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Comprehensive Procedure for the Skagerrak Coast

Common Procedure for Identification of the Eutrophication Status of Maritime Area of the Oslo and Paris Conventions

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Comprehensive Procedure for the Skagerrak Coast

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Common Procedure for Identification of the Eutrophication Status of Maritime Area of the Oslo and Paris Conventions

Report on the Comprehensive Procedure
for the Norwegian Skagerrak Coast

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. Previously the Comprehensive Procedure has been applied to

- the coastal water of the Norwegian Skagerrak coast
- the coastal water of the Norwegian west coast

The Comprehensive Procedure is here applied to the inshore waters of the Norwegian Skagerrak coast which has been divided into 44 subareas. *The classification is summarised in* **Figure 15-Figure 16** *and described in detail for each area in* ***Table 59****. Of a total of 44 subareas 17 are classified as Problem Areas and 27 areas as Potential Problem areas.*

Many of the comments to the choice of classification concern lack of relevant observations, either because

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

The frequent registrations of harmful algae and mussel toxins at a limited number of monitoring stations on the Skagerrak coast represent a problem in the classification process as such a registration alone may classify an area as a potential problem area. The causes behind toxic algae blooms and mussel toxin is still uncertain- either naturally occurring, trigged by local anthropogenic changing loads of nutrients or generally effects from transboundary loads. For most areas

- no specific data on algal toxins exist
- there is none significant environmental effects from the local nutrient load

and there is a basic uncertainty about the existence of a problem from harmful algae. A general approach has been to classify such areas as Potential Problem Areas.

The classification is based on the Norwegian Classification System where that has been appropriate, in combination with the OSPAR criteria. Otherwise the Ospar criteria has been used alone.

The classification below fits reasonably well with previous registrations of a regional nutrient enrichment in the coastal water west to Lindesnes. There is no sharp western delimitation of the regional nutrient enrichment, but rather a transition zone.

Areas where the coastal water has been classified as Potential Problem Area, and where there is sparse data for classification of fjords/skerries, have in general a final classification as Potential Problem Areas. This corresponds with a general conclusion that fjords receive a substantial load of nutrients and organic matter through the water exchange with coastal water.

1. Introduction

1.1 Background

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

- the coastal water of the Norwegian Skagerrak coast
- the coastal water of the Norwegian west coast

The Comprehensive Procedure is here applied to the inshore waters of the Norwegian Skagerrak coast.

1.2 General setting

Outside the Oslofjord area the average population density along the coast is low and only 15 cities have between 20 000 and 100 000 inhabitants, and only four (Oslo, Stavanger, Bergen and Trondheim) have more than 100 000 inhabitants. All these are located along the coast with wastewater discharges to the sea with 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 designed as a sensitive area, while the coast further to the west and to the north has been designed a less sensitive area (**Figure 1**).

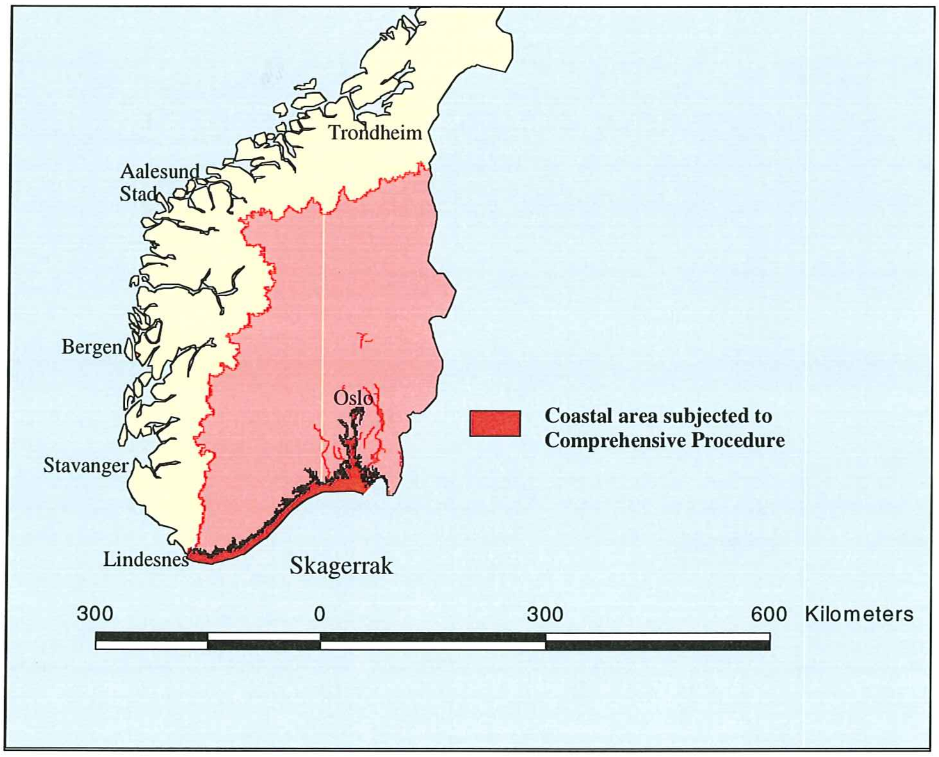

Figure 1. Overall view of the coastline of southern Norway, showing the coastal area subjected to the Comprehensive Procedure. West and north of Lindesnes the coastal areas are defined as less sensitive under the Urban Waste Water Directive and will later be subjected to Screening under the Common Procedure.

1.3 The coastal zone

The coastal zone of Norway has an extremely varied topography and spans a range of habitats and ecosystems from very sheltered fjords to fully open and exposed headlands. The most characteristic features are the fjords, which may reach 200 km into the mainland (the Sognefjord), and the archipelagos and skerries, which in many regions form a broad intermediate zone between the mainland and the open sea. A typical fjord has a deep fjord basin (up to 1300 m) and a shallow threshold at the fjord entrance. The archipelagos are characterised by a mixture of shallow and deep sounds, channels and basins. With few exceptions the offshore waters are deep (> 200 m) close to the shore all along the coast.

The coastal waters along the Norwegian North Sea 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 coast of west Norway.

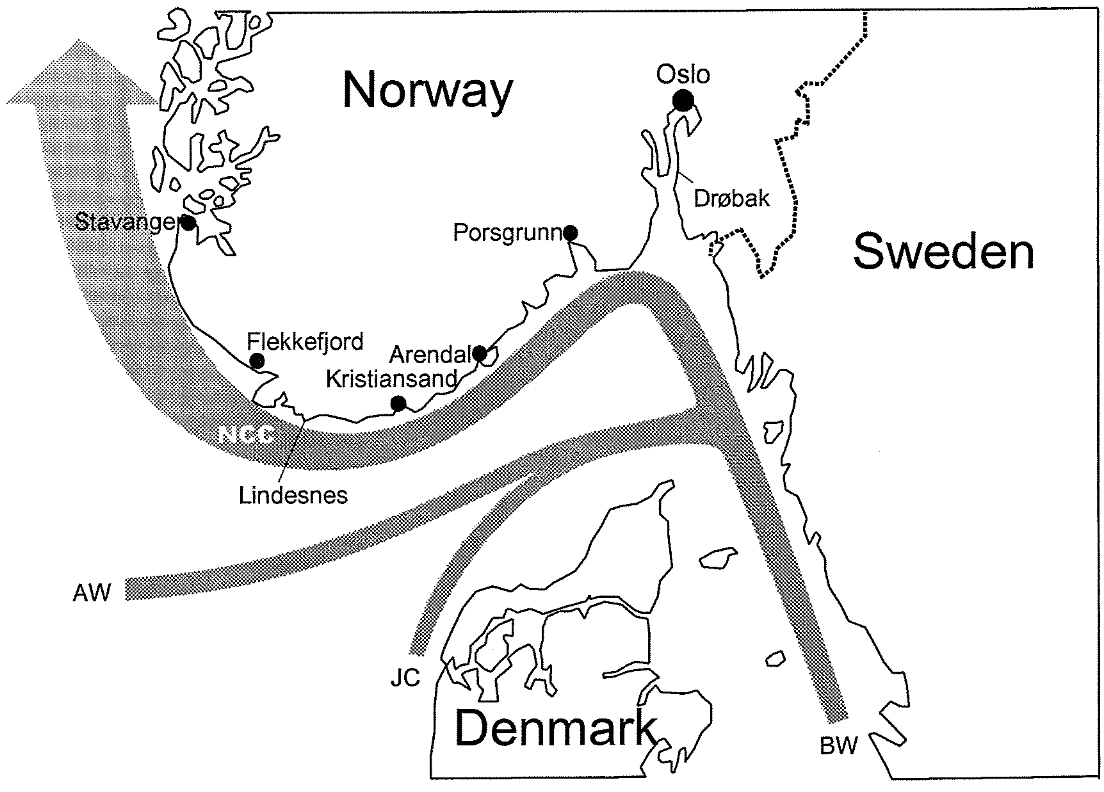

Figure 2. Dominating current pattern in the coastal area of southern Norway. The width of the arrows is not directly related to the current volume transport (AW: Atlantic Water, BW: Baltic Water, JC: Jutland Current, NCC: Norwegian Coastal Current. From ANON 1997).

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 increases from 0.1 m on the Skagerrak coast to more than 1 m in northern Norway. Combined with similar increasing meteorological forces, this leads generally to higher water exchange on the coast of western and northern Norway than on the Skagerrak coast.

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. On the Skagerrak coast the oxygen consumption in the fjords has increased significantly since 1980. This is considered to be mainly an effect from a regional nutrient enrichment in the coastal water mass in Skagerrak (ANON 1997).

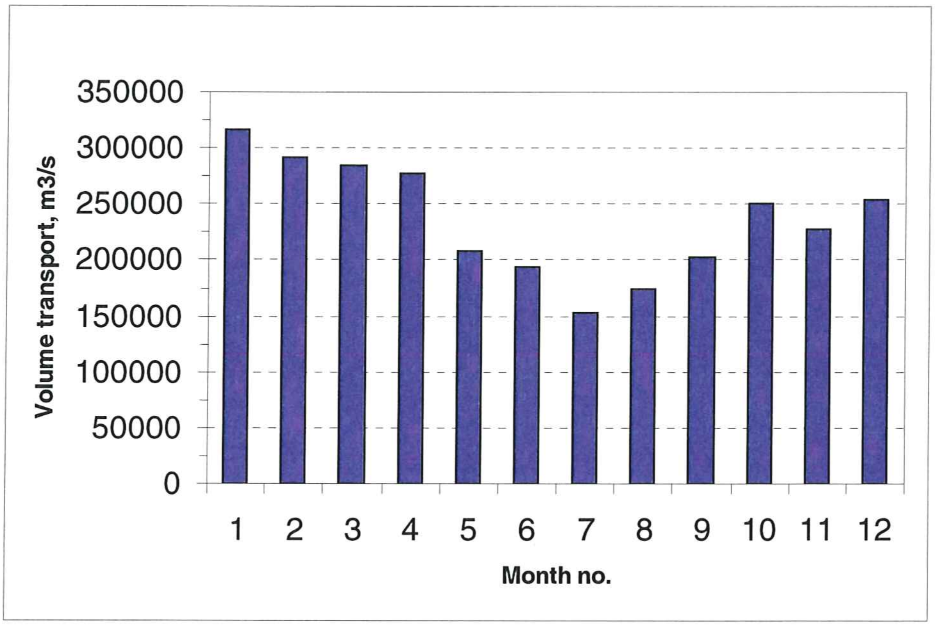

Figure 3. Calculated monthly average of water volume transport in the NCC off Arendal for the period 1988 - 95. (ANON, 1997).

Most of the population lives in 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.

2. Method and data

2.1 Assessment criteria

2.1.1 The OSPAR classification scheme

The assessment is based on the OSPAR common assessment criteria, which is summarised in **Table 1**.

Table 1. The Agreed Harmonised Assessment Criteria and their respective assessment levels of the Comprehensive Procedure (from OSPAR 2002).

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

These effects are all related to anthropogenic enrichment by nutrients (see footnotes 1-3) and in many cases is it very difficult/impossible to separate these effects from a natural situation caused by topography or local freshwater runoff. Category III effects in fjord basin – 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 much 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 skerries and in the fjords (see ANON 1997). These effects are difficult to separate from corresponding effects from a local riverine or anthropogenic nutrient load.

The second step (initial classification) is the integration of the categorised assessment parameters mentioned in **Table 1** 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 as defined in the OSPAR Strategy to Combat Eutrophication (OSPAR agreement number 1998-18, Annex 1, §1(d-f))[1]. The results of this step are summarised in **Table 2** and explained below:

A. Areas showing an increased degree of nutrient enrichment accompanied by direct and/or indirect/ other possible effects are regarded as **'problem areas'**[1];

B. Areas may show direct effects and/or indirect or other possible effects when there is no evident increased nutrient enrichment, e.g. as a result of transboundary transport of (toxic) algae and/or organic matter arising from adjacent/remote areas. These areas could be classified as **'problem areas'**[1];

C. Areas with an increased degree of nutrient enrichment, but without showing direct, indirect/ other possible effects, are classified initially as **'potential problem areas'**[1];

D. Areas without nutrient enrichment and related (in)direct/ other possible effects are considered to be **'non-problem areas'**[1].

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1 "problem areas with regard to eutrophication" are those areas for which there is evidence of an undesirable disturbance to the marine ecosystem due to anthropogenic enrichment by nutrients;

"potential problem areas with regard to eutrophication" are those areas for which there are reasonable grounds for concern that the anthropogenic contribution of nutrients may be causing or may lead in time to an undesirable disturbance to the marine ecosystem due to elevated levels, trends and/or fluxes in such nutrients;

"non-problem areas with regard to eutrophication" are those areas for which there are no grounds for concern that anthropogenic enrichment by nutrients has disturbed or may in the future disturb the marine ecosystem.

Table 2. Integration of Categorised Assessment Parameters (see **Table 1**) for 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	Category III and IV Indirect effects/ other possible effects Oxygen deficiency Changes/kills zoobenthos, fish kills Organic carbon/matter Algal toxins	Initial Classification
A	+	+	+	problem area[1]
A	+	+	-	problem area[1]
A	+	-	+	problem area[1]
B	-	+	+	problem area[2]
B	-	+	-	problem area[2]
B	-	-	+	problem area[2]
C	+	-	-	potential problem area[1]
C	+	?	?	potential problem area[1]
C	+	?	-	potential problem area[1]
C	+	-	?	potential problem area[1]
D	-	-	-	non-problem area[1]

(+) = Increased trends, elevated levels, shifts or changes in the respective assessment parameters in Table 1
(-) = Neither increased trends nor elevated levels nor shifts nor changes in the respective assessment parameters in Table 1
? = 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 respective assessment parameters is showing an increased trend, elevated level, shift or change.

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

As many of the fjords and coastal areas already have been classified according to the Norwegian criteria for classification (NCS) of environmental quality in fjords and coastal waters (Molvær et al., 1997); these will be applied. The NCS is based on nutrient concentration ("normalised" for salinity between 0-20) for winter and summer. In this report 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 assessment criteria, but the overall differences are small.

In Norway, most nutrient observations are made in April-October. The discharge from agriculture and other precipitation dependent nutrient sources will vary during the year and with climatic variations. Cold winters means lower discharges and warm winters the opposite. In **Figure 4** the discharge from the major river in the Oslofjord area in 1990-99 shows the largest transport in summer. 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.

[2] caused by transport from other parts of the maritime area.

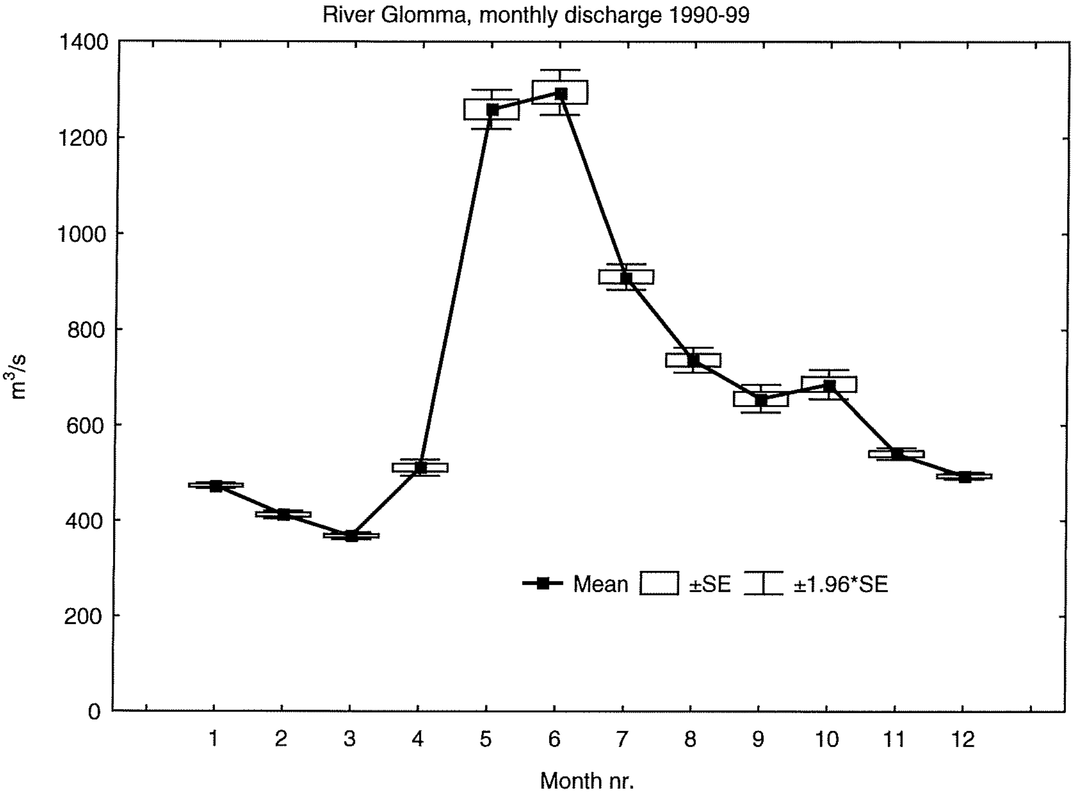


Figure 4. Monthly freshwater discharge, the river Glomma 1990-99.

The Norwegian criteria for marine water quality related to nutrients are shown in **Table 3** and **Table 4.** In addition to these criteria, there are criteria for organic carbon in sediments and soft bottom fauna (**Table 5**). There are no assessment criteria for soft bottom fauna or organic carbon in sediments.

The classification is elsewhere according to OSPAR. In the Summary of Classification tables, the use of the NCS is marked.

Table 3. Norwegian classification criteria for nutrients, chlorophyll *a*, secchi depth and oxygen. For surface water criteria for summer and winter is included. Oxygen saturation refers to a water mass with temperature 6° and salinity 33.

		Classes				
	Parameters	**I** **Very Good**	**II** **Good**	**III** **Fair**	**IV** **Bad**	**V** **Very bad**
Surface layer Summer (June-August)	Total phosphorus (µg P/l)	<12	12-16	16-29	29-60	>60
	Phosphate (µg P/l)	<4	4-7	7-16	16-50	>50
	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 Winter (December-February)	Total phosphorus (µg P/l)	<21	21-25	25-42	42-60	>60
	Phosphate(µg P/l)	<16	16-21	21-34	34-50	>50
	Total nitrogen (µg N/l)	<295	295-380	380-560	560-1300	>1300
	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 4. 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 5. Classification of soft-bottom fauna and sediment organic content.

	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

2.2 Previous classification of the Skagerrak coastal waters

The coastal waters off the Norwegian Skagerrak coast were classified according to the Common Procedure in 1999 (NEUT 99/5/7-E). **Figure 5** is a summary of the classification for three areas:

- **Area 1: a problem area,** as seen from nutrient enrichment in the upper layer, increased planktonic biomass, reduced lower depth for growth of macroalgae and a trend towards lower oxygen concentrations in the deep layers.
- **Area 2: a potential problem area,** with many of the same indications on eutrophication as Area 1. However, as the data basis is smaller and the effects are weaker the classification should be less definitive than for Area 1.
- **Area 3: a potential problem area - or non-problem area.** It is difficult to give a definite classification to this area, as it is a transition zone from a potential problem area in the northeast to

Lindesnes in the southwest, which clearly is a non-problem area. The available hydrochemical and biological data do not allow a precise location of the potential problem part of Area 3, but for practical purposes it may include the coastal water east of Kristiansand.

One need to take into consideration that except for Area 1, the eutrophication effects are mainly associated with a regional increase in nutrients and organic loads transported to the Norwegian Skagerrak coast with the coastal current. Se also chapter 2.5.2.

This assessment is used in this report as follows: *Areas where there are sparse or no information about environmental quality, are in general assigned the same classification as the coastal water.*

Data describing the coastal water quality was also reported to OSPAR in 2001 (OSPAR Tables B1-B13).

