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Common Procedure for the Skagerrak coast

Report 983/2007

Eutrophication Status of the Norwegian Skagerrak Coast

Norwegian Institute for Water Research

– an institute in the Environmental Research Alliance of Norway

REPORT

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Abstract

The Norwegian Skagerrak coast has been classified according to the OSPAR Common Procedure. Compared to the previous assessment in 2002, this classification is based on new data on nutrient load, oxygen conditions, hardbottom fauna and flora (especially sugar kelp), harmful planktonic algae, as well as other data from a number of recipient studies.

Fourteen areas have been studied and classified. The data has been of varying quality, but the overall classification of the coastline is Problem Area.

One should note that the classification assumes that the decline of sugar kelp on the Norwegian Skagerrak coast to some extent is caused by eutrophication. For some areas this assumption is crucial for the classification. If future studies of the kelp disappearance prove otherwise, this classification should be revised.

4 keywords, Norwegian	4 keywords, English
1. OSPAR	1. OSPAR
2. Eutrofi	2. Eutrophication
3. Kystvann	3. Coastal water
4. Skagerrakkysten	4. Skagerrak coast

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Preface

As a contracting party to OSPAR, Norway has agreed to apply the Common Procedure for the Identification of Eutrophication Status of the Maritime Area of the Oslo and Paris Commissions on its coastal waters. This is the second classification of the Norwegian Skagerrak coast, carried out by Norwegian Institute for Water Research (NIVA) according to Norwegian Pollution Control Authority (SFT) contract no. 6006150. We thank Jon Fuglestad for helpful comments and guiding through the project.

At NIVA Torulv Tjomsland has calculated the nutrient load to the designed coastal areas, while Are Pedersen and Wenche Eikrem have classified according to biological data. Jan Magnusson and Jarle Molvær have classified and worked with water quality and the nutrient loads, the latter also as project leader.

Oslo, 18.4.2007

Jarle Molvær

Contents

Summary

As a contracting party to OSPAR, Norway has agreed to apply the Common Procedure for the Identification of Eutrophication Status of the Maritime Area of the Oslo and Paris Commissions on its coastal waters. The procedure has been applied to the coastal water off the Norwegian Skagerrak coast (1999), as Comprehensive Procedure to the fjords and archipelago along the Skagerrak coast (2002-2003), screening of the Norwegian west coast in 2002-2003 and screening of the coastline from Stad to the Norwegian/Russian border in 2003.

The present study reports the results from the second Comprehensive Procedure for the Norwegian Skagerrak coast.

Method and data

The coastline was divided into 14 areas as compared to 44 areas in the previous assessment. The OSPAR classification system has been used wherever possible. In some instances the classification uses the Norwegian Classification System (NCS) for nutrients, chlorophyll *a*, oxygen and soft-bottom fauna. The classification has mainly been based on data from the period 2001-2006, and especially:

- Calculation of the nutrient load for each area
- Oxygen measurements from at number of fjord basins
- Observations of the macroalgae along the coastline, especially in connection with the decline of the sugarkelp
- Observations of harmful planktonic algae

In addition the assessment has incorporated data from a number of local recipient studies.

Results

With fewer areas this assessment has been less detailed than the previous assessment. Within each area there are certainly subareas which could have a different classification other than the "overall" area classification. The overall classification for the Norwegian Skagerrak coast is **Problem Area.**

One may note that the classification below fits reasonably well with ANON (1997) which found a regional nutrient enrichment in the coastal water west to Lindesnes. The degree of this regional nutrient enrichment is relatively marked and constant along the Norwegian Skagerrak coast to about Arendal, but decreases west of Arendal due to admixture of Atlantic water. There is no sharp western delimitation of the regional nutrient enrichment, but rather a transition zone.

Many of the comments to the choice of classification are limitations and uncertainties due lack of relevant observations, either because

- there are no data
- the data are from studies more than 5 year back and may not be representative for the present situation
- data covers only a minor part of the area.

We have tried to take these limitations into account for each area, also when considering the state in neighbouring areas.

One should note that the classification assume that the decline of sugar kelp on the Norwegian Skagerrak coast to some extent is caused by eutrophication (high temperature in July/August is assumed to have been the direct cause). For some areas this assumption is crucial for the classification. If future studies of the kelp disappearance prove otherwise, this classification should be revised.

1. 1. Introduction

As a contracting party to OSPAR, Norway has agreed to apply the Common Procedure for the Identification of Eutrophication Status of the Maritime Area of the Oslo and Paris Commissions on its coastal waters. Previously the Procedure has been applied to

- Comprehensive Procedure for fjords and archipelagos of the Norwegian Skagerrak coast (Molvær et al., 2003a)
- Screening of fjords and archipelagos of the Norwegian west coast (Molvær et al., 2003b)
- Screening of fjords and archipelagos from Stad to the Norwegian/Russian border (Aure and Skjoldal, 2003).

In the previous report the Norwegian Skagerrak coast was divided into 44 areas, of which 17 areas were classified as “Problem Areas” and 27 areas as “Potential Problem Areas”. Many of the comments to the classification concerned uncertainties due to lack of relevant observations, either because

I. there were no data
II. the existing data were too old and considered not representative for the present situation, or
III. data covered only a minor part of the area.

Areas where the coastal water was classified as “Potential Problem Area”, and where there was sparse data for classification of fjords/archipelago, were in general given a final classification as “Potential Problem Areas”. This corresponded with a general conclusion that these fjords receive a substantial load of nutrients and organic matter through the water exchange with coastal water.

In this report the Comprehensive Procedure is applied to the inshore waters of the Norwegian Skagerrak coast, and with special focus on the Potential Problem areas.

2. Description of the assessed area

2.1 Overall description of the Norwegian Skagerrak coast

The Norwegian Skagerrak coast covers the area from the border between Norway and Sweden in the east to Lindesnes to the west (***Figure 1***). Outside the Oslofjord area the average population density along the coast is low and of 22 cities at - or near the coastline – 11 cities have less than 30 000 inhabitants, and only Oslo (535 000) have more than 75 000 inhabitants. All have wastewater discharges to the sea with secondary treatment or better, submerged outfalls, high primary dilution and trapping of the plume below the surface layer.

According to the Urban Waste Water Directive the coast between the Swedish border and Lindesnes has been designated as a sensitive area, while the coast further to the west and to the north has been identified as a less sensitive area.

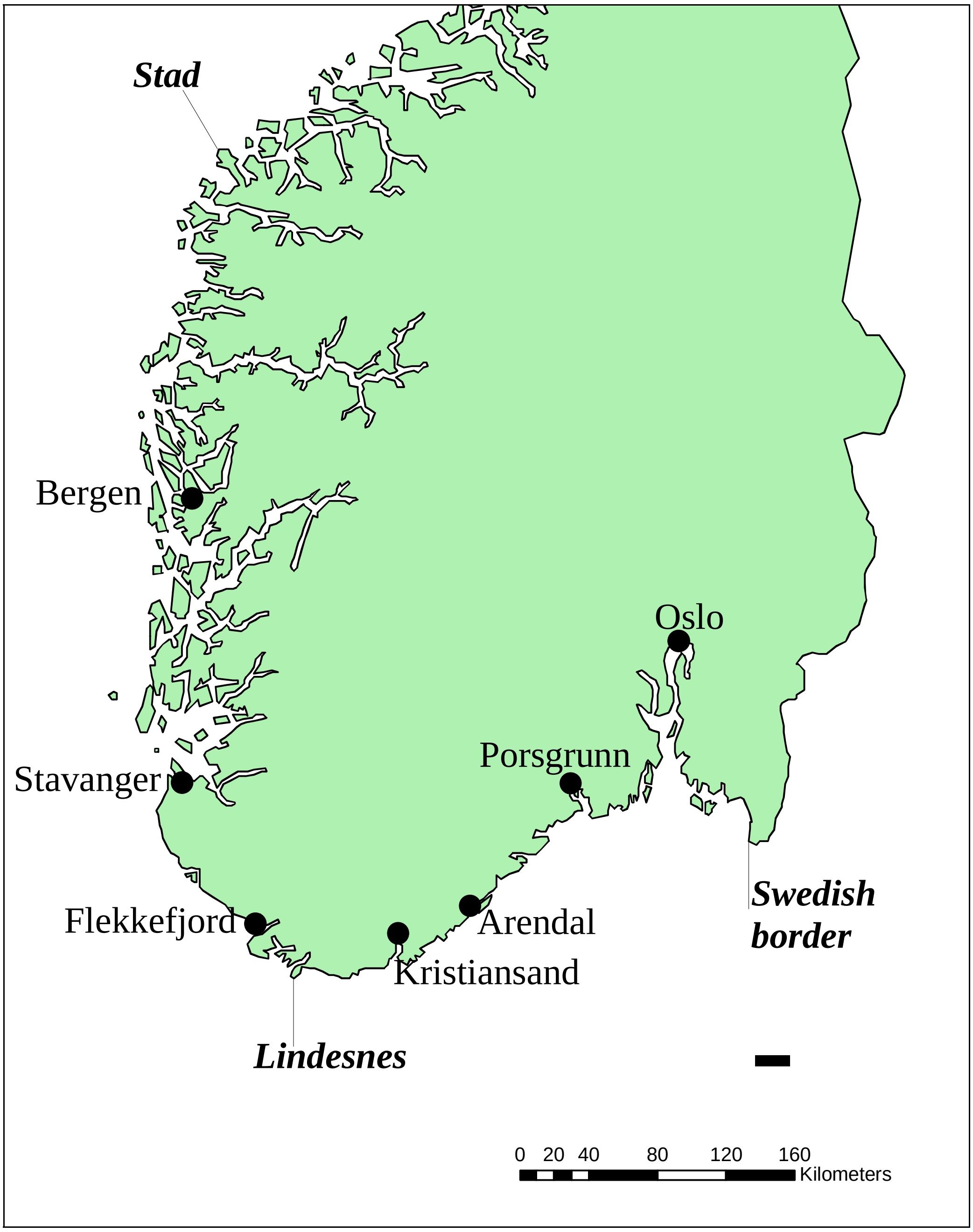

Figure 1. *Overall view of the coastline of southern Norway, showing the Norwegian Skagerrak coast from the Swedish border to Lindesnes, subjected to the Comprehensive Procedure in this report.*

The coastal waters along the Norwegian Skagerrak coast are basically a mixture of two water masses: Atlantic water (salinity>35) and freshwater. Most of the Atlantic water enters the North Sea through the passages between the Faroe Islands and Scotland and between the Faroe Island and Norway. Most of the freshwater comes from three sources, namely from local runoff to the coast, the Baltic Sea and the large rivers draining to the southern part of the North Sea. These water masses combine to form the Norwegian Coastal Current (NCC, see **Figure 2**). The water volume transport of the NCC increases from typically 0.2-0.3 million m^3/s at the Skagerrak coast (**Figure 3**) to 1 million m^3/s or more off the west coast of Norway.

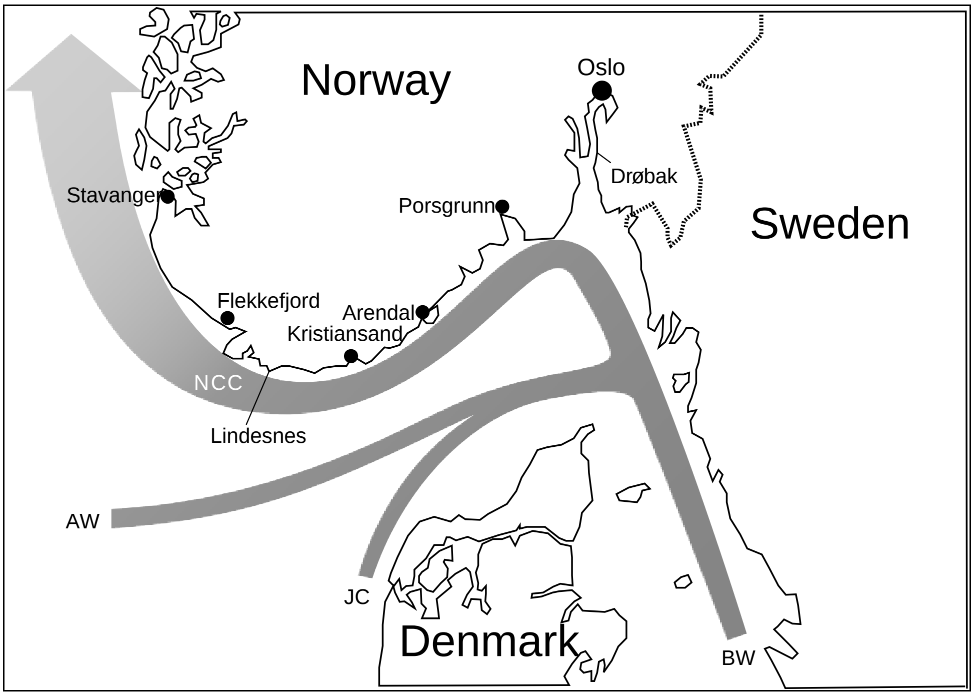

Figure 2. *Dominating current pattern in the coastal area of southern Norway. The width of the arrows is not directly related to the current volume transport (AW: Atlantic Water, BW: Baltic Water, JC: Jutland Current, NCC: Norwegian Coastal Current. From ANON, 1997).*

The water exchange in the coastal zone is driven by input of fresh water, tidal currents and meteorological forces (wind stress and air pressure variations). In most areas, the exchange of surface and intermediate water masses is rapid and extensive, often the matter of a couple of days or weeks. The tidal amplitude on the Skagerrak is typically 0.1-0.3 m.

The fjords with shallow sills in southern Norway are of particular concern with regard to the discharge of effluent waters. In most of these fjords, the water masses are salinity-stratified with brackish water on top and seawater in the deep basin. The deep water is stagnant for shorter or longer periods and is only exchanged with oxygen-rich coastal water at intervals varying from months to several years. At the end of long stagnation periods the oxygen concentration in the deep water will be low, and in many cases hydrogen sulphide is formed. For some fjords this has been a natural condition. However, the oxygen consumption has increased significantly since 1980. This is considered mainly an effect from a regional nutrient enrichment in the coastal water mass in Skagerrak (ANON 1997, Buhl-Mortensen et.al., 2006).

Most of the population lives in cities or towns situated in inner parts of fjords, or in other topographically sheltered areas along the coast. Generally, the topography and the water exchange of the local recipients vary considerably, spanning from fjords with shallow sills and stagnant bottom water to bays and inlets with free exchange of water. Consequently, the sensitivity of the receiving waters to loading of nutrients and organic matter varies depending on the local conditions. Fjords, with more or less stagnant deep water are particularly sensitive to organic loading, which accelerates the oxygen depletion in the deep waters. Coastal areas with high water exchange are far less sensitive to discharges of organic matter and nutrients.

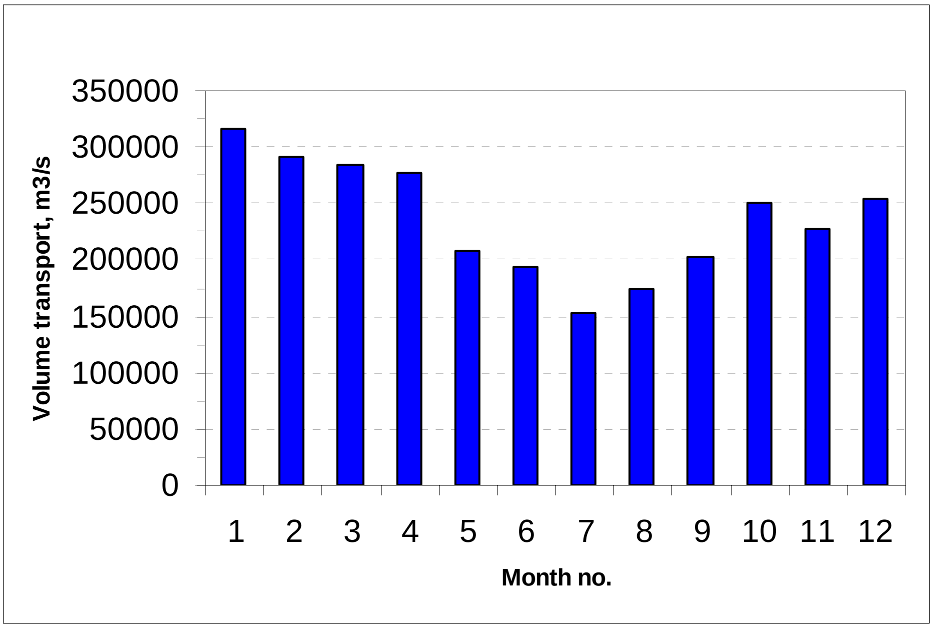

Figure 3.*Calculated monthly average of water volume transport in the NCC off Arendal for the period 1988 - 95. (ANON, 1997).*

2.2 Catchment information

Norway is a country with vast natural resources, and large parts of the country are covered by forests and mountainous areas. The land cover of the mainland may be divided into areas covered by forest, agriculture and artificial surfaces, mountains and mountain plateaus, as well as lakes and wetlands, ***Figure 4***. The land use is shown in **Figure 5**.

