	16.00	25.00	-	-	-
Cat II	Max Chl (µg/l)	3.65	3.57	-2.3					
	Mean mar-oct Chl (µg/l)	2.03	1.98	-2.3	2.00	2.25	-	-	-
	Net production (gCm^{-2}yr^{-1})	62.46	60.69	-2.8					
	Sedimentation (gCm-2yr-1)	32.06	31.80	-0.8					
B02	**Kattegatt offshore**	**Reference**	**Reduce**	**Diff %**	**CP 2002**	**Treshold**	**Reference**	**Reduce**	**CP 2002**
Cat I	Max DIN (µM)	11.60	8.89	-23.3					
	Max DIP (µM)	0.78	0.64	-17.6					
	N:P ratio	14.94	13.90	-7.0					
Cat I	Mean jan-feb DIN (µM)	9.82	7.30	-25.7	7.00	6.00	+	+	+
	Mean jan-feb DIP (µM)	0.65	0.51	-20.8	0.65	0.60	+	-	+
	N:P ratio	15.20	14.27	-6.2	16.00	25.00	-	-	-
Cat II	Max Chl (µg/l)	4.87	4.35	-10.8					
	Mean mar-oct Chl (µg/l)	2.40	2.24	-6.8	2.00	2.25	+	-	-
	Net production (gCm^{-2}yr^{-1})	69.28	60.08	-13.3					
	Sedimentation (gCm-2yr-1)	47.78	43.18	-9.6					
B03	**Skagerrak coastal**	**Reference**	**Reduce**	**Diff %**	**CP 2002**	**Treshold**	**Reference**	**Reduce**	**CP 2002**
Cat I	Max DIN (µM)	8.94	8.10	-9.43					
	Max DIP (µM)	0.63	0.61	-3.62					
	N:P ratio	14.16	13.31	-6.02					
Cat I	Mean jan-feb DIN (µM)	8.17	7.42	-9.10	8.00	15.00	-	-	-
	Mean jan-feb DIP (µM)	0.59	0.56	-5.38	0.60	0.90	-	-	-
	N:P ratio	13.91	13.36	-3.93	16.00	25.00	-	-	-
Cat II	Max Chl (µg/l)	3.45	3.38	-2.01					
	Mean mar-oct Chl (µg/l)	2.08	2.01	-3.62	3.00	2.25	-	-	+
	Net production (gCm^{-2}yr^{-1})	66.97	63.16	-5.7					
	Sedimentation (gCm-2yr-1)	27.90	27.72	-0.6					
B04	**Skagerrak coastal**	**Reference**	**Reduce**	**Diff %**	**CP 2002**	**Treshold**	**Reference**	**Reduce**	**CP 2002**
Cat I	Max DIN (µM)	10.75	8.67	-19.3					
	Max DIP (µM)	0.70	0.62	-11.2					
	N:P ratio	15.42	14.01	-9.1					
Cat I	Mean jan-feb DIN (µM)	8.99	7.48	-16.8	8.00	15.00	-	-	-
	Mean jan-feb DIP (µM)	0.61	0.54	-11.5	0.60	0.90	-	-	-
	N:P ratio	14.76	13.87	-6.03	16.00	25.00	-	-	-
Cat II	Max Chl (µg/l)	6.26	5.53	-11.74					
	Mean mar-oct Chl (µg/l)	2.33	2.17	-6.89	3.00	2.25	+	-	+
	Net production (gCm^{-2}yr^{-1})	61.95	56.32	-9.1					
	Sedimentation (gCm-2yr-1)	40.15	38.91	-3.1					
B05	**Kattegatt coastal**	**Reference**	**Reduce**	**Diff %**	**CP 2002**	**Treshold**	**Reference**	**Reduce**	**CP 2002**
Cat I	Max DIN (µM)	13.84	10.09	-27.09					
	Max DIP (µM)	0.76	0.63	-17.19					
	N:P ratio	18.24	16.06	-11.96					
Cat I	Mean jan-feb DIN (µM)	9.96	7.35	-26.22	7.00	6.00	+	+	+
	Mean jan-feb DIP (µM)	0.60	0.48	-20.33	0.65	0.60	+	-	+
	N:P ratio	16.69	15.46	-7.40	16.00	25.00	-	-	-
Cat II	Max Chl (µg/l)	6.24	5.34	-14.46					
	Mean mar-oct Chl (µg/l)	2.68	2.44	-9.11	2.50	2.25	+	+	+
	Net production (gCm^{-2}yr^{-1})	74.15	62.80	-15.3					
	Sedimentation (gCm-2yr-1)	40.13	38.84	-3.2					
B06	**Kattegatt coastal**	**Reference**	**Reduce**	**Diff %**	**CP 2002**	**Treshold**	**Reference**	**Reduce**	**CP 2002**
Cat I	Max DIN (µM)	12.94	9.47	-26.81					
	Max DIP (µM)	0.78	0.64	-17.31					
	N:P ratio	16.60	14.69	-11.49					
Cat I	Mean jan-feb DIN (µM)	8.12	5.93	-26.91	7.00	6.00	+	-	+
	Mean jan-feb DIP (µM)	0.52	0.40	-22.62	0.65	0.60	-	-	+
	N:P ratio	15.60	14.73	-5.54	16.00	25.00	-	-	-
Cat II	Max Chl (µg/l)	6.50	5.67	-12.76					
	Mean mar-oct Chl (µg/l)	2.80	2.55	-8.99	2.50	2.25	+	+	+
	Net production (gCm^{-2}yr^{-1})	86.98	75.30	-13.4					
	Sedimentation (gCm-2yr-1)	47.13	43.43	-7.8					