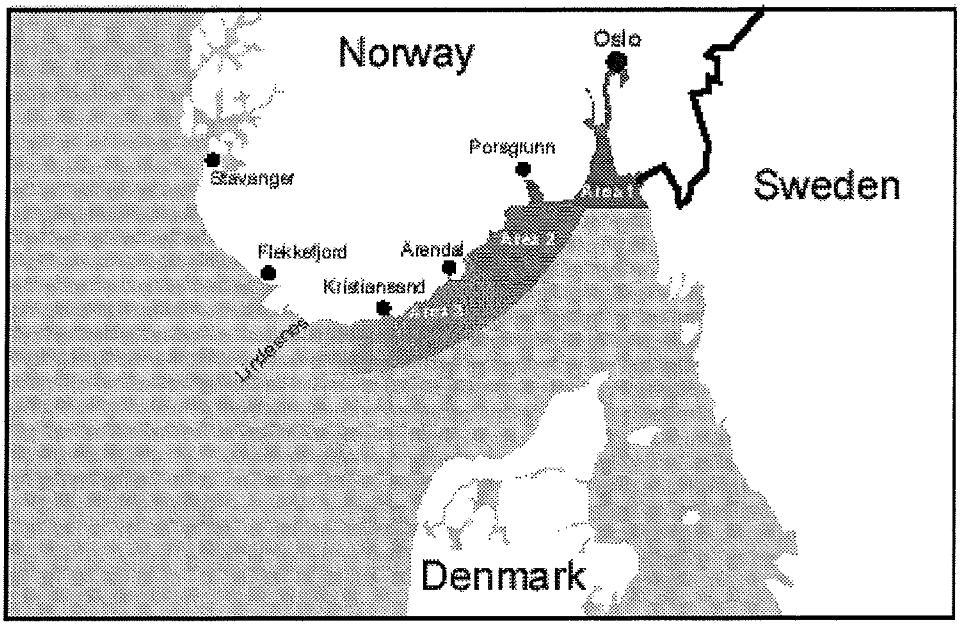


Figure 5. Classification of the coastal waters of the Norwegian Skagerrak coast. Shades of grey indicate problem areas (darkest), potential problem areas (lighter) and non-problem areas (lightest).

2.3 Selection of areas

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 skerries on the Norwegian Skagerrak coast (see **Figure 1**).

Statististics Norway assemble statistics for so-called Statistical Areas, of which there are 121 areas with runoff to the coastal water of the Norwegian Skagerrak coast. From topographic and demographic parameters and taking into considerations that relatively homogenic areas are preferable, the coast was divided into 44 "Subareas" each including one or more statistical 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 also wanted to avoid defining fjord areas so large that a 'concentration averaging effect' of the nutrient load and the water quality could be introduced. The associated fjord areas still vary from approximately 2 km^2 to 356 km^2 (southern part of Oslofjord).

2.4 Calculation of nutrient loads

2.4.1 Local load

The nutrient inputs from various sources to each Subarea for the years 1985, 1990 and 1995-2000 have been quantified. For large rivers with monthly or fortnightly 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 and for each source. The model takes account of data from industrial sources, municipal wastewater, scattered dwellings, agriculture and aquaculture.

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 1985-1999 the total input of phosphorus and nitrogen from landbased anthropogenic sources to the Norwegian Skagerrak coast was reduced by 40% and 18 % respectively **(Figure 6)**. However, the changes illustrated here do not take into account yearly variations in fresh water discharge.

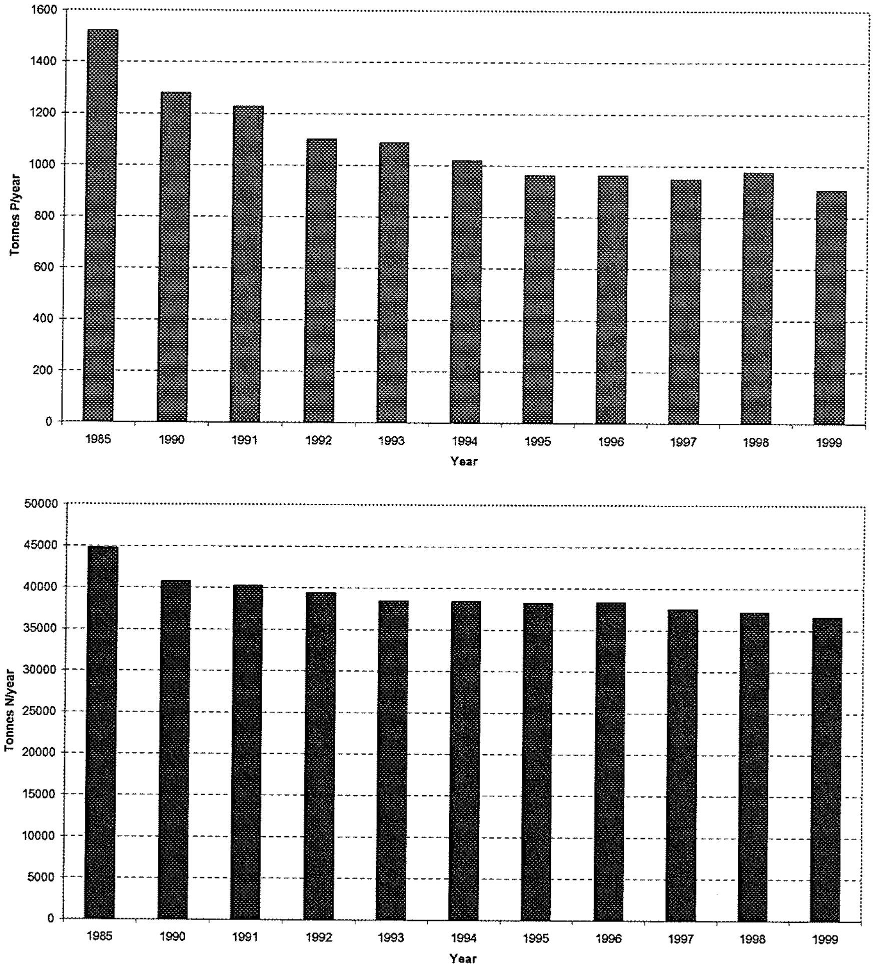


Figure 6. Total input of phosphorus (upper figure) and nitrogen (lower figure) from landbased sources between the Swedish border and Lindesnes (after Borgvang and Tjomsland 2001).

In the assessment we use the average annual nutrient load for the period 1997-2000. The trend is in general evaluated from the period 1990-2000, and in some cases going back to 1985.

2.4.2 Transboundary load

The Norwegian south coast is situated downstream other polluted areas and are therefore a potentially 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 is still not evident, but together with unfavourable climatic changes, this is looked upon as a problem. Compared to the direct discharges of nutrients from Norway to the Skagerrak coast, the transboundary transports are significant. However, effects caused on the marine system is still discussed.

Estimates of transboundary transport from the Kattegat and the Southern North Sea has been made (Aure and Johannessen, 1997). The analyses is build on long time records from a station at the Norwegian South Coast (Arendal St. 2) run by the Institute for Marine Research and since 1990 a central station in the Norwegian Coastal Monitoring Programme.

The mean winter/spring DIN concentrations (NO_3+NO_2-N) after 1990 at Arendal St 2 have increased from 1970-80 to 1990-96 80-100 %, while the mean DIP concentrations (PO_4-P) increased only by 10 %. Hence, the DIN/DIP ratio has increased. The yearly mean increase of total nitrogen and total phosphorus was 35 % and 20 % respectively.

Johannessen and Dahl (1996) analysed long time observations of oxygen and found significant decreasing trends in the Oslofjord and some other fjords along the Norwegian Skagerrak Coast from the Swedish boarder to Kristiansand. The regional character of this decrease suggests a common source causing the effect. Apart from local impact of nutrients and organic matter, transboundary transport can be an explanation.

Water analyses with observations from the Kattegat and the Skagerrak (Aure and Johannessen, 1997) was used to estimate the contribution of nutrients from different areas to the Norwegian Skagerrak Coast (outside Arendal). German Bight water contributed to the mean winter/spring period with about 77% (DIN), 42% (DIP) and 33-57 % (Silicate). The mean contribution of Kattegat surface water was between 6 – 15 % and 20-27 % for DIP and Silicate. Water transport from the German Bight and the Kattegat was estimated to about the same amount in winter (about 20%), but the high nutrient concentrations in German Bight water explains the differences in concentration contribution.

The ecological effect of the transboundary transport is uncertain. Eutrophication effects on the outer coastal waters can be moderate due to short residence times, but the effect on inner coastal waters and the fjords can be more serious. This remains to be investigated. However, according to the Norwegian Classification System the nutrient concentration in winter during 1990-1999 varied between I-III (DIN and DIP) and chlorophyll *a* concentrations mostly between I-II.

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 **Table 6** the coastal water at Arendal is classified. See **Chapter 2.3** for a general classification of the coastal water.

Table 6. 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. Slightly elevated DIP concentrations.**	+
	Increased winter N/P ratio (Redfield N/P = 16)	Increased winter N/P ratio**	+
Direct Effects (II)	Maximum and mean chlorophyll *a* concentration		-
	Region/area specific phytoplankton indicator species	c.f. chapter 2.5	
	Macrophytes including macroalgae (region specific)		
Indirect Effects (III)	Degree of oxygen deficiency		-
	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).** (Aure and Johannessen, 1997).

2.5 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 1995-2000. In general methods approved as national standards have been used, but the data (Tables and Figures) have been checked for obvious outliers that may indicate faulty data.

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**), see also chapter 2.1.1. 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,PSP, YTX, ASP, AZA and PTX.

The evaluation is based on data from 1998-2000 and in brief, from 2000:

- In the Oslofjord toxic algae were observed most of the season followed by warnings against toxic blue mussels (DSP).
- On stations 5-7 extensive problems from *Dinophysis* spp. were observed, again with warnings against DSP. At station 6 only one week between March and October was without warning against toxic mussels.

In this study the observations are used and classified according to the OSPAR criteria. It is however uncertain what approach one should have. The cause behind toxic alga blooms is uncertain- naturally occurring, trigged by local anthropogenic changing loads of nutrients or generally an effect from transboundary load. As the whole coastal area treated in this assessment, this will be taken in consideration when judging the importance of this part in the general classification. <u>However, for areas where no specific data on algal toxins exist – and there is none significant environmental effects from the local nutrient load - a general approach will be to classify as a Potential Problem Area in the Final Classification.</u>

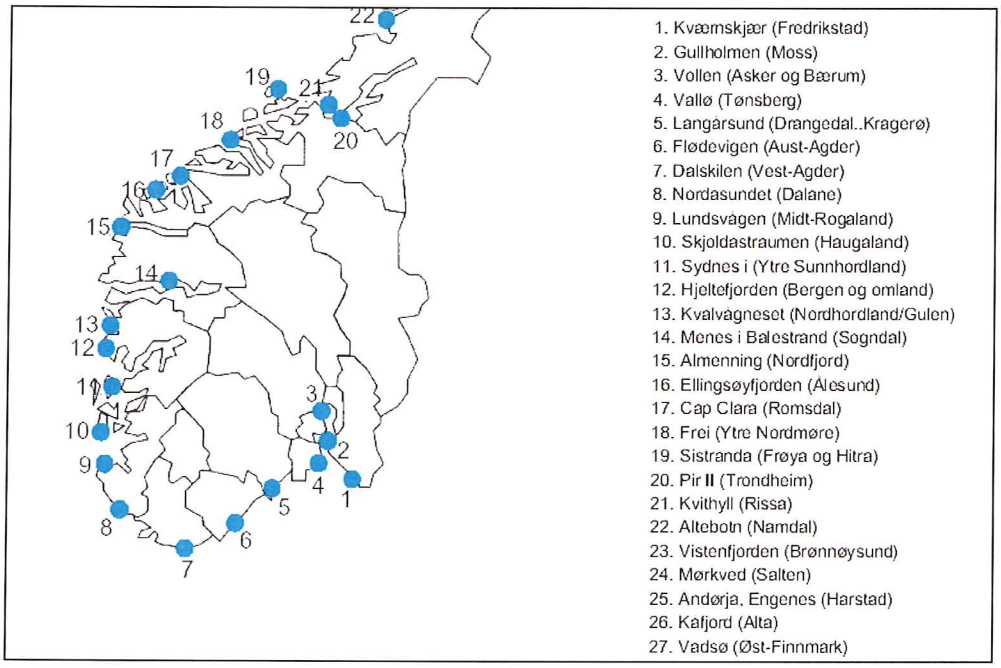


Figure 7. Stations for monitoring of toxic algae and mussel toxins in southern Norway (from Hestdal et al., 2001).

3. Norwegian Skagerrak coast – Comprehensive Procedure

3.1 Introduction

Reporting format on the results of the OSPAR Comprehensive Procedure will in general follow the outline in (OSPAR 2002), 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 1**
4. Classification according to **Table 2** or the Norwegian classification system. First an initial classification and then a final classification taking into consideration other available information.

3.2 Classification

3.2.1 The Oslofjord with suba reas

For classification purposes the Oslofjord is divided into 11 subareas. In the following the areas will be classified according to the procedure outlined in chapter 3.1.

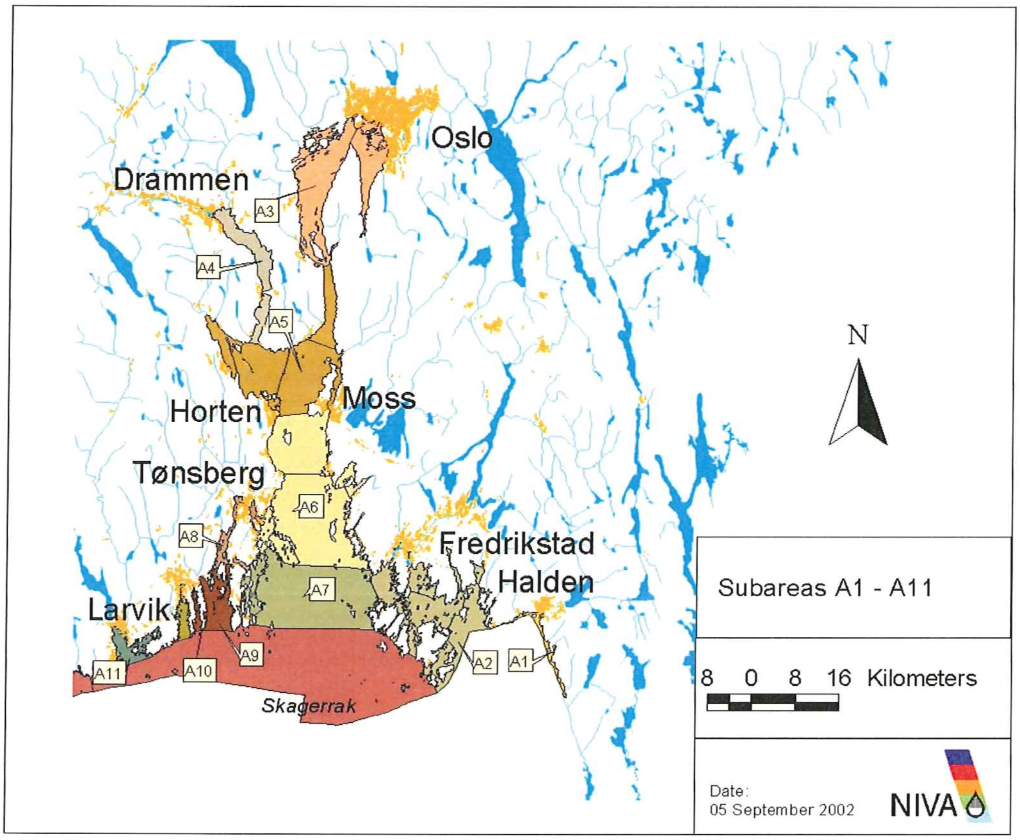


Figure 8. The Oslofjord with subareas A1-A11.

A1 Iddefjord

Hydrophysical characteristics.

The Iddefjord is situated in southeast Norway. The boarder 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.

Table 7. Main characteristics for subarea A1. The total nutrient load is averaged for 1997-2000, with characteristic anthropogenic load in parenthesis.

Fjord	Area, km^2	Freshwater runoff, m^3/s	Nutrient load, avg. 1997-2000		Maximum depth, m	Sill depth, m	Surface layer residence time, days
			Nitrogen, tonnes	Phosphorus, tonnes			
Iddefjord	12.6	37	1245 (672)	28 (14)	48	9	12

Sill-fjord with fresh water discharge from two small rivers. Semidiurnal tidal amplitude 0.1 m. Surface layer salinity range between 1 – 25, and deep-water range 28-31. Deep-water renewal varies between 1-3 time's pr. year.

Degree of Nutrient Enrichment.

The Iddefjord has been heavily polluted by industry (paper industry), during the 20'th century and received untreated sewage water from Halden City as well as nutrients from agriculture. The organic load were large, giving hydrogensulphide in the whole fjord, sometimes even in the upper layer (above sill depth). Benthic fauna and flora was sparse. Due to changes in the 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.

Today there are elevated levels of winter surface water nitrogen concentration (Tot-N and DIN, very bad (V) according to NCS). Elevated levels of winter N/P according to the assessment criteria. (Berge et al., 1996)

Direct effects of nutrient enrichment.

Elevated levels of chlorophyll *a* (IV), according to the NCS. Increased plankton concentration in the 1990'ies including observations of nuisance species (*Prorocentrum* spp.), due to increased secchi depth and reduced industrial outlet. Elevated N/P levels (DIN/DIP = 340 (mol) during winter) according to assessment criteria.

Positive shifts of species of macro algae in the outer parts of the fjord, mainly due to less industrial pollution. The inner parts are still dominated by short-lived species like *Ulva*)(Rueness et al., 1998).

Indirect effects of Nutrient Enrichment.

Oxygen deficiency in waters below sill depth in the outer part of the fjord. Anoxic conditions occur in the inner part. Reduced bottom fauna. Fish kills have been observed. The conditions have improved from 1970 to1990. According to NCS the conditions varies between class V – III. Elevated levels of sediment carbon (mainly due to earlier outlet from industry) and elevated levels of surface TOC (7.9 mg/l winter and 8.7 mg/l summer), but significant lower in 1990-91 compared to 1993-94 (Berge et al., 1996).

Other possible effects.

Observations of nuisance species (*Prorocentrum* spp.), that now seems to be locally established in the fjord.

Evaluation.

Table 8. Subarea A1. Summary Classification Table. Score based on the Norwegian Classification System (NCS) is marked with 1.

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.	+
	Winter DIN- and/or DIP concentrations	Elevated DIN-concentrations (1)	+
	Increased winter N/P ratio (Redfield N/P = 16)	Increased winter N/P ratio	+
Direct Effects (II)	Maximum and mean chlorophyll a concentration	Elevated maximum and mean chl. a concentrations (1)	+
	Region/area specific phytoplankton indicator species	Shifts in phytoplankton indicator species.	+
	Macrophytes including macroalgae (region specific)	Improved, but still reduced vegetation	+
Indirect Effects (III)	Degree of oxygen deficiency	Oxygen deficiency. Hydrogen sulphide in bottom water (1)	+
	Changes/kills in Zoobenthos and fish mortality	Fish kills have been observed.*	?
	Organic Carbon/Organic Matter	Elevated levels of sediment carbon and TOC in surface waters**	
Other Possible Effects (IV)	Algae toxins (DSP/PSP mussel infection events)	No data	

**Mostly due to outlet from paper industry

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

A2 Hvaler/ Singlefjord

Hydrophysical characteristics.

The Hvaler/Singlefjorden area 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 islands in Hvaler there are basins with restricted water exchange. About 25 % of the bottom area have depths less than 6 m, and 50% less than 20 m depth. There are depths up to 160 m in the Singlefjord. The hydrophysical regime is dominated by the river Glomma, 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 has a residence time between 5-16 days. The deeper water renews from once a year to several times a year. As the Singlefjord to a lesser degree is influenced by the river Glomma the area is subdivided into two: Hvaler and the Singlefjord.

Table 9. Main characteristics for subarea A2. The total nutrient load is averaged for 1997-2000, with characteristic anthropogenic load in parenthesis

Fjord	Area, km^2	Freshwater runoff, m^3/s	Nutrient load, avg. 1997-2000		Maximum depth, m	Sill depth, m	Surface layer residence time, days
			Nitrogen, tonnes	Phosphorus, tonnes			
Hvaler/-Single-fjorden	194	836	17274 (10701)*	666 (366)*	163	-	5-16
Hvaler					60	30-40 m	
Single-fjorden					163	60-70 m	

* Reduced since 1985.

Degree of Nutrient Enrichment.

The estuary is a recipient of industrial, sewage outlets and agriculture. Since 1985 there are reductions in the industry outlets and sewage (chemical treatment). In 1993 the sources for nitrogen were 47 % from agriculture, 11 % from sewage and 0.2 % from industry. For phosphorus it was 38%, 11 % and 0.5 %. Natural sources contributed with 42 % of the nitrogen load and 50 % of the phosphorus load. Since 1980 to 1990 the environmental conditions have improved due to reduction in loads from industry (heavy metals) and nutrients, mainly phosphorus (sewage).

The NSC gives conditions between IV – I (salinity taken into consideration). Elevated levels of nitrogen are evident as low concentrations of phosphorus. Poor Secchi depth is mainly a function of particles and humic acid. DIN/DIP in winter varies between 46-360 (Berge et .al., 1996, Magnusson and Sørensen, 1996).