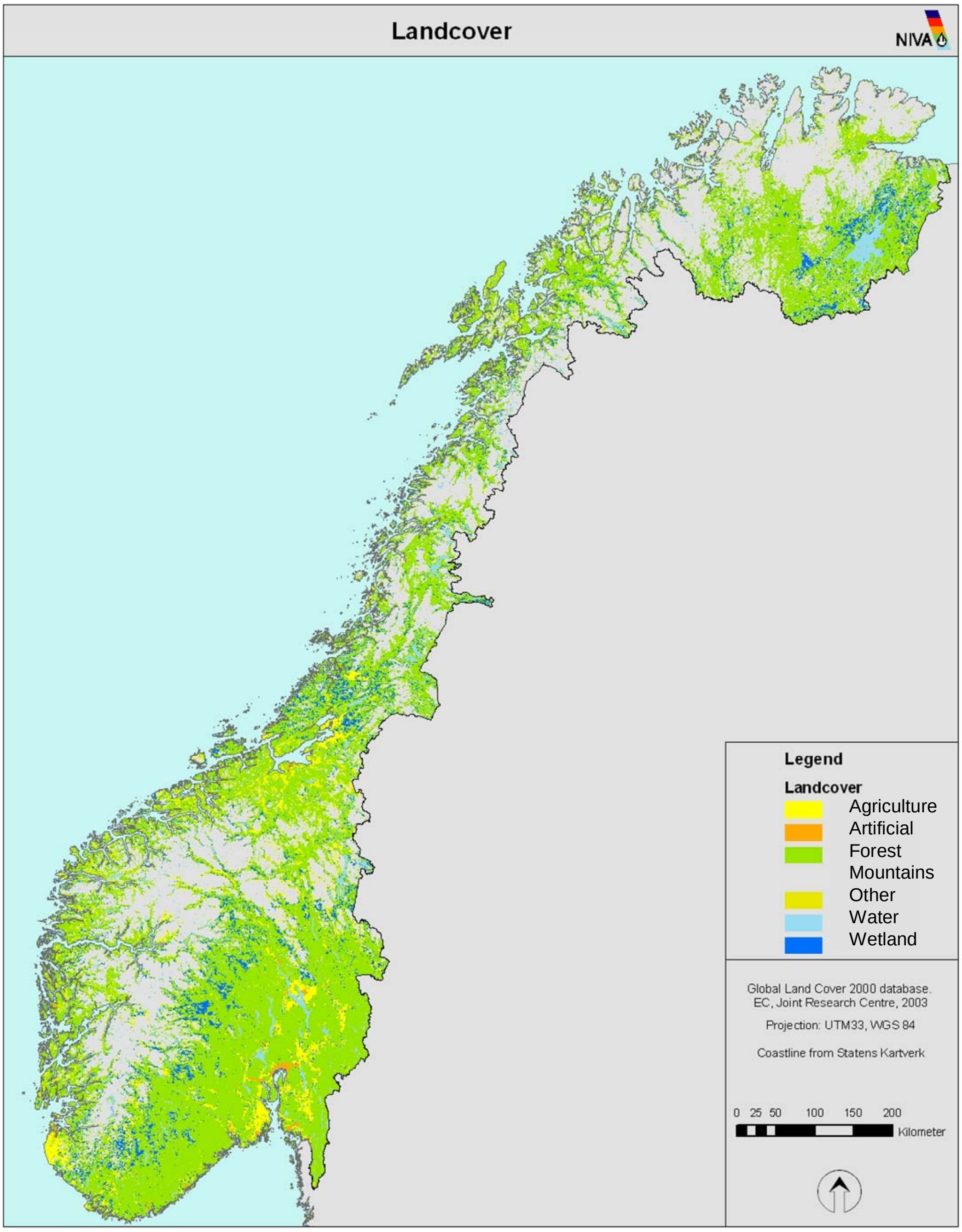

Figure 4. *Land cover map of Norway. See also* ***Figure 5*** *where the land use is shown.*

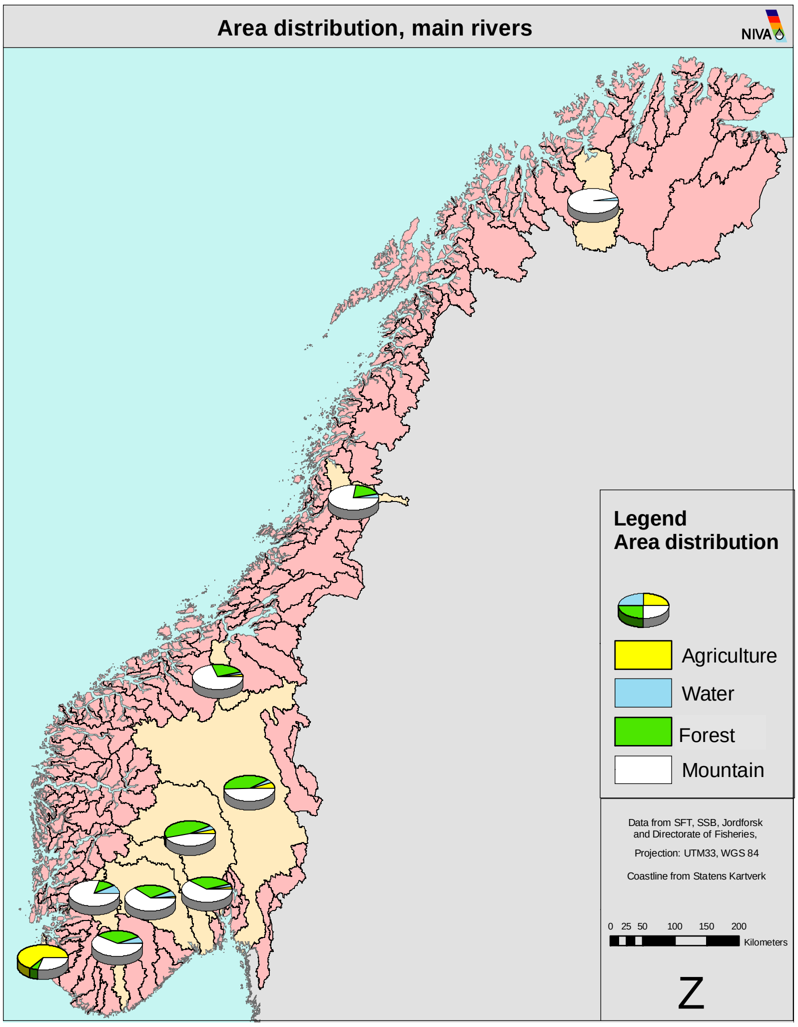

Figure 5. *Land use in the catchment areas of the 10 mainRID rivers. "Water" signifies proportion of lakes in the catchment; "Mountains" include moors and mountain plateaus not covered by forest. Based on data from SFT, Statistics Norway, Bioforsk, Directorate of Fisheries, and Statens Kartverk.*

The rivers *Glomma, Drammenselva, Numedalslaagen, Skienselva,* and *Otra* drain into the Skagerrak area. These five rivers also represent the major load bearing rivers in Norway. Of these, the River *Glomma* is the largest river in Norway, with a catchment area of about 42 000 km^2, or about 13 % of the total land area in Norway.

Table 1. *The main rivers draining to the Skagerrak area, their coastal area, catchment size and long term average flow.*

Discharge area	Name of river	Catchment area (km^2)	Long term average flow (1000 m^3/day)	County with river outlet
	Glomma	41918	61350	Østfold
	Drammenselva	17034	28850	Buskerud
	Numedalslågen	5577	10200	Vestfold
	Skienselva	10772	23535	Telemark
	Otra	3738	12870	Vest-Agder

2.3 Areas for assessment

Norwegian coastal waters may be divided into three categories, namely fjords including estuaries, archipelagos and the coastal water outside. This assessment deals with fjords and archipelago on the Norwegian Skagerrak coast (see ***Figure 1***).

A typological classification of the Norwegian coastline under the Water Framework directive was suggested in 2003. The system was based on 23 types of water bodies, whereof 5 were applied to the Skagerrak coastline. (Moy et al., 2003). The main characteristics are shown in ***Figure 6***.

Statististics Norway assembles statistics for so-called "Statistical Areas", of which there are 121 with runoff to the Norwegian Skagerrak coast. From topographic and demographic parameters and taking into considerations that relatively homogenic areas are preferable, the Skagerrak coast has in this study been divided into 14 areas each including several "statistical areas":

- The Oslofjord: 4 areas
- Telemark county, the coastline and selected fjords: 3 areas
- East Agder county: the coastline and selected fjords: 5 areas
- West Agder county: the coastline and selected fjords: 2 areas

Nutrients from urban wastewater are usually discharged as point sources and nutrients from runoff are often concentrated to a few large rivers. Within a coastal area, this may create strong gradients in nutrient load and in environmental quality. We wanted to avoid defining coastal areas so large that a 'concentration averaging effect' of the nutrient load and the water quality would be introduced. The 14 areas in this report still vary from approximately 10 km^2 (specific fjords) to 450 km^2.

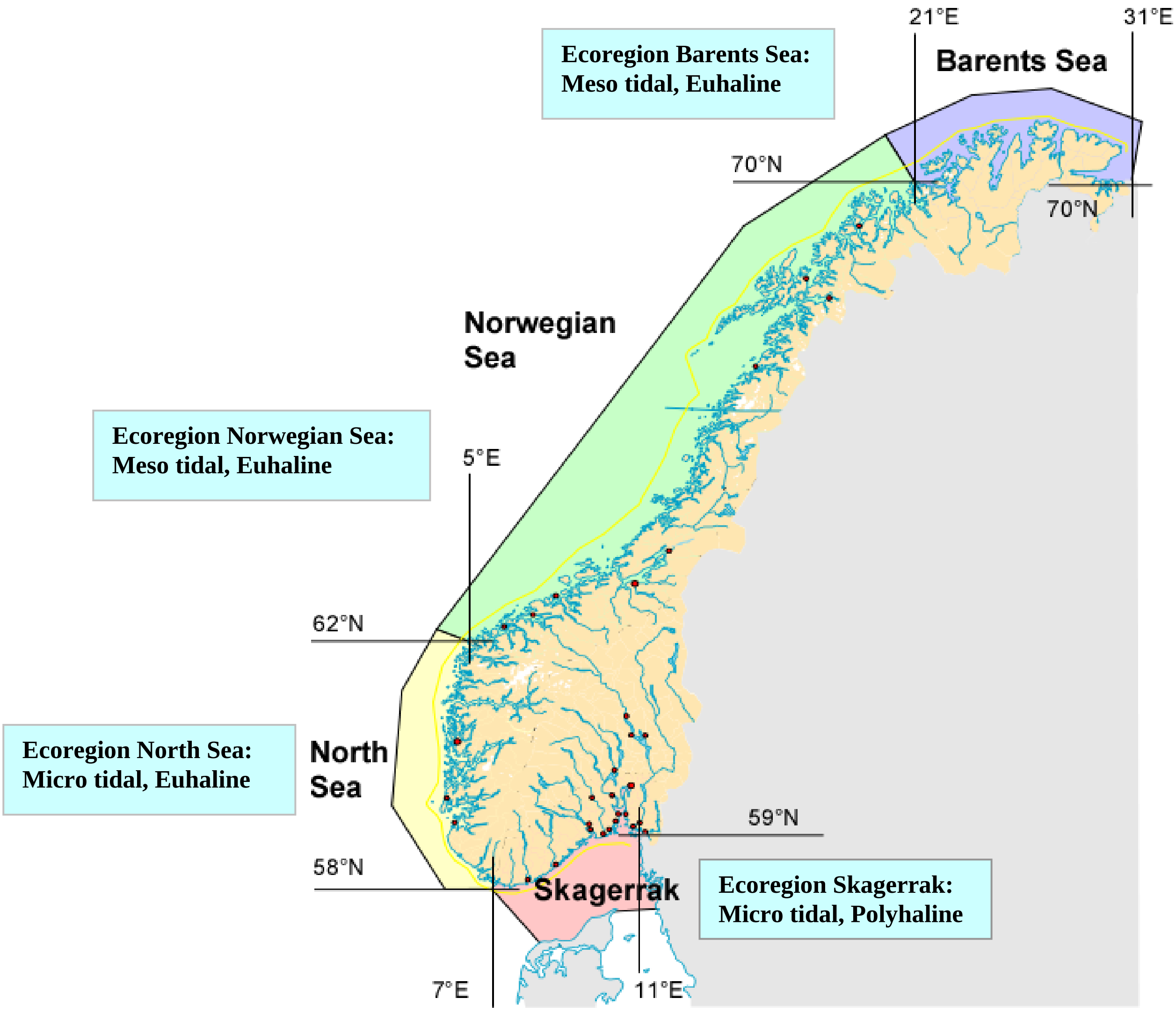

Figure 6. *The present suggestion of Norwegian typology with 4 ecoregions (based on Moy et al., 2003).*

3. Methods and data

3.1 The OSPAR classification scheme

The assessment is based on the OSPAR common assessment criteria, which is summarised in ***Table 2***.

Table 2. *Harmonised assessment parameters and related elevated levels (from OSPAR, 2005).*
Note: Parameters found at levels above the assessment level are considered as "elevated levels" and entail scoring of the relevant parameter category as (+) (cf. 'score' table at Annex 5). For concentrations, the "assessment level" is defined as a justified area-specific % deviation from background not exceeding 50%.

Assessment parameters		
Category I	**Degree of nutrient enrichment**	
	1	**Riverine inputs and direct discharges**[1] **(area-specific)** Elevated inputs and/or increased trends of total N and total P (compared with previous years)
	2	**Nutrient concentrations (area-specific)** Elevated level(s) of winter DIN and/or DIP
	3	**N/P ratio (area-specific)** Elevated winter N/P ratio (Redfield N/P = 16)
Category II	**Direct effects of nutrient enrichment (during growing season)**	
	1	**Chlorophyll *a* concentration (area-specific)** Elevated maximum and mean level
	2	**Phytoplankton indicator species (area-specific)** Elevated levels of nuisance/toxic phytoplankton indicator species (and increased duration of blooms)
	3	**Macrophytes including macroalgae (area-specific)** Shift from long-lived to short-lived nuisance species (e.g. *Ulva*). Elevated levels (biomass or area covered) especially of opportunistic green macroalgae).
Category III	**Indirect effects of nutrient enrichment (during growing season)**	
	1	**Oxygen deficiency** Decreased levels (< 2 mg/l: acute toxicity; 2 - 6 mg/l: deficiency) and lowered % oxygen saturation
	2	**Zoobenthos and fish** Kills (in relation to oxygen deficiency and/or toxic algae) Long-term area-specific changes in zoobenthos biomass and species composition
	3	**Organic carbon/organic matter (area-specific)** 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** Incidence of DSP/PSP mussel infection events (related to II.2)

[1] Principles of the Comprehensive Study on Riverine Inputs and Direct Discharges (RID) (reference number: 1998-5, as amended).

These effects are all related to enrichment by anthropogenic nutrients. In many cases is it difficult/impossible to separate them from a natural situation caused by topography or local freshwater runoff. Category III-effects in fjord basins – behind shallow sills – are typical examples. Along the Norwegian Skagerrak coast there is a very large number of this type of fjord basins. Application of these criteria on the Skagerrak coast is also difficult as a significant part of the eutrophication effects in all categories are combined with a transboundary load in the coastal water. Through the water exchange this load has a heavy impact on the marine environment in archipelagos and in the fjords (see ANON 1997, Buhl-Mortensen et. al., 2006)). These effects are difficult to separate from corresponding effects from a local riverine or anthropogenic nutrient load.

Following the first assessment according to **Table 1,** the second step is the integration of the categorised assessment parameters to obtain a more coherent classification. For each assessment parameter of Categories I, II, III and IV mentioned in **Table 1** it can be indicated whether its measured concentration relates to a "Problem Area", a "Potential Problem Area" or a "Non-Problem Area".The results of this step are summarised in ***Table 3***.

Table 3.*Examples of the integration of categorised assessment parameters (****Table 2****) for an initial classification.*

	Category I Degree of nutrient enrichment Nutrient inputs Winter DIN and DIP Winter N/P ratio	Category II Direct effects Chlorophyll *a* Phytoplankton indicator species Macrophytes	Categories III and IV Indirect effects/other possible effects Oxygen deficiency Changes/kills in zoobenthos, fish kills Organic carbon/matter Algal toxins	Initial Classification
a	+	+	+	"Problem Area"
	+	+	-	"Problem Area"
	+	-	+	"Problem Area"
b	-	+	+	"Problem Area"[2]
	-	+	-	"Problem Area"[2]
	-	-	+	"Problem Area"[2]
c	+	-	-	"Non-Problem Area" [3]
	+	?	?	"Potential Problem Area"
	+	?	-	"Potential Problem Area"
	+	-	?	"Potential Problem Area"
d	-	-	-	"Non-Problem Area"

\+ = Increased trends, elevated levels, shifts or changes in the respective assessment parameters in Table 2

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

? = Not enough data to perform an assessment or the data available is not fit for the purpose

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

[2] For example, caused by transboundary transport of (toxic) algae and/or organic matter arising from adjacent/remote areas.

[3] The increased degree of nutrient enrichment in these areas may contribute to eutrophication problems elsewhere.

3.2 The Norwegian classification system and its use in this report.

The Norwegian criteria for marine water quality related to nutrients are shown in ***Table 4*** and ***Table 5*** (Molvær et al., 1997)**.** In addition to these Tables, there are criteria for organic carbon in sediments and soft bottom fauna (***Table 6***). There are no OSPAR assessment criteria for soft bottom fauna or organic carbon in sediments.

Some of the fjords and coastal areas have been classified according to the Norwegian classification system (NCS), and like the previous classification (Molvær et. al., 2003) these will be applied where they can be a supplement to the OSPAR harmonised assessment criteria. The classification elsewhere is according to OSPAR, or in lack of background levels through historical trends.

The NCS is based on nutrient concentration ("normalised" for salinity between 0-20) for winter and summer. An elevated winter concentration (>50%) is generally a Class III situation, compared to a Class I, or the lower limit of a Class II situation. There will be minor differences from the OSPAR assessment criteria, but the overall the systems compare very well.

In Norway, most nutrient observations are made in April-October. The discharge from agriculture and precipitation dependent nutrient sources will vary during the year and with climatic variations. Cold winters results in lower discharges and warm winters the opposite. In **Figure 5** the discharge from the major river in the Oslofjord area in 1990-99 shows the largest transport in May-July due to snow melting in the mountains. Thus summer observations of nutrients are of interest, especially in areas dominated by agriculture, and because they will be more associated with biological effects than winter observations. As the OSPAR assessment criteria for nutrients are limited to winter observations, the Norwegian classification system (NCS) is used.