4.2.9. Reduction case 9

Results from Case 9: Reduction 35% TotN and 20% TotP from land, all counties + reduction from the Baltic Sea 35% DIN and DIP in winter, and 10% TotN and TotP in summer + reduction from the North Sea 10% DIN and DIP in winter, and 10% TotN and TotP in summer.

The absolute values of average winter nutrient concentrations in the results of the Reference run and the Original run show greatest differences on the nitrate values with the largest reduction effects found in the Kattegat (29%-30%) and the coastal areas of Kattegat. The phosphate values are reduced by 25%-26% in the same area. The effects in the Swedish parts of the Skagerrak coastal area are 19% and 23% for phosphate and nitrate, respectively. The central Skagerrak and the Norwegian coastal basin show 15%-17% reduction of nitrate and phosphate values. The reduction of the average chlorophyll values is 8%-11% in the Kattegat and the coastal areas of Kattegat and the Swedish parts of the Skagerrak. The effects are 5%-7% in the rest of the Skagerrak. The netproduction is reduced by 17%-20% in the Kattegat. The effects in the Skagerrak coastal area is somewhat less (12%-15%). The effects on sedimentation are 10%-12% in Kattegat basin B02 and B06 and 5%-7% in basin B04 and B05. Sedimentation in the central Skagerrak and the Norwegian coastal basin is reduced by 4% and 2%, respectively.

OSPAR assessment: The differences between the reference run and the reduction case are found in B02 and B05 where the DIP value is changed, and in B06 where the Din value is changed and in B02 and B04 where the mean chlorophyll value is changed. The greatest difference of the assessment is in the Kattegat B02 and the Skagerrak coastal basin B04 which is classified as a problem area by the reference run but not by the reduction case.

Table 9. Results of reduction case 9.