Direct effects of nutrient enrichment.

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.

Of nuisance species, the area is known for episodes of high concentrations of *Prorocentrum minimum* (Dragsund et al., 2002). Since it first was observed in 1979 (Tangen 1980), there has been almost yearly blooms.

Improved conditions for macro algae since 1980 is probably a direct effect of reduction in industrial pollution. Over all it seems as the hard bottom communities are close to what can be expected in a brackish water area. A slightly higher portion of green algae is observed (Dragsund et al., 2002).

Indirect effects of nutrient enrichment.

The oxygen conditions varies during the year, with highest values in connection to water renewals in the winter and the lowest normally in the autumn. In a few locations close to the bottom there was observed hydrogen sulphide. According to the NCS the conditions varies between class V–I in the Hvaler area and class II in the Singlefjord area. There has been a slight improvement since 1980-1983.

The soft bottom fauna is classified from IV – I (NCS), clearly improved from 1980-82 to 1990 (Berge et al., 1996). Only a few stations close to the mouth of the river Glomma are still suggested as pollution effected, mainly as a consequence of low oxygen and high sedimentation of particles. Observations from 2001 confirms the situation, showing slightly improved conditions (Dragsund et al., 2002)

Other possible effects of nutrient Enrichment.

Observed algae toxins in shellfish (DSP, PSP and ASP, Tangen pers. comm., Tangen et al. 1996, Tangen 1985, Dahl and Tangen 1993, Hestdal et al., 2001)

Table 10. Subarea A2. Summary Classification Table. Score based on the Norwegian Classification System (NCS) is marked with 1.

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.	+
	Winter DIN- and/or DIP concentrations	Elevated DIN-concentrations* (1)	+
	Increased winter N/P ratio (Redfield N/P = 16)	Increased winter N/P ratio	+
Direct Effects (II)	Maximum and mean chlorophyll a concentration	Elevated maximum and mean chl. a concentrations* (1)	+
	Region/area specific phytoplankton indicator species	Observed	+
	Macrophytes including macroalgae (region specific)	Improved, but still reduced vegetation but not associated with eutrophication	-
Indirect Effects (III)	Degree of oxygen deficiency	Oxygen deficiency. Hydrogen sulphide in bottom water. (1)	+
	Changes/kills in Zoobenthos and fish mortality	Fish kills have been observed. Soft bottom fauna almost normal.	-
	Organic Carbon/Organic Matter	TOC in sediments, normal for coastal areas (1)	-
Other Possible Effects (IV)	Algal toxins (DSP/PSP mussel infection events)	Observed	+

*Decreased since 1980.

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

A3 Inner Oslofjord

Table 11. Main characteristics for subarea A3. The total nutrient load is averaged for 1997-2000, with characteristic anthropogenic load in parenthesis.

Fjord	Area, km^2	Freshwater runoff, m^3/s	Nutrient load, avg.1997-1999.*		Maximum depth, m	Sill depth, m	Surface layer residence time, days
			Nitrogen, tonnes	Phosphorus, tonnes			
Inner Oslofjord	192	27	3132 (2634)	81 (61)	164	19.5	10-20 days

* During the period nitrogen reduction was implemented (start in 1995). Estimated nitrogen load will be (2002) about 2000 tonnes and phosphorus 73 tonnes. Since 1982 the phosphorus load has decreased.

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 discharge 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 river discharge 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.

Degree of Nutrient Enrichment.

The fjord 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 will be completed in 2001/2002.

According to NCS the water quality varies between very bad (V) to very good (I). Winter surface values with elevated nitrogen concentrations. Decreasing phosphorus concentration results in elevated N/P ratios, according to the assessment criteria (Magnusson et al. 2001).

Direct effects of nutrient enrichment.

The surface (0-2 m depth) concentration of chlorophyll *a* has decreased during the last 20 years (Magnusson et al. 2001). 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 has been reversed and the Fucasè community has increased and the short lived green algae decreases (Bokn et al., 1992, Magnusson et al. 2001). The lower growth limit has increased (increased depth distribution).

Indirect effects of nutrient enrichment.

The fjord has naturally low oxygen concentration (limited water exchange). Sediment observations can not 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 mid. 1970. From here 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 (1997-2001) are 1.2 ml/l (Class V) 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).

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

The hyperbenthos population has decreased since 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 about 1985 to a positive development (Beyer and Indrehus, 1995, Magnusson et al. 2001).

The soft bottom fauna in the deeper parts of the Bunnefjord and the inner basins are more or less extinguished (oxygen depletion in the water or reduced sediments) (Olsgard, 1995). In the Vestfjord there was a gradient from north to south with the best conditions in the south. Compared to observations from 1914 there has been a reduction in species in the inner and northern part of the fjord, but the fauna has improved since 1970's. In 1993 the fjord was classified from (V) to (I) according to NCS.

Other possible effects of nutrient enrichment.

Episodes of shellfish poisoning occurs, recently from toxic algae as *Dinophysis* spp. and *Alexandrium* spp (Hestdal, et al., 2001)

As the fjord is extremely sensitive to frequency and quantity of the deep-water renewals, a change here will counteract the reduction of outlets to the fjord. Deep-water renewals are dependent on northerly winds over the area for a prolonged time (several weeks) a situation which coincides with cold winters. The climatic change during the 1990's has raised the frequency of relatively warm winters, and thus the deep-water exchange has been reduced.

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 12. Subarea A3. Summary of Classification for the inner Oslofjord. Score based on the Norwegian Classification System (NCS) is marked with 1.

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.*	+
	Winter DIN- and/or DIP concentrations	Elevated DIN-concentrations (1)	+
	Increased winter N/P ratio (Redfield N/P = 16)	Increased winter N/P ratio	+
Direct Effects (II)	Maximum and mean chlorophyll *a* concentration	Elevated maximum and mean chl. *a* concentrations** (1)	+
	Region/area specific phytoplankton indicator species		
	Macrophytes including macroalgae (region specific)	Improved, but still reduced vegetation	+
Indirect Effects (III)	Degree of oxygen deficiency	Oxygen deficiency. Hydrogen sulphide in bottom water. (1)	+
	Changes/kills in Zoobenthos and fish mortality	Fish kills have been observed. Poor or lacking hyperbenthos fauna in part of the fjord. Improved in the Vestfjord since 1985. Soft bottom communities have improved since 1970's. Horizontal gradients from extinguished to normal. Fish kills observed, but several years between observations.	+
	Organic Carbon/Organic Matter	Not observed	
Other Possible Effects (IV)	Algal toxins (DSP/PSP mussel infection events)	Episodes of shell poisoning.	+

*Improved since 1982
** decreasing since 1973-82.

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

A4 Drammensfjord

Table 13. Main characteristics for subarea A4 (Drammensfjord to Rødtangen). The total nutrient load is averaged for 1997-2000, with characteristic anthropogenic load in parenthesis.

Fjord	Area, km^2	Freshwater runoff, m^3/s	Nutrient load		Maximum depth, m	Sill depth, m	Surface layer residence time, days
			Nitrogen, tonnes	Phosphorus, tonnes			
Drammens-fjorden	62.3	354	6309 (3336)	167 (91)	123	10	16

Hydrophysical characteristics

The Drammensfjord is a sill fjord with fresh water discharge. Semidiurnal tides are 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).

Degree of nutrient enrichment

The Drammensfjord has been heavily polluted by industry, agriculture, and sewage. The industrial pollution reached its peak around 1960/70. Introduction of chemical treatment on the communal purification plants has reduced the anthropogenic load of nutrients.

Surface observations are few in the fjord, especially during winter, when the fjord normally is ice-covered. According to NCS (salinity corrected) the surface nutrient concentrations are moderately elevated in summer.

Direct effects of nutrient enrichment (during growing season)

Elevated levels of chlorophyll *a* especially in the areas with a rising salinity gradient (fronts). Elevated N/P levels based on totN/totP in the summer (40/1, weight) (Magnusson, 1995, Jensen et al., 2002).

Marine macro algae is poor or non-existent mainly because low salinity in the surface layer. Outside the sill there was an increased amount of green algae in 2001 (Jensen et al. 2002), compared to the amount of different species of brown algae (*Fucus*). Due to low salinity in the fjord studies of higher vegetation in 1983 concluded that the fjords surface water varied from mesotrophic to eutrophic (Mjelde, 1986).

Indirect effects of nutrient enrichment.

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).

Reduced bottom fauna due low oxygen concentration. Anoxic water from 35-45 meters depth (1984) is the lower limit for bottom fauna.

Table 14. Subarea A4. Summary of Classification for Drammensfjorden. Score based on the Norwegian Classification System (NCS) is marked with 1.

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.*	+
	Winter DIN- and/or DIP concentrations	Summer values are elevated (1)	
	Increased winter N/P ratio (Redfield N/P = 16)	No data	
Direct Effects (II)	Maximum and mean chlorophyll *a* concentration	Elevated maximum and mean chl. a concentrations** (1)	+
	Region/area specific phytoplankton indicator species	No data	
	Macrophytes including macroalgae (region specific)	Higher vegetation indicates mesotrophic to eutrophic situation	+
Indirect Effects (III)	Degree of oxygen deficiency	Oxygen deficiency. Hydrogen sulphide in bottom water, partly a natural situation	+
	Changes/kills in Zoobenthos and fish mortality	Soft bottom fauna is reduced or lacking due to oxygen deficiency.	+
	Organic Carbon/Organic Matter		
Other Possible Effects (IV)	Algal toxins (DSP/PSP mussel infection events)	No data	

* Decreased since 1980's
** Horizontal variations.

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

A5. Sandebukta. Mossesundet, Horten Bay and outer Oslofjord north Horten (Breiangen).

Table 15. Main characteristics for subarea A5. The total nutrient load is averaged for 1997-2000, with characteristic anthropogenic load in parenthesis.

Fjord	Area, km^2	Freshwater runoff, m^3/s	Nutrient load, 1997-200		Maximum depth, m	Sill depth, m	Surface layer residence time, days
			Nitrogen, tonnes	Phosphorus, tonnes			
Sandebukta, Horten Bay Mossesundet and Breiangen	243	28	1545 (1199)	48.8 (38.1)	200	Ca. 150	8 – 14

Hydrophysical characteristics

The area is partly brackish as it receives water from the Drammensfjord. There are some small rivers (Sandebukta and Mossesundet) with more or less a local impact. The tides are weak (semidiurnal 0.1 m). There are more restricted areas as Horten Bay (sill depth 8 m and max. depth 27 m) but overall the topography is more or less without shallower sills. Salinity in the surface layers varies locally and with distance from river mouths, but in the main area the salinity varies over the year and the time of flooding of the major river, Drammenselva. 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 continuos.

Degree of nutrient enrichment.

Apart from river input and transport from the neighbouring Drammensfjord and inner Oslofjord there are a few industry outlets to the area (mostly paper industry).

The main part of the area (Breiangen) has slightly elevated concentrations in winter and summer (DIN and DIP), according to NCS. Locally in Sandebukta and Mossesundet nutrient concentrations are some times higher (III-V). Sandebukta has elevated levels of winter surface DIN/DIP (according to the assessment criteria).

Direct effects of nutrient enrichment.

Elevated levels of chlorophyll *a*, especially in Sandebukta, Horten Harbour and Mossesundet (Class III-IV according to the NCS). Observed potentially toxic phytoplankton species (*Alexandrium* spp. *Dinophysis* spp. *Karenia mikimotoi* (earlier *Gyrodinium aureolum*)). Almost yearly occurrence (Tangen, et.al.1996). Fish kills observed.

Some species of macro algae observed in the area about 50 years ago are not observed today and species earlier described are now more seldom found. However large amounts of mussels can cause this effect and eutrophication is not the only explanation (Rueness and Fredriksen, 1990).

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).

Indirect effect of nutrient enrichment.

Oxygen concentration has decreased from 1930-1990 (Johannessen and Dahl, 1996, Magnusson, 1990, Magnusson et al., 2001) but am overall in class I according to NCS. In the bottom water the concentration can be as low as 2 ml/l (class IV) and locally as in Horten Harbour there are hydrogensulphide (Class V) and reduced concentration (Class III-IV) in Mossesundet (mainly as a consequence of industrial outlets). Sandebukta is also an example of reduced oxygen concentrations (Class II-III), most probably an effect of outlets from industry.

The soft bottom communities are classified as good (Class I-II) in the central parts, but in vicinity to the industrial outlets in Sandebukta and Mossesundet poor or almost non-existent (Dragsund, 2002, Baalsrud and Magnusson, 1990).

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

Other possible effects of nutrient enrichment.

Toxic plankton blooms (DSP/PSP) in amounts that can cause effects on shellfish (see Category II direct effects). Observed toxins in mussels (Hestdal, et al., 2001).

Table 16. Subarea A5. Summary of Classification. Score based on the Norwegian Classification System (NCS) is marked with 1.

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.*	+
	Winter DIN- and/or DIP concentrations	Elevated DIN (1)	+
	Increased winter N/P ratio (Redfield N/P = 16)	Elevated in part of the area	+
Direct Effects (II)	Maximum and mean chlorophyll *a* concentration	Elevated (1)	+
	Region/area specific phytoplankton indicator species	Observed heavy blooms in the area	+
	Macrophytes including macroalgae (region specific)	Reduced lower growth limit	+
Indirect Effects (III)	Degree of oxygen deficiency	Oxygen deficiency (1)	+
	Changes/kills in Zoobenthos and fish mortality	Fish kills (toxic algae)	+
	Organic Carbon/Organic Matter		
Other Possible Effects (IV)	Algal toxins (DSP/PSP mussel infection events)		+

* Decreased since 1980's

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

A6 Middle part of outer Oslofjord

Table 17. Main characteristics for subarea A6 (middle part of the outer Oslofjord). The total nutrient load is averaged for 1997-2000, with characteristic anthropogenic load in parenthesis.

Fjord	Area, km^2	Freshwater runoff, m^3/s	Nutrient load, 1997-2000		Maximum depth, m	Sill depth, m
			Nitrogen, tonnes	Phosphorus, tonnes		
Middle part of the Oslofjord	356	4	452 (391)	11.7 (9.9)	355	125

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 (Breading) 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. The deep-water salinity is more or less over 34.5. Major deep-water renewals are normally once a year (winter/spring), but intermediate water exchange is more or less continues. There are observations of more than one deep-water renewal pr. year.

Degree of nutrient enrichment.

There are three outlets of sewage from purification plants in the area (Horten City, Moss City and part of Tønsberg City). The area receives water and nutrients from neighbouring areas as Breiangen and is also exposed from long range transport from the Skagerrak.

The main part of the area has slightly elevated levels of nitrogen (DIN) according to the NCS. Locally, in the influence of small rivers and semi- enclosed areas the concentration can be higher, especially during flooding. DIN/DIP in winter are close to 25.

Direct effects of nutrient enrichment.

Elevated levels of chlorophyll *a*, (Class II-III (NCS)). Observed potentially toxic phytoplankton species (*Alexandrium* spp., *Dinophysis* spp., *Karenia mikimotoi* (earlier *Gyrodinium aureolum*)). Almost yearly occurrence.

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).

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).

Table 18. Subarea A6. Summary of Classification. Score based on the Norwegian Classification System (NCS) is marked with 1.

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.*	-
	Winter DIN- and/or DIP concentrations	Elevated DIN (1)	+
	Increased winter N/P ratio (Redfield N/P = 16)	Elevated in part of the area	+
Direct Effects (II)	Maximum and mean chlorophyll *a* concentration	Elevated (1)	+
	Region/area specific phytoplankton indicator species	Observed	+
	Macrophytes including macroalgae (region specific)	Reduced lower growth limit	+
Indirect Effects (III)	Degree of oxygen deficiency	Oxygen deficiency (1)	+
	Changes/kills in Zoobenthos and fish mortality		-
	Organic Carbon/Organic Matter		
Other Possible Effects (IV)	Algal toxins (DSP/PSP mussel infection events)	At station Vallø	+

* Decreased since 1980's

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

A7 Southern part of outer Oslofjord

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 discharges from Glomma and weather. 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.

Table 19. Main characteristics for subarea A7 (southern part of the outer Oslofjord). The total nutrient load is averaged for 1997-2000, with characteristic anthropogenic load in parenthesis.

Fjord	Area, km^2	Freshwater runoff, m^3/s	Nutrient load, 1997-2000		Maximum depth, m	Sill depth, m	Surface layer residence time, days
			Nitrogen, tonnes	Phosphorus, tonnes			
Southern part of outer Oslofjord	267	1	45 (36)	1.7 (1.5)	465	125-150	5-10?

Degree of nutrient enrichment.

The area receives water and nutrients from neighbouring areas primary from Hvaler, but is also exposed from long range transboundary transport from the Skagerrak.

The main part of the area has slightly elevated levels of winter nitrogen (DIN) according to the NCS, but can be locally higher when brackish water from Hvaler is present, especially during flooding. DIN/DIP in winter are close to 25 (mol).

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 *Chatonella* spp. 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).

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.

Evaluation

Table 20. Subarea A7. Summary of Classification. Score based on the Norwegian Classification System (NCS) is marked with 1.

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	Elevated DIN (1)	+
	Increased winter N/P ratio (Redfield N/P = 16)	Elevated	+
Direct Effects (II)	Maximum and mean chlorophyll *a* concentration	Elevated in episodes (1)	?
	Region/area specific phytoplankton indicator species	Probably elevated	?
	Macrophytes including macroalgae (region specific)	Reduced lower growth limit	+
Indirect Effects (III)	Degree of oxygen deficiency		+
	Changes/kills in Zoobenthos and fish mortality	Soft bottom fauna	-
	Organic Carbon/Organic Matter		
Other Possible Effects (IV)	Algal toxins (DSP/PSP mussel infection events)		?

Initial classification: Problem area.
Final classification: Potential Problem area, due to Transboundary load of nutrient and organic matter. Extended residence time in basin water.

A8 Tønsbergfjord

Hydrophysical characteristics.

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 river in the inner part. 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 freshwater from the river has some times an impact over the whole area.

Table 21. Main characteristics for subarea A8 (Tønsbergfjorden including Vrengen). The total nutrient load is averaged for 1997-2000, with characteristic anthropogenic load in parenthesis.

Fjord	Area, km^2	Freshwater runoff, m^3/s	Nutrient load, 2000		Maximum depth, m	Sill depth, m
			Nitrogen, tonnes	Phosphorus, tonnes		
Tønsberg-fjorden	22	13	1124 (912)	40.1 (34.5)	15	8

Degree of nutrient enrichment.

Nutrient transport into the area mainly originates from the river (Auli) and the sewage outlet from Tønsberg City (Chemical treatment, 1993). The sewage outlet is submerged and moved outside the sills at 40 m depth (1990).

Elevated summer nutrient levels varying between Class IV – I according to NCS. The most exposed part is the area close to the river and Tønsberg City. Concentrations decreased from 1976-89 to 1990-96.

Direct effects of nutrient enrichment

Elevated levels of chlorophyll *a* (Class II-IV) according to the NCS. Decreasing levels since 1990. There are few observations of phytoplankton from this area. An observation of macro algae from Vrengen 1986 (Bokn, 1986) showed that the area was in a negative development compared to observations by Sundene in the beginning of 1950's. The area seems moderately eutrophicated.

Indirect effects of nutrient enrichment.

Oxygen 2 m above bottom was measured during summer, perhaps not the most critical period. Minimum concentrations on 5 stations were between 0.5-5.6 ml/l in the area (1990-1996), which is in Class I-VI according to the NCS and Class I in 2001 on one station (Østlandskonsult, 1997, Jensen et al., 2002). Average minimum concentration 1990-96 was 2.52 ml/l.

The soft bottom fauna was observed close to the City's main sewage outfall, where the fauna is influenced of organic matter. This could be a local effect of the sewage outfall or a more general effect from the combined nutrient transport from the City and the river (agriculture).

Other possible effects of nutrient enrichment.

Algal toxins (DSP/PSP mussel infection) have been observed (Hestdal et al., 2001).

Evaluation

Table 22. Subarea A8. Summary of Classification. Score based on the Norwegian Classification System (NCS) is marked with 1.

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.*	+
	Winter DIN- and/or DIP concentrations	Not observed. Summer observations elevated in the area. (1)	
	Increased winter N/P ratio (Redfield N/P = 16)		
Direct Effects (II)	Maximum and mean chlorophyll *a* concentration	Elevated (1)	+
	Region/area specific phytoplankton indicator species		
	Macrophytes including macroalgae (region specific)	Moderately influenced. Few observations	?
Indirect Effects (III)	Degree of oxygen deficiency	Oxygen deficiency (1)	+
	Changes/kills in Zoobenthos and fish mortality		
	Organic Carbon/Organic Matter		
Other Possible Effects (IV)	Algal toxins (DSP/PSP mussel infection events)		

*Decreased phosphorus input since 1989, due to chemical treatment of sewage.