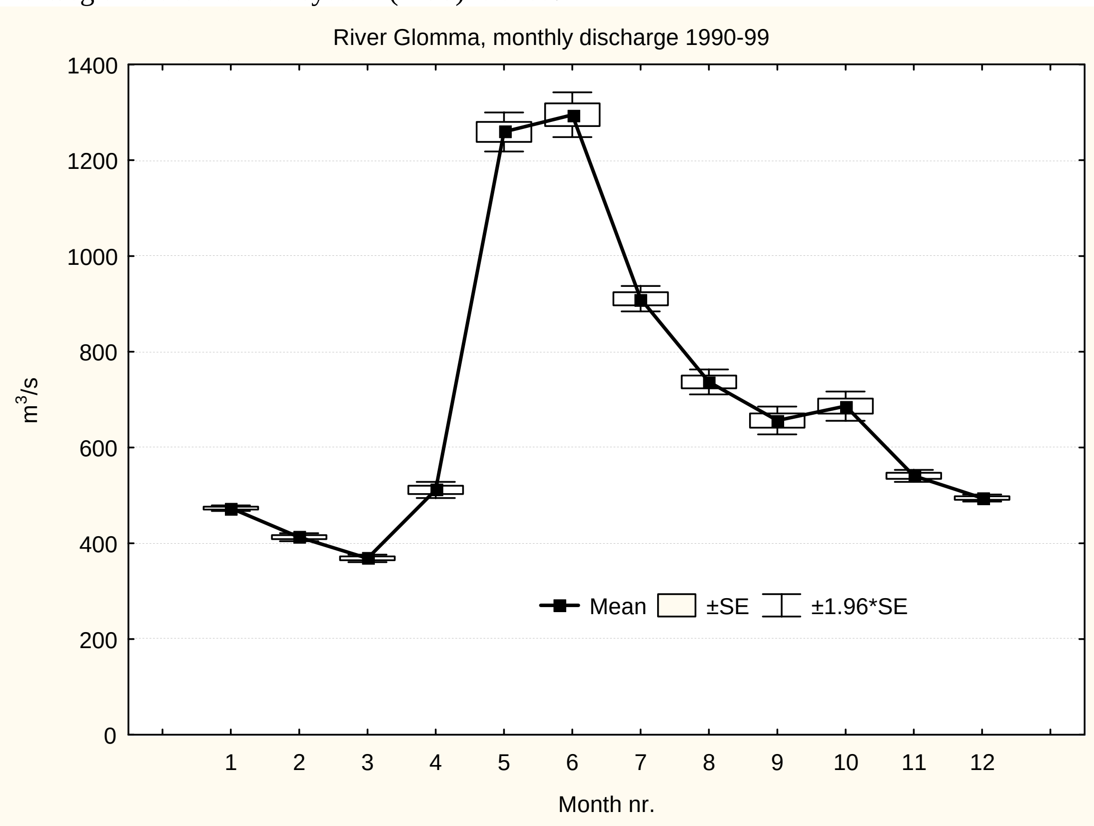

Figure 7. *Monthly freshwater discharge, the river Glomma 1990-99.*

Table 4. *Norwegian classification criteria for nutrients, chlorophyll a, secchi depth and oxygen. For surface water criteria, summer and winter have different values. Oxygen saturation refers to a water mass with temperature 6°C and salinity 33.*

		Classes				
	Parameters	**I** **Very Good**	**II** **Good**	**III** **Fair**	**IV** **Bad**	**V** **Very bad**
Surface layer	Total phosphorus (µg P/l)	<12	12-16	16-29	29-60	>60
Summer	Phosphate (µg P/l)	<4	4-7	7-16	16-50	>50
(June-August)	Total nitrogen (µg N/l)	<250	250-330	330-500	500-800	>800
	Nitrate (µg N/l)	<12	12-23	23-65	65-250	>250
	Ammonium (µg N/l)	<19	19-50	50-200	200-325	>325
	Chlorophyll *a* (µg/l)	<2	2-3.5	3.5-7	7-20	>20
	Secchi depth (m)	>7.5	7.5-6	6-4.5	4.5-2.5	<2.5
Surface layer	Total phosphorus (µg P/l)	<21	21-25	25-42	42-60	>60
Winter	Phosphate(µg P/l)	<16	16-21	21-34	34-50	>50
(December-	Total nitrogen (µg N/l)	<295	295-380	380-560	560-1300	>1300
February)	Nitrate (µg N/l)	<90	90-125	125-225	225-350	>350
	Ammonium (µg N/l)	<33	33-75	75-155	155-325	>325
Deep water	Oxygen (ml O_2/l)	>4.5	4.5-3.5	3.5-2.5	2.5-1.5	<1.5
	Oxygen saturation (%)	>65	65-50	50-35	35-20	<20

Table 5. *Norwegian classification criteria for nutrients and secchi depth for salinity in the 0-20 range.*

Surface layer	Parameter	Salinity	Classes				
			I Very good	**II Good**	**III Less good**	**IV Bad**	**V Very bad**
Summer:	Total phosphorus (µgP/l)	0	<7	7-11	11-20	20-50	>50
		20	<12	12-16	16-29	29-60	>60
(June-August)	Phosphate (µgP/l)	0	<1.5	1.5-2.5	2.5-4.5	4.5-11	>11
		20	<4	4-7	7-16	16-50	>50
	Total nitrogen (µgN/l)	0	<250	250-400	400-550	550-800	>800
		20	<250	250-330	330-500	500-800	>800
	Nitrate (µgN/l)	0	<125	125-200	200-275	275-400	>400
		20	<12	12-23	23-65	65-250	>250
	Secchi depth (m)	0	>7	4-7	2-4	1-2	<1
		20	>7.5	6.2-7.5	4.5-6.2	2.5-4.5	<2.5
Winter:	Total phosphorus (µgP/l)	0	<7	7-11	11-20	20-50	>50
		20	<21	21-25	25-42	42-60	>60
(December-February)	Phosphate (µgP/l)	0	<4	4-5	6-10	10-25	>25
		20	<16	16-21	21-34	34-50	>50
	Total nitrogen (µNg/l)	0	<250	250-400	400-550	550-800	>800
		20	<295	295-380	380-560	560-800	>800
	Nitrate (µgN/l)	0	<160	160-260	260-360	360-520	>520
		20	<90	90-125	125-225	225-350	>350

Table 6. *Classification of soft-bottom fauna biodiversity and organic content in sediments.*

	Parameter	Classes				
		I Very good	**II Good**	**III Less good**	**IV Bad**	**V Very bad**
Sediment	Organic carbon (mg/g)	<20	20-27	27-34	34-41	>41
Biodiversity of soft bottom fauna	Hurlbert index ($ES_{n=100}$)	>26	26-18	18-11	11-6	<6
	Shannon-Wiener index (H)	>4	4-3	3-2	2-1	<1

3.3 Data and quality of time series

3.3.1 Calculation of nutrient loads

Local load

The annual nutrient input from anthropogenic sources (industrial, municipal wastewater, scattered dwellings, agriculture and aquaculture) to each Area for the years 1985, 1990 and 1995-2005 have been quantified. For large rivers with fortnightly or monthly observations, these data are used for the calculations. For the other areas the nutrient load has been calculated by running the input model "TEOTIL" (Bratli and Tjomsland, 1996). The nutrient load has also been calculated pr. month.

Run-off coefficients from various types of agricultural fields have been developed and are adjusted according to measures implemented. Concerning background losses of nutrients, fixed run-off coefficients have been developed for non-cultivated areas, as well as for deposition on water bodies. The inputs are theoretical and the annual meteorological variations are averaged out over the years. Over the period 1997-2005 the total input of phosphorus and nitrogen from landbased anthropogenic sources to the Norwegian Skagerrak coast was reduced by 18-20% (Selvik et al., 2007). However, the changes do not take into account yearly variations in fresh water discharge.

In the assessment we use the annual nutrient load for the period 1997-2005, with exception for the phosphorus load where data for 1999-2003 have been discarded due to analytical problems with the river samples.

Transboundary load

The Norwegian south coast is situated downstream other polluted areas and are therefore a recipient of water and properties associated with these areas. The current system favour transports from the Kattegat and the Southern North Sea. The impact of these sources has, together with unfavourable climatic changes, possibly changed the environment in the more sheltered areas of the coast (Moy et. al., 2006, Buhl-Mortensen et.al., 2006). Compared to the direct discharges of nutrients from Norway to the Skagerrak coast, the transboundary transport are significant.

Estimates of transboundary transport from the Kattegat and the Southern North Sea has been made by Aure and Johannessen (1997). The analyses are build on long time records from a station at the Norwegian South Coast off Arendal (see ***Figure 1***) operated by the Institute for Marine Research and since 1990 a main station in the Norwegian Coastal Monitoring Programme.

Water analyses with observations from the Kattegat and the Skagerrak have been used to estimate the contribution of nutrients from different areas to the Norwegian Skagerrak coastal water outside Arendal (Aure and Johannessen, 1997). During winter/spring the contribution of inorganic nutrients as nitrate from the Kattegat was about 6-20 % and German Bight Water with 60-80 % to the concentrations off Arendal. For phosphate the contribution to the concentrations off Arendal was 20-30 % and 40-50 % respectively.

The mean winter/spring DIN concentration (NO_3+NO_2-N) in the coastal water off Arendal, have increased by 80-100 % from 1970-80 to 1990-96, while the mean DIP concentrations (PO_4-P) increased only by 10 %. Hence, the DIN/DIP ratio has increased. The annual mean increase of total nitrogen and total phosphorus were 35 % and 20 %, respectively.

However, during the period 2000-2006 the winter concentrations have decreased (***Figure 8***). This could be explained from decreasing concentrations in the transboundary transport as there are no

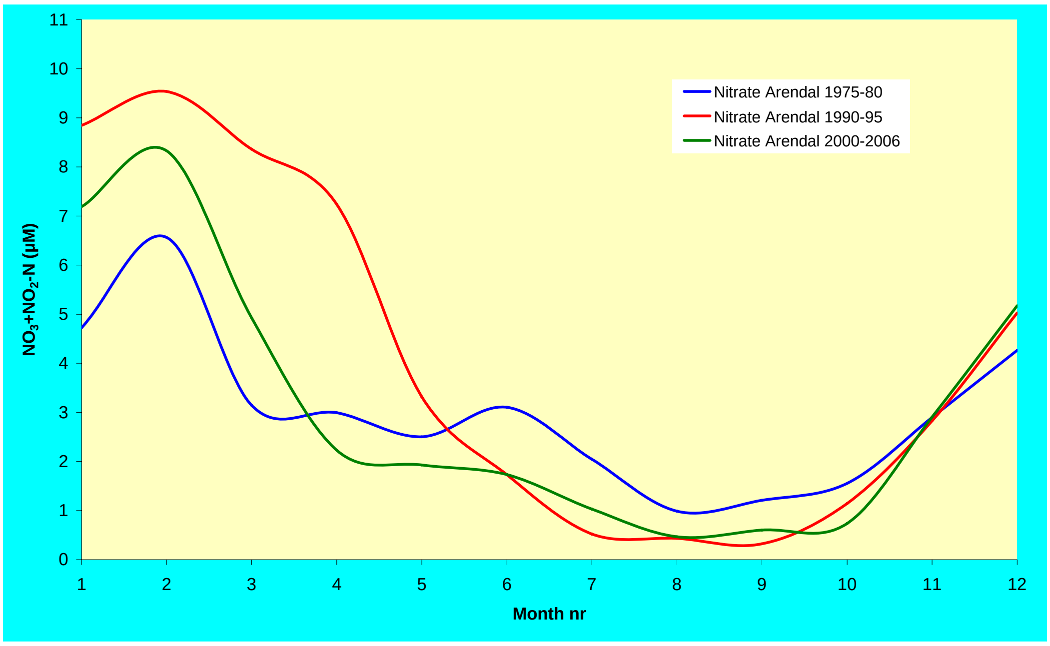

Figure 8. *Nitrate+nitrite concentrations at the south coast of Norway (Arendal), averaged from surface to 30 meters depth for three different periods (observations from Marine Research Institute, Flødevigen, and The Norwegian Coastal Monitoring Programme).*

indications of reduced local (Norwegian) loads to the coast at that level. The winter DIN/DIP ratios are still elevated compared to 1970-80, but the ratio is close to Redfield (12-16:1).

The ecological effect of the transboundary transport varies. Eutrophication effects in the main coastal water can be moderate, but the effect on inner coastal waters, among the archipelago and in the fjords can be more serious. Johannessen and Dahl (1996) analysed long term observations of oxygen. They found a significant decrease in oxygen levels over the years in different fjords along the Norwegian Skagerrak Coast from the Swedish border to Kristiansand. The regional character of this decrease suggested a common source.

Investigations in 2003-2004 (Buhl-Mortensen et al., 2006) has shown decreasing oxygen concentration in the fjord as an effect of transboundary transport of nutrients and organic matter. The oxygen consumption has increased by 50-60 % in the fjord basins along the Skagerrak Coast, which has reduced the number of bottom living species in areas with oxygen concentration less then 2 ml/l with 50-90 %, with 50-35 % with oxygen concentration 2-3 ml/l, but no clear effects at concentrations above 3 ml/l. In some areas effects of local loads interfere. This study clearly demonstrates the effect of transboundary transport, on fjords from the Grenland fjords in Telemark to Kristiansand.

Climatic changes seem to favour this transboundary transport. Episodes with flooding in northern Germany and the Netherlands as well as changes in the wind system during winter, has brought more nutrient rich water from the German Bight area to the Norwegian Skagerrak Coast. This was monitored especially in 1995 (Magnusson and Nygaard, 1995, Moy et al. 2002) and to a certain extent in 1994.

In 2004, a strong reduction in sugar kelp (*Saccharina latissima*) was observed along the sheltered parts of the Norwegian Skagerrak Coast. Compared to observations from 1975/1983/1989 about 90 % of the sugar kelp had been replaced with ephemeral algae (Moy et. al., 2007). The sudden change can be explained by high water temperatures in late summer, but the absence of recovery and the large scale shift from sugar kelp to turf algae dominated system of rocky coasts, also points to eutrophication effects (Moy et. al., 2007).

In **Table 6** the coastal water at Arendal is classified.

Table 7. *Summary Classification Table for the transboundary load from the German Bight/Kattegat to the Norwegian Skagerrak Coast, based on observations at Arendal St. 2.*

Category	**Assessment Parameters**	**Description of Results**	Score
Degree of Nutrient Enrichment (I)	Riverine total N and total P inputs and direct discharges (RID)	Elevated inputs of DIN to the German Bight.*	-
	Winter DIN- and/or DIP concentrations	Elevated DIN-concentrations**. “Normal DIP-concentrations	+
	Increased winter N/P ratio (Redfield N/P = 16)	Increased winter N/P ratio** (close to 16:1)	+
Direct Effects (II)	Maximum and mean chlorophyll *a* concentration		
	Region/area specific phytoplankton indicator species	c.f. chapter 3.1	
	Macrophytes including macroalgae (region specific)	Changes from sugar kelp to turf algae-dominated systems along the sheltered part of the coast.	+
Indirect Effects (III)	Degree of oxygen deficiency	Increased oxygen consumption and decreasing concentrations in fjords.	+
	Changes/kills in Zoobenthos and fish mortality		
	Organic Carbon/Organic Matter		
Other Possible Effects (IV)	Algae toxins (DSP/PSP mussel infection events)		

* Increased inputs since 1980 compared to 1962-80 (Hickel, Mangelsdorf and Berg, 1993, Kørner and Weichart 1991). Decreasing river inputs in 2000-2005.
** (Aure and Johannessen, 1997). Still elevated DIN levels compared with 1962-80, but decreasing winter values at both sites. Decreasing phosphate-concentrations in 2000-2006 back to the 1975-80 levels maintains the elevated DIN/DIP levels.

3.3.2 Water quality and biological data

The data on water quality and biological conditions are mainly collected through a large number of regional and local recipient studies, mainly during the period 1995-2006. The Norwegian Coastal Monitoring Programme, which monitors water quality and biological conditions in coastal water and archipelagos from outer Oslofjord and Stavanger-Bergen since 1990, constitutes a central part of this information pool.

The evaluation of toxic algae and mussel infection (blue mussel) are mainly based on data from weekly sampling on 7 stations on the Skagerrak coast (**Figure 7**). Stations 1- 4 are located in the Oslofjord area, station 5 in Telemark county, station 6 in East Agder county and station 7 in West Agder county. In general these stations are considered representative for the situation on the coast.

The sampling period is March-October. Water samples from the upper 3-10 m of the water column are analysed for *Dinophysis* spp., *Alexandrium* spp. and *Pseudo-nitzschia* spp. In addition dominating algae species and occurrence of other potential harmful algae are registered. The blue mussels are tested for DSP (toxins causing diarethic shellfish poisoning), PSP (toxins causing paralytic shellfish poisoning, YTX (Yessotoxins), ASP (toxins causing amnesic shellfish poisoning), AZA (Azaspiracids) and PTX (Pectenotoxins).

With the exception of *Prorocentrum minimum* that in some geographical regions may be used as an indicator species of eutrophication, the indicator species suggested by OSPAR seem unsuitable for the Norwegian coast (Dragsund and Tangen, 2003). In Norwegian coastal waters species of the genus *Alexandrium* may reach bloom concentrations in areas that cannot be regarded as eutrophic. *Dinophysis* is a natural component of the plankton of Norwegian coastal waters and its occurrence and distribution can not be correlated with eutrophication. *Chrysochromulina polylepis* has not been causing extensive and harmful blooms since 1988, but may be considered to be linked to eutrophication and special nutrient condition. Elevated levels of *Karenia mikimotoi* has been related to large scale eutrophication trends by OSPAR and others, but not necessarily to local eutrophication. During the period 2000-2005 it has occurred in modest concentration in Norwegian coastal waters. *Verrucophora* sp (*Chattonella* aff *verruculosa*) has caused fish kills along the Norwegian Skagerrak coast during the 2001-2005 period, but the blooms have not been considered to be related to local eutrophication.

In general, it seems that high numbers of small diatome species (e.g. *Chaetoceros tenuissimus*, *C. throndsenii*) in areas with reduced salinity, may be local indicators of eutrophication (Jensen et al. 2003, Dragsund et al. 2006). In areas of higher salinity, blooms and increase in plankton biomass may indicate eutrophication. Some Norwegian phycologists advocate the view that every geographical region has their own set of indicator species that may be identified after many years of monitoring. Our knowledge of the link between eutrophication and species composition in marine waters is poor and we need to increase our knowledge of the autecology of important phytoplankton species and the species composition along the Norwegian coast.