	Area	Results				OSPAR	assessment		
B01	**Skagerrak offshore**	**Reference**	**Reduce**	**Diff %**	**CP 2002**	**Treshold**	**Reference**	**Reduce**	**CP 2002**
Cat I	Max DIN (µM)	8.79	7.30	-16.9					
	Max DIP (µM)	0.65	0.57	-13.1					
	N:P ratio	13.52	12.92	-4.5					
Cat I	Mean jan-feb DIN (µM)	8.11	6.78	-16.4	8.00	15.00	-	-	-
	Mean jan-feb DIP (µM)	0.60	0.51	-14.7	0.60	0.90	-	-	-
	N:P ratio	13.46	13.19	-2.0	16.00	25.00	-	-	-
Cat II	Max Chl (µg/l)	3.65	3.43	-6.0					
	Mean mar-oct Chl (µg/l)	2.03	1.92	-5.3	2.00	2.25	-	-	-
	Net production (gCm^{-2}yr^{-1})	62.46	56.50	-9.5					
	Sedimentation (gCm-2yr-1)	32.06	30.77	-4.0					

B02	**Kattegatt offshore**	**Reference**	**Reduce**	**Diff %**	**CP 2002**	**Treshold**	**Reference**	**Reduce**	**CP 2002**
Cat I	Max DIN (µM)	11.60	8.45	-27.1					
	Max DIP (µM)	0.78	0.60	-22.5					
	N:P ratio	14.94	14.04	-6.0					
Cat I	Mean jan-feb DIN (µM)	9.82	6.98	-28.9	7.00	6.00	+	+	+
	Mean jan-feb DIP (µM)	0.65	0.48	-25.1	0.65	0.60	+	-	+
	N:P ratio	15.20	14.43	-5.1	16.00	25.00	-	-	-
Cat II	Max Chl (µg/l)	4.87	4.15	-14.9					
	Mean mar-oct Chl (µg/l)	2.40	2.21	-8.0	2.00	2.25	+	-	-
	Net production (gCm^{-2}yr^{-1})	69.28	57.53	-17.0					
	Sedimentation (gCm-2yr-1)	47.78	41.83	-12.4					

B03	**Skagerrak coastal**	**Reference**	**Reduce**	**Diff %**	**CP 2002**	**Treshold**	**Reference**	**Reduce**	**CP 2002**
Cat I	Max DIN (µM)	8.94	7.37	-17.53					
	Max DIP (µM)	0.63	0.55	-12.82					
	N:P ratio	14.16	13.40	-5.40					
Cat I	Mean jan-feb DIN (µM)	8.17	6.76	-17.18	8.00	15.00	-	-	-
	Mean jan-feb DIP (µM)	0.59	0.50	-14.51	0.60	0.90	-	-	-
	N:P ratio	13.91	13.47	-3.13	16.00	25.00	-	-	-
Cat II	Max Chl (µg/l)	3.45	3.24	-5.90					
	Mean mar-oct Chl (µg/l)	2.08	1.94	-6.69	3.00	2.25	-	-	+
	Net production (gCm^{-2}yr^{-1})	66.97	58.76	-12.3					
	Sedimentation (gCm-2yr-1)	27.90	27.27	-2.2					

B04	**Skagerrak coastal**	**Reference**	**Reduce**	**Diff %**	**CP 2002**	**Treshold**	**Reference**	**Reduce**	**CP 2002**
Cat I	Max DIN (µM)	10.75	8.10	-24.6					
	Max DIP (µM)	0.70	0.57	-18.1					
	N:P ratio	15.42	14.19	-8.0					
Cat I	Mean jan-feb DIN (µM)	8.99	6.94	-22.7	8.00	15.00	-	-	-
	Mean jan-feb DIP (µM)	0.61	0.49	-18.8	0.60	0.90	-	-	-
	N:P ratio	14.76	14.04	-4.87	16.00	25.00	-	-	-
Cat II	Max Chl (µg/l)	6.26	5.15	-17.76					
	Mean mar-oct Chl (µg/l)	2.33	2.11	-9.25	3.00	2.25	+	-	+
	Net production (gCm^{-2}yr^{-1})	61.95	52.74	-14.9					
	Sedimentation (gCm-2yr-1)	40.15	37.49	-6.6					