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

A9 Southern part of Tønsbergfjord incl. Mefjord

Southern part of the Tønsbergfjord is a shallow exposed area. There are few observations (almost none) from this part of the fjord. Local anthropogenic nutrient load is low and nutrient supply is from the neighbouring areas as the Tønsbergfjord, the outer Oslofjord and from the Skagerrak.

Table 23. Main characteristics for subarea A9 (the outer Tønsbergfjord and Mefjorden). The total nutrient load is averaged for 1997-2000, with characteristic anthropogenic load in parenthesis.

Fjord	Area, km^2	Freshwater runoff, m^3/s	Nutrient load, 1997-2000		Maximum depth, m	Sill depth, m
			Nitrogen, tonnes	Phosphorus, tonnes		
Outer Tønsberg-fjord and Mefjord	55	0	45 (39)	1.2 (1.1)	37	-

Hydrophysical characteristics.

The area has weak semi-diurnal tidal currents (0.1 m amplitude). No direct freshwater discharge means a salinity about the same as the coastal area outside the fjord. High salinities in winter (perhaps 32 and higher) and less in the summer (perhaps about 25). Water exchange should be good.

Mefjorden is a narrow and shallow fjord (max. depth from 24-27 m) more or less without a sill. River discharge is limited (one little river). Except from the area close to the river the salinity variations follows the general variation in the coastal area, with surface salinities between 24 – 31 and bottom salinities between 27-32.

Degree of nutrient enrichment.

Nutrient transport into the area mainly originates from the river and sewage.

Elevated winter nutrient (nitrogen) levels varying between class I-IV. Elevated winter N/P ratio, 16 (weight) for the inner part of the fjord (Nygaard, et. al., 1998).

Direct effects of nutrient enrichment.

Elevated levels of chlorophyll *a* (Class III) according to the NCS. Observations of phytoplankton from Mefjorden in 1997 indicate an increasing nutrient pressure on the fjord going inwards in the fjord. Toxic algae are observed (several species of *Dinophysis*) in concentrations above admissible limit for catch and consumption of mussels. Macro flora in the inner part of the fjord shows impact of eutrophication, but has slightly improved between 1978 and 1983 (increased number of species and decreasing amount of green algae) due to reduced outlets from sewage (Miljøplan, 1984). Improved depth distribution of some benthos algae in 1997, but still a considerable amount of green algae, reflecting a general eutrophication in sheltered areas of Oslofjorden (Nøland, S-A. et al. 1998).

Indirect effects of nutrient enrichment.

Oxygen deficiency is observed during summer/autumn in the bottom water (2.5 –3.2 ml/l).

The soft bottom fauna classified as good (Class I-II, according to NCS (Nøland et al., 1998)).

Other possible effects of nutrient enrichment.

Observed amounts of *Dinophysis* spp. that exceeds levels for possible shellfish poisoning.

Evaluation

Table 24. Subarea A9. Summary of Classification. Score based on the Norwegian Classification System (NCS) is marked with 1.

Category	Assessment Parameters	Description of Results	Score
Degree of Nutrient Enrichment (I)	Riverine total N and total P inputs and direct discharges (RID)	Decreasing local inputs since 1977.	-
	Winter DIN- and/or DIP concentrations	Elevated in Mefjord (1)	?
	Increased winter N/P ratio (Redfield N/P = 16)	Elevated in Mefjord	?
Direct Effects (II)	Maximum and mean chlorophyll *a* concentration	Elevated episodes in Mefjord (1)	?
	Region/area specific phytoplankton indicator species	*Dinophysis* spp. (Mefjord)	?
	Macrophytes including macroalgae (region specific)	Moderately influenced (Mefjord)	?
Indirect Effects (III)	Degree of oxygen deficiency	Oxygen deficiency in bottom water (Mefjord) (1)	?
	Changes/kills in Zoobenthos and fish mortality	Soft bottom fauna normal	?
	Organic Carbon/Organic Matter	No data	
Other Possible Effects (IV)	Algal toxins (DSP/PSP mussel infection events)		

Initial classification: Non Problem area, except for Mefjord (problem area).
Final classification: Potential Problem area, as an overall classification.

A10. Sandefjordsfjord.

Table 25. Main characteristics for subarea A10 (Sandefjordsfjord). The total nutrient load is averaged for 1997-2000, with characteristic anthropogenic load in parenthesis.

Fjord	Area, km^2	Freshwater runoff, m^3/s	Nutrient load, 2000		Maximum depth, m	Sill depth, m	Surface layer residence time, days
			Nitrogen, tonnes	Phosphorus, tonnes			
Sandefjords-fjorden	16	1	284 (40)	7.2 (6.6)	85	55-60	<20

Hydrophysical characteristics

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 main load of nutrients to the fjord is from sewage. The sewage outlet has been moved from the inner harbour to the middle fjord and submerged to 40 meters depth. Hence, a slight improvement has been observed in the harbour area, but outfalls to the surface layer is still a problem.

Observed elevated levels of winter nitrogen, but mostly limited to the inner parts of the fjord. Elevated winter N/P-ratio in the inner part 15-22 (weight) (Nygaard et. al., 1998).

Direct effects of nutrient enrichment.

Chlorophyll *a* levels are in Class II according to the NCS. Observed toxic phytoplankton (*Dinophysis spp.*) in the area.

Macro algae have improved in the inner part of the fjord since the relocalisation of the main sewage outlet to the middle part between 1977-83. Indications of increased pollution in this area can possible be en effect of the new sewage outlet. Observation from 1997 confirms earlier investigations, with increasing sign of eutrophication towards the harbour.

Indirect effects of nutrient enrichment.

Oxygen deficiency is observed in the near bottom water in the fjord, but varying from Class I -V according to the NCS. The lowest concentrations observed varies between 0 – 5.4 ml/l.

Secchi-depth measurements in the harbour area were bad (Class IV) according to the NCS probably a combined effect of outfalls to the surface layer and resuspension of sediments by ships.

Soft bottom fauna is classified between I-III, according to the NCS (Shannon-Wieners index)(Nøland et al., 1998).

Other possible effects of nutrient enrichment.

Observed amounts of *Dinophysis* spp. over the levels for mussel infection (DSP).

Evaluation

Table 26. Subarea A10. Summary of Classification. Score based on the Norwegian Classification System (NCS) is marked with 1.

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	Elevated in the inner part (1)	+
	Increased winter N/P ratio (Redfield N/P = 16)	Elevated in the inner part (!)	+
Direct Effects (II)	Maximum and mean chlorophyll *a* concentration		-
	Region/area specific phytoplankton indicator species	Observed levels of *Dinophysis* spp above limits for mussel infection.	+
	Macrophytes including macroalgae (region specific)	Moderately influenced	+
Indirect Effects (III)	Degree of oxygen deficiency	Oxygen deficiency in bottom water (1)	+
	Changes/kills in Zoobenthos and fish mortality	Soft bottom fauna (1)	+
	Organic Carbon/Organic Matter	Not observed	
Other Possible Effects (IV)	Algal toxins (DSP/PSP mussel infection events)		

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

A11 Larviksfjord and Viksfjord

Hydrophysical characteristics.

Larviksfjorden is an open sill-free fjord with depths from about 120 m in the mouth. Viksfjorden is a semi-enclosed bay with depths from 11-24 m. While there are almost none freshwater discharge to Viksfjorden, Larviksfjorden 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 establish 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.

Table 27. Main characteristics for subarea A11 (Larviksfjorden and Viksfjorden). The total nutrient load is averaged for 1997-2000, with characteristic anthropogenic load in parenthesis.

Fjord	Area, km^2	Freshwater runoff, m^3/s	Nutrient load, 2000		Maximum depth, m	Sill depth, m
			Nitrogen, tonnes	Phosphorus, tonnes		
Larviksfjord And Viksfjorden	29	144	2397 (1206)	125.8 (65.9)	120 m	-

Degree of nutrient enrichment.

Larviksfjorden 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 water observations exists from July and August 2000 (Magnusson, 2000) and summer 2001 (Jensen et. al., 2002), but no recent winter observations.

From the sparse material, it seems that only phosphorus is slightly elevated.

Direct effects of nutrient enrichment.

Few observations of chlorophyll *a* in the area. 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 (80 %) (Jensen et. al 2002). The station is influenced by river water.

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 was classified as II according to NCS (Jensen et al. 2002). However, it is uncertain if this deficiency is caused by eutrophication or by the industrial outlet.

Other possible effects and nutrient enrichment

No other data has been found.

Evaluation

Table 28. Subarea A11. Summary of Classification. Score based on the Norwegian Classification System (NCS) is marked with 1.

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	+
	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)	Larger amount of green algae at one station	?
Indirect Effects (III)	Degree of oxygen deficiency	Earlier observations indicates problems	?
	Changes/kills in Zoobenthos and fish mortality		?
	Organic Carbon/Organic Matter		
Other Possible Effects (IV)	Algal toxins (DSP/PSP mussel infection events)		?

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

3.2.2 Telemark County

For classification purposes the coast of Telemark county is divided into 5 subareas (**Figure 9**). The areas will be classified according to the procedure outlined in chapter 3.1.

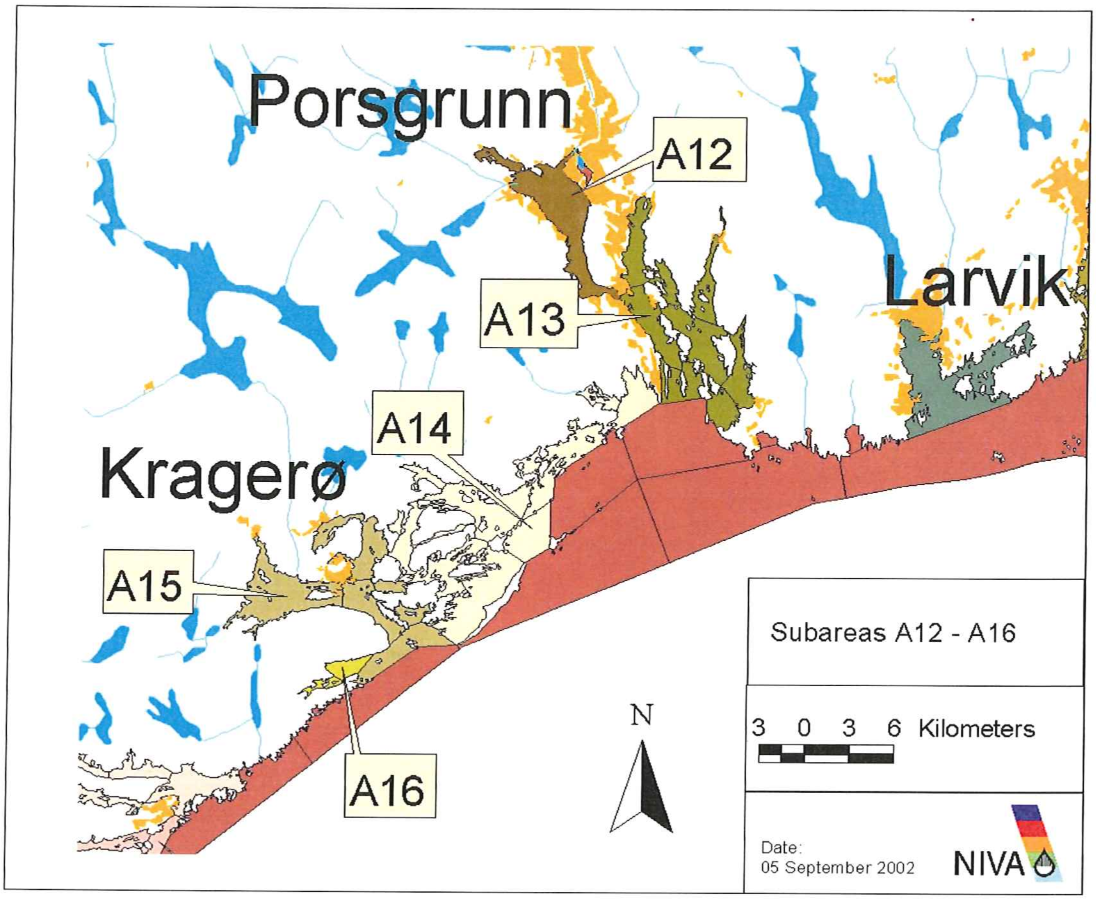
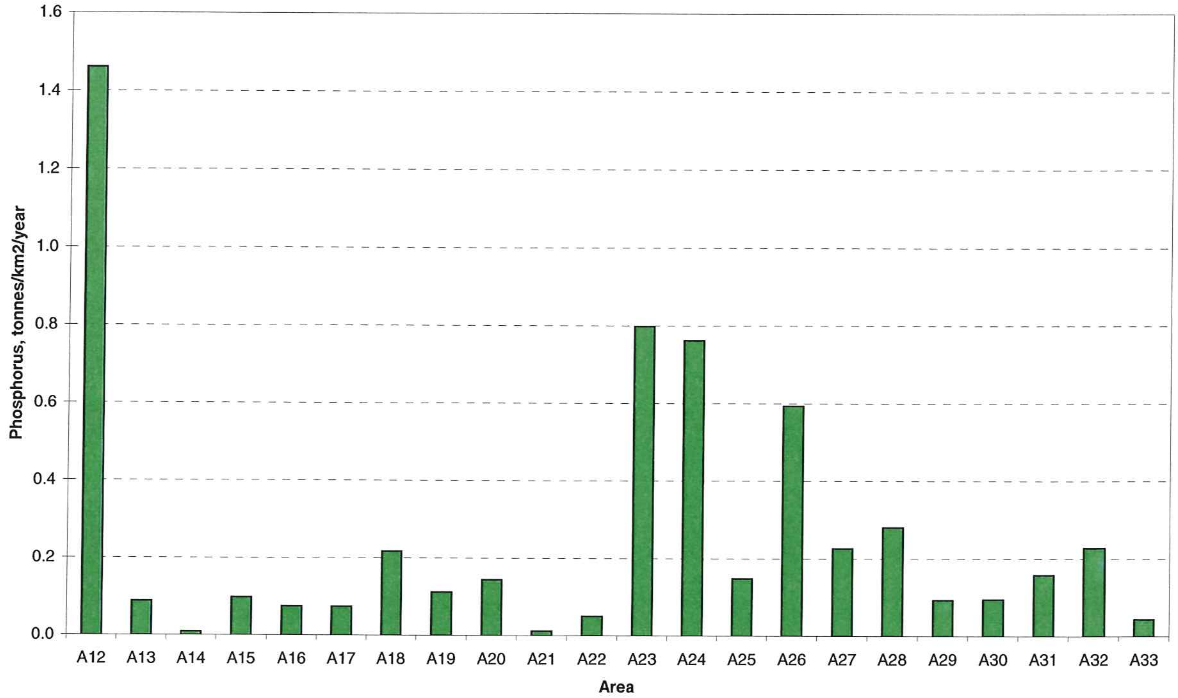


Figure 9. Telemark county with subareas A12-A16.

The nutrient load along the coast is variable and as a first estimate the anthropogenic nutrient load per km^2 of the fjord surface has been calculated for each area as average for 1997-2000 (**Figure 10**). We shall focus on the areas with highest loads (in Telemark areas A12 and A13 downstream of A12) which typically represent areas with high fresh water runoff and/or high load of sewage. These are also areas where in general the best environmental data is available.



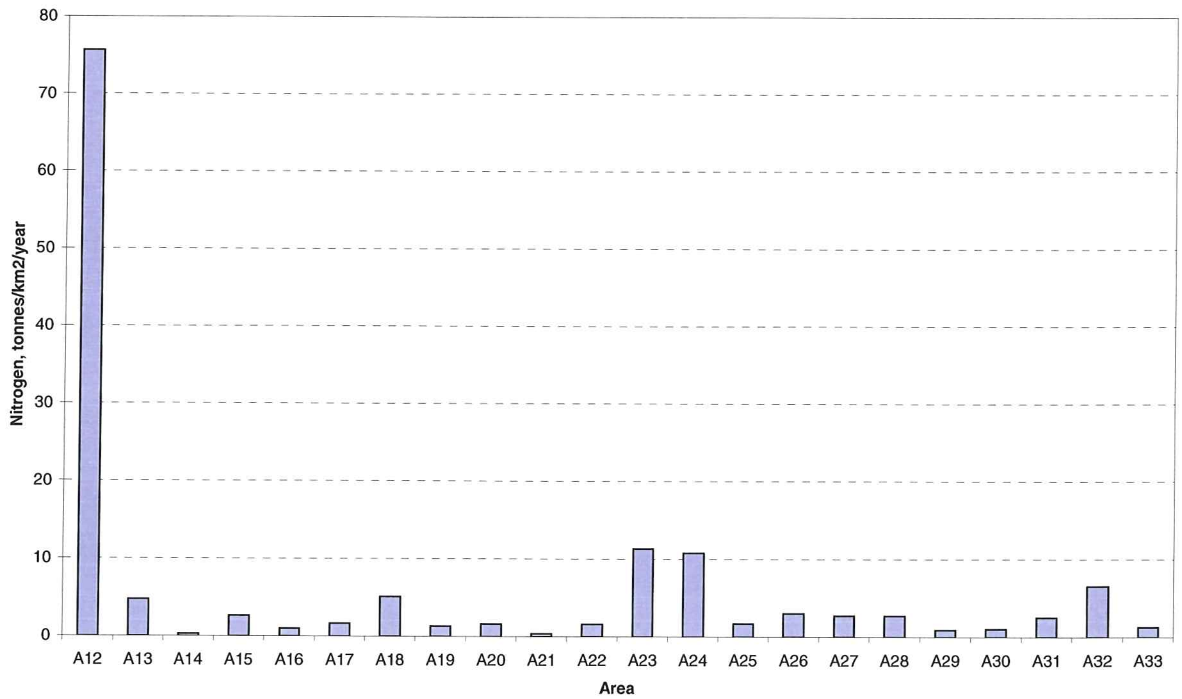


Figure 10. Anthropogenic nutrient load from local landbased sources pr. square km of coastal areas in Telemark and East Agder counties. Upper figure: Phosphorus. Lower figure: Nitrogen.

A12-A13 Grenland fjords

The Grenland fjords are situated south of the cities of Porsgrunn and Skien (**Figure 9**). Being a typical fjord area with high freshwater supply, 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 paper industry, production of fertilisers and other chemical industry over the last 40-50 years. The main characteristics are summarised in **Table 29.**

Table 29. Main characteristics for subareas **A12-A13.** The total nutrient load is average for 1997-2000, with the anthropogenic load in parenthesis.

Area	Area, km^2	Freshwater runoff, m^3/s	Nutrient load, 1997-2000		Maximum depth, m	Sill depth, m
			Nitrogen tonnes	Phosphorus tonnes		
A12: Frierfjord	19.6	279	3980 (1696)	64 (33)	98	23
A13: Rest of Grenland fjords	46.6	2+278	250 (220)	4.9 (4.1)	210	30

Adverse effects due to heavy discharges of nutrients and organic matter have been documented since monitoring studies started in 1974. The Frierfjord was then characterised by dense blooms of planktonic algae, excessive growth of benthic green algae in intertidal areas, and hydrogen sulphide in the water masses below 40 m. During the following 25 years the discharges of nutrients and organic matter were considerably reduced, for nitrogen and phosphorus respectively by 50% and 80-85%. The wastewater from a population of approx. 80.000 is treated by chemical precipitation (Molvær 2001).

After these reductions of the pollution load, lower nutrient concentrations, reduced plankton biomass (chlorophyll *a*) and improved secchi depth have been documented for the surface layer of the whole fjord area (Appendix A, **Table 72**).

In the basin water of the Frierfjord the oxygen consumption rate has been reduced to about half of the consumption in the 1970s, and compared with the situation at the beginning of the 1970s, the volume of the periodic anoxic water mass had been reduced by 70%. In the fjord basins outside Brevik serious oxygen depletion have been observed in two basins (the Håøyfjord and the Ormefjord), and no change has been observed since the early 70-ies.

The shallow hard-bottom communities were investigated in 1998-99, and indicated an improvement since the previous study in 1974. The lower depth for attached foliaceous algae had increased and the relative numbers of red, brown and green algae had improved. The number of sessile animals had also increased (Walday, Moy and Green, 2001). The effects were clearest inside Brevik.

Investigations of soft-bottom fauna in 1998 and 2001 showed a lack of fauna at depths below 50-60 m in the Frierfjord, as was the case in 1987 and 1994. In the Langesundsfjord the softbottom fauna showed stable and relatively normal communities (Rygg, 2000, 2002). No observations of soft bottom fauna from the Ormefjord or the Håøyfjord, but low oxygen concentrations indicate lack of fauna.

Evaluation:

Table 30. Subareas A12-13. Summary of Classification. Score based on the Norwegian Classification System (NCS) is marked with 1.