In this study the observations are used and classified according to the OSPAR criteria. Data describing water quality and biological conditions (hardbottom flora and fauna, softbottom fauna and phytoplankton) are sampled at distinct locations. As the whole coastal area is covered in this assessment, a broader view is often taken when judging the importance of data from specific locations.

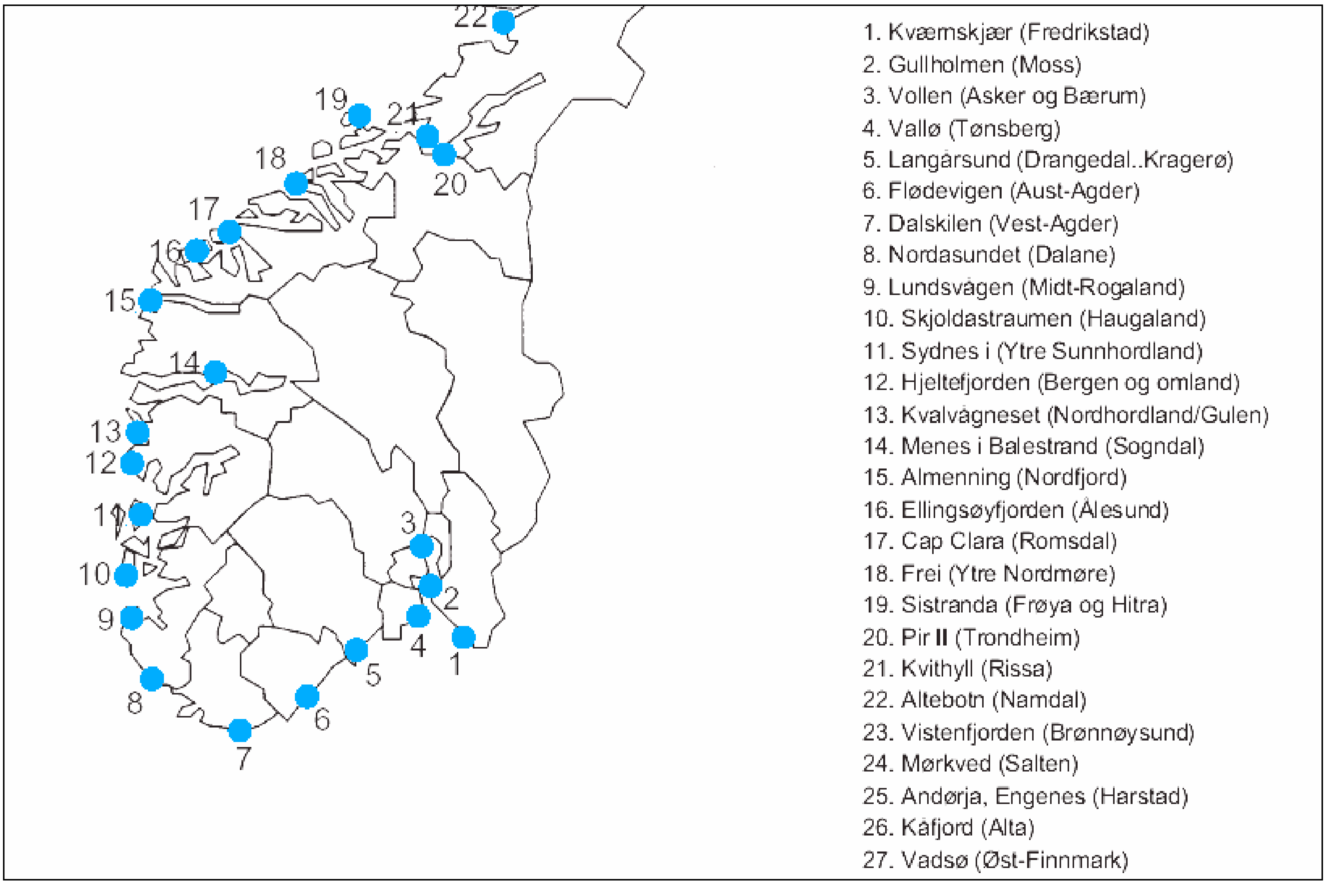

Figure 9. *Stations for monitoring of toxic algae and mussel toxins in southern Norway (from Hestdal et al., 2001).*

3.3.3 Data for the overall area

The observations used in this assessment are mainly from monitoring programmes like “The Inner Oslofjord”, “The outer Oslofjord” and “the Norwegian Coastal Monitoring Programme”. Observations from local recipient studies in East-Agder and West-Agder counties are sparse in our primary assessment period 2001-2005. Some observations from “Ships of Opportunity” (FerryBox) are incorporated. Oxygen conditions and bottom fauna in fjord basins along the Skagerrak Coast has been investigated by Buhl-Mortensen et.al. (2006) and is a major contribution to the assessment of the Skagerrak Coast.

4. Eutrophication assessment by area

4.1 Introduction

Reporting format in this report will in general follow the outline described in OSPARs "Comprehensive Procedure" (OSPAR 2005), with four main items:

1. Area (names and map showing geographical location)
2. Description of the area, including environmental information
3. Assessment according to***Table 2.***
4. Classification according to ***Table 3,*** or the Norwegian classification system.

First an initial classification and then a final classification taking into consideration other available information.

The assessment focuses on areas which inn 2002 were classified as Potential Problem Area (PPA) or/and areas where there are new and substantial information for some of the assessment parameters in***Table 2***. The other areas will be briefly mentioned.

Four important factors are updated since the previous classification in 2002:
- The anthropogenic nutrient loads: (Category I)
- Macroalgae, and especially sugarkelp: (Category II)
- Phytoplankton species and algae toxins: (Categories II and IV)
- Oxygen conditions and trends: (Category III)

4.2 Classification

4.2.1 The Oslofjord

For classification purposes the Oslofjord is divided into 4 areas which are classified according to the procedure outlined in Chapter 3 (***Figure 10***).

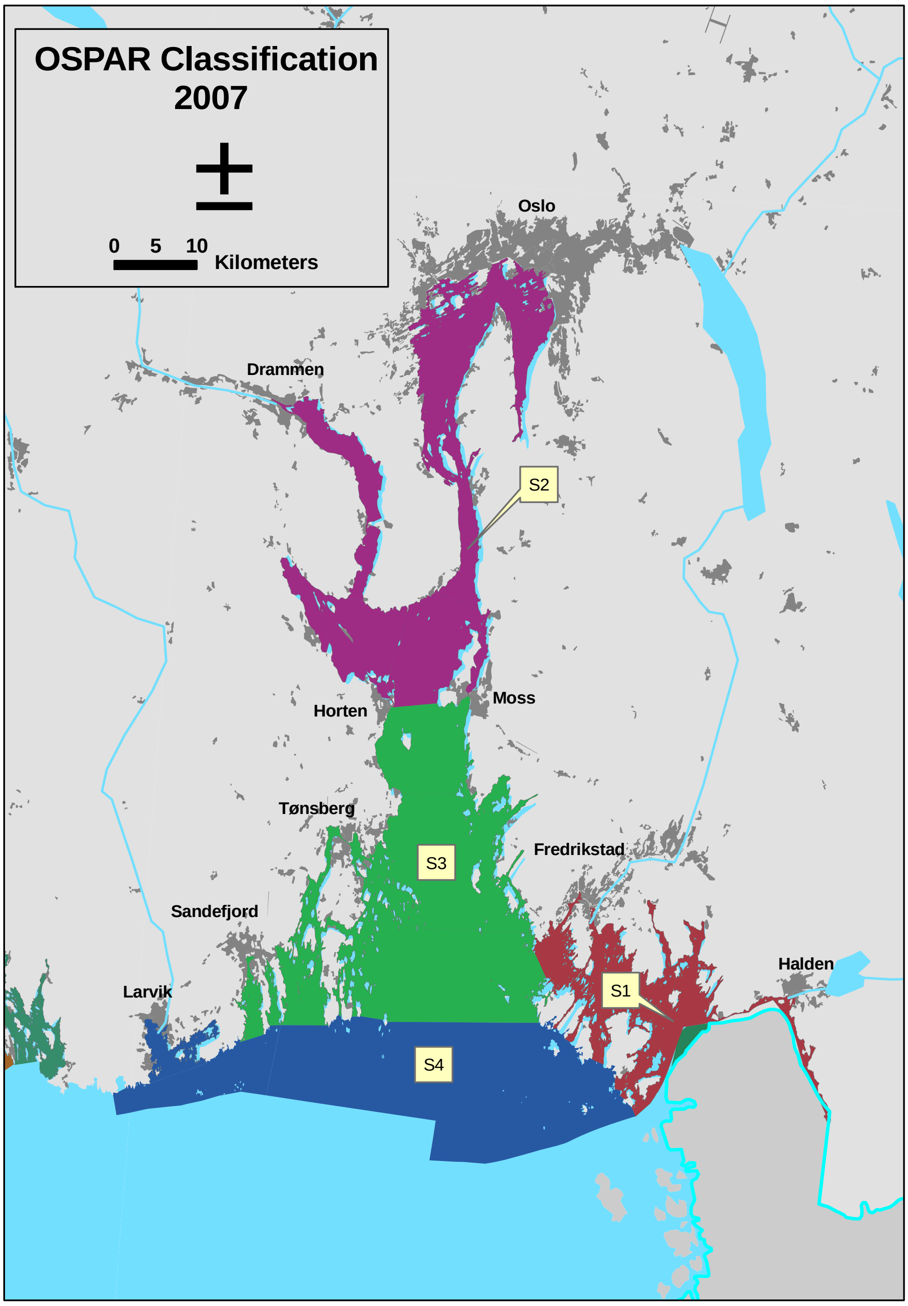

Figure 10. *The Oslofjord with areas S1-S4.*

S1 Iddefjord, Hvaler and Singlefjord

The basis for classification is briefly discussed. For a broader description, see Molvær et al. (2003a).

Nutrient load
The average anthropogenic nutrient load has been fairly constant during the last 10 years (***Table 8***).

Table 8. *Anthropogenic nutrient load for area S1. Averages for 1997-2000 and 2001-2005, with exception for phosphorus where data from 2004-2005 is used.*

Nitrogen load, tonnes		Phosphorus load, tonnes	
1997-2000	2001-2005	1997-2000	2004-2005
12042	11124	2329	2350

Hydrophysical characteristics.

The Iddefjord is situated near Halden in southeast Norway. The border between Sweden and Norway runs more or less in the middle of the fjord. It is a typical fjord with freshwater discharge, and basins, separated by several sills. Surface layer salinity range between 1 – 25, and deep-water range 28-31. Deep-water renewal varies between 1-3 times pr. year.

The Hvaler/Singlefjorden is a brackish water estuary situated south of Fredrikstad. The tides are weak (semidiurnal amplitude 0.1 m). The area is sheltered from the Skagerrak by islands. The Singlefjord is more or less without sills, but inside the Hvaler archipelago there are basins with restricted water exchange. About 25 % of the bottom area has depths less than 6 m, and 50% has less than 20 m depth. There are depths up to 160 m in the Singlefjord. The hydrophysical regime is dominated by the major river Glomma (water flow ca. 700 m3/s), creating a typical estuarine circulation. Salinity varies between 0 – 20 in the surface water (0-5 m depth), and in the deep water from 33-34. The surface layer residence time is 5-16 days. Deeper water renewals take place once a year to several times a year.

Degree of Nutrient Enrichment.

The Iddefjord has been heavily polluted by industry (pulp and paper), during the 20'th century and received untreated sewage water from Halden City as well as nutrients from agriculture. The organic load was large, giving hydrogen sulphide in the whole fjord, sometimes even in the upper layer (above sill depth). Benthic fauna and flora was sparse. Due to changes in the pulp and paper industry's processes and other reduction actions, including chemical treatment of the city sewage, anthropogenic nutrient load is reduced and the fjord has improved since the middle of the 1970'ies. Due to the industrial pollution, the phytoplankton production was low (bad light conditions and toxic effects), but as the industrial outlets decreased, the primary production increased. Due to less organic load the deep water became oxic, except in the inner part. The natural benthic algae recaptured the shores and the benthic fauna improved.

The Hvaler/Singlefjord estuary receives effluents from industrial, sewage and agriculture. The surface layer is strongly influenced by the river Glomma. High turbidity and low phytoplankton production in the brackish water, due to reduced light conditions, rapidly changing salinity and short residence time. In the brackish area the phytoplankton growth normally is phosphorus limited, but at the fronts between brackish water and seawater the conditions are favourable for blooms. The phytoplankton biomass is highest at salinities between 8-20. High numbers of small diatom species (e.g. *Chaetoceros tenuissimus*, *C. throndsenii*) and *Prorocentrum minimum* may be local indicators of eutrophication in this area (Jensen et al. 2003, Dragsund et al. 2006). The presence of algal toxins and toxic shellfish incidents is not necessarily a sign of eutrophication as this occurs also in pristine waters.

In 2002 this area was classified as Problem Area. The updated classification is shown in ***Table 9.***

Table 9. *Area S1. Classification Table.*

Category	Assessment Parameters	Description of Results	**Score**
Degree of Nutrient Enrichment (I)	Riverine total N and total P inputs and direct discharges (RID)	No significant change in anthropogenic load	**-**
	Winter DIN- and/or DIP concentrations	Elevated	**+**
	Increased winter N/P ratio (Redfield N/P = 16)	Elevated	**+**
Direct Effects (II)	Maximum and mean chlorophyll a concentration	Elevated Chl.a vaulues (Rygg et al 2000, 2001), (Dragsund et. al, 2006).	**+**
	Region/area specific phytoplankton indicator species	Bloom concentrations of indicator species : Area specific eutrophication indicator species; *Chaetoceros throndsenii*, *C. tenuissimimus*, *Cyclotella choctawatcheana*, *Prorocentrum minimum* (Dragsund et al, 2006) Elevated levels/bloom concentrations: Nucience species/harmful species *Dinophysis* spp and *Alexandrium* spp, *Verrucophora* sp, *Heterosigma akashiwo Noctiluca scintillans, Protocertium reticulatum, Prorocentrum minimum* Castberg et al 2005, Dahl 2002, 2003, 2005, Dahl et al 2003, 2004, 2006), *Pseudo-nitzschia calliantha*, *Phaeocystis pouchetii* (Dragsund and Tangen 2004)	**+**
	Macrophytes including macroalgae (region specific)	Some decline in sugar kelp (Moy et al 2007) Status – moderate to bad (Dragsund et al 2006)	**+**
Indirect Effects (III)	Degree of oxygen deficiency	Oxygen deficiency (Dragsund et.al., 2006)	**+**
	Changes/kills in Zoobenthos and fish mortality	Softbottom fauna	**-**
	Organic Carbon/Organic Matter		
Other Possible Effects (IV)	Algae toxins (DSP/PSP mussel infection events)	Detection of DSP, PSP, Azaspiracid, Yessotoxins (Castberg et al 2005, Dahl et al 2005, Hestdal 2001-2003)	**?**

Initial classification: Problem Area
Final classification: Problem Area

S2 Oslofjord to Breiangen, Drammensfjord and Sande bay

The basis for classification is briefly discussed. For a broader description, see Molvær et al. (2003a).

Nutrient load
The average anthropogenic nutrient load has decreased by 67% during the last 10 years (**Table 10**).

Table 10. *Anthropogenic nutrient load for area S2. Averages for 1997-2000 and 2001-2005, with exception for phosphorus where data from 2004-2005 is used.*

Nitrogen load, tonnes		Phosphorus load, tonnes	
1997-2000	2001-2005	1997-2000	2004-2005
6718	4565	175	129

Hydrophysical characteristics
The inner Oslofjord is a sill fjord, where the sill (19.5m) is situated in the narrow entrance to the fjord at Drøbak. The tides are semidiurnal (0.28 m) and freshwater input about 27 m^3/s. The estuarine circulation is thus relatively weak (50-200 m^3/s, Gade 1967) and even reversed in periods with high freshwater input from the larger rivers outside the fjord (Glomma and Drammen river) and high evaporation in the summer. The intermediate (pressure driven) water exchange due to varying density in the water outside the sill (above sill depth) is estimated to 1450 m^3/s (Stigebrandt and Magnusson, 2002).

The fjord has to larger basins- the Vestfjord with depths up to 164 m and the Bunnefjord with depths up to 154 m, separated by a sill (ca. 50 m depth). Two smaller basins are situated in the north – Bærum basin (max. depth 30 m) and Bekkelag basin (max. depth 72 m), both basins with sills (16 m and 40 m respectively).

The deep water is renewed about once a year in the Vestfjord and more or less in the smaller basins, but only about each third year in the Bunnefjord. The renewal is limited to the winter and the stagnation period is normally between May and October.

The surface salinity varies between 20-30, except in the close vicinity of the rivers. The deep-water salinity varies between 32 – 34.

The Drammensfjord is a typical sill fjord with a maximum depth of ca. 120 m and a sill of 10 m depth. The average fresh water discharge from Drammen river is 330 m^3/s. The amplitude of the semidiurnal tide is about 0,1 m. Surface salinity varies between 0-12, and deep water between 30-31. Deep-water renewals are rare – perhaps 10 years between total renewals (Magnusson and Næs, 1986).

Sande bay is partly brackish as it receives brackish water from the Drammensfjord in addition to freshwater from a local river. Normally the salinity varies between 20-34 in the surface layer but can occasionally be less than 10 in summertime. The deep-water salinity varies between 34-35. Major deep-water exchanges are normally once a year (winter/spring), but intermediate exchanges are more or less continuous.

Degree of Nutrient Enrichment.

The Oslofjord is mainly a recipient of sewage and to a lesser degree industry. Since 2001 the three major purification plants has phosphorus as well as nitrogen removal. Phosphorus removal started in the 1970-ies and has successively been improved since then. Nitrogen removal started in 1996/97 and was completed in 2001/2002. The reduction in anthropogenic load since 1985 has been about 67 % for us and nitrogen.