B05	**Kattegatt coastal**	**Reference**	**Reduce**	**Diff %**	**CP 2002**	**Treshold**	**Reference**	**Reduce**	**CP 2002**
Cat I	Max DIN (µM)	13.84	9.71	-29.85					
	Max DIP (µM)	0.76	0.59	-22.28					
	N:P ratio	18.24	16.46	-9.74					
Cat I	Mean jan-feb DIN (µM)	9.96	7.03	-29.35	7.00	6.00	+	+	+
	Mean jan-feb DIP (µM)	0.60	0.45	-24.90	0.65	0.60	+	-	+
	N:P ratio	16.69	15.71	-5.92	16.00	25.00	-	-	-
Cat II	Max Chl (µg/l)	6.24	5.01	-19.68					
	Mean mar-oct Chl (µg/l)	2.68	2.40	-10.65	2.50	2.25	+	+	+
	Net production (gCm^{-2}yr^{-1})	74.15	59.70	-19.5					
	Sedimentation (gCm-2yr-1)	40.13	37.99	-5.3					

B06	**Kattegatt coastal**	**Reference**	**Reduce**	**Diff %**	**CP 2002**	**Treshold**	**Reference**	**Reduce**	**CP 2002**
Cat I	Max DIN (µM)	12.94	9.07	-29.88					
	Max DIP (µM)	0.78	0.60	-22.38					
	N:P ratio	16.60	15.00	-9.66					
Cat I	Mean jan-feb DIN (µM)	8.12	5.70	-29.74	7.00	6.00	+	-	+
	Mean jan-feb DIP (µM)	0.52	0.38	-26.49	0.65	0.60	-	-	+
	N:P ratio	15.60	14.91	-4.43	16.00	25.00	-	-	-
Cat II	Max Chl (µg/l)	6.50	5.37	-17.28					
	Mean mar-oct Chl (µg/l)	2.80	2.49	-10.88	2.50	2.25	+	+	+
	Net production (gCm^{-2}yr^{-1})	86.98	71.74	-17.5					
	Sedimentation (gCm-2yr-1)	47.13	42.30	-10.2					

5. Discussion and conclusions

The model response to nutrient reductions (cases 1-3) shows that reducing nutrient inputs from land by 50% have the largest effect on the nitrate concentration in the Kattegat and along the Swedish coast in the Skagerrak area. The change of phosphorus concentrations for this reduction scenario is relatively small. Reducing the fluxes of nutrients from the Baltic Sea by 50% show larger response on phosphate and the main effects are also found in the Kattegat and along the Swedish coast in the Skagerrak. Reducing the fluxes of nutrients by 30% from the North Sea show a similar size of response as obtained in the Baltic Sea case, but the largest effects are obtained in the Skagerrak. The reduction of nitrate concentrations in this case in the Kattegat is slightly less than seen from the effect from a reduced land runoff while the reduction of phosphate is larger.

A number of model experiments have been performed to predict the environmental consequences if the 50% nutrient reduction target was achieved.

The nutrient reduction scenarios (cases 4-7) indicate that a 50% reduction of anthropogenic nitrogen and phosphorus from the land runoff mainly reduces the nitrate concentrations. The final change of phosphorus concentrations for these reduction scenarios is very small.

The largest effect obtained from a 50% reduction of anthropogenic nitrogen and phosphorus from the runoff in one country alone is obtained for Sweden (Case 5). This model experiment reduces the nitrate and chlorophyll concentrations in the Swedish coastal waters with 5%-10% and 3%-6%, respectively. The net production is reduced 2%-4% and changes in sedimentation are less than 1%. The largest reduction is found in the Kattegat.

The combined effect from a 50% reduction of anthropogenic nutrient supplies from land and an anticipated reduction from the adjacent seas (see Case 9) aim to give an estimate of the reduction potential that might be realistic when the Baltic Sea and the North Sea has achieved the nutrient reduction targets. In the Kattegat and the Swedish parts of the Skagerrak coastal area this model experiment reduces the nitrate and phosphate concentrations with 20%-30%, the average chlorophyll values with 8%-11%, the netproduction with 12%-20%, and the sedimentation by 5%-12%.