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	+
	Winter DIN- and/or DIP concentrations	Elevated concentrations (1)	+
	Increased winter N/P ratio (Redfield N/P = 16)	Increased winter N/P ratio	+
Direct Effects (II)	Maximum and mean chlorophyll *a* concentration	Elevated maximum and mean chl. a concentrations (1)	-
	Region/area specific phytoplankton indicator species	No data	
	Macrophytes including macroalgae (region specific)	Community changes/effects	+
Indirect Effects (III)	Degree of oxygen deficiency	Severe oxygen deficiency over several years in several basins (1)	+
	Changes/kills in Zoobenthos and fish mortality	Have been observed during deep water renewals	+
	Organic Carbon/Organic Matter	Dominated by industrial discharges	
Other Possible Effects (IV)	Algal toxins (DSP/PSP mussel infection events)	No data	

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

A14 Telemark coastline (incl. smaller fjords)

The area is divided into a number of inlets and sounds inside a number of islands (**Figure 9**). The local nutrient input is low and mainly from municipal sewage (**Table 31**), but there is also a significant transboundary nutrient load from Subareas "upstream" of Area A14.

Table 31. Main characteristics for subarea **A14.** The total nutrient load is average for 1997-2000, with the anthropogenic load in parenthesis.

Area, Km^2	Freshwater runoff, m^3/s	Nutrient load, 1997-2000	
		Nitrogen, tonnes	Phosphorus, tonnes
70	0.6	35 (19)	1,0 (0.6)

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

The water quality was studied at 5 stations in June-October 2001 (unpublished data from Telemark county administration). The data material is fairly small as the surface layer was sampled twice and the bottom layer 4-5 times. No data represents winter conditions. The average values for the surface layer and minimum oxygen concentration are shown in Appendix A, **Table 73.**

We have not found any recent information about the biological status from recipient studies in Area 14. However, through extensive observations and notes from scuba-diving between 1980 and 1997 Stene (2001) suggests that the marine environment is degrading due to episodes with harmful algae and increasing organic load. Occurrence of harmful algae may be suspected because of its closeness to Area 15, where such are observed.

Evaluation:

Table 32. Subarea A14. Summary of Classification. Score based on the Norwegian Classification System (NCS) is marked with 1.

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	-
	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	Elevated maximum and mean chl. a concentrations (1)	?
	Region/area specific phytoplankton indicator species	No data	
	Macrophytes including macroalgae (region specific)	No data	
Indirect Effects (III)	Degree of oxygen deficiency	Oxygen deficiency not observed, but may be suspected	?
	Changes/kills in Zoobenthos and fish mortality	Some observations (Stene 2001)	?
	Organic Carbon/Organic Matter	No data	
Other Possible Effects (IV)	Algal toxins (DSP/PSP mussel infection events)	No data. Problems are suspected.	

Initial classification: Non Problem area.
Final classification: Potential Problem area, due to Transboundary load, possible local areas with oxygen problems and possibly algal toxins.

A15-A16 Kragerøfjords and Stølefjord

These areas are situated in the southwestern part of Telemark county (**Figure 9**). 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 outfall. The freshwater input is mostly to the Kilsfjord. The main characteristics are summarised in **Table 33.**

Table 33. Main characteristics for subareas **A15-A16.** The total nutrient load is average for 1997-2000, with the anthropogenic load in parenthesis.

Area	Area, km^2	Freshwater runoff, m^3/s	Nutrient load, 1997-2000		Maximum depth, m	Sill depth, m
			Nitrogen, tonnes	Phosphorus, tonnes		
A15: Kragerøfjords	43	35.7	534 (112)	9.7 (4.2)	106	18
A16: Stølefjord	3.7	1.3	8 (4)	0.4 (0.3)		

The anthropogenic nutrient (especially phosphorus) load is reduced during the last 10 years due to use of chemical treatment plants for municipal wastewater.

Like Area 14 the water quality was studied at 5 stations in June-October 2001. The data material is therefore fairly small as the surface layer was sampled twice and the bottom layer 4-5 times. No data represents winter conditions. For practical purposes Area 15 is divided into a fjord area and a coastal area. The average values for the surface layer and minimum oxygen concentration are shown in **Table 71** (Appendix A).

We have not found any recent information about hardbottom or softbottom fauna from recipient studies in Areas 15-16, but like Area 14 Stene (2001) suggests that the marine environment is degrading due to episodes with harmful algae and increasing organic load. At the station for algal and mussel toxin monitoring frequent observations of high concentrations of *Dinophysis spp.* and *Alexandrium spp.* have been made the last 3-4 years. Problems with mussel toxins (mainly DSP) have varied (Hestdal et al., 2001).

Evaluation:

Table 34. Subareas A15-16. Summary of Classification. Score based on the Norwegian Classification System (NCS) is marked with 1.

Category	Assessment Parameters	Description of Results	Score
Degree of Nutrient Enrichment (I)	Riverine total N and total P inputs and direct discharges (RID)	Small load. Decreasing	-
	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	Elevated maximum and mean chl. <u>a</u> concentrations (1)	?
	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 over period of months-years (1)	+
	Changes/kills in Zoobenthos and fish mortality	Observations during renewals of stagnant fjord basins.	+
	Organic Carbon/Organic Matter	No data	
Other Possible Effects (IV)	Algal toxins (DSP/PSP mussel infection events)	Frequent observations	+

Initial classification: Problem area.
Final classification: The Kragerø fjords are classified as <u>Problem areas</u> and sensitive to organic load from local sources and transboundary load from upstream sources.
The Stølefjord has a more open topography and relatively high water exchange at all depths. The local anthropogenic nutrient load is low. ***Classification:*** Potential problem area

3.2.3 East Agder County

For classification purposes the coast of East Agder county is divided into 17 Subareas as indicated in **Figure 11**. In the following the areas will be classified according to the procedure outlined in chapter 3.1. We shall focus on areas 18, 20, 23-24 and 27 which are situated close to cities and represents areas with low water exchange and mostly have relatively high nutrient loads either from sewage and as runoff, and for which the recipient is best described. Other areas where very little information is available are given a more summary classification at the end of this chapter.

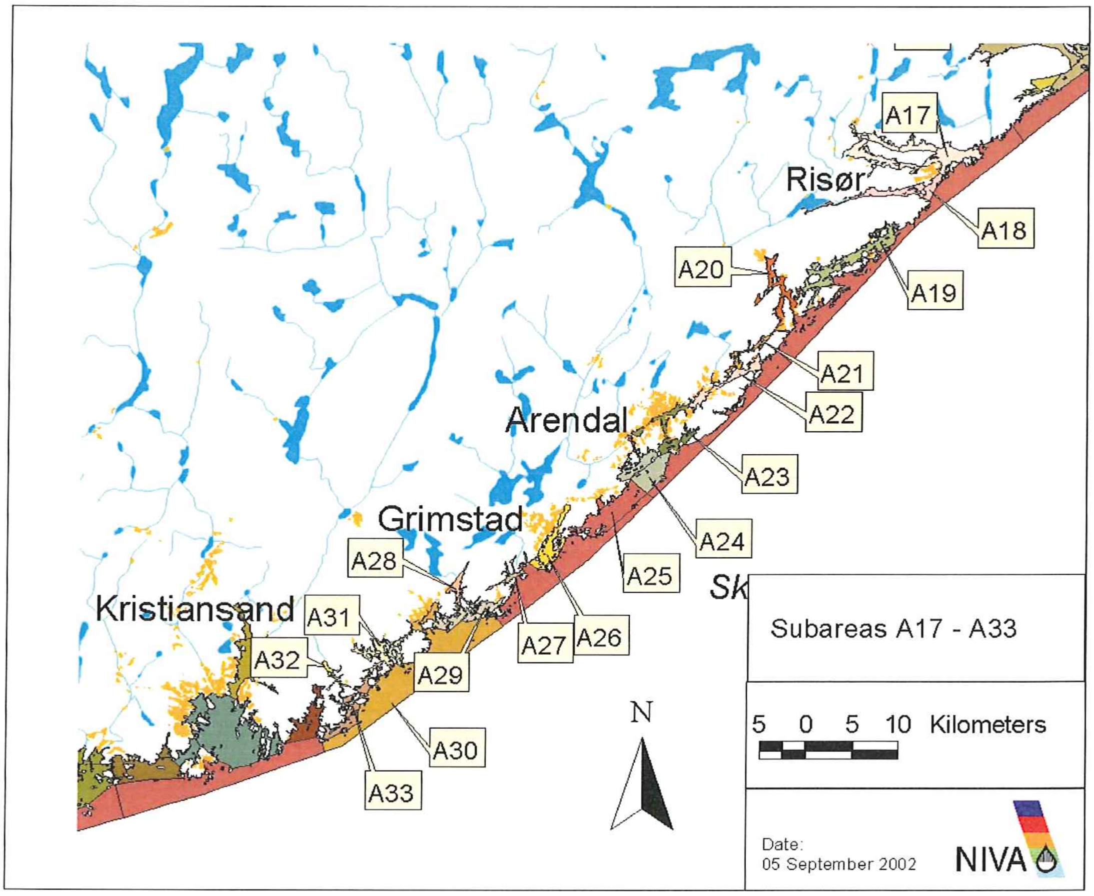


Figure 11. East Agder county with subareas A17-A33.

A17-A18 Søndeledfjord and Sandnesfjord

These areas are situated in the north-eastern part of East-Agder county (**Figure 11**). The municipal waste water from city of Risør (4000 PE) is processed with biological treatment before discharge to coastal water through a deep water outfall. In general the anthropogenic nutrient load is low. The main characteristics are summarised in **Table 35**.

Table 35. Main characteristics for subarea **A17-A18.** The total nutrient load is average for 1997-2000, with the anthropogenic load in parenthesis.

Fjord	Area, km^2	Freshwater runoff, m^3/s	Nutrient load, 1997-2000		Maximum depth, m	Sill depth, m
			Nitrogen, tonnes	Phosphorus, tonnes		
Søndeledfjord	23	47	237(38)	3.3 (1.7)	188	30
Sandnesfjord	7.8	50	268 (40)	3.7(1.7)	64	24

The anthropogenic nutrient (especially phosphorus) load is reduced during the last 10 years due to use of chemical treatment plants for municipal wastewater.

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

Evaluation:

Table 36. Subareas A17-18. Summary of Classification. Score based on the Norwegian Classification System (NCS) is marked with 1.

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 over periods of several months (1)	+

	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: Problem area.
Final classification: Potential Problem area. New classification because oxygen problems are mainly caused by topographic constrictions and not by local loads.

A20 Tvedestrandsfjord

The Tvedestrand fjord area is situated in the north-eastern part of East-Agder county (**Figure 11**). 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 main characteristics are summarised in **Table 37**. The area is divided into 3 basins separated by sills, where the inner sill to the Tvedestrand proper is 15 m deep.

Table 37. Main characteristics for subarea **A20.** The total nutrient load is average for 1997-2000, with the anthropogenic load in parenthesis.

Area, km^2	Freshwater runoff, m^3/s	Nutrient load, 1997-2000		Maximum depth, m	Sill depth, m
		Nitrogen, tonnes	Phosphorus, tonnes		
8	2.7	24 (13)	1.4 (1.2)	85	15

The anthropogenic nutrient and organic load is reduced during the last 5 years due to use of treatment plants for municipal wastewater. The evaluation is mainly based on a study from 1997, just prior to start of a plant for biological treatment of municipal sewage (Kroglund et al., 1998). The study included oxygen, hard- and softbottom fauna. The minimum oxygen concentration in all three basins was found to be 1.6 ml/l and lower, which corresponds to class V (Very bad) in the Norwegian classification system. However, except for the innermost basin the softbottom fauna showed only moderate effects from organic load and low oxygen conditions. In the two innermost basins the hardbottom flora and fauna showed marked signs of eutrophication with moderate-small effects in the basin nearest the coastal water. The information is summarised in **Table 38**

Evaluation:

Table 38. Subarea 20. Summary of Classification. Score based on the Norwegian Classification System (NCS) is marked with 1.

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	-
	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 marked eutrophication effects	+
Indirect Effects (III)	Degree of oxygen deficiency	Severe oxygen deficiency over period of several months in fjord basins (1)	+
	Changes/kills in Zoobenthos and fish mortality	No data	
	Organic Carbon/Organic Matter	Varying, from high in enclosed basins to moderate and low in open areas (1).	+
Other Possible Effects (IV)	Algal toxins (DSP/PSP mussel infection events)	No data	

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

A23-A24 Arendal fjord and Utnes

These areas are situated in the middle part of East-Agder county (**Figure 11**). 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 (Utnes) 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 main characteristics are summarised in **Table 39**.

Table 39. Main characteristics for subareas **A23-A24.** The total nutrient load is average for 1997-2000, with the anthropogenic load in parenthesis.

Fjord	Area, Km^2	Freshwater runoff, m^3/s	Nutrient load, 1997-2000	
			Nitrogen, tonnes	Phosphorus, tonnes
Arendal fjord	8.3	94	681 (93)	14.6 (6.6)
Utnes	13.7	94	738 (148)	18.5 (10.5)

The anthropogenic nutrient and organic load is reduced during the last 10 years due to use of treatment plants for municipal wastewater. The evaluation is mainly based on a study from 1992-94, just prior to start of a plant for biological treatment of municipal sewage (Jacobsen et al., 1995). That study included hydrochemistry, hard- and softbottom fauna.

Topographically the area is very varying. In the innermost areas, with limited water exchange and closest to the river Nidelva, marked eutrophication effects were observed.

In the outfall area for municipal sewage and further offshore, the Norwegian Coastal Current flows to the south-west with a typical speed of 0.25-0.5 m/s, corresponding to a volume transport of 200-300 000 m^3/s. This creates a high capacity for receiving wastewater without adverse effects on oxygen conditions or other eutrophication effects. The oxygen concentration in the water mass at the outfall site was higher than 6 ml O_2/l and classified as 'Very Good' according to the Norwegian classification system for marine waters. No adverse effects on bottom fauna were found. Station 6 in the program for monitoring of toxic algae and mussel toxins is located in this area (**Figure 7**) and extensive problems from *Dinophysis* spp. have been observed every year since 1998 – followed by warnings against DSP.

Evaluation:

Table 40. Subareas A23-24. Summary of Classification. Score based on the Norwegian Classification System (NCS) is marked with 1.

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	Elevated for innermost stations (1)	?
	Increased winter N/P ratio (Redfield N/P = 16)	Elevated for innermost stations	?
Direct Effects (II)	Maximum and mean chlorophyll *a* concentration		-
	Region/area specific phytoplankton indicator species	Regular occurrence of *Dinophysis* spp. and *Alexandrium* spp.	?
	Macrophytes including macroalgae (region specific)	Marked local effects in inner areas, disappearing in outer areas	-
Indirect Effects (III)	Degree of oxygen deficiency	Generally good conditions, except for a very small basin in innermost area (1)	-
	Changes/kills in Zoobenthos and fish mortality	Some local effects on zoobenthos (1)	-
	Organic Carbon/Organic Matter	Varying, from high in enclosed basins to moderate and low in open areas (1).	+
Other Possible Effects (IV)	Algal toxins (DSP/PSP mussel infection events)	Regular observations	+

Initial classification: Problem area.
Final classification: Inner part (A23): Problem area. Outer part (A24): Potential Problem area. As effects, loads and natural conditions change from one area to another.

A26-A27 Grosfjord, Vikkil and Bufjord

These areas are situated in the southern part of East-Agder county (**Figure 11**). The municipal waste water from city of Grimstad (16000 PE) is processed with biological treatment before discharge to the fjord through a deep water outfall. Both Grosfjord-Vikkilen and Bufjord have sills separating them from the coastal water. The main characteristics are summarised in **Table 41**.

Table 41. Main characteristics for subareas **A26-A27.** The total nutrient load is an estimated average for 1997-2000, with the anthropogenic load in parenthesis.

Fjord	Area, km^2	Freshwater runoff, m^3/s	Nutrient load, 1997-2000		Maximum depth, m	Sill depth, m
			Nitrogen, tonnes	Phosphorus, tonnes		
Grosfjord and Vikkil	8.4	0.4	- (25)	- (5)	85	22
Bufjord	2.2	2.4	- (6)	- (0.5)	45	35

The numbers for the nutrient load are estimates due to lack of exact data. The anthropogenic organic and nutrient load is reduced during the last 10 years due to use of treatment plants for municipal wastewater.

The evaluation is mainly based on a study from 1995, just prior to start of a plant for biological treatment of municipal sewage (Jacobsen et al., 1997). This study included hydrochemistry, hard- and softbottom fauna and all results indicated that the deep water of Grosfjord had a too high load of organic matter. The nutrient concentrations in the surface layer were elevated during winter, but about normal during summer. The hard bottom communities indicated moderate or low eutrophication effects. The situation in the surface layer may be explained as a results of trapping of the sewage plume well below the surface layers and high water exchange between the fjord and the coastal water.

Since 1995 biological treatment of the wastewater discharge to the Grosfjord has been carried out, giving an estimated reduction in the load at about 70% for nutrients and organic matter (COD). In 1998 there were rather small changes in the conditions in the recipient, but nutrient concentrations were reduced and the oxygen condition in the deep water was improved. The estimated oxygen consumption (0.75 ml O2/ litre /month), however, was at the same level as previous estimates (Dahl 1998). Generally, the changes were within normal fluctuations in the fjord system. The rather small changes contrast with the significant reduction in effluent loads, but it is possible that the fjord system will need a longer period to respond to the reductions.

Bufjord was not covered by the abovementioned study. The area is relatively open and in the 80-ies a study concluded that the oxygen conditions were good throughout the water column (Dahl and Danielssen, 1987)

Evaluation:

Table 42. Subareas A26-27. Summary of Classification. Score based on the Norwegian Classification System (NCS) is marked with 1.

Category	Assessment Parameters	Description of Results	Score
Degree of Nutrient Enrichment (I)	Riverine total N and total P inputs and direct discharges (RID)	Moderate load, decreasing due to treatment plant	-
	Winter DIN- and/or DIP concentrations	Elevated	+
	Increased winter N/P ratio (Redfield N/P = 16)		?
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 or small eutrophication effects	-
Indirect Effects (III)	Degree of oxygen deficiency	Severe oxygen deficiency over period of weeks-months (1). *)	+
	Changes/kills in Zoobenthos and fish mortality	Marked effects on zoobenthos *)	-
	Organic Carbon/Organic Matter	Varying, from high in enclosed basins to moderate and low in open areas. *)	+
Other Possible Effects (IV)	Algal toxins (DSP/PSP mussel infection events)	No data	

*) Probably mostly topographically dependent

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

A31-A33 Blindleia, Steindalsfjord and Isefjærfjord

These areas are situated in the north-eastern part of East-Agder county (**Figure 11**) 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. The local nutrient load comes from runoff and from small communities. The main characteristics are summarised in **Table 43**. Topographically the area includes both very enclosed fjords (Isefjærfjord), semi-enclosed skerries and relatively open coast.

Table 43. Main characteristics for subareas **A31-A33.** The total nutrient load is average for 1997-2000, with the anthropogenic load in parenthesis.

Fjord	Area, km^2	Freshwater runoff, m^3/s	Nutrient load, 1997-2000		Maximum depth, m	Sill depth, m
			Nitrogen, tonnes	Phosphorus, tonnes		
Blindleia and Steindalsfjord	7.6	1.7	27 (19)	1.3 (1.2)	45	15
Isefjærfjord	1.7	0.3	13 (11)	0.4 (0.3)	22	3

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.

The evaluation is mainly based on studies from 1995-98 (Kroglund et al., 1999) and 2001 (Molvær et al., 2002) which included hydrochemistry, hard- and softbottom fauna. In addition we use an overall assessment of the marine environment of East Agder county (Jacobsen et al. 1994). We also note that in March 2001 *Chatonella* caused massive death in a fish farm in this area.

Evaluation:

Table 44. Subareas A31-33. Summary of Classification. Score based on the Norwegian Classification System (NCS) is marked with 1.

Category	Assessment Parameters	Description of Results	Score
Degree of Nutrient Enrichment (I)	Riverine total N and total P inputs and direct discharges (RID)	Relatively low load, decreasing for phosphorus and organic	-
	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	Low concentrations (1)	-
	Region/area specific phytoplankton indicator species	Harmful algae (*Chatonella* and others)	+
	Macrophytes including macroalgae (region specific)	Varying from marked eutrophication effects in enclosed areas to no effects in open areas	+
Indirect Effects (III)	Degree of oxygen deficiency	Severe oxygen deficiency over a period of several weeks in several basins (1). *)	+

	Changes/kills in Zoobenthos and fish mortality		+
	Organic Carbon/Organic Matter	Varying, from high in enclosed basins to moderate and low in open areas.	+
Other Possible Effects (IV)	Algal toxins (DSP/PSP mussel infection events)	No data	

*) Mainly topographic and coastal water load dependent

Initial classification: Problem areas.
Final classification: The nutrient load, topography and available data indicates that Areas 31-32 are Problem areas while Area 33 is Potential Problem area.

Other areas on the East Agder coast

These areas are spread along the coast of East-Agder county (**Figure 11**). The nutrient input comes from runoff and from small communities and is relatively low. Recent data describing the marine environment is very sparse. Our main data source is a report from 1994 giving the overall status for the marine recipients in East Agder county (Jacobsen et al., 1994). The main characteristics are summarised in **Table 45**.

Table 45. Main characteristics for a number of subareas on the coast of East Agder county**.** The total nutrient load is average for 1997-2000, with the anthropogenic load in parenthesis.