According to NCS the water quality varies between bad (V) to very good (I). Winter surface values with elevated nitrogen concentrations in spite of decreasing concentrations the last years. Decreasing phosphorus concentration results in elevated N/P ratios, according to the assessment criteria (Magnusson et al. 2006).

In the Drammensfjord the water quality varies between II-IV for nitrate (NCS), but with low phosphorous-concentrations (NSC quality I) due to the influence of river water. Thus this brings elevated N/P-levels.

Direct effects of nutrient enrichment.

In the Oslofjord the surface (0-2 m depth) concentration of chlorophyll *a* has decreased during the last 20 years (Magnusson et al. 2006). Concentrations are still elevated in some parts of the fjord according to the NCS. Earlier heavy local phytoplankton blooms seems moderated, but there are still observations of toxic species like *Dinophysis* spp. and *Alexandrium* spp. in concentrations above toxic levels for shellfish poisoning.

Negative shifts in macro algae have been reversed and the Fucasè community has increased and the short lived green algae decrease (Bokn et al., 1992, Magnusson et al. 2001). The lower growth limit has increased (increased depth distribution).

In Drammensfjord elevated levels of chlorophyll *a* are registered, especially in the areas with a rising salinity gradient (fronts) as well as elevated levels of summer nitrogen (NCS) (Dragsund et al., 2006).

Marine macro algae are poor or non-existent mainly due to low salinity in the surface layer. Outside the sill, green algae dominate, but different species of brown algae (*Fucus*) were also observed (Dragsund et al. 2006).

In Breiangen elevated levels of nitrate is observed (Figure 9) as well as elevated ratios of (winter) nitrate/phosphate (Dragsund et.al., 2006). Reduced secchi depth in the whole area (Dragsund et.al. 2006) is probably due to a mixture between high particles concentrations and phytoplankton blooms and has reduced the lower growth limit of macro algae compared to earlier observations (Rueness and Fredriksen, 1990). Parts of the area have elevated chlorophyll-a concentrations (Dragsund et.al. 2006).

Indirect effects of nutrient enrichment.

The Oslofjord has naturally low oxygen concentration (limited water exchange). Early sediment observations were not able to detect regular anoxic conditions in the Bunnefjord before 1940. A negative trend in observations from the deep water in the fjord, is detected from 1930 to the mid. 1970-ies. From then on the deep water of the Vestfjord shows a slight positive trend, while no trend is evident in the Bunnefjord. Minimum oxygen levels in the Vestfjord today (2001-2005) are about 2 ml/l (Class IV) according to NCS, but it is not expected to reach higher than 2 ml/l as an autumn average over a couple of years (Class IV). Since the middle 1970-ies the oxygen consumption has decreased to about the same level as in the 1950-ies, a significant effect of the reduced anthropogenic load (Magnusson, 2006).

Episodes of fish kills are observed in the inner part of the fjord, mainly in connection to deep-water renewals, when water of low oxygen content rises towards the surface. There are several years between the observations.

The hyper benthos population has decreased or in some parts extinguished mainly caused by low oxygen levels or hydrogen sulphide development in the bottom water. The trend was negative from 1950-1970 in the northern Vestfjord, but changed around 1985 to a positive development (Magnusson et al. 2006).

In Drammensfjord oxygen deficiency in the waters below sill depth is only partly a consequence of pollution. The deep water of the fjord is naturally anoxic due to long residence time. However, model simulations and earlier observations suggest possible improvements with reduced loads down to about 80 m depth (Sørensen et al., 1995). Due to very good water exchange the last years the oxygen levels were improved (Dragsund et.al., 2006), but the overall situation has not changed.

The bottom fauna is reduced due to low oxygen concentration. Anoxic water from 35-45 meters depth (1984) coincides with the lower limit for bottom fauna.

Breiangen: The soft bottom communities are classified as Class II/III in the central part of Breiangen (Dragsund et.al., 2006), but in vicinity to the industrial outlets in Sandebukta and Mossesundet poor or almost non-existent (Dragsund, 2002).

Fish kills have been observed in the area coinciding with plankton blooms.

Other possible effects of nutrient enrichment.

In Oslofjord episodes of shellfish poisoning occurs, recently from toxic algae as *Dinophysis* spp. and *Alexandrium* spp (Hestdal, et al., 2001). The presence of ichthyotoxic species (e.g *Karenia*) and algal toxins or an increase in toxic shellfish incidents is not necessarily a sign of eutrophication as this occurs also in pristine waters.

The quality of the water masses in the outer Oslofjord that potentially can be part of the deep-water renewal in the inner fjord, has also changed. The oxygen concentration has decreased since 1930 to 2000 from above 5 ml/l to slightly below 5 ml/l, thus sometimes decreasing the oxygen transport to the inner fjord (Johannessen and Dahl, 1996 and Magnusson et al. 2001). This change can probably be explained by changing environmental conditions in the outer Oslofjord, probably caused by local as well as long-range transboundary transport of nutrients.

Table 11. *Area S2. Summary of Classification.*

Category	**Assessment Parameters**	**Description of Results**	Score
Degree of Nutrient Enrichment (I)	Riverine total N and total P inputs and direct discharges (RID)	Anthropogenic load has significantly decreased.	**-**
	Winter DIN- and/or DIP concentrations	Elevated in areas	**+**
	Increased winter N/P ratio (Redfield N/P = 16)	Elevated in areas	**+**
Direct Effects (II)	Maximum and mean chlorophyll *a* concentration	Elevated in areas	**+**
	Region/area specific phytoplankton indicator species	Elevated levels/bloom concentrations Nuisance species/harmful species; *Alexandrium tamarense, Karenia mikimotoi, Prorocentrum minimum* ((Magnusson et al 2002,2003, 2004, 2005, 2006)) *Pseudo-nitzshia* spp (Magnusson et al 2002,2003, 2004, 2005, 2006) including *P. calliantha (*Dragsund and Tangen, 2005)	**?**
	Macrophytes including macroalgae (region specific)	Improving but still affected (Magnusson et al 2001, 2003. Pedersen et al., 2006)	**+**
Indirect Effects (III)	Degree of oxygen deficiency	Varies a lot with variation in annual water exchange from Outer Oslofjord. (Magnusson et al 2001, 2003) Breiangen SFT class III (Dragsund et al. (2006)	**+**
	Changes/kills in Zoobenthos and fish mortality	Varies a lot with variation in annual water exchange from Outer Oslofjord, but seems to improve (Magnusson et al 2001, 2003) (Rygg 2001)	**(+)**
	Organic Carbon/Organic Matter		
Other Possible Effects (IV)	Algae toxins (DSP/PSP mussel infection events)	Detection of DSP, Yessotoxins, ASP (Castberg et al 2005, Dahl et al 2005, Hestdal 2001-2003) Magnusson et al (2001, 2003)	**?**

Initial classification: Problem area.
Final classification: Problem area.

S3 Main outer Oslofjord , including Tønsberg and Sandefjord

The basis for classification is briefly discussed. For a broader description, see Molvær et al. (2003a).

Nutrient load

The average anthropogenic nutrient load has decreased by ca. 20% during the last 10 years (**Table 12**).

Table 12. *Anthropogenic nutrient load for area S3. Averages for 1997-2000 and 2001-2005, with exception for phosphorus where data from 2004-2005 is used.*

Nitrogen load, tonnes		Phosphorus load, tonnes	
1997-2000	2001-2005	1997-2000	2004-2005
1639	1271	54	44

Hydrophysical characteristics.

The middle part of the outer Oslofjord is a transition area between the inner parts and the outer parts. The surface layer is partly brackish depending on the influence from low saline water from the Drammensfjord and the river Glomma in the south east, with small rivers with direct outlets. The tides are weak and semidiurnal (ca. 0.1 m). The surface layer (0-30m) salinity varies between 15 (summer)-34 (winter) normally between 22-32/33. There are observations of more than one deep-water renewal pr. year.

The inner part of the Tønsbergfjord is a sheltered sill fjord with sill depths about 8 m and maximum bottom depth 15 meters. The fjord receives freshwater from a small river Aulie at the bottom of the fjord. There are few observations of salinity in the area. The surface layer salinity varies between 16 – 24 in the summer and probably about 30 in winter. Deep-water salinity is probably between 30-32 (salinity variation in the outer Oslofjord surface layer). The outer part is open with direct communication with the outer Oslofjord and inner Skagerrak.

The Sandefjordsfjord is an open fjord with a few constrictions, about 85 meters depth with sill between 55 - 60 m. Due to little local freshwater influence and the open connection to the coast, the salinity variation follows the coastal variation. Surface salinity varies between 31 in winter and about 20 in summer, with a depth about 10 m. The deep-water salinity varies between 32-34.

Degree of nutrient enrichment.

The middle part of the outer Oslofjord

The major parts of the outer Oslofjord seem moderately influenced of elevated nutrients. Winter nitrate concentrations vary between Class I and II, touching Class III. DIN/DIP ratios in some areas are elevated, and Chlorophyll-a concentrations are mostly in NCS class I-II, touching Class III. Therefore the area seems to balance in the lower range of eutrophication scale (***Figure 11***).

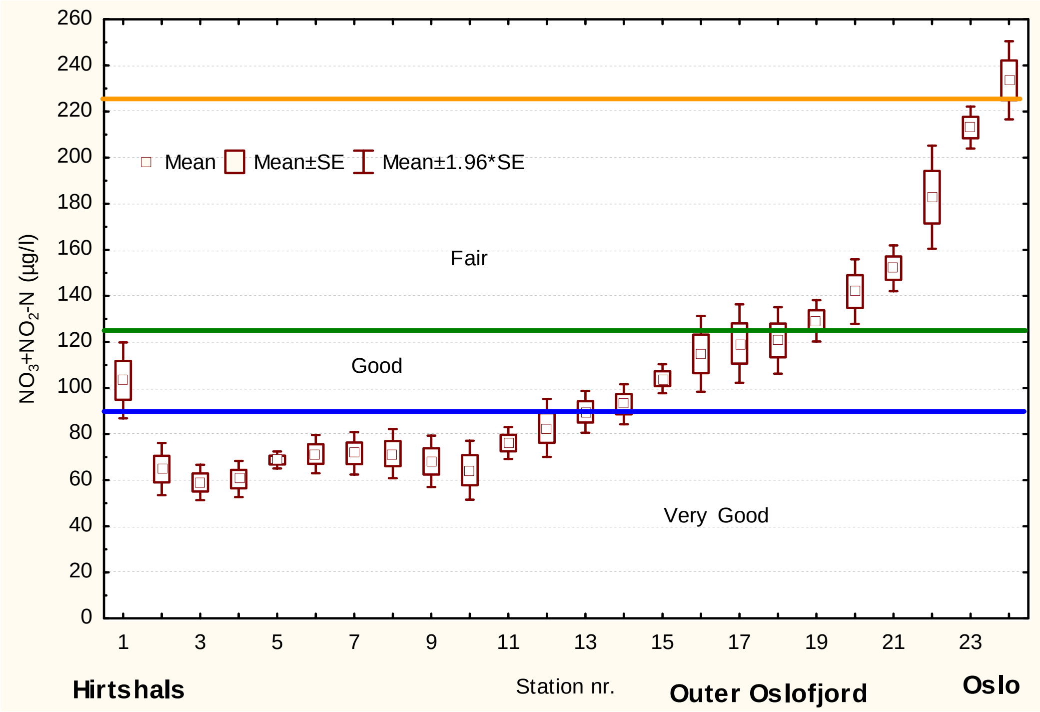

Figure 11 .*Winter (December-February) nitrate concentrations 2004 sampled at 4 m depth between Denmark (Hirtshals) and Norway (Oslo). Number of samples varies between 6 and 18 for the different stations. Station 15 – 18 covers main outer Oslofjord, station 19-21 Breiangen and the Drøbak sound, Station 22-23 the inner Oslofjord.*

The Tønsbergfjord

The inner part of the Tønsbergfjord has elevated levels of tot-P in winter (Dragsund et. al. , 2006). The main part of the outer Tønsbergfjord lacks information about nutrients.

The Sandefjordsfjord

There is no new winter nutrient information from the fjord. Summer values are in Class 1-II.

Direct effects of nutrient enrichment.

Chlorophyll-a concentrations are mostly in NCS class I-II, touching Class III . Macroalgae is classified as moderately influenced (Dragsund et.al., 2006), but there is a reduction in sugar kelp (Moy et.al., 2007).

Indirect effect of nutrient enrichment.

Oxygen concentration normally over 4.5 ml/l, but has been observed down to below 4 ml/l, which means Class I-II according to the NCS in the bottom water. In semi-enclosed areas the concentration can be lower (Class III).

The soft bottom communities are classified as good (Class I-II) in the central parts (Dragsund, et al., 2002).

Other possible effects of nutrient enrichment.

High numbers of small diatom species (e.g. *Chaetoceros tenuissimus*, *C. throndsenii*) may be local indicators of eutrophication in this area (Jensen et al. 2003, Dragsund et al. 2006). The presence of ichthytoxic algae (e.g. *Verrucophora*) may not be and indicator of Eutrophication.

Tønsberg fjord: Algal toxins (DSP/PSP mussel infection) have been observed (Hestdal et al., 2001), but the presence of algal toxins or an increase in toxic shellfish incidents is not necessarily a sign of eutrophication as this occurs also in pristine waters.

Evaluation

Table 13. *Area S3. Summary of Classification.*

Category	Assessment Parameters	Description of Results	**Score**
Degree of Nutrient Enrichment (I)	Riverine total N and total P inputs and direct discharges (RID)	Decreased during the last 10 years	**-**
	Winter DIN- and/or - concentrations	Touching elevated levels	**+?**
	Increased winter N/P ratio (Redfield N/P = 16)		**-**
Direct Effects (II)	Maximum and mean chlorophyll a concentration	Touching elevated levels	**-**
	Region/area specific phytoplankton indicator species	Bloom concentrations: Area specific eutrophication indicator species; *Diatoma eleongatum, Chaetoceros tenuissimus,C. throndsenii. C subtilis, Cyclotella* sp.,*Dinobryon divergens* (Dragsund et al., 2006) Elevated levels/bloom concentrations: Nuisance species/harmful species; *Prorocentrum minimum, Dinophysis* spp. *Verrucophora* sp. (Dragsund and Tangen, 2002), *Pseudo-nitzschia calliantha* (Dragsund and Tangen, 2005), *Pseudo-nitzschia* spp. (Castberg et al 2005, Dahl et al 2006, Hestdal 2001-2003)	+
	Macrophytes including macroalgae (region specific)	Mainly moderately affected (Dragsund et al 2006) Major decline in sugarkelp (Moy et al. 2007)	+
Indirect Effects (III)	Degree of oxygen deficiency	Locally low O2, but generally good (Dragsund et al 2006)	+
	Changes/kills in Zoobenthos and fish mortality	Sandefjord very low O2 –no life under 50-60m (Rygg 2002). Little effect on soft bottom (Dragsund et al 2006).	**(-)**
	Organic Carbon/Organic Matter		
Other Possible Effects (IV)	Algae toxins (DSP/PSP mussel infection events)	Detection of DSP (Castberg et al 2005, Dahl et al 2005, Hestdal 2001-2003)	**?**

Initial classification: Problem area.
Final classification: Problem area.

S4 Southern part of outer Oslofjord

Nutrient load

The average anthropogenic nutrient load has decreased significantly during the last 10 years (**Table 14**).

Table 14. *Anthropogenic nutrient load for area S4. Averages for 1997-2000 and 2001-2005, with exception for phosphorus where data from 2004-2005 is used.*

Nitrogen load, tonnes		Phosphorus load, tonnes	
1997-2000	2001-2005	1997-2000	2004-2005
1206	1000	66	34

Hydrophysical characteristics

The southern part of the outer Oslofjord connects the Oslofjord area to the Skagerrak. The sill depth to Skagerrak is between 125-150 m depth and the deepest part (the Hvaler depth) up to 465 m. The tides are weak (0.1 m) and semi-diurnal. The area is influenced by the river Glomma and receives brackish water from the inner parts during flooding season. Surface layer is about 30 m depth with salinity between 15-33 dependent on the inputs from Glomma river and weather conditions. The surface salinity can be much lower in part of the area due to the river impact. The deep-water salinity varies from 33-35. Regularly deep-water renewals occur yearly and sometimes to times a year. Intermediate water exchange with the Skagerrak is more or less continuous.

Degree of nutrient enrichment.

The area receives water and nutrients from neighbouring areas primary from Hvaler (e.g. the river Glomma), but is also exposed from long range transboundary transport from the Skagerrak.

The main part of the area has no indication of elevated nutrient levels.

Direct effects of nutrient enrichment.

The phytoplankton biomass varies both in time and space. The area is often characterised by fronts between nutrient rich (nitrogen) brackish water and Skagerrak water. Heavy phytoplankton blooms occur in the fronts. In 1999-2000 the concentration reach maximum values of more than 6 µg chl.*a*/l (Class III, according to the NCS, Aure and Danielssen, 2001). Analyses of dinoflagellate cyst in the sediments (Dale, 1990) can be interpreted as there has been an increased productivity from about 1950-1980.

The area is known for blooming of toxic species. Partly this is locally ignited, but also as a part of the general phytoplankton situation in the inner Skagerrak. Frequent blooms of *Karenia mikimotoi* (earlier *Gyrodinium aureolum*), occasionally fish kills. Other toxic algae observed are *Dinophysis* spp, *Alexandrium* spp., and *Verrucophora* spp (=*Chattonella aff verrucolosa*). The presence of ichthyotoxic algae (e.g. *Verrucophora, Karenia, Heterosigma*) and algae causing shellfish poisoning may not be an indicator of Eutrophication as elevated levels of these species may occur in pristine waters as well. DSP in bivalves/mussels are reported almost every year (Tangen pers. comm.).

Reduced depth distribution of macro algae compared to the situation about 50 years ago (Fredriksen and Rueness, 1990). Secchi depth has also decreased (in average 0.7 m since 1940), reducing the photosynthetic layer with about 2 m (Andresen, 1993, Baalsrud and Magnusson, 1990). Reduction of sugar kelp is observed (Moy, et.al., 2007).