In comparison with the reference run the OSPAR assessment of Case 9 re-classifies the Kattegat central basin B02 and the Skagerrak coastal basin B04 from problem area to a potential problem area and a non problem area, respectively. There are however still elevated levels of average chlorophyll left in the coastal Kattegat basin B05 and B06.

Application of the model results to the OSPAR 2002 assessment

In Table 10 the estimated ranges of reduction from the Case 9 results are applied to the OSPAR 2002 assessment. The results shows that the average chlorophyll values of the Skagerrak coastal basins B03 and B04 remains elevated while all other parameters reduces below the threshold values.

Table 10. The results from the OSPAR 2002 data assessment of the 1990s (CP 2002) are reduced by the reduction factor (Diff) obtained from Case 9. The results after reduction are shown in column Reduce.

	Area	Results				OSPAR assessment			
B01	**Skagerrak offshore**	**CP 2002**	**Reduce**	**Diff %**		**Treshold**	**CP 2002**	**Reduce**	
Cat I	Max DIN (µM)								
	Max DIP (µM)								
	N:P ratio								
Cat I	Mean jan-feb DIN (µM)	8.00	6.69	-16.4		15.00	-	-	
	Mean jan-feb DIP (µM)	0.60	0.51	-14.7		0.90	-	-	
	N:P ratio	16.00	15.67	-2.0		25.00	-	-	
Cat II	Max Chl (µg/l)								
	Mean mar-oct Chl (µg/l)	2.00	1.89	-5.3		2.25	-	-	
	Net production ($gCm^{-2}yr^{-1}$)								
	Sedimentation (gCm-2yr-1)								

B02	**Kattegatt offshore**	**CP 2002**	**Reduce**	**Diff %**		**Treshold**	**CP 2002**	**Reduce**	
Cat I	Max DIN (µM)								
	Max DIP (µM)								
	N:P ratio								
Cat I	Mean jan-feb DIN (µM)	7.00	4.97	-28.9		6.00	+	-	
	Mean jan-feb DIP (µM)	0.65	0.49	-25.1		0.60	+	-	
	N:P ratio	16.00	15.19	-5.1		25.00	-	-	
Cat II	Max Chl (µg/l)								
	Mean mar-oct Chl (µg/l)	2.00	1.84	-8.0		2.25	-	-	
	Net production ($gCm^{-2}yr^{-1}$)								
	Sedimentation (gCm-2yr-1)								

B03	**Skagerrak coastal**	**CP 2002**	**Reduce**	**Diff %**		**Treshold**	**CP 2002**	**Reduce**	
Cat I	Max DIN (µM)								
	Max DIP (µM)								
	N:P ratio								
Cat I	Mean jan-feb DIN (µM)	8.00	6.63	-17.18		15.00	-	-	
	Mean jan-feb DIP (µM)	0.60	0.51	-14.51		0.90	-	-	
	N:P ratio	16.00	15.50	-3.13		25.00	-	-	
Cat II	Max Chl (µg/l)								
	Mean mar-oct Chl (µg/l)	3.00	2.80	-6.69		2.25	+	+	
	Net production ($gCm^{-2}yr^{-1}$)								
	Sedimentation (gCm-2yr-1)								

B04	**Skagerrak coastal**	**CP 2002**	**Reduce**	**Diff %**		**Treshold**	**CP 2002**	**Reduce**	
Cat I	Max DIN (µM)								
	Max DIP (µM)								
	N:P ratio								
Cat I	Mean jan-feb DIN (µM)	8.00	6.18	-22.7		15.00	-	-	
	Mean jan-feb DIP (µM)	0.60	0.49	-18.8		0.90	-	-	
	N:P ratio	16.00	15.22	-4.87		25.00	-	-	
Cat II	Max Chl (µg/l)								
	Mean mar-oct Chl (µg/l)	3.00	2.72	-9.25		2.25	+	+	
	Net production ($gCm^{-2}yr^{-1}$)								
	Sedimentation (gCm-2yr-1)								