Area	Area, km^2	Freshwater runoff, m^3/s	Nutrient load, 1997-2000	
			Nitrogen, tonnes	Phosphorus, tonnes
A19 Lyngør area	15	8	40 (20)	2.2 (1.7)
A21 Flostadøysund	3	0.7	4 (1)	0.1 (<0.1)
A22 Tromøysund	6.5	6.3	40 (10)	0.8 (0.3)
A25 Fevik coast	17.5	1.2	35 (29)	2.7 (2.6)
A28 Kaldvellfjord	2.9	2	15 (8)	0.9 (0.8)
A29 Outer Lillesandsfjord	8.8	2	15 (8)	0.9 (0.8)
A30 Skallefjord and Tingsakerfjord	64	11	114 (66)	7 (6)

As also may be seen from **Figure 10** the anthropogenic nutrient load in these subareas is low. The topography is varying, from semi-enclosed areas like Flostadøysund and Kaldvellfjord to open areas like Fevik coast. The environmental data include basically some samples of oxygen, to some degree nutrients, hard- and softbottom flora and fauna and organic contents in sediments, all showing wide variations.

Evaluation:

The Lyngør area (A 19) is mostly semi enclosed with many islands. There are few observations from the area. Local oxygen deficiency is observed (less than 1 mlO_2/l, Aure and Danielssen, 1993). Soft bottom fauna in the eastern part does not indicate eutrophication. As the local load is low, the environmental status is more or less a consequence of the coastal water quality (transboundary load) and is classified as **potential problem area**.

Flostadøysund and Eikelandfjorden (A 21) are sheltered areas with deep basins and sills. A few winter surface concentrations (2 observations in 1992/93) show elevated levels for Tot-N, TOT-P, DIN and DIP, according to the NCS (Jacobsen et al., 1996). Phytoplankton blooms starting in the coastal water, rapidly penetrate the area and fish kills have been observed (Dahl et al., 1982, Dahl, 1988). Reduced sediments are observed. The area is classified as a **potential problem area,** mainly due to the sensitivity for transboundary nutrient transports.

Tromøysundet (A 22) is a semi enclosed area inside Tromøya. Elevated winter surface concentrations of Tot-N, according to the NCS (in 1992/93, 2 observations (Jacobsen et. al., 1996)), while Tot-P and DIP concentrations were normal. The water exchange with the coastal water is high. Hardbottom communities shows impact of organic matter and particles in the whole sound. The area is classified as a **potential problem area**.

Fevik Coast (A 25) is an open exposed area. The only observations in the area are from soft bottom fauna and sediments in the outer part. No eutrophication problems have been observed. Due to few observations and the situation in the coastal water the area is still classified as **a potential problem area.**

Kaldvellfjorden (A 28) is a sheltered sill fjord with naturally occurring hydrogen sulphide in the deep water (Bøhle, 1986). The local nutrient load is small. The fjord is sensitive to increases in local load and changes in the coastal water. Uncertainty due to lack of observations and influence from coastal water justifies a classification to a **potential problem area**.

Outer Lillesandsfjord (A 29) is a relatively open coastal area, but with some parts sheltered from the open coast by sills. The only observation is from one soft bottom fauna observation at 40 m depth (Wikander, 1986) and no sign of eutrophication was observed. The deepest part is at 70 m, but there are no observations here. Strictly speaking it could be classified as a non-problem area, but uncertainty due to lack of observations and influence from coastal water justifies a classification to a **potential problem area**.

Skallefjorden and Tingsakerfjorden (A 30) are basins with sill depth between 20-32 m and max. depth 73-83 m. The sewage load is from the city (Lillesand) and is discharged to Tingsakerfjorden and Skallefjorden. Since 1990 the sewage load has been reduced due to change of outfalls to locations with better water exchange and treatment plants.

Oxygen deficiency was observed in the area (<2 mlO_2/l), but there are differences depending of the rate of water exchange with the coastal water. Oxygen consumption in the deep water was large (1.3 mlO_2/l/month), suggesting a local organic load on the deep water (Kroglund et al., 1999). The water exchange seems to be high enough to avoid oxygen deficiency in the Tingsakerfjord and the soft bottom fauna is classified as very good (Class I in the NCS), except in the harbour area (op. cit.).

In Skallefjorden, however, periods of oxygen deficiency were observed and samples of the soft bottom fauna showed a reduced number of species.

The overall situation justifies a classification as a **Problem Area.**

3.2.4 West Agder County to Lindesnes

For classification purposes the coast of West Agder county west to Lindesnes is divided into 11 subareas (A34-A44) which in **Figure 12** are shown in different colours. In the following the areas will be classified according to the procedure outlined in chapter 3.1.

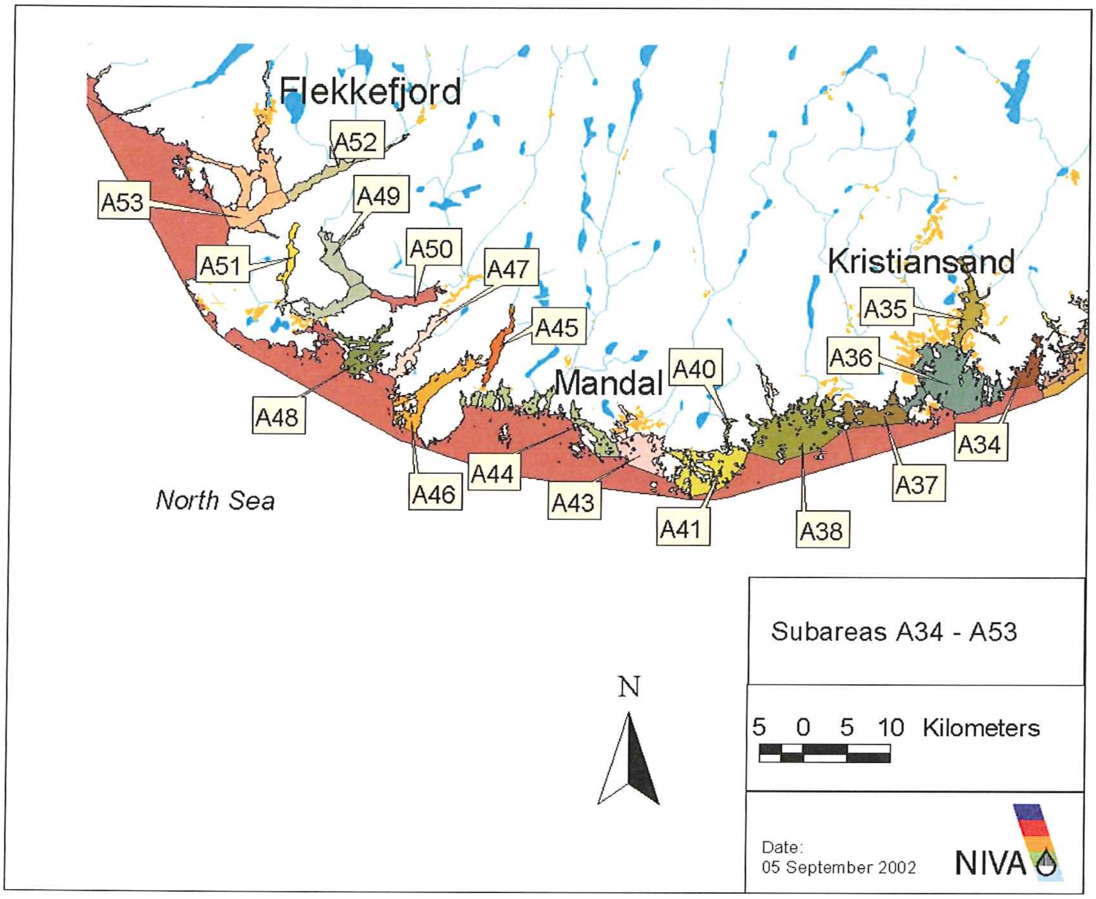
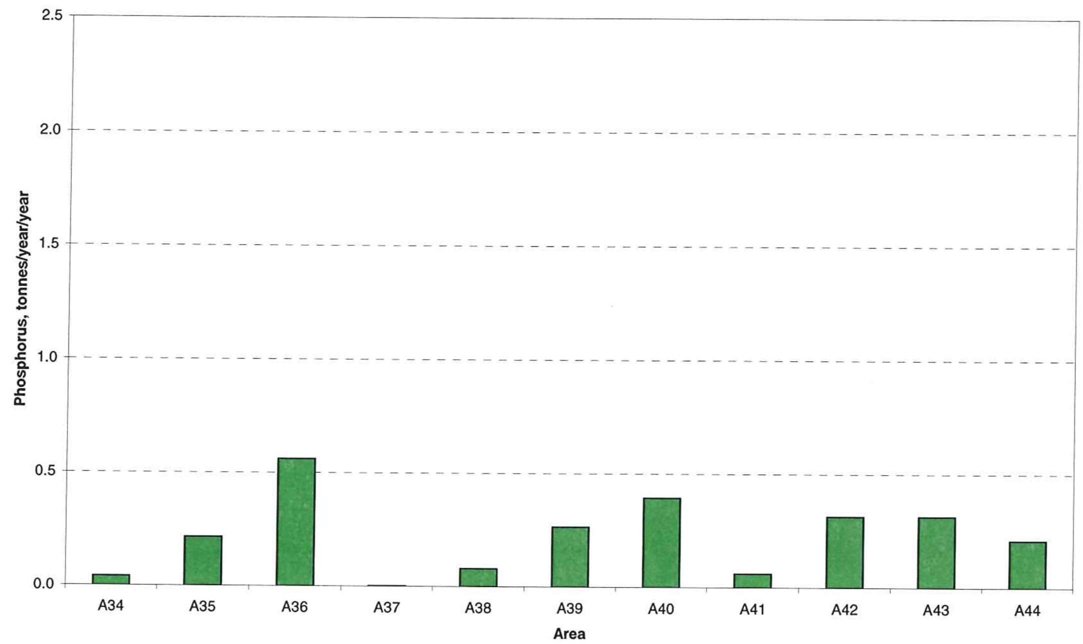


Figure 12. West Agder county with subareas A34-A53.

The nutrient load along the coast is very varying and as a first estimate the anthropogenic nutrient load per km^2 of the fjord surface has been calculated for each area as average for 1997-2000 (**Figure 13**). We shall focus on the areas with highest loads which typically represents area with high fresh water runoff and outfall from cities of towns. These are also areas where in general the best environmental data is available.



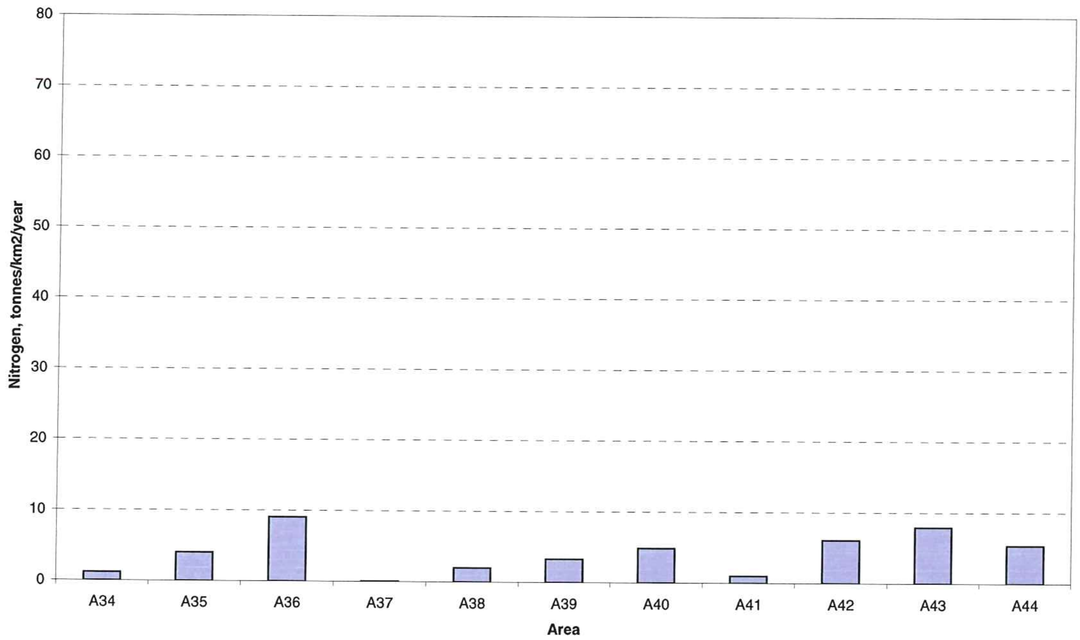


Figure 13. Nutrient load from local landbased sources pr. square km of coastal areas in West Agder county, east of Lindesnes. The scale on the vertical axis equals those in **Figure 10** for Telemark and East Agder. Upper figure: Phosphorus. Lower figure: Nitrogen.

From 1979 to 1989 the West Agder county environmental authorities carried out studies of water quality in most of the main fjord areas (Molvær, 1992). However, since these mostly data are 15-20 years old, they will not be actively used in this evaluation.

A35-A36 Ålefjærfjord, Topdalsfjord and Kristiansandsfjord

The Ålefjærfjord and the Topdalsfjord are typical fjords with sill and deep basins inside, while the waters in the Kristiansandsfjord has 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 46. Main characteristics for subareas **A35-A36.** The total nutrient load is average for 1997-2000, with the anthropogenic load in parenthesis.

Area, km^2	Freshwater runoff, m^3/s	Nutrient load, 1997-2000		Maximum depth, m	Sill depth, m
		Nitrogen, tonnes	Phosphorus, tonnes		
62	218	2520 (493)	77 (30)	75	40

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.

Effects from nutrients and organic load have not been studied in the Ålefjærfjord and the Topdalsfjord since 1990, but observations of oxygen each autumn in the Topdalsfjord has 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 Kristiansandsfjord proper (Oug et al., 1994).

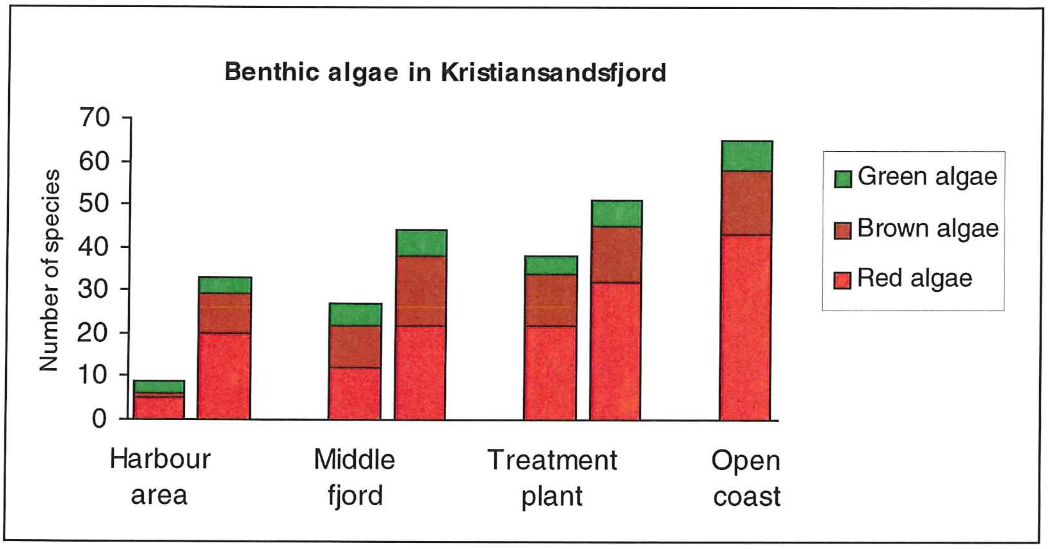


Figure 14. Distribution of shallow-water benthic algae in the Kristiansandsfjord and close to the Korsvik treatment plant in 1982 (left columns) and 1992 (right columns) and open coast. Data from Oug et al. (1994).

Evaluation:

Table 47. Subareas A35-36. Summary of Classification. Score based on the Norwegian Classification System (NCS) is marked with 1.

Category	Assessment Parameters	Description of Results	Score
Degree of Nutrient Enrichment (I)	Riverine total N and total P inputs and direct discharges (RID)	Locally elevated inputs and decreasing trend	-
	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)	Weak to moderate effects, probably reduced during later years	-
Indirect Effects (III)	Degree of oxygen deficiency	Severe oxygen deficiency over a period of several months in fjord basins. Possibly a downward trend in inner areas due to transboundary load	+
	Changes/kills in Zoobenthos and fish mortality	No data	+
	Organic Carbon/Organic Matter	Local effect, but general normal	?
Other Possible Effects (IV)	Algal toxins (DSP/PSP mussel infection events)	No data	

Initial classification: Problem area.
Final classification: Potential Problem area. The identified problems are local or to a large extent caused by topography (sills) and transboundary loads. There is also a lack of data for evaluation.

A37-A38 Vågsbygd and Songvårdsfjord

An archipelago area with many bays sheltered from the open coast partly by the islands and partly by sills. Main freshwater discharge from the river in Søgne. There are no recent observations from this area. Earlier observations has shown local impact of eutrophication close to Høllen, mainly caused by the pollution from the river (Kvalvågnes et al., 1978).

The local load of nutrients are low for this area (**Table 48**) and have decreased during the last 10 years. Except for sheltered bays, there should be no eutrophication problems caused by these loads. Transport of nutrients by the coastal current from other areas and the effect is unknown.

In Dalskilen there are a monitoring station for phytoplankton observations and analyses of mussel infection. Events of algal toxin in mussels are reported (*Dinophysis* spp.).

Table 48. Main characteristics for subarea **A37-A38.** The total nutrient load is average for 1997-2000, with the anthropogenic load in parenthesis.

Fjord	Area, km^2	Freshwater runoff, m^3/s	Nutrient load, 1997-2000	
			Nitrogen, tonnes	Phosphorus, tonnes
Vågsbygd and Songvård-fjord	63	45	232 (90)	6.5 (3.6)

Evaluation:

Table 49. Subareas 37-38. Summary of Classification. Score based on the Norwegian Classification System (NCS) is marked with 1.

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)	No data	
Indirect Effects (III)	Degree of oxygen deficiency	No data	
	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)	From monitoring station	+

Initial classification: Problem area.
Final classification: Potential Problem area. Uncertainty due to lack of observations is the main reason for this classification

A39 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 main fjord characteristics are shown in**Table 50**. The anthropogenic nutrient load is relatively low and have decreased during the last 5-10 years.

Table 50. Main characteristics for Subarea **A39.** The total nutrient load is average for 1997-2000, with the anthropogenic load in parenthesis.

Area, km^2	Freshwater runoff, m^3/s	Nutrient load, 1997-2000		Maximum depth, m	Sill depth, m
		Nitrogen, tonnes	Phosphorus, tonnes		
2.6	1	13 (9)	0.8 (0.7)	85	10

There is no data describing the marine environment in the 1990-ies, but the main feature is oxygen depletion below 20-30 m depth with obvious consequences for the biological communities. This situation is probably more caused by the topographic restrictions in the water exchange than the local anthropogenic nutrient load.

Evaluation:

Table 51. Subarea **A39**. Summary of Classification. Score based on the Norwegian Classification System (NCS) is marked with 1.

Category	**Assessment Parameters**	**Description of Results**	Score
Degree of Nutrient Enrichment (I)	Riverine total N and total P inputs and direct discharges (RID)	Moderate and probably decreasing	-
	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 over a period of months/years below 20-30 m (1). Partly natural conditions	+
	Changes/kills in Zoobenthos and fish mortality	Occurs during deep water renewals.	+
	Organic Carbon/Organic Matter	High in deep parts of fjord basin (1)	?
Other Possible Effects (IV)	Algal toxins (DSP/PSP mussel infection events)	No data	

Initial classification: Problem area.
Final classification: Problem area

A40 Harkmarksfjord

Hydrophysical characteristics

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 decides 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.

Table 52. Main characteristics for Subarea **A40.** The total nutrient load is average for 1997-2000, with the anthropogenic load in parenthesis.

Fjord	Area, Km^2	Freshwater runoff, m^3/s	Nutrient load, 1997-2000		Maximum depth, m	Sill depth, m	Surface layer residence time, days
			Nitrogen, tonnes	Phosphorus, tonnes			
Harkmarks-fjorden	1.8	1	13 (9)	0.8 (0.7)	22	2	5

Degree of nutrient enrichment.

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 (Kroglund et al., 1998). The anthropogenic nutrient load has decreased during the last 5-10 years. Based on summer surface observations the fjord is classified in Class 1-II (NCS), The concentrations are however elevated compared to the coastal water concentrations outside the fjord.

Direct effects and nutrient enrichment.

Surface chlorophyll *a* concentrations are in Class I-II. Macrophyte algae showed that the inner part of the fjord had eutrophication problems, as these parts were strongly overgrown by fast-growing green algae or the vegetation was covered by particles of organic material (Kroglund, et al., 1998).

Indirect effects of nutrient enrichment.