Indirect effects of nutrient enrichment.

Oxygen concentration normally over 4.5 ml/l but has been observed down to below 4 ml/l, which means Class I-II according to the NCS in the bottom water.

The soft bottom communities are classified as good (Class I-II) in the central parts.

Other possible effects of nutrient enrichment.

Phytoplankton in amounts to cause DSP/ASP in shellfish is observed. The presence of algal toxins or an increase in toxic shellfish incidents is not necessarily a sign of Eutrophication as this occurs also in pristine waters.

Larviksfjord including the Viksfjord

Hydrophysical characteristics.
Larviksfjord is an open sill-free fjord with depths from about 120 m in the mouth. Viksfjord is a semi-enclosed bay with depths from 11-24 m. While there are almost none freshwater discharge to Viksfjord, Larviksfjord receives river water from Numedalslågen. The river dominates the surface water salinity throughout the year, but is most prominent during flooding. Surface salinity varies with the river discharge from 1 –16 in the inner part with a depth between 1– 4 m. Under this layer there are gradually rising salinities down to about 10 m (25-30). The deeper water salinities vary between 33-34.5.

The river establishes an estuarine circulation, but the width of the fjord is sufficient for an uneven distribution of the brackish water masses, that preferably leaves the fjord on the right side.

Surface salinity in the Viksfjord is slightly higher as the fjord is situated on the left side of the Larviksfjord. The fjord will import water from the Larviksfjord, but is probably in normal situations less influenced by fresh water.

Degree of nutrient enrichment.
Larviksfjord receives nutrients from the main river Numedalslågen and from sewage from Larvik. Agriculture load with the river is about 60 % of the nitrogen load, while the City's sewage load is about 14 %. In Larvik there is a factory (chemical pulp industry) with outlets to a small river, and at 15 and 25 m depth in the harbour basin. The city's sewage outlets are distributed to the middle of the fjord at about 40 m depth.

There are few observations from the area in the last 10 years. Surface summer observations from 2001-2005 are good (Class I/II)(Dragsund et.al., 2006).

Direct effects of nutrient enrichment.
Chlorophyll-a observation are sparse but in Class I. (Dragsund et.al., 2006).

Indirect effects of nutrient enrichment.

Earlier observations in 1989 (Miljøplan A/S, 1990) show oxygen deficiency at intermediate depths, but not in the deep water. Bottom water (2 m above the bottom) from one station in 2001- 2005 was classified as Class I according to NCS (Dragsund et. al, 2006). The bottom fauna was classified as Class I(NCS) (op. cit),

The area has probably the same problems with toxic alga blooms as the coastal area at large. Macro algae at one station was characterised with a greater amount of green algae indicating eutrophication (Dragsund et.al., 2007). The presence of ichthyotoxic algae (e.g. *Verrucophora*) and algae causing shellfish poisoning may not be an indicator of Eutrophication as elevated levels of these species may occur in pristine waters as well. Sugar kelp is slightly reduced the last years (Moy et al., 2007).

Other possible effects and nutrient enrichment
No other data has been found.

Evaluation

Table 15. *Area S4. Summary of Classification.*

Category	Assessment Parameters	Description of Results	Score
Degree of Nutrient Enrichment (I)	Riverine total N and total P inputs and direct discharges (RID)		
	Winter DIN- and/or DIP concentrations		-
	Increased winter N/P ratio (Redfield N/P = 16)		-
Direct Effects (II)	Maximum and mean chlorophyll a concentration		-
	Region/area specific phytoplankton indicator species	Elevated levels/bloom concentrations: Nuisance species/harmful species; *Prorocentrum minimum*, *Dinophysis* spp. *Verrucophora* sp. (Dragsund and Tangen, 2002), *Pseudo-nitzschia calliantha* (Dragsund and Tangen, 2005)	?
	Macrophytes including macroalgae (region specific)	Moderate to good status, locally moderate (Moy et al. 2006) (Dragsund et al 2006). None or minor decrease in sugarkelp (Moy et al. 2007)	(+)
Indirect Effects (III)	Degree of oxygen deficiency		
	Changes/kills in Zoobenthos and fish mortality	Softbottom fauna mainly good but one local stations moderate (Dragsund et al. 2006)	(-)
	Organic Carbon/Organic Matter		
Other Possible Effects (IV)	Algae toxins (DSP/PSP mussel infection events)	No data	

Initial classification: Potential Problem area.
Final classification: Problem area.

4.2.2 Telemark County

For classification purposes the coast of Telemark county is divided into 3 areas (***Figure 12***). The areas will be classified according to the procedure outlined in chapter 4.1. In general there is far less data than for Oslofjord, and the presentation and discussion is therefore briefer.

The nutrient load along the coast is variable and we shall focus on areas S5 and S6 downstream of S5 which typically represent areas with high fresh water runoff and/or high load of sewage.

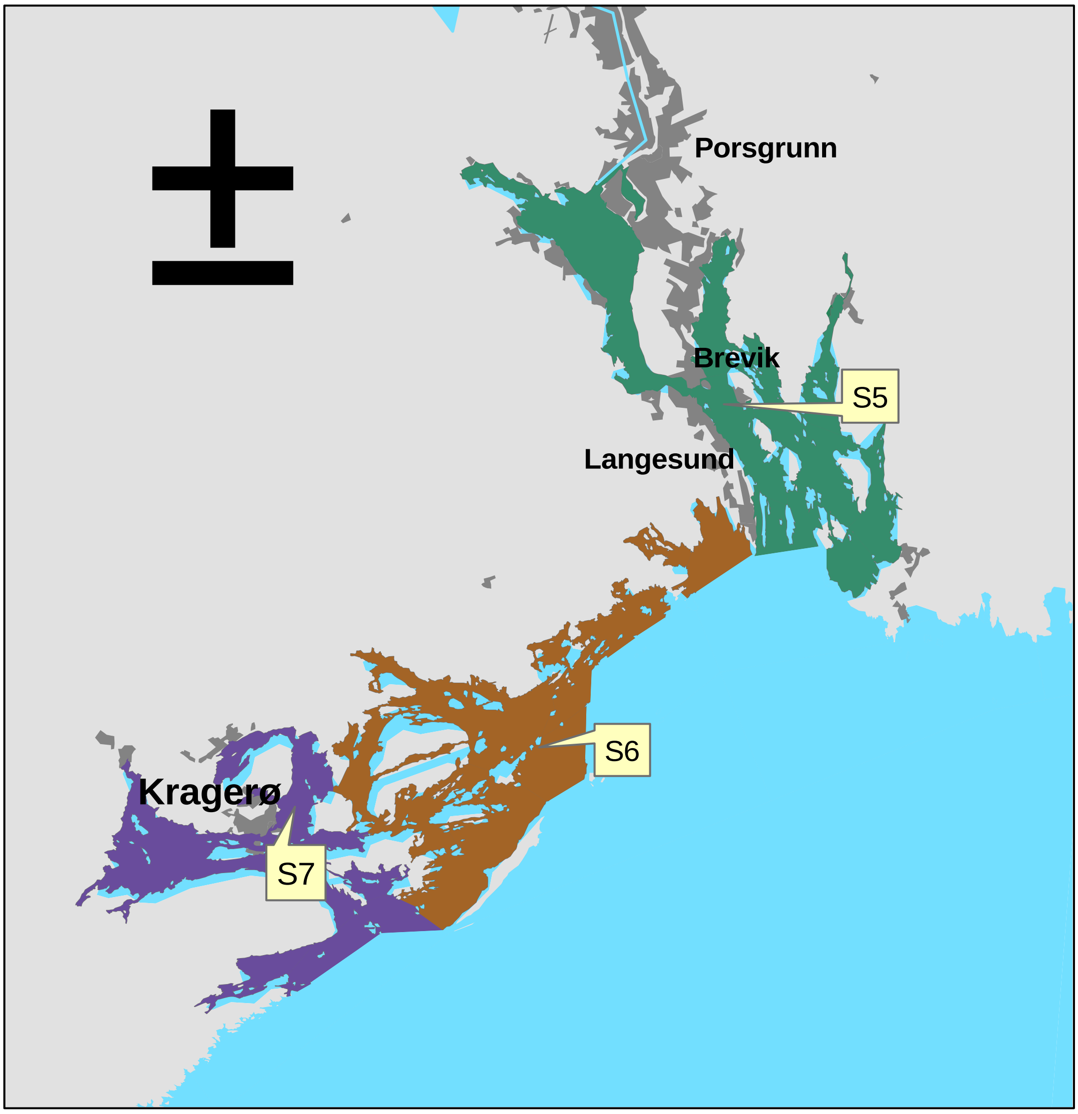

Figure 12. *Telemark county with areas S5-S7.*

S5 Grenland fjords

The Grenland fjords are situated south of Porsgrunn city (***Figure 12***). Being a typical fjord area with high freshwater supply (annual average approx. 250 m^3/s), deep basins and shallow sills, the hydrophysical regime is characterised by an estuarine circulation where the outflowing brackish layer is 3-5 m deep with a salinity from 4 (Frierfjord) to 12-15 (outside Brevik). The basin water undergoes stagnation periods of 2-5 years. Frierfjord has received wastewater from the cities and industrial effluents from pulp and paper industry, production of fertilisers and other chemical industry over the last 40-50 years. The anthropogenic nutrient load is shown in***Table 16.***

Table 16. *Anthropogenic nutrient load for area S5. Averages for 1997-2000 and 2001-2005, with exception for phosphorus where data from 2004-2005 is used.*

Nitrogen load, tonnes		Phosphorus load, tonnes	
1997-2000	2001-2005	1997-2000	2004-2005
1916	2223	36.8	33.4

In 2002-2003 the fjord system was classified as Problem Area based on data up to 2001 (Molvaer et al., 2003a). Monitoring studies in 2001-2005 (Dragsund et al., 2006) has shown small changes in biological conditions:

- Significant effects on hardbottom flora and fauna
- Soft bottom fauna in NCS classes IV-V (Bad-Very bad)

However, the oxygen conditions in two (Frierfjord, Langesundsfjord) and possibly all three major fjord basins have improved. The improvement in Langesundsfjord may be contrary to the conclusion in Buhl Mortensen et al., (2006).

Nutrients have not been sampled in winter and therefore difficult to classify, but in spring-summer concentrations of total nitrogen and chlorophyll a in the brackish surface layer correspond to classes II-III according to NCS.

High numbers of small diatom species (e.g. *Chaetoceros tenuissimus*, *C. throndsenii*), may be local indicators of eutrophication in this area (Jensen et al. 2003, Dragsund et al. 2006).

Evaluation:

Table 17. Area *S5. Summary of Classification.*

Category	**Assessment Parameters**	**Description of Results**	Score
Degree of Nutrient Enrichment (I)	Riverine total N and total P inputs and direct discharges (RID)	Insignificant changes	**-**
	Winter DIN- and/or DIP concentrations	No data since previous classification	**? (+)**
	Increased winter N/P ratio (Redfield N/P = 16)	No data since previous classification	**? (+)**
Direct Effects (II)	Maximum and mean chlorophyll *a* concentration	No data since previous classification	**?(+)**
	Region/area specific phytoplankton indicator species	Elevated concentrations: Area specific eutrophication indicator species; *Chaetoceros throndsenii, Chaetoceros tenuissimus* (Dragsund et al., 2006), *Prorocentrum minimum* (Dragsund and Tangen, 2005) Nuisance species/harmful species: *Prorocentrum minimum* (Dragsund and Tangen, 2005)	+
	Macrophytes including macroalgae (region specific)	Affected (Dragsund et al., 2006). Major decline in sugarkelp (Moy et al 2007)	+
Indirect Effects (III)	Degree of oxygen deficiency	Inner part bad (Dragsund et al 2006), Langesund good (Dragsund et al ., 2006)	+
	Changes/kills in Zoobenthos and fish mortality	Softbottom fauna dead in inner part below 50-60m (Rygg 2002)	+
	Organic Carbon/Organic Matter		
Other Possible Effects (IV)	Algae toxins (DSP/PSP mussel infection events)	No data	

Initial classification: Problem area.
Final classification: Problem area.

S6 Telemark coastline

The area is divided into a number of inlets and sounds inside a number of islands (***Figure 12***). The local nutrient input is low and mainly from municipal sewage, but there is also a significant transboundary nutrient load from Areas “upstream” of Area S5.

Table 18. *Anthropogenic nutrient load for area S6 Averages for 1997-2000 and 2001-2005, with exception for phosphorus where data from 2004-2005 is used.*

Nitrogen load, tonnes		Phosphorus load, tonnes	
1997-2000	2001-2005	1997-2000	2004-2005
19	11	0,6	0,9

The anthropogenic nitrogen load may have decreased during the last 10 years, but the changes of phosphorus in uncertain. Due to upstream freshwater discharges and some small local input, the surface salinity will typically vary between 15 and 25, and in general the surface water flows to the south-west.

There is not any new hydrochemical data since the classification in 2002-2003.

We have not found any recent information about the biological status from recipient studies in Area S6. However, the previously cited study of sugar kelp shows minor changes (Moy et al., 2007).

Evaluation:

Table 19. *Area S6. Summary of Classification.*

Category	**Assessment Parameters**	**Description of Results**	Score
Degree of Nutrient Enrichment (I)	Riverine total N and total P inputs and direct discharges (RID)	Varying trends for N and P, but hardly any significant changes	**-**
	Winter DIN- and/or DIP concentrations	No data	
	Increased winter N/P ratio (Redfield N/P = 16)	No data	
Direct Effects (II)	Maximum and mean chlorophyll *a* concentration	No data	
	Region/area specific phytoplankton indicator species	No data	
	Macrophytes including macroalgae (region specific)	Moderate to good status, locally moderate (Moy et al., 2006, Dragsund et al 2006). None or minor decrease in sugarkelp (Moy et al., 2007)	**(+)**
Indirect Effects (III)	Degree of oxygen deficiency	In local basins	+
	Changes/kills in Zoobenthos and fish mortality	Softbottom fauna mainly good but on local stations moderate changes (Dragsund et al., 2006)	**(-)**
	Organic Carbon/Organic Matter	No data	
Other Possible Effects (IV)	Algae toxins (DSP/PSP mussel infection events)	No data	

Initial classification: Potential Problem area.
Final classification: Problem area,. The final assessment takes into consideration the transboundary load, possible local areas with oxygen problems and algal toxins.

S7 Kragerøfjord and Stølefjord

These areas are situated in the southwestern part of Telemark county (***Figure 12***). The Kragerø fjord system consists of several fjords where the Hellefjord (2.7 km2, sill depth 10 m, and max. depth 75 m), the Kilsfjord (15 km2, sill depth 30 m, and max depth 106 m) and the Berøfjord (6 km2, sill depth 18 m, max. depth 66 m) are the largest. The municipal waste water from city of Kragerø (10000 PE) is processed with chemical precipitation before discharge to the Berøfjord through a deep water outlet. The freshwater input is mostly to the Kragerøfjord (ca. 36 m3/s). The main characteristics are summarised in ***Table 20***.

Table 20. *Anthropogenic nutrient load for area S7. Averages for 1997-2000 and 2001-2005, with exception for phosphorus where data from 2004-2005 is used.*

Nitrogen load, tonnes		Phosphorus load, tonnes	
1997-2000	2001-2005	1997-2000	2004-2005
116	142	4,5	2,1

The anthropogenic phosphorus load is reduced during the last 10 years due to use of chemical treatment plants for municipal wastewater, while the nitrogen load shows a significant increase.
.
The oxygen conditions in the Kragerø fjord system are generally “Bad-Very bad” according to NCS (see also Buhl Mortensen et al., 2006). Otherwise there are no new hydrochemical data since the classification in 2002-2003.

We have not found any recent information about the biological status from recipient studies in Area S6. However, the previously cited study of sugar kelp shows major changes (Moy et al., 2007).

The presence of algal toxins and elevated levels of the organisms causing them is not necessarily an indicator of Eutrophication as this occurs in pristine waters as well.

Evaluation:

Table 21. *Area S7. Summary of Classification.*

Category	**Assessment Parameters**	**Description of Results**	Score
Degree of Nutrient Enrichment (I)	Riverine total N and total P inputs and direct discharges (RID)	Varying trends for N and P	**?**
	Winter DIN- and/or DIP concentrations	No data	
	Increased winter N/P ratio (Redfield N/P = 16)	No data	
Direct Effects (II)	Maximum and mean chlorophyll *a* concentration	No data	
	Region/area specific phytoplankton indicator species	Nuicance species/harmful species *Dinophysis* spp., *Pseudon-nitzschia* spp., *Alexandrium* spp. (Castberg et al 2005, Dahl et al 2005, Hestdal 2001-2003)	**?**
	Macrophytes including macroalgae (region specific)	Major decline in sugar kelp (Moy et al. 2007)	+
Indirect Effects (III)	Degree of oxygen deficiency	In bottom water O2<2.5 mlO2/l	+
	Changes/kills in Zoobenthos and fish mortality	No data	
	Organic Carbon/Organic Matter	No data	
Other Possible Effects (IV)	Algae toxins (DSP/PSP mussel infection events)	Algal toxins; DSP, Yessotoxins, PSP, Azapiracid (Castberg et al 2005, Dahl et al 2005, Hestdal 2001-2003)	**?**

Initial classification: Problem area.
Final classification*:* Problem area

4.2.3 East Agder County

For classification purposes the coast of East Agder county is divided into 5 Areas (S8-S12) as indicated in **Figure 13**. In the following the areas will be classified according to the procedure outlined in chapter 4.1. In general there is very few data since the previous assessment and the description of each area will be brief.