B05	**Kattegatt coastal**	**CP 2002**	**Reduce**	**Diff %**		**Treshold**	**CP 2002**	**Reduce**	
Cat I	Max DIN (µM)								
	Max DIP (µM)								
	N:P ratio								
Cat I	Mean jan-feb DIN (µM)	7.00	4.95	-29.35		6.00	+	-	
	Mean jan-feb DIP (µM)	0.65	0.49	-24.90		0.60	+	-	
	N:P ratio	16.00	15.05	-5.92		25.00	-	-	
Cat II	Max Chl (µg/l)								
	Mean mar-oct Chl (µg/l)	2.50	2.23	-10.65		2.25	+	-	
	Net production ($gCm^{-2}yr^{-1}$)								
	Sedimentation (gCm-2yr-1)								

B06	**Kattegatt coastal**	**CP 2002**	**Reduce**	**Diff %**		**Treshold**	**CP 2002**	**Reduce**	
Cat I	Max DIN (µM)								
	Max DIP (µM)								
	N:P ratio								
Cat I	Mean jan-feb DIN (µM)	7.00	4.92	-29.74		6.00	+	-	
	Mean jan-feb DIP (µM)	0.65	0.48	-26.49		0.60	+	-	
	N:P ratio	16.00	15.29	-4.43		25.00	-	-	
Cat II	Max Chl (µg/l)								
	Mean mar-oct Chl (µg/l)	2.50	2.23	-10.88		2.25	+	-	
	Net production ($gCm^{-2}yr^{-1}$)								
	Sedimentation (gCm-2yr-1)								

The reduction scenarios have shown that to reach the target non problem area in the Skagerrak and Kattegat area we need to reduce nutrient supplies also from the North Sea and the Baltic Sea boundaries. It seems that the reduction target is not entirely obtained from the anticipated reduction scenarios suggested in case 9. It is however not clear from the present results how to perform the remaining reduction since there is a difference between the model and the OSPAR 2002 assessment which has some impact on the interpretation of the results. The model has lower average chlorophyll values in the Skagerrak and higher values in the Kattegat as compared to the OSPAR 2002 assessment. This parameter has a major impact on the classification since it defines the limit of a problem area in the OSPAR comprehensive procedure. The cause of this disagreement between the model and the OSPAR 2002 assessment should therefore be further investigated.

Suggestions of future work

The results from the model validation show that the model mainly produces reliable results, especially in the surface layers of the modelled areas. In general the model seems to be well suited for the evaluation of long-term effects and long-term statistical characteristics of nutrient conditions in the Skagerrak and the Kattegat. There are some points mentioned before that could be done in order to enhance the model performance below the summer pycnocline in the Skagerrak and in the lower layers of the Kattegat. Improving the boundary conditions may give a better correspondence with the temporal variations and possibly also improve some of the statistical results. The low oxygen concentrations occurring in the bottom waters of the Kattegat are however not captured accurately enough by the model. The modelled minimum oxygen concentration is about 4.5 ml/l while observations from both Anholt and Fladen regularly show minimum concentrations below 4 ml/l in autumn. A reliable assessment of this parameter therefore requires an improvement of the Kattegat model. The runoff from the river Göta Älv has its outlet from the coastal zone to the model basin B05. It is however likely that a fraction of the river runoff should be directed to the Skagerrak coastal basin B04 instead. This would likely increase the biological production in the Skagerrak coastal basin B04 and reduce it in the Kattegat coastal basin B05. The reference run for the reduction cases are based on the year 1994 repeated 10 times. It might be valuable to investigate the model response for reductions performed on some other years as well. Looking at two years with quite different characteristics could give an estimation of the ranges for the model response under different environmental conditions.

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Appendix A: Comprehensive procedure

Appendix B: Model description

Appendix C: Time series model validation

Appendix D: Kattegat statistical model validation

Appendix E: Skagerrak statistical model validation

Appendix F: Surface layer Cost Function

Appendix G: Open boundary transports, supply from land and atmosphere

Appendix H: OSPAR model assessment 1994