Anoxic conditions in the basin water were observed (Class V, according to the NCS). The oxygen consumption rate was estimated to 2-3 ml/l/month, which is a high consumption rate. However only about 8 % of the consumption can be explained from local load of organic matter. The remaining consumption must be caused by organic load from the coastal water, thus the fjords anoxic condition to a major part is a naturally situation.

Soft bottom sediments had a high content of organic material at 5 and 10 m depth in the fjord. The quality status was Class V, according to the NCS. High C/N ratio suggests that the source for the organic material is terrestrial plants.

Evaluation:

Table 53. Subarea A40. Summary of Classification. Score based on the Norwegian Classification System (NCS) is marked with 1.

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		-
	Region/area specific phytoplankton indicator species	No data	
	Macrophytes including macroalgae (region specific)	Macr. algae shows eutrophication effects.	+
Indirect Effects (III)	Degree of oxygen deficiency	Severe oxygen deficiency, only partly as a consequence of local load of organic matter (1)	+
	Changes/kills in Zoobenthos and fish mortality		
	Organic Carbon/Organic Matter		
Other Possible Effects (IV)	Algal toxins (DSP/PSP mussel infection events)	No data	

Initial classification: Problem area.
Final classification: Potential Problem area. This fjord is extremely sensitive for increased loads, mainly from transboundary sources.

A43 Mannefjord

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 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.

Table 54. Main characteristics for subarea **A43.** The total nutrient load is average for 1997-2000, with the anthropogenic load in parenthesis.

Area, km^2	Freshwater runoff, m^3/s	Nutrient load, 1997-2000	
		Nitrogen, tonnes	Phosphorus, tonnes
16.8	120	1048 (133)	21 (5.3)

The anthropogenic nutrient load has decreased during the last 5-10 years.

In the 1990-ies a study of softbottom fauna and sediments has been carried out around the deep water outfall (Oug, 1998). The effects on bottom fauna and sediments in the vicinity of the outfall was classified as moderate to marked.

Evaluation:

Table 55. Subarea A43. Summary of Classification. Score based on the Norwegian Classification System (NCS) is marked with 1.

Category	Assessment Parameters	Description of Results	Score
Degree of Nutrient Enrichment (I)	Riverine total N and total P inputs and direct discharges (RID)	Moderate and slightly decreasing	-
	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	No data	
	Changes/kills in Zoobenthos and fish mortality	Locally negative development, but in general moderate or weak effects	+
	Organic Carbon/Organic Matter	Locally high concentrations in sediments, but in general moderate or weak effects	+
Other Possible Effects (IV)	Algal toxins (DSP/PSP mussel infection events)	No data	

Initial classification: Problem area.
Final classification: Potential Problem area. Observed effects are very local around outfall.

A42 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 (**Table 56**). Studies of water quality up to 1987 showed hydrogensulphide below 10 m depth. In 1988 a long diffuser was placed on the bottom and air pumped through in order to increase the water exchange.

Table 56. Main characteristics for Subarea **A42.** The total nutrient load is average for 1997-2000, with the anthropogenic load in parenthesis.

Area, km^2	Freshwater runoff, m^3/s	Nutrient load, 1997-2000		Maximum depth, m	Sill depth, m
		Nitrogen, tonnes	Phosphorus, tonnes		
2,9	11	62 (18)	1.8 (0.9)	21	3

The anthropogenic nutrient load has decreased during the last 5-10 years.

A study in 1995 included both water quality, hard- and softbottom flora and fauna as well as the basis for fish production (Jacobsen et al., 1996). Because of the aeration project the oxygen conditions were satisfactory for marine life, but concentrations of nutrients and chlorophyll *a* were high because of strong vertical mixing of the water column.

Hardbottom flora and fauna showed some moderate eutrophication effects and an increase in number of species after start of the aeration, but no major changes. The softbottom fauna was established after start of the aeration, but not yet fully developed in 1995.

Evaluation:

Table 57. Subarea A42. Summary of Classification. Score based on the Norwegian Classification System (NCS) is marked with 1.

Category	Assessment Parameters	Description of Results	Score
Degree of Nutrient Enrichment (I)	Riverine total N and total P inputs and direct discharges (RID)	Moderate and constant 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	Elevated maximum and mean chl. a concentrations *)	?
	Region/area specific phytoplankton indicator species	Dominance of dinoflagellates	-
	Macrophytes including macroalgae (region specific)	None or moderate eutrophication effects	?
Indirect Effects (III)	Degree of oxygen deficiency	None, or minor problems due to aeration of bottom water *)	-
	Changes/kills in Zoobenthos and fish mortality	No data	
	Organic Carbon/Organic Matter	High in sediments	+
Other Possible Effects (IV)	Algal toxins (DSP/PSP mussel infection events)	No data	

*) Effects from the aeration

Initial classification: Problem area.
Final classification: Potential Problem area. Aeration of deep water improves water quality and biological conditions.

Other areas on the West Agder coast

These areas are spread along the coast of West-Agder county (**Figure 12**). The nutrient input comes from runoff and from small communities and is relatively low, and recent data. describing the marine environment is also sparse. The main characteristics are summarised in **Table 58**.

Table 58. Main characteristics for a number of subareas on the coast of East Agder county**.** The total nutrient load is average for 1997-2000, with the anthropogenic load in parenthesis.

Area	Area, km^2	Freshwater runoff, m^3/s	Nutrient load, 1997-2000	
			Nitrogen, tonnes	Phosphorus, tonnes
A34 Kvåsefjord	3	0.32	13 (11)	0.4 (0.3)
A41 Buøysund	26.5	12	75 (26)	2.6 (1.6)
A44 Hillesund – Snigsfjord	21	50	436 113)	8.0 (4.4)

The topography s relatively open and indicates regular water exchange with coastal water. Calculations of nutrient loads indicate that the anthropogenic nutrient load has decreased during the last 5-10 years.

Evaluation:

We have not found any relevant data which can be used for a classification of the **Kvåsefjord** and the **Buøysund**. Until more observations are available the area is classified as **a potential problem area.**

A small part of **Area 44** (Tredge) was studied in 1999 in connection with a new location for an outfall of municipal sewage (Kroglund and Oug (1999). They found that oxygen conditions ranged from NCS class I (>4.5 mlO_2/l) in open areas to NCS class V (<1.5 mlO_2/l) in semi-enclosed basins.

Studies of littoral flora and fauna showed in general very small effects from nutrients, but local signs of eutrophication were found.

Samples of softbottom fauna showed normal conditions at a distance of 300-400 m from the outfall. Closer to the outfall both the softbottom fauna and the sediments showed effects from an increasing organic load.

The initial classification is **Problem Area.** Taking into account that the effects represent a very small part of the area, the final classification is **Potential Problem area.**

4. Summary classification

The overall conclusions are summarised in **Figure 15 -Figure 16** and described in detail for each subarea in **Table 59**. Note that the size of the areas vary from approximately 2 km^2 to more than 350 km^2 , indicating the extent of the classification.

Many of the comments to the choice of classification are lack of relevant observations, either because

IV. there are no data
V. the existing data are too old and considered not representative for the present situation, or
VI. data covers only a minor part of the area.

The frequent registrations of harmful algae and mussel toxins at a limited number of monitoring stations represent a problem in the classification process as such a registration alone may classify an area as a potential problem area (Classification Category II and Category IV). The causes behind toxic algae blooms and mussel toxin is still uncertain- either naturally occurring, trigged by local anthropogenic changing loads of nutrients or generally effects from transboundary loads. For areas where

- no specific data on algal toxins exist
- there is none significant environmental effects from the local nutrient load

there is a basic uncertainty about the existence, extent and origin of problems related to harmful algae. A general approach has been to classify such areas as Potential Problem Areas.

The classification is based on the Norwegian Classification System for nutrients, chlorophyll *a*, oxygen and soft-bottom fauna, in general assigning a '+' in the classification tables for NCS-classes 3-5. Otherwise the OSPAR criteria is used.

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.

Also note that in areas where the coastal water has been classified as Potential Problem Area, and where there is sparse data for classification of fjords/skerries, these areas in general also have a final classification as Potential Problem Areas. This corresponds with a general conclusion in ANON (1997) that fjords on the Norwegian Skagerrak coast receive a substantial load of nutrients and organic matter through the water exchange with coastal water.

Finally note that many of the recipient studies have focussed 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 outfalls. Where the results are found to describe only a small part of the area, this is taken into account in the Final Classification.

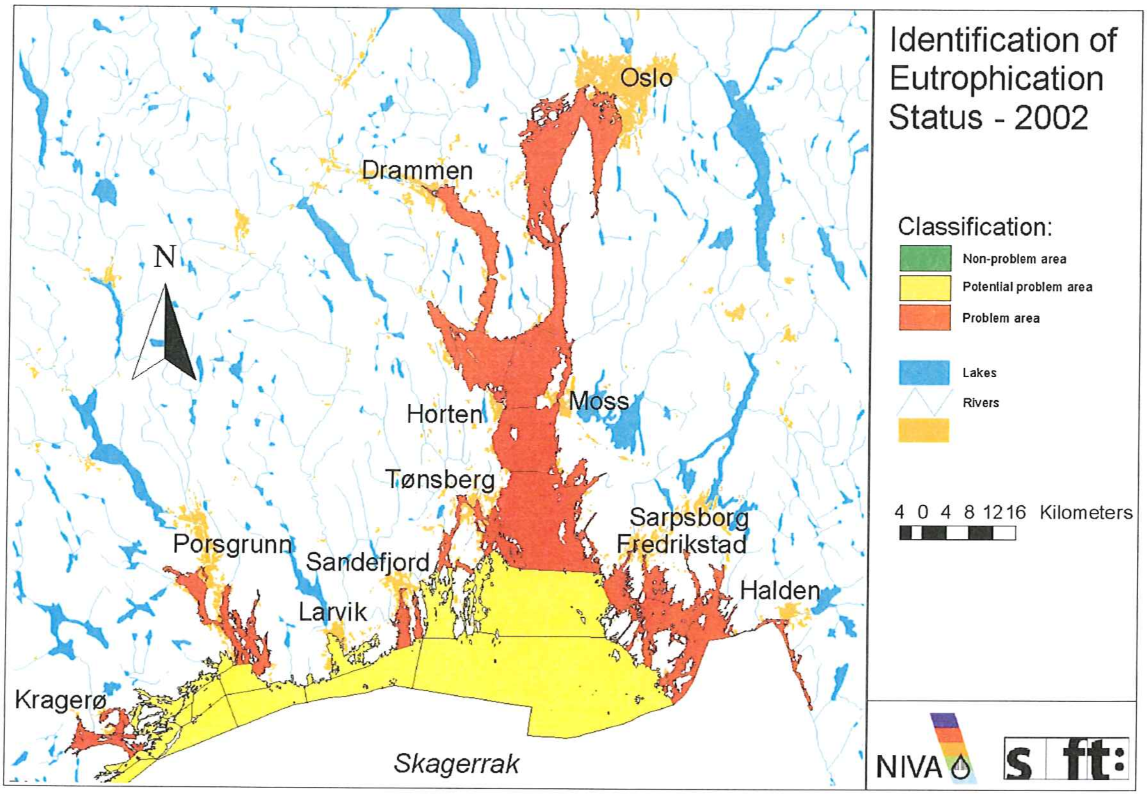


Figure 15. Classification of subareas A1-A18.

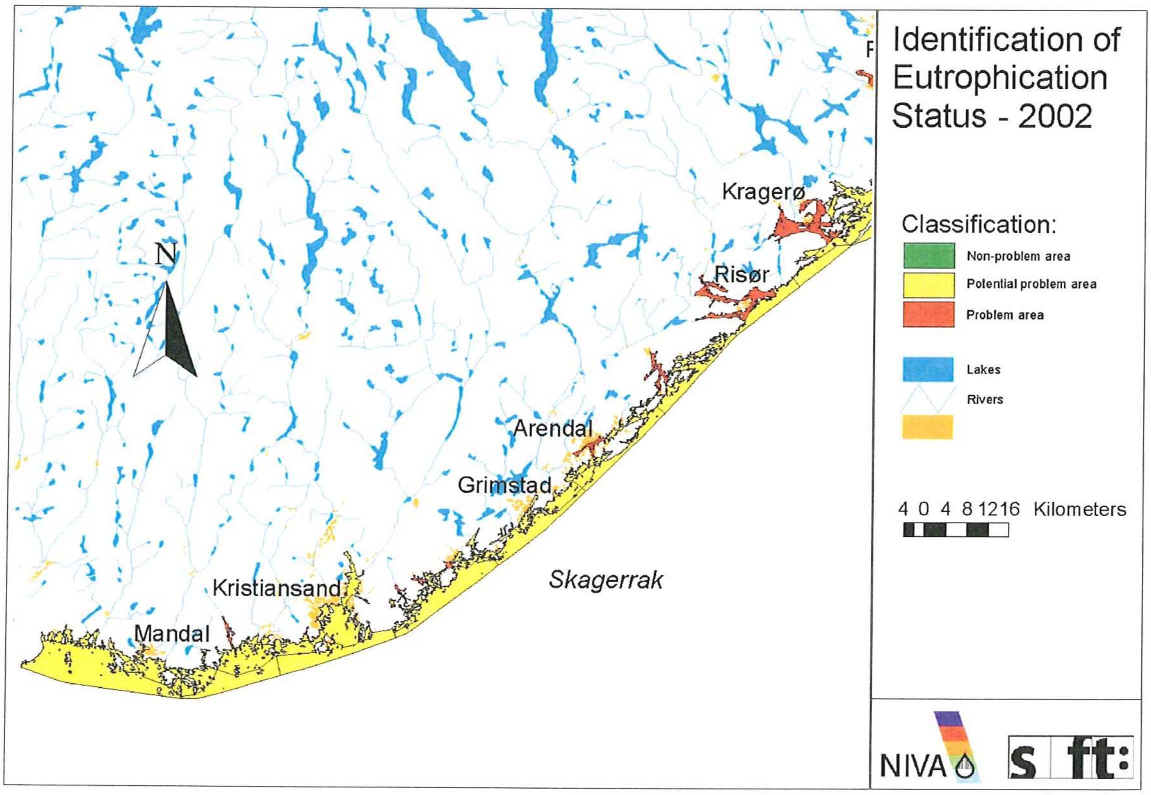


Figure 16. Classification of subareas A19-A44.

Table 59. Summarised classification of sub areas along the Norwegian Skagerrak coast. Overall Classification. Mostly data from 1990-2000. Periods where important studies have been completed are listed under assessment periods.

Key to the table

NI	Riverine total N and total P inputs and direct discharges	Mp	Macrophytes including macroalgae	+	= Increased trends, elevated levels, shifts or changes in the respective assessment parameters
DI	Winter DIN and/or DIP concentrations	O_2	Degree of oxygen deficiency	-	= Neither increased trends nor elevated levels nor shifts nor changes in the respective assessment parameters
NP	Increased winter N/P ratio	Ck	Changes/kills in zoobenthos and fish kills	?	= Not enough data to perform an assessment or the data available is not fit for the purpose
Ca	Maximum and mean chlorophyll *a* concentration	Oc	Organic carbon/organic matter		
Ps	Region/area specific phytoplankton indicator species	At	Algal toxins (DSP/PSP mussel infection events)		

Area	**Category I** Degree of nutrient enrichment		**Category II** Direct effects		**Category III and IV** Indirect effects/ other possible effects				Initial classification	Appraisal of all relevant information (concerning the harmonised assessment criteria their respective assessment levels and the supporting environmental factors)	Final classification	Assessment period.
A1 Iddefjorden	NI	+	Ca	+	O_2	+	At		PA		PA	1990-94
	DI	+	Ps	+	Ck	?						
	NP	+	Mp	+	Oc							
A2 Hvaler/Singlefjord	NI	+	Ca	+	O_2	+	At	+	PA		PA	1990-94
	DI	+	Ps	+	Ck	-						
	NP	+	Mp	-	Oc	-						
A3 Inner Oslofjord	NI	+	Ca	+	O_2	+	At	+	PA		PA	1990-2000
	DI	+	Ps		Ck	+						
	NP	+	Mp	+	Oc							
A4 Drammensfjord	NI	+	Ca	+	O_2	+	At		PA	Extreme sill fjord. Extended residence time in deep water	PA	1984, 1995, 2001
	DI		Ps		Ck	+						
	NP		Mp	+	Oc							
A5 Sandebukta etc.	NI	+	Ca	+	O_2	+	At	+	PA	Extended residence time in bottom waters, Transboundary load of nutrients and organic matter.	PA	1987-90, 1999-2001
	DI	+	Ps	+	Ck	+						
	NP	+	Mp	+	Oc							
A6 Middle part of outer Oslofjord	NI	-	Ca	+	O_2	+	At	+	PA	Extended residence time in deep water, transboundary load of nutrients and organic matter.	PA	1999-2001
	DI	+	Ps	+	Ck	-						
	NP	+	Mp	+	Oc							
A7 Southern part of outer Oslofjord	NI	-	Ca	?	O_2	+	At	?	PA	Transboundary load of nutrients and organic matter. Extended residence time in deep water.	PPA	1999-2001
	DI	+	Ps	?	Ck	-						

	NP	+	Mp	+	Oc							
A8 Tønsbergfjord	NI	+	Ca	+	O_2	+	At		PA		PA	1990-1997, 2000-2001
	DI		Ps		Ck							
	NP		Mp	?	Oc							
A9 Southern part of Tønsbergfjord	NI	-	Ca	?	O_2	?	At		NPA	Transboundary load of nutrients and organic matter. Local area (Mefjorden): PA	PPA	1997-98
	DI	?	Ps	?	Ck	?						
	NP	?	Mp	?	Oc							
A10 Sandefjordsfjord	NI	+	Ca	-	O_2	+	At		PA	Strong horisontal gradients. Classification based on inner part.	PA	1997-98, 2001
	DI	+	Ps	+	Ck	+						
	NP	+	Mp	+	Oc							
A11 Larviksfjord and Viksfjord	NI	+	Ca		O_2	?	At	?	PPA		PPA	2000-2001
	DI		Ps		Ck	?						
	NP		Mp	?	Oc							
A12-A13 Grenland fjords	NI	+	Ca	-	O_2	+	At		PA	Extended residence time deep water behind sills. Transboundary load of nutrients and organic matter. Industrial load of organic matter.	PA	1990-2001, numerous studies
	DI	+	Ps		Ck	+						
	NP	+	Mp	+	Oc							
A14 Telemark coastline	NI	-	Ca	?	O_2	?	At		NPA	Transboundary load of nutrients, organic matter and phytoplankton. Possibly local areas with oxygen problems in bottom water. Possibly harmful algae.	PPA	2001
	DI		Ps		Ck	?						
	NP		Mp		Oc							
A15-A16 Kragerøfjord - Stølefjord	NI	-	Ca	?	O_2	+	At	+	PA	Extended residence time deep water behind shallow sills. Transboundary load of nutrients, organic matter and phytoplankton. Monitoring station for harmful algae/shellfish poison.	Area 15:PA Area 16: PPA	1990-2000
	DI		Ps		Ck	+						
	NP		Mp		Oc							
A17-A18 Søndeledfjord - Sandnesfjord	NI	-	Ca		O_2	+	At		PA	Extended residence time in deep water behind sills. Transboundary load of nutrients, organic matter and phytoplankton.	PPA	1990-2000
	DI		Ps		Ck							
	NP		Mp		Oc							
A19 Lyngør archipelago	NI	-	Ca		O_2	+	At		PA	Few data. Extended residence time and oxygen problems in local basins. Transboundary load of nutrients, organic matter and phytoplankton. In general small effects.	PPA	1990-2000
	DI		Ps		Ck							
	NP		Mp	-	Oc							
A20 Tvedestrandsfjord	NI	-	Ca		O_2	+	At		PA	Extended residence time deep water behind sills. Local and transboundary load of nutrients and organic matter.	PA	1996-97
	DI		Ps		Ck							
	NP		Mp	+	Oc	+						
A21 Flostadøysund	NI	-	Ca		O_2	+	At		PA	Few data. Local effects on oxygen and softbottom fauna in semi-enclosed basins. In general small effects.	PPA	1990-2000
	DI	?	Ps		Ck							
	NP	?	Mp		Oc	+						