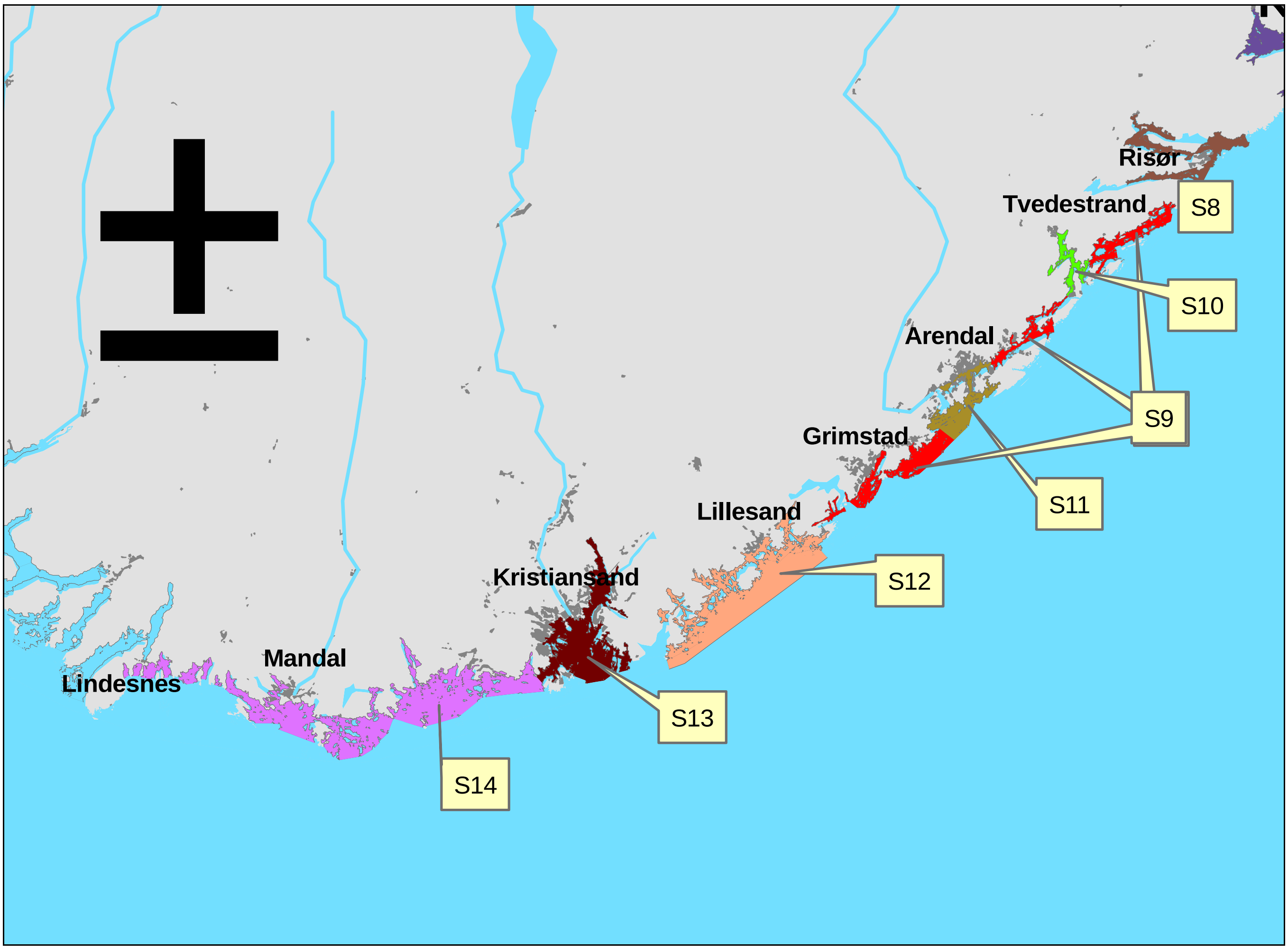

Figure 13. *Norwegian Skagerrak coast with areas S8-S14*

S8 Søndeledfjord and Sandnesfjord

These areas are situated in the north-eastern part of East-Agder county (***Figure 13***). The municipal waste water from city of Risør (4000 PE) is processed with biological treatment before discharge to coastal water through a deep water outlet. In general the anthropogenic nutrient load is low. The main characteristics are summarised in Table 21.

Table 22. *Anthropogenic nutrient load for area S9. Averages for 1997-2000 and 2001-2005, with exception for phosphorus where data from 2004-2005 is used.*

Nitrogen load, tonnes		Phosphorus load, tonnes	
1997-2000	2001-2005	1997-2000	2004-2005
77	52	3.4	2.1

The anthropogenic nutrient load is reduced during the last 10 years.

Except from annual sampling of oxygen by Institute of Marine Research, there have been no systematic studies of the marine environment in these two fjord systems. A study in 2006 confirmed serious oxygen problems (<1.5 mlO2/l) in the Søndeledfjord (Kroglund et al., 2007a). In Sandnesfjord the minimum values are slightly below 2.5 mlO2/l (Buhl Mortensen et al., 2006).

The oxygen shows large variations from one year to another, but during the last 40-50 years there is a decline in minimum values. As a similar trend is found in fjords, coastal water and in the Skagerrak upstream this area, this trend has been mainly explained as a combination of local and regional development in the coastal water – where as the regional signal is strongest (Aure et al. 1997, ANON 1997, Buhl Mortensen et al., 2006,).

Evaluation:

Table 23. *Area S8. Summary of Classification.*

Category	Assessment Parameters	Description of Results	Score
Degree of Nutrient Enrichment (I)	Riverine total N and total P inputs and direct discharges (RID)	Low and decreasing input from landbased sources.	-
	Winter DIN- and/or DIP concentrations	No data	
	Increased winter N/P ratio (Redfield N/P = 16)	No data	
Direct Effects (II)	Maximum and mean chlorophyll *a* concentration	No data	
	Region/area specific phytoplankton indicator species	No data	
	Macrophytes including macroalgae (region specific)	No data	
Indirect Effects (III)	Degree of oxygen deficiency	Severe oxygen deficiency (<2,5 mlO2/l) over periods of several months	+
	Changes/kills in Zoobenthos and fish mortality	No data	
	Organic Carbon/Organic Matter	No data	
Other Possible Effects (IV)	Algal toxins (DSP/PSP mussel infection events)	No data	

Initial classification: Potential problem area.
Final classification*:* Problem area. There is reason to believe that this would be the classification with more data describing the biological communities.

S9 Agder coastline to Kristiansand

The coast of East-Agder county includes a large number of fjords and more open areas. The nutrient input comes from runoff and from small communities and is relatively low and the data indicates a significant decrease during the last 5 years. Municipal sewage is treated in secondary treatment plants and in general discharged through deep outlets and with trapping of the plumes. The nutrient load is summarised in ***Table 24***. The reduction from 1997-2000 to 2004-2004 is caused by transfer of municipal sewage from area S9 to a secondary treatment plant in area S11.

Table 24. *Anthropogenic nutrient load for area S9. Averages for 1997-2000 and 2001-2005, with exception for phosphorus where data from 2004-2005 is used.*

Nitrogen load, tonnes		Phosphorus load, tonnes	
1997-2000	2001-2005	1997-2000	2004-2005
129	69	10,7	1,2

Several of minor fjord basins experiences serious oxygen problems, and in Groosefjord outside Grimstad city, oxygen concentration in the basin water usually decreases to 0.5 mlO2/l during stagnation periods (Buhl Mortensen et al., 2006)

Recent data describing the marine environment is mainly from the Norwegian Coastal Monitoring Programme (Moy et al., 2007 in prep) and from studies of the disappearing sugar kelp (Moy et al., 2007).

The presence of ichthyotoxic algae (e.g. *Verrucophora*, *Heterosigma*) and algae causing shellfish poisoning may not be indicators of Eutrophication as elevated levels of these species may occur in pristine waters as well.

Evaluation:

Table 25. *Area S9. Summary of Classification.*

Category	**Assessment Parameters**	**Description of Results**	Score
Degree of Nutrient Enrichment (I)	Riverine total N and total P inputs and direct discharges (RID)	Low and decreasing input from landbased sources.	**-**
	Winter DIN- and/or DIP concentrations	No data	
	Increased winter N/P ratio (Redfield N/P = 16)	No data	
Direct Effects (II)	Maximum and mean chlorophyll *a* concentration	No data	
	Region/area specific phytoplankton indicator species	Nuicance species/harmful species; *Dinophysis* spp., *Alexandrium* spp. , *Verrucophora* sp, *Heterosigma* sp. (Castberg et al 2005, Dahl 2002, 2003, 2005, Dahl et al 2003, 2004, 2006)	**?**
	Macrophytes including macroalgae (region specific)	Major decline of sugar kelp expect in exposed areas (Moy et al. 2007)	+
Indirect Effects (III)	Degree of oxygen deficiency	Lyngør possible at risk due to low O_2 (Hindar et al .,2005)	+
	Changes/kills in Zoobenthos and fish mortality	Fish kills (Dahl et al. 2000, 2002)	+
	Organic Carbon/Organic Matter		
Other Possible Effects (IV)	Algae toxins (DSP/PSP mussel infection events)	Algal toxins; DSP, Azaspiracid (Castberg et al 2005, Dahl et al 2005, Hestdal 2001-2003)	**?**

Initial classification: Problem area.
Final classification: Problem area.

S10 Tvedestrandsfjord

The Tvedestrand fjord area is situated in the north-eastern part of East-Agder county (***Figure 13***). The municipal waste water from city of Tvedestrand (3000 PE) is processed with biological treatment before discharge to the inner fjord through a deep water outfall. The nutrient load is summarised in ***Table 26***. The fjord is divided into 3 basins separated by sills, where the inner sill to the basin outside Tvedestrand city is 15 m deep.

Table 26. *Anthropogenic nutrient load for area S10. Averages for 1997-2000 and 2001-2005, with exception for phosphorus where data from 2004-2005 is used.*

Nitrogen load, tonnes		Phosphorus load, tonnes	
1997-2000	2001-2005	1997-2000	2004-2005
13	10	1.2	0.5

The anthropogenic nutrient and organic load is reduced during the last 5 years due to increased treatment of municipal wastewater.

The oxygen conditions in the Tvedestrand fjord system have previously been described as “Bad-Very bad” according to NCS (see Molvaer at al., 2003a). However, there are no new hydrochemical data since the classification in 2002-2003.

The study of sugar kelp shows major changes (Moy et al., 2007), but otherwise we have not found any recent information about the biological status in Area S6.

Evaluation:

Table 27. *Area S10. Summary of Classification.*

Category	Assessment Parameters	Description of Results	Score
Degree of Nutrient Enrichment (I)	Riverine total N and total P inputs and direct discharges (RID)	Decrease	**-**
	Winter DIN- and/or DIP concentrations	No data	
	Increased winter N/P ratio (Redfield N/P = 16)	No data	
Direct Effects (II)	Maximum and mean chlorophyll *a* concentration	No data	
	Region/area specific phytoplankton indicator species	No data	
	Macrophytes including macroalgae (region specific)	Major decline in sugar kelp (Moy et al., 2007)	**+**
Indirect Effects (III)	Degree of oxygen deficiency	No data, but presumed severe as in the previous assessment (<2,5 mlO2/l)	**+?**
	Changes/kills in Zoobenthos and fish mortality	No data	
	Organic Carbon/Organic Matter	No data	
Other Possible Effects (IV)	Algae toxins (DSP/PSP mussel infection events)	No data	

Initial classification: Potential Problem area.
Final classification: Problem area. There is no reason to believe that major changes have taken place since the previous assessment.

S11 Arendal fjord and Utnes-Ærøy

These areas are situated in the middle part of East-Agder county (***Figure 13***). The municipal waste water from city of Arendal (37000 PE) is processed with chemical treatment before discharge through a deep water outfall in an area (Ærøy) well connected to the coastal water. Due to the river Nidelva the annual average freshwater input is as high as 60 m^3/s. The nutrient load is described in ***Table 28***.

Table 28. *Anthropogenic nutrient load for area S11. Averages for 1997-2000 and 2001-2005, with exception for phosphorus where data from 2004-2005 is used.*

Nitrogen load, tonnes		Phosphorus load, tonnes	
1997-2000	2001-2005	1997-2000	2004-2005
241	189	17,1	17,0

Since the previous classification in 2002-2003 a new study has been carried out around the Ærøy outfall and the previous site (Utnes) of the outfall (Moy et al., 2002b). The main conclusions were that the water quality was improving and generally in NCS-classes I-II with regard to nutrients and oxygen. The softbottom fauna showed none to moderate effects from the outfall.

There is no updated information from the inner more sensitive part of the area – which in 2002-2003 was classified as a Problem area.

Evaluation:

Table 29. *Area S11. Summary of Classification.*

Category	**Assessment Parameters**	**Description of Results**	Score
Degree of Nutrient Enrichment (I)	Riverine total N and total P inputs and direct discharges (RID)	Reduced N-load, but constant P-load	—
	Winter DIN- and/or DIP concentrations	No data	
	Increased winter N/P ratio (Redfield N/P = 16)	No data	
Direct Effects (II)	Maximum and mean chlorophyll *a* concentration	No data	
	Region/area specific phytoplankton indicator species	No data	
	Macrophytes including macroalgae (region specific)	Major decline of sugar kelp (Moy et al. 2007)	+
Indirect Effects (III)	Degree of oxygen deficiency	Moderate O_2 at Utnes - improved (Moy et al., 2002b)	-
	Changes/kills in Zoobenthos and fish mortality	Soft bottom fauna moderate status at Utnes better at Ærøy deep water - improved (Moy et al ., 2002b)	-/+
	Organic Carbon/Organic Matter	Moderate	-
Other Possible Effects (IV)	Algae toxins (DSP/PSP mussel infection events)	No data	

Initial classification: Problem area.
***Final classification**:* Problem Area.

S12 Lillesand coast

These areas are situated in the north-eastern part of East-Agder county (***Figure 13***) and are semi-enclosed and nearly enclosed relative to the coastal water. The water exchange is therefore low and sensitivity relative to nutrients is high. Specific and sensitive areas are:

- **Kaldvellfjord:** a sheltered sill fjord with naturally occurring hydrogen sulphide in the deep water
- **Outer Lillesandsfjord:** a relatively open coastal area, but with some parts sheltered from the open coast by sills.
- **Skallefjord and Tingsakerfjord:** basins with sill depths between 20-32 m and max. depths 73-83 m. The sewage load is from the city (Lillesand) and is discharged to Tingsakerfjord and Skallefjord.

The local nutrient load comes from Lillesand city and runoff from small communities. The main characteristics are summarised in ***Table 30***.

Table 30. *Anthropogenic nutrient load for area S12. Averages for 1997-2000 and 2001-2005, with exception for phosphorus where data from 2004-2005 is used.*

Nitrogen load, tonnes		Phosphorus load, tonnes	
1997-2000	2001-2005	1997-2000	2004-2005
134	65	10,1	2,6

The anthropogenic phosphorus load is reduced during the last 10 years due to use of chemical treatment plants for municipal wastewater, while the situation for nitrogen is unclear.

Since the previous assessment there has been a study of local recipients (Kroglund et al., 2007) and of the sugar kelp (Moy et al., 2007). Except for Outer Lillesandsfjord the fjord basins experience various degrees of oxygen problems (“Less good” to “Very bad” according to NCS). The sugar kelp shows a serious decline.

Evaluation:

Table 31. *Area S12. Summary of Classification.*

Category	**Assessment Parameters**	**Description of Results**	Score
Degree of Nutrient Enrichment (I)	Riverine total N and total P inputs and direct discharges (RID)	Decline	**-**
	Winter DIN- and/or DIP concentrations	No data	
	Increased winter N/P ratio (Redfield N/P = 16)	No data	
Direct Effects (II)	Maximum and mean chlorophyll *a* concentration	No data	
	Region/area specific phytoplankton indicator species	No data	
	Macrophytes including macroalgae (region specific)	Major decline in sugar kelp (Moy et al. 2007)	+
Indirect Effects (III)	Degree of oxygen deficiency	Serious (<2,5 mlO2/l) in several fjord basins	+
	Changes/kills in Zoobenthos and fish mortality	No data	
	Organic Carbon/Organic Matter	No data	
Other Possible Effects (IV)	Algae toxins (DSP/PSP mussel infection events)	No data	

Initial classification: Problem area.
Final classification: Problem area.

4.2.4 West Agder county

For classification purposes the coast of West Agder county is divided into areas (S13-S14) as indicated in ***Figure 13***. In the following the areas will be classified according to the procedure outlined in chapter 4.1.

S13 Ålefjærfjord, Topdalsfjord and Kristiansandsfjord

The Ålefjærfjord and the Topdalsfjord are typical fjords with sill and deep basins inside, while the waters in the Kristiansandsfjord have a free connection to the coastal water. The Topdal river (avg. 63 m^3/s) empties into the Topdalsfjord and thereby creating a brackish surface layer flowing into the Kristiansandsfjord. The river Otra (avg. 149 m^3/s) empties into the Kristiansandsfjord.

Table 32. *Anthropogenic nutrient load for area S13. Averages for 1997-2000 and 2001-2005, with exception for phosphorus where data from 2004-2005 is used.*

Nitrogen load, tonnes		Phosphorus load, tonnes	
1997-2000	2001-2005	1997-2000	2004-2005
492	510	30,1	14,2

Due to the high freshwater input the nutrient load is relatively high. The municipal wastewater is processed through chemical treatment plants before discharge and trapping at 15-30 m depth in the more open parts of the fjord system. These measures have reduced the anthropogenic nutrient (especially phosphorus) and organic load considerably during the last 10 years. There is also a decreasing trend for nitrogen loads.

Effects from nutrients and organic load have not been studied in the Ålefjærfjord and the Topdalsfjord since 1990, but observations of oxygen levels each autumn in the Topdalsfjord have indicated a weak decreasing trend (Aure at al., 1996). In the middle 1980-ies 0.5 ml O_2/l and 2.5 ml O_2/l were observed as minimum oxygen concentration in the Ålefjærfjord and Topdalsfjord respectively.

Follow-up studies of benthic biota in the vicinity of the Korsvik treatment plant in the Kristiansandsfjord (approx. 15.000 PE) 15 years after it became operational in 1978, showed that soft-bottom fauna and shallow-water organisms close to the outfall, were only slightly or not at all affected (Oug et al., 1994). During the 1980s and early 1990s when the wastewater treatment plants came fully into effect, the diversity of species communities have increased considerably in the inner bays and most affected parts of the fjord.

No oxygen problems have been found in the main Kristiansandsfjord (Oug et al., 1994).

Since the 2002-2003 assessment there have been three studies which give new information about the water quality and biological status. The sugar-kelp study (Moy et al., 2007a) and the study of oxygen and bottom fauna by Buhl-Mortensen et al. (2006) are already mentioned. In addition a study of oxygen, nutrients and bottom fauna in Topdalsfjord was carried out in 2002-2003 (Molvær et al., 2003).

Evaluation:

Table 33. *Area S13. Summary of Classification.*

Category	**Assessment Parameters**	**Description of Results**	Score
Degree of Nutrient Enrichment (I)	Riverine total N and total P inputs and direct discharges (RID)		-
	Winter DIN- and/or DIP concentrations	No data	
	Increased winter N/P ratio (Redfield N/P = 16)	No data	
Direct Effects (II)	Maximum and mean chlorophyll *a* concentration	No data	
	Region/area specific phytoplankton indicator species	No data	
	Macrophytes including macroalgae (region specific)	Major decline in sugar kelp (Moy et al 2007)	+
Indirect Effects (III)	Degree of oxygen deficiency	Serious (<2,5 mlO2/l), and may be increasing	+
	Changes/kills in Zoobenthos and fish mortality	Damage to softbottom fauna	
	Organic Carbon/Organic Matter	High organic content in basins	+
Other Possible Effects (IV)	Algae toxins (DSP/PSP mussel infection events)	No data	

Initial classification: Problem area.
Final classification: Problem area. The identified problems are local or to a large extent caused by topography (sills) and transboundary loads.

S14 Coastal area Kristiansand – Lindesnes including minor fjords

The overall nutrient load for this area has been relatively constant during the last 10 years, and relatively low (***Table 34***). The outfalls of municipal sewage are in general directed to recipients with relatively high water exchange.

Table 34. *Anthropogenic nutrient load for area S14. Averages for 1997-2000 and 2001-2005, with exception for phosphorus where data from 2004-2005 is used.*

Nitrogen load, tonnes		Phosphorus load, tonnes	
1997-2000	2001-2005	1997-2000	2004-2005
397	462	17,2	15,0

The topography of this coastline resembles area S9, with a number of fjords combined with bays sheltered from the open coast partly by the islands and partly by sills. There are several fjords with sills and high sensitivity to nutrient and organic load resulting in very low oxygen concentrations in the basins. They were all classified in 2002-2003:

Trysfjord
The fjord is divided into two basins each 85 m deep and connected through a narrow channel 5 m deep. A 10 m deep sill separates the fjord and the coastal water. The anthropogenic nutrient load is relatively low and has decreased during the last 10-15 years.

Harkmarksfjord
The Harkmarksfjord is a sheltered 4-km long fjord with narrow and shallow constrictions. The two most distinct constrictions are 30-75 meters wide with depths of about 2 m. Tidal amplitude is about 0.1m. The river defines the surface salinity inside the sills during spring/summer/autumn. Surface salinity varies between 24-29 in the upper 2-3 m and the deeper layer between 30-33.5. The residence time of the bottom water is probably less than a year.

The anthropogenic nutrient load on the fjord is mainly with the river. Dominating anthropogenic load of nitrogen is from agriculture, while sewage load is about 20 %. The phosphorus load is about 37 % from sewage. The anthropogenic nutrient load has decreased during the last 10-15 years.

Mannefjord, Hillesund-Snigsfjord
Mannefjord is a relatively open area with free connection to the coastal water. The fresh water runoff is dominated by the Mandal river with an average flow of 85 m^3/s. The nutrient load is also dominated by the freshwater runoff. The fjord is recipient for the city of Mandal where the municipal wastewater from 11500 pe is directed to a biological treatment plant and then to a deep outfall with trapping of the plume below the surface. The anthropogenic nutrient load has decreased during the last 10-15 years.

Skogsfjord
Skogsfjord is a very enclosed area north of the city of Mandal. The freshwater runoff is relatively high and the anthropogenic nutrient load is moderate and has decreased during the last 10-15 years.

Except from the sugar kelp study (Moy et al., 2007a) and newer data about harmful algae, there is very little new information to support an updated classification. However, there is no reason to expect that the serious oxygen problems (Class IV-V in NCS) in Trysfjord, Harkmarksfjord and Skogsfjord has changed substantially. On the other side, these fjord basins amount to a small part of the overall area.

Evaluation:

Table 35. *Area S14. Summary of Classification.*

Category	**Assessment Parameters**	**Description of Results**	Score
Degree of Nutrient Enrichment (I)	Riverine total N and total P inputs and direct discharges (RID)	Varying, but probably relatively constant over time	**-**
	Winter DIN- and/or DIP concentrations	No data	
	Increased winter N/P ratio (Redfield N/P = 16)	No data	
Direct Effects (II)	Maximum and mean chlorophyll *a* concentration	No data	
	Region/area specific phytoplankton indicator species	Elevated levels: Nuicance species/harmful species; *Dinophysis* spp., *Alexandrium* spp. (Castberg et al 2005, Dahl et al 2005, Hestdal 2001-2003)	**?**
	Macrophytes including macroalgae (region specific)	Major decline in sugar kelp (Moy et al 2007) Decline in sugar kelp and reduced biodiversity (Åsen 2006)	+
Indirect Effects (III)	Degree of oxygen deficiency	No updated info, but very low concentrations (<2,5 mlO2/l) in several fjord basins	+
	Changes/kills in Zoobenthos and fish mortality	No updated info, but too low O2-conc. to support marine life in basin water of several fjord.	
	Organic Carbon/Organic Matter		
Other Possible Effects (IV)	Algae toxins (DSP/PSP mussel infection events)	Algal toxins; DSP, ASP, Azaspiracid (Castberg et al 2005, Dahl et al 2005, Hestdal 2001-2003)	**?**

Initial classification: Problem area.
Final classification: Problem area

5. Overall assessment

Compared to the previous classification in 2002-2003, this classification is based on new information about
- nutrient load
- oxygen
- hardbottom fauna and flora (especially sugar kelp information)
- harmful planktonic algae

In general the OSPAR criteria are used. In some instances the classification also uses the Norwegian Classification System for nutrients, chlorophyll *a*, oxygen and soft-bottom fauna.

One may note that the classification below fits reasonably well with ANON (1997) which found a regional nutrient enrichment in the coastal water west to Lindesnes. The degree of this regional nutrient enrichment is relatively marked and constant along the Norwegian Skagerrak coast to about Arendal, but decreases west of Arendal due to admixture of Atlantic water. There is no sharp western delimitation of the regional nutrient enrichment, but rather a transition zone.

Finally, note that many of the recipient studies have focused on obvious local problems, like oxygen conditions in basins behind fjord sills, soft bottom fauna in fjord basins with oxygen problems or near outfalls of municipal waste water, or hard bottom flora and fauna near such outfalls. Where the results are found to describe only a small part of the area, this is taken into account in the "Final Classification".

Due to limited or no new relevant observations, the classification is made with some reservations. These are given as comments and focuses on limitations like;
- there are no data
- the data are from studies more than 5 year back and may not be representative for the present situation
- data covers only a minor part of the area.

We have tried to take this into account for each area, also considering the status in neighbouring areas.

One should note that the classification assume that the decline of sugar kelp on the Norwegian Skagerrak coast to some extent is caused by eutrophication (high temperature in July/August is assumed to have been the direct cause) . For some areas this assumption is crucial for the classification. If future studies of the kelp disappearance prove otherwise, this classification should be revised.

The classification area by area is shown in***Table 36*****.** Based on this table the overall classification for the Norwegian Skagerrak coast is "**Problem Area"**, see also ***Figure 14***

Compared with the 2002-2003 assessment, this assessment has been carried out with 14 areas as opposed to the previously 44 - and is therefore more of an overall classification. We have relied heavily on updated data for the nutrient load, oxygen conditions in the fjords. New elements have been data from the studies related to the sugar kelp on the coast. We have also had the opportunity to a closer study of data on harmful planktonic algae on the coast. As a result the major change has been a shift from Potential Problem Areas to Problem Areas.

Table 36. *Overall classification of the Norwegian Skagerrak coast. Mostly data from 2001-2005.*

Area	Category I Degree of nutrient enrichment	Category II Direct effects	Category III and IV Indirect/possible effects	Final Classi-fication	Assessment period.
S1 Iddefjord-Hvaler-Singlefjord	+	+	+	PA	2001-2005
S2 Inner Oslofjord and Drammensfj.	+	+	+	PA	2001-2005
S3 Middle Oslofjord	**(+)**	+	+	PA	2001-2005
S4 Southern Oslofjord	**-**	+	**(-)**	PA	2001-2005
S5 Grenland fjords	+	+	+	PA	2001-2005
S56Telemark coastline	**(+)**	+	+	PA	2001-2005
S7 Kragerø and Stølefjord	**?**	+	+	PA	2001-2005
S8 Søndeledfjord and Sandnesfj.	**-**		+	PA	2001-2005
S9 Agder coastline to K.sand		+	+	PA	2001-2005
S10 Tvedestrandsfj	**-**	+	**+/?**	PA	2001-2005
S11 Arendal	**-**	+	**+/-**	PA	2000-2001
S12 Lillesand	**-**	+	+	PA	2001-2005
S13 Kristiansand	**?**	+	+	PA	2001-2005
S14 Kristiansand – Lindesnes	**-**	+	+	PA	2001-2005

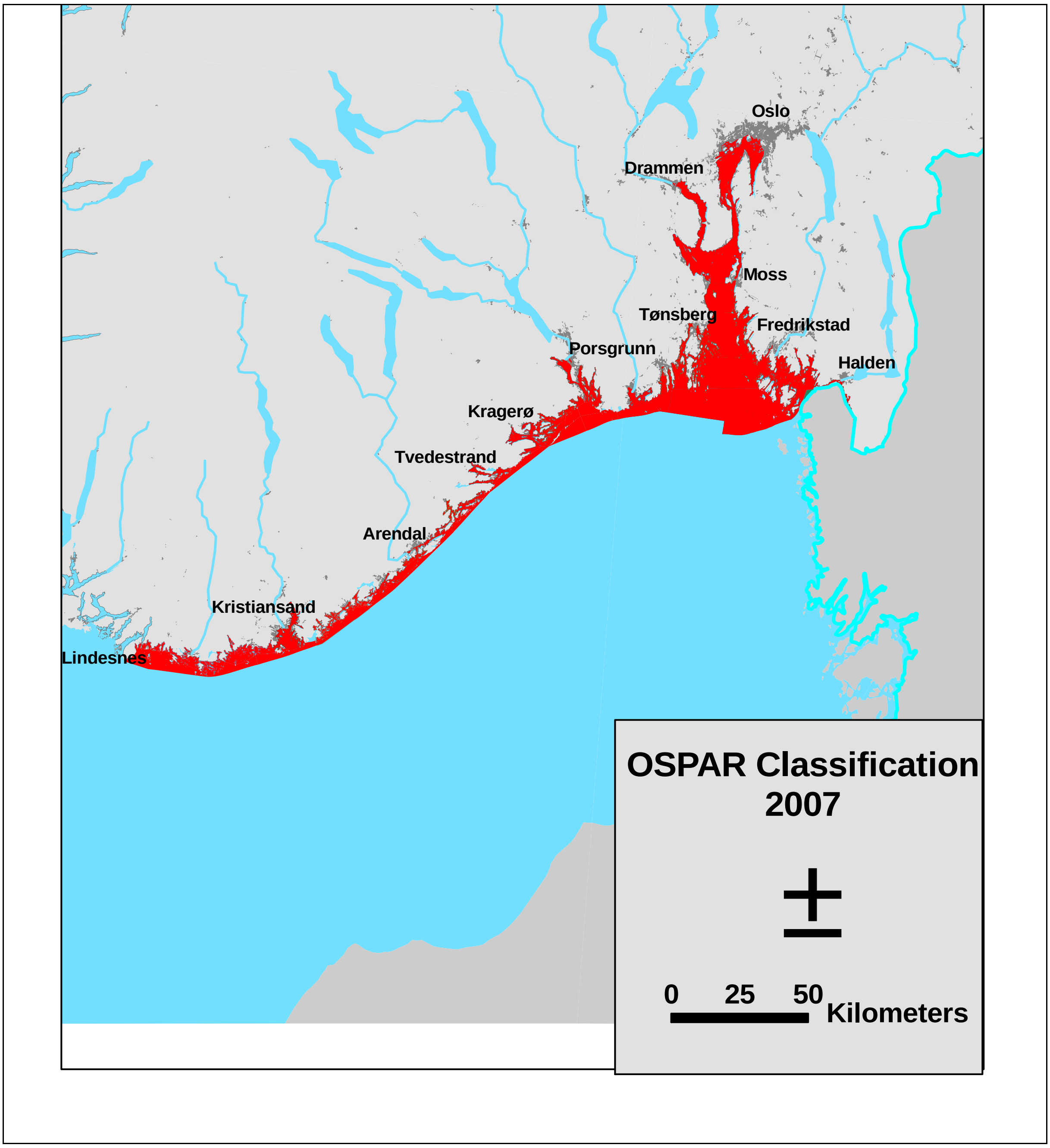

Figure 14. *Overall classification of the Norwegian Skagerrak coast as Problem Area.*

6. Perspectives

6.1 Implemented and further planned measures

Regarding inputs of nutrients from sewerage, new municipal waste water treatment regulations came into force 1.1.2007. All discharges into sensitive areas have to undergo 90 % phosphorous removal from 31.12.2008. In addition six waste water treatment plants have requirements to remove 70 % of nitrogen.

Measured related to agriculture are and will be highly connected to the Water Framework Directive (WFD). Although the WFD is not yet a part of the EEA agreement, Norway has given high priority to its follow-up. In 2001, Norway started to prepare for implementation by focusing especially on characterisation of water bodies. In addition we looked at what could be done at the national level to help regional authorities to prepare for their tasks. The regulation (the Water Management Regulation) which transposes the WFD into Norwegian legislation was adopted on 15 December 2006 and entered into force on 1 January 2007. WFD will be important in the work to further reduce the inputs of particles, nutrients and hazardous chemicals into Norwegian coastal waters.

6.2 Outlook

6.2.1 Expected trends

There are no immediate actions that will reduce Norwegian discharges of nitrogen, phosphorous and organic matter to the Skagerrak coast, but further work on measures related to the sugar kelp problems are in progress. In one area, the inner Oslofjord, the last reduction was implemented in 2001 and a further improvement in the fjord is expected.

The future state of environment along the sheltered parts of the Skagerrak Coast depends on changes in local discharges, in the transboundary transport and development in connection with climatic changes. Reduced nutrient concentrations (mainly nitrogen) in the southern North Sea (eg. The German Bight) has reduced winter concentrations of nitrate along the Norwegian South Coast (Moy et al., 2007b) and further improvement is dependent on a decrease in this long range transport and to a lesser degree of changes in the Kattegat. However, in some fjords the local discharge of nutrients is large enough to explain part of the negative development.

The impact of climatic changes will probably change the winter wind system with a weakening of the strength and frequency of northerly winds to stronger and more frequent southerly winds. This shift will favor the current system in the Skagerrak that brings nutrients from the southern North Sea (German Bight) to the Norwegian Skagerrak Coast. As northerly winter winds also decides the strength of the water renewal below sill depth in the fjords, the wind change can weaken this process, extending the residence time and further reduce the oxygen concentration.

Models of climatic changes also predict changes in the freshwater runoff to the Norwegian Skagerrak coast. The models predict a moderate decline in the annual runoff, but due to higher winter temperature the freshwater runoff during winter will increase (Beldring et al, 2006). With higher temperature the nitrogen leakage from agricultural, forests and mountainous areas is expected to increase. The perspective for these trends is 50-75 years and they are therefore difficult to use in an assessment.

However, seeing the expected changes in the transboundary transport in combination with changing runoff, the climatic change seems to strengthen the eutrophication of the Skagerrak Coast. These effects have recently been discussed in a study of the Gullmaren fjord at the Swedish West Coast (Erlandsen et al., 2006).

6.2.2 Improvement of assessment.

From the Norwegian point of view, we see a need to improve/update the assessments background concentrations of nutrient during winter (area –specific) for the Skagerrak Coast and fjords. As for Category II - the same comment is relevant for the Chlorophyll-a mean and maximum concentration during growing season. However, there is a general weak definition in the OSPAR assessment of Chl-a, among them the definition of the growing season, the minimum number of observations and the definition of the maximum Chl-a.

Assessment of oxygen deficiency (Category III) could incorporate oxygen consumption in basins with stagnant waters during at least a part of the year. Changes in oxygen consumption imply directly changes in the nutrient and organic load, while concentration changes over time also incorporates the water renewal efficiency.

The classification assumes that the decline of sugar kelp on the Norwegian Skagerrak coast to some extent is caused by eutrophication. For some areas this assumption is crucial for the classification. If future studies of the kelp disappearance prove otherwise, the classification should be revised.

Use of phytoplankton data for classification purposes is difficult, and needs improved knowledge.

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Title
Common Procedure for Identification of the Eutrophication Status of Maritime Area of the Oslo and Paris Conventions.
Report on the Eutrophication Status for the Norwegian Skagerrak Coast

Summary
The Norwegian Skagerrak coast has been classified according to the OSPAR Common Procedure. Compared to the previous assessment in 2002, this classification is based on new data on nutrient load, oxygen conditions, hardbottom fauna and flora (especially sugar kelp), harmful planktonic algae, as well as other data from a number of recipient studies.
Fourteen areas have been studied and classified. The data has been of varying quality, but the overall classification of the coastline is Problem Area.
One should note that the classification assume that the decline of sugar kelp on the Norwegian Skagerrak coast to some extent is caused by eutrophication. For some areas this assumption is crucial for the classification. If future studies of the kelp disappearance prove otherwise, this classification should be revised.

4 emneord	4 subject words
OSPAR	OSPAR
Eutrofi	Eutrophication
Kystvann	Coastal water
Skagerrakkysten	Skagerrak coast