A22 Tromøysund	NI	-	Ca		O_2	-	At		PA	Local effects in semi-enclosed basins. In general small effects.	PPA	1990-2000 (espec. 1992-94)
	DI	?	Ps		Ck							
	NP	?	Mp	+	Oc							
A23-A24 Arendal fjord and Utnes	NI	+	Ca	-	O_2	-	At	+	PA	Transboundary load of nutrients, organic matter and phytoplankton. Local oxygen problems in inner areas. Monitoring station for harmful algae/shellfish poison.	Area 23:PA Area 24: PPA	1990-2000 (espec. 1992-94)
	DI	?	Ps	?	Ck	-						
	NP	?	Mp	-	Oc	+						
A25 Fevik coast	NI	-	Ca		O_2		At		NPA	Open coast with transboundary load of nutrients, organic matter and phytoplankton. Upgraded to PPA due to uncertainty from lack of data.	PPA	1990-2000
	DI		Ps		Ck							
	NP		Mp	-	Oc							
A26-A27 Grosfjord, Vikkil and Bufjord	NI	-	Ca		O_2	+	At		PA	Extended residence time and oxygen problem in deep water behind sill. Local and transboundary load of nutrients and organic matter.	PPA	1990-2000
	DI	+	Ps		Ck	-						
	NP	?	Mp	-	Oc	+						
A28 Kaldvellfjord A29 Lillesand outer A30 Skallefjord and Tingsakerfjord	NI	-	Ca		O_2	+	At		PPA-PA	Extended residence time deep water behind sills. Local and transboundary load of nutrients and organic matter.	A28-29: PPA A30: PA	1990-2000 (espec. 1995-98)
	DI		Ps		Ck	+						
	NP		Mp	-	Oc	?						
A31-A33 Steindalsfjord, Isefjærfjord and Blindleia south	NI	-	Ca	-	O_2	+	At		PA	Region specific phytoplankton indicator species: *Chatonella* Basins with local oxygen problems, local nutrient and organic load. Transboundary load of nutrients and organic matter.	Areas 31-32:PA Area 33: PPA	1990-2000 (espec. 1995-98,2001))
	DI		Ps	+	Ck	+						
	NP		Mp	+	Oc	+						
A 34 Kvåsefjord	NI	-	Ca		O_2		At		NPA	Classification upgraded to PPA due to lack of data	PPA	1990-2000
	DI		Ps		Ck							
	NP		Mp		Oc							
A35-A36 Ålefjærfjord, Topdalsfjord and Kristiansandsfjord	NI	-	Ca		O_2	+	At		PA	Extended residence time deep water behind sills. Local and transboundary load of nutrients and organic matter.	PPA	1990-2000 (1990,1993)
	DI		Ps		Ck	+						
	NP		Mp	-	Oc	?						
A37-A38 Vågsbygd and Songvårdsfjord	NI	-	Ca		O_2		At	+	PA	Monitoring station for harmful algae/shellfish poison.	PPA	1990-2000
	DI		Ps		Ck							

	NP		Mp		Oc							
A39 Trysfjord	NI	-	Ca		O_2	+	At		PA	Long residence time for deep water behind sills. Fish kills during deep water renewals.	PA	1990-2000
	DI		Ps		Ck	+						
	NP		Mp		Oc	?						
A40 Harkmarksfjord	NI	-	Ca	-	O_2	+	At		PA	Extended residence time of bottom water. Transboundary load of nutrient and organic matter	PPA	1990-2000 (1997)
	DI		Ps		Ck							
	NP		Mp	+	Oc							
A41 Buøysund	NI	-	Ca		O_2		At		NPA	Classification upgraded to PPA due to lack of data	PPA	1990-2000 (1999)
	DI		Ps		Ck							
	NP		Mp		Oc							
A42 Skogsfjord	NI	-	Ca	?	O_2	-	At		PA	Aeration of the fjord deep water improves deep water exchange and water quality. Classification upgraded to PPA.	PPA	1990-2000 (1995)
	DI		Ps	-	Ck							
	NP		Mp	?	Oc	+						
A43 Mannefjord	NI	-	Ca		O_2		At		PA	Local effects on softbottom fauna and sediments.	PPA	1990-2000 (1990,1997)
	DI		Ps		Ck	+						
	NP		Mp		Oc	+						
A44 Hillesund-Snigsfjord	NI	-	Ca		O_2	+	At		PA	Local effects on oxygen in small enclosed basins .	PPA	1990-2000 (1999)
	DI		Ps		Ck							
	NP		Mp	+	Oc	+						

5. Literature

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Appendix A. Data Tables

The following Tables show water quality data which has actively been used for classification purposes. For many other areas the available data has not been sufficient, and has been taken into consideration with any attempt to a formal classification. These data are not included.

Table 60. Subarea A1. Classification of the water quality (as medians) in the surface layer of the Iddefjord during the winter/summer 1990, 91,93 and 1994. (Berge m.fl., 1996). The roman numbers refers to classes in the Norwegian Classification System (NCS).

	Period	Winter	NCS	Summer	NCS
Total nitrogen	1990,91,93,94	887 µg/l	V	508 µg/l*	III
Total phosphorus	1990,91,93,94	19 µg/l	IV	26 µg/l*	IV
DIP (PO_4-P)	1990,91,93,94	4.2 µg/l	II		
DIN (NO_3+NO_2-N)	1990,91,93,94	545 µg/l	V		
Chlorophyll *a*	1990,91,93,94			12 µg/l *	IV
Secchi depth	1990,91,93,94			2 m **	V

*Significant lower in 1990-94, compared to 1980-83.
** Significant higher secchi depth in 1990-94, compared to 1980-83.

Table 61. Subarea A2. Classification of the water quality (as medians) in the surface layer of Hvaler during the winter/summer 1990,91,93 and 94. (Berge m.fl., 1996). The roman numbers refers to classes in the Norwegian Classification System (NCS).

	Period	Winter	NCS	Summer	NCS
Total nitrogen*	1990,91,93,94	515 – 728 µg/l	III-IV	325-428 µg/l	II-III
Total phosphorus	1990,91,93,94	18-24µg/l	II-III	10.3 – 13.2 µg/l	II-III
DIP (PO_4-P)	1990,91,93,94 2001	3.5-8.7 µg/l	I	1.2-1.8 µg/l	I
DIN (NO_3+NO_2-N)	1990,91,93,94	234- 447 µg/l	III-IV	128-222 (µg/l)	III-IV
Chlorophyll *a*	1990,91,93,94			1.2 – 2.9µg/l	I-II
Secchi depth**	1990,91,93,94			1.9 – 3.4	IV

*Reduced concentrations since 1980-93
** increased since 1980-83

Table 62. Subarea A2. Classification of the water quality (as averages) in the surface layer of the Singlefjord during the winter/summer 1990,91,93 and 94. (Berge m.fl., 1996). The roman numbers refers to different classes in the Norwegian Classification System (NCS).

	Period	Winter	NCS	Summer	NCS
Total nitrogen*	1990,91,93,94	499-594 μg/l	III-IV	277-309μg/l	II
Total phosphorus	1990,91,93,94	20-21μg/l	I-II	10-15 μg/l (I-II)	I-II
DIP (PO_4-P)	1990,91,93,94 2001	10-12 μg/l	I	1.3-1.9	I
DIN (NO_3+NO_2-N)	1990,91,93,94	215 - 296 μg/l	III-IV	44-46 (μg/l)	II
Chlorophyll *a*	1990,91,93,94			4-5.6 μg/l	III
Secchi depth**	1990,91,93,94			4.1 – 4.7 m	III

* Reduced concentrations since 1980-83.
**Increased since 1980-83.

Table 63. Subarea A3. Classification of the water quality (as averages) in the surface layer of inner Oslofjord during the winter/summer 1997-2001. (Magnusson et.al. 2001). The roman numbers refers to classes in the Norwegian Classification System (NCS).

	Period	Winter	NCS	Summer	NCS
Total nitrogen*	1997-2001	357-547 μg/l	III-IV	223- 268 μg/l	I-II
Total phosphorus**	1997-2001	21-22 μg/l	II	8.6 – 11.7 μg/l	(I-II)
DIP (PO_4-P)**	1997-2001	16.6 – 19.8 μg/l	II	1.1 – 1.4 μg/l	I
DIN * (NO_3+NO_2-N)	1997-2001	200-287 μg/l	III-IV	9-15.5 μg/l	I-II
Chlorophyll *a* ***	1997-2001			3.1 – 5.5 μg/l	II-III
Secchi depth ****	1997-2001			3.9 – 5.9 m	III-V

* Decreasing winter concentrations from 1997.
**Decreasing winter concentrations 1973-2001.
*** Decreasing summer concentrations 1973-82 to 1983-90 and 1991-01.
****Increasing summer values from 1973-82 to 1983-90 and 1990-01.

Table 64. Subarea A4. Classification of the water quality (as averages) in the surface layer of the Drammensfjord during the summer 1995 an 2001. (Magnusson et.al. 2001, Jensen et.al., 2002). The roman numbers refers to classes in the Norwegian Classification System (NCS).

	Period	Winter	Summer	NCS
Total nitrogen	1995* 2001		430-398 µg/l	III II
Total phosphorus	1995* 2001		6-7.5 µg/l (I-II)	I-II II
DIP (PO_4-P)	1995*		2.6-5.2 µg/l	III
DIN (NO_3+NO_2-N)	1995* 2001		231-251 (µg/l)	III II
Chlorophyll *a*	1995* 2001		2.2 – 9.9 µg/l	II-IV II
Secchi depth	1995*		2.5 – 3-8 m	III

* Extreme flooding this summer.

Table 65. Subarea A5. Classification of the water quality (as averages) in the surface layer (0-5 m) of Beriangen during the winter/summer 1999-2001. (Aure and Daniselssen, 2001, Dragsund et.al., 2002). The roman numbers refers to classes in the Norwegian Classification System (NCS).

Breiangen	Period	Winter	NCS	Summer	NCS
Total nitrogen	1999-2000 2001	362 µg/l	II II	246 µg/l	I I
Total phosphorus	1999-2000 2001	23 µg/l	II II	9 µg/l	I III-IV
DIP (PO_4-P)	1999-2000 2001	13 µg/l	I I	1.7 µg/l	I I
DIN (NO_3+NO_2-N)	1999-2000 2001	175 µg/l	III III	38 µg/l	III I-II
Chlorophyll *a*	1999-2000 2001			4 µg/l	III II-III

Table 66. Subarea A6. Classification of the water quality (as averages) in the surface layer (0-5 m) of the middle part of outer Oslofjord. (Aure og Danielssen, 2001, Jensen et.al., 2002)).

	Period	Winter	NCS	Summer	NCS
Total nitrogen	1999-200 2001	349-355µg/l (I	II II	233-274 µg/l	II I-II
Total phosphorus	1999-2000 2001	23 µg/l	II II	5.6 – 8.7 µg/l	I I-V
DIP (PO_4-P)	1999-2000 2001	12.4 µg/l	I I	0.8- 1.2µg/l	I I
DIN (NO_3+NO_2-N)	1999-2000 2001	140-148 µg/l	III II-III	25-27 µg/l	III I-II
Chlorophyll *a*	1999-2000 2001			3.6 – 3.9 µg/l	III II
Secchi depth					

Table 67. Subarea A7. Classification of the water quality (as averages) in the surface layer (0-5 m) of the southern part of outer Oslofjord. (Aure og Danielssen, 2001, Jensen et.al., 2002).

	Period	Winter	NCS	Summer	NCS
Total nitrogen	1999-200 2001	347 µg/l	II II	256 µg/l	II I-II
Total phosphorus	1999-2000 2001	24 µg/l	II II	10 µg/l	I III
DIP (PO_4-P)	1999-2000 2001	12 µg/l	I II	1 µg/l	I I
DIN *(NO_3+NO_2-N)	1999-2000 2001	134µg/l	III II	9 µg/l	I I
Chlorophyll *a*	1999-2000 2001			2.5 µg/l	II II
Secchi depth					

Table 68. Subarea A8. Classification of the water quality (as averages) in the surface layer (0-2 m) of the Tønsberg fjord (Østlandskonsult, 1997, Magnusson 2001, Jensen et.al., 2002).

	Period	Winter	Summer	NCS
Total nitrogen	1990-96 2000 2001		210-500 µg/l 119-335 µg/l	I-IV** I-III* I-II
Total phosphorus	1990-1997 2000 2001		8-19 µg/l 6-35 µg/l	I-III** I-IV* III
DIP (PO_4-P)	1990-1997 2001		2-9 µg/l	I-III** I
DIN *(NO_3+NO_2-N)	1990-1996 2001		8-195 µg/l	I-IV** I
Chlorophyll *a*	1990-1996 2000 2001		2.2-3 µg/l 2.2.-8 µg/l	II** II-IV* II
Secchi depth	1990-1997 2000		2.9-5.8 m 1.8 – 7 m	III-V*** II-V*

* Two observations in summer only on 8 stations in the area. One observation after heavy rainfall.
** Decreased, compared to observations from 1976-1989.
*** Increased, compared to observations from 1976-89.

Table 69. Subarea A9. Classification of the water quality (as medians) in the surface layer (0-2 m) of the Mefjord (Nygaard et.al., 1998).

	Period	Winter	NCS	Summer	NCS
Total nitrogen	1997-98	340-580 µg/l	II-IV	235-280 µg/l	I-II
Total phosphorus	1997-98	20-23 µg/l	I-II	9-13 µg/l	I-II
DIP (PO_4-P)	1997-98	12-17 µg/l	I-II	1 µg/l	I
DIN (NO_3+NO_2-N)	1997-98	60-280 µg/l	I-IV	4 µg/l	I
Chlorophyll *a*	1997			1.25-2 µg/l	I-II
Secchi depth	1997-98			4.5-5.5 m (III)	III

Table 70. Subarea A10. Classification of the water quality (as medians) in the surface layer (0-2 m) of the Sandefjordsfjord (Nygaard et.al., 1998, Jensen et.al., 2002).

	Period	Winter	NCS	Summer	NCS
Total nitrogen	1997-98 2001	490-220 µg/l	I-III	208-260 µg/l	I-II I
Total phosphorus	1997-98 2001	17-23 µg/l	I-II	7-13 µg/l	I-II III
DIP (PO_4-P)	1997-98 2001	9-14 µg/l	I	1-2 µg/l	I I
DIN *(NO_3+NO_2-N)	1997-98 2001	51-260 µg/l	I-IV	4-4.5 µg/l	I I
Chlorophyll *a*	1997 2001			0.9-2.4 µg/l	I-II I
Secchi depth	1997-98			4-7.3 m (II-IV)	II-IV

Table 71. Subarea A11. Classification of the water quality in the surface layer (0-2 m) of the Larviksfjord (Magnusson, 2000, Jensen et.al., 2002).

	Period	Winter	Summer	NCS
Total nitrogen	2000 2001		170-330 µg/l	I-II* I**
Total phosphorus	2000 2001		7-18 µg/l	I-III* II**
DIP (PO_4-P)	2001			I**
DIN *(NO_3+NO_2-N)	2001			I**
Chlorophyll *a*	2000 2001		1.3-2.85 µg/l	I-II* I*
Secchi depth	2000		3-10 m	I-IV*

*6-7 stations in the area. Max. and min. concentrations.
** 1 station 6 times (averaged).

Table 72. Subareas A12-13. Classification of the water quality (as medians) in the surface layer of the Grenlandsfjords and Langesund bay during the summer of 1988-89 and 1996-97 according to the Norwegian classification system (classes are shown in roman characters). Asterisks (*) after the values for 1996-97 show that the value is statistically significantly different from the corresponding value for 1988-89 (after Molvær 1999).

	Period	Frierfjord	Langesundsfjord	Håøyfjord	Langesund bay
Total nitrogen	1988-89	852 µgN/l (V)	560 µgN/l (IV)	430 µgN/l (III)	299 µgN/l (II)
	1996-97	635 µgN/l (IV)***	397 µgN/l (III) ***	255 µgN/l (I-II) ***	210 µgN/l (I) ***
Total phosphorus	1988-89	14 µgP/l (III)	13 µgP/l (II)	15 µgP/l (II-III)	12 µgP/l (I-II)
	1996-97	11 µgP/l (II)*	9.5 µgP/l (I-II) ***	9 µgP/l (I-II) ***	7 µgP/l (I) ***
Chlorophyll *a*	1988-89	2.9 µg/l (II)	3.9 µg/l (III)	3.9 µg/l (III)	1.4 µg/l (I)
	1996-97	4.6 µg/l (III)	3.0 µg/l (II) ***	2.0 µg/l (I-II) ***	1.0 µg/l (I)

***) $p<0.05$
*) $p<0.1$, but $p>0.05$

Table 73. Subarea A14. Classification of the water quality (as medians) in the surface layer and bottom layer (oxygen) 14 in June-October 2001 according to the Norwegian classification system (classes are shown in roman characters). Few data. Source: Telemark county, Environmental department.

Parameter	Average	Maximum	Minimum
Total nitrogen	143 µgN/l (I)		
Total phosphorus Chlorophyll *a* Oxygen	12 µgP/l (I-II) 2.4 µg/l (II), range 1.3-4.1 µg/l 8.0 mlO_2/l	2.4 µg/l (II), range 1.3-4.1 µg/l	2.4 µg/l (II), range 1.3-4.1 µg/l 3.7 mlO_2/l (II)

Table 74. Subareas A15-A16. Classification of the water quality (as medians) in the surface layer and bottom layer (oxygen) 14 in June-October 2001 according to the Norwegian classification system (classes are shown in roman characters). Few data. Source: Telemark county, Environmental department.

Area	Parameter	Average
Kragerø fjords	Total nitrogen	179 µgN/l (I)
	Total phosphorus Chlorophyll *a* Oxygen minimum	12 µgP/l (I-II) 2 µg/l (II), range 0.9-5.9 µg/l 0-3 mlO_2/l
Kragerø coast	Total nitrogen	172 µgN/l (I)
	Total phosphorus	13 µgP/l (I-II)
	Chlorophyll *a*	1.8µg/l (II), range 0.9-2.6 µg/l
	Oxygen minimum	0-6.6 mlO_2/l
Stølefjord	Total nitrogen	150 µgN/l (I)
	Total phosphorus	15 µgP/l (I-II)
	Chlorophyll *a*	2 µg/l (II), range 1.3-2.7 µg/l
	Oxygen minimum	5.4 mlO_2/l

Table 75. Subarea A21 Flostadøysund. Classification of of water quality in 1992 - 1993. Roman numbers refers to classification according to NCS. Few data. From Jacobsen, Oug and Magnusson (1996).

Area	Summer						Winter				
	Tot-N	NO_3	NH_4	Tot-P	PO_4	Secchi depth	Tot-N	NO_3	NH_4	Tot-P	PO_4
A21 Flostadøysund	I	I	-	I	I	II	II-III	II	II	III	III

Table 76. Subarea A22 Tromøysund. Classification of of water quality in 1992 - 1993. Roman numbers refers to classification according to NCS. Few data. From Jacobsen, Oug and Magnusson (1996).

Stations	Summer						Winter				
	Tot-N	NO_3	NH_4	Tot-P	PO_4	Secchi depth	Tot-N	NO_3	NH_4	Tot-P	PO_4
Tromøybrua	I	II	I	I	-	I	I-II	II-III	I	I	I
Nattholmen	I	I	I	I	-	I	II	III	I-II	I	I
Skibvigen	I	I	I	I	-	I	I-II	II-III	I	I	I
Buøy	I	I	I	I	I	I	II	II-III	I	I-II	I-II

Table 77. Subarea A24 Utnes. Classification of of water quality in 1992 - 1993. Roman numbers refers to classification according to NCS. Few data. From Jacobsen, Oug and Magnusson (1996).

Stations	Summer						Winter				
	Tot-N	NO_3	NH_4	Tot-P	PO_4	Secchi depth	Tot-N	NO_3	NH_4	Tot-P	PO_4
1 Ærøy	I	I	I	I	I	I	I-II	I-III	I	I-II	I
2 Utnes	I	III	I	I	I	I	I	I-II	I-II	II-III	II

Table 78. Subareas A31-A32. Classification of of water quality in Blindleia and Steindalsfjord summer 2001. Roman numbers refers to classification according to NCS. Few data. From Molvær et al. (2001).

Parameter	Tot-N	NO_3	NH_4	Tot-P	PO_4	Chlorophyll
Class	I	I	I	III	I	I

Table 79. Subarea A40. Classification of the water quality in the surface layer of the Harkmarksfjord during summer 1997 (min. and max. concentrations). (Kroglund m .fl., 1998). The roman numbers refers to different classes in the Norwegian Classification System (NCS).

	Period	Winter	Summer	NCS
Total nitrogen	1997		215 - 275µg/l	I-II
Total phosphorus			6-11µg/l	II-III
DIP (PO_4-P)				
DIN (NO_3+NO_2-N)				
Chlorophyll *a*			0.5-3.1µg/l	I-II
Secchi depth			6-8.3 m	I-II

Table 80. Subarea A42 Skogsfjord. Classification of of water quality in 1995. Roman numbers refers to classification according to NCS. Few data. From Jacobsen et al. (1996).

Period	Tot-P	PO_4	Tot-N	NO_3	NH_4	Chlorophyll	Secchi
Summer	III	III	I	I	III	III	III
Winter	II	I	II	III	III		

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Tittel - norsk og engelsk
Common Procedure for Identification of the Eutrophication Status of Maritime Area of the Oslo and Paris Conventions. Report on the Comprehensive Procedure for the Norwegian Skagerrak Coast

Sammendrag – summary

The Comprehensive Procedure has been applied to the inshore waters of the Norwegian Skagerrak coast, which has been divided into 44 areas. A total of 17 areas are classified as Problem Areas and 27 areas as Potential Problem areas.

The frequent registrations of harmful algae and mussel toxins at a limited number of monitoring stations represents a problem in the classification process as such a registration alone may classify an area as a potential problem area. The causes behind toxic algae blooms and mussel toxin is still uncertain. For most areas there is a basic uncertainty about the existence of problems from harmful algae. A general approach has been to classify such areas as Potential Problem Areas.